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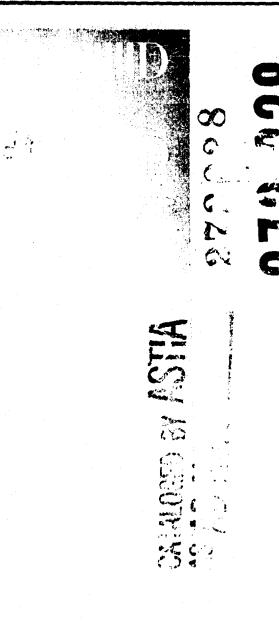
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REPORT NO: FGT-2727 DATE: 16 January 1962

PTAINLESS STEEL SANDWICH PANEL BRAZING -DEVELOPMENT TESTS OF

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GENERAL DYNAMICS FORT WORTH

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#### STAINLESS STEEL SANDWICH PANEL BRAZING -

#### DEVELOPMENT TESTS OF -

#### INTRODUCTION:

#### A. SCOPE OF REPORT:

The problems encountered during the development and production application of the stainless steel sandwich panel brazing program were numerous and varied widely in scope. This report represents an effort to compile all the data obtained by the Metallurgical Laboratory of the Engineering Test Laboratories relative to stainless steel sandwich panel brazing. This work was accomplished under Test Request F-4696 from May 1954 through December 1959.

Since the investigations reported herein were so diversified in nature, this report consists of several independent sections arranged in systematic order under the various subject headings. The subject material reported in these sections are the results of investigations previously not formally reported. In most instances this material had been furnished to interested departments in the form of memoranda or loose data sheets.

Section I of this report concerns investigations relating to the structural materials used in brazed, honeycomb, sandwich panels. Section II contains material pertaining to the brazing alloy investigations and methods used in brazing the žtructural members of the sandwich panels. In instances where several investigations were conducted on related items, the items are arranged under a common heading. The discussion section of each individual report is treated separately; however, the introductory remarks and conclusions are combined for the group asta whole.

#### B. HISTORY OF SANDWICH PANEL BRAZING

In order to provide some clarification and background on the material reported herein, a brief chronological summary of the sandwich ganel brazing program is included in this section.

The decision to use brazed sandwich panel structures on the B-58 was made in March 1953. The major advantage in the use of a Bandwich type structure was the possibility of obtaining athighstrength, light-weight part. The panels proposed for use on the B-58 also required stability in the 600 F to 900 F temperature

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This requirement eliminated the use of a bonded structure range. and for all practical purposes made the development of brazed panels the logical method.

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A basic honeycomb sandwich panel consists of the following three components:

- A core section, made from thin gage metal foil strips (less 1. than 0.003" thick) which are tack welded together in such a manner that round, square or hexagonal cells are formed, See Figure 1.
- 2. Facing sheets or skins which are fastened to both sides of the honeycomb core so that the open ends of the core are covered. The core cells then run perpendicularly to the facing sheets. The core to skin attachment is performed by brazing.
- Edge members are necessary in most, cases. 3. These are , heavier metal strips around the pagel perimeter in the form of a Z or U. The edge members are subsequently used to fasten the sandwich panel in place on the airplane. The strips are brazed in position at the same time that the skins are brazed to the core.

After the decision to use brazed sandwich panel structures had been made, an initial engineering survey was initiated and the first test panel was brazed at Convair in April 1953. In November, of the isame year, test panel contract; were given to various cutside producers. [Although almost all of the developmental research concerning sandwich panel brazing was accomplianed by Convair, a large percentage of all production type sandwich panels has been brazed by outside manufacturers. The major purpose of the test panel contracts was to allow these producers to determine their costs in brazing sandwich panels in accordance with Convair specifications.

Original plans called for the development of both a low; and a high temperature brazing procedure. The low temperature method specified a brazing range of 1300 F to 1750 F. It was to provide panels for use at operating temperatures to 600 F. The high temperature process called for a brazing temperature above 1750 F and the panels brazed by this process were for use at temperatures to 900 F.

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The low temperature brazing development program was begun in April 1954. The high temperature program was started in November 1954. H.E.M. #H35.0001 with enclosure A, dated April 28, 1954, covers the proposed low temperature panel brazing program. This was revised and superseded on July 28, 1955 by enclosure B to include the high temperature development program.

In the interval between the issuing of H.E.M. #H 35.0001 enclosure A and enclosure B, considerable research and development work was accomplished. Brazing alloy investigations, heat treat cycle development, and general furnace brazing procedures were investigated. Published reports covering work done during this period in the Engineering Test Laboratories are abstracted in Section III of this report. See references 2-7 of Section III covering FGT-1340, MR 54-5, FTDM-1415, FGT-1347, FGT-1363, and FGT-1362.

- 1. Operating temperatures were limited to 600 F.
- 2. Panels, brazed by this process had high susceptibility to corrosion because of prazing alloy flux entrappent within the panel.

Consequently, although some panels brazed by this process were tested on the engine test stand, this method was gradually discontinued. The major effort was then directed toward, the high temperature process.

17-7PH stainless steel was chosen as the basic material for use with both the low and high temperature processes. Initial work however was accomplished with "C" condition material and later changed to annealed with added heat treatment. It was found that braze and model not produce the CH properties of 17-7FH. Results welliminary evaluation tests on the heat treatment of 17-7PH steel were reported in FGT-1153 published in November 1953. An abstract of this report appears as reference 1 of Section III in this report. Section A and B list 17-7PH heat treat results which were previously reported only in that sheet form. The heat treat results given under B were used to determine the origin nal high temperature brazing cycle.

The brazing alloy used in connection with the low temperature cycle was Easy-Flo #3. This alloy has a nominal composition of 50% Ag, 15-1/2% Cu, 15-1/2% Zn, 16% Cd, and 3% Ni. It melts at 1170 F and flows above 1270 F. This process was used only during

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|         |   | gram and so is of historic interest  |
| 5 . La  | only.   |  |
|         | brazing program was 85% Ag-15%<br>1745 F. A brazing temperature<br>the panels brazed with the Ag<br>test and production panels un<br>cause of its poor corrosion re | ed for use with the high temperature<br>Mn alloy. This alloy melts at<br>e of 1820 F was used on most of<br>-Mn alloy. This alloy was used on<br>til July 1957. It was replaced be-<br>esistance. See Sections IIA, IIB, |
| ·       | IIC, and IID of this report for   | or further information. r  |
| v       |   | 33 for 17-7PH stainless steel panels<br>major prerequisites were found to  |
|         | <ol> <li>A rigid brazing form of<br/>the brazing operation.</li> </ol>  | f desired contour for use during   |
|         | 2. An inert or reducing a cycle.  | tmosphere during the brazing   |
|         | 3. A means of providing in  | ntimate contact between the  |
|         | various, detail parts o   | f the panel during brazing.  |
|         | Tnitial sandwich panel brazin   | g was carried out by the use of  |
|         | matched steel brazing forms p   | laced on both sides of the panel   |
| ·       | being brazed. The entire ass  |  |
|         |   | under a hydrogen atmosphere. Many  |
| ł       |   | this procedure. However, the item by item, is the brazing 5  |
| 1       | program progressed.   |  |
|         |   | · · · ·  |
| · • • • | In December 1954 a vacuum enve  | elope nothod was introduced which  |
| .       | replaced the top brazing form   | in July 1955. This method consisted  |
| 1.      | in placing the panel to be or   | azed on top of a single braze form<br>welded stainless steel envelope.   |
|         |   | g envelope consisted of a 0.012"   |
|         | thick, storl diaphragm sheet.   | By reducing the pressure inside  |
|         | the envelope below atmospheric  | d pressure, the sandwich panel was   |
| ł       | forced down against the brazin  | ng form. Thus, contact between the   |
|         | detail parts of the panel bou   | Id be maintained during brazing.   |
| · .     | ants me mod, in addition to e   | liminating the need for matched de effective in equalizing the pressure  |
| ·       | on the various panel parts who  | en slight discrepancies were present   |
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|    | in the mating of the panel det  | ails.   | А.   |
|    | In April 1955 graphite was sub<br>form material. This step was<br>has a much lower coefficient of<br>therefore is less subject to of<br>Section I comments on the effe  | advantageous because p<br>of expansion than does<br>limensional change upon   | graphite<br>steel and<br>n heating.  |
|    | As previously mentioned, the f<br>" a hydrogen atmosphere. Mixtur<br>from 4% - 74% hydrogen by volu<br>In August 1955 good brazes wer<br>flux in an argon atmosphere.<br>with the use of hydrogen, argo<br>flux was adopted in October 19   | es of hydrogen and ain<br>me at room temperature<br>e obtained using sodiu<br>Because of the safety<br>n used in conjunction  | r containing<br>e are explosive.<br>um tetraborate<br>hazard connected           |
| ч. | In June 1955, a tack brazing m<br>panel parts for brazing. It of<br>Figure 1 that the various panel<br>tion during the brazing operat<br>parts together, while they wer<br>panels could be pre-assembled  | an be readily understo<br>l parts must be in a c<br>ion. By tack brazing<br>e clamped in a holding  | ood from<br>definite posi-<br>the panel  |
|    | During the remainder of 1955 a<br>changed from the test phase in<br>December 1955 Fiberfrax insula<br>constituent of Fiberfrax is al<br>manufactured in sheet form and<br>nesses. It proved an ideal in<br>brazing process. Use was made<br>panel brazing packages so that<br>on the sandwich panels during | to the production phas<br>tion was introduced.<br>uminum oxide. The pro-<br>is available in sever<br>sulating material for<br>of this material to is<br>more even heating cov | se. In f<br>Ing primary<br>oduct is ,<br>ral thick-<br>the panel<br>insulate the |
|    | X-ray radiological methods and<br>as test procedures for determined<br>Also, butt; welding standards<br>as panel facings were set up  | ning over-all panel qu<br>or joining thin sheet   | uality in 1956.  |
|    | Concurrently with the develop<br>the configurations of the var<br>airplane were determined. The<br>classified into three types:<br>2) contoured or curved panels  | ous structural panel p<br>se configurations can<br>1) Flat panels of unif   | barts for the  |
|    | The brazing of flat panels of<br>cannot be faid for the contour   |   |  |
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| •       | nonale of both these turner.                                  | the bound during 105     | t the beach the                       |
|         | panels of both these types of flow characteristics of the     | brazing allov presente   | ed problems.                          |
| •       |   |                          | _                                     |
| :       | The brazing alloy flow in the                                 |                          |                                       |
|         | gravitational forces moving<br>regions in the panel. The f    |                          |                                       |
| ••      | contoured production panels                                   |                          |                                       |
| . :     | by reducing the amount of cu                                  |                          |                                       |
|         | gations were carried out on                                   | possible methods of co   | ontrólling                            |
|         | this type of brazing alloy is modifications are reported      | Llow. Tests regarding    | brazing alloy                         |
|         | this report. Section II Q                                     |                          |                                       |
|         | for controlling alloy flow.                                   |                          |                                       |
|         |   | •                        | · · · · · · · · · · · · · · · · · · · |
|         | In wedge shaped panels the p                                  | problem was caused by h  | brazing alloy                         |
|         | flow into the core capillar<br>core regions. This decrease    |                          |                                       |
|         | able to form the skin-to-con                                  |                          |                                       |
|         | on brazing alloy flow in thi                                  | ick core sections are g  |                                       |
|         | II N and JI Q of this report                                  | t i                      | t n                                   |
|         | Late in 1956 investigations                                   | wore conducted by the    | Monufootuning                         |
|         | Research & Development Depar                                  | riment and the Engineer  | ring Test                             |
|         | Laboratories regarding the                                    | purity of the argon atm  | nosphere in the                       |
| · .     | sandwich panel during brazin                                  |                          |                                       |
|         | package had been purged by f<br>retort for a set period price |                          |                                       |
|         | in the flow type purge the a                                  |                          |                                       |
|         | panel and rarely penetrated                                   | into the core region.    | Itiwas _                              |
| · . [   | · . further found that alternate                              | ely evacuating the braz  | zing <sub>f</sub> retort and          |
|         | filling it with argon gas we<br>entire panel. This method of  | ould provide purging ac  | ction on the                          |
|         | January 1957  | of cyclic burging was a  | adopted in                            |
|         | ······································                        | E                        | 1<br>F 11                             |
|         | At the same time the cyclic                                   |                          |                                       |
|         | panels, the two tube brazing<br>tube served as the argon in   | garetort was introduced  | i. The second                         |
| · · ]   | amount of fargon through the                                  | retort during brazing.   | The flowing                           |
|         | argon actéd as a carrier gas                                  | sto remove foreign gas   | ses evolved by                        |
|         | the graphite during brazing.                                  | . The use of flowing a   | argon plus the                        |
| · :     | cycle purging technique prod                                  |                          | rovement in                           |
| · · · · | the quality of brazed sandw                                   | reu bauera. <sup>5</sup> |                                       |
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In April 1957 the use of stainless steel type 3-10 core was discontinued. In designating core material, the first digit indicates the diameter of the core cell in sixteenths of an inch. The last two digits indicate the thickness of steel foil used in the core in ten-thousandths of an inch. Both type 3-10 and 3-15 core had been used in panels prior to this time. The use of type 3-10 core was discontinued because it sometimes collapsed during brazing. Investigations of factors affecting the strength of 17-7PH steel core material are presented in Sections I, F, I G, and I H of this report.

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During the spring of 1957 a problem of contamination in the corner region of brazed sandwich panels was investigated. It was concluded that the contamination was caused by the presence of oxygen and carbon in the brazing atmosphere. The method of admitting argon into the brazing retort was modified to ensure that a positive pressure was maintained in the argon lines during the entire brazing cydle. Section I J presents the results of tests performed by the ETL on the causes of corner, contamination. Later in 1957 this problem was virtually eliminated by adoption of the vapor barrier or picture frame concept into the brazing package. This modification was developed by the Manufacturing Research & Development Department.

In July 1957 a sterling silver plus 0.2% lithium allog was, adopted to replace the Ag-Mn brazing alloy. This step was taken in order to provide indreased corresion resistance in the brazed padels. Section LI E presents results of the preliminary survey on the Ag-Cu-Li alloys conducted by the ETL. preliminary heat treat data for use with Ag-Cu-Li are given in Section INC.

Several brazing problems arose or were accentuated with the adoption of Ag-Cu-Li as the trazing alloy. The brazing alloy flow problems, mentioned in a preceding paragraph, continued to be troublesome. The problem of voias in brazed edge member joints begame, increasingly acute. Section II L and II M discuss this problem. Eventually, it was found that by exercising cleser control in the forming of the edge member detail parts this problem could, be firtually eliminated.

Until the summer of 1958 no appreciable corrosion attack on Ag-Cu-Li brazed panels was observed. At this time, an oxidized region was observed in Ag-Cu-Li fillets after exposure at temperatures above 550 F. Investigation showed that this condition

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did not seriously affect panel strength after 300 hours at 700 F. See Section II E and the abstract listed under Section III "reference 12. There have been a few indications that Ag-Cu-Li brazed panels do undergo corrosion phenomena of a electrochemical nature. These indications have not been sufficiently pronounced to cause serious concern.

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In March 1959 the standard heat treat cycle for brazed panels was simplified by the elimination of the 1400 F conditioning step. The use of a 1650 F brazing temperature for the Ag-Cu-Li brazing alloy made elimination of this step feasible. Test results listed in Section I D were the basis for this change. The possibility of eliminating the -20 F transformation treatment is being investigated at the present time. This work is being done under a separate test request and the results will be reported separately.

This sequence of events completes the development of the stainless steel brazing program until the present time. Seemingly, the sandwich panels brazed with the Ag-Cu-Li alloy are adequate to perform their intended function. The effect that future increased operational requirements will have on brazed panel is still an unknown quantity.

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#### STAINLESS STEEL SANDWICH PANEL BRAZING -

#### DEVELOPMENT TESTS OF -

#### **PURPOSE:**

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> To develop procedures for brazing 17-7PH stainless steel sandwich panels and to determine the cause of and remedies for difficulties that arose during the fabrication of sandwich panels.

#### TEST PROCEDURES, SPECIMENS AND EQUIPMENT

This item is intended to explain the procedures followed in obtaining the test data and other information presented in this report.

#### TENSILE TESTS:

The standard flat specimen used in ETL for tensile tests at room temperature is shown in Figure 2. Baldwin universal machines with capacity of 5000, 60,000, and 120,000 lbs. were used for tensile testing. The specimens were usually held in position by Templin grips. In some instances, a clevis and pin arrangement was employed. The specimen for tensile tests at elevated temperatures is similar to that of Figure 2. It is provided with holes in the ends for loading with a pin.

In tensile testing, the load was usually specified in pounds per minute at a rate which would break the specimen within 2 to 3 minutes. [Unless otherwise stated, the elongation was measured on a 2" reduced section. The yield strength was calculated from the stress-strain curve for a .2% offset.

The accuracy of elongation measurements, especially of thin sheet having relatively low ductility, is often questioned. This subject is discussed briefly at the endlof this statement on test procedures.

A notched tensile specimen for sheet is shown in Figure 3. This specimen was used in some tests for which the results are given in Item I<sub>1</sub>D of this report.

#### FATIGUE TESTS:

The standard flat specimen used for fatigue tests in axial tensiontension is shown in Figure 4. All the fatigue tests were carried out on Sonntag SF-1-U universal fatigue testing machines.

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#### IAP SHEAR TESTS:

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> Figure 5 (a and b) shows two types of lap shear specimens. The double lap shear type of Figure 5-a affords even loading but is troublesome to prepare properly. This specimen was used mainly in the tests for which data are given in this report. The single lap shear specimen of Figure 5-b is objectionable because its geometry results in eccentric loading. The specimen shown in Figure 6 (AWS) type specimen, is the one presently used for shear tests. Although the single and double lap shear specimens more nearly represent the load conditions imposed on edge member sections of sandwich panels, it is felt the new specimen given a more accurate value for the shear strength of the brazing alloy.

#### X-RAY EQUIPMENT:

The X-ray diffraction and fluorescence analyses mentioned in this report were made on Norelco equipment. The diffraction patterns were obtained by either film or electronic recording methods.

#### METALLOGRAPHY;

Ordinarily the specimens for metallography were sectioned in the desired manner and mounted in bakelite. The surface to be examined was ground flat on an abrasive belt (180 grit). Further grinding was done on 0 through 0000 metallographic papers. Final finishing was effected on an 8" lap wheel using a suspension of diamond dust (1 migron) in keroscae as the abrasive agent.

Visual examination was made and photomicrographs were taken on a Bausch and Lomb Research Metallograph. This apparatus affords magnifications of 50X to 2000K. Flotomacrographs were taken with a Bausch and Lomb macro camera.

#### SPECIMEN FROM PANELS:

Specimens cut from brazed honeycomb sandwich panels were tested in accordance with the procedures set forth in Convair Specification FMS-0036.\*

#### **ELONGATION**:

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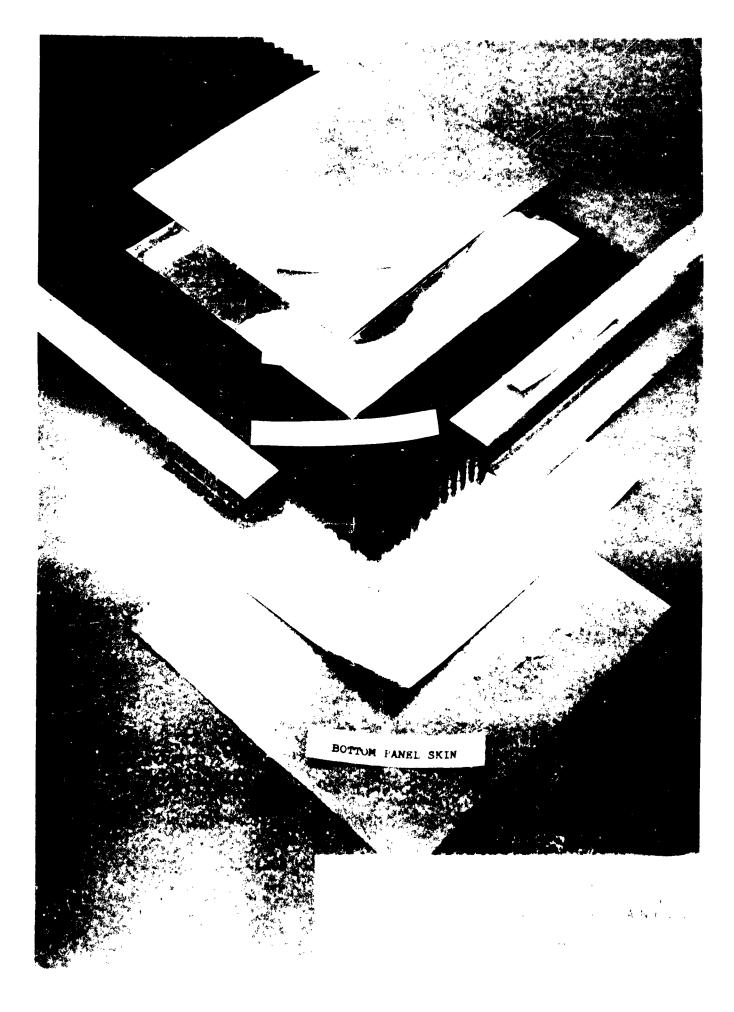
Elongation as determined in the tensile test is commonly regarded as a measure of ductility. In general, the percent elongation may be expected to decrease with decreasing pross-sectional area of the

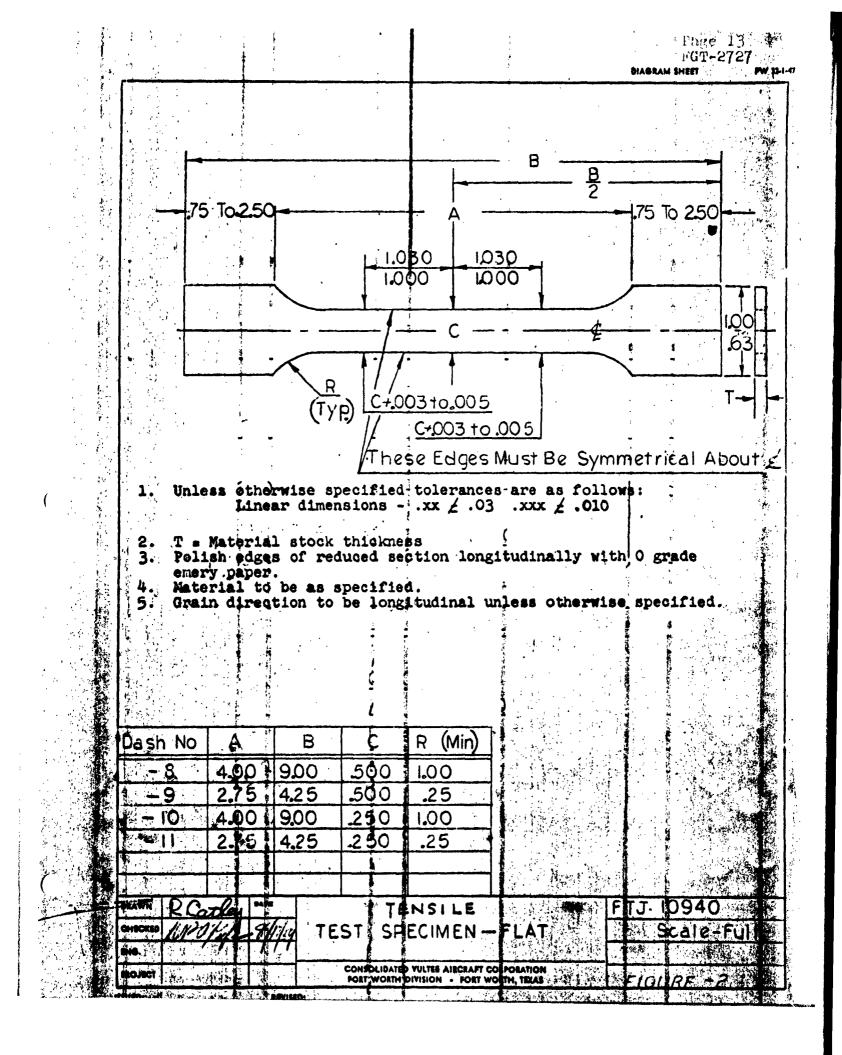
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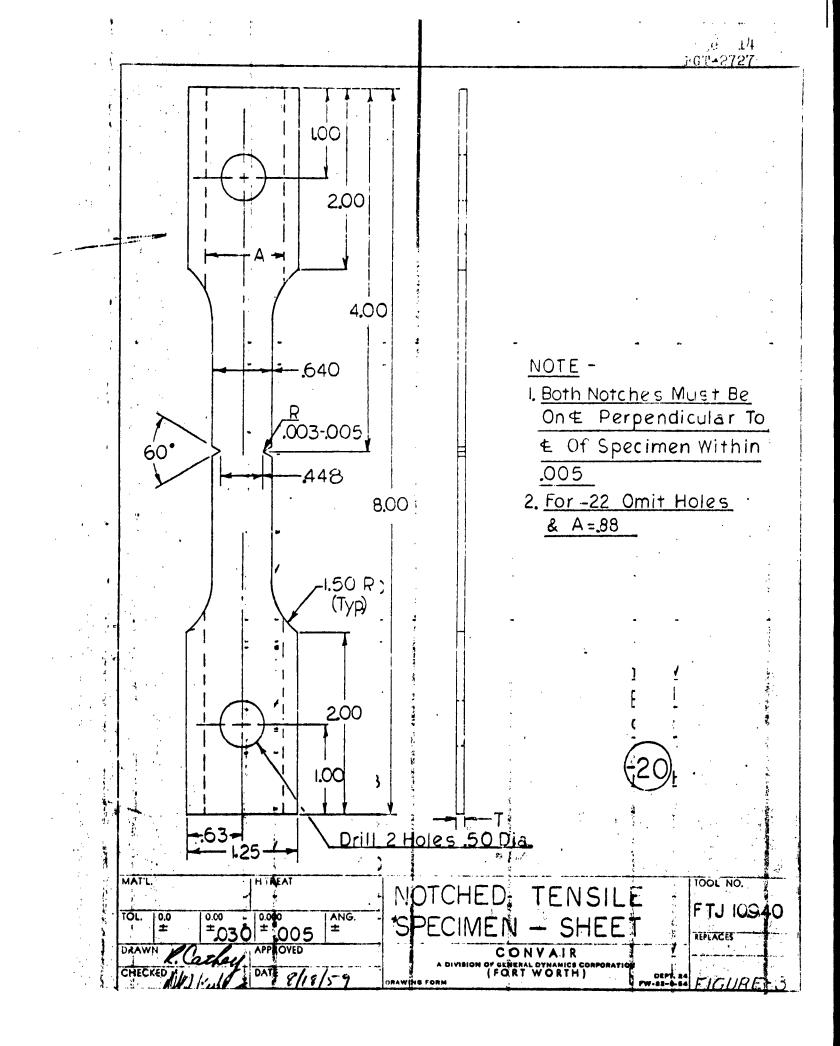
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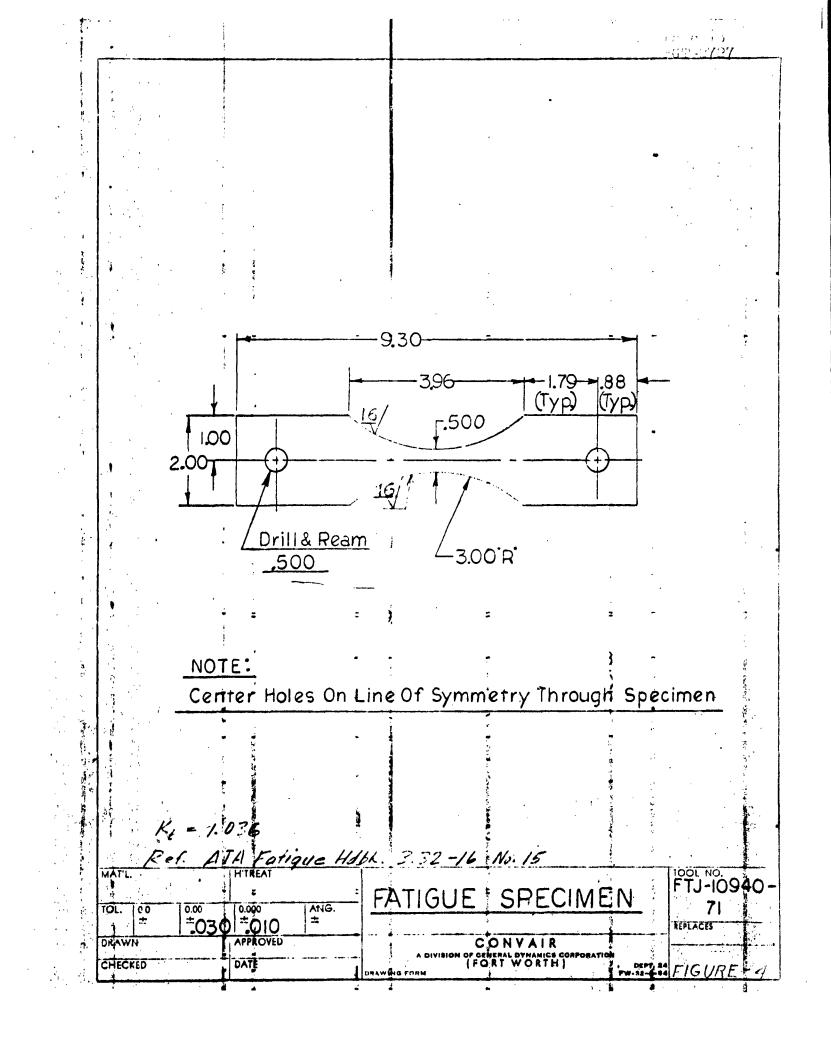
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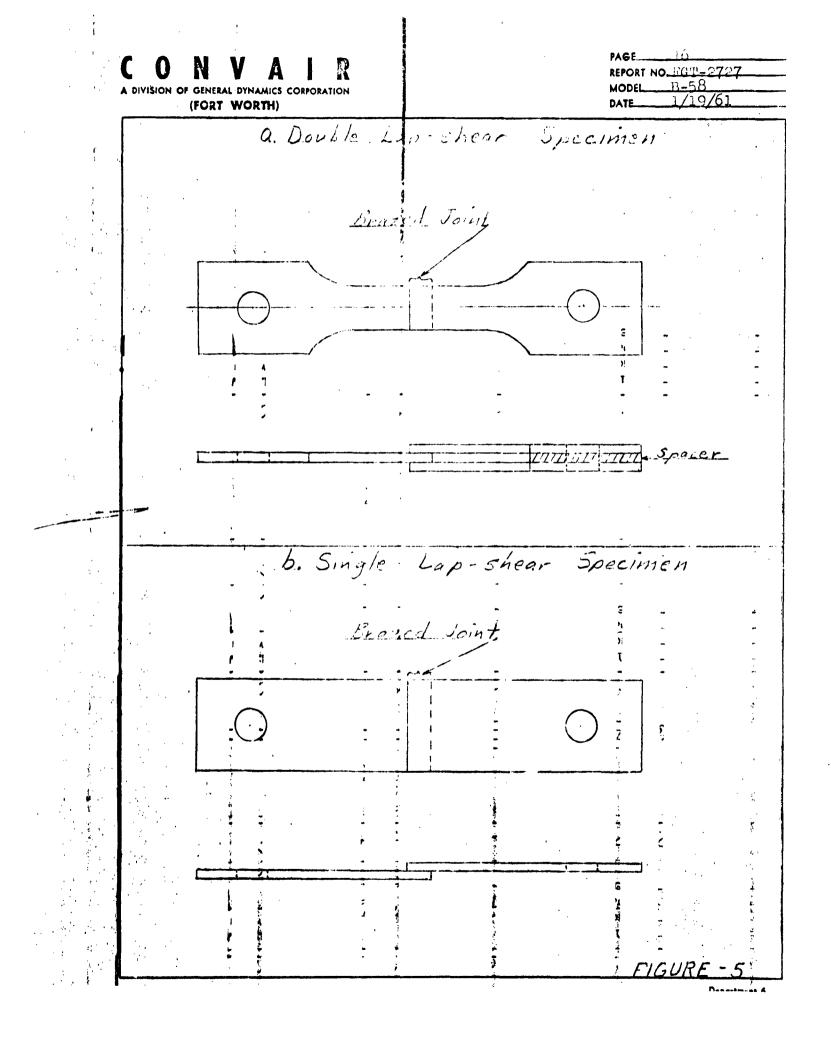
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## SECTION I - STUDIES CONCERNING MATERIALS USED IN SANDWICH PANELS

# 17-7PH STAINLESS STEEL

#### HEAT TREATMENT

### ITEM A - INITIAL HEAT TREAT RESPONSE STUDIES ON 17-7PH STEEL

During 1954-1956, several investigations were conducted on the heat treatment characteristics of 17-7PH steel. The results of this work were not published or reported by memoranda. They are summarized here. These results represent test data which were either not directly applicable or utilized in the development of any particular heat treatment subsequently adopted for production.

The investigations fall into two categories. These are: (1) Determination of the tensile properties of 17-7PH steel obtained by heat treatments corresponding to various brazing cycles; and (2) measurements of the dimensional changes in this steel caused by heat treatment. All tests were performed on sheet stock. All heat treatments, except transformation and some coolings as indicated in tables or figures, were carried out in argon.

The results of some tensile tests, mostly on .005",  $_{\rm P}$ 008%, and .020" thick-material, are listed in Tables IA-I through fA-VI. In each table, the heat treatment is given. The tensile data are not presented in graphical form.

Tables IA-I and IA-II give the tensile values obtained on specimens which had received heat treatments similar to the Armoo RH 1050. The time at the conditioning temperature was varied for specimens of Table IA-I. As snown, holding for 30 to 90 minutes at 1750 F gave satisfactory tensile properties. Table IA-II makes evident that holding for 10 minutes or 60 minutes at the transformation temperature, -100 F, gave satisfactory properties except for the .085" thick sheet. Both the tensile yield and ultimate strengths of this sheet were below the minima of Convair specification FSZ-4-046. One set of .085" thick speciment of Table IA-IV just met the specification as to strengths. Perhaps, both sets of specimens had been taken from one lot of sheet which was sensitive to the cooling rate and did not properly respond to the heat treatments.

The heat treatment, H.T. -3, given in Tables IA-III, IA-IV, and IA-V corresponds to the Armeo TH 1050 treatment with certain variations. The data appear to show that the transformation temperature of 454 F gave more consistent results than did the

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lower temperatures. Also, the elongations were generally higher for transformation at +54 F. From the data of Table IA-V, aging at 950 F gave higher strength values and lower elongations than aging at 1050 F. The elongation of the .005" thick sheet aged at 950 F was exceptionally low.

The heat treatment, H.T. -4, given in Table IA-IV afforded acceptable tensile properties without a conditioning step. The reason why this type of treatment was not investigated further is not apparent. One explanation may be that the primary concern, at the time this work was in process, was high strength rather than high elongation. Subsequent experience has proven that adequate glongation is more difficult to maintain than high strength, especially in thin sheet. This refers to specification values.

Table IA-VI gives the tensile properties of .010" thick sheet in 17-7PH steel, processed with two sandwich panels during brazing. The tabler shows the brazing pycles. Inc both cases, the material placed at one end of the brazing retort acquired acceptable tensile properties, but material placed at the opposite end had low ultimate strength. This indicates the presence of a temperature gradient, présumably reflecting its most adverse effects during the aging operation.

Figures IA-1, IA-3, and IA-5, show curves indicating the progression in cooling small batches; of tensile speciments of 17-7PH steel from three different temperatures to 1100 F. The results of tensile tests on material cooled as depicted in these figures are plotted in Figures IA-2, IA-4, and IA-6, respectively. Other details of the heat treatment are given, in the latter figures.

As shown in Figures IA-2, IA-4, and IA-5, sheet specimens .005", .008", and .020" thick were heated to 2100, 2000, and 1900 F, and then cooled and aged. For each of these temperatures, the tensile properties are plotted against the time, held at the shelving or conditioning, temperature of 1700 F.

As may be seen from the above figures, there are appreciable variations in the tensile properties depending on several factors. These are the temperature to which heated, the time at the conditioning temperature, and the thickness of the sheet. The following pattern is apparent as concerns the effect of increasing time at the conditioning temperature: For the highest heating temperature, 2100 F, the strengths increase and the elongation tends to decrease. For the intermediate temperature, 2000 F, both the strength and the elongation tend to remain at about the same levels of values. For the lowest heating temperature, 1900 F,

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|               |  | 1-1 01                                |   |   |
|               |  |                                       | -4, and IA-6) show that the tensile                                       |   |
|               |  |                                       | s, were high for all treatments. In                                       |   |
|               |  |                                       | es the elongation was below the speci-                                    |   |
|               |  |                                       | ion was pronouncedly characteristic of                                    |   |
|               |  |                                       | on of the graphs indicates that two                                       | • |
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| produc        | ed acceptab.                               | le elongat                            | ion values for all three thicknesses.                                     | - |
|               |  | 0                                     |   | - |
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| On the        | telle ev th                                | operuies of                           | f 17-7PH steel sheet, aged at 1050 F.                                     |   |
| the de        | calls of the                               | e neat trea                           | atment are given in the figures. Three                                    |   |
| Excont        | with the                                   | 005" shoot                            | ested, viz., .005", .008", and .020".<br>no definitive pattern of effects |   |
|               | nnonenties                                 | wor devel                             | oped. For this thickness the general                                      |   |
|               |  |                                       | sile properties as the conditioning                                       |   |
|               |  |                                       | rom 1700 to 1400 F. The effect of   |   |
|               |  |                                       | marked and consistent as concerns   |   |
|               |  |                                       | fime giving the higher values. As   |   |
| to the        | $\sim 0.08"$ and                           | 1000000000000000000000000000000000000 | k sheet, the general trends was toward                                    |   |
|               |  |                                       | asing shelving tennaratures. The  |   |
| elonge        | tion develo                                | ned for the                           | e.008" sheet tended to decrease with                                      |   |
| decres        | sing temper                                | ature of s                            | helving for the shorter exposure  |   |
| For th        | e longer ex                                | oosure. the                           | hélving for the shorter exposure.   | • |
| temper        | atures and                                 | times had m                           | minor effect on the elongation of the                                     |   |
| .020"         | sheet.                                     | · · · · · · · · · · · · · · · · · · · |   | - |
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| Figure        | 23 IN-10. IA-                              | -11. and I                            | A+12 show the effects of the shelving                                     |   |
| temper        | ature and co                               | ooling fime                           | e on the tensile properties of 17-7PH                                     | - |
| steel         | sheet. aged                                | at 1075 F                             | The offects are more or, less   |   |
| compar        | able to those                              | se resultin                           | ng from aging at 1050 F, but obvious                                      |   |
| diver         | encles may                                 | be noted.                             | The ultimate strengths for the aging                                      |   |

for both the short and long times but much a re markedly with the former. The elongation tended to increase for the .005" and .008" sheet for both short and long times with decreasing shelving temperature, but that of the .020" sheet decreased. Both .005" and .008" sheet, aged at 1050 and 1075 F, had marginal or low tensile yield and ultimate strengths with acceptable elongation. The .020" sheet acquired satisfactory strengths with both aging temperatures but marginal elongation on aging at 1050 F.

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at 1075 F tended to level off or decrease a little with decreasing

shelving temperature for the longer time of holding. They increased for the shorter time. The yield strengths increased

Figures IA-13 through IA-19 show the effects of the aging temperature, on the tensile properties of 17-7PH steel sheet,

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| <ul> <li>ultimate strength decrease and the elongation increases with increasing aging temperature for the three thicknesses.</li> <li>The effects of the combined treatments (heating, cooling, and aging) are readily apparent from the graphs of Figures IA-13 through IA-10. Irrespective of the treatment, all the tensile yield and ultimate strengths were above the specification minima except in four instances. With the treatment given in Figure IA-16, the ultimate strengths were below the minima for all the thicknesses of sheet aged at 1100 F. With the treatment of Figure IA-19, the ultimate strength was below for the .020" sheet aged at 1100 F. Both the strengths and the elongations were above the specification infima for all thicknesses, with the prior treatment of Figures IA-17 and IA-18, on aging at 1100 F.</li> <li>The effects of the various heat treatments, given in Figures IA-13 through IA-19, on the elongations of the 17-7PH steel sheet specification minum. Of 21 average elongation values in total, 35 were below the minum. Of 21 average values for .009" sheet, 11 were below the minum.</li> <li>Figure IA-20 shows an S/N curve for .008" thick sheet in 17-7PH steel, tested in tension-tession fatigue. An R factor of .25 was used. The material was heat treated with a modified Armco TH 1050 procedure. The endmance limit was determined as 106 ks1.</li> <li>The test. Act are no longer valiable. The values plbtted for the tensile properties are the averages of tests on three specimens.</li> <li>The measurements of the dimensional changes, in 17-7PH steel sheet for three thicknesses, asset by different heat treatments are listed in Tables IA-VII through IA-20.</li> </ul>  |   |                                  |                                      |
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CONVAIR A Division of General Bynamics Corporation (Fort Worth) PAGE F0T57727 REPORT NO. DATE Effect of Holding Time at 1700F on 17-7.PH Steel HT. - Heated to 21005 & held 30 min. Cooled as shown in Figure I. Transformed at 20F Aged at 1050 F for 90 min. shown in Figure IA. 210 0 ULT. 200 日の KS1. Ð ÷ : F ÷., 7, رفوا 1 Ş 4 . ji 191  $\overline{\Delta}$ ž 180 YIELD Ŀ t 11.51 • ţ 11 000 11 ÷  $\odot$ 170 .: .1 ÷÷ . Symbo  $\Theta$ Gaye 160 005 91 0 0. X 0. 77 沟 008 <u>u</u> • 020 à -----Y 11-Ĩ ÷. - H - T į % e 4 1 2 1.0 . 2 -Tresha 16 30 ..... 6 ------÷ AT 1700F TME - MYN. 2 ..... 1 FIGURE : IA-2 ----

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|   |        |                 |              |                 |       |   |              | ĻĿĔ         |            |        |              |              |                  |          |           |            |          |               |               |                               |                 |                    |            |            | 111<br>777         |               |                |             |                 |            |           | H         |
|   |        |                 |              |                 |       |   |              |             |            |        |              | i ri         |                  | <u> </u> |           |            |          | E             | -             |                               |                 | Щ                  |            |            |                    |               |                |             | <u> :</u> :::   | II.        | 脚         | H         |
|   |        |                 | •            | 11              | 4     |   |              |             |            |        |              | <u>] </u>    | <u></u>          | • : !    |           |            |          |               |               | ļ!                            |                 | ; <b>;</b> ; ; ; ; |            |            |                    |               |                |             | 1:              | •••        |           |           |
|   | [f     |                 |              |                 |       |   |              | (<br>(<br>( |            |        | 0            |              | .9               |          | Z         | · . ] ·    | 2        |               |               |                               |                 | q                  |            | 19         |                    | 4             |                |             |                 |            |           | i         |
|   | ···. [ |                 | HT.          |                 | ų.    | ΨI                                      |              |             |            |        | hi li        |              |                  |          |           |            |          | 11111         |               | H                             | HI.             |                    |            | H          | 詽                  |               |                |             | -               | THE        |           |           |
|   | ÷E     | E               |              | i ti            |       |   |              |             | H          |        |              |              |                  |          | . (       | 0/         | X        | 1             |               |                               |                 | 44                 | ER         | Jh         | Ð                  |               |                |             |                 |            |           |           |
|   |        |                 |              | <b>H</b>        |       | ţ١                                      |              |             |            |        |              |              |                  |          |           | 1          |          |               |               |                               |                 |                    |            |            |                    |               | <br> <br> <br> |             |                 |            |           | ſ         |
|   |        | - 11            |              | 1211            | بلك   | 1                                       |              |             | 1.11       | 111    | area :       | بنبد         | <del>ا ن</del> ې |          | <u>.</u>  | <u>ц.:</u> | <u></u>  | <u>11:1-1</u> | 1:01          | 1                             | unt             | 1111               | цŗ         | <u>u+1</u> | щ                  |               |                |             | $\mathcal{E}$ : | <u>ст</u>  |           | ų         |

| · · · ·           |             |          |  |            |                       |                  |          |           | •                     |                                       |     |     | P              | age                                     |            | 28<br>FOT<br>1/19                       | -272 <sup>.</sup><br>9/61 | 7      |
|-------------------|-------------|----------|--|------------|-----------------------|------------------|----------|-----------|-----------------------|---------------------------------------|-----|-----|----------------|---|------------|---|---------------------------|--------|
|                   |             | Eft      | ect                                    | 07         | ¢ H                   | olde             | 1        | T         | nc                    | int                                   | 17  | 001 |                | m                                       | 17-7       | 199                                     |                           | sel    |
|                   |             |          |  |            |                       | ļ                | 1        | 4 .       | 190                   | 1                                     | ł,  |     | 1              |   |            |   |                           |        |
|                   |             |          |  |            | ()<br>T               | ole              | d        | d5<br>med | 540<br>101            | NIA.                                  | 14  | Fig | 410            |   | <i>- A</i> | 5                                       | -                         |        |
|                   |             |          |  |            | A                     | geo              | 10       | t.        | 050                   | ,                                     | for | 90  | 1,000          | in.                                     |            |   |                           |        |
|                   |             |          | •••••••••••••••••••••••••••••••••••••• | 220        |                       |                  |          |           |                       |                                       |     |     |                |   |            |   |                           |        |
|                   |             | ·•·••••• | ••••••••                               |            |                       |                  | 1        |           |                       |                                       |     |     |                |   |            |   |                           |        |
|                   |             | ULT      | •                                      | 210        | · ·<br>· ·            | · •              |          |           |                       | 1                                     |     |     | +-,- +-+-<br>+ |   |            |   |                           |        |
|                   |             | K5.L     | · · · ·                                |            | •                     | - <b></b>        |          |           |                       |                                       |     | +   |                | +++++++++++++++++++++++++++++++++++++++ | -          |   |                           |        |
| · · · ·           |             |          | •                                      | 200        | •••• • • •••          |                  |          |           |                       |                                       |     |     |                |   |            |   |                           |        |
|                   | ••••<br> -• |          |  |            |                       |                  |          |           |                       | -                                     |     |     | <del> </del> г |   |            |   |                           |        |
| 1                 |             |          |  | č          |                       |                  |          | 4         |                       | • • • • • •                           |     |     |                | 1 2                                     | je.        | <u>Dra</u>                              | 2001                      |        |
| -                 |             |          |  |            |                       | <br>!            |          |           |                       | · · · · · · · · · · · · · · · · · · · |     |     | .<br>          | .00                                     | 2          |   | <u>φ</u>                  |        |
| · ·               |             |          |  | 200        |                       | Δ                |          |           |                       | · · · · · ·                           |     |     | _<br>          | .02                                     | <i>p</i>   |   | <u>u</u>                  |        |
|                   |             |          |  |            | . !                   | 0                |          |           |                       |                                       |     |     |                | <br>                                    |            |   |                           | +      |
|                   | · · · · ·   | KS.      | D ·                                    | 190        | · · · · ·             |                  |          |           |                       |                                       |     |     |                |   | 1          |   |                           |        |
| n l               |             |          |  |            |                       |                  |          |           | · · ·                 | 0                                     |     |     |                |   |            |   |                           |        |
| :<br>بر چ<br>بر ج |             |          | X                                      | 180-       |                       | •<br>•<br>•<br>• |          |           |                       |                                       |     | t.  |                |   |            |   |                           | -      |
|                   |             |          |  | łi         |                       | · 1.             |          |           |                       |                                       |     |     |                |   |            | ž                                       |                           |        |
|                   |             |          |  |            |                       |                  | ·<br>. · |           | • • • • • • • • • • • |                                       |     |     |                |   |            |   | •                         |        |
|                   | · · · · · · |          |  |            | 2                     |                  | 1        |           |                       | : ····· 6                             |     |     |                |   |            | +++++++++++++++++++++++++++++++++++++++ |                           |        |
|                   |             |          |  | -6-        |                       | Ū                |          |           |                       |                                       |     |     |                |   |            |   |                           |        |
| 1                 |             | 6 e      |  | 4          |                       | 0                |          |           |                       |                                       | 2   |     |                |   |            |   |                           |        |
|                   |             |          |  | 2          | 11.<br>1.<br>1.<br>1. | <u>A</u> :       |          |           |                       |                                       |     |     |                |   |            |   |                           |        |
|                   |             |          |  | *          |                       | 12               | •        |           |                       | 3                                     | 5   |     |                |   |            |   | 5                         |        |
|                   |             |          |  |            |                       |                  | 17       | IME       | AT                    | 4                                     | DØ. |     | IN             |   |            |   |                           | Lafe . |
|                   | <u></u>     |          |  | Luit.<br>T |                       |                  |          |           |                       | ، ، ، ، ، ، ، ، ، ، ، ، ، ، ، ، ، ، ، |     |     | bide           | F1                                      | GUR        | Ę:                                      | I.A -                     | 6      |

|  |             | COI<br>FORT  | W             | ORTH              | I D       | (V) (<br>EX/ | SION<br>AS      | 4             |         |                 |               |                           |               |          |               |          |          |             |          |          |      |             |                       |      |                                       |                  | PAG<br>REP<br>DAT  | ORT            | N          | <b>)</b> .     | FC<br>I          | л<br>Т-<br>19 |           | 27          | · · · ·     |              |
|--|-------------|--------------|---------------|-------------------|-----------|--------------|-----------------|---------------|---------|-----------------|---------------|---------------------------|---------------|----------|---------------|----------|----------|-------------|----------|----------|------|-------------|-----------------------|------|---------------------------------------|------------------|--------------------|----------------|------------|----------------|------------------|---------------|-----------|-------------|-------------|--------------|
| · ·  |             | H ::         | : <u>1</u> ., | 1:                | 1::       | 21           |                 |               | 0.05    | 15              |               |                           | INI           |          |               | 40       |          | hΤ          |          | <u>_</u> |      | NIN.        | ¢0                    |      | N                                     | T                | ME                 | k I            | ₹<br>I     | τv             | YE               | -N            | 7         | HE          |             |              |
|  |             |              |               | L .               | à         |              |                 |               | ER      |                 |               |                           |               | ND.      |               |          |          |             |          |          |      |             |                       |      |                                       | AL               |                    |                |            |                | 1                |               |           | 7-7         | · p         | H            |
|  |             | - ف - م طبق  |               |                   | 1.00      |              | A               |               | L       |                 |               |                           |               |          |               |          |          |             |          |          |      |             |                       |      |                                       |                  |                    |                |            |                | AN               |               |           | DA          | FI:         |              |
|  |             |              | 190           | b'T.              | FO        | R            | 5               | IRS           | F       | UR              | NF            | ICE                       | ÷C            | 601      | E             | 61       | 0        | ін          | : -:     | SHI      | Ē    | VIN         |                       |      |                                       |                  | 4                  | 1              | · 🎍 🕴      | 1              | 恺                | 1 * '.        | 1 11      |             |             |              |
|  |             |              | SHE           | Ŀγ                | 4         | <b>6</b>  -  | TE              | MP            | ÊR      | A7              | uh            | RE                        | 2.            | +¢       | à             | ΡĿ       | Ē₽       | FR          | 46       | 計        | ΗE   | S           | EL                    | ψı   | 4                                     | ŦĘ               | MF                 | <del>ER/</del> | Ŧ          | +₹             | E T              | ۰             | ЩÒ        | q۳          |             |              |
| E  |             |              | in I          | MIN               | μī        | C F          | 5. <sup>3</sup> | 1             | ΉE      | N.              | ¢             | 00                        | ίĒ            | Þ.,      | T,            |          |          |             |          |          |      | RA          | tu                    | RE   |                                       | For              | 140                | WE             | Þ          | -8             | ¥./              |               | 2(        | <u>ז</u> רב |             | 1            |
| 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1      |             |              | 200           |                   | A         | GE           | Ð               | AT            | K       | )5              | 0             | <u>F.</u>                 | F             | dR:      | -             | 10       | M        | INI         | 17       | ΈŚ       | 5.11 | 111         |                       |      | 1.                                    |                  |                    |                | L          |                | 1111             |               |           |             |             |              |
|  |             |              |               |                   |           | ļ            |                 |               |         |                 |               |                           |               |          |               |          |          | <b>.</b> :. |          |          | E    |             |                       |      |                                       |                  |                    |                |            |                |                  |               |           |             |             |              |
|  |             |              |               |                   | H         |              |                 |               | 80      | :               |               |                           | 3             |          |               |          |          |             |          |          | ,    |             |                       |      | 1                                     |                  |                    | <b>b</b> :     | , i        |                |                  |               |           |             |             |              |
| •  |             |              |               |                   |           |              |                 | 1111          | 1       |                 |               |                           |               |          |               |          |          | 8-          |          |          |      |             | ¥-                    |      |                                       |                  |                    | <b>9</b>       |            |                |                  |               |           |             |             | H            |
| ۰.   |             |              | 11:1          | 1                 | :1::      | - † †        |                 | 1.::          |         |                 |               | ÷                         | ) <sup></sup> |          | -+            |          |          | 1.          |          |          | . 11 |             |                       |      |                                       |                  |                    | tii            |            | Ţ.             |                  |               | 1.        |             |             |              |
| 12   |             | 1            | : .           | 1:                | 114       | - : 1        |                 | 111           | 10      |                 |               | .11                       |               |          | - <u> </u> -  |          |          | +           |          |          | Ē    |             |                       |      |                                       |                  |                    |                |            |                |                  | 1             |           |             |             |              |
| ••   |             |              | ****          | Si                | ·   · -   |              | 1 t t t         | nt ti i i     | 11-1    |                 | -             |                           |               |          |               | +        |          |             | -        |          |      |             |                       |      |                                       |                  |                    | F              |            |                |                  |               |           |             |             |              |
|  | •           |              |               |                   | <u>45</u> | 4            |                 | - 1           | 40      | <del>1</del> :- | <u>;;</u>     |                           | -             |          | _             |          |          | <u> </u>    |          |          |      |             |                       |      |                                       |                  |                    | 11<br>1        | +          |                | 111              |               |           |             |             |              |
| 4  | ·<br>·      |              |               | ЩI.               |           | 4            |                 |               |         |                 |               |                           |               |          | -             | <b>İ</b> | <u> </u> |             | 4.       |          | -    |             |                       |      |                                       |                  |                    |                |            |                |                  |               | ₩!        | +           | ₩           |              |
|  |             | <u>ttill</u> | ĽЦ            |                   |           | <u>H</u>     | <u>;;;;</u>     |               | 50      | <u>.</u>        |               |                           | :<br>:<br>:   |          |               |          |          | <u> </u>    |          |          |      |             |                       |      |                                       |                  |                    |                |            | ii-            |                  |               |           |             |             | <u> </u>     |
| · •  |             |              |               |                   |           |              | :        <br>   | F .           |         |                 |               |                           |               |          | <u> </u>  _   |          |          |             |          |          | E    | 1           |                       |      |                                       |                  |                    | 1              |            | 17             |                  |               |           |             |             | j.           |
|  |             | <b>H</b> 1   |               |                   |           |              |                 | ł.,           | j<br>BO |                 |               |                           | :::           |          |               |          |          |             |          |          | Ē    |             |                       |      |                                       |                  |                    | 3              |            |                | ų :              | .:*:<br> .:*: |           |             |             | 4.           |
| 1  |             |              |               | YIE               |           | 3            |                 |               |         |                 |               | 1                         |               |          |               |          |          |             |          |          |      |             |                       |      |                                       | ::.,             |                    |                | :          |                |                  |               |           |             | 1           | т.<br>Т.     |
|  |             |              | E11           | I                 | ŧ.        | :11          |                 |               |         |                 |               |                           |               |          |               |          | ••••     |             | :        |          | . 11 | 1.1         |                       |      |                                       | : ; i            |                    | 0              |            |                | 1.11             |               |           | 1           |             |              |
|  |             |              |               | ST                | :         | -it          | 1. H            | <b>-</b>      |         | t:              |               |                           | <b>-</b>      | <u> </u> | -+            |          |          |             |          |          | ÷F.  |             |                       |      | ـــــــــــــــــــــــــــــــــــــ |                  |                    |                |            |                |                  |               |           |             | Πİ          |              |
| '  |             |              | +++           | 1                 | (S        | -            | • •             |               |         |                 | +             |                           |               | H        | -             |          |          |             |          |          |      |             | 0                     |      |                                       |                  |                    | <b>e</b>       |            |                |                  |               |           |             |             |              |
| •  |             | TIL.         | بك            | I.                | T: .      | 21           |                 | :: <i>'</i> / | 60      |                 |               | ÷                         |               | -        | +             |          |          | the second  | Ŧ        |          |      | 1           |                       |      |                                       |                  |                    |                | +          |                |                  |               |           |             |             | -            |
| ·.   |             |              | 2             | Ģē                | sμo       | Ħ            |                 |               |         |                 | -             |                           |               |          | 4             |          |          | -           | -        |          |      | H           |                       |      |                                       |                  |                    |                | -          |                | -                |               |           | -           |             |              |
|  |             |              |               | E                 | ŅG        | Ť.           | H.              | 1             | 50      |                 |               | Ļ,                        | ₽             |          |               |          | • •      |             | -        |          |      | ::<br>      | - + <sub>2</sub><br>- |      | <u>i i i</u>                          |                  |                    |                | ÷          | +++            |                  |               | <u> '</u> | 1:          | 4           |              |
|  | · .         | 111          |               |                   |           | 1            |                 |               |         |                 | 1             |                           | 1<br>1        |          | -1-           |          |          |             | ÷+       |          |      | <u> :'.</u> |                       |      |                                       |                  |                    |                | +          |                |                  |               | -         |             |             |              |
| 0 <b>2</b> 0                               | ,           | <u>ti</u> ii |               |                   |           | 3            |                 | •             |         |                 |               |                           |               |          |               | ļ        |          |             |          |          |      | 11          | i i                   |      |                                       | :,               |                    |                |            |                |                  | <u> .:</u> '  |           | ، ا<br>خاب  | :+ +        |              |
|  |             |              | i!!           |                   |           |              | :H              |               |         |                 |               | :                         |               |          | :             |          | •••      |             |          |          | Ē    |             |                       | . 1  |                                       |                  |                    | Ĩ              |            |                |                  | 111           |           |             |             | ţr.          |
| ី អ្ន 🛛 🕹                                  |             |              |               |                   |           | 1            |                 |               |         |                 |               |                           |               |          |               |          |          |             |          |          |      |             |                       |      | ļ                                     | الم و ا<br>سور ا | ار از ا<br>سر از ا | <b>Q</b> -     |            |                |                  |               |           |             |             |              |
| 10   |             |              |               |                   | 0         | 月            | 1.1             |               |         |                 |               |                           |               |          |               |          |          |             |          | 1        |      | بليني:      | $\hat{\Gamma}$        | -    |                                       | tir              | 1                  | 9              | :11        |                |                  |               |           |             |             | 17           |
| SHE .                                      | •           |              | <del> :</del> | ţ.+               | -T.:      | ġ            | TIO             |               |         |                 |               | Ð                         |               |          | -             |          |          | <u>نې</u>   |          |          | F    | 14          |                       |      | E                                     |                  | <b>†</b> ↑.++      |                |            |                |                  |               |           |             |             |              |
|  | · · ·       | <u></u>      | <b>-</b><br>  | 1 <b>1.C</b>      |           | ţ            | 1.10            |               |         |                 |               | 9                         |               |          |               |          |          | <b>•</b> -  |          |          | Ē    |             |                       | +    | : []-                                 |                  |                    | 1              |            |                |                  |               |           |             |             |              |
| IO X 10 10 THE 1, INCH<br>RUTTL & POINT CO |             |              |               |                   | HE.       | ╢            |                 |               |         |                 | 닄             |                           |               |          | #             | E        |          |             |          |          |      |             |                       |      |                                       |                  | <u> </u>           |                |            |                |                  |               |           |             |             | 111<br>]   [ |
|  | ĺ           |              |               |                   |           |              |                 |               |         |                 | 1:1:<br>:     | 172                       | 0             |          |               |          | 7        | 500         |          |          | E    |             | 500                   | i fi | <u>11</u>                             |                  | 1.15               | Q0             |            |                | 11.11.<br>11.11. |               | +         | <u>   -</u> |             |              |
| М<br>Х                                     | ÷           |              | -[[]]         |                   |           | F]           |                 |               | H       | 4-1++           | ÷             |                           |               |          |               | E        | vi       | NG          | -#       | Ē        | M    | E,          | ₹A                    | +    | ,<br>, ,                              | E                | a,                 | #              |            |                |                  |               |           | ΗH          |             | +            |
| <b></b>                                    |             |              |               | SF                |           |              | KIC             |               | M       |                 | <u></u>       | 2                         | HEI           | <b> </b> |               | 5        | FT       | VIL         | <u>d</u> | TE       | M    |             | 5                     |      | F                                     | R                | T                  |                | 1          | ; †1<br>       | मम               | Evr           | NG        | +           | i i i<br>Ma | n h<br>P     |
| •  | •           |              |               |                   |           | 1            | 1.4             |               |         |                 | 1             | ار <b>مرد</b><br>بر ندر ا |               | [[       |               |          |          |             |          |          | 2    |             |                       |      |                                       | 81<br>210        | ŧī                 | dio            | °F         |                |                  | <b>F</b> ili  |           | <u> </u>    | 1           |              |
| · · ·                                      |             | E H          |               | <u>i i</u>        | 70        | ğ¦           | F               | <b>H</b>      |         |                 | iil           | Ηļ                        |               | Ľé       | ¢.            | М        | N.       |             |          | H        | E    | <u>[1]</u>  | <u>iþ.</u>            |      |                                       | 210              | Mi                 | N              |            |                |                  |               |           |             |             | 11           |
|  | •           |              |               | 97<br>97<br>97    | 50        |              | E               |               |         |                 |               | †141<br>111               |               |          |               |          |          |             |          |          |      |             |                       |      |                                       | 62<br>58<br>58   | lié                |                |            |                |                  |               |           | 11:-        | ii ii       |              |
|  | •           |              |               | φī                | 40        | ą            | F               | P             | F       | 旧               | 11            |                           |               |          |               |          |          |             |          |          | E    | H           |                       | Ŧ    | H                                     | 58               |                    |                |            | : : :<br>: : : |                  |               |           |             |             |              |
| ·  | :           |              |               | <del>Li.</del>    | 111       | 쓂            | 101.0           | <b>.</b>      | Ē       |                 | ij            |                           |               |          | Ħ             |          |          |             |          |          | F    |             |                       |      | 2                                     | 20               | The second         | Ħ              |            |                |                  |               |           |             |             |              |
| · · ·                                      |             |              |               | € 1<br>8:1<br>8:1 | Šŏ        | đ            | F               |               |         | +1tt            | 1. E          |                           |               |          |               |          |          |             |          |          | HĒ   |             |                       | H    | 2                                     | 20<br>25<br>20   |                    |                |            |                |                  |               |           |             | 5#          |              |
|  |             |              |               |                   | 40        | <u>9</u>     | Fil             |               |         |                 | $\frac{1}{1}$ |                           |               |          | $\frac{1}{1}$ |          |          |             | 出        |          | H    |             |                       |      | H.                                    | 20               |                    |                | 1          |                |                  |               |           | ╢╢          |             |              |
| 1 * .                                      | 1.4 - 1<br> |              |               | <u> !!</u>        | 1         |              |                 | Ę             |         | :               | 끸             |                           |               |          | +             |          |          |             |          |          |      |             |                       |      |                                       |                  |                    |                | #          |                |                  | <b>  </b>   - |           | H           |             | ļ.           |
|  | • •         | 田田           |               |                   | Ш         |              |                 | Ell           |         | : E             | H             | 11,,                      |               | UE,      | Щ             |          |          | ([H]        |          | Ш        | IF   | 臣           |                       |      | 114                                   |                  | LHH                | Î.             | <u>ill</u> | 1              | <u>ti li</u>     |               |           | Ш           | Ш           |              |

| ł   | FORT WO         | RTH        |                  |       | N   |                        |              |              |              |   |                  | •        |                                |              |       | ,            |                |           |             | PAGI<br>REPC<br>DATE | ORT I   | NO.  | F(<br>1 | /19<br>/19 | 27       | 27.      | ,<br>                                   |
|-----|-----------------|------------|------------------|-------|-----|------------------------|--------------|--------------|--------------|---|------------------|----------|--------------------------------|--------------|-------|--------------|----------------|-----------|-------------|----------------------|---|------|---------|------------|----------|----------|---|
|     | Ere             |            |                  | VAL   |     |                        | L.<br>Filin  | No.1         | Er Mil       | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>- |                  |          | AND                            | Ċ            |       | T            | Mai            | P.        | 7.00        |                      |   | ہ ہے | Lipi    | L.N        |          |          | ;                                       |
| •   | TEMP            |            |                  |       |     |                        |              |              |              |   |                  |          |                                |              |       |              |                |           |             |                      |   |      |         |            |          | 0A       | i                                       |
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| · • | POR             |            |                  |       |     |                        |              |              |              | i:  |                  |          |                                |              |       |              |                |           | 1           |                      |   |      |         |            |          |          | 1                                       |
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|     | ELTIMA          |            |                  |       |     |                        | •            |              | ••           |   | <b>†</b>         |          | † <del></del>                  |              |       |              |                |           | Ē           |                      |   |      |         |            |          |          |   |
|     | STREN           | us l       | . Li.            |       |     |                        |              |              | <del> </del> | <u> </u>  |                  |          |                                |              |       |              | A              |           |             | ,                    |   |      |         |            |          |          |   |
|     | IN SI           | <u> </u>   |                  |       |     |                        |              |              | <u>.</u>     | +   |                  |          | میں<br>مسینہ ا                 |              |       |              |                |           |             |                      |   |      |         |            |          |          |   |
|     |                 |            | <u>.</u><br>     |       | 1.7 | <u>Bo</u>              |              |              |              | <u> </u>  | <b>-</b>         | F.       | <u>} :</u>                     |              |       | <u> </u>     |                |           |             |                      |   |      |         |            |          |          | 1                                       |
|     |                 |            |                  | ;     |     |                        |              |              |              |   | Į                | ļ        | · • • •                        |              |       |              |                |           |             |                      |   |      |         |            |          |          | 1                                       |
|     | 177   1   1   1 |            | E                | 1:: 1 |     | <u></u>                | ·            | <u> </u>     |              | .   | <u> </u>         | ļ        |                                |              |       |              |                |           | :: <u>-</u> |                      | يرسيا   |      |         | 111        |          |          |   |
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|     |                 | KS         |                  |       |     |                        |              |              |              |   | <b>I</b> .       |          |                                |              |       |              | <u>.</u>       | /         | جنبانا      | - 1                  |   |      |         |            |          |          |   |
|     | 2%0             |            | er.              |       | 1.  |                        |              |              |              |   |                  | 1.       |                                |              |       |              | - <b>-</b>     |           |             |                      |   |      |         |            |          |          | ••••                                    |
| ٠,  | ZGA             | üğĘ        | Ē                |       |     | 601                    | <b> </b>   - |              | 11.5         |   |                  | شتيتها   |                                |              |       | 1            | . <u>11:1</u>  |           |             |                      |   |      |         |            |          |          |   |
| ,   |                 | Len        | e <del>,</del> ⊓ |       |     |                        |              |              |              |   |                  |          | <u>.</u>                       |              | 5     |              | 1              |           |             |                      |   |      |         |            |          |          | -                                       |
|     |                 | <u> </u>   |                  |       |     | fo.                    | ₽∐.          |              | <u> </u>     |   | ļ                | ļ.:      | جر 📖                           | 1            | • • • |              |                | <b></b> . |             |                      |   |      |         |            |          |          | -                                       |
|     |                 |            | <u>++-:</u>      |       |     |                        |              | ļ            | <u> </u> -   |   | <u> </u>         |          |                                |              |       |              |                |           |             |                      |   |      |         |            | <u> </u> |          |   |
| •   |                 |            | ·f···            |       | 1   | 40                     |              | ļ:           |              |   |                  | <b>.</b> | •                              |              |       |              |                |           | <br>        |                      |   |      |         |            | 1        |          | 1                                       |
| r   |                 |            |                  |       |     |                        | .÷.          | .·           |              |   | Ľ                |          |                                |              |       |              | <u> </u>       |           |             |                      | :   |      |         |            |          |          |   |
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|     |                 |            | -                |       |     |                        |              |              | -            |   |                  |          |                                |              |       |              |                |           |             |                      |   |      |         |            | <u> </u> | ╞╧       | -                                       |
|     |                 | <u></u>    | -                |       |     |                        |              | <u> :</u>    |              |   | <u> </u>         | ļ '      |                                | :•.•<br>:••• |       |              |                |           |             |                      |   |      |         | -          |          |          |   |
|     |                 |            |                  |       | ¢   | 2                      | <b>İ</b>     |              | 1:1          | 1.  |                  | <u> </u> | 3                              |              |       |              |                | <u></u>   |             |                      |   |      |         | <u> </u>   |          | 1        | -                                       |
|     |                 | H.         |                  |       |     |                        | · ·          |              | 1            |   |                  | -::6     | 5                              |              |       |              |                |           |             |                      |   |      |         |            | 100      | Ľ.,      | •                                       |
| .,  |                 |            | Ŧ                |       |     |                        |              |              | E.           | l   |                  |          |                                | :            |       |              | <u> А</u> ::   |           |             |                      | N. F.   |      |         |            |          |          | ;                                       |
|     |                 | 2          |                  |       |     |                        |              |              | Ē            |   |                  |          |                                |              | 1     |              |                |           |             |                      |   |      |         |            |          |          | ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;; |
|     | EL.             | SHG.       | ALI              | an    |     |                        |              |              | <b>A</b>     |   |                  |          |                                |              |       |              |                |           |             |                      |   |      |         | 1          |          |          |   |
|     |                 |            |                  |       |     |                        |              |              |              |   |                  | 1.1.1    |                                |              |       | 1            | <b>A</b>       |           | • : ; ; ;   |                      |   |      |         |            |          |          | -                                       |
|     |                 |            |                  |       |     |                        |              | <b>†</b> === |              |   |                  |          |                                |              |       |              |                |           |             |                      |   |      |         |            |          | f        | +                                       |
|     |                 |            |                  |       |     |                        | <u> </u>     |              |              |   |                  |          |                                |              |       |              |                |           | =           |                      |   |      |         |            |          | IT.      | 1                                       |
|     |                 |            |                  |       |     |                        |              | 11           | <u>rð</u>    |   | <u>; ; ; ; ;</u> | 116      | 00                             |              | +     | 1.           |                |           |             | M                    | 00_   |      |         |            |          |          | 1                                       |
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|     | 1 SHE           | VIN        | 1                | ΈŇ    | P   | 2.                     | HEL          | p A          | 755          | ute<br>I  | lin              | G.Te     | MP                             |              | 17    | ME           | 82<br>58<br>58 | тwе<br>Mi | EN.         | 5, 2<br>             | LVII  | VG.  | ΓεΜ     | ¢          | TI       | 1.2      | )<br>ا                                  |
| 1   | A 15            | 10 T       |                  |       |     |                        |              | 60           | 117<br>117   | UTE   | <b>b</b>         |          |                                |              |       | li ji i      | 58             |           | HT.         | <b>* S</b> :         |   |      |         |            |          |          |   |
|     |                 | 01         |                  | 14    |     |                        |              |              |              |   |                  |          |                                |              |       |              | 58:            |           |             | iti s                |   |      |         |            |          |          | 1                                       |
|     |                 | 101<br>101 |                  |       |     |                        |              |              |              |   |                  |          | i.r.                           |              |       |              | 20             |           |             | Ħ                    |   |      |         |            |          |          |   |
|     | A 15            | xit        | i i              | 臣     |     |                        |              |              |              | 1   |                  |          |                                |              |       |              | 29252          |           | İΠ          |                      |   |      |         |            |          |          |   |
|     | A               | 107        |                  |       |     |                        |              |              |              |   |                  |          |                                |              | ÷     |              | ZD             |           |             |                      |   |      |         |            |          |          | 1                                       |
| · · | HHHH            | :##F       | : <b>#</b> :     | 115   | HH. | 1:11<br> 1:11<br> 1:11 | 171          |              |              | 1::::   |                  | 1.1:1    |                                | LH.          | :Ti   | <u>1; †i</u> | 1:1:1          | ŧΞ        | :;;!        |                      | HH  |      | 1.00    |            | liii:    |          | į                                       |

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| 1   | CON<br>FORT<br>FORT | wo        | RTH          | DIV               | ISIO<br>(AS | N      |             |           |            |                   |                    |          |               |          |               | •        |           | <u>.                                    </u> |              | •           | PAG<br>REPO<br>DAT | ORT          | NO    | ،<br>مسبحہ ،<br>مربعہ م | د هد. به<br>مدر ارتوار<br>مرجود | FO     |               | 27       |
|---|---------------------|-----------|--------------|-------------------|-------------|--------|-------------|-----------|------------|-------------------|--------------------|----------|---------------|----------|---------------|----------|-----------|--|--------------|-------------|--------------------|--------------|-------|-------------------------|---------------------------------|--------|---------------|----------|
|   |                     | - 1       |              | H                 | 1.1         |        |             | : .:      |            | T-                |                    |          |               |          |               |          |           |  |              | E.          |                    |              |       |                         |                                 |        |               |          |
|   |                     |           |              |                   |             |        |             |           |            |                   | MPEI<br>Y TI       |          |               |          |               |          |           | li nr<br>Kalo                                | 1.4          | 1           | HW.                | 7-1          | 4 i - | 1 1 1 1                 | ∯ - × • •                       | 1      | 1             |          |
| <b>.</b>  |                     |           |              |                   |             |        |             |           |            |                   | <u>γ 1</u><br>αΞΑΤ |          |               |          |               |          |           |  |              |             |                    | ****         |       | ***                     | ÷                               | ****** |               |          |
|   |                     |           | 5 K A - 1    |                   | 4           | 1      | * • •       | 3 - A - A | •          | 4                 |                    |          | • •           |          |               |          | *         | 1.1.1.1                                      |              | ŧ. **       | Þ A                | T* * '       | 1111  | TT T T                  | <b>T</b> : ' ' ' '              |        | 1             |          |
|   |                     | ал<br>+ 1 | (AS          |                   | UK N        | Z      | 4           |           |            |                   | не<br>гне          |          | •             |          |               |          | 1         | 1.1.4.4                                      | 1            | ••••        |                    |              |       |                         | مد                              |        |               |          |
|   |                     | i. l      |              |                   |             |        | 1.411       | 1         | 1          |                   | URE                |          | 1.            |          |               | 4        |           | 1  | 1 1 1        | 1 +         |                    | A            | έÞ    | AT                      | 10                              | 50     | $\frac{1}{2}$ |          |
|   |                     |           | * * * * *    |                   |             | ite    |             | * · · · · | 1:.::      |                   |                    |          |               |          |               |          |           |  |              |             |                    |              |       |                         |                                 |        |               |          |
|   |                     | 111       | 1111         | 1111              | 1111        |        |             |           |            |                   |                    |          |               |          |               |          |           |  |              |             |                    |              | IIII  |                         |                                 |        |               | II.      |
|   |                     | Щ         | TI           | dat               | E           |        |             |           |            |                   |                    |          |               |          |               |          |           |  |              |             | 世                  | 1            |       |                         |                                 |        |               |          |
| •   |                     | Te        | NSI          | L E               |             | 2      | 0           |           |            |                   | <b>¦</b> ∸         |          | :             |          |               |          | 1.        |  |              |             |                    |              |       |                         |                                 |        |               | +        |
| 1 A. 1  |                     | 5         | RE           | Nda               | H.          |        | ii!!        |           | L <u>i</u> | <b>a</b> -1       |                    |          |               | 1        |               |          |           |  |              |             | +-+-<br>           |              |       |                         |                                 | [i4;   |               | <u>i</u> |
| 1   | 、間間                 |           | ĸs           |                   |             | 2      | 60          |           |            |                   |                    |          |               |          |               |          | 1         | 1111   | 11.          |             |                    |              |       |                         |                                 |        |               |          |
|   |                     |           | H.           |                   |             |        |             | 1         |            |                   |                    |          | li: ·         | · : : .  |               |          |           |  |              |             |                    |              |       |                         |                                 |        |               |          |
|   |                     |           | 1 H          |                   |             |        |             |           |            |                   |                    |          |               |          | :             |          | :         |  |              |             |                    |              |       |                         |                                 |        |               |          |
| · · ·   |                     | L.        |              |                   |             |        |             |           |            |                   |                    |          |               |          |               |          |           |  |              |             |                    | 1            | 1     |                         |                                 |        |               |          |
| · · ·   |                     |           |              | TRE               | NG1         | H 2    | 00:         | †::::     |            | <b>k</b>          |                    | •        |               | <u>.</u> |               | •        |           |  |              |             |                    |              |       |                         | <b></b> ,                       |        |               |          |
|   | · Hill              |           | 15           |                   | <u> </u>    |        |             |           |            | 1 3               |                    |          |               |          |               |          |           | Ŋ  |              |             |                    | 2            |       |                         |                                 |        |               |          |
|   | 4                   |           | OFF          |                   |             |        | 90.         | <u> </u>  |            | 2                 |                    | -:       |               |          | +             | 1        |           | <u> </u>                                     |              |             |                    |              |       | <b>.</b>                |                                 |        |               |          |
| ,   |                     | G         | iúc,         |                   |             |        |             |           |            | 1                 |                    | <b>.</b> |               | j        |               |          | ļ         |  | <u> </u>     | :::<br>     |                    | <b>1</b>     |       |                         |                                 |        |               |          |
| 4   |                     |           |              | NG                | H           |        | 80          |           |            |                   |                    | Į.'      |               |          |               |          |           |  |              |             |                    | -            |       |                         |                                 |        |               |          |
|   |                     | 7         |              |                   | l:i         |        |             |           |            |                   |                    | 1.       |               | ·        |               |          |           |  |              |             |                    |              |       |                         |                                 |        |               | Ē        |
|   |                     |           |              |                   |             |        | 1.5         |           |            |                   |                    |          |               |          |               |          |           |  |              |             |                    | <b>i</b>     |       |                         |                                 |        |               | Ē        |
| 1   |                     |           |              |                   |             |        |             |           | †          | + <b>-</b> -      | •                  |          |               | 1        |               |          | 1.        |  |              |             |                    |              |       |                         |                                 |        |               | T        |
| 1   |                     |           |              |                   |             |        |             | 4         | 1          |                   |                    |          | +             |          | <u> </u>      |          | 1         |  | 1            |             |                    |              |       |                         |                                 |        |               | F        |
|   |                     | <u>.</u>  |              | 3                 |             |        | 1           | +         | 1:         | i C               | ; -:               |          |               | • • • •  | 1             |          | -         |  |              |             |                    | <b>1</b>     |       |                         |                                 |        |               | Ŧ        |
|   |                     |           |              |                   |             |        | ¢           |           |            | <b>n</b> -        |                    |          |               | <u>.</u> |               |          |           |  | 111.<br>111. |             |                    |              | 1     |                         |                                 |        |               | 1.       |
|   |                     | E         | <u>No</u>    | GAT               | ION         |        | \$ <b>.</b> |           |            |                   | 1<br>4             |          |               | <u>}</u> |               | FF.      | <b>.</b>  | <u>N</u>                                     | ti.          |             |                    | <b>b</b>     |       |                         |                                 | 1      |               |          |
| ហិ ៖<br>ហិ ៖  |                     |           | :-:          |                   |             |        | 4           | <u> </u>  | ļ          |                   |                    | ļ        | ļ             |          | <u>[i : :</u> | <u> </u> | 1 · · · · |  |              |             |                    | <u> </u>     |       | <b>.</b>                |                                 |        |               | -        |
| i   |                     |           | 111          |                   |             |        |             |           | 1.1        | 200               |                    |          | 1.16          | !<br>    |               | E.       | 1.7       | 50   |              | 1.1         | Linp               | 100          |       | 1                       | <u> </u>                        | 1      |               | 11       |
| HON   |                     |           |              |                   |             |        |             |           |            | SHÆ               |                    |          | EM            | PE's     | AZL           | 113.14   | F         | 50.  |              |             |                    |              |       |                         |                                 |        |               |          |
| 20<br>20  |                     |           |              |                   |             |        |             |           |            | 1000              |                    |          | ::::          |          |               | Me       |           |  | 1            |             |                    |              |       |                         | H                               |        |               |          |
| THE   |                     |           | <            |                   |             | TE     |             |           | 2 1        | i <u>Eu</u>       | 11.<br>11. A T     |          |               | NO       | 1             |          | 1.        | 110  | IME          | B.          |                    | EN           | Sa    |                         |                                 | T      | MP            |          |
| 04  |                     |           | <u></u>      |                   |             |        |             |           |            | i <del>r (i</del> | TA_K               |          |               |          |               |          |           |  |              |             | Tw1                | h °F         |       |                         |                                 |        |               |          |
| 10 X 10 TO THE Y <sub>s</sub> INCH<br>KEUFTLL & 5396F CO. |                     |           |              | 2                 | 1 1 1 1     | ;:::   |             |           |            |                   | <b>\$0</b>         |          |               |          |               |          |           | LT.  |              |             | 10                 | VU7          |       |                         | 1.:                             |        |               |          |
|   |                     |           |              | 160<br>50(<br>40( | φΕ          |        | i Fi        |           |            |                   | ခုဝ                | Mis      | μŢ            |          |               | 1:E:<br> |           |  |              | 5<br>5<br>5 | 1 M                | 17 <u>17</u> | 5     |                         | ::::                            |        |               |          |
| N<br>N<br>N   | · ,                 |           |              | 496               | 1 F         | 1 :tl/ |             |           |            |                   |                    |          | <b> </b>      |          |               |          |           |  |              | 5           |                    |              |       |                         |                                 |        | H             |          |
| <b>T</b>  |                     |           |              |                   |             | r      |             |           |            |                   |                    |          | 1             |          |               |          |           |  | 11E          | ĽH.         |                    |              |       |                         |                                 | ЦЦ     | 4             |          |
| •   |                     |           |              | 600               |             |        |             |           |            |                   |                    |          |               |          |               |          |           |  |              | ŻŻ          | φШ                 |              |       |                         | <u>li i</u>                     |        |               |          |
| и<br>1  | li ili              |           |              | 500               | 团           |        |             |           |            | THE REAL          |                    |          |               | H        |               |          |           |  |              | 22          | 5                  |              |       |                         |                                 |        |               | Ŧ        |
|   |                     |           |              |                   |             |        |             |           |            | 1.¥               |                    |          |               | H        | 曲             |          | 11        |  | 围            | 22          |                    |              |       |                         | 日日                              | ŧ      |               |          |
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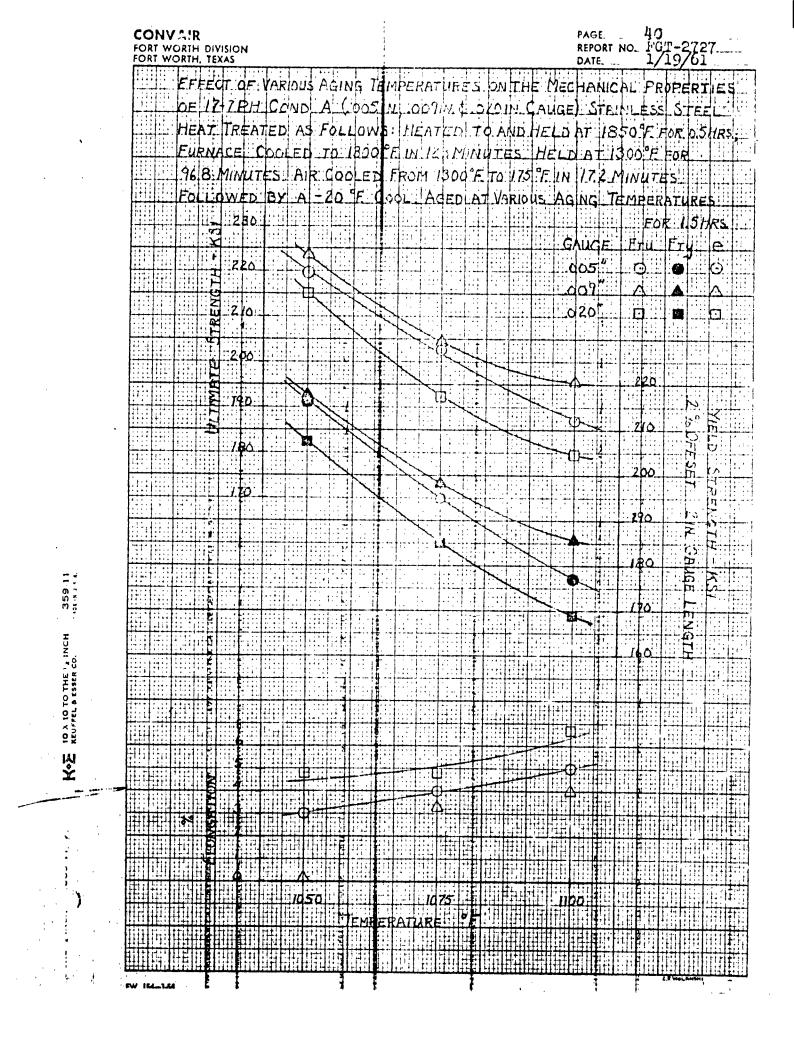
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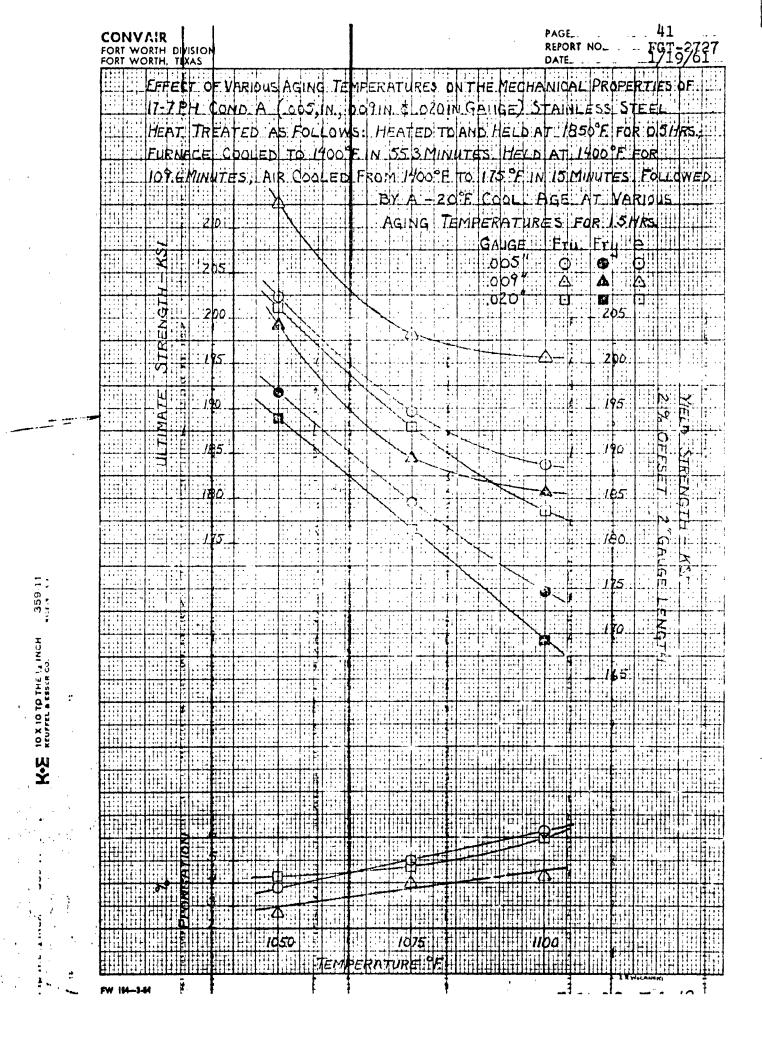
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|                     |     |                  |                             |           |                   |             | (          | Þ5.         | +           |   | •        |             |           |              | <b>-</b> - ; |                    | •                   |            |             |                         |  |              | 0            |                    |                     | 1          | + -             |               |                         |              | •             |
|                     |     |                  |                             |           |                   |             |            |             |             |   |          |             |           |              |              | <u> </u>           | ·   · · ·           | +          |             | +                       | ÷                                      |              |              |                    |                     | <u>.</u> ; | :               |               |                         |              | -             |
| •                   |     | :::::<br>        |                             |           |                   | 4           |            | po.         |             |   | <u></u>  |             |           |              |              |                    |                     |            |             |                         |  |              |              |                    |                     |            | :::::<br>-::::: |               |                         |              |               |
|                     |     |                  | 111<br>1                    |           | : <b>X</b><br> -1 | 7           | <u>.</u>   |             | <u> </u>    |   |          | N           |           |              |              | ļ.,                |                     |            | :<br>       |                         | 1                                      |              |              |                    |                     |            | :               |               |                         |              | í             |
|                     |     |                  |                             |           | .1                |             | ľ          | 75_         |             |   | P.       |             |           | $\mathbb{N}$ |              | 1                  |                     | ļ. •.      |             |                         |  | <u> </u> :   |              |                    |                     |            |                 |               |                         |              |               |
|                     |     | i i i i i        |                             |           |                   |             | •   •      |             |             |   |          |             |           |              |              |                    |                     | İ.         |             | 1                       |  |              |              |                    |                     |            |                 | 206           | 1                       |              | 1             |
|                     | ,   |                  |                             |           |                   | H           |            | 20          | :           | 1.11  |          |             |           | $\mathbb{N}$ |              | $\mathbb{N}$       | · ·                 | +<br>      |             | 1 :                     | 1 .                                    | <b>†</b>     | 1            |                    | 1                   |            |                 |               |                         | <u> </u>     | -             |
|                     |     |                  |                             |           |                   | š           |            | 10          |             |   |          |             |           | े            |              | Ľ.                 |                     |            |             |                         |  |              | †:           |                    |                     |            |                 |               |                         |              | Ì             |
|                     |     |                  | •                           |           | ij                | 7           |            | ╎           | <u> .</u>   | ++++  | +        |             |           | ÷            | >            | 1                  | <u>'</u>            | 12-        |             | +                       |  | 1            | <u> </u> -   | 1                  | <u> </u>            |            |                 | 95            |                         | - <u></u> -  | _             |
|                     |     |                  |                             |           |                   | 4           | [          | <b>5</b> 5. | $\vdash$    | - <b> </b>                                    |          |             | : .   .   |              | •• • •       |                    | • • •               |            |             | ŧ                       | :'<br>                                 |              | ;            | ;                  |                     |            |                 | -             |                         |              | -             |
|                     |     |                  | <u></u>                     |           |                   |             |            | <u> </u>    | <u></u> -   | -   |          |             |           |              |              |                    | ··{                 |            | her-        | <u>.</u><br>            |  |              |              |                    | ¦ '<br><del> </del> |            |                 | \$j           | 10                      | <u></u>      | -             |
|                     |     |                  |                             |           |                   | <u></u>     |            | BO L        |             | $\sum$  | ],>      | جلر:        | 1         | ]            |              | ••••               | · · · · ·           | Ĺ.         |             |                         | N.<br>Ny S                             |              | 1            |                    | E.:.                |            |                 | .<br> .       | %                       |              | 1             |
|                     |     |                  | <u> </u>                    |           |                   | 3:          |            | r ·         |             |   | Ĩ.       |             | <u> \</u> |              | : •          | ŀ                  | ,<br>,<br>,         | 1          |             |                         |  | Ľ            |              | 1*                 |                     | 1          | ÷,              | 55            | Q.                      | Nie -        | .             |
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|                     |     |                  |                             |           | <u> </u> .        | : .         | 7          |             | Γ           |   |          |             | ~         |              |              |                    |                     |            |             |                         | IN.                                    |              | N            |                    |                     |            |                 | B0            | 1                       |              |               |
|                     | i   |                  |                             | :         |                   | :           |            |             | <u> </u>    | 1   | 1::      |             |           | 2            |              | <b>`</b>           | 5                   |            |             | 1                       | •                                      |              |              | N.F                |                     |            |                 | 1.<br> -      | i manana<br>i           | 1<br>1<br>1  | t             |
| -                   |     |                  |                             |           |                   |             |            | 70_         |             |   |          |             |           | =            | 1            |                    |                     | <b>)</b> – |             |                         | <u>       </u>                         | l· :ī        |              |                    | N.                  |            |                 |               |                         | 2            | 1             |
| <b>9</b> . 10       | -   |                  | ••••                        | · · · · · |                   |             |            |             |             | 1   |          |             |           |              | <u> </u>     | 2                  | <del></del>         |            | <u>.</u>    |                         |  |              |              | 13                 |                     |            |                 | <u>75</u> _   |                         | n.           | 1             |
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| ń                   |     |                  |                             |           |                   |             |            |             |             | ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ;         |          |             |           |              |              |                    |                     |            |             | X                       | •••••••••••••••••••••••••••••••••••••• | · · · · ·    | <u> </u>     |                    |                     |            | 1               | <u>to </u>    | ž.                      |              |               |
| Ŭ                   |     |                  |                             |           |                   | 1           |            |             |             | ↓. :<br>↓                                     |          |             |           | , i          | : .<br>      | •                  | . <b>!</b><br> +⊥-! | 5          |             |                         | $\sum_{i=1}^{n}$                       |              |              |                    |                     |            |                 |               | 2                       | X'S          | İ             |
| 5<br>6<br>1         |     | <u>.</u>         |                             |           | i t               |             |            |             |             |   |          |             |           | :            |              | •••                |                     |            | X           | K.                      | N                                      |              |              |                    |                     |            |                 | 65            | a)<br>In                |              |               |
| KEUFFEL & ESSER CO. |     |                  |                             |           |                   |             |            | ::::<br>:   |             |   |          |             |           |              |              |                    |                     |            | 3           | $\overline{\mathbb{N}}$ | N:!!                                   | X            |              | E                  |                     |            |                 |               | LENC                    |              | ł             |
|                     |     |                  |                             |           |                   |             |            |             |             |   |          | ł           |           |              |              |                    |                     |            |             |                         | Ň                                      |              | $\mathbf{N}$ |                    | 1                   |            |                 |               | NC 1                    |              | t             |
|                     |     |                  |                             | 1.11      |                   |             |            | H H         | itir        |   |          |             |           |              |              |                    |                     | 2112       |             | - 4                     | <br>11.11                              | $\mathbf{X}$ | <u> </u>     |                    |                     | 111        |                 | 60            | *-                      | <u>.</u><br> | 4             |
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|                     |     |                  |                             |           |                   |             |            |             |             |   |          |             |           |              |              |                    |                     |            | -           |                         |  |              |              | $\mathbb{H}$       |                     |            |                 | -5            |                         |              | +             |
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|                     |     |                  | H                           |           | Z num z           |             |            |             |             |   |          |             |           |              |              | 111<br>            |                     |            |             |                         |  |              |              | <b>)</b>           | il:                 | U <b>I</b> |                 |               |                         |              |               |
|                     |     |                  |                             |           |                   |             |            | 詽           | [[F]        |   |          | ++          |           |              |              |                    |                     | ii ri      |             |                         |  |              | 1            |                    |                     |            | <u>li ii</u>    |               |                         |              | İ             |
|                     |     |                  |                             | Hil       | K                 | I           | 12         |             | 1           | HI  |          |             |           |              |              | . i j i<br>. j j i | (                   | 끮          | <b>;</b> ;; |                         | THE                                    |              |              |                    | L.                  |            |                 |               |                         | :Fi          | ł             |
| •                   |     |                  |                             | *****     |                   |             | Ħ          | 間           |             | Ľ   | Pitt     |             |           |              |              | · • • • •          |                     | Шİ         |             |                         | 詽                                      |              |              |                    |                     | ₩          |                 |               |                         |              | ł             |
| •                   |     |                  |                             |           | 6                 | ⋕           |            |             |             |   |          |             |           |              |              |                    |                     |            |             |                         |  |              |              |                    |                     |            |                 |               |                         |              | ł             |
|                     |     |                  |                             |           | H                 | $\ $        |            |             |             | 10  | 50       |             |           |              |              |                    | 10                  | 75 °       |             |                         |  |              | ЩИ           | 20                 |                     | ЦĮ         |                 |               |                         |              | ļ             |
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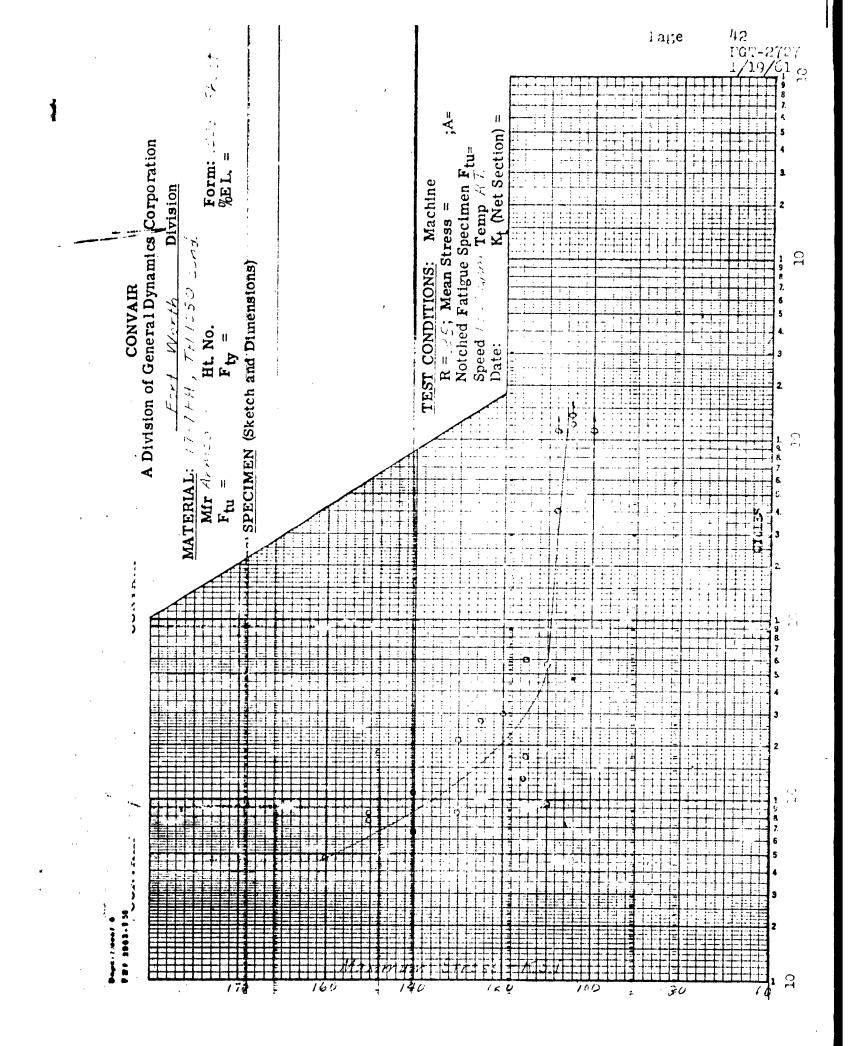
|                 |                  |             |           |                        |              |   |            |                    |                                       |                  |                   |                  |              |          |           |         |                        |                  |                       |                         |            |          |  |            |               |              | ,          |                    | ۲<br>۲      | ror<br>LLJ   | [-2       | 72<br>61 | 7<br>1757 | <del>.</del>        |
|-----------------|------------------|-------------|-----------|------------------------|--------------|---|------------|--------------------|---------------------------------------|------------------|-------------------|------------------|--------------|----------|-----------|---------|------------------------|------------------|-----------------------|-------------------------|------------|----------|--|------------|---------------|--------------|------------|--------------------|-------------|--------------|-----------|----------|-----------|---------------------|
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|                 | - 1    <br> <br> | 1           |           |                        |              |   |            | <u>i</u>           | 5                                     | \$               |                   | <u></u>          |              | <b>.</b> |           | · • • • |                        |                  |                       |                         |            | -        |  |            |               |              |            |                    |             |              |           |          |           |                     |
|                 |                  | <u></u>     |           |                        |              | - 21  | 0          |                    |                                       | 4                |                   | V                |              | ţ.       |           |         |                        |                  |                       |                         |            |          |  |            |               |              |            |                    |             |              |           |          |           |                     |
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|                 |                  |             |           |                        |              |   |            |                    |                                       |                  |                   |                  |              | L.       |           |         |                        |                  | $\frac{1}{\sqrt{2}}$  |                         |            |          |  | · • •      |               | 1            |            |                    |             |              |           |          |           |                     |
|                 |                  |             |           | ire                    |              | 20  | 20<br>11:  |                    |                                       |                  | ••••  <br>• • • ! |                  |              |          |           |         |                        | $\sum_{i=1}^{n}$ |                       | $\overline{\mathbf{X}}$ |            |          |  | • • • • •  |               | · • • • •    |            |                    |             |              |           |          |           |                     |
|                 |                  | ŜŦF         | EA        | 167                    | h            |   | 5          |                    | ·  <br>                               | •                |                   | · · · ·          |              |          |           |         |                        | <br>ر            | ``.`;<br>`.`,         |                         |            |          |  |            | · · · · ·     |              |            | -++-               | 2           | 05           |           |          |           |                     |
|                 |                  |             | KS        | 1) - <del>7</del><br>- |              |   | .:<br>1    | <u>е</u> :<br>Г. і |                                       |                  |                   |                  | -            |          |           |         |                        |                  | $\overline{}$         |                         | <u> </u>   |          | $\frac{1}{2}$                                  | <u>.</u>   |               |              |            |                    |             | 00           | <u>.</u>  |          | :         | - <u> </u> ;<br>; ; |
|                 |                  |             |           |                        |              | - 19  | 0          | -<br>-             | : <u> .</u><br>:                      | 3                |                   |                  |              |          |           |         |                        |                  | ·                     |                         |            | N.       | X.<br>   | viine<br>X |               | ി."          | 17.<br>Ft: |                    |             | r            |           |          |           | t i                 |
|                 | : '              | <u>_</u>    |           | _                      |              | Ā   | 35.        |                    |                                       |                  |                   | :                | · :<br>  . : |          |           |         | /                      | 5                | • • • •               |                         |            |          |  | . ?<br>    |               |              |            |                    |             | 95           |           |          |           |                     |
| l               |                  |             |           |                        | ;            |   | :.<br>     | 4.<br>  -          | .1<br>                                |                  |                   |                  | <u>}</u>     | 4<br>    |           |         | •.<br>                 | •                |                       |                         | •.<br>•    | <u>.</u> |  | <u>``</u>  | $\frac{1}{D}$ | <-           |            |                    |             | <br>         | ΄. Υ<br>Ι | '!∉l     | LD.<br>St |                     |
|                 |                  |             | :<br>     | -1<br> <br>            |              | _4  | BO.        |                    | ندر .<br>مدانی<br>ا                   |                  |                   | •••              | ;:           |          |           |         |                        | . :              | `\                    |                         | • • •      |          | <b>لا</b> بين<br>ا                             | X          |               | ۰ <b>۱</b> ۳ |            | . <del>:    </del> |             | 90           | <br>      | 10.0     | H'S       | n.                  |
|                 |                  | <br> <br>   |           |                        |              |   | 75         | -                  |                                       |                  | · · · · · ·       |                  |              |          |           | 1       |                        |                  | •<br>• `<br>•1        |                         |            |          |  |            |               | 005          | 5 <b>F</b> | гц                 |             | 85           | 1.2       | "G       | С≓<br>Au  | F S<br>IGE          |
|                 |                  |             |           |                        |              | · · ·   |            | -                  | :                                     | ;<br>;<br>;      | • •               | , '<br>;         | -            |          | . <br>    | -       |                        |                  | <i>مر</i> .<br>۲۰۰۰ ۲ |                         |            | () (<br> | ، ``   |            | 1             | 01           |            |                    |             | <del>.</del> |           |          | 15        | he                  |
| •               |                  | ':<br><br>{ |           |                        | -            | ::<br>:-::<br>::::<br>::::::::::::::::::::::::: | · · ·      |                    |                                       | ان <u>۔</u><br>ا |                   |                  |              |          |           |         | • • •<br>• • • •       |                  | ·· •                  |                         | ,<br>N     |          |  |            | 1.7           | · † · •      | FT         |                    | 1           | 90.<br>1     | ! .       |          |           |                     |
| TE BOTH         |                  | :           | ·   · · · |                        |              |   |            |                    |                                       |                  |                   | <br>  :<br>  :   |              |          |           |         | 1                      | +<br><br>        | • •<br>  ·<br>1. ·    | +<br>                   | Ì          |          | . T:   |            |               | 69<br> }     |            |                    | : <b>/</b>  | <b>7</b> 5.  |           |          |           |                     |
|                 |                  |             |           |                        |              |   |            |                    | •                                     | :.  <br>:        | :                 | <u> </u>         |              | A Starts |           | -       | <br>                   |                  | ·                     |                         |            | <u> </u> | <b>\</b>                                       |            | ĽΥ            |              |            | 111                | . 11        | . 11         | I I.      |          |           |                     |
| 0<br>1<br>1     |                  | · 1<br><br> |           |                        |              |   |            | 1                  |                                       |                  | •                 | 11<br>           |              |          |           |         |                        |                  |                       |                         |            |          | ->)<br>:-H                                     | N          |               |              | 5 61       | -4-                |             | 70           |           |          |           |                     |
| KEUFFEL A ESTIT |                  | Ē           |           |                        |              |   | 4          | 1                  | · · · · · · · · · · · · · · · · · · · |                  |                   |                  |              |          |           |         |                        |                  | 1.1                   |                         |            |          | •  |            |               |              |            |                    | _ /         | 65           |           |          |           |                     |
|                 |                  |             |           |                        |              |   |            | 1                  |                                       |                  |                   |                  |              | 7        |           |         |                        | ::<br>           |                       |                         |            |          |  |            | $\downarrow$  | +10          | 20         | "P1                | 4           |              |           |          |           |                     |
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|                 |                  |             |           |                        |              |   |            |                    |                                       |                  |                   |                  |              |          |           |         |                        |                  |                       |                         |            |          |  |            | <b>d</b>      | 1            | 6          | 09                 | e           |              |           |          |           |                     |
|                 |                  | 1,141       |           |                        |              |   | 5          |                    | -                                     | E                | <b>a</b>          |                  |              | 博        |           |         |                        |                  |                       |                         | #          |          | T : ا<br>الله الله الله الله الله الله الله ال |            | Ł             |              | 20 0 0     | <b>6</b> 5         | "e          |              | <br>      |          |           |                     |
|                 |                  | E           | ØŴ        | GA                     | E IO         | W   |            |                    |                                       |                  |                   |                  |              |          |           |         |                        | ₽<br>            |                       |                         |            |          |  |            | Δ             |              |            |                    |             |              |           |          |           |                     |
| :               |                  |             |           |                        |              |   |            |                    | t :                                   |                  | ₿                 | بينيان<br>موجو ا |              | 1        | 1         | +       |                        | 0                | 1                     |                         |            | ļi.      | 1  |            |               |              |            |                    |             |              |           |          |           |                     |
| <u>)</u>        |                  |             |           |                        |              |   |            |                    |                                       | 10               | 50                |                  |              | Τ.       | +         | 1       | <b>C R r</b><br>1 + †1 | 075              |                       |                         | I STEED    |          |  |            | 1100          |              |            |                    | 14 :-       |              |           |          |           |                     |
| :               |                  |             |           |                        | :::!<br>.1*: |   |            |                    |                                       |                  | 11                |                  |              | - LU     | TE        | A F     | CRI                    | tu               | 4                     | •                       | 2          |          |  |            |               |              |            |                    | <u>ti i</u> |              | ЦĽ        | ЩË       |           | <u></u>             |

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| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$   |                      |         | 1884     | 196.5                                  | 8.0                                      | 205.7       |                  | 2.1                                   | 15       | M.                                    |                       | 0.0                       |
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| 3R $13R0$ $19R0$ $55$ $1015$ $55$ $1015$ $55$ $1015$ $523$ $722$ $1717$ $1272$ $1325$ $55$ $1015$ $55$ $1015$ $252$ $2233$ $722$ $3C$ $1717$ $1275$ $55$ $1115$ $2017$ $2027$ $2233$ $722$ $3C$ $1717$ $125$ $55$ $1115$ $2017$ $2027$ $2292$ $5293$ $1716$ $1771$ $125$ $455$ $22027$ $2593$ $5202$ $1716$ $1771$ $55$ $1015$ $2017$ $2027$ $2592$ $2563$ $2017$ $2027$ $2027$ $2027$ $2027$ $2027$ $2057$ $55$ $1716$ $1777$ $225$ $2127$ $2252$ $22027$ $2557$ $55$ $1717$ $2202$ $257$ $2027$ $2557$ $55$ $1717$ $2252$ $22027$ $2557$ $2567$ $55$ $1717$ $22027$ $22027$ $2567$ $2567$ $2567$ $55$ $1756$ $1226$ $22027$ $22027$ $2567$ $2567$ <t< td=""><td>(22 1 1 1 1<br/>cover</td><td></td><td>1276</td><td>1455</td><td>6.7</td><td></td><td></td><td></td><td>7</td><td>1</td><td></td><td></td></t<>  | (22 1 1 1 1<br>cover |         | 1276     | 1455                                   | 6.7                                      |             |                  |                                       | 7        | 1                                     |                       |                           |
| 3R     1820     1920     1930     55     1715     2115     55     1715     2115     222     1930     2233     72       1921     1912     1912     1913     55     1115     211     2233     72       1912     1912     1911     1911     211     255     1115     211     2233     2291     2533     72       1912     1912     1711     25     2017     2013     35     22021     2593     50       1912     1711     25     2016     2017     232     2523     2523     2533     25       1912     1711     25     2103     315     25     22027     2523     25       1912     1711     25     2103     215     252     2523     255     25       1912     171     25     2103     255     2103     255     25     25       1713     253     212     252     2521     255     25     25       172     253     252     2521     25     2502     255     25       172     253     252     2521     2521     255     255     255     255       172   | 1 79 612             |         | 0,01     |  |  |             |                  |                                       |          |                                       |                       | 9                         |
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| $ \begin{array}{ c c c c c c c c c c c c c c c c c c c$  |                      |         | 1872     | 1930                                   | )<br> <br>                               | 1.5.6.1     |                  | 5                                     | 5        |                                       |                       | 0                         |
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| 36 1911 1967 45 2017 2013 35 2002 2054 50<br>1912 1913 1914 15<br>1912 1913 1914 15<br>1912 1915 1714 5<br>1916 1714 5<br>1916 1714 5<br>1916 1714 5<br>1917 252 2012 55<br>2103 2321 45<br>1912 1724 55<br>2103 2321 45<br>2103 2321 45<br>2103 2321 45<br>2103 2321 45<br>2103 2321 45<br>2103 2321 45<br>2103 2321 45<br>2103 2321 45<br>2103 2321 45<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 212 20<br>2113 215 20<br>2113 215 20<br>2113 215 20<br>2113 215 20<br>2113 215 20<br>2113 215 20<br>2113 215 20<br>2113 215 20<br>2113 215 20<br>2113 215 20<br>2113 215 20<br>2113 215 20<br>2113 215 20<br>2113 215 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>2113 20<br>211   | ERAGE                |         | 1577     | 0:51                                   | 5.5                                      | 1.1.5       |                  | 2 2                                   | <b>`</b> |                                       |                       |                           |
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| 20 $1914$ $171$ $45$ $115$ $171$ $45$ $115$ $171$ $45$ $115$ $171$ $45$ $111$ $171$ $45$ $111$ $171$ $45$ $121$ $2111$ $211$ $211$   | 56                   | -       | 192.2    | 1973                                   | 60                                       | 11          |                  |                                       |          |                                       | - •                   | ð                         |
| 20     1916     171     201 <td>57</td> <td></td> <td>1914</td> <td>1. 1. 1. C. 1. 1.</td> <td>ر کر<br/>کر</td> <td>Ì</td> <td>'<br/>'<br/>\<br/>{</td> <td></td> <td></td> <td>· · · · · · · · · · · · · · · · · · ·</td> <td></td> <td>•</td>  | 57                   |         | 1914     | 1. 1. 1. C. 1. 1.                      | ر کر<br>کر                               | Ì           | '<br>'<br>\<br>{ |                                       |          | · · · · · · · · · · · · · · · · · · · |                       | •                         |
| 20. 17.21.17.1 25. 1.1.5 1.1.2 1.2. 1.2. 1.2. 2.2.2. 45. 17.5 2.2. 17.5 2.2. 2.2.2.2 2.2.5 2.2. 2.2. 2.2. 2.   | ERACE                |         | 1916     | 1261                                   | ر از از از از از از از از از از از از از |             |                  | · · · · · · · · · · · · · · · · · · · | 57       |                                       |                       |                           |
| $\frac{17}{12} = \frac{17}{12} = 17$ |                      |         |          |  |  | ۱.<br>-     |                  |                                       |          | 1.                                    |                       |                           |
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|  |                      |         | 127      | 11/1                                   |  | 「シントーー      |                  | 10                                    |          | 200                                   |                       |                           |
|  | 193                  |         | 1671     | 10:01                                  |  | ~ ~ ~ ~ ~ ~ | 2/50             | 1 C<br>V<br>V                         | •        |                                       | a<br>A<br>A Vo        | Υ <sup>Ω</sup>            |
| HT-3     Heat     te     1912     127     201     212     212     212     212     212     212       HT-3     Heat     te     1912     127     20     197     212     20     201     212     20       HT-3     Heat     te     1910     41     42     1970     201     201     201     202     202     202     202     202     202       HT-3     Heat     te     1275     te     1270     201     201     202     202     202     202     202     202     202     202       HT-3     Heat     te     1275     te     1276     te     1270     te     1272  | 124                  |         | 1959     | 1010                                   |  | ► // C      |                  | 1 4<br>1 1                            | 1        | 00 651                                |                       |                           |
| -3E - 1914 1975 45 1977 2236 5.0 1967 204 25 50<br>1912 1912 1975 20 2017 95 75 50<br>1912 1912 1975 35 1979 2010 2017 95 2009 2057 60<br>1925 1942 35 1979 2010 2021 95 2009 2057 60<br>1979 1048 47 1999 2052 60<br>HT-3 Heat to 1210 E that 9 min A tsur<br>Cool aut at Eurise to B t30 E 20F   | 125                  |         | 1251     | 50.                                    |  |             | 、 ~              | 1 2                                   |          |                                       |                       | 5                         |
| -35 - 1914 1975 41977 2.36 50 1927 2.4. 70<br>   | LERAGE               |         | 194: 2 . | 1. 1                                   |  |             | 10202            | 3.7                                   | 1-4      |                                       |                       |                           |
| 32     1912     1275     3.0     1977     3.36     5.0     1977     3.64     7.0       1912     1275     3.0     2010     2017     7.5     5.0     1977     2.64     7.0       1     1283     177     3.5     1970     2.021     45     2.003     2.557     5.0       1     1     1     177     3.5     1973     704     45     2003     2.557     5.0       1     1     1     1     45     2003     2.557     5.0       1     1     1     104.8     47     1489     2.553     6.3       1     1     1     104.8     47     1489     2.553     6.3       1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1       1   |                      |         |          |  |  |             |                  |                                       |          |                                       |                       | 1                         |
| 1912     1224     3,0     2010     2027     45     2009     2557     60       1     1/233     1/77     3.5     1/970     2041     45     2002     2057     60       1     1/235     1/77     3.5     1/970     2041     45     2002     2057     60       1     1/755     1/72     3.5     1/970     2041     45     2000     2057     60       1     1/755     1/72     3.5     1/971     1058     4.7     1/989     2053     6.3       1     HT<-3   | - 25                 |         | 191.91   | 1775                                   | 57                                       | 1527        | 22.26            | 5.0                                   |          | N                                     | -                     | $\langle \langle \rangle$ |
| 25     1     1     1     1     1     2000 2057 60       25     1     1     1     2     2     1     2     2       26     1     1     1     2     3     1     3     4     1     2       1     1     1     1     1     2     3     1     1     2     2       1     1     3     1     1     1     3     3     3     3     3       1     1     3     1     1     3     3     3     4     3     3       1     1     1     1     1     1     1     1     3     3     5     5     5       1     1     1     1     1     1     1     1     1     3     5 <td>62</td> <td>•  <br/> </td> <td>191.2</td> <td>1224</td> <td>07</td> <td>2010</td> <td>2227</td> <td>50</td> <td>72</td> <td>0-01</td> <td>r,</td> <td>0</td>   | 62                   | •  <br> | 191.2    | 1224                                   | 07                                       | 2010        | 2227             | 50                                    | 72       | 0-01                                  | r,                    | 0                         |
| 1     1 <td>63</td> <td></td> <td>123.3.</td> <td>1573</td> <td>3.5</td> <td>1920</td> <td>2021</td> <td>4 5</td> <td>ř</td> <td>0 20</td> <td></td> <td>0</td>  | 63                   |         | 123.3.   | 1573                                   | 3.5                                      | 1920        | 2021             | 4 5                                   | ř        | 0 20                                  |                       | 0                         |
| - 3 Heat to 1240F & hald 90 min A +54F<br>Cool aut at fucuised to min B +30F   | CRAGE                |         | 5        | 1742                                   | 35                                       |             | 104.8            | 4.7                                   | 7        | 0                                     | 53                    | 3                         |
| Cool ant at furniss to min 12 t30F   | 11                   |         |          |  |  | // //       |                  |                                       |          |                                       |                       | -6                        |
| 104 at turning to  | -712                 |         |          |  | 100                                      | pold .      |                  | <u>}</u>                              | *        |                                       | -+-                   |                           |
|  |                      | -+-     | 4        | +                                      | t turk                                   | 1-2-20      |                  |                                       | +        |                                       |                       | - (                       |

| •         |          |            |  | Į.                 |                        |
|-----------|----------|------------|--|--------------------|------------------------|
| CONV      | AIR FORT | NÖRTH 7005 | CONVAIRFORTWÖRTH 7005, 0.018, 0.020, 7A8L<br>TABULATION. SHEET-0.040, 0.063, 2, 0.085, 6464  | E, 17-7PH STEEL    | TENSILES I             |
|           | HFAT     | GRAIN      | M.174  | 1 2 900            | 2685 6465 2141         |
| SAMP NO T | REAT     | DIR        | the transformed and transformed and the transf | τ <mark>τ</mark> α | ۲ <u>ـ</u>             |
| 000       | 02       | 1040       | 1.6.   | 1924               | 8 12                   |
| 201       |          | han        | 5 1894   | 2026               | 5.0 1                  |
| 122       |          | -          |  | 1991 2015 - 40     | 1                      |
| AVERAGE   |          |            | 1786 1103 7.5  | 6 1071 0           |                        |
|           |          | -          | -  -<br>  -  | 131 8 21 55 70     | 1766 1927 11.0         |
| 23        | 30       |            | 1201 1761 60   | 2652               | 171.2                  |
| 124       |          |            | •<br>••• •   | 1221               | 1733 1337 23           |
| 01150125  |          |            | 5  | 127 - 2521 63      | 1744 1122 127          |
| 72120     |          |            | 1  |                    | - ( 1                  |
| +         | UFAT     | GRAIN'     | 6000 549E 1227   | 2228 5355 1144     |                        |
| ON GUEVS  | TREAT    | 01/5       | - Kel 5 - Kel  | Fritter Eren Le    | 6-431 15-4             |
|           | 4 12     |            | · · · · · · · · · · · · · · · · · · ·  |                    | 1/7/ 122: 5            |
| 144       | 2        | Long.      |  | 1627 1271 52       | 16 167 16791           |
| 45        |          |            | , , , , , , , , , , , , , , , , , , ,  |                    | 1121                   |
| 1410      |          |            |  | 1221 2221          | 173.2.1 5              |
|           |          | <b>k</b>   |  |                    |                        |
|           |          |            |  |                    | free an Inc. F         |
| H.T3      | Heat     | 140        | 04 P   |                    | 40 17 75 F             |
|           | 1007     | e f        | TURNACC LJ:  | F16 000            | 1000 1275 F. to 1120,5 |
|           | t        | 16         |  | 11 36              | OULS                   |
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|           | 472      | 50-10-0    |  | +                  |                        |
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|           |          |            |  |                    |                        |

CONVAIR Fort worth

TABLE IAI

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| 34     Long     320.0     4.0     192.6     192.6     200.6     60       191.6     191.6     191.6     191.6     191.6     191.6     60       191.6     191.6     191.6     191.6     191.6     191.6     60       101.6     202.6     203.6     4.0     191.6     191.6     60       101.6     202.6     203.6     4.0     191.6     191.6     60       101.7     202.6     203.6     4.0     191.6     201.7     60       101.7     202.6     203.6     4.0     191.6     201.7     60       201.7     202.6     203.6     4.0     191.6     201.7     60       201.7     203.6     4.0     202.7     203.7     202.7     202.7       201.7     203.6     203.6     203.6     203.6     203.7     202.7       201.7     203.6     203.6     203.6     203.6     202.7     202.7     202.7       201.7     202.7     202.7     202.7     202.7     202.7     202.7     202.7       201.7     203.7     203.7     203.7     203.7     203.7     203.7     203.7       201.7     203.7     203.7     203.7  | SAMP NO TREAT  | GRAIN<br>DIR     | 12.451          | 175V-1-        | Má12<br>%C | 0.010                                 | 6.46E        | MAT'L<br>%C | C.020<br>Fr-451 | 15455                     | MAT'I<br>:.e       |
|--|----------------|------------------|-----------------|----------------|------------|---------------------------------------|--------------|-------------|-----------------|---------------------------|--------------------|
| 1     1     1     1     1     202.0     205.5     50     172     70       1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1       1     1     1     1     1     1     1  |                | Lona             | 2020            | 208.0          | 40         | 1661                                  | 1000         | 07          | 1950            | 2752                      | 2                  |
| 14     14     14     14     14       14     206.     206.     4.0     171.     171.     171.     171.       17.     206.     206.     206.     206.     171.     171.     171.       17.     201.     216.     216.     217.     171.     171.       17.     201.     216.     216.     216.     211.     211.       21.     217.     217.     217.     217.     211.       21.     217.     217.     217.     211.     211.       21.     217.     217.     217.     211.     211.       21.     217.     217.     217.     217.     211.       21.     217.     217.     217.     217.     212.       21.     217.     217.     217.     217.     217.       21.     21.     21.     21.     21.     21.       21.     21.     21.     21.     21.     21.       21.     21.     21.     21.     21.     21.       21.     21.     21.     21.     21.     21.       21.     21.     21.     21.     21.     21.       21.     21. <td></td> <td></td> <td></td> <td></td> <td></td> <td>1892</td> <td>1972</td> <td>02</td> <td>1007</td> <td><del>-</del></td> <td>マイ</td>   |                |                  |                 |                |            | 1892                                  | 1972         | 02          | 1007            | <del>-</del>              | マイ                 |
| 191     191     191     191     191     191       111     111     111     111     111     111       111     111     111     111     111     111       111     111     111     111     111     111       111     111     111     111     111     111       111     111     111     111     111     111       111     111     111     111     111     111       111     111     111     111     111     111       111     111     111     111     111     111       111     111     111     111     111     111       111     111     111     111     111     111       111     111     111     111     111     111       111     111     111     111     111     111       111     111     111     111     111     111       111     111     111     111     111     111       111     111     111     111     111     111       111     111     111     111     111     111       111     111     111 <td>V. I. I. I. V.</td> <td>•<br/>•<br/>•<br/>•</td> <td>10.201 - 102.De</td> <td>2.9050</td> <td></td> <td>·185.62</td> <td>1521</td> <td>50.</td> <td>1946</td> <td></td> <td>50-</td>   | V. I. I. I. V. | •<br>•<br>•<br>• | 10.201 - 102.De | 2.9050         |            | ·185.62                               | 1521         | 50.         | 1946            |                           | 50-                |
| 3A'     13256 2096 9.3     1737 50     195       3A'     218.7     2255     1.5     225.9     195       3A'     218.7     2255     1.0     229.7     20     195       218.7     2255     1.0     225.7     21.2     21.2     21.2       218.7     225.5     1.0     225.7     21.2     21.2     21.2       218.8     225.5     1.0     225.7     21.2     21.7     21.2       219.8     225.5     1.0     225.7     21.7     20     21.7       219.8     225.5     1.0     225.7     21.7     21.2     21.7       219.8     225.5     1.0     225.7     21.7     20     21.6       219.8     225.1     2.1     2.5     225.7     21.7     21.1       219.8     22.7     2.5     22.8     2.1     21.1     21.1       219.9     21.4     2.1     2.1     2.1     21.1     21.1       219.9     21.4     2.1     2.1     2.1     21.1     21.1       219.9     21.1     2.1     2.1     2.1     21.1     21.1       219.9     21.1     2.1     2.1     2.1     21.1     21.1   <   |                |                  | 200.8           | 206.5          |            | 131.5                                 | 1984         | 60          | 197.4           |                           | 5.0                |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$   | in the second  |                  | Sr 6.5          | 12 4/21        |            | 186210                                | 195.7.       | 50          | 1950            |                           | 50)                |
| 34 2187 2254 15 206.9 2123 - 211<br>212 2251 10 2292 2121 40 211<br>2139 2251 10 2292 2121 40 211<br>2199 2271 20 2252 2121 40 211<br>2199 2271 20 2252 2121 40 211<br>2199 2271 20 2052 15 201<br>2199 2271 20 2052 15 201<br>2199 2271 20 205 15 201<br>2199 2271 20 200 45 45 45 45 45 40 45 40 40 40 40 40 40 40 40 40 40 40 40 40   | AVERAGE        |                  | 2026            | 2026           |            | 129.7                                 | 1927         | 0,9         | 1965            |                           | n<br>V             |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$   | -              |                  |                 |                |            |                                       |              |             |                 |                           |                    |
| 49-91 1050 - 4-12 2011 40 211 40 211<br>Heat to 1400 - 4 - 12 2052 112 2052 2171 40 211<br>2199-217 20 2052 12 201<br>2199-217 20 2052 12 20<br>2199-21 1050 - 4 - 12 - 12 - 211<br>179-21 1050 - 4 - 12 - 12 - 12 - 12 - 12 - 12 - 12   |                |                  | 1.1.4           |                |            | 7.707                                 |              |             |                 | <b>N</b>                  | 5                  |
| 1     1 <td></td> <td></td> <td>1.0/2</td> <td></td> <td>1.0.</td> <td>7707</td> <td>20</td> <td>4.0</td> <td>r</td> <td>14 1<br/></td> <td></td>  |                |                  | 1.0/2           |                | 1.0.       | 7707                                  | 20           | 4.0         | r               | 14 1<br>                  |                    |
| $\begin{array}{ c c c c c c c c c c c c c c c c c c c$   |                |                  | 12/2            | 1440.1         |            |                                       | 21112        | 4.0         | 2112            | 2251                      |                    |
| $\frac{Het}{Het} = 1914 = 252 + 5 = 2024 = 124 + 2 = 211 + 12 = 12 = 12 = 12 = 12 = 12$  | <u></u>        |                  | 5510            | モーレート          | Lakimments |                                       | -1.5.1+      | 10          | 107-            |                           | <b>)</b>           |
| Het to 1406 \$ h.11 50 m. HT.3h. 101 100 5 4<br>metal and of larnace to 454 F HT.3h. 100 5 4 100 5 4<br>Age at 1050 F to 30 mm. 199 at 350 50<br>  | - 411-24CE     |                  | 7 6 6 6         |                |            |                                       |              | 1           | <u></u>         |                           |                    |
| Heat to 1400 A h. 12 Fin. H. 3h. 1.2. 120 F f<br>ne front out of turning to 154 Fin. H. 3h. 1.2. 120 F f<br>Ag al 105 L F tr 32 min.<br>Ag al 105 L F tr 32 min.   |                |                  |                 |                |            |                                       | يتعادف فكمعا |             |                 |                           | , j                |
| Heat to 1406 A h. 12 Firm, HT. 3h. 1 + + 120 E A<br>no Erret and at humace to + + 54 F HT. 3h. 1 - + + + + + + + + + + + + + + + + + +   |                |                  |                 | <br> <br> <br> | · · · ·    | •                                     | • •          |             |                 |                           |                    |
| Heef to 1400 A h. 12 Jun.<br>41.34 12.5 A 12 Jun.<br>49. al 105 1 40 - 10 120 - 10 - 1 |                |                  |                 |                | •          | •                                     |              |             |                 |                           | ι                  |
| 192 al 1056 75 72 mm.<br>192 al 1056 75 72 mm.<br>192 al 1056 75 75 75 75 10 10 10 10 10 10 10 10 10 10 10 10 10   | 7 34           | ot t             | -4              | 1.1 7.         |            | 47.72                                 | 1 t          | +           |                 |                           |                    |
| Age al 105ú Fár 32 mm.<br>196 al 15ú Fár 32 mm.  | 2 2            | 4 04             |                 |                |            |                                       |              |             | *<br>*<br>*     |                           |                    |
|  |                | 10               | 5               | 000            |            |                                       | 1000         | 100         | 24              |                           | し、よ                |
|  |                |                  |                 |                |            | • •                                   |              | -<br>-<br>  |                 | hine -                    | •                  |
| يريدهم والمستحد والمتحد والمتحد والمتحد والمتحد والمتحد والمتحد والمتحد والمتحد والمتحد والمتحد والمتحد والمتحد  |                |                  |                 | •<br>•         |            | •                                     |              |             |                 |                           | -                  |
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| James Libra L.   |                | - <b> </b>       |                 |                | -          |                                       |              |             |                 |                           | u 1                |
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|  |                |                  | -               | <br> <br> <br> |            | •                                     | - +          |             |                 |                           | ן י<br>ו<br>ו<br>ו |

| TABULATION SHEET JELPT Steel - Tensiles = Processed $ZA-I$ $HT$ $SAGE$ $Postilog$ $ZA-I$ $T$ $aolo$ $HT$ $Sage$ $Postilog$ $ZA-I$ $T$ $aolo$ $HT$ $Sage$ $Postilog$ $ZA-I$ $T$ $aolo$ $LendA$ $Aultical B$ $Postilog$ $ZB-I$ $T$ $T$ $aolo$ $LendA$ $Aultical B$ $Aultical B$ $ZB-I$ $T$ $T$ $T$ $T$ $aolo$ $LendA$ $Aultical B$ $LendA$ $LendA$ $L$ $ZB-I$ $T$ $T$ $T$ $T$ $L$ |
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| د. <i>۱</i> ۱               | C. 11 1/0m 1/1 | Heat                 | Growfr =   | Lontract                              | 101     | ид г      | 6200 H |     |
|-----------------------------|----------------|----------------------|------------|---------------------------------------|---------|-----------|--------|-----|
|                             | - 622          | 110.1                | - To/In    | 1050 230                              | 1075192 | 1120 232  | 24720  |     |
|                             | 0.005          | 8                    | .0060      | .0003                                 |         |           | .6057  |     |
| 1                           | 6.008          |                      | 0254       | 2000.                                 |         |           | 000    |     |
| in the second second        |                |                      | .0055      | 000 4                                 |         |           | 1500-  |     |
| 4                           | 0.005          |                      |            |                                       | 2000.   |           | .0059  |     |
|                             | 7              | ×                    | -          |                                       | 8000    |           | .0046  |     |
| ,                           | 0.020          |                      | .0054      |                                       | 10006   |           | 22021  |     |
| ~~~                         | 0000           | 1<br>                | ,00521     |                                       |         | 10001     | 1.6025 | :   |
|                             | 0000           | •                    |            |                                       |         | 11001     | .2222  |     |
|                             | 2000           | ► ¢                  |            |                                       |         | 0100      | 0200.  |     |
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|                             | 0000           |                      | alar the   | 9777                                  |         |           |        | í   |
|                             | 2027           |                      |            | 1000                                  | 1       | · •       |        | +   |
| 20                          | 2000           |                      |            |                                       | 12001   |           |        |     |
| R                           | 0.020          | •                    |            | •                                     |         |           |        | •   |
| Μ                           | 0.005          | •                    |            |                                       |         | 0.002     |        |     |
| £                           | 0.08           |                      |            | • • • • • • • • • • • • • • • • • • • | •       | 0:00      |        |     |
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| × - + 7                     |                | ار<br>بر<br>بر<br>بر |            |                                       |         |           |        |     |
| ]                           |                | - 11 725.            | 10/2 201   | in win                                |         |           |        |     |
|                             | + 1000         | 10011                | そう. この.    |                                       |         |           |        |     |
|                             | ر<br>۲         | log to to to         |            |                                       |         | -         |        |     |
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|                             |                |                      |            |                                       |         | E IN MICH |        |     |
| H. T 8                      | 11221 +5       | 19005                | 202        | 111110                                |         |           |        |     |
| I WA LARES I WITTELL REPART | + Cashrha      | 12005120             |            | 2                                     |         |           |        |     |
|                             | (201 × 2       | 11. 1.0011           | 220 25.5   | ł                                     |         |           |        |     |
|                             | 10-2-11-       | いいと                  | 12121 - EX | 225 11732                             | 'n      | reration  |        | . 9 |
|                             | 49:4 31        |                      | L          | et column                             | 11-2-2  | 90 m n    |        |     |
|                             | • • •          |                      |            |                                       |         |           |        | 27  |
|                             |                |                      |            |                                       |         |           |        | с.  |

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| HT-C Heat to 1350E and held 20 min.<br>2020<br>HT-C Heat to 1350E and held 30 min.<br>Cool to 1700E and held 30 min.<br>HT-D Heat to 1250 min.<br>HT-D Heat to 1250 min.<br>HT-D Heat to 1250 min.<br>Alie and to 1700E and hold 50 min.<br>Alie and to 1700E and hold 50 min.<br>Alie and to 100E and hold 50 min.<br>Alie and to 100E and hold 50 min.<br>Alie and to 100E and hold 50 min.<br>Alie and to 100E and hold 50 min.<br>Alie and to 100E and hold 50 min.<br>Alie and to 100E and hold 50 min.   | 71        |
| HT-C Heat to 1350E and 1512 20 min.<br>HT-C Heat to 1350E and 1512 20 min.<br>Caol to 1100E in 200 min.<br>Ali ceal to 1350 in 200 min.<br>HT-D Keat to 1352 and 151 50 min.<br>Caol to 1700E and hold 50 min.<br>Ali cal to 100E in 200 min.<br>Ali cal to 100E in 200 min.<br>Ali cal to 100E in 200 min.<br>Ali cal to 100E in 200 min.<br>Ali cal to 100E in 200 min.  | <u> </u>  |
| - H. T. C. Heat to 1250E 3. 1 15/2 30 120 120<br>Cast to 1750E 3. 1 15/2 30 10 10<br>Cast to 1700E 10 200 mm<br>Ali ceal to 1700E 10 200 mm<br>H. T - D. Heat to 1252 and 12 1 20 mm<br>H. T - D. Heat to 1255 and 12 1 20 mm<br>Cast to 1700E and hold 50 mm<br>Cast to 1000E 10 200 mm<br>Ali cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Ali cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Ali cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 200 mm<br>Cast to 1000E 10 0000E 10 000E 10 000E 10   | 12:       |
| HT-C Heat to 1350E and 1512 30 1210.<br>Caol to 1350E and 1512 20 10.<br>Aur ceal to 100F 10 200 10.<br>HT-D 1100F 10 200 10.<br>HT-D 1100F 10 100F 10.<br>Caol to 1700E and hold 50 10.<br>An mon Cad to 1700E and hold 50 10.<br>An mon Cad to 1700E and hold 50 10.<br>An mon Cad to 1700E and hold 50 10.<br>An mon Cad to 1700E and hold 50 10.<br>An mon Cad to 1700E and hold 50 10.<br>An mon Cad to 1700E and hold 50 10.<br>An mon Cad to 1700E and hold 50 10.<br>An mon Cad to 1700E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and hold 50 10.<br>An mon Cad to 1000E and 10.<br>An mon Cad to 1000E and 10.<br>An mon Cad to 1000E and 10.<br>An mon Cad to 1000E and 10.<br>An mon Cad to 1000E and 10.<br>An mon Cad to 1000E and 10.<br>An mon Cad to 1000E and 10.<br>An mon Cad to 1000E and 10.<br>An mon Cad to 1000E and 10.<br>An mon Cad to 1000E and 10.<br>An mon Cad to 1000E and 10.<br>An mon Cad to 1000E and 10.<br>An mon Cad to 1000E and 10.<br>An mon Cad to 1000E and 10.<br>An mon Cad to 1000E and 10.<br>An mon Cad to 10.<br>An mon Cad to 10.<br>An mon Cad to 10.<br>An mon Ca   |           |
| - H. T C Heat to 1250E 3. 1 1212 30 1210.<br>Cast to 100 1 200 mm 10 10 100<br>Au cast to 100 10 200 mm 20 200<br>H T - D Heat to 255 and 1012 0 mm<br>Au cast to 1200E and hold 60 mm<br>Cast to 1200E and hold 60 mm<br>Au cast to 1006 16 200 mm<br>Au cast to 1006 16 200 mm<br>Au cast to 1006 16 200 mm<br>Au cast to 1006 16 200 mm<br>Au cast to 1006 16 200 mm<br>Au cast to 1006 16 200 mm<br>Au cast to 1006 16 200 mm<br>Au cast to 1006 16 200 mm<br>Au cast to 1006 16 200 mm<br>Au cast to 1006 16 200 mm<br>Au cast to 1006 16 200 mm<br>Au cast to 1006 16 200 mm<br>Au cast to 1006 16 200 mm<br>Au cast to 1006 10 200 mm<br>Au cast to 1006 16 200 mm<br>Au cast to 1006 16 200 mm<br>Au cast to 1000 10 200 mm<br>Au cast to 1000 10 200 mm<br>Au cast to 1000 10 200 mm<br>Au cast to 1000 10 200 mm<br>Au cast to 1000 10 200 mm<br>Au cast to 1000 10 200 mm<br>Au cast to 1000 10 200 mm<br>Au cast to 1000 10 200 mm<br>Au cast to 1000 10 200 mm<br>Au cast to 1000 10 200 mm<br>Au cast to 1000 10 200 mm<br>Au cast to 1000 10 200 mm<br>Au cast to 1000 10 200 mm<br>Au cast to 1000 10 200 mm<br>Au cast to 1000 10 200 mm<br>Au cast to 1000 10 200 mm<br>Au cast to 1000 10 200 mm<br>Au cast to 1000 10 200 mm<br>Au cast to 1000 10 200 mm<br>Au cast to 1000 10 200 mm<br>Au cast to 1000 10 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au cast to 200 mm<br>Au  |           |
| Cool     c     7001     200     200       Que     cool     40     cool     40     200       H     7     0     1801     40     1200     201       H     7     0     1801     40     1200     40       Ann     Cool     40     1200     40     200       Ann     Cool     40     1200     40     20       Ann     Cool     40     1000     10     20     40       Ann     Cool     40     1000     10     20     40       Ann     Cool     40     20     40     20     40  |           |
| HT-D Kest to 11605 11 200 miles at 205<br>HT-D Kest to 1252 and 121 30 miles<br>HT-D Kest to 1252 and 1512 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 120 1205 ded hald 50 miles<br>Ali da 120 1205 ded hald 50 miles<br>Ali da 120 1205 ded hald 50 miles<br>Ali da 120 1205 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>Ali da 12005 ded hald 50 miles<br>A   |           |
| HT-D Hest to 1255 and 1:1 20 min.<br>HT-D Hest to 1255 and 1:1 20 min.<br>Cool to 11005 and hold 50 min.<br>Air do 1 7005 and hold 50 min.<br>Air do 1 to 11005 in 200 min.<br>Air do 1 to 1005 in 200 min.  |           |
| HT-D Hest to 1252 and hald Ed min.<br>HT-D Hest to 1252 and hald Ed min.<br>Cool to 11005 and hald 62 min.<br>Avi do 1 2011005 in 200 min.<br>Avi do 1 2011005 in 200 min.<br>Avi do 1 201005 in 200 min.  |           |
| HT-D 11801 to 1252 and 14 20 min.<br>Aur Coal to 1252 and hold 50 min.<br>Coal to 11005 the 200 min.<br>Air do 1 to 127 then transformed of 05   | - 90 min. |
| HT-D Heat to 1255 and 1: 1 20 mm.<br>Cast to 17005 and hald 50 mm.<br>   |           |
| Aur and to 17005 and hold 60 min.<br>Cool to 11005 16 200 min.<br>Air do 1 to 17 then transformed 27 0F  |           |
| as 1 to 1201 vi 200 ministerned at 01<br>at town return of the of at an of   |           |
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| 0.008<br>0.020<br>0.020<br>0.025<br>0.025<br>147 - I Head to 1<br>Alr cup1   | .2050                                  |                                   | 1        | .6239                                 |     |
| 0.020<br>0.005<br>0.005<br>0.005<br>147 - L Heat to 1<br>147 - L Heat to 1<br>147 - C 0.02<br>0.02 1<br>147 - C 0.02   | .00+9.                                 |                                   | .0009    | 1.224                                 |     |
| 2005<br>0005<br>0005<br>0005<br>0025<br>0025<br>14.1 - 1 Heat to 1<br>Age 27 1   | .0050.                                 |                                   | 10005    | 15025                                 |     |
| 0.002<br>0.005<br>0.005<br>0.025<br>0.025<br>147 - I Heat to 1<br>Age 27 1   | 2264                                   | 10100                             |          | 1.000                                 |     |
| 6.620<br>0.963<br>0.963<br>0.020<br>0.025<br>14.1 - 1 Heat to 1<br>Alr 6.021<br>Alr 6.021  | · • 1                                  | 0210                              |          |                                       |     |
| 0.005<br>0.020<br>0.025<br>0.025<br>147 - I Head to 1<br>Aye 27 1<br>Aye 27 1  | ドレン                                    | 0150                              |          |                                       | ;   |
| 0.201<br>0.220<br>0.225<br>0.225<br>14<br>17 - L Heat to 1<br>10<br>14<br>10<br>10<br>10<br>10   | 6052                                   | 0100                              |          | $\mathcal{L}$                         |     |
| 4.7 - 1 Head to 1<br>4.7 - 1 Head to 1<br>Aur cuel to 1<br>Age 27 1  | 6050.                                  | 12221                             |          | 1775                                  | 1   |
| 4.1 - 1 Head to 1<br>Age 27 1<br>Age 27 1  | .222                                   | 0100                              |          |                                       |     |
| HEAT - L HEAT TO 1<br>HEAT TO 1<br>Aur cup/  | 2052.                                  | ,<br>,<br>,<br>,                  | 2010     |                                       |     |
| 41-1 0.02 n<br>41-1 Head to 1<br>Aur civel   |  |                                   | .072.0.  | · · · · · · · · · · · · · · · · · · · | 1   |
| T-L Head to 1<br>Liel to 1<br>Aur cuel   | 150%                                   |                                   | 11101    |                                       |     |
| T- I Heat to 1<br>Col to 1<br>Aur cu21<br>Age 27 1   |  |                                   | •        |                                       |     |
| 7-1 Head to 1<br>Ciel to 1<br>Aur ciel   | • •<br>•<br>•                          |                                   |          |                                       |     |
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| CONVAIR FORT WORTH<br><b>TABULATION SHEE</b><br>Samo, No. |  |                       |

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## CONVAL R A DIVISION OF GENERAL DYNAMICS CORPORATION (FORT WORTH)

#### HEAT TREATMENT

ITEM B - COMPARISON OF BRAZING CYCLES FOR HEAT TREATMENT OF 17-7PH STEEL SHEET BRAZED WITH 85:15 SILVER-MANGANESE ALLOY

An investigation was carried out beginning late in 1954 and extending into early 1956 to determine a satisfactory brazing cycle for 17-7PH steel sandwich panels using 85:15 silvermanganese alloy for brazing. The primary object was to develop data on which the optimum brazing cycle combining heat treatment could be based.

Standard "tensile-test specimens were prepared from 17-7PH steel sheet, condition A, in the following nominal thicknesses: .005", .008", .020", .040", .063", and .080". The testing was mostly limited to the first three.

Several basic cycles of heat treatment were investigated. Certain variations as concerns cooling and aging were studied. The test data obtained, together with the neat treatments applied, are given in Tables IB-I to IB-VII.

Figure IB-I is a chart in which the tensile properties of .005", .008", and .020" sheet, heat treated according to different cycles, are compared. All the specimens were aged for 90 minutes at 1050 f. The test values were all above the minima specified for 17-7PH steel sheet of the three thicknesses. These minima were 150 ksi yield strength and 180 ksi ultimate strength with elongation of 3.5% for .005" and .008" thick sheet and 5.5% for .020" sheet.

With only one exception, Figure IB-I and the pertinent tables show that the .008" thick sheet had higher yield and ultimate strengths than the .005" and .020" materials for all heat treatments. The elongation of the .020" thick sheet was highest for these treatments. Also, the transformation temperature of -100 F conferred higher elongations for the three thicknesses than did the -20 F temperature.

Figure IB-2 shows the effect of aging temperature on the tensile properties of the three sheet materials. All were heat treated according to the cycle given in Table IB-I. The aging time was 90 minutes and the temperature was varied in the range 1050 to 1080 F. As may be seen, the yield and ultimate strengths decreased with increasing aging temperature. The slopes for the .005" and .008" materials are about the same, but the slope for the .020" sheet is considerably less steep. The elongation increased with

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increasing aging temperature for the .005" and .008" materials but decreased for the .020" sheet.

In Figure IB-3, the top graph shows the effect of time at the transformation temperature 100 F, for a given heat treatment, on the tensile strength of the three thicknesses of sheet. The middle graph shows the effect on the elongation. As is evident, the strength increases and the elongation decreases with increasing time at -100 F. The slopes for the strengths are practically parallel, but those for the elongations differ appreciably.

The bottom graph in Figure IB-3 shows the effect of the transformation temperature, for a given heat treatment, on the elongation of the three thicknesses of sheet. For both the .005" and .020" materials the trend of values was upward with increasing temperature. For the .008" sheet the trend was downward. The elongation values for the .008" and .020" sheet did not all lie close to the straight line indicating the trend.

The test data obtained in this investigation were analyzed to determine whether they afforded information on which the optimum brazing cycle could be based. For this purpose maximum yield and strength values together with elongations above the specified minima were selected from the results for each heat treatment as set forth in the tables. Likewise, the maximum elongations together with acceptable yield and strength values were similarly chosen. For both sets of maxima, the corresponding heat treatment was noted. The data of Table IB-VI were not included because the material was in the solution annealed, A, condition prior to transformation and aging. The data is included, to show that annealed material cannot be hardened without the conditioning step. The values selected from Tables IB-I to IB-V and IB-VII were rated numerically, and the results are scored in Table IB-VIII

Patterns of sorts are apparent in both the upper and lower sections of Table IB-VIII. First, the thickness of sheet is a factor affecting the properties conferred by a particular heat treatment. This is thought to be associated with the percentage of reduction in rolling to Finished thickness after annealing.

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| 84          |              |                                       |                        | 936             | 1983  | 2000   |                                | 202.6  | 21012         |            |               | 1220                    | 9 1250      | 0.00  |
| 85          |              | 1+2C+3                                |                        | 93.3            | 200.7 |        |                                | 2035   | 2126          | 50         | ,<br>,<br>,   | 124                     | c + 61 - 6  | 001   |
| 20          |              | · · · · · · · · · · · · · · · · · · · |                        | Sri (           | 2025  | 0      |                                | 10.1   | 213.          | • • •      |               | 15                      |             |       |
| 915         |              |                                       | 77                     | 18.2            | 2007  |        | ۱                              | 203.5  | 2112          |            |               | 121                     |             | 10.   |
|             |              | 7                                     | Heat 1                 | 10 18           | 2,518 | te.    | <i>p</i> / <i>o</i> / <i>q</i> |        | · · · · · · · |            | • • • • • • • |                         |             | • • • |
|             |              | 0700                                  | 2001<br>20<br>60<br>60 | 2 2 x.          | 20.05 |        | hold                           |        |               |            |               |                         |             |       |
| -           |              | D<br>M                                | col to                 | R               | L'in  | 245.   |                                | Cool   | to            | 7.001      | fer           | 2hes.                   |             |       |
|             | -            |                                       | Age @                  | 9               | 50.1  | 4      | 401                            | inim   | -             |            |               |                         |             |       |
|             |              | N.I.                                  | an c                   | erbove<br>argon |       | excep: | 1- t a                         | 100 F  | treat         | nen        | 0             | onc                     |             |       |
|             |              |                                       |                        |                 |       |        |                                | -      |               |            |               |                         |             |       |

| CONVAIR — FORT WORTH | TABLE TB |
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| 10               | 120  | 10.5   |             |  | Proje 63<br>FUT-27 |
|------------------|--|--|-------------|--|--------------------|
| Ex-Ksintru Ksi   | 1522 1220<br>1523 1220<br>1576 1221                          | 1620 1857  | 12.27 12.12 |  |                    |
| 1,6              | 0.25<br>0.25<br>0.25<br>0.25<br>0.25<br>0.25<br>0.25<br>0.25 | 2.0<br>2.2<br>2.2<br>2.2<br>2.2                    |             | - dir cool                             | here               |
| Further Further  | 2010 2053<br>2015 2036<br>1996 2036                          | 203.5 2101<br>203.6 2100<br>2031 2100<br>2031 2100 | 1.77        | d 20 mm.                               | 90 min.<br>A Amesp |
| 406              | 20<br>20<br>20<br>20   |  |             | 1750° F & hei<br>-1'22 2.2             | 10° 6 for          |
| Ex-Asi Few-Ksi 4 | 180.5 1867<br>181.2 1867<br>1799 1873<br>180.5 1284          | 1826 1957<br>1833 1957<br>184 1 1965               | 1231 1361   | Heat to 17<br>Los to -<br>A. On is hos | 3. Wer             |
| H.T.             | 1+24+3   | 112813   | 1+2(+2      | 7777                                   |                    |
| NIC DIR          | 100 Lang.<br>101 Lang.<br>102 AVG                            | 103<br>109<br>109<br>105                           | 102 102     |  |                    |

| GRA<br>DII   | │                                     | 125.                                    | 166<br>232.5<br>232.5<br>237.5 | 536 1426<br>536 1425<br>534 1426 | - 4.00, 0.00 7 4.000<br>- 4.151 56<br>- 4.151 56<br>- 14.26 30.0<br>- 14.26 30.0 | 60.30 G<br>60.451 Funk<br>45.7 123.<br>46.9 123.        | 137.5    |
|--|---------------------------------------|---|--------------------------------|----------------------------------|--|---|----------|
| AVG<br>AVG<br>87<br>87<br>89<br>89<br>81<br>81<br>81<br>81<br>81<br>81<br>81<br>81<br>81<br>81<br>81<br>81<br>81 | 10+2<br>10+2<br>10+2                  | 513 513 513 513 513 513 513 513 513 513 |                                | 553 1416                         | 302<br>302<br>27.0<br>27.0<br>27.0<br>27.0<br>27.0<br>27.0<br>27.0<br>27         | 7155 1227<br>464 1227<br>112151<br>1172<br>1172<br>1172 |          |
|  | × 3.22                                | 13/ 13/                                 | 1 - 1 - 1                      |                                  |  |   |          |
|  | 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 | La min<br>La min<br>Cres Ho<br>Four Ho  | 11. m 4                        | 2.0.71- 07                       |  |   |          |
|  | N I                                   | A9C @ 10                                | 2                              | 72.11.15                         | Argen 2  | 22.25.  | ovr-2727 |

Før-2727 120 0000 <u>11261 18-11 0000 0000 0000</u> Stantess Steet-0040,0063 \$ 0.060 6age Tensiles</u> 100 E. Kal E. La .. C. 0"11 ۱, 145.9 180.2 155.0 182.2 149.3 1803 220.2 2053 129.2 2285 194 5 181 1 17:51 1 14.2 1501 0 Į. 2/2 • : -----\$ i) 10 0 m 0 V ~ 2023 3 20 15 4 10 m 0.00 Extent En 121, 2 C 1 0] MIN 1968 2055 1961 2055 1977 2071 1972 2011 186.3 1994 1896 2006 1896 2026 1886 2020 Ì. 1.215 11 1.153 1. TABLE IB-W 90 10 2211 The second second Ų 1 いいい 1.2.2.1 2.11.9 . 2103 :-マンク hald. () () 11 ۱ HO. 122 Ł i( 1, \*\*\* 2.7\*\* Q 1050 200 19.25 2 ない 1) 14 () ; 54 ۱ -20 °F A. 159.05 11 4 •• CZ / 192.3 1920 203.0. .201. et a Hear to 196.7 1522 1729 192.3 2-221.3 <u>ن</u> - 2323 ł Age 10 10 4 † 196.1 1210 1771 1776 1791 1781 17-7 PH 1 12 1.261 Strand Strand 1221 55 196 1 ١ ∿-4 r 1. 7 5 Ч Ń 30+4 5 34+4 30+4 TABULATION SHEET ΗT H T. CONVAIR --- FORT WORTH N 4 page GRAIN Leng-7 6 GRAIN DIR DIR 521 AVERAGE 2 AVERAGI · · · /1217 · · AVERAG AVERAS .' SPEC SPEC 120 123 A0 121 124 125 125 212 124 120 123 123 121 •

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C NV 0 R Α A DIVISION OF GENERAL DYNAMICS CORPORATION

(FORT WORTH)

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| , (FORT W            | /ORTH)                       |                 |                           |               | DATE                     | 9/61  |
|----------------------|------------------------------|-----------------|---------------------------|---------------|--------------------------|-------|
|                      | VIII Voot                    | <b>One</b> when | nte Deted                 | On The De     |                          | ,     |
|                      | VIII - <u>Heat</u>           |                 | 1                         |               | H Steel Sheet            |       |
|                      | Tensile rre                  | oper clea       | Comerreu                  |               | n Steer Sheer            |       |
| <u></u>              | Hig                          | hest Y          | eld & Ulti                | .mate Stre    | ngth                     |       |
|                      | With                         | Elongat         | ion Above                 | Specified     | Minima                   | ····  |
|                      | 005" Th                      | Lck             | .008"                     | Thick         | 020" Th                  | lck_  |
|                      | 1 - 3D+4 ;                   |                 | 1 <b>-</b> 3D+4           | - VII         | 1 - 3D+4                 | - 111 |
| of Heat \<br>Treat-  | 2 - 1+20+3                   | - IV            | 2 - 1420                  | 273 - V       | 2 = 3D+4                 | - VII |
| ment                 | <b>3 -</b> 2                 | - II            | 3 - 1420                  | 2+3 - IV      | 3 - 1+20+3               | - IV  |
| -                    | 4 :- 3D+4                    | - III           | 4 - 3A+4                  | ) - III       | 4 - 2                    | - II  |
|                      | 5 <u>1</u> - 1+20+           | - V             | 5 - 2                     | - II          | 5 - 1+A                  | - I   |
|                      | 6 - 1+A                      | - I             | 6 - 1+A                   | - I           | 6 - 1+20+3               | - V   |
| •                    | <u>Highe</u>                 | , F             | ngation Wit<br>& Ultimate | :             | <u>ble +</u><br><u>r</u> |       |
| 2<br>C               | 1;- 3A+4                     |                 | 1 <b>- 1+</b> 2E          | #3 - V        | 1 - 1+2B+3               | - V   |
| ¥<br>                | 21-1+24+3                    | r †             |                           | 3+3 - IV<br>1 |                          | - IV  |
|                      | 3 - 3A+4                     | ,               | -                         | 1             | 3 - 38+4                 | - III |
|                      | 4 - 1+20+3                   | - I             | 4 - 2                     | ' - II        | 4 - 3A+4                 | - VII |
| •                    | 5 <sup>1</sup> - 1+A         | - 1             | 5 - 3E+4                  |               | 5 - 2                    | - 11  |
| <del></del>          | 6!-2                         | - <u>1</u>      | 6 <b>-</b> 3A+4           | - VII         | 6 - 1+Å                  | - I   |
| 3                    | 8                            | -               |                           | -             | Na <del>x</del>          |       |
| * 1, high<br>for eac | est; 6, lowe<br>h thickness. | est. 1          | reatments a               | nd tables     | of data giver            | ı     |
| + Substan            | tially above                 | speci           | lied minima               | •             |                          |       |
| 1                    | 1<br>(1                      | Ţ               | ī                         |               |                          | ·     |
| <b>Y</b>             | )<br>-                       | Ţ,              | 1                         | ,<br>         | n z ·                    |       |
|                      |                              | . ]             |                           |               | 5 H                      |       |

| (        | ONVAIR   | PAGE 67                                  |
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| -        |  | REPORT NO. FUT-2727                      |
| A DIVI   | ISION OF GENERAL DYNAMICS CORPORATION<br>(FORT WORTH)  | MODEL <u>5-58</u><br>Date <u>1/19/61</u> |
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|          |  |  |
| · ·      |  |  |
| 1        |  |  |
| · ·      |  |  |
| ÷ .      | HEAT TREATMENT   |  |
| ľ        | ITEM C - COMPARISON OF BRAZING CYCLES  | HOR HEAT TREATMENT OF 17-7PH             |
| Ľ        | STEEL SHEET BRAZED VITH STER   | LING SILVER PLUS 0.2% LITHIUM            |
| ·        | ALLOY  |  |
|          |  |  |
|          | Early in 1957, work was carried out of   |  |
|          | sterling silver plus 0.2% lithium all<br>As one result, the lowest satisfacto  |  |
|          | this alloy was found to be 1650 F (cf  |  |
| K        | production brazing temperature for the   |  |
| 5        | alloy, then in use, was 1820 F. An i.  | avestigation was conducted               |
| ľ        | to determine what effects the lower bi   | razing temperature might have            |
|          | on the response to heat treatment and  | on the tensile properties                |
|          | of 17-7PH steel. Also, two different   |  |
|          | examined.' This investigation is summa   | arized here.                             |
| }        | In the best treatment of 37 Thus steel   | the three enconties stars                |
|          | In the heat treatment of 17-7PH steel arc: (1) austenite conditioning; (2)   |  |
|          | ation of austenite to martensite; and  | (3) precipitation hardening              |
|          | treatment. The Convair heat treatmen   | t evele for sandwich panels              |
|          | brazed with the 85:15 sliver manganes  | alloy included condition-                |
|          | ing for 90 minutes at 1400 F after bra   | azing. As mentioned, the                 |
|          | brazing was performed above 1800 F. 1  | Brazing with the sterling                |
|          | silver plus 0.2% lithium alloy was to  |  |
|          | using thiş alloy, the need for the con   |  |
|          | questioned. With the object of settl:  |  |
|          | specimens were heat treated with the o   | conditioning step at 1400 F              |
|          | incorporated in the procedure; other a   | sets were heat treated with-             |
| ,        | out it. The former are identified as   | A <sub>2</sub> and the latter as B.      |
|          | The heat treatments were based on the  | following simulated brazing              |
| 1        | cycle:   |  |
|          |  |  |
| ;        | 1. Heat to 1650 F and pold 15 m  | inutes.                                  |
|          | 2. cool to 1400 F in 60 minutes  | t hold 00 minutor                        |
|          | 2. COOL CO 1400 F In Ou minutes  | and nord 90 minutes.                     |
| t        | 3. Cool to -20 F within 8 hours  | and hold 30 minutes.                     |
| ; .      |  |  |
| :        | 4. Age at 1050 F for 90 minutes.   | • 1 e ÷                                  |
| , ·,     |  |  |
|          | The transformation temperature (step   |  |
|          | some sets of specimens and the aging t   |  |
|          | Most of the tensile tests were perform   |  |
|          | and .010" <sup>5</sup> thick. Small numbers of spe<br>were alsoftested. In addition, variou  |  |
| ,        | Mere arouf reprede the state of a state of the state of t | ASE ACARA MET C MET CIT                  |
| •        |  | a 🗄 🛃 🖓                                  |
|          | 3  | ₹ 10 <b>₽</b> . <b>4</b>                 |
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samples cut from a few brazed sandwich panels. These were brazed in the range 1620 to 1700 F and otherwise processed according to the B cycle.

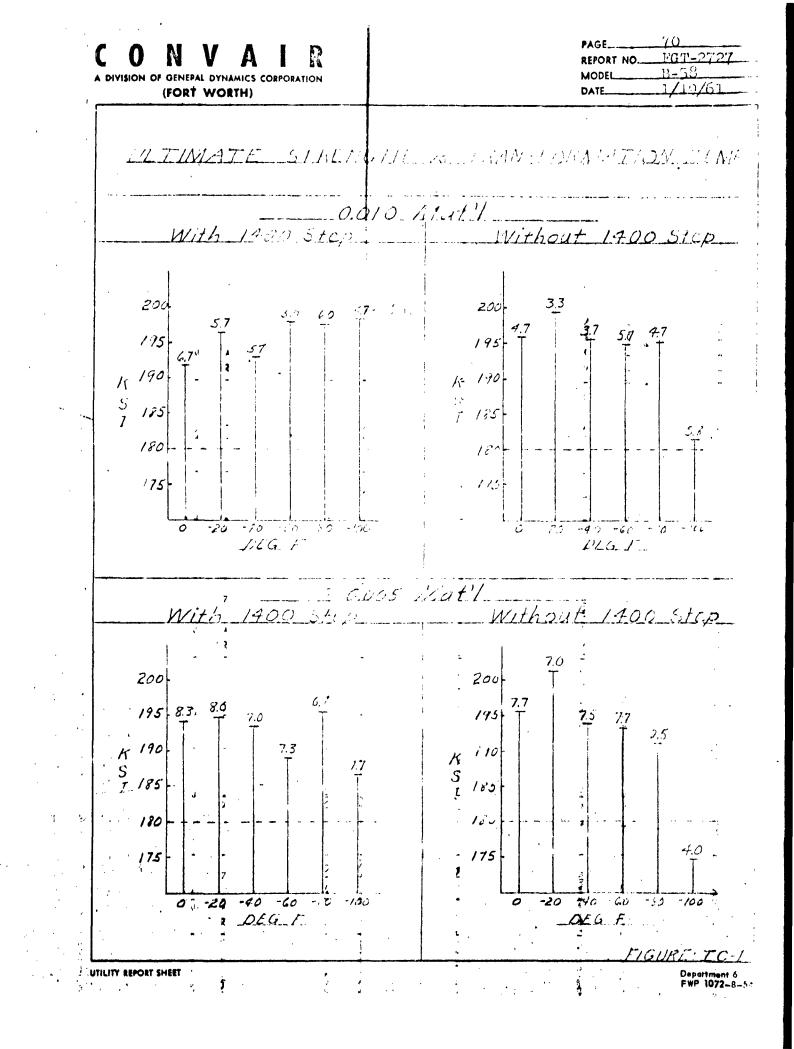
Table IC-I gives the results of tensile tests on 17-7PH steel specimens .005" thick, and Table IC-II gives the results on specimens .010" thick. The transformation temperature was varied from 0 to -100 F. Otherwise, the heat treatment was in accordance with the A or B cycles as designated in the tables. Table IC-III lists additional results on specimens .005" and .010" thick and also some test values for specimens .021", .044", and .061" thick. Table IC-IV gives the results of tensile, edge compression, flat compression, and axial tension-tension fatigue tests on samples cut from the brazed panels.

In Figure IC-1 bar charts show the effect of the transformation temperature on the tensile strength and elongation of 17-7PH steel sheet. The charts cover test data on specimens .005" and .010" thick, heat treated with and without the 1400 F step. For the .010" material the strength tended to increase with decreasing temperature of transformation when the 1400 F step, was used; the elongations were relatively high. For the same material without the 1400 F step, there was a pronounced loss of strength with transformation temperature of -100 F; the elongations pended to be relatively low.

Referring further to Figure IC-1, for the .005" sheet with the 1400 step, the strength followed no pronounced trend with decreasing temperature of transformation but was appreciably lowered for .-60 and -100 F. The elongations were relatively high. For this thickness without the 1400 F step the strength tended to decrease noticeably with decreasing transformation temperature with a marked loss for -100 F. The elongations were relatively high for temperatures down to -60 F.

Table IC-III shows that, .005", .044", and .061" sheet, heat treated according to the simulated brazing cycle both with and without the 1400 F step, had acceptable tensile properties. The .020" sheet, with and without the step, and the .010" sheet, without the step, had elongation values below the specified minima.

|                  | CON                  | νΔι   | R                        |                           |                          | PAGE                                  | 69<br>FGT-2727             |
|------------------|----------------------|---|--------------------------|---------------------------|--------------------------|---------------------------------------|----------------------------|
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|                  | (FORT                | WORTH)  |                          |                           |                          | DATE                                  | 1/19/61                    |
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|                  |                      |   |                          |                           |                          |                                       |                            |
| • :              | The te               | st results  | on specian               | ns out from               | the braze                | d sandwic                             | h panels                   |
|                  | were a specim        | bove the sp<br>ens from th<br>ecified min<br>ailed at 66<br>m is 1 x 10 | ecifiea mi<br>e skins of | nima with t<br>panel 45 f | two exceptionad elongat. | ons. Ten<br>ion of 2%                 | sile<br>in 2".             |
|                  | The sp<br>mens f     | ecified min<br>ailed at 66  | imum is 5%<br>9 x 103 an | . The tens<br>d 316 x 103 | sion-tension<br>cycles.  | n fatigue<br>The speci:               | speci-<br>fied             |
|                  | minimu               | m is 1 x 10   | <b>6 cycles</b> w        | ithout fail               | lure.                    | -                                     |                            |
|                  |                      |   |                          |                           |                          |                                       |                            |
|                  |                      |   |                          |                           |                          | <u>ે</u><br>ર                         | - ·                        |
|                  | - An                 | + 5 -   |                          |                           |                          | :1                                    | -                          |
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|                  |                      |   |                          |                           |                          |                                       |                            |
|                  |                      |   |                          |                           |                          |                                       |                            |
|                  |                      | 1 ;   |                          | ,                         |                          | .4                                    | 5                          |
|                  | 1 Y                  | ( î   |                          | •                         | r<br>L                   | ۰.                                    | 3                          |
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|                  |                      |   |                          |                           |                          |                                       |                            |
| ·                | . •                  | 1   |                          |                           |                          | ~                                     | ~                          |
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| - <b>6</b> ,     | -                    | · • • •   |                          |                           | 1                        | 1.                                    |                            |
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| -                |                      | , <b>.</b> .  |                          |                           | Ĩ,                       |                                       |                            |
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| •                |                      | a -   | -                        | 2                         | 2                        | <b>ن</b><br>ب                         |                            |
|                  | UTILITY REPORT SHEET | · · ·   |                          |                           | Ĩ                        |                                       | Department 6<br>FWP 1072-8 |



| FABULATION"      | TABULATION SHEET '. T' WS/LF        | PROPERTH                          | S DF 11      | Hd 1-1 | STE        | 1-77                     | - 0010 -                                 | 6490                                    | •  |
|------------------|-------------------------------------|-----------------------------------|--------------|--------|------------|--------------------------|--|---|----|
| SPEC NO          |                                     | CAGE                              | VIELD<br>MSY | 177    | %<br>0     | AL Z                     | Z  | 0%                                      |    |
|                  | -100F 20NG                          | C295                              | 1975         | 1202   | 60         | 5                        | 83                                       |   |    |
| 2                |                                     | 9098                              | 1822         | 1960   | 50         | 1915                     | 198.0                                    | 5.7                                     |    |
| 5                | _                                   | 0010                              | 1977         | 1939   |            |                          |  |   |    |
|                  |                                     | 00960                             |              | 2006   | 60-        |                          |  |   |    |
| S                | ,                                   | 2600                              | 1892         | 195.0  | 2.0        | 191.0                    | 196.9                                    | <b>D</b> , <b>d</b>                     |    |
|                  |                                     | -2600-                            | 2821         | 1950   | 50         |                          |  |   |    |
| 7                | -60 5                               | 1600                              | 1939         | 6661   | 50         |                          |  |   |    |
| 0                |                                     | 6600                              | 1272         | 1941   | 50         | 1905                     | 197.5                                    | 50                                      |    |
| 6                |                                     | 0057                              | 2061         | 1925   | 50         |                          |  |   |    |
| 10               | -405                                | 0042                              | 1053         | 1561   | 20         | -                        |  |   | -  |
| //               |                                     | 2097                              | 1221         | 1941   | 0          | 1863                     | 1929                                     | 5                                       |    |
| A lilbrau        |                                     |                                   | 12/21        | 1916   | 56         |                          | + -                                      | · · · · · · · · · · · · · · · · · · ·   | 1  |
|                  | 1                                   | 0000                              |              | 10     | 101        | •••••<br> <br> <br> <br> | 1  | · · · · · · · · · · · · · · · · · · ·   |    |
| pi -             |                                     | 1100                              | 1000         |        | ) (<br>) ( | < 0.07                   | 101                                      | - C<br>- V                              |    |
|                  |                                     | Cook                              |              | 1001   |            |                          |  |   |    |
| //               |                                     |                                   | 1.21         | d r    | 20         |                          |  | • · · · · · · · · · · · · · · · · · · · | •  |
| 13               | -                                   | 0076.<br>1111                     | 1121         |        | 9 L<br>9 C | 1025                     |  |   | F  |
|                  |                                     | <b>グワ・レ</b> ・<br>・<br>・<br>・<br>・ |              | 171.6  |            | 11 22                    | 1- | - 0.1 -                                 | ı  |
| 77               |                                     | 1076                              |              | 146.6  | 20         |                          |  |   |    |
|                  | -1001- 22NS.                        |                                   | 174.6        | 1846   | 6.0        |                          | İ  |   |    |
| 1. Factoria      | The set a lar inter a contra la set | 14GA                              | 11. 7794     | 1224   | 50         | 1715                     | 1215                                     | 57                                      |    |
| 5                |                                     | 009.                              | 165.4        | 180.94 | 60         |                          |  |   |    |
| 4                | -20F                                | 0637                              | 189.7        | 1978   | 40         |                          |  |   |    |
| 5                |                                     | 0033                              | 1223         | 1921   | 60         | 1868                     | 195.0                                    | 47                                      |    |
| 9                |                                     | 029.2                             | 1563         | 1951   | 40         |                          |  |   |    |
| 7                | -605                                | 2600                              | 182.3        | 1991   | 6.0        |                          | • • •                                    |   |    |
| 2                |                                     | C 292                             | 1273         | 1991   | 50         | 1866                     | 194.4                                    | 53                                      |    |
| 6                | ,,<br>,,                            | 0098                              | 1            | 1951   | 50         |                          |  |   | •  |
| 01               | -405-                               | 5600                              | 1222         | 196.1  | 30         |                          | <br> <br> <br>                           | •                                       |    |
| 11               |                                     | 6603                              | 1223         | 195.1  | 9.0        | 184.9                    | 195.4                                    | 3.7                                     |    |
| - view / 2 2 min | 1                                   | 10000                             |              | 1351   | 40         |                          |  | (                                       |    |
| 73               | -205                                | 0098                              | 1902         | 1961   | 20         |                          |  | • •                                     | 1  |
| /4               |                                     | 26 00                             | 1715         | 2026   | 30         | 1906                     | 199.0                                    | 3                                       | GI |
| 15               |                                     | .0097                             | 190.2        | 1922   | 40         |                          |  |   | -2 |
| /6               |                                     | 2039                              | 186.7        | 1955   | 6.0        |                          |  |   | 72 |
| 12               |                                     | 0038                              | 1253         | 1963   | 40         | 1852                     | 195.8                                    | 47                                      | 1  |
| ¢                |                                     |                                   |              |        |            | -                        |  |   |    |

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| 0.020,<br>53. 609e |                            | 2                       |                         |         | N <sub>1</sub> |               | m     |                | <i>m</i>       | FOT-2727   |
|--------------------|----------------------------|-------------------------|-------------------------|---------|----------------|---------------|-------|----------------|----------------|--|
| 010,               | 65<br>% C                  | 2                       | 9                       | 6.0     | ~;             | 4.            | 4     | 2.2            | 9              | 7 0  |
| 0055 0.010 0.063   | AVERAG<br>Ev               | 134.1                   | 187.2                   | 116.3   | 196.2          | . 2021        | 206.1 | 194.4          | 198.1          | 198.2  |
| TZ an              | E.                         | 175.6                   | 181.7                   | 173.3   | 1345           | 198.4         | 200.3 | 1.281          | 186.5          | 196.0  |
| 5166               | ۵<br>۲                     |                         | 202                     | 6.0     | 14114          | · · · · · · · | 444   | 1000           | 20<br>20<br>20 | 20<br>20<br>20<br>75<br>75<br>75                   |
| ZEH.               | ULT<br>KSL                 | 186.9<br>181.1<br>184.8 | 182.9<br>189.0<br>189.8 | 195.5   | 134.2          | 2030          | 202.0 | 1925           | 1972           | 197.6<br>197.6<br>197.5<br>204.6<br>201.2<br>201.2 |
| C-11               | YIELD<br>KSL               | <br>172.3<br>172.3      | 176.1<br>176.1<br>184.5 | 192.5   | 1332           | 2011          | 1771  | 187.2          | 1833           | 179.5<br>190.3<br>190.2<br>198.8<br>191.8          |
| TABLE 1<br>DERTUS  | GAGE                       | .0099                   |                         | 00/     | · · · · ·      |               |       | 2437           | -              | 0790   |
| <b>P</b> KOPE      | GRAIL                      | LaNG0.                  | 2                       | DNG .01 |                | 20 JA         |       | ONG .0         | -<br>-<br>-    |  |
| <u> </u>           | 19<br>19<br>19             |                         | 3                       |         |                | NO7 7         |       |                | i<br>C         | 207  |
| 5110E              | AG2<br>TEM                 | 10501                   | 7                       | 1050°F  |                | 1050%         |       | 1250°F         |                | 2.0371   |
|                    | TEINE                      | 2.02-                   |                         | 7.02.   | >              | 7.02-         |       | -20 .5         | -              | -20°E  |
| 1 · · ·            | HT TRANS AGE<br>GROUP TEMP |                         | 8                       | V       | • \$2          | ZZ            |       | ₹ <del>,</del> |                | <b>4-0</b>   |
|                    | ND                         | 100                     | -/<br>3                 |         | ~~~~~          | - 12 m-       | - E M | - 10-          |                | 96-1<br>36-1                                       |
| CONVAIR-           | SPEC.                      | AC-                     | 96-                     | AC      | 01-78<br>1-78  | A.            |       | AC             |                | AC BC  |

| Tensile     1920     2004       Tensile     1920     2005       1918     1918       1918     1918       1918     1918       1918     1918       1918     1918       1918     1918       1918     1918       1918     1918       1918     1918       1918     1918       1918     1918       1918     1918       1918     1918       1918     1918       1918     1918       1918     1918       1918     1918       1918     1114       1116     1116       1116     1116       1116     1116       1116     1116       1116     1116       1116     1116       1116     1116       1116     1116       1116     1116       1116     1116       1116     1116       1116     1116       1116     1116       1116     1116       1116     1116       1116     1116       1116     1116       1116     1116       1116     1118 <t< th=""><th>PANEL - SAMP NO SKIN CORE TEMP TPEA</th><th>T<br/>T<br/>T<br/>T<br/>T<br/>T<br/>T<br/>T<br/>T<br/>T<br/>T<br/>T<br/>T<br/>T</th><th>YIELD ULT<br/>KSL ASL</th><th>s<br/>v</th></t<>  | PANEL - SAMP NO SKIN CORE TEMP TPEA | T<br>T<br>T<br>T<br>T<br>T<br>T<br>T<br>T<br>T<br>T<br>T<br>T<br>T | YIELD ULT<br>KSL ASL             | s<br>v          |
|--|-------------------------------------|--|----------------------------------|-----------------|
| - 2010 - 4 6 - 1650 F Hundrod tenside 1899 1953 .<br>2010 - 6 (3:15) 1620 ° F Hundrod Lenside 1892 2042 1995 .<br>2010 - 6 (3:15) 1620 ° F Hundrod Lenside 1995 .<br>2013 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2015 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2015 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>2014 .<br>20  | (51-2)5                             |  | _┨_ ┾_ ┉┝━╺╋╸                    | 4.0<br>30<br>30 |
| 2010 \$ (3:15 1620 * TH-1400 Lensile 1952 2021<br>2010 \$ (3:15) 1207 The 1700 Lense 1952 2021<br>2010 \$ (3:15) 1207 The 120 Lens 100 Lens 100 125 0<br>2010 \$ (3:15) 1207 The 120 Lens 100 Lens 100 125 0<br>2010 \$ (3:15) 1207 The 120 Lens 100 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 Lens 10 125 0<br>210 \$ (3:15) 1207 The 120 The 120 The 120 Lens 10 125 0<br>220 \$ (3:15) 1207 The 120 The 1   | стого + 5 43 - 46) [6.50° F 7H на   |  |                                  | 3.0             |
| . 210 \$ (3-15) 120°F. The 1900 Elye Camp. 2019.   | 0                                   | tensi  | ·                                | 20              |
| 010 £(3-15) 1650 F74n 120 E3ge Ente 11616<br>163.6<br>175.8<br>100 \$(3-15) 1700 F74n 1400 F1at Comp. 1758<br>175.8<br>155.8<br>150 \$(3-15) 120 F74n 1400 F1at Comp. 1535<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8<br>155.8 | 21-52                               | 00 Edge Cemp   | 2219-2219-2219-2219-2225         |                 |
| 210 \$(3.15) 1707 74, 420 Flat Comp.<br>. 210 \$(3.15) 1208 721 and Flat Comp.   | (51-2) 7                            | 7657   | 114.6<br>123.6<br>123.6<br>173.0 | Uneven harding  |
| · 210- 3(3-15) 1450-71, mar + 14   | \$63-15) 17005                      | 20 Flat 1  | 1400                             |                 |
|  |                                     | F/a+   | 1221                             |                 |
| 010 6(4.15) 1650°F 74m 140 Flat Campa 838  | 51.612                              | Flat   | . 677                            | •               |

# CONVAL R

(FORT WORTH)

PAGE 75 REPORT NO. FGT-2727 MODEL B-58 DATE 1/19/61

## HEAT TREATMENT

## ITEM D - ELIMINATION OF CONDITIONING TREATMENT AT 1400 F FOR 17-7PH STEEL.

In the Spring of 1957, an investigation was undertaken to determine the necessity of the conditioning treatment at 1400 F for brazed sandwich panels in 17-7 PH steel. This investigation was occasioned by the adoption of the sterling silver .2% lithium brazing alloy. As a result of this together with subsequent and related investigations, the 1400 F step was discontinued in March 1959.

The data given here are the results of tensile and fatigue tests carried out before and after the elimination of the conditioning step. These tests were performed on 17-7PH steel sheet both with and without conditioning at 1400 F.

Table ID-I through ID-IV give the tensile-test values obtained in 1957 for different thicknesses of sheet. The values in the first three tables are summarized in Table ID-V. The values in Table ID-IV were not included in the summary of Table ID-V because of the long cooling times from the conditioning temperatures. These long cooling times, 6 and 12 hours, apparently had relatively small effects on the tensile properties. All the specimens for which data are given in Table ID-I to ID-IV were cut with the rolling direction parallel to their long axes (longitudinal). The specimens were prepared from sheet stock and heat treated in the ETL. In Tables ID-II and ID-III the identification "Heats 5, 5, 7, and 8" refers to different lots.

The specimens of the first three tables were heat treated according to the following simulated brazing cycles:

1. Heated to 1650 7 in 30 minutes and held 10 minutes.

2. A. Cooled from 1650 F to room temperature in 3 hours.

- B. Cooled to 1400 F in 60 minutes, held 90 minutes, and then cooled to room temperature in 3 hours.
- 3. Cooled to -20F and held for 30 minutes.
- 4. Aged at 1050 F for 90 minutes.

Reference may again be made to Table ID-V. As shown there, the averages of the tensile properties are above the minimum required by Convair specification FZS-4-046(C) except for the

TULITY REPORT SHEET

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Department's FWP 1072-8-54

|             | C O                                  |  | DYNAMICS CO                            | R R  |   |  | 4  | MODEL   | 76<br>NO. FGT-27<br>B-58            |              |
|-------------|--------------------------------------|--|--|--|---|--|--|---|-------------------------------------|--------------|
|             | ,<br>                                | (FORT  | VORTH)                                 |  |   |  |  | DATE  | 1/19/6                              |              |
| ( · ·       |                                      |  | ,<br>1                                 |  |   |  | *  | •   | · .                                 |              |
| i i         |                                      | :  | i                                      |  |   |  | •<br>*<br>*  |   | · ·                                 |              |
| . • 1       |                                      |  |  |  |   |  | *  |   |                                     |              |
|             |                                      | ,  |  |  | , second s |  |  |   |                                     |              |
|             | elo                                  | nastie   | ns of                                  | the 010                                      | " 001   | 020" th  | Lck sheet  |   | · · ·                               |              |
|             |                                      | -  |  |  |   |  |  |   |                                     |              |
|             | adeo<br>1400<br>tes<br>dire          | quate<br>OF.<br>ted.<br>ectiop                             | basis i<br>This wa<br>Tensila<br>of 17 | for disc<br>as mainl<br>e specim<br>-7PH ste | ontihu<br>y beca<br>ens pu<br>el she  | ing the c<br>use no tr<br>lled trar<br>et usual] | condition<br>ransverse<br>naversely<br>ly exhibi   | egarded as<br>ing step a<br>speciment<br>to the re<br>t noticeal<br>sted long | at<br>s were<br>olling<br>bly lower | -<br>*• -    |
|             | stej<br>for                          | p wer <b>e</b><br>one r                                    | eason (                                | cted dur<br>or anoth                         | ing <b>1</b> 9<br>er. [F  | 58. The<br>prexampl                              | results a le, where  | ty for, the<br>were unsa<br>low tens<br>1thout the                            | tisfactory<br>ile proper            | -<br>-<br>?- |
|             | tion                                 | ning s<br>s. Th  | itep, sj                               | pecimens                                     | treit   | ed with i  | it likewi  | se had lor<br>not inclu   | v proper-                           |              |
|             | spec<br>bra:<br>.010<br>.1400<br>The | cimen <mark>s</mark><br>zing f<br>O" an <b>d</b><br>O F st | acilit:<br>acilit:<br>.Q25"<br>ep in f | rom shee<br>ies at C<br>thick.<br>the prod   | ts whi<br>onvair<br><sub>r</sub> They<br>uction   | ch were h<br>, Ft. Wor<br>were heat<br>equipmer  | th. The treat treat the treat the treated of the treated of the treated of the treat t | sile lest<br>ted in pro<br>sheets we<br>without<br>ged at, the<br>btained ea  | oduction<br>ere<br>the<br>e ETL.    |              |
| •           |                                      | r  | 1                                      |  | € I<br>€ I  |  | £<br>3   | E<br>L  |                                     |              |
|             | - as 1                               | furnač   | e and s                                | salt-bat                                     | h cy <b>e</b> le  | es. The  | former wa<br>salt bat  | are refe<br>as carried<br>th. These   | rred to<br>i out in<br>e heat       | -            |
|             | trea                                 | atment   | s were                                 | as foll                                      | qws:  |  | 2  | 2   | 4                                   |              |
|             |                                      | l<br>E   | 3                                      |  |   | leroft Fu  | urnace   | (   | .(<br>(                             | بو           |
| ļ           |                                      | 1  | )<br>Heated                            | from 10                                      | 00 Ft   | 5 1400 F   | In 15 min  | nute <b>s.</b>  | 3                                   | n netto      |
| ,<br>,      |                                      |  | -                                      |  |   |  | in 75 mir  | •   | . <b>N</b>                          |              |
|             |                                      |  |  |  |   |  | E  | iuces.  | 4                                   | ţ            |
| 1 1<br>1    |                                      | 3. ş   | Held at                                | t 1650 F                                     | for 1   | ) minutes  | 1  |   | <b>1</b>                            | j'<br>se     |
| • • •       |                                      | 4. 4   | Furnace                                | e cooled                                     | fron  | 1650 F to  | 1400 F :   | in 65 <b>min</b>  | ites.                               | Ĺ            |
| 11          |                                      | 5.   | Air co                                 | oled from                                    | 1400  | F to 100   | F in 45  | 5 minutes.  | 1                                   | <b>S</b>     |
|             |                                      | •  | , E                                    |  | 3   |  | j minutes  | 4   | , T                                 | 1<br>1<br>1  |
| • •         | . 🖌 👘                                | F. F   | i i                                    |  | 5   |  | 8  |   |                                     | н <b>і</b>   |
| •<br>•<br>• |                                      | 1  |  | 5 JUSU P                                     | JOT 19  | ) minutes  |  |   | 2                                   | 42           |
|             |                                      | 7.   | Aged at                                |  | : 1   |  | •<br>•   | ·   | 1                                   |              |
|             |                                      | 7.   | Aged at                                |  |   |  |  |   | 2                                   | 861. J 74    |

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|------|-------------------|
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| PAGE       | _77                                   |  |
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| REPORT NO. | FOT-2727                              |  |
| MODEL      | B=58                                  |  |
| DATE       | B-58<br>1/19/61                       |  |
|            | · · · · · · · · · · · · · · · · · · · |  |

]1- W

Salt Bath

Heated to 1650 F in 60 minutes and held for 10 minutes.

Cooled from 1650 H to 1400 F in 30 minutes,

Cooled from 1400 H to 1000 F in 45 minutes.

Cooled to -20/F and held for 30 minutes.

Aged at 1050 F for 90 minutes.

As shown in Tables ID-VI and ID-VII, the tensile yield and ultimaterstriength were considerably above the minimum required by Convair specification FZS-4-046 (C), but the elongations were below.

The reason for the low elongations was not understood at the time the tests were made. Subsequently, information was received that the aging temperature in production was usually between 1060 and 1070 F (in order to obtain adequate elongation) as contrasted with 1050 F as used at the ETL. The lower aging temperature, would be expected to result in lower elongation.

Th March 1959, decision was reached to eliminate the conditioning treatment at 1400 F of production nacelle panels. However, additional tests on .025" material were requested.

Tables ID-VIII through ID-XII give test results on specimens but from filler sheets, .025" thick, processed with standard nacule panels in production brazing facilities. All the material was heat treated without the 1400 F step except that for which test values are given in Table ID-XI. The values in this table are for filler sheets processed with the last panels for which the 1400 F step was included in the brazing syste.

As in evident from the data in Tables ID-VIII to ID-X1, all the strength values were above the minima required by Cenvair Desification FZS-4-046(C). The average elongation values were above and below the minimum specified, both with and thout the 1400 F step. Following is a summary of the contaction values:

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|---|-------------------------|--|------------|
| Average E   | longation Values        | Below Minimum                          |            |
| With 1400 F Step  | Without 1               | 100 F Step                             |            |
| As Heat Treated Aft   | er Salt As Heat<br>pray | Treated After                          | Salt Spray |
| 5 of 7 2  | of 3 10 o               | r 16 4                                 | of 16      |
| n 1997 <u>an de an Anna, fair a brithean an an Anna an Anna.</u><br>1997 - Sail |                         | ······································ |            |

Referring to the fatigue data in Tables ID-VIII to ID-XI, the average numbers of cycles to failure were as follows: For specimens with the 1400 F step as heat treated and after salt spray, 261 x 103 and 97 x 103 cycles, respectively; and for corresponding specimens-without the step, 191 x 103 and 97 x 103 cycles.

Table ID-XII gives the results of tests on notched tensile specimens of .025" thick sheet. The specimens were taken from filler stock processed with sandwich panels brazed in production. Based on the data, the sheet heat treated without the 1400 F step was somewhat notch sensitive. However, the tests were insufficient to fix the probable notch sensitivity. The results of the tests on the material processed with panel No. 687918 are to be ignored as all the specimens except one were out of alignment in the grips.

Table ID-XIII gives the results of tests designed to determine the effort of specimen geometry on the elongation of thin 17-7PH steel sheet. Representative measurements are plotted in Figure ID-1. The data show considerable scatter, but certain trends are proadly apparent. First, with increasing width of specimen the elongation increased. Second, with decreasing gage lengths there was less scatter. Third, with increasing segs length the measured elongation increased although the

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expersent elongation is decreasing.

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| 15-001 GRAIN | יאסבארטיהאוא מעבדי ידחוריי פראיוורי |                 |        | 2090-1 | 17-724 | Steel    | Tensile  |       | Deta   | •   |     |
|--------------|-------------------------------------|-----------------|--------|--------|--------|----------|----------|-------|--------|---|-----|
|              | JMPS .                              |                 | Y151D  | 1.47   | 6      | SAMP     |          | VIE   | 111    |   |     |
|              | 010                                 | 27125           | 121    | 137    | ม<br>ง | 0N       | GAGE     | X51   | KSA    | 2%  |     |
| No long      | 1-1-4                               | 0.00.5          | 1780   | 1229   | 0 2    | 4-1-4    | 000      | 1763  | 5101   | 7   |     |
|              | 2                                   |                 | 1772   | 1814   | 20     | 6        | 8        | 179:  | 0201   | 24  |     |
|              | 3                                   |                 | 128.0  | 1824   | 45     | <b>m</b> |          | 2 661 | 1000   | 24  |     |
|              | 4                                   |                 | 1764   | 152.0  | 55     | 4        |          | 1755  | 1522   |   |     |
|              | 5                                   |                 | 1724   | 183.2  | i leis | +<br>ر   |          | 2321  | 1239   | 24  |     |
|              | A-2-1                               |                 | 176.0  | 181.6  | 2.0    | 1-2-4    |          | 1773  | 8201   | 40  |     |
|              |                                     |                 | 182.1  | 1221   | 55     | N        |          | 1777  | 1842   | 12  |     |
|              | <b>N</b>                            |                 | 1752   | 120.0  | 5.5    | M<br>    |          | 1777  | 2581   | 40  |     |
|              | 4                                   |                 | 1833   | 137.9  | 6.0    | 4        |          | 173.0 | 1759   | 0   |     |
|              | 5                                   |                 | 1229   | 1224   | 6.2    | 5        |          | 1706  | 1863   | 40  |     |
|              | 916                                 |                 | 1782   | 1527   | 5 2    | DAR      | r        | 1720  | 6      | 42  |     |
|              |                                     | k<br>- 1<br>- 1 |        | 1      |        |          |          |       |        | 1   |     |
| Yes Long     | 1-18                                | 0.005           | 18:23  | 1225   | 020    | 1-1-1    | 0100     | 1727  | 1803   | 50  |     |
|              |                                     |                 | 120.0  | 186.3  | 20     | R        |          | 172.0 | 1856   | 25  |     |
|              | M                                   |                 | 124.2  | 1500   | 7.5    | ŝ        |          | 1746  | 1223   | 4   |     |
|              | 0-2-1                               |                 | 120.0  | 1526   | 7.0    | 6-2-1    |          | 1226  |        | 4   |     |
|              | n                                   |                 | 1.0.17 | 1252   |        | n        |          | 176.9 | 1337   | 2.5   |     |
|              |                                     | - ]-<br>        | 102    | 1953   | 20     | m        | -        | N     | 123.9  | 4.5   |     |
|              | 9776                                |                 | 1293   | 1250   | 2.2    | AVG      |          | 1779  | 1841   | 4.6   |     |
| ┽            |                                     |                 |        |        |        |          |          |       |        |   |     |
| No 404.9.    | 4                                   | 000             | 1838   | 1223   | 6.0    | 1-1-8    | 0.970    | 1292  | 1943   | 6.0   |     |
|              | N                                   |                 | 1100   | 1267   | 6.0    | <b>~</b> |          | 1321  | 1347   | 25  |     |
|              | 5                                   |                 | C727   | 1841   |        | ۳<br>    |          | 1829  | 1945   | 28  |     |
|              | * '                                 |                 | 117    | 1879   | 6,0    | 4        |          | 188.7 | 1551   | 75  |     |
|              |                                     | ╺┼              | 1212   | 1293   | 6.0    | ა<br>-   |          | 1884  | 1927   | 55  |     |
|              | AVG                                 |                 | 1861   | 1875   | 58     | AVG      |          | 188.6 | 1947   | 7.4   |     |
|              |                                     |                 |        | -      | -      | -        | •<br>}   |       |        |   | ••• |
| es Leng      | 1-1-8                               | 0200            | 1805   | 136.4  | کر کر  | 1-1-0    | 0600     | 186.1 | 192.0  | 59  |     |
|              | 1                                   |                 | 1791   | 1859   | •      | 2        |          | 1221  | 123.5  | 20  |     |
|              | •                                   | <br>            | 181.7  | 1221   | 20     | 3        | <b>→</b> | 1218  | 5161   | 5.0   |     |
|              | AVG.                                |                 | 1804   | 18681  |        | AVG      |          | 16    | 0201   | 60  |     |
|              |                                     |                 |        |        |        |          |          |       |        |   | -27 |
| NOTE:        | The first                           | digit           | IN G   | ach_   | Samele | numbe    | × 115    | tingu | ulshes | See 2   | 20  |
|              |                                     | · · ·           | -+     |        |        |          |          | 5     |        | <u>ا</u> ــــــــــــــــــــــــــــــــــــ |     |

| Lang     A:5-1     2005     1727     1744     A:5-1       Au     3     1725     1725     1745     53     4.5-1       Au     4u     1726     1726     1726     1725     1725     1725       Au     4u     1726     1726     1726     1726     1725     1725       Au     1726     1726     1726     1726     1725     1725       Au     1726     1726     1726     1725     1725       Au     1726     1726     1725     1725     1725       Au     1726     1726     1726     1725     1725       Au     1726     1725     1725     1725     1725       Au     1726     1725     1725     1725     1725       Au     1726     1725     1725     1725     1725       Au     1726     1725     1725     1725     1725       Au     1726     1726     1725     1725     1725       Au     1726     1726     1725     1725     1725       Au     1726     1726     1725     1725     1725       Au     1726     1726     1726     1766       Au  | 1400 F GRAIN<br>STEP DUR | 1400 CRAIN SAMP VIELD UNT "E | 0.16F          | 1211  | 1551  | 1 is             | 54:20<br>NO           | С<br>Ц    | AGE KSI | 177   | %<br>0     |
|--|--------------------------|------------------------------|----------------|-------|-------|------------------|-----------------------|-----------|---------|-------|------------|
| $ \begin{array}{ c c c c c c c c c c c c c c c c c c c$  |                          | - 2-                         |                | 001   | 1942  |                  |                       | 0         |         | 191.0 |            |
| 416     1335     1325     53     415     1325     1325     53     415     1325     53     415     1325     53     415     1325     53     415     1325     53     415     1325     53     415     1325     53     415     1325     53     415     1325     53     415     1325     53     415     1325     53     415     1325     53     415     1325     53     36     35     36       416     1326     1325     53     345     37     315     36     35     36       416     1356     1355     55     36     37     36     36     36       416     1355     55     36     37     36     36     36     36       416     1355     55     36     37     36     36     36       416     1355     55     36     36     36     36     36       416     1355     55     36     36     36     36     36       416     1355     55     36     36     36     36     36       416     1355     36     36     36     36     36     36   |                          |                              | J              | 1001  | 1353  | 0 %              | 'n                    |           |         | 1261  |            |
| Auc       (121.0)       (134.6)  |                          |                              | 3              | 1935  | 1592  | 45               |                       | ~         |         | • •   | <i>c °</i> |
| A: 6 - 1 $1/32.0$ $1/34.6$ $2.0$ $4.6 - 1$ $1/32.0$ $1/34.6$ $3.0$ $4.6 - 1$ $1/32.0$ $1/34.6$ $3.0$ $4.6 - 1$ $4.7 - 1$ $1/22.6$ $1/32.6$ $3.02.6$ $3.02.7$   | -                        | AUG                          |                | :761  | 1 1   | 53               | $ \langle n \rangle $ |           | 1       | 4     |            |
| NOT     NOT     NUT     NUT       3     1916     1920     1945     30     3       1916     1720     1745     30     3     NOT     RUX       3     1916     1720     1745     20     3     1912       4     1     1720     1745     20     3     1912       3     1720     1745     20     3     1912     1912       3     1720     1725     32     4     11     1912       3     1725     1725     52     4     11     1913     30       3     1725     1725     52     4     11     1715     2027     2043       3     1725     1725     52     3     1913     1725     3       445     1726     1725     52     3     2     2027     2045       3     1726     1725     56     3     2     2027     2045     3       445     1726     1725     56     3     2     2027     2045     3       446     1726     176     1725     3     3     2     2     3       446     1726     176     176     1   |                          | -7-8                         |                | 1000  | 1244  |                  |                       | + -       |         |       |            |
| $1/3$ $1/71(1, 1/7) \le 2/7$ $3/5 \ge 7$ $4/5$ $1/5$ $1/5$ $2/5 \ge 7$ $3/5$ $1/22$ $2/22$ <  |                          | 9<br>C                       | - (1           |       | 1952  |                  |                       |           | NOT     | RUN   |            |
| 146     1320     1345     27     4-7     1322     1227     202       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1     1     1     1     1       1     1     1     1     1   | -                        | -                            | ~              |       | 1940  | ) I              |                       | 3         |         |       |            |
| 4.71 $1650$ $721$ $522$ $321$ $3201$ $3201$ $4.71$ $471$ $1725$ $523$ $321$ $320$ $4.6$ $4.6$ $1735$ $52$ $32$ $1712$ $1732$ $3217$ $320$ $4.6$ $4.6$ $1735$ $52$ $32$ $446$ $1712$ $1735$ $32$ $4.6$ $4.6$ $1735$ $52$ $32$ $3207$ $2202$ $3293$ $4.6$ $4.6$ $1735$ $52$ $32$ $3207$ $2292$ $2292$ $4.6$ $4.6$ $1715$ $52$ $3207$ $2292$ $2292$ $2292$ $4.6$ $4.6$ $4.6$ $4.6$ $4.6$ $4.6$ $4.6$ $6.7$ $4.6$ $4.6$ $4.6$ $4.6$ $4.6$ $6.7$ $6.7$ $6.7$ $7.6$ $3.6$ $6.7$ $7.6$ $5.2$ $2.2027$ $2.2027$ $175.5$ $175.5$ $5.2$ $3.2027$ $2.2027$ $175.6$ $3.2027$ $2.2027$ $2.2027$ $2.2027$ $1.7$ $1.7$ $1.7$ $1.7$ $1.7$ $1.7$  |                          | 5/12                         |                |       | 1325  | 1.1              | 51.8                  |           |         |       |            |
| A-CI     120.7     72.1     72.5      72.5     72.5     72.5  |                          |                              |                |       | 1     |                  |                       |           | - 10    |       | ÷          |
| AUG $173.5$ $123.5$  |                          | 7-8                          |                | 1750  | N.    | 5.0              |                       |           |         | 2057  | 0          |
| AVG $I73.0$ $I172.0$   | -+-                      |                              |                | 1221  |       | -<br>N           | - 1                   |           | 191.2   | 1922  | 7.5        |
| Aré-1     1345  |                          |                              |                | 11.   | 1565  |                  |                       |           |         | •     | 11         |
| A-5-1     - 136. 132. 5.5     A-7.1     172.5     5.5       3     125.5     172.5     5.5     3     2027     2045       3     125.5     172.5     5.5     3     2027     2045     3       445     125.5     172.5     5.5     3     2027     2045     3       MDTE:     75     176.5     176.5     176.5     3     176.5     3       MDTE:     75     403.15     176.5     5     3     2027     2045     3       MDTE:     75     403.15     176.5     5     3     2027     2045     5       MDTE:     75     403.15     176.5     5     3     7     5       MDTE:     75     403.15     176.5     5     4     176.5     5       MDTE:     76     176.5     7     7     7     7       MDTE:     76     176.5     176.5     176.5     176.5       MDTE:     76     176.5     176.5     176.5     176.5       MDTE:     76     176.5     176.5     176.5     176.5       MDTE:     76.5     176.5     176.5     176.5     176.5       MDTE:     76.5     1   |                          | AV6                          |                | •     | 1:25  | <u>م</u> ر       | SVIA                  | -         |         | 7     | 3          |
| 3     1773     725     55     3     2021     2045     35       3     176     176     176     176     176     176     176     176     201     2045     35       NDTE     756     176     176     176     176     176     201     2045     35       NDTE     756     176     176     176     176     176     204     25       NDTE     756     176     176     176     176     451     205     25       NDTE     756     176     204     57     176     451     26       NDTE     76     176     24a     176     176     26       NDTE     176     176     24a     176     176       NDTE     176     176     24a     176     176       NDTE     176     176     176     176     176   |                          | -2-4                         |                | 1360  | 1725  | -<br>-<br>-<br>- | 4-2-                  |           | 1725    | 2049  |            |
| NDTE: The first digit in each sample number distinguishes<br>detween risats of material The actual heat number   |                          |                              | 2              | 127.2 | 1920  | 0                | (                     | - C¥      | 2007    | 2045  | ; •        |
| NDTE: The first digit in cach sample number distinguishes<br>between insels of material The defaal heat number<br>remmander in the defaal heat number<br>in in in the defaal heat number<br>in in in the defaal heat number<br>in in in in the defaal heat number<br>in in in in the defaal heat number<br>in in in in the defaal heat number<br>in in in in the defaal heat number<br>in in in in the defaal heat number<br>in in in in the defaal heat number<br>in in in in the defaal heat number<br>in in in in the defaal heat number<br>in in in in the defaal heat number<br>in in in in the defaal heat number<br>in in in in in the defaal heat number<br>in in in in the defaal heat number<br>in in in in the defaal heat number<br>in in in in the defaal heat number<br>in in in in the defaal heat number<br>in in in the defaal heat number<br>in in in the defaal heat number<br>in in in in the defaal heat number<br>in in in in the defaal heat number<br>in in in in the defaal heat number<br>in in in in the defaal heat number<br>in in in in the defaal heat number<br>in in in in the defaal heat number<br>in in in the defaal heat number<br>in in in the defaal heat number<br>in in the defaal heat number<br>in in the defaal heat number<br>in in the defaal heat number<br>in in the defaal heat number<br>in in the defaal heat number<br>in in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat number<br>in the defaal heat |                          |                              | m              | 121   | 170.7 |                  |                       | 0         |         |       |            |
| NDTE: The first digit in each sample number distinguishes<br>between instruction the detual heat number<br>nummer were in the detual heat number<br>in the detual heat number  |                          | ALG                          |                | 126.6 | 121.6 | 5 2              | Ň                     |           | 1865    |       | 3 5        |
| NOTE: The first digit in each sample number distinguishes<br>between neats of material The actual heat number<br>memory of the set of the  | ,                        |                              |                |       |       |                  |                       |           |         |       |            |
| NOTE: The first digit in each sample number distinguishes<br>between vests of material The detual kest number<br>remained with a findupa.  |                          |                              |                |       |       |                  |                       |           |         |       |            |
| between vests er material The detal kest number  | NOTE                     | 73e F.                       | ch No          |       |       | 140              |                       |           | 11-21   | Ľ.    | 0          |
| between vests en material The defual keat number   |                          |                              |                |       |       | <b>x</b>         |                       | ¥         |         | 1     |            |
|  |                          | between                      |                | 0     | Ŋ     | 1                | 70                    | 214       | 1 100   | t nu  | 20         |
|  |                          | 4-11/1-P                     |                | -5    |       |                  |                       | <b>*</b>  |         |       |            |
|  | -                        |                              | 1              |       |       |                  |                       |           |         |       |            |
|  |                          |                              | <br> <br> <br> |       |       |                  |                       | -         |         |       |            |
|  |                          |                              |                |       | -     | -                | •                     | •         |         |       |            |
|  |                          |                              |                |       |       |                  |                       | <br> <br> |         |       |            |
|  |                          |                              |                |       |       |                  |                       |           |         |       |            |
|  |                          |                              |                |       |       |                  |                       |           |         |       |            |
|  | · · ·                    |                              |                |       |       |                  |                       |           |         |       |            |

|                               |                 |       |       |       |       | -            |        |        |        | <u> </u> | an a u da fa |        | . الجيني |       |   | 6.0. <b></b> |       | Pa          | ge      | 81<br>FG | r-2' | 727 |       |
|-------------------------------|-----------------|-------|-------|-------|-------|--------------|--------|--------|--------|----------|--------------|--------|----------|-------|---|--------------|-------|-------------|---------|----------|------|-----|-------|
|                               |                 |       |       |       |       |              |        |        |        |          |              |        |          |       |   |              |       |             |         |          |      |     |       |
|                               | <i>y</i> ;<br>0 | 10    |       | M     |       | 2<br>7       | 50     | 3.0    |        | 5. C     | 0            | 0      |          |       |   | 507          | 57    |             |         |          |      |     |       |
| 728                           | 171<br>KS1      | 135.2 | 12    | 1252  | 37    | 1925         | 1337   | 196.0  | 1.25.0 | 14       | 2007         | 5      | 221.7    |       |   | - guir       | umbe  |             |         |          |      |     |       |
| 0-Ш<br>Tensiles Heats 5,6,728 | VIE10           | 1804  | 10    | 121.0 | NI    | 126.7        | 1.8.31 | 1923   | 1741   | 171.4    | 1359         | 1721   | 1925     |       |   | distu        | 4 700 | . 2         |         |          |      |     |       |
| - 11001                       | GAGE            | 0.010 |       |       |       |              |        |        | •      | -        | _            |        | <b>-</b> |       |   | 621          | ab    | 1           |         | •        |      |     | ×     |
| ./es                          | 5.H.MP          | 6-5-8 | ١m    | AUG   | 1-5-2 | NM           | AVG    | 1-2-21 | ~      | 746      | 6.2.         | 2      | r7,      | 5 F   |   | unu          | actu  | -           |         |          |      |     | <br>- |
|                               |                 |       |       |       | -     |              |        |        |        |          |              |        | -        |       |   | a da         | The   |             | -       | -        |      |     |       |
|                               | 2%              | 0.4   | 40    | 0.4   | 6.0   | 44<br>00     | 40     | 0<br>0 |        | 52       |              |        | 5.0      | 4<br> |   | NES          | 1012  |             |         | -        |      |     |       |
| TABLE<br>RH S180              | 1717            | 193.7 | 12:45 | 182.4 | 191.3 | 121.4        | 1231   | 1725   | 1.0    | 152.6    | 11161        | 127.4  | Lo.      |       |   | Eac          | 270.4 | . * . • 2 • |         |          |      |     |       |
| -27                           | VIELL           | 191   | 1246  | 7451  | . ]   | 1222         | 1250   | 1221   | 1744   | 1757     | 0711         | 1:27   | 1627     | 1804  |   | 4/1          | ot    |             | M M.    | -        |      |     |       |
| 6000                          | GAGE            | 2000  |       |       | -     |              |        |        |        |          |              |        | ~        |       |   | + dig.       | 6-015 |             | umou ur |          |      |     |       |
| 10100                         | SALE<br>ND      | 8-5-1 | a n   | AVG   | 1-9-0 | nri          | AVG    | 1-2-2  | 2      | 4062     | )<br>  <br>  | 1-0-17 | m        | ANG   |   | 373          | Hoola |             | N 1     | 4        |      |     |       |
| WONTH Z                       |                 |       |       |       | 1 1 1 |              |        |        |        |          |              |        |          |       |   | The          | 601   |             | NIA     | -        |      |     |       |
| CONVAIR-FOIL WORTE 2.0101     | GRAIN<br>DIR    | Leng. | >     |       |       |              |        |        |        | ->-      |              |        | >        |       | 5 | NOTE         |       |             |         |          |      |     |       |
| CONVA                         | 1400F           | YES   |       |       |       | ┝╌╄╼<br>┥╌┼┥ |        |        |        | ┝╌╋╌     | ┽╼┾╸         |        |          |       |   |              |       |             |         |          |      |     |       |

| CAGE YIELD W. 451 46<br>2005 1724 1828 45<br>1724 1828 1828 70<br>1724 1839 25<br>1724 25<br>1724 25<br>1725 1724 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 1744 25<br>1205 175 175 25<br>1205 175 175 25<br>1205 175 25<br>1205 175 25<br>1205 175 25<br>1205 175 25<br>1205 175 25<br>1205 175 25<br>1205 175 25<br>1205 175 25<br>1205 175 25<br>1205 175 25<br>1205 175 25<br>1205 175 25<br>1205 175 25<br>1205 175 25<br>1205 175 25<br>1205 175 25<br>1205 175 25<br>1205 175 25<br>1205 175 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1205 25<br>1 |
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|--------------------------|-------|-------|----------|--------|-----------|-------|-------|-------|-------------------|---|---|---|---|----|-----------------|----|----------|----|----|
| 517%                     | 43    | 54    | 26       | 42     |           | 2     | 7.2   | 7.4   |                   |   |   |   |   |    |                 |    |          |    |    |
| \$ 1.11 - 111<br>X-X MAX | 202   | 20    | 2.2      | 0 7    |           | 50    | 63    | 5.5   |                   |   |   |   | + |    |                 |    |          |    |    |
| 4<br>17:X:<br>18:X:      | 3.5   | 2.0   | 3.0      | 2.0    | 2.2       | 50    | 6.5   | 6.0   |                   |   |   | ` |   |    |                 |    |          |    |    |
| 5/7                      | 1864  | 1225  | 1901     | 190.7  |           | C7 71 | 1930  | 194.7 | -                 | · |   |   |   |    |                 |    |          |    |    |
| XFAX<br>Z                | 193.7 | 1322  | 2.01.7   | . 2043 | 1221      |       | 194.0 | 1951  |                   |   | · |   |   |    |                 |    |          |    |    |
| 121N<br>54               | 179.5 | 120.0 | 170.7    | 1223   | 125.9     |       | 1715  | 174.3 | والمركبة والمركبة |   |   |   |   |    |                 |    |          |    |    |
| 5/2                      | 1804  | 194.0 | 1.25.1   | 1816   | 1204      | 13/1/ | 1250  | 1326  |                   |   |   |   |   |    |                 |    |          |    |    |
| 14X                      | 192.0 | 1935  | 876,1    | 2.00.2 | 6121      |       | 1221  | 1292  | :<br>-<br>+       |   |   |   |   |    |                 |    |          |    |    |
| HEATS SECS F             | 173.6 | 2527  | 172.7    | 175.2  | 1721      |       | 1218  | 6221  |                   |   |   |   |   |    | •               |    |          |    | -  |
| N.J.<br>57-73            | 18    | 22    | 81-      | 17     | m v       |       | m     | δ     |                   |   |   |   |   |    | <u>ب</u><br>ب   | 1  |          |    |    |
| NO<br>HEAT               | 9     | 6     |          | 5      | · · ·     |       | 1     |       |                   |   |   |   |   |    | 1               |    |          |    |    |
| GAGE                     | 5000  |       | 2,0,2    | •      | 2:020     |       | 0600  |       |                   |   |   |   |   |    | 1               |    |          |    |    |
| 1400F<br>STE25           | Yes   | No    | -5-24 -4 | 110    | les<br>Nn |       | Xe S  | ۵Ŋ    |                   |   |   |   |   |    | TALANS A ACALLY |    |          |    |    |
|                          |       |       |          |        | -         |       |       |       |                   |   |   |   |   |    |                 |    |          |    |    |

| CONVAIR-         | R-Fort WoktH             |                  |                                       | N          | IT.      | N.         |                   | ۲.<br>۲. ۲.                            |         |   | ¥.           |
|------------------|--------------------------|------------------|---------------------------------------|------------|----------|------------|-------------------|--|---------|---|--------------|
| TABULA           | - JABULATION SHEET 0.024 | 0.02.5 . Eraige  | -77                                   | - Har      | Steel -T | S          | No.               | 10071                                  | 5 C 1 C |   |              |
| RAIN<br>DIR G    | GAGE                     | SAMP<br>NO CYCLE | 1217<br>1217                          | 111<br>124 | %<br>0   | Nar        | CYCLE             | 173X                                   | 1754    | 2   |              |
| Trans. 0.        | 570                      | JJT-1 Furnace    | 213.3                                 | 219.2      | 35       | 3KT-1 2    | Salt C.           | 215.8                                  | 222.8   | <b>Å</b><br>0                             |              |
|                  |                          | <u> </u>         | 214.9                                 | 122.3      | 3.5      |            |                   |  | 2151    | 5.0                                       |              |
|                  |                          | 101              |                                       | 2722       | 35       | -2-        |                   |  | 215.3   | o<br>V                                    |              |
| ·                |                          | 6                |                                       | 219.0      | 5,0      | 6          |                   | 241                                    | 2211    | 050                                       |              |
|                  |                          |                  | 12.0                                  | 2. Letter  |          | 10         |                   |  |         | 1 r                                       |              |
|                  |                          | 2                | 2-                                    | 120.V      | ر.5<br>م | <b>;</b> t |                   | 2 10.2                                 | 1222    | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>- |              |
|                  | -                        | 27               | 1 6/ 6                                | - 10 01 -  | 25       | 1 m        |                   | a v<br>P P                             | 2244    | 1 v<br>1 v                                |              |
| <b>.</b>         |                          | - V              |                                       | 1/1 2      | 50       | 0          |                   | 4                                      | 7229    | رد ا<br>رم ا                              |              |
|                  |                          | 2                |                                       |            | - n-     | Ś          |                   | 101                                    | 2201    | 5   |              |
|                  |                          | AVG              | 1.7                                   | 2 4 7      | 3.5      | AVG        |                   | 13.2:                                  |         | 1   |              |
|                  |                          |                  | • • • • • • • • • • • • • • • • • • • |            | • • •    |            | <b>i</b><br> <br> | •- • • • • • • • • • • • • • • • • • • |         | - •                                       |              |
| 2                | 2.00                     | 2760, 20-176     | 0206                                  | 12.21      | 40       | 1-146      | d He              | 1115                                   | 1415    |   |              |
| any. la          | 1_                       | 1                | 5 50 CY                               | 21         | 0.4      | 1          |                   | 2111                                   | 2154    | 40  | -            |
|                  |                          | 9                | 209.0                                 | i m        | 40       | m          |                   | 223.7                                  | i Si    | 35  |              |
|                  |                          | 5                | 207.8                                 | n          | 5        | 9          |                   | 209.7                                  | N       | 40  |              |
|                  | -                        | - /              | 205.6                                 | 5          | 04       | 8          |                   | 202.9                                  | 216.5   | 35  |              |
|                  |                          | 2                | 2032                                  | 202        | 35       | 01         |                   | 2093                                   | 2161    | 50  |              |
|                  |                          | 3                | 2098                                  | 210.2      | 50       | S          |                   | 209.4                                  | 217.2   | 4<br>0                                    |              |
|                  |                          | s                | 2029                                  | 2          | 4.0      | 10         |                   |  | 2187    | 90  |              |
|                  |                          | 6                | 206.9                                 | シノム        |          | 7          |                   | 2113                                   | 0       | 50  |              |
| >                |                          | 1 01             | 2056                                  | 212        | 40       | 2          | "\<br>>           | 2086                                   |         | 9   |              |
|                  |                          | AVG              | 205.7                                 | 213.0      |          | AVG        |                   | 2096                                   | 2178    | 39  |              |
|                  |                          |                  |                                       |            |          |            |                   |  |         |   |              |
|                  |                          |                  |                                       |            |          |            |                   |  |         |   |              |
|                  |                          | •                |                                       |            |          |            | +                 | +                                      |         |   |              |
|                  |                          |                  |                                       |            | -        |            | +                 | +                                      |         |   |              |
|                  |                          |                  |                                       | +          |          |            | +                 | <br> <br>                              |         |   |              |
|                  |                          |                  |                                       |            |          |            |                   |  |         |   |              |
|                  |                          |                  |                                       |            |          |            |                   |  |         |   |              |
|                  |                          |                  |                                       |            |          |            |                   | -                                      |         |   | с <b>О</b> . |
|                  | _                        |                  |                                       |            |          |            |                   |  |         |   |              |
| MARK & ARR IN. P |                          |                  | •                                     |            | •        |            |                   |  |         |   | -            |

| ·  |                  | -        |       |        |       |               |            |       |        |       |       |         |        |         | -                                       |       |                   |       |      |       |            | P | ngo |   | -5<br>ra1 | ľ-2 | 272 | 7 |                                       |
|--|------------------|----------|-------|--------|-------|---------------|------------|-------|--------|-------|-------|---------|--------|---------|---|-------|-------------------|-------|------|-------|------------|---|-----|---|-----------|-----|-----|---|---------------------------------------|
|  | -0-%             | 40       | 5     | 4<br>0 | 9.0   | 90            | ) n<br>0 0 |       | 9.0    | 50    | 2.5   | 40      | 25     | 3.5     | 35                                      |       | 0 8<br>0 8<br>0 8 | 4     | 35   | 00    | 3.6        |   | +   |   | 4-        |     |     | - | •                                     |
| E Step   | 21/2             | 2043     | 207.0 | 2159   | 2111  | 102           | 1000       | 1202  |        | 2.231 | 1107  | 1991    | 2054   | 2221    | 193.0                                   | 4     | 1202              | 4 V   | 2074 | 209.6 | 202.6      |   |     |   |           |     |     |   |                                       |
| 14005  | YIELD<br>KSI     | 1774     | 2020  | 2103   | 205.2 | 203.2         | 2012       | 200.0 | 176.8  | Т.    | 77/17 | 1245    |        | 0       | i i                                     | 123.5 | 1022              | 1987  | M    | 2     |            |   |     |   |           |     |     | - |                                       |
| - No.  | CVCLE            | Salt B   | 1 1   | -      |       |               |            |       |        | ~     |       | Salt B  |        |         |   |       |                   |       |      |       |            |   |     |   |           |     |     |   |                                       |
| - 0 - III<br>Tænsiles -                          | SAMP<br>NO       | 347-5    | 9     | N      | ولار  | • •           |            | 4     | 90     |       |       | 342-65  | 100    | 7       | 17                                      | N !   |                   | 72    | m    | 0     | AVG        |   | -   |   |           |     |     |   |                                       |
| 117 - U II<br>112 - S II<br>112 - Jacob II       |                  |          | ,     |        |       |               |            | -     |        |       |       |         | 1      |         | + |       |                   |       |      |       |            |   | -   |   |           |     |     |   |                                       |
| TABLE -  | Q1<br>2/2        | 6.0      | 40    | 32     | 30    | 34            | 10<br>10   | SM    | M (    | 20    |       | 50      | 40     | 4.<br>0 | ر ار<br>م آرد<br>                       | 70    | 202               | 3.5   | 8.5  | 2     | 5:0        |   |     |   |           |     |     |   |                                       |
| - 1912 - 1<br>1 1 - 1 - 1 - 1                    | 17: 77<br>77: 77 | 1822     | 201.5 | 1927   | 1902  | 2000          | 195.0      | 1929  | 1.161  | 1210  |       | 1726.   | 2123.  | 2044    | 1.2.5.                                  |       | 1250              | 1.00% | 2001 | 2026  | 1989       |   | -   |   |           |     |     |   |                                       |
|  | YIELD<br>KSK     |          | 196.0 | 1203   | 1860  | 1957          | 191.7      | 1957  | 127.5. | 1020  |       | 194.5.  | 203.9. | 2000    | 70                                      | 100   | 193. 3            | 1956  | 1351 | 92.   | 5.27       | + | •   |   |           |     | -   |   |                                       |
| Gage   | 127              | Fur nace |       |        |       | - <br>- <br>3 |            |       |        |       |       | Furnace |        |         |   |       |                   |       |      |       | - <b>}</b> |   |     |   |           |     |     |   |                                       |
| 0.040  | 2 AND<br>NO      | 2KT-31   |       | 4      | ł     |               | 6          | 4     | NU     | A116  |       | 2KL-7K  | Ō      | mo      | r ( )                                   | 20    |                   | ~     | 9    | 5     | 27.7       |   | -   | - |           |     |     |   |                                       |
| HEET   | •                |          |       |        |       | 1             |            |       |        |       |       |         |        |         |   |       |                   |       |      |       |            |   | •   |   |           |     |     |   |                                       |
| CONVAIR FORT WORTH TABULATION. SHEET 0.010 - 692 | GAGE             | 0100     |       |        |       |               |            | +-    |        |       |       | 0100    | -+-    | -       |   |       |                   |       | -+-  | •     | -+         |   |     |   |           |     |     |   | · · · · · · · · · · · · · · · · · · · |
| CONV.  | ZAIN<br>DIR      | Trans.   |       |        |       |               |            |       |        |       |       | . buc   |        |         |   |       |                   |       |      |       |            | , |     |   |           |     |     |   |                                       |

| PANEL GRAIN<br>NO DIR<br>KR7917 LONA                 | 1E1 GRAIN AS Acat Treated<br>0 DIR 6, 451 % C      | 51, F-451,<br>51, 12, 1201  |   |
|--|--|---|---|
|  | 1884   | 1791 1852 9.0<br>1802 1887 40<br>1803 1880 40                                     | NOT RUN   |
| 219058 Trans   | 2 1832   | 1772 1847 60<br>1720 1830 60<br>1720 1214 40                                      | 003;  |
| AVG<br>719272  | 1761 1830 50<br>1716 1200 60<br>1720 1200 60       | 1751 1230 53<br>1724 1783 50<br>1720 1783 50                                      | 202 140   |
| AVG.<br>687329                                       | 171.2 1800 60<br>172.7 1803 8.5<br>172.6 129.9 8.0 | 179,5 1788 53<br>1660 1740 80<br>169,2 1757 5.9<br>166,7 176,1 70<br>1657 1753 67 | 197 123<br>NDT RUN  |
| 687356<br>AVG  | 7 196.7  | 189.5 1920 5.5<br>187.5 1920 5.5<br>1913 1976 60<br>1913 1976 50                  | 176 32<br>177 20<br>192 29                                  |
| 687300<br>1915-10-10-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1 | 173.6 1840 80<br>                                  | 1699 1813 60<br>1293 1813 60<br>1710 1811 63<br>1701 1811 63                      | Fage 80<br>56<br>101 2121<br>101 2121<br>102 562<br>105 105 |
| 691936<br>AVG  | 1878 1948 50<br>1766 1948 50<br>1872 1948 25       | 171.2 1796 40<br>176.5 1949 50<br>177 0 185.8 47                                  | 124 84<br>124 84  |

| PANEL CRAIL   | As Heat Treslad | Here SOhe Self Spiral | 6,411 AS H. T. 50 hr 2 1 |
|---|-----------------|-----------------------|--------------------------|
| ┝╌╟╸  | 28. 13          | site test             | DIR 103 Creles 103 Creks |
| 107220 / 144  |                 |                       | Trans 134 20             |
| - filmer I and  | 192.3 199.3 5.0 | 2.8 199.2             | 333                      |
|   |                 | 12-1922 1             | 2 2                      |
|   | 1928 1996       | 1923 1974 52          | 183 126                  |
| 107927  | 1001102555      | . 19                  |                          |
|   | 1 1887 5.       | 3 189.8               | NOT RUN                  |
| 41/6  | 182.1 1825 55   | 182.3 1861 57         |                          |
|   |                 |                       |                          |
| ( 273 CA  | 1829 1222 55    | 1852 1911 70          |                          |
|   | 183.8 191.2 65  | 1230 190.0 5.5        | · NOT RUN                |
|   |                 |                       |                          |
| AVG   | 183.4 192.0 6.0 | 183.8 1309 60         |                          |
| 16391   |                 | 1752-1226 6.0         | 286 110                  |
|   | 1913 7          | 1893                  | 92                       |
|   |                 | 1774 1285 25          | 1 297 322                |
| AUG   | 1258 1904 20    | 1711 1928 72          | 301. 220                 |
| 719395  |                 | 187.1 192.7 5.5       |                          |
|   | 196.0           | 9 1<br>M C            | NOT AUN                  |
| AVG T   | 199 2 1948 6.0  | 1819 1899 62          |                          |
| 627249  | 1224 126.8      | 1692 1207 6.5         |                          |
|   |                 | -1227 6.              | INT RUIL                 |
| _   | 101 1 101       | 1237 1535 60          |                          |
| The Logit Martin and the second |                 | 4                     |                          |
| 269916  | 1781            | 175.7 181.1 60        | 77                       |
|   | 166.7 179.3 80  |                       | 2<br>S                   |
|   | - 1             | 1.47 1794 40          | rry<br>S                 |
| - SVA   |                 | 172.4 100.4. 6.0      | -<br>7                   |

| 1910 1 1 2 Hear The row Attack of the Share of the start of the   |   |  |  |   |   |  |  |   |  |   |  |  |   |  |
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| QIR $\overline{\xi}$ - $\overline{\xi}$ is $\overline{\xi}$ <t< td=""><td><math display="block">\begin{array}{ c c c c c c c c c c c c c c c c c c c</math></td><td>Diff       <math>\xi_{1}</math> Ki, <math>\xi_{2}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{2}</math> Ki, <math>\xi_{2}</math> Ki, <math>\xi_{2}</math> Ki, <math>\xi_{2}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{2}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> Ki, <math>\xi_{3}</math> 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<math>F_2</math>-Ki       <math>F_2</math>-Ki       <math>F_2</math>-Ki       <math>F_2</math>-Ki       <math>F_2</math>-Ki       <math>F_2</math>-Ki       <math>F_2</math>-Ki       <math>F_2</math>-Ki       <math>F_2</math>-Ki       <math>F</math></td><td>Diff       East free for the transmission of the free form       Diff for the transmission of the free form       Diff for the free form       Diff form&lt;</td><td>Mile       <math>4.5</math> <math>4.6</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> 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<math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <th< td=""><td>Mile       <math>4.5</math> <math>4.6</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <th< td=""></th<></td></th<></td></t<>   | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$  | Diff $\xi_{1}$ Ki, $\xi_{2}$ Ki, $\xi_{3}$ Ki, $\xi_{2}$ Ki, $\xi_{2}$ Ki, $\xi_{2}$ Ki, $\xi_{2}$ Ki, $\xi_{3}$ Ki, $\xi_{2}$ Ki, $\xi_{3}$ Ki, $\xi_{4}$ Ki, $\xi_{3}$ Ki, $\xi_{4}$ Ki, $\xi_{3}$ Ki, $\xi_{4}$ Ki, $\xi$   | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$   | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$  | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$  | Diff $\xi_{1}$ Ki, $\xi_{2}$ Ki, $\xi_{3}$ Ki, $\xi_{2}$ Ki, $\xi_{2}$ Ki, $\xi_{2}$ Ki, $\xi_{2}$ Ki, $\xi_{3}$ Ki, $\xi_{2}$ Ki, $\xi_{3}$ Ki, $\xi_{4}$ Ki, $\xi$   | Diff $F_2$ -Ki $F$   | Diff $F_2$ -Ki $F$  | Diff       East free for the transmission of the free form       Diff for the transmission of the free form       Diff for the free form       Diff form<  | Mile $4.5$ $4.6$ $5.4$ <th< td=""><td>Mile       <math>4.5</math> <math>4.6</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> <math>5.4</math> 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| $\begin{array}{c ccccccccccccccccccccccccccccccccccc$   | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$   | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$  | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$  | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$   | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$   | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$  | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$  | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$   | $\begin{array}{c c c c c c c c c c c c c c c c c c c $   | Mill $4.5$ $1.6$ $5.7$ <th< td=""><td>Mill       <math>4.5</math> <math>1.6</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <math>5.7</math> <th< td=""></th<></td></th<>  | Mill $4.5$ $1.6$ $5.7$ <th< td=""></th<>   |  |   |  |
| OLR $E_1 - K_{11}$ $K_{20}$ $F_2 - K_{21}$  | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$   | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$   | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$  | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$   | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$  | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$   | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$   | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$  | Nill $G_{1}$ $G_{2}$   | Mile $f_2$ -Kin $K_1$ -Kin $K_1$ -Kin $K_2$ -Kin $K_2$ -Kin $K_2$ -Kin $K_1$ -Kin $K_2$ -Kin $K_2$ -Kin $K_1$ -Kin $K_2$ -Kin $K_2$ -Kin $K_2$ -Kin $K_1$ -Kin $K_2$ -Kin  | Mile $f_2$ -Kin $K_1$ -Kin $K_1$ -Kin $K_2$ -Kin $K_2$ -Kin $K_2$ -Kin $K_1$ -Kin $K_2$ -Kin $K_2$ -Kin $K_1$ -Kin $K_2$ -Kin $K_2$ -Kin $K_2$ -Kin $K_1$ -Kin $K_2$ -Kin   |  |   |  |
| DIR $F_{1} K_{1} K_{2} K_{1} K_{2}$ $F_{2} K_{31} K_{2}$ $F_{2} K_{31} K_{2}$ $F_{2} K_{31} K_{2}$ $F_{2} K_{31} K_{2}$ ears $ 8E4  1935 40$ $ 7E6  1335 30$ $T_{22} K_{2}$ $22$ $ 8E0  1334 35$ $1234 35$ $124 27$ $ 1E  12  12  2  20$ $1262 1237 35$ $124 27$ $ 122  12  2  20     60  6f2  1737 55 50 116 724  11E  724 727 - 1327 35 50 124 72  122  12  2  20     60  6f2  1737 55 50 116 724  112  12  2  2  0     50  52  1737 55 50 116 724  112  12  2  2  0     50  52  1737 55 50 116 724  112  12  0     50  52  1737 55 50 116 724  112  12  0     50  52  1737 55 50 116  112  12  12  0     50  52  1732 55 50 116  112  12  12  12  12  12  12  12  12  12$  | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$  | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$   | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$   | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$  | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$   | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$   | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$   | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$  | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$   | Mile $f_2$ -Ki $K_2$ -Leat       Mile $f_1$ -Ki $K_2$ -Leat $Mile$ $f_1$ -Ki $f_2$ -Ki $f_1$ -Ki $f_1$ -Ki $f_1$ -Ki $f_2$ -Ki $f_1$  | Mile $f_2$ -Ki $K_2$ -Leat       Mile $f_1$ -Ki $K_2$ -Leat $Mile$ $f_1$ -Ki $f_2$ -Ki $f_1$ -Ki $f_1$ -Ki $f_1$ -Ki $f_2$ -Ki $f_1$   |  |   |  |
| DIR $E_1 K_0 (E_1 K_1 K_2)$ $E_2 K_{S1} (E_1 K_1 K_2)$ $E_2 K_{S1} (E_1 K_1 K_2)$ eans $   R (E_1 K_1 K_2)$ $E_1 K_{S1} (E_1 K_1 K_2)$ $E_1 K_{S1} (E_1 K_1 K_2)$ eans $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ eans $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ eans $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ eans $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ eans $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ eans $   R (E_1 K_2)$ $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ eans $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ eans $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ eans $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ eans $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ $   R (E_1 K_1 K_2)$ eans $   R (E_1 K_1 K_2)$   | DIR     F-Ku   | Diff $F_{7}$ -Ku   | DIR     F-Ku  | DIR     FKu <t< td=""><td><math display="block">\begin{array}{ c c c c c c c c c c c c c c c c c c c</math></td><td>Diff     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     <math>F_{7}</math>-Ku     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$C_{4}$   | NIR $C_{3}$ $C_{4}$  |  |   |  |
| QIR $F \cdot K_{11}$ $F \cdot K_{2$   | Dir $F \cdot k_{3}$ <   | Diff $f_2^{-}$ Ki $f_3^{-}$ Ki $f_4^{-}$ Ki $f_5^{-}$ Ki $f_4^{-}$ Ki $f_5^{-}$ Ki $f_4^{-}$ Ki $f_5^{-}$ Ki $f_4^{-}$ Ki $f_6^{$  | Dir $F \cdot k_{3}$ <  | DIR $F_{7}$ + Ki $F_{-}$  | DIR $F_7$ -Ku, $F_6$ $F_1$ -Ku, $F_6$ $F_1$ -Ku, $F_6$ $F_1$ -Ku, $F_6$ $F_1$ -Ku, $F_6$ $F_1$ -Ku, $F_6$ $F_1$ -Ku, $F_6$ $F_1$ -Ku, $F_1$ $F_1$ -Ku, $F_1$ $F_1$ -Ku, $F_1$ $F_1$ -Ku, $F_1$ $F_1$ -Ku, $F_1$ $F_1$ -Ku, $F_1$ $F_1$ -Ku, $F_1$ $F_1$ -Ku, $F_1$ $F_1$ -Ku, $F_1$ $F_1$ -Ku, $F_1$ $F_1$ -Ku, $F_1$ $F_1$ -Ku, $F_1$ $F_1$ -Ku, $F_2$ $F_1$ -Ku, $F_2$ $F_2$ -Ku,  | Diff $f_2^{-}$ Ki $f_3^{-}$ Ki $f_4^{-}$ Ki $f_5^{-}$ Ki $f_4^{-}$ Ki $f_5^{-}$ Ki $f_4^{-}$ Ki $f_5^{-}$ Ki $f_4^{-}$ Ki $f_6^{$  | Nill $f_2^- K_1 = f_{2,0}$ $f_1 = f_{3,1} = f_{3,2}$ $f_1 = f_{3,1} = f_{3,2}$ $f_1 = f_{3,1} = f_{3,2}$ vans $1 = f_1 = f_1 = f_2$ $f_1 = f_2 = f_2$ $f_2 = f_3 = f_2$ $f_1 = f_2 = f_1 = f_2$ vans $1 = f_1 = f_1 = f_2$ $f_1 = f_2 = f_2$ $f_2 = f_2 = f_2$ $f_1 = f_2 = f_2$ vans $1 = f_1 = f_2$ $f_2 = f_2$ $f_2 = f_2 = f_2$ $f_2 = f_2 = f_2$ $f_2 = f_2 = f_2$ vans $1 = f_2 = f_2$ $f_2 = f_2 = f_2$ $f_2 = f_2 = f_2$ $f_2 = f_2 = f_2 = f_2$ $f_2 = f_2 = f_2 = f_2$ vans $1 = f_2 = f_2 = f_2$ $f_2 = f_2 = f_2 = f_2$ $f_2 = f_2 = f_2 = f_2$ $f_2 = f_2 = f_2 = f_2$ $f_2 = f_2 = f_2 = f_2$ vans $1 = f_2 = f_2 = f_2$ $f_2 = f_2 = f_2 = f_2$ $f_2 = f_2 = f_2 = f_2$ $f_2 = f_2 = f_2 = f_2$ $f_2 = f_2 = f_2 = f_2$ vans $1 = f_2 = f_2 = f_2$ $f_2 = f_2 = f_2 = f_2$ $f_2 = f_2 = f_2 = f_2$ $f_2 = f_2 = f_2 = f_2$ $f_2 = f_2 = f_2 = f_2$ vans $1 = f_2 = f_2 = f_2 = f_2 = f_2 = f_2$ $f_2 = f_2 = f_2 = f_2 = f_2$ $f_2 = f_2 = f_2 = f_2$ $f_2 = f_2 = f_2 = f_2$ vans $1 = f_2 = f_2 = f_2 = f_2 = f_2 = f_2 = f_2 = f_2 = f_2 = f_2$ $f_2 = f_2 = f_2 = f_2$ <t< td=""><td>Nill       <math>f_2^- K_1 = f_{2,0}</math> <math>f_1 = f_{3,1} = f_{3,2}</math> <math>f_1 = f_{3,1} = f_{3,2}</math> <math>f_1 = f_{3,1} = f_{3,2}</math>         vans       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| DIR $F_{1} - K_{1}$ $F_{2}$ $F_{2} - K_{1}$ $F_{2}$ $F_{2} - K_{1}$ $F_{2}$ $F_{2} - K_{1}$ $F_{2} - K_{2}$ $F_{2$  | Dir $F \cdot 4x_1 \in -4x_1 = 5x_0$ $F \cdot 4x_1 \in -6x_1 = 5x_0$ $F \cdot 4x_1 \in -6x_1 = 5x_0$ $F \cdot 4x_1 \in -6x_1 = 5x_0$ $F \cdot 4x_1 \in -6x_1 = 5x_0$ $F \cdot 4x_1 \in -6x_1 = 5x_0$ $F \cdot 4x_1 \in -6x_1 = 5x_0$ $F \cdot 4x_1 = 5x_0$ $F \cdot 4x_1 \in -6x_1 = 5x_0$ $F \cdot 4x_1 = 5x_0$   | NR $F_2$ -Ki $F_4$ $F_1$ -Ki $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ $F_2$ $F_1$ $F_2$ $F_2$ $F_1$ $F_2$   | Dir $F \cdot 4x_1 \in -4x_1 = 5x_0$ $F \cdot 4x_1 \in -6x_1 = 5x_0$ $F \cdot 4x_1 \in -6x_1 = 5x_0$ $F \cdot 4x_1 \in -6x_1 = 5x_0$ $F \cdot 4x_1 \in -6x_1 = 5x_0$ $F \cdot 4x_1 \in -6x_1 = 5x_0$ $F \cdot 4x_1 \in -6x_1 = 5x_0$ $F \cdot 4x_1 = 5x_0$ $F \cdot 4x_1 \in -6x_1 = 5x_0$ $F \cdot 4x_1 = 5x_0$  | DIR $F \cdot K_1 = F \cdot $  | DIR $F - K_1$ <   | NR $F_2$ -Ki $F_4$ $F_1$ -Ki $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ $F_2$ $F_1$ $F_2$ $F_2$ $F_1$ $F_2$   | NIR $F_2$ -Ki $F_2$ -Cal $T_1$ -Col $F_2$ -Ki  | NIR $F_2$ -Ki $F_2$ -Cal $T_1$ -Col $F_2$ -Ki   | NIR $45 \text{ Km}$ $127 \text{ Km}$ $57 \text{ Km}$ $517 \text{ Km}$  | Mile       As   | Mile       As  |  |   |  |
| UR $E - K_{11}$ $K_{20}$ $E - K_{21}$ $K_{20}$ $E - K_{21}$ $K_{20}$ $E - K_{21}$ $K_{20}$ $E - K_{21}$ $K_{20}$ $E - K_{21}$ $K_{20}$ $E - K_{21}$ $K_{20}$ $E - K_{21}$ $K_{20}$ $E - K_{21}$ <td>DIR       <math>\overline{F}</math>-Ku       <math>\overline{F}</math>-Ku       <math>\overline{F}</math>-Ku       <math>\overline{F}</math>-Ku       <math>\overline{F}</math>-Ku       <math>\overline{F}</math>-Ku       <math>\overline{F}</math>-Ku       <math>\overline{F}</math>-Ku       <math>\overline{F}</math>-Ku       <math>\overline{F}</math>-Ku       <math>\overline{F}</math>-Ku       <math>\overline{F}</math>-Ku       <math>\overline{F}</math>-Ku       <math>\overline{F}</math>-Ku       <math>\overline{F}</math>-Ku       <math>\overline{F}</math>-Ku       <math>\overline{F}</math>-Ku       <math>\overline{F}</math>-Ku       <math>\overline{F}</math>-Ku       <math>\overline{F}</math>-Ku       <math>\overline{F}</math>-Ku       <math>\overline{F}</math>-Ku       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$\frac{1}{7}$ -ki $\frac{1}{6}$ -ki $\frac{1}{5}$ -   | DIR $\overline{F}$ -Ku  | DIR $\overline{F}$ -Ki   | DIR $F_{7}$ -Ki $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$   | NR $\frac{1}{7}$ -ki $\frac{1}{6}$ -ki $\frac{1}{5}$ -   | NIR $F_{1}$ -Ku $F_{2}$ -Ku  | NIR $F_{1}$ -Ku $F_{2}$ -Ku   | Mile $6.5 - 4ci$ $7.5 - 4ci$ $7.5 - 4ci$ $5.6 + 5i$ $722 - 5i$ $5.6 + 5i$ $722 - 5iiii$ $722 - 5iiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiii$   | Mile $f_2$ -Ku $f$  | Mile $f_2$ -Ku $f$   |  |   |  |
| DIR $F - 4x_1$ $5x_2$ $F - 4x_1$ $5x_2$ $7x_{10}$ $5x_{10}$   | DIR $F - kx$ $E - kx$ $2 - kx$ $2 - kx$ $2 - kx$ $2 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$  | Diff $\frac{1}{7}$ -Ki $\frac{1}{5}$   | DIR $F - kx$ $E - kx$ $2 - kx$ $2 - kx$ $2 - kx$ $2 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$ $1 - kx$   | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$  | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$  | Diff $\frac{1}{7}$ -Ki $\frac{1}{5}$   | NIR $F_1$ -Ki $F_2$ -Ki $F_1$ $F_2$ -Ki $F_1$ $F_2$ -Ki $F_1$ $F_2$ -Ki $F_1$ $F_2$ -Ki $F_1$ $F_2$ -Ki $F_1$ $F_2$ -Ki $F_1$ $F_2$ -Ki $F_1$ $F_2$ -Ki $F_1$ $F_2$ -Ki $F_1$ $F_2$ $F_1$ $F_2$ eans $1864$ $1760$ $1753$ $32$ $722$ $22$ $22$ $1874$ $1720$ $35$ $722$ $722$ $22$ $722$ $7177$ $1727$ $275$ $7920$ $35$ $722$ $27$ $7181$ $1935$ $20$ $1662$ $1662$ $1672$ $702$ $57$ $712$ $1212$ $60$ $1662$ $1293$ $50$ $102$ $124$ $712$ $1712$ $1712$ $1712$ $1712$ $50$ $102$ $1520$ $1112$ $1712$ $1712$ $50$ $102$ $1522$ $50$ $102$ $1002$ $50$ $1722$ $55$ $50$ $102$ $102$ $1121$ $1712$ $1712$ $50$ $102$ $102$ $102$ $1002$ $50$ $102$ $102$   | NIR $F_1$ -Ki $F_2$ -Ki $F_1$ $F_2$ -Ki $F_1$ $F_2$ -Ki $F_1$ $F_2$ -Ki $F_1$ $F_2$ -Ki $F_1$ $F_2$ -Ki $F_1$ $F_2$ -Ki $F_1$ $F_2$ -Ki $F_1$ $F_2$ -Ki $F_1$ $F_2$ -Ki $F_1$ $F_2$ $F_1$ $F_2$ eans $1864$ $1760$ $1753$ $32$ $722$ $22$ $22$ $1874$ $1720$ $35$ $722$ $722$ $22$ $722$ $7177$ $1727$ $275$ $7920$ $35$ $722$ $27$ $7181$ $1935$ $20$ $1662$ $1662$ $1672$ $702$ $57$ $712$ $1212$ $60$ $1662$ $1293$ $50$ $102$ $124$ $712$ $1712$ $1712$ $1712$ $1712$ $50$ $102$ $1520$ $1112$ $1712$ $1712$ $50$ $102$ $1522$ $50$ $102$ $1002$ $50$ $1722$ $55$ $50$ $102$ $102$ $1121$ $1712$ $1712$ $50$ $102$ $102$ $102$ $1002$ $50$ $102$ $102$  | NIR $6.5$ $6.64$ $1.5$ $6.64$ $5.64$ $7.64$   | Allow $\frac{45}{7}$ $\frac{12}{7}$ $\frac{11}{6}$ $\frac{12}{7}$ $\frac{11}{12}$ $\frac{12}{12}$ $\frac{12}{6}$ $\frac{12}{6}$ $\frac{12}{6}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{11}{6}$ $\frac{12}{7}$ $\frac{11}{6}$  | Allow $\frac{45}{7}$ $\frac{12}{7}$ $\frac{11}{6}$ $\frac{12}{7}$ $\frac{11}{12}$ $\frac{12}{12}$ $\frac{12}{6}$ $\frac{12}{6}$ $\frac{12}{6}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{12}{7}$ $\frac{11}{6}$ $\frac{12}{7}$ $\frac{11}{6}$   |  |   |  |
| DIR $F - K_{11}$ $F - K_{1$   | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$  | Diff $F_{1}$ Ki   | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$   | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$   | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$   | Diff $F_{1}$ Ki   | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$  | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$   | $\begin{array}{c c c c c c c c c c c c c c c c c c c $   | $\frac{1}{2} \frac{1}{12} $  | $\frac{1}{2} \frac{1}{12} $   |  |   |  |
| QIR $F_7 - K_1$ $F_7$   | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$   | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$  | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$  | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$   | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$   | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$  | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$   | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$  | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$  | Diff $A_{2}$  | Diff $A_{2}$   |  |   |  |
| DIR $F_7 - K_5$ $F_7 - K_7$   | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$   | NIR $\xi_{1}^{-1} \xi_{1}$ $\xi_{2}^{-1} \xi_{1}$ $\xi_{2}^{-1} \xi_{1}$ $\xi_{2}^{-1} \xi_{1}$ $\xi_{2}^{-1} \xi_{1}$ $\xi_{2}^{-1} \xi_{1}$ $\xi_{2}^{-1} \xi_{1}$ $\xi_{2}^{-1} \xi_{1}$ $\xi_{2}^{-1} \xi_{1}$ $\xi_{2}^{-1} \xi_{2}$ $\xi_{2}^{-1} \xi_{2}$ $\xi_{2}^{-1} \xi_{2}$ $\xi_{2}^{-1} \xi_{2}$ $\xi_{2}^{-1} \xi_{2}$ $\xi_{2}^{-1} \xi_{2}$ $\xi_{2}^{-1} \xi_{2}$ $\xi_{2}^{-1} \xi_{2}$ $\xi_{2}^{-1} \xi_{2}^{-1} \xi_{2}^{-1}$ $\xi_{2}^{-1} \xi_{2}^{-1} \xi_{2}^{-1} \xi_{2}^{-1}$ $\xi_{2}^{-1} \xi_{2}^{-1} \xi_{2}^{-1} \xi_{2}^{-1} \xi_{2}^{-1}$ $\xi_{2}^{-1} \xi_{2}^{-1} \xi_{2}^{-1} \xi_{2}^{-1} \xi_{2}^{-1}$ $\xi_{2}^{-1} \xi_{2}^{-1}   | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$  | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$  | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$  | NIR $\xi_{1}^{-1} \xi_{1}$ $\xi_{2}^{-1} \xi_{1}$ $\xi_{2}^{-1} \xi_{1}$ $\xi_{2}^{-1} \xi_{1}$ $\xi_{2}^{-1} \xi_{1}$ $\xi_{2}^{-1} \xi_{1}$ $\xi_{2}^{-1} \xi_{1}$ $\xi_{2}^{-1} \xi_{1}$ $\xi_{2}^{-1} \xi_{1}$ $\xi_{2}^{-1} \xi_{2}$ $\xi_{2}^{-1} \xi_{2}$ $\xi_{2}^{-1} \xi_{2}$ $\xi_{2}^{-1} \xi_{2}$ $\xi_{2}^{-1} \xi_{2}$ $\xi_{2}^{-1} \xi_{2}$ $\xi_{2}^{-1} \xi_{2}$ $\xi_{2}^{-1} \xi_{2}$ $\xi_{2}^{-1} \xi_{2}^{-1} \xi_{2}^{-1}$ $\xi_{2}^{-1} \xi_{2}^{-1} \xi_{2}^{-1} \xi_{2}^{-1}$ $\xi_{2}^{-1} \xi_{2}^{-1} \xi_{2}^{-1} \xi_{2}^{-1} \xi_{2}^{-1}$ $\xi_{2}^{-1} \xi_{2}^{-1} \xi_{2}^{-1} \xi_{2}^{-1} \xi_{2}^{-1}$ $\xi_{2}^{-1} \xi_{2}^{-1}   | NIR $\xi_1^{-1} \xi_1 (\xi_1 - \xi_1) (\xi_2 - \xi_2) (\xi_1 - \xi_2) (\xi_2 - \xi_2) ($   | NIR $\xi_1^{-1} \xi_1 (\xi_1 - \xi_1) (\xi_2 - \xi_2) (\xi_1 - \xi_2) (\xi_2 - \xi_2) ($  | DIR $6^{-5}$ $6^{-4}$ $7^{-2}$ $M_{12}$ $5^{-4}$ <  | Dig $6^{12}$ $6^{12}$ $6^{12}$ $6^{12}$ $6^{12}$ $6^{12}$ $6^{12}$ $6^{12}$ $6^{12}$ Pars $1864$ $176$ $75$ $75$ $72$   | Dig $6^{12}$ $6^{12}$ $6^{12}$ $6^{12}$ $6^{12}$ $6^{12}$ $6^{12}$ $6^{12}$ $6^{12}$ Pars $1864$ $176$ $735$ $30$ $7e^{16}$ $31$ $62$ Pars $1864$ $175$ $32$ $35$ $122$ $-2$ Pars $1860$ $175$ $32$ $35$ $123$ $62$ Pars $1781$ $175$ $32$ $35$ $123$ $62$ Pars $1781$ $1935$ $40$ $1860$ $1934$ $35$ $1234$ Pars $1781$ $1935$ $40$ $1860$ $1757$ $727$ $35$ $1234$ Pars $112$ $170$ $35$ $1237$ $55$ $116$ $724$ Pars $112$ $120$ $50$ $1692$ $1793$ $50$ $1007$ Pars $112$ $170$ $50$ $100$ $1007$ $1007$ $1007$  |  |   |  |
| $\begin{array}{c ccccccccccccccccccccccccccccccccccc$   | DIR     F-Ki   | NR     E - Kii     E Kii     E - Kii     E - Kii     E - Kii     E - Kii     E - Kii     E - Kii     E Kii     E - Kii     E Kii     E Kii     E Kii     E Kii     E Kii     E   | DIR     F-Ki  | DIR     F-Kit <t< td=""><td>DIR     F - Kii</td><td>NR     E - Kii     E Kii     E - Kii     E - Kii     E - Kii     E - Kii     E - Kii     E - Kii     E Kii     E - Kii     E Kii     E Kii     E Kii     E Kii     E Kii     E</td><td>NR     <math>F_1 - F_1</math> <math>F_2</math> <math>F_1 - F_2</math> <math>F_1 - F_2</math> <math>F_1 - F_2</math> <math>F_1 - F_2</math> <math>F_1 - F_2</math>       Pans     <math>18E4</math> <math>1746</math> <math>40</math> <math>1766</math> <math>733</math> <math>30</math> <math>7797</math> <math>31</math>       Pans     <math>18E4</math> <math>1935</math> <math>40</math> <math>1766</math> <math>733</math> <math>32</math> <math>7797</math> <math>31</math>       Pans     <math>1872</math> <math>1935</math> <math>40</math> <math>1766</math> <math>1334</math> <math>35</math> <math>1234</math>       Pans     <math>1731</math> <math>1935</math> <math>40</math> <math>1762</math> <math>1732</math> <math>35</math> <math>1234</math>       Pans     <math>1186</math> <math>1232</math> <math>1292</math> <math>356</math> <math>1124</math>       Pans     <math>1231</math> <math>1819</math> <math>60</math> <math>1692</math> <math>1293</math> <math>55</math> <math>1116</math>       Pans     <math>1121</math> <math>1712</math> <math>1710</math> <math>50</math> <math>1293</math> <math>56</math> <math>1107</math>       Pans     <math>1121</math> <math>1712</math> <math>1710</math> <math>50</math> <math>1293</math> <math>50</math> <math>1107</math></td><td>NR     <math>F_1 - 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Kii   | NR     E - Kii     E Kii     E - Kii     E - Kii     E - Kii     E - Kii     E - Kii     E - Kii     E Kii     E - Kii     E Kii     E Kii     E Kii     E Kii     E Kii     E   | NR $F_1 - F_1$ $F_2$ $F_1 - F_2$ $F_1 - F_2$ $F_1 - F_2$ $F_1 - F_2$ $F_1 - F_2$ Pans $18E4$ $1746$ $40$ $1766$ $733$ $30$ $7797$ $31$ Pans $18E4$ $1935$ $40$ $1766$ $733$ $32$ $7797$ $31$ Pans $1872$ $1935$ $40$ $1766$ $1334$ $35$ $1234$ Pans $1731$ $1935$ $40$ $1762$ $1732$ $35$ $1234$ Pans $1186$ $1232$ $1292$ $356$ $1124$ Pans $1231$ $1819$ $60$ $1692$ $1293$ $55$ $1116$ Pans $1121$ $1712$ $1710$ $50$ $1293$ $56$ $1107$ Pans $1121$ $1712$ $1710$ $50$ $1293$ $50$ $1107$  | NR $F_1 - F_1$ $F_2$ $F_1 - F_2$ $F_1 - F_2$ $F_1 - F_2$ $F_1 - F_2$ $F_1 - F_2$ Pans $18E4$ $1746$ $40$ $1766$ $733$ $30$ $7797$ $31$ Pans $18E4$ $1935$ $40$ $1766$ $733$ $32$ $7797$ $31$ Pans $1872$ $1935$ $40$ $1766$ $1334$ $35$ $1234$ Pans $1731$ $1935$ $40$ $1762$ $1732$ $35$ $1234$ Pans $1186$ $1232$ $1292$ $356$ $1124$ Pans $1231$ $1819$ $60$ $1692$ $1293$ $55$ $1116$ Pans $1121$ $1712$ $1710$ $50$ $1293$ $56$ $1107$ Pans $1121$ $1712$ $1710$ $50$ $1293$ $50$ $1107$   | Mark $F_2 - K_{11}$ $F_2$ $K_{12}$ $K_{1$  | Dig $G_2^{-}$ for $F_2^{-}$ for   | Dig $G_2^{-}$ for $F_2^{-}$ for  |  |   |  |
| QIR $F - K_{51}$ $F - 4^{-$   | DIR     F-Ksi     F-     Train     Train     Train       Pans     186.4     176.6     75.4     75.7     75.7     75.7     72.4     20.0       Pans     186.4     176.6     176.6     75.7     73.4     35     1.3       Pans     186.4     186.0     176.6     7.5     7.7     7.7     7.4       Pans     186.0     176.1     7.5     7.7     7.7     7.7     7.4       Pans     171.2     171.2     6.0     1.69.2     10.7     5.5     11.6       Pans     161.2     170     5.0     1.67.2     5.2     11.6       Pans     161.2     170     5.0     1.6.7     5.2     11.6       Pans     1.6.7     170     5.0     1.6.7     5.2     11.6       Pans     1.6.7     170     5.0     1.6     1.16  | NR     FK.     FK.     FK.     FK.     FK.     FK.     FK.       eans     1864     1946     40     1766     1933     30     1724     31       eans     1864     1860     1933     32     1724     32     124       eans     1860     1934     35     122     124       eans     1860     1934     35     124       eans     111     121     1845     1933     55     124       eans     1131     1813     1612     100     55     124       eans     1131     1813     60     1692     1793     50     116       eans     112     1813     60     1692     1793     50     116       eans     112     1712     1710     50     55     116  | DIR     F-Ksi     F-     Train     Train     Train       Pans     186.4     176.6     75.4     75.7     75.7     75.7     72.4     20.0       Pans     186.4     176.6     176.6     75.7     73.4     35     1.3       Pans     186.4     186.0     176.6     7.5     7.7     7.7     7.4       Pans     186.0     176.1     7.5     7.7     7.7     7.7     7.4       Pans     171.2     171.2     6.0     1.69.2     10.7     5.5     11.6       Pans     161.2     170     5.0     1.67.2     5.2     11.6       Pans     161.2     170     5.0     1.6.7     5.2     11.6       Pans     1.6.7     170     5.0     1.6.7     5.2     11.6       Pans     1.6.7     170     5.0     1.6     1.16   | NIR     F Kil E L     Mark Mill     Mark Mill     Mark Mill       Pans     1864     1766     1766     1766     1766     1766       Pans     1864     1766     1766     1766     1766     1766       Pans     1864     1766     1766     1766     1766     1766       Pans     1860     1766     1766     1766     1767     1746       Pans     1860     1766     1766     1767     1724     1724       Pans     11612     170     60     1692     1798     50     1116       Pans     1121     1712     1710     50     1798     50     1116       Pans     1612     1700     50     1692     1798     50     1116       Pans     1121     1712     1710     50     55     1116   | NIR     FKu <t< td=""><td>NR     FK.     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<math>1270</math> <math>55</math> <math>1000</math>       vans     <math>1020</math> <math>55</math> <math>1000</math> <math>1000</math>       vans     <math>1002</math> <math>1570</math> <math>55</math> <tr< td=""><td>NR     <math>F_1 - F_{11}</math> <math>F_1 - F_{12}</math> <math>F_1 - F_{12}</math> <math>F_1 - F_{12}</math> <math>F_1 - F_{12}</math> <math>F_1 - F_{12}</math>       VIR     <math>F_1 - F_{12}</math> <math>F_1 - F_{12}</math> <math>F_2 - F_{21}</math> <math>F_2 - F_{21}</math> <math>F_1 - F_{12}</math>       vans     <math>1864</math> <math>1761</math> <math>1935</math> <math>40</math> <math>1766</math> <math>1373</math> <math>32</math> <math>172n</math>       vans     <math>7771</math> <math>7927</math> <math>732</math> <math>35</math> <math>172n</math> <math>122</math>       vans     <math>1721</math> <math>1935</math> <math>40</math> <math>1860</math> <math>1934</math> <math>35</math> <math>172n</math>       vans     <math>7771</math> <math>7927</math> <math>757</math> <math>7927</math> <math>35</math> <math>172n</math>       vans     <math>11612</math> <math>1020</math> <math>1073</math> <math>55</math> <math>172n</math>       vans     <math>1231</math> <math>1812</math> <math>1692</math> <math>1793</math> <math>50</math> <math>1116</math>       vans     <math>1121</math> <math>1212</math> <math>1020</math> <math>55</math> <math>1020</math> <math>102n</math>       vans     <math>1121</math> <math>1212</math> <math>1020</math> <math>560</math> <math>1012</math>       vans     <math>11231</math> <math>1212</math> <math>50</math> <math>1020</math> <math>55</math>       vans     <math>11231</math> <math>1270</math> <math>55</math> <math>1000</math>       vans     <math>1020</math> <math>55</math> <math>1000</math> <math>1000</math>       vans     <math>1002</math> <math>1570</math> <math>55</math> <tr< td=""><td>Mark     <math>f_{7}^{*}</math> <math>f_{7}^{*}</math> <math>f_{7}^{*}</math> <math>f_{7}^{*}</math> <math>f_{7}^{*}</math> 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<math>F_{7}^{-}</math> + Ki     <math>F_{7}^{-}</math> + Ki</td></tr<>   | Mark $f_{7}^{*}$   | Dig $f_{7}^{-}$ + Ki $F_{7}^{-}$ + Ki  | Dig $f_{7}^{-}$ + Ki $F_{7}^{-}$ + Ki   |  |   |  |
| QIR $F \cdot K_1$ $F \cdot K_1$ $F_2$ $F \cdot K_2$ $F \cdot K_3$   | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$  | NIR $F_1$ -Ku $F_1$ -Ku $F_2$ -Ku $F_1$ -Ku $F_2$ -Ku $F_1$ -Ku $F_2$ -Ku $F_1$ -Ku $F_2$ -Ku $F_1$ -Ku $F_2$ -Ku $F_1$ -Ku $F_1$ -Ku $F_2$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_2$ -Ku $F_1$ -Ku $F_2$ -Ku<   | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$   | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$  | NIR $F_1$ -Ku $F_1$ $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ $F_1$ $F_1$ $F_1$ $F_1$ $F_1$ $F_1$ $F_1$ $F_1$ $F_1$ $F_1$ $F_1$ $F_1$ $F_1$ $F_1$ $F_1$ $F_2$ $F_1$ $F_1$ $F_1$ $F_1$ $F_2$   | NIR $F_1$ -Ku $F_1$ -Ku $F_2$ -Ku $F_1$ -Ku $F_2$ -Ku $F_1$ -Ku $F_2$ -Ku $F_1$ -Ku $F_2$ -Ku $F_1$ -Ku $F_2$ -Ku $F_1$ -Ku $F_1$ -Ku $F_2$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_1$ -Ku $F_2$ -Ku $F_1$ -Ku $F_2$ -Ku<   | NIR $F_2$ -Ki $F_1$ $Y_1$ $Y_2$ $Y_1$ $Y_2$ $Y_1$ $Y_2$ $Y_1$ $Y_2$ $Y_1$ $Y_2$ $Y_1$ $Y_2$ $Y_1$ $Y_2$ $Y_1$ $Y_2$ $Y_1$ $Y_1$ $Y_1$ ears $ISLR$ $IPL6$ $IPL6$ $IPL6$ $IPL6$ $IPL6$ $IPL6$ $IPL6$ $IPL6$ $IPL6$ $IPL6$ $IPL6$ $IPL6$ $IPPL6$ $IPL6$ $IPPL6$   | NIR $F_2$ -Ki $F_1$ $Y_1$ $Y_2$ $Y_1$ $Y_2$ $Y_1$ $Y_2$ $Y_1$ $Y_2$ $Y_1$ $Y_2$ $Y_1$ $Y_2$ $Y_1$ $Y_2$ $Y_1$ $Y_2$ $Y_1$ $Y_1$ $Y_1$ ears $ISLR$ $IPL6$ $IPL6$ $IPL6$ $IPL6$ $IPL6$ $IPL6$ $IPL6$ $IPL6$ $IPL6$ $IPL6$ $IPL6$ $IPL6$ $IPPL6$ $IPL6$ $IPPL6$  | Mark $E_2$ -Ki $E_1$ -Ki $E_2$ -Ki   | Dig $45 + 16 = 4$ $175 + 73$ $5 - 53$ $123 - 123 - 123$ $2 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - $   | Dig $45 + 16 = 4$ $175 + 73$ $5 - 53$ $123 - 123 - 123$ $2 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - $  |  |   |  |
| QIR $\frac{7}{7}$ -Kxi $\frac{6}{7}$ -Kxi $\frac{7}{7}$ -Kxi  | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$  | NR $F_1 - F_1$ $F_2$ $F_1 - F_2$ $F_2 - F_2$ $F_1 - F_2$ $F_2 - F_2$ $F_2 - F_2$ $F_1 - F_2$ vans $1864$ $176$ $173$ $30$ $777$ $737$ $35$ $172$ vans $777$ $737$ $737$ $35$ $172$ $134$ vans $777$ $7379$ $35$ $172$ $134$ vans $11612$ $172$ $20$ $152$ $134$ vans $1151$ $1812$ $102$ $1672$ $1737$ $55$ vans $1121$ $1210$ $50$ $1612$ $170$ $50$ $101$ vans $1121$ $1210$ $50$ $1572$ $55$ $101$  | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$   | NIR     E-Ku   | DIR     FKri  | NR $F_1 - F_1$ $F_2$ $F_1 - F_2$ $F_2 - F_2$ $F_1 - F_2$ $F_2 - F_2$ $F_2 - F_2$ $F_1 - F_2$ vans $1864$ $176$ $173$ $30$ $777$ $737$ $35$ $172$ vans $777$ $737$ $737$ $35$ $172$ $134$ vans $777$ $7379$ $35$ $172$ $134$ vans $11612$ $172$ $20$ $152$ $134$ vans $1151$ $1812$ $102$ $1672$ $1737$ $55$ vans $1121$ $1210$ $50$ $1612$ $170$ $50$ $101$ vans $1121$ $1210$ $50$ $1572$ $55$ $101$  | NIR $\frac{1}{5} \cdot \frac{5}{5} \cdot \frac{5}{5} \cdot \frac{1}{5} \cdot $   | NIR $\frac{1}{5} \cdot \frac{5}{5} \cdot \frac{5}{5} \cdot \frac{1}{5} \cdot $  | Column $45 - 6 - 4$ $12 - 5 - 45$ $5 - 45$ <   | Dig $\frac{45}{7}$ $\frac{45}{7}$ $\frac{1}{7}$   | Dig $\frac{45}{7}$ $\frac{45}{7}$ $\frac{1}{7}$  |  |   |  |
| QIR $F - Kx_1$ $F - fx_1$ $7x_2$ $F - fx_1$ $7x_2$ $F - fx_1$ $7x_2$   | DIR     F-Ks. <t< td=""><td>NR     <math>7 - 5x_1 - 5x_2 - 5x_1 </math></td><td>DIR     F-Ks.     <t< td=""><td>OIR     F-Ks.     <t< td=""><td><math display="block">\begin{array}{ c c c c c c c c c c c c c c c c c c c</math></td><td>NR     <math>7 - 5x_1 - 5x_2 - 5x_1 </math></td><td>NIR       <math>6^{-5}</math> <math>12</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> <math>5^{-1}</math> 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| QIR $F \cdot K_1$ $F \cdot K_1$ $F \cdot K_2$ $F \cdot K_2$ $F \cdot K_2$ $F \cdot K_2$ $F \cdot K_2$ $F \cdot K_2$ $200$ $200$ $200$ Parts $1864$ $1766$ $1753$ $30$ $7226$ $31$ Parts $1578$ $1935$ $40$ $1766$ $1753$ $32$ $1226$ Parts $1578$ $1935$ $40$ $1766$ $1734$ $35$ $1226$ Parts $1578$ $1926$ $1935$ $40$ $1860$ $1734$ $35$ $1226$ Parts $1231$ $1935$ $40$ $1860$ $1734$ $35$ $1226$ Parts $1231$ $1812$ $102$ $202$ $1293$ $50$ $1166$ Parts $1162$ $120$ $50$ $1693$ $50$ $1166$ Parts $1122$ $1210$ $50$ $1503$ $50$ $1166$  | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$  | DIR $E_1 \cdot E_1$ $E_2 \cdot E_2$ $E_1 \cdot E_2$ $E_2 \cdot E_3$  | $\begin{array}{ c c c c c c c c c c c c c c c c c c c$   | DIR $F_1 - K_1$ $F_2 - K_2$ $F_1 - K_2$ $D_{12} - K_2$ $D_{12} - K_2$ eans $18E4$ $17L6$ $17L6$ $1753$ $30$ $772n$ eans $18E4$ $17L6$ $1755$ $720$ $35$ $172n$ eans $18E4$ $17L6$ $1755$ $720$ $35$ $172n$ eans $18E0$ $1734$ $35$ $720n$ $35$ eans $1781$ $1935$ $40$ $18E0$ $1734$ $35$ eans $1781$ $1935$ $40$ $18E0$ $1734$ $35$ $172n$ eans $1781$ $1935$ $40$ $18E2$ $1736$ $35$ $1734$ eans $1781$ $1935$ $40$ $1672$ $1793$ $55$ eans $1162$ $1202$ $50$ $1672$ $1793$ $55$ eans $1122$ $1710$ $50$ $1.720$ $55$ $1116$ eans $1622$ $1292$ $52$ $1793$ $55$ $1116$  | DIR $F_{1} - K_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ <   | DIR $E_1 \cdot E_1$ $E_2 \cdot E_2$ $E_1 \cdot E_2$ $E_2 \cdot E_3$  | Diff $E \cdot E \cdot E \cdot E \cdot E \cdot E \cdot E \cdot E \cdot E \cdot E \cdot$   | Diff $E \cdot E \cdot E \cdot E \cdot E \cdot E \cdot E \cdot E \cdot E \cdot E \cdot$  | Diff $45$ $6ct$ $7c$ $5t$ $aus$ $1712$ $1212$ $50$ $125t$ $125t$ $127t$ $127t$ $122t$ $124t$ $122t$ $aus$ $1781$ $60$ $1862$ $1720$ $35$ $55$ $1116$ $aus$ $1712$ $1210$ $50$ $1652$ $1292$ $55$ $1116$ $aus$ $1212$ $1210$ $50$ $1652$ $1292$ $55$ $1116$ $aus$ $1112$ $1210$ $50$ $1502$ $55$ $1116$  | Diff $45$ $4cdt$ $7c$ $5c$  | Diff $45$ $4cdt$ $7c$ $5c$   |  |   |  |
| QIR $F - KS1$ F - KS1     F - KS1     F - KS1<  | DIR $F_{1} - K_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ <   | DIR $F_1 - F_3$ $F_1 - F_3$ $F_1 - F_3$ $F_1 - F_3$ $F_1 - F_3$ $F_1 - F_2$ Pars $1864$ $1753$ $20$ $1723$ $72$ $71$ Pars $1864$ $1733$ $30$ $71236$ $71$ Pars $1864$ $1733$ $30$ $71236$ $712$ Pars $1713$ $1935$ $40$ $1860$ $1733$ $35$ $1724$ Pars $1727$ $7727$ $7724$ $7726$ $7727$ $7724$ Pars $1712$ $7557$ $7729$ $35$ $7134$ Pars $1716$ $7557$ $7729$ $50$ $1116$ Pars $1715$ $60$ $1692$ $1793$ $50$ $116$ Pars $1715$ $50$ $1793$ $50$ $116$  | DIR $F_{1} - K_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ $F_{1}$ $F_{2}$ <  | DIR $F_{1} - K_{11} - K_{21} - K_{21} - K_{21} - K_{21} - K_{21} - K_{22} - K_{21} - K_{22} - K_{21} - K_{22} - K_{21} - K_{22} - K_{21} - K_{22} - K_{21} - K_{22} - K_{21} - K_{22} - K_{21} - K_{22} - K_{22} - K_{21} - K_{22} - K_{2$  | DIR $F_1 - F_{31}$ $F_2 - F_{31}$   | DIR $F_1 - F_3$ $F_1 - F_3$ $F_1 - F_3$ $F_1 - F_3$ $F_1 - F_3$ $F_1 - F_2$ Pars $1864$ $1753$ $20$ $1723$ $72$ $71$ Pars $1864$ $1733$ $30$ $71236$ $71$ Pars $1864$ $1733$ $30$ $71236$ $712$ Pars $1713$ $1935$ $40$ $1860$ $1733$ $35$ $1724$ Pars $1727$ $7727$ $7724$ $7726$ $7727$ $7724$ Pars $1712$ $7557$ $7729$ $35$ $7134$ Pars $1716$ $7557$ $7729$ $50$ $1116$ Pars $1715$ $60$ $1692$ $1793$ $50$ $116$ Pars $1715$ $50$ $1793$ $50$ $116$  | NR $K_{1}^{2} - K_{3}$ $K_{1}^{2} - K_{3}$ $K_{2}^{2} - K_{3}$ $K_{2}^{2} - K_{3}$ $K_{2}^{2} - K_{3}$ $K_{2}^{2} - K_{3}$ $K_{2}^{2} - K_{3}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2} - K_{$   | NR $K_{1}^{2} - K_{3}$ $K_{1}^{2} - K_{3}$ $K_{2}^{2} - K_{3}$ $K_{2}^{2} - K_{3}$ $K_{2}^{2} - K_{3}$ $K_{2}^{2} - K_{3}$ $K_{2}^{2} - K_{3}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2} - K_{3}^{2}$ $K_{2}^{2} - K_{3}^{2} - K_{$  | Old $45$ $1627$ $17$ $56$ $51$ $2as$ $171$ $51$ $175$ $179$ $52$ $52$ $116$ $52$ $aus$ $171$ $52$ $179$ $52$ $52$ $116$ $171$ $52$ $179$ $52$ $116$ $52$ $116$ $171$ $52$ $52$ $116$ $126$ $126$ $126$ $126$ $171$ $52$ $52$ $116$ $126$ $129$ $52$ $116$ $171$ $121$ $52$ $52$ $116$ $127$ $127$ $127$ $171$ $121$  | Dig $45$ $1627$ $17$ $57$ $515$ $575$ $575$ $575$ $575$ $575$ $575$ $575$ $575$ $575$ $575$ $575$ $575$ $575$ $723$ $723$ $723$ $723$ $723$ $722$ $723$ $722$ $724$ $7$   | Dig $45$ $1627$ $17$ $57$ $515$ $575$ $575$ $575$ $575$ $575$ $575$ $575$ $575$ $575$ $575$ $575$ $575$ $575$ $723$ $723$ $723$ $723$ $723$ $722$ $723$ $722$ $724$ $7$  |  |   |  |
| QIR $F - K_{S1}$ $F - K_{11}$ $F_{S0}$ $F - K_{S1}$ $K_{S0}$ $K_{S0}$ $K_{S1}$ $K_{S0}$ $K_{S1}$ <  | DIR $F_{7}$ -KSI $F_{1}$ $Y_{60}$ $F_{7}$ -KSI $F_{10}$ $Y_{60}$ $F_{10}$ $Y_{$   | DIR $F_1 - F_{S1}$ $F_2$ $F_1$ $F_1$ $F_2$ $F_2$ $F_1$ $F_1$ $F_1$ $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ $F_1$ $F_2$ </td <td>DIR     <math>F_{7}</math>-KSI     <math>F_{1}</math> <math>Y_{60}</math> <math>F_{7}</math>-KSI     <math>F_{10}</math> <math>Y_{60}</math> <math>F_{10}</math> <math>Y_{10}</math> > <td><math display="block">\begin{array}{c c c c c c c c c c c c c c c c c c c </math></td> <td>DIR     <math>F_1 - K_{51}</math> <math>F_{5-4}</math> <math>F_{5-4}</math> <math>F_{5-4}</math> <math>F_{5-4}</math> <math>F_{5-4}</math> <math>F_{5-4}</math> <math>F_{5-4}</math> <math>F_{5-4}</math> <math>F_{5-4}</math> <math>F_{5-4}</math> <math>F_{5-4}</math> <math>F_{5-4}</math> <math>F_{5-4}</math> <math>F_{5-4}</math> <math>F_{5-4}</math> <math>F_{5-4}</math> <math>F_{5-4}</math> 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| QIR     F-Ksi     F- <thf-< th=""> <thf-< th="">     F-     F-</thf-<></thf-<>  | DIR $F_{1} - K_{S1}$ $F_{2} - K_{S1}$  | DIR $\frac{1}{7}$ <  | DIR $F_{1} - K_{S1}$ $F_{2} - K_{S1}$   | DIR $F_1 - K_{51}$ $F_{5} - K_{11}$ $K_{50}$ $F_{7} - K_{51}$ $K_{50}$ $K_{7} - K_{51}$ $K_{60}$ $M_{12} - K_{51}$ $M_{12} - K_{51}$ Pans $1864$ $1946$ $40$ $1766$ $1935$ $30$ $122$ Pans $1864$ $1935$ $40$ $1766$ $1934$ $35$ $122$ Pans $1872$ $1935$ $40$ $1766$ $1934$ $35$ $122$ Pans $1872$ $1936$ $1734$ $35$ $122$ $122$ Pans $1731$ $1935$ $40$ $1764$ $7329$ $35$ Pans $1731$ $1937$ $35$ $50$ $122$ Pans $1231$ $1292$ $702$ $55$ $116$ Pans $1231$ $1292$ $1293$ $50$ $107$   | DIR $F_1 - F_{S1}$ $F_$   | DIR $\frac{1}{7}$ <  | DIR $\frac{1}{7}$ <  | DIR $\frac{1}{7}$ <   | Dig $f_{2} - k_{S1}$   | $\begin{array}{c c c c c c c c c c c c c c c c c c c $  | $\begin{array}{c c c c c c c c c c c c c c c c c c c $   |  |   |  |
| QR $F - 451$ $F - 451$ $F - 651$ </td <td><math display="block">\begin{array}{c c c c c c c c c c c c c c c c c c c </math></td> <td>DIR     <math>F_1 - F_{11}</math> <math>F_2 - F_{21}</math> <math>F_{12} - F_{21}</math> <math>F_{22} - F_{21}</math> <math>F_{22} - F_{21}</math> <math>F_{22} - F_{21}</math> <math>F_{22} - F_{21}</math>       Pans     <math>1864</math> <math>176</math> <math>176</math> <math>1935</math> <math>40</math> <math>1766</math> <math>1732</math> <math>35</math> <math>122</math>       Pans     <math>1872</math> <math>1935</math> <math>40</math> <math>1860</math> <math>1934</math> <math>35</math> <math>122</math>       Pans     <math>1872</math> <math>1936</math> <math>172</math> <math>35</math> <math>122</math>       Pans     <math>1781</math> <math>1935</math> <math>40</math> <math>1860</math> <math>1934</math> <math>35</math> <math>122</math>       Pans     <math>1782</math> <math>1936</math> <math>7929</math> <math>35</math> <math>122</math> 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| QIR     F-Ksi     F-Ksi     F-Gamma     F-Ksi     F-Ksi     F-Ksi       eans     1864     1746     40     1766     1755     7354     35     112       eans     1864     1935     40     1860     1734     35     112     122       eans     1864     1781     1935     40     1860     1734     35     1234       eans     1860     1782     1934     35     122     1234       eans     1781     1935     40     1860     1734     35     1234       eans     1781     1935     7959     7959     35     1234  | $\begin{array}{c c c c c c c c c c c c c c c c c c c $  | DIR $F_1 - F_{11}$ $F_2 - F_{21}$ $F_1 - F_{21}$ $F_2 - F_{21}$  | $\begin{array}{c c c c c c c c c c c c c c c c c c c $   | $\begin{array}{c c c c c c c c c c c c c c c c c c c $  | DIR $F_1 - K_{51}$ $F_{5-4}$ $F_{5$   | DIR $F_1 - F_{11}$ $F_2 - F_{21}$ $F_1 - F_{21}$ $F_2 - F_{21}$  | Dig $\frac{1}{7}$ $\frac{1}{8}$ $\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{18}$ $\frac{1}{18}$ $\frac{1}{18}$ $\frac{1}{18}$ $\frac{1}{18}$ $\frac{1}{12}$ $\frac{1}{12}$ $\frac{1}{11}$ $\frac{1}{1$   | Dig $\frac{1}{7}$ $\frac{1}{8}$ $\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{18}$ $\frac{1}{18}$ $\frac{1}{18}$ $\frac{1}{18}$ $\frac{1}{18}$ $\frac{1}{12}$ $\frac{1}{12}$ $\frac{1}{11}$ $\frac{1}{1$  | $\begin{array}{c c c c c c c c c c c c c c c c c c c $   | $\begin{array}{c c c c c c c c c c c c c c c c c c c $  | $\begin{array}{c c c c c c c c c c c c c c c c c c c $   |  |   |  |
| DLR     E-Ksi     E-Ksi     E-Ksi     E-Ksi     E-Ksi     E-Ksi       eans     1864     1766     1766     1733     30     1724     31       eans     1878     1935     40     1860     1934     35     122       eans     1877     1935     40     1860     1934     35     122       eans     1873     1935     70     35     122     122  | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$   | DIR $F_{2}$ -Ksi $F_{1}$ -Ksi $F_{2}$ -Ksi   | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$  | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$   | DIR $F_1 - F_{S1}$ $F_$   | DIR $F_{2}$ -Ksi $F_{1}$ -Ksi $F_{2}$ -Ksi   | DIR $\frac{1}{7}$ $1$ <t< td=""><td>DIR     <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>\frac{1}{7}</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <math>1</math> <t< td=""><td><math display="block">\begin{array}{c c c c c c c c c c c c c c c c c c c </math></td><td><math display="block">\frac{1}{2010} = \frac{1}{7} \frac{1}{5}</math></td><td><math display="block">\frac{1}{2010} = \frac{1}{7} \frac{1}{5}</math></td></t<></td></t<>   | DIR $\frac{1}{7}$ $1$ <t< td=""><td><math display="block">\begin{array}{c c c c c c c c c c c c c c c c c c c </math></td><td><math display="block">\frac{1}{2010} = \frac{1}{7} \frac{1}{5}</math></td><td><math display="block">\frac{1}{2010} = \frac{1}{7} \frac{1}{5}</math></td></t<> | $\begin{array}{c c c c c c c c c c c c c c c c c c c $   | $\frac{1}{2010} = \frac{1}{7} \frac{1}{5}$  | $\frac{1}{2010} = \frac{1}{7} \frac{1}{5}$ |  |   |  |
| QIR     F-Ksi     F-Ksi     F-Ksi     F-Ksi     F-Ksi     F-Ksi       eans     1864     1946     40     1766     1935     30     7123       eans     1864     1946     40     1766     1935     30     722       eans     1864     1935     40     1766     1935     30     122       7777     7947     70     35     124     35     124       116     7757     7957     7957     7957     716  | OLR     E-451 <the-451< th="">     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     <the-451< th="">     E-251     <the-251< th=""> <the-251< th=""> <the-251< th=""> <the-25< td=""><td>DIR     Fraction     Attract     Attract     Attract     Attract       Pans     1864     1766     1766     173     30     173       Pans     1860     1761     737     35     173     122       Pans     1860     1761     737     35     123       Pans     1860     1755     7959     35     134       Pans     1767     7959     35     116</td><td>OLR     E-451     <the-451< th="">     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     <the-451< th="">     E-251     <the-251< th=""> <the-251< th=""> <the-251< th=""> <the-25< td=""><td>DIR     E-Ksi     <the-ksi< th="">     E-Ksi     <th< td=""><td>DIR     F: - 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KSI </td <td>DIR     Fraction     Attract     Attract     Attract     Attract       Pans     1864     1766     1766     173     30     173       Pans     1860     1761     737     35     173     122       Pans     1860     1761     737     35     123       Pans     1860     1755     7959     35     134       Pans     1767     7959     35     116</td> <td>Diff     <math>F_{1} - F_{1}</math> <math>F_{2} - F_{1}</math> <math>F_{2} - F_{2}</math> <math>F_{1} - F_{2}</math> <math>F_{2} - F_{1}</math> <math>F_{2} - F_{2}</math> <math>F_{2} - F_{2}</math> <math>F_{2} - F_{2}</math> <math>F_{2} - F_{2}</math> <math>F_{2} - F_{2}</math> <math>F_{2} - F_{2}</math> <math>F_{2} - F_{2}</math> <math>F_{2} - F_{2}</math> <math>F_{2} - F_{2}</math> <math>F_{2} - F_{2}</math> <math>F_{2} - F_{2}</math> <math>F_{2} - F_{2}</math> <math>F_{2} - F_{2}</math> <math>F_{2} - F_{2}</math> <math>F_{2} - F_{2}</math> <math>F_{2} - F_{2}</math> <math>F_{2} - F_{2}</math> <math>F_{2} - F_{2}</math> <math>F_{2} - 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| QIR     F-KSI     F-A     F-A     F-A     F-A     F-A     F-A     F-A       eans     1864     1946     40     1766     1935     30     7121     31       eans     1864     1946     40     1860     1934     35     124       122     1926     1935     40     1860     1934     35     134       7771     1945     20     1939     35     116  | OLR     E-451 <the-451< th="">     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     <the-451< th="">     E-251     <the-251< th=""> <the-251< th=""> <the-251< th=""> <the-25< td=""><td>DIR     F - KSI        <th -<="" td=""><td>OLR     E-451     <the-451< th="">     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-451     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     E-251     <the-451< th="">     E-251     <the-251< th=""> <the-251< th=""> <the-251< th=""> <the-25< td=""><td>DIR     F:-Ksi     F:-Ksi     F:-Ksi     F:-Ksi     F:-Ksi     F:-Ksi     F:-Ksi       eans     1864     1766     1753     30     1784     1753     30       1860     1935     40     1860     1934     35     1234     35       1787     1935     40     1860     1934     35     134       1787     1935     40     1860     1934     35     134       116     1757     1939     35     174     124</td><td>DIR     F: - 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1935     40     176.6     1934     35     122       Pans     1860     1934     35     122     124</td><td>DIR     Grad     Mirer Stri Sult Yrad     Gain Nas HT       018     17     100     100     100       108     17     15     15     15     100       186     134     10     176.6     133     30     175.6       186     134     136     134     35     122       186     134     134     35     124</td><td>DIR     Grad     Mirer Stri Sult Yrad     Gain Nas HT       018     17     100     100     100       108     17     15     15     15     100       186     134     10     176.6     133     30     175.6       186     134     136     134     35     122       186     134     134     35     124</td><td>Dig     As</td><td>Dilk     As     Heat     If     Total     Arrest     Arrest     Arrest     Arrest     Arrest       Dilk     F-4si     F-4si     F-6si     Arrest     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si</td><td>Dilk     As     Heat     If     Total     Arrest     Arrest     Arrest     Arrest     Arrest       Dilk     F-4si     F-4si     F-6si     Arrest     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-4si     F-6si     F-6si   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173.7     31       Pans     1864     1935     40     176.6     1934     35     122       Pans     1860     1934     35     122     124  | DIR     F - 451 <thf -="" 451<="" th=""> <thf -="" 451<="" th=""> <thf -="" 451<="" th=""> <th< td=""><td>DIR     F - KSI        <th -<="" td=""><td>DIR     F KSI<!--</td--><td>DIR     F-451     F-651     F-651     F-651     F-651     F-651     F-651       Pans     1864     1946     40     176.6     1953     30     1700     175.6       Pans     1864     1935     40     176.6     1933     30     173.7     31       Pans     1864     1935     40     176.6     1934     35     122       Pans     1860     1934     35     122     124</td><td>DIR     Grad     Mirer Stri Sult Yrad     Gain Nas HT       018     17     100     100     100       108     17     15     15     15     100       186     134     10     176.6     133     30     175.6       186     134     136     134     35     122       186     134     134     35     124</td><td>DIR     Grad     Mirer Stri Sult Yrad     Gain Nas HT       018     17     100     100     100       108     17     15     15     15     100       186     134     10     176.6     133     30     175.6       186     134     136     134     35     122       186     134     134     35     124</td><td>Dig     As</td><td>Dilk     As     Heat     If     Total     Arrest     Arrest     Arrest     Arrest     Arrest       Dilk     F-4si     F-4si     F-6si     Arrest     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si</td><td>Dilk     As     Heat     If     Total     Arrest     Arrest     Arrest     Arrest     Arrest       Dilk     F-4si     F-4si     F-6si     Arrest     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si</td></td></th></td></th<></thf></thf></thf>   | DIR     F - KSI <th -<="" td=""><td>DIR     F KSI<!--</td--><td>DIR     F-451     F-651     F-651     F-651     F-651     F-651     F-651       Pans     1864     1946     40     176.6     1953     30     1700     175.6       Pans     1864     1935     40     176.6     1933     30     173.7     31       Pans     1864     1935     40     176.6     1934     35     122       Pans     1860     1934     35     122     124</td><td>DIR     Grad     Mirer Stri Sult Yrad     Gain Nas HT       018     17     100     100     100       108     17     15     15     15     100       186     134     10     176.6     133     30     175.6       186     134     136     134     35     122       186     134     134     35     124</td><td>DIR     Grad     Mirer Stri Sult Yrad     Gain Nas HT       018     17     100     100     100       108     17     15     15     15     100       186     134     10     176.6     133     30     175.6       186     134     136     134     35     122       186     134     134     35     124</td><td>Dig     As</td><td>Dilk     As     Heat     If     Total     Arrest     Arrest     Arrest     Arrest     Arrest       Dilk     F-4si     F-4si     F-6si     Arrest     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si</td><td>Dilk     As     Heat     If     Total     Arrest     Arrest     Arrest     Arrest     Arrest       Dilk     F-4si     F-4si     F-6si     Arrest     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si</td></td></th>  | <td>DIR     F KSI<!--</td--><td>DIR     F-451     F-651     F-651     F-651     F-651     F-651     F-651       Pans     1864     1946     40     176.6     1953     30     1700     175.6       Pans     1864     1935     40     176.6     1933     30     173.7     31       Pans     1864     1935     40     176.6     1934     35     122       Pans     1860     1934     35     122     124</td><td>DIR     Grad     Mirer Stri Sult Yrad     Gain Nas HT       018     17     100     100     100       108     17     15     15     15     100       186     134     10     176.6     133     30     175.6       186     134     136     134     35     122       186     134     134     35     124</td><td>DIR     Grad     Mirer Stri Sult Yrad     Gain Nas HT       018     17     100     100     100       108     17     15     15     15     100       186     134     10     176.6     133     30     175.6       186     134     136     134     35     122       186     134     134     35     124</td><td>Dig     As</td><td>Dilk     As     Heat     If     Total     Arrest     Arrest     Arrest     Arrest     Arrest       Dilk     F-4si     F-4si     F-6si     Arrest     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si</td><td>Dilk     As     Heat     If     Total     Arrest     Arrest     Arrest     Arrest     Arrest       Dilk     F-4si     F-4si     F-6si     Arrest     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si</td></td>   | DIR     F KSI </td <td>DIR     F-451     F-651     F-651     F-651     F-651     F-651     F-651       Pans     1864     1946     40     176.6     1953     30     1700     175.6       Pans     1864     1935     40     176.6     1933     30     173.7     31       Pans     1864     1935     40     176.6     1934     35     122       Pans     1860     1934     35     122     124</td> <td>DIR     Grad     Mirer Stri Sult Yrad     Gain Nas HT       018     17     100     100     100       108     17     15     15     15     100       186     134     10     176.6     133     30     175.6       186     134     136     134     35     122       186     134     134     35     124</td> <td>DIR     Grad     Mirer Stri Sult Yrad     Gain Nas HT       018     17     100     100     100       108     17     15     15     15     100       186     134     10     176.6     133     30     175.6       186     134     136     134     35     122       186     134     134     35     124</td> <td>Dig     As</td> <td>Dilk     As     Heat     If     Total     Arrest     Arrest     Arrest     Arrest     Arrest       Dilk     F-4si     F-4si     F-6si     Arrest     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si</td> <td>Dilk     As     Heat     If     Total     Arrest     Arrest     Arrest     Arrest     Arrest       Dilk     F-4si     F-4si     F-6si     Arrest     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si</td>   | DIR     F-451     F-651     F-651     F-651     F-651     F-651     F-651       Pans     1864     1946     40     176.6     1953     30     1700     175.6       Pans     1864     1935     40     176.6     1933     30     173.7     31       Pans     1864     1935     40     176.6     1934     35     122       Pans     1860     1934     35     122     124  | DIR     Grad     Mirer Stri Sult Yrad     Gain Nas HT       018     17     100     100     100       108     17     15     15     15     100       186     134     10     176.6     133     30     175.6       186     134     136     134     35     122       186     134     134     35     124  | DIR     Grad     Mirer Stri Sult Yrad     Gain Nas HT       018     17     100     100     100       108     17     15     15     15     100       186     134     10     176.6     133     30     175.6       186     134     136     134     35     122       186     134     134     35     124   | Dig     As   | Dilk     As     Heat     If     Total     Arrest     Arrest     Arrest     Arrest     Arrest       Dilk     F-4si     F-4si     F-6si     Arrest     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si   | Dilk     As     Heat     If     Total     Arrest     Arrest     Arrest     Arrest     Arrest       Dilk     F-4si     F-4si     F-6si     Arrest     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-4si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     Arrest     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     Arrest       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si     F-6si     F-6si       Pile     F-6si     F-6si     F-6si   |   |  |
| DLR     F-KSI <t< td=""><td>DIR     F-451     <thf-451< th="">     F-451     F-451     <th< td=""><td>DIR     F-451     F-71     Mire 5/11     Mire 5/11     Mire 5/11     Mire 5/11     Mire 5/11       DIR     F-451     F-651     F-651     F-651     F-651     Mire 5/11       eans     1864     1946     40     1866     1935     30     Tran 7/1       eans     1878     1935     40     1860     1936     35     122       eans     1878     1935     40     1862     1930     35     124</td><td>DIR     F-451     <thf-451< th="">     F-451     F-451     <th< td=""><td>DIR     F - 451        F</td><td>DIR     Fighthank<!--</td--><td>DIR     F-451     F-71     Mire 5/11     Mire 5/11     Mire 5/11     Mire 5/11     Mire 5/11       DIR     F-451     F-651     F-651     F-651     F-651     Mire 5/11       eans     1864     1946     40     1866     1935     30     Tran 7/1       eans     1878     1935     40     1860     1936     35     122       eans     1878     1935     40     1862     1930     35     124</td><td>MR     Grant     March Strict Strict     March Strict     March Strict       MR     Grant     March Strict     March Strict     March Strict     March Strict       MR     Grant     March Strict     March Strict     March Strict     March Strict       MR     Grant     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March String       March Strint     March St</td><td>MR     Grant     March Strict Strict     March Strict     March Strict       MR     Grant     March Strict     March Strict     March Strict     March Strict       MR     Grant     March Strict     March Strict     March Strict     March Strict       MR     Grant     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March String       March Strint     March St</td><td>Diff     E - 451     E - 451     E - 451     E - 451     E - 451     E - 451     A - 451     <tha -="" 451<="" th=""> <tha -="" 451<="" th=""> <tha -="" 451<="" th=""> <t< td=""><td>DIR E-tsu E-tsu tres to Atter Str Str Str Str Str Str Str St Str St Str St St St St St St St St St St St St St</td><td>DIR E-tsu E-tsu tres to Atter Str Str Str Str Str Str Str St Str St Str St St St St St St St St St St St St St</td></t<></tha></tha></tha></td></td></th<></thf-451<></td></th<></thf-451<></td></t<>   | DIR     F-451 <thf-451< th="">     F-451     F-451     <th< td=""><td>DIR     F-451     F-71     Mire 5/11     Mire 5/11     Mire 5/11     Mire 5/11     Mire 5/11       DIR     F-451     F-651     F-651     F-651     F-651     Mire 5/11       eans     1864     1946     40     1866     1935     30     Tran 7/1       eans     1878     1935     40     1860     1936     35     122       eans     1878     1935     40     1862     1930     35     124</td><td>DIR     F-451     <thf-451< th="">     F-451     F-451     <th< td=""><td>DIR     F - 451        F</td><td>DIR     Fighthank<!--</td--><td>DIR     F-451     F-71     Mire 5/11     Mire 5/11     Mire 5/11     Mire 5/11     Mire 5/11       DIR     F-451     F-651     F-651     F-651     F-651     Mire 5/11       eans     1864     1946     40     1866     1935     30     Tran 7/1       eans     1878     1935     40     1860     1936     35     122       eans     1878     1935     40     1862     1930     35     124</td><td>MR     Grant     March Strict Strict     March Strict     March Strict       MR     Grant     March Strict     March Strict     March Strict     March Strict       MR     Grant     March Strict     March Strict     March Strict     March Strict       MR     Grant     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March String       March Strint     March St</td><td>MR     Grant     March Strict Strict     March Strict     March Strict       MR     Grant     March Strict     March Strict     March Strict     March Strict       MR     Grant     March Strict     March Strict     March Strict     March Strict       MR     Grant     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March Strict       March Strict     March Strict     March Strict     March String       March Strint     March St</td><td>Diff     E - 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| 186 5-451 6-41 360 5-451 5-651 36 2010 105 46 100 105 65 10 105 105 105 105 105 105 105 105 105   | DIR     F - 451        F  | DIR     F - Ksi  | DIR     F - 451        F   | 018 6-451 6-4 4 4 6 75 6 1938 4 75 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1  | DIR     F: - KSI </td <td>DIR     F - Ksi</td> <td>DIR     Grant     Mile Shi Shi Shi Shi Shi Shi Shi Shi Shi Shi</td> <td>DIR     Grant     Mile Shi Shi Shi Shi Shi Shi Shi Shi Shi Shi</td> <td>DIR E-451 E-451 No 17 - 651 No 17 - 651 No 101 No 102 No 1</td> <td>DIR E-451 E-451 No 12 - 651 No</td> <td>DIR E-451 E-451 No 12 - 651 No</td>   | DIR     F - Ksi  | DIR     Grant     Mile Shi Shi Shi Shi Shi Shi Shi Shi Shi Shi   | DIR     Grant     Mile Shi Shi Shi Shi Shi Shi Shi Shi Shi Shi  | DIR E-451 E-451 No 17 - 651 No 17 - 651 No 101 No 102 No 1   | DIR E-451 E-451 No 12 - 651 No  | DIR E-451 E-451 No 12 - 651 No   |  |   |  |
| DIR     E-Asil E-La ve     F-date     E-date     E-date     Part of the second s  | DIR     F - KSI <th -<="" td=""><td>DIR     F-451     F-651     F-651     F-651     F-651     F-651       Pans     1864     1746     40     1766     1733     30     71-345     71       Pans     1864     1766     1766     1733     30     71-345     71</td><td>DIR     F - KSI        <th -<="" td=""><td>DIR     F - KSI     F - M     DITEC SVI SUID SU2     DID     DID     DID     DID     DID     DID     DID     DID     DIS     M - L     SU       Pans     1864     1935     40     1860     1935     30     1735     31     31</td><td>DIR     F - 451     F - 451     F - 451     F - 451     F - 451     M - 261     M - 15       Pans     1864     1766     1766     1753     30     17-35     31</td><td>DIR     F-451     F-651     F-651     F-651     F-651     F-651       Pans     1864     1746     40     1766     1733     30     71-345     71       Pans     1864     1766     1766     1733     30     71-345     71</td><td>DIR         Contract Strict Strict         Stract Stract Strict         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract Stract         Stract Stract         Stract Stract</td><td>DIR         Contract Strict Strict         Stract Stract Strict         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract Stract         Stract Stract         Stract Stract</td><td>Dilk     As     Acat     Mire     Str&lt;</td><td>Dill     As     Heat     I's     Total     Attec Strick of Strick     Strat     Strick of Strick       DIR     5-451     5-651     5-651     5-651     5-651     50     010       Pans     1864     176.6     176.6     173.3     3.0     17-36     71       Pans     186.4     193.5     4.0     186.0     173.4     3.5     1.22</td><td>Dill     As     Heat     I's     Total     Attec Strick of Strick     Strat     Strick of Strick       DIR     5-451     5-651     5-651     5-651     5-651     50     010       Pans     1864     176.6     176.6     173.3     3.0     17-36     71       Pans     186.4     193.5     4.0     186.0     173.4     3.5     1.22</td></th></td></th>  | <td>DIR     F-451     F-651     F-651     F-651     F-651     F-651       Pans     1864     1746     40     1766     1733     30     71-345     71       Pans     1864     1766     1766     1733     30     71-345     71</td> <td>DIR     F - KSI        <th -<="" td=""><td>DIR     F - KSI     F - M     DITEC SVI SUID SU2     DID     DID     DID     DID     DID     DID     DID     DID     DIS     M - L     SU       Pans     1864     1935     40     1860     1935     30     1735     31     31</td><td>DIR     F - 451     F - 451     F - 451     F - 451     F - 451     M - 261     M - 15       Pans     1864     1766     1766     1753     30     17-35     31</td><td>DIR     F-451     F-651     F-651     F-651     F-651     F-651       Pans     1864     1746     40     1766     1733     30     71-345     71       Pans     1864     1766     1766     1733     30     71-345     71</td><td>DIR         Contract Strict Strict         Stract Stract Strict         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract Stract         Stract Stract         Stract Stract</td><td>DIR         Contract Strict Strict         Stract Stract Strict         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract Stract         Stract Stract         Stract Stract</td><td>Dilk     As     Acat     Mire     Str&lt;</td><td>Dill     As     Heat     I's     Total     Attec Strick of Strick     Strat     Strick of Strick       DIR     5-451     5-651     5-651     5-651     5-651     50     010       Pans     1864     176.6     176.6     173.3     3.0     17-36     71       Pans     186.4     193.5     4.0     186.0     173.4     3.5     1.22</td><td>Dill     As     Heat     I's     Total     Attec Strick of Strick     Strat     Strick of Strick       DIR     5-451     5-651     5-651     5-651     5-651     50     010       Pans     1864     176.6     176.6     173.3     3.0     17-36     71       Pans     186.4     193.5     4.0     186.0     173.4     3.5     1.22</td></th></td>   | DIR     F-451     F-651     F-651     F-651     F-651     F-651       Pans     1864     1746     40     1766     1733     30     71-345     71       Pans     1864     1766     1766     1733     30     71-345     71   | DIR     F - KSI <th -<="" td=""><td>DIR     F - KSI     F - M     DITEC SVI SUID SU2     DID     DID     DID     DID     DID     DID     DID     DID     DIS     M - L     SU       Pans     1864     1935     40     1860     1935     30     1735     31     31</td><td>DIR     F - 451     F - 451     F - 451     F - 451     F - 451     M - 261     M - 15       Pans     1864     1766     1766     1753     30     17-35     31</td><td>DIR     F-451     F-651     F-651     F-651     F-651     F-651       Pans     1864     1746     40     1766     1733     30     71-345     71       Pans     1864     1766     1766     1733     30     71-345     71</td><td>DIR         Contract Strict Strict         Stract Stract Strict         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract Stract         Stract Stract         Stract Stract</td><td>DIR         Contract Strict Strict         Stract Stract Strict         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract Stract         Stract Stract         Stract Stract</td><td>Dilk     As     Acat     Mire     Str&lt;</td><td>Dill     As     Heat     I's     Total     Attec Strick of Strick     Strat     Strick of Strick       DIR     5-451     5-651     5-651     5-651     5-651     50     010       Pans     1864     176.6     176.6     173.3     3.0     17-36     71       Pans     186.4     193.5     4.0     186.0     173.4     3.5     1.22</td><td>Dill     As     Heat     I's     Total     Attec Strick of Strick     Strat     Strick of Strick       DIR     5-451     5-651     5-651     5-651     5-651     50     010       Pans     1864     176.6     176.6     173.3     3.0     17-36     71       Pans     186.4     193.5     4.0     186.0     173.4     3.5     1.22</td></th>  | <td>DIR     F - KSI     F - M     DITEC SVI SUID SU2     DID     DID     DID     DID     DID     DID     DID     DID     DIS     M - L     SU       Pans     1864     1935     40     1860     1935     30     1735     31     31</td> <td>DIR     F - 451     F - 451     F - 451     F - 451     F - 451     M - 261     M - 15       Pans     1864     1766     1766     1753     30     17-35     31</td> <td>DIR     F-451     F-651     F-651     F-651     F-651     F-651       Pans     1864     1746     40     1766     1733     30     71-345     71       Pans     1864     1766     1766     1733     30     71-345     71</td> <td>DIR         Contract Strict Strict         Stract Stract Strict         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract Stract         Stract Stract         Stract Stract</td> <td>DIR         Contract Strict Strict         Stract Stract Strict         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract Stract         Stract Stract         Stract Stract</td> <td>Dilk     As     Acat     Mire     Str&lt;</td> <td>Dill     As     Heat     I's     Total     Attec Strick of Strick     Strat     Strick of Strick       DIR     5-451     5-651     5-651     5-651     5-651     50     010       Pans     1864     176.6     176.6     173.3     3.0     17-36     71       Pans     186.4     193.5     4.0     186.0     173.4     3.5     1.22</td> <td>Dill     As     Heat     I's     Total     Attec Strick of Strick     Strat     Strick of Strick       DIR     5-451     5-651     5-651     5-651     5-651     50     010       Pans     1864     176.6     176.6     173.3     3.0     17-36     71       Pans     186.4     193.5     4.0     186.0     173.4     3.5     1.22</td>  | DIR     F - KSI     F - M     DITEC SVI SUID SU2     DID     DID     DID     DID     DID     DID     DID     DID     DIS     M - L     SU       Pans     1864     1935     40     1860     1935     30     1735     31     31  | DIR     F - 451     F - 451     F - 451     F - 451     F - 451     M - 261     M - 15       Pans     1864     1766     1766     1753     30     17-35     31  | DIR     F-451     F-651     F-651     F-651     F-651     F-651       Pans     1864     1746     40     1766     1733     30     71-345     71       Pans     1864     1766     1766     1733     30     71-345     71  | DIR         Contract Strict Strict         Stract Stract Strict         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract Stract         Stract Stract         Stract Stract   | DIR         Contract Strict Strict         Stract Stract Strict         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract         Stract Stract Stract Stract Stract Stract Stract Stract         Stract Stract         Stract Stract  | Dilk     As     Acat     Mire     Str<   | Dill     As     Heat     I's     Total     Attec Strick of Strick     Strat     Strick of Strick       DIR     5-451     5-651     5-651     5-651     5-651     50     010       Pans     1864     176.6     176.6     173.3     3.0     17-36     71       Pans     186.4     193.5     4.0     186.0     173.4     3.5     1.22   | Dill     As     Heat     I's     Total     Attec Strick of Strick     Strat     Strick of Strick       DIR     5-451     5-651     5-651     5-651     5-651     50     010       Pans     1864     176.6     176.6     173.3     3.0     17-36     71       Pans     186.4     193.5     4.0     186.0     173.4     3.5     1.22  |  |
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|   |   | LAS DEPT //C.T.C. MAN // C.T.C. I MAN / // SAM SAMA / // SAMA  |  |   |   | LAS DEAT //C.TOM // MAN // C.TOM   | Law LAS dear // C. Ten Maria She Solar / Las 111 - 15  | Law LAS dear // C. Ten Maria She Solar / Las 111 - 15   | Jaw 145 Hear Neerran Manuer Rive Sun 120: 111 . The  | 1411 AS Heat /re.red Anor she S./ Sers / 120:001 - 1-510  | 1411 AS Heat /re.red Anor she S./ Sers / 120:001 - 1-510   |  |   |  |
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ONVAIR REPORT NO. FGT-2727. DATE\_\_\_\_\_1/19/61\_\_\_\_ APED BY FFI A DIVISION OF GENERAL DYNAMICS CORPORATION FED BY ... (FORT ACPTH) Effect of Gage Length and Specimen Width on Elongation .005 X 010 N .005 X .010 .005 X.500-"005 X. 010-.005 X .. 500 0 S ,002' x .. 010 "002<sup>°</sup>x "500 8 ,001'; X ,010 S ,001 x . 50 8 Ø 2027 ar, a 1.0 , 4 , 416427 2609 FIGURE: I

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A DIVISION OF GENERAL DYNAMICS CORPORATION (FORT WORTH)

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HEAT TREATMENT

#### ITEM E - DETERMINATION OF RETAINED AUSTENITE IN 17-7 PH STAINLESS STEEL SHEET

In certain high carbon and alloy steels, rapid cooling causes a metastable, body-centered-tetragonal phase, martensite, to form. These steels usually contain residual untransformed austenite in addition to the martensite phase. The retained austenite is thought to have extensive effects on the mechanical properties of these steels. If the amount of retained austenite could be determined, this knowledge should be useful in predicting the properties which a particular steel will possess.

Dilatometric and magnetic methods of analysis can be used to determine the presence of retained austenite when it is present in amounts of 15% and above. X-ray diffraction techniques (1, 2, 4, 7) have been used to determine the amount of retained austenite when this phase is present in lesser amounts. The work reported in this section is the result of an attempt to adapt the X-ray diffraction method to 17-7PH stainless steel sheet.

The X-ray method for the determination of retained austenite in steel, first described by Averbach and Cohen (1), was used in this investigation. The method may be described as follows:

If a polycrystalline material containing austenite and martensite is irradiated with X-rays, each crystal will diffract independently according to Bragg's Law.

 $n\lambda = 2d sin \Theta$ 

1

where j n - any integer

(hKI)

Ø

wavelength of Xirays

interplaner spacing in crystal

 $\Theta$  = angle of incidence of X-rays with the sample

٩

The diffracted energy at any Bragg angle can be shown to be:

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= integrated intensity of martensite (hkl)

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em Va AVO)

= constant for a given experiment

m(L.A.)e

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| C<br>A DIV | <b>O</b><br>VISION C | N<br>of gener<br>(FOR) | V<br>RAL DYN | A I<br>NAMICS CORPO<br>DRTH)         | R                          | PAGE 94<br>REPORT NO. FGT-2727<br>MÓDEL B-58<br>DATE 1/19/61 |
|------------|----------------------|------------------------|--------------|--------------------------------------|----------------------------|--|
|            |                      |                        | 1            |                                      |                            |  |
|            |                      |                        | 1            | ΨS                                   | * struct                   | ure factor squared   |
|            |                      | •                      | 1            | m                                    | <pre>multip</pre>          | icity of (nkl)   |
|            |                      |                        |              | L.P.                                 | = Lorent                   | Polarization factor  |
|            |                      |                        |              | e <sup>2</sup> m                     | . Debye-                   | Waller temperature factor                                    |
|            |                      |                        | ,<br>,       | A(9)                                 |                            | absorption factor (constant for<br>ctometer)                 |
|            |                      |                        | Ļ            | u V~                                 | <ul> <li>volume</li> </ul> | fraction of martensite                                       |
|            |                      |                        | •            | ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ | <pre>volume</pre>          | of unit cell of martensite                                   |

A similar equation may be written for each diffraction peak of austenite ( $\gamma$ ). The factors V, F, m, (L.P.) and e<sup>-2m</sup> can be obtained for each interplaner spacing furnishing a diffraction peak. The values listed in Table IE-I were taken from Taylor's book "X-ray Metallography" (8). These constants can be combined into the coefficient R, and the following equations written:

 $P_{\sim} = KR_{\sim}V_{\sim}^{\prime} (Eq. A)$   $P_{\sim} = KR_{\gamma}V_{\sim}^{\prime} (Eq. B)$ 

The volume irradiated is then the only unknown. If the sample can be assumed to contain only sustenite and martensite:

 $v_{x} + v_{y} = 1$ 

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Since K depends only on the experimental conditions and is independent of the kind and quantity of the diffracting substance:

 $\frac{P_{\alpha}}{R_{\alpha}}$  ::  $V_{\alpha}$  and  $\frac{P_{\alpha}}{R_{\gamma}}$  ::  $V_{\gamma}$ 

Using these ratios for V and V, the percent austenite in the sample may be calculated from the following:

$$\%$$
 austenite =  $\frac{V_{\gamma}}{V_{\gamma}}$  X 100 (Eq

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This investigation was concerned with the amount of retained austenite present in heat treated 17-7PH stainless steel, After heat treatment, this steel is primarily martensitic; however,

| · ·          |                 | 17 'A                                   | I D                     | 1                  | k                                   | PAGE   | 95           |
|--------------|-----------------|---|-------------------------|--------------------|-------------------------------------|--|--------------|
| . <b>V</b> . | N V             | V A                                     | IK                      |                    | 1                                   | REPORT NO.                                   | FGT-272      |
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|              |                 | •                                       |                         |                    | P .                                 |  |              |
|              | thoma of        | an atham                                |                         |                    | Bannetsa I.a.                       | Index to a surr                              |              |
|              |                 |   |                         |                    | a ferrite (a                        |  |              |
|              |                 |   |                         |                    | intermetalli                        |  |              |
| e e          |                 | aned aus                                | cenice are              | all Iound 1        | In varying am                       | iounts.                                      | he           |
|              |                 |   |                         |                    | oper metallo                        |  |              |
|              | ation ar        | ia can co                               | mprise as m             | uch as 20%         | of the steel                        | . This p                                     | nase         |
|              | 18 indis        | itinguish.                              | able in ord             | inary X-ray        | diffraction                         | patterns                                     | s from       |
|              | either n        | nartensit                               | e or alpha              | iron. This         | is because                          | the diffe                                    | rences       |
| ·            | in inter        | planer s                                | pacing with             | <b>in the crys</b> | talline latt                        | ices of, t                                   | he <b>se</b> |
|              | phases a        | are extre                               | mely slight             | . The carb         | oides can be                        | seen meta                                    | 110-         |
| ]            | graphics        | ally but a                              | are not pic             | kpediup by c       | ordinary X-ra                       | y <b>diffra</b> c                            | tion         |
|              | procedur        | es. This                                | s fact and              | theoretical        | calculation                         | s based c                                    | n            |
|              | stoichic        | ometry and                              | d carbon co             | ntent indic        | ate that 17-                        | 7PH steel                                    | . contai     |
|              | less the        | an 1% carl                              | bide phases             | by weight.         | The interm                          | etallic c                                    | ompound      |
| 1            |                 |   |                         |                    | as to leave                         |  |              |
|              |                 |   |                         |                    | d austenite                         |  |              |
|              | the heat        | treatmen                                | nt. Howeve              | r. this pha        | se is usuall                        | v picked                                     | up on        |
| Ì            | X-ray di        | ffraction                               | 1 patterns              | and so can         | be assumed t                        | o be in e                                    | TCORR        |
| 1            | of 5% of        | the tot                                 | al alloy co             | ntent.             |                                     |  | ACCUD        |
|              | 2/              |   |                         |                    |                                     |  |              |
|              | The pres        | ence.                                   | norbidee on             | dintermeto         | llic phases                         | word tanor                                   | had          |
|              | duning t        |   | tigetion                |                    | entration is                        |  | eu           |
|              | have be         | approved al                             | ble offert              | inen conc          |                                     | SQ IOW 8                                     | IS LO        |
| ·            | datamata        | apprecia                                |                         | un une anal        | ytical resul                        | ts of the                                    | .•           |
| 1            | decermin        |   | me assumpt              | ion was mad        | le that delta                       | lerrite                                      | and          |
|              | austenit        | e were pi                               | resent belo             | re neat tre        | atment. Aft                         | er neat, t                                   | reating,     |
|              | martensi        | te, delta                               | a re <b>rrite</b> a     | nd austenit        | e were consi                        | dered to                                     | be           |
|              | present.        | Noeatte                                 | empt was ma             | de to disti        | nguish betwe                        | en the ma                                    | rtensite     |
|              | and delt        | a ferrite                               | e phases, in            | the X-ray          | diffraction                         | pațtern <b>ș</b> .                           |              |
|              |                 | 1 E                                     | 1                       | 1                  | •                                   | Î Î  |              |
|              | A major         | portion d                               | of the time             | spent on t         | his investig                        | at <b>f</b> on wäs                           | con-         |
|              | cerned w        | ith surve                               | eving the p             | ertinent li        | terature and                        | determin                                     | ing a        |
|              | possible        | itest pro                               | ocedure. I              | t was decid        | ed to use an<br>ion pattern         | X-ray di                                     | ffrac-       |
|              | tometer         | (2, 4) ar                               | nd record t             | he diffract        | ion pattern                         | with a Br                                    | own          |
|              | Recorder        | ., The of                               | ther altern             | ative was t        | o use a came                        | ra film p                                    | roce-        |
|              | dure. N         | o densito                               | ometer was              | available f        | o use a came<br>or reading f        | ilm inten                                    | sities.      |
|              | and the         | diffracto                               | ometer seem             | d to provi         | de a more st                        | raightfór                                    | ward         |
|              | method.         | 5                                       | •                       |                    |                                     | , <b>, , , ,</b> , , , , , , , , , , , , , , |              |
|              |                 | 1 ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( |                         | 1                  |                                     |  |              |
| Į            | Tt soon         | became at                               | parent tha              | 17-7PH sh          | eet is a tro                        | untesome                                     | material     |
|              | for this        | It vne of                               | enalvelle               | Previous           | drkers had a                        | voided on                                    | lontotad     |
| · · · .      | tortunes        | in the n                                | atoniol <sup>1</sup> ha | ng analyse         | d. This was                         | obviouel                                     | r            |
|              | dex cureb       | tio the the                             |                         | ang analyse        | Alaa, tha                           |  | y<br>amhar   |
|              |                 |   | case of s               | fier succ.         | AIBO, the                           | merallogr                                    | apny         |
|              | or 17-7P        | H STEEL I                               | osed sever              | al problems        | Also, the Metallogr<br>Oss-checking | apurc bio                                    | cedures      |
|              | could pr        | qvide a c                               | invenient i             | eans of er         | oss-cnecking                        | results                                      | obtained     |
|              | •by the X       | igray difi                              | raction me              | hod. In 1          | 7-7PH steel                         | several, p                                   | hases        |
|              |                 |   |                         | 1                  | l .                                 | ê h  |              |
|              |                 | 13 Z -                                  | ł                       | 1                  | e<br>L                              |  |              |
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| i .          | · · ·           |   |                         | •                  | A 4 4 4 1                           | · Z · #                                      |              |

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| <u> </u>  | (F)   |                                       | <b>n</b> /   |   |  | ·····  |   |   |                       |
|           |   | ¢.                                    |  |   |  | •  |   | ·   |                       |
|           |   |                                       | 4<br>▶<br>₽  | ,   |  | 3  |   |   |                       |
|           | are pr  | esent.                                | i<br>and als   | o the gr  | sin size   | :<br>in heat   | treated   | l mater   | ial is                |
|           |   | small.                                | !  | 0-  |  |  |   |   |                       |
|           | Throug  | shout th                              | e proje  | ct, atte  | mpts wer   | e made t   | o use th  | ne delt   | 8                     |
|           | was de  | etermine                              | d by the   | e lineal  | janalysi   | d. The<br>s or point   | nt count  | ing me  | thod                  |
|           | did no  | ot agree                              | with the   | h <b>ose o</b> bt   | ained by   | ts obtain<br>the X-r   | ay diffr  | raction   | -                     |
| ¥         | proced<br>later.  |                                       | he reas<br>I   | on for t  | his lack   | of corr  | elation   | is dis  | cussed                |
| V         |   | ,                                     | H<br>H<br>#t fow /   | d <b>iffm</b> oot   | ton natt   | erns wer   | e obteir  | 5<br>And 1+   | -<br>-<br>            |
|           | evider  | it that                               | severe (   | grain or  | ientatio   | n was pr   | esent in  | the 1   | <b>7 –</b> 7 PH       |
|           | Assumi  | ing that                              | the cal  | lculatio  | ns for R   | R value<br>are cor:  | rect, th  | e P/R   | values                |
|           | should<br>sample  |                                       | al for a   | all refl  | ections  | in a par   | ticular   | phase   | and                   |
|           | A rota  | ting se                               | mple ho  | lder was  | introdu  | ced to a   | ttempt t  |   | ensate                |
|           |   |                                       |  | ientatio  |  |  |   |   |                       |
|           |   | d the e                               | ned mon  | - nound   | d TU CUG   | specime  | $a_{1}$   | the ex  | wafeee                |
|           | rotate<br>being   | d the s<br>irradia                    | pecimen  | around  | an axis  | perpendi<br>e r <mark>qtate</mark>   | cular to  | the s   | urface                |
|           | rotate  | d the s<br>irradia                    | pecimen  | around  | an axis  | perpendi   | cular to  | the s   | urface                |
|           | rotate<br>being<br>as fol   | id the s<br>irradia<br>lows:          | pecimen<br>ted. Th<br>c<br>17-7Pl  | around<br>ne resul<br>t   | an axis  | perpendi<br>e rotate   | cular to  | the silens we   | urface<br>re<br>t     |
|           | rotate<br>being<br>as fol<br>(hkl   | d the s<br>irradia                    | pecimen<br>ted. Th<br>c<br>17-7Pl  | around<br>ne resul<br>(<br>F/R  | an axis<br>ts of th  | perpendi<br>e rotate   | cular to<br>d specim  | the spinens we  | urface<br>ge          |
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|                            | irradiatin<br>the 17-7P<br>which the<br>identify t<br>tables.     | ng specim<br>H steel s<br>17-7PH s<br>the sampl<br>Results f | ens taken<br>heet. Fig<br>heet was s<br>e directio<br>rom three 1      | from three (<br>ure IE-1 11)<br>actioned and<br>a with respo            | the orientatio<br>irections wit<br>lustrates the<br>i the notation<br>act to the she<br>terial are giv<br>varied. | h respect to<br>manner in<br>used to<br>et in the                   |
|                            | (3). Aust<br>rolling to<br>the llO pl<br>The (llO)                | tenite ha<br>axture fo<br>lane will<br>'planes w             | s a face-co<br>r this pha<br>tend to b<br>ill tend t                   | antered cub<br>se is (110)<br>a parallel<br>be alined                   | was obtained<br>ic lattice. T<br>[112]. This<br>to the rolling<br>in a [112] di                                   | he primary<br>indicates that<br>plang.<br>rection with              |
|                            | the primar<br>tation of<br>would depe<br>prior to t               | ry textur<br>the mart<br>end on th<br>transform              | e shouid b<br>ensite pha<br>e orientat<br>ation.                       | s (100) [01]<br>se was n <b>ot</b> (<br>ion present                     | ne case of del<br>[]. The expec<br>letermined. It<br>in the austen  | ted orien-<br>s orientation<br>ite phase                            |
| <b>1 1 1 1 1 1 1 1 1 1</b> | surface of<br>from ferri<br>have been<br>experiment               | f the stc<br>ite and t<br>stronges<br>tal resul              | el sheet w<br>he (220) r<br>t. This w<br>ts. Howeve                    | as irradiate  | een that, whe<br>ed, the (200)<br>fom austenite<br>be in agreeme<br>see to which t<br>ample.                      | reflertion<br>should  |
|                            | specimens<br>angles bet<br>these angl<br>that the (<br>were least | taken fr<br>ween ref<br>les and t<br>(211) lin<br>t affecte  | om other d<br>lecting pla<br>he experime<br>e of marter<br>d by the re | rections in<br>nes can als<br>ntal P/R ra<br>site and th<br>olling text | mation can be<br>the sheet.<br>to be calculate<br>tios it was d<br>te (200) line<br>tre. The aver                 | The interplane<br>d. From<br>termined<br>of austenite<br>age values |
| 4                          |   |  |  |   | ermined by ad   |   |
|                            | Integrated  | a intensi<br>hv three  | The aver   | e IIal, eq  | e, and end sp<br>obtained was   | then divided  |
| 1                          | by R and s  | ubstitut   | ed in equa   | ion C. The  | se results to   | rether  |
|                            |   |  |  |   | Int counting a  |   |
|                            | in Table 1  | İΕ-ΠΙΙ.  | The tensil   | results f   | om each heat  | f 17 <sup>e</sup> -7 PH   |
| · 1                        |   |  |  |   | and 4 are ph  |   |
|                            | of A cond   | ition 17-  | 7PH stgel  | tched to s  | ow the delta :  | ferrite   |
|                            | phase. The specimens  |  |  | entation 1  | the flat, ed  | se, and end .   |
| 1 - E                      | The calcul  | lated val  | ues for the  | percent de  | lta ferrite i   | n the three   |
|                            | heats of I  | aonditi  | on 17-7PH  | teel do no  | t agree with t  | he measured   |
|                            | percentage  | s. In h  | eat 47660  | the amount (  | of delta ferri  | te determined   |
| 1 . I                      | by the X-1  | ay metho   | d is almos   | t twice the   | measured amou   | at. This is   |
|                            | in contra   | șt to hea  | ts 67200 a   | nd 67177 in   | which the X-r   | ay value is   |
|                            |   | t T  | , i i i i i i i i i i i i i i i i i i i                                |   | •   |   |
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A DIVISION OF GENERAL DYNAMICS CORPORATION (FORT WORTH)

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|   | lower than the measured value. This can be explained only if the<br>A condition 17-7PH steel from heat 47660 contained some martensite.<br>Carwile and Rosenbery (5) show photomicrographs of A condition<br>material which seemingly contained martensite. Attempts to show<br>that A condition material from heat 47660 contained martensite<br>were inconclusive. The appearance of a substructure in the aus-<br>tenite grains was observed after severe etching. However, the<br>same type of structure was observed in the other two heats of<br>material after similar metal ographic treatment. |
|---|---|
|   | It is apparent that, based on the present experimental results,<br>the validity of the retained austenite values cannot be stated.<br>The possibilities of this method of determining retained austenite<br>have not been fully explored. It seems entirely possible, given<br>sufficient time, that a workable method could be determined.   |
|   | REFERENCES:<br>1. B. L. Averbach and M., Cohen, "X-ray Determination of Retained<br>Austenite by Integrated Intensities", Tech. Pub. No. 2343,<br>February 1948, AIMME.   |
|   | 2. B. L. Averbach, "Retained Austenite by Geiger Counter Spectro-<br>meter", Jour. of Metals, January 1953, p. 87.  |
|   | 3. C. S. Barrett, "Structure of Metals", 1952, McGraw-Hill<br>Book Company, New York, N. Y., 631 pages.   |
|   | 4. K. E. Beul "Notes on Retained Austenite Determination"<br>Trans. AIME, Met. Soc., November 1953, p. 1539.  |
|   | 5. N. L. Carwile and S. J. Rosenberg, "A Study of 17-7PH Stain-<br>less Steel", WADC Tech. Report 58-653, June 1959, 36 pages.  |
|   | 6. R. T. Howard and M. Cohen, "Quantitative Metallography by<br>Point Sounting and Lineal Analysis", Met. Tech., August 1947.   |
|   | 7. R. E. Ogilvie, "Retained Austenite by X-rays", Norelco Reporter,<br>May-June 1959, Vol. VI, No. 3, p. 60.  |
| ĸ | 8. A. Taylor, "An Introduction to X-ray Metallography", 1952,<br>John Wiley and Sons Inc., New York, N. Y., 325 pages.  |
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|   | UTILITY REPORT SHEET  |

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99 PAGE N V A FGT-2727 0 C REPORT NO. B-58 MODEL A DIVISION OF GENERAL DYNAMICS CORPORATION 19761 Ϊ. DATE (FORT WORTH) Surface with Respect to Rolling Direction in Determination of Retained Austenite Fulling Dir T.it. Edge : (4"×1") (4x1") 11 ÷ Note Arrows point to surface irradiated. in each case. £ FIGURE: UTILITY REPORT SHEET Į, Departmént é FWP 1072-8-54 1 . . . . Ż

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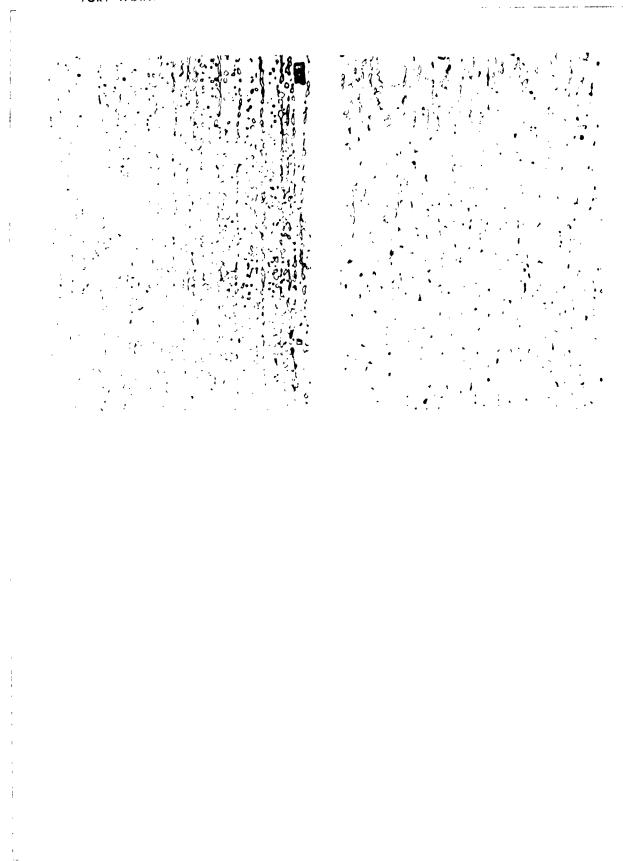
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| 2000-1005-10-1 |  | HEAT        | 67200    |        |        |      |         |       |       |      |     |        |            | 67177  |       |         | -         |            |           |           |          |           |         |    |   |                  |          |           | and the second |          |          |         |                                       | -<br>-<br>-<br>- |

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|                                     | TABULATION SHEET  | SHEET                     | X-ra            | 76-60-                       | of          | ction<br>17-7Ph                          | Result<br>Steel     | 55       | s from<br>Sheet A       | n Heat<br>Matl | +      | ·      | ,<br>,<br>, | •••••••••••••••••••••••••••••••••••••• |
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| \$7460                              | 0.025   | Flat                      |                 | 4                            | (011)       | 10.7                                     | $\langle m \rangle$ | 54.0     |                         | ΗI             | τοιή   | 41.0   | (111)       | 2.4                                    |
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| 67200                               | A   |                           | (172)           | 14.1                         |             | (200)                                    | 115.3               |          | 142                     |                | 18.7   |        |             |  |
| 67177                               | A   |                           | (112)           | 131                          |             | (200)                                    | 71.7                |          | 155                     |                | 18.7   |        |             |  |
| 47660                               | A   |                           | (117)           | 263                          |             | (002)                                    | 20.7                |          | 176                     |                | 121    |        |             |  |
| 67200                               | TH  |                           | (11)            | 676                          |             | (225)                                    | 5                   |          |                         | 0              | 9      |        |             |  |
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| 1.1.1.1                             | Ĩ   | and much in               | 11121           | 22.9                         | 1<br>1<br>1 | 2001                                     | 10.8                |          |                         | 12.9           |        | 1.791  | 87          |  |
| 42660                               | TH  |                           | [211]           | 73.0                         |             | (200)                                    | 37                  |          |                         | 4.8            |        | 2179   | 6.2         | ge<br>                                 |
|                                     | T JEYA  |                           |                 |                              |             | -  |                     |          |                         |                |        |        |             | 10<br>F0                               |
|                                     |   |                           |                 |                              |             |  |                     | -+       |                         | <b>†</b>       |        |        |             | <b>r</b> -2                            |
|                                     |   |                           |                 |                              |             |  |                     |          |                         |                |        |        |             | 272                                    |
|                                     |   | ;                         | •               | +-                           |             |  |                     |          | ╄ <del>╸</del> ┼<br>┃ ┃ |                |        |        |             | 7                                      |
| and any of the second second to the | And Andrewson and Andrewson and Andrewson and Andrewson and Andrewson and Andrewson and Andrewson and Andrewson | Standard and Annual State | A HARLIN BRINGS |                              |             | +<br> <br> <br> <br> <br>                |                     |          |                         |                |        |        |             |  |
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| C         |  | PAGE 106<br>REPORT NO. <u>FGT-2727</u>                                   |
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|           | ITEM - CONCLUSIONS FOR ITEM                        | IS A THRU E  |
|           |  |  |
|           |  | e several investigations relating  |
|           | A to E, are given in the follo                     | PH steel sheet, summarized in Items                                      |
|           | A CO E, are given in one tout                      | owing paragraphs.  |
| ·         | ITEM A - INITIAL HEAT TREAT RI                     | ESPONSE STUDIES ON 17-7 PH STEEL.  |
|           |  | ······································                                   |
|           |  | eet after various heat treatments.                                       |
| 1.        |  | imens .005", .008", and .020" thick                                      |
| ~         |  | tment, a conditioning time of 30   |
| 1         |  | tensile properties. Times of   |
|           |  | sformation temperature of -100 F<br>perties except for sheet .085" thick |
|           | In the TH 1050 type of treatmo                     | ent with variations of the trans-  |
|           |  | ormation at +54 F gave more consis-                                      |
|           |  | mperatures. Aging at 950 F gave  |
|           | higher strength values and low                     | wer elongations than aging at  |
|           | 1050 F. J  | I  |
|           | A postion bout incommon but                        | ithout a conditioning step gave  |
|           |  | . This suggested a suitable braz-  |
|           |  | ut for elimination of the 1400 F   |
|           | step. In some tests, apprecia                      | able variations in tensile proper-                                       |
| •         | ties were npted, depending on                      | several factors. These included  |
| 1'        |  | ed, the time at the conditioning   |
| Ϊ,        | temperature cooling rate, and                      | d thickness of the sheet. The  |
| P         | as the conditioning temperatur                     | rength were generally increased  |
|           |  | decreased and the elongation in-   |
| 1         | creased with increasing aging                      | temperature from 1050 to 1100 F.   |
|           | Specimens of 17-7 PH steel she                     | eet processed at opposite ends of  |
| [         | a retort during the braging of                     | f a sandwich panel showed an   |
|           |  | in yield strength and 11 ks1 in  |
|           | ultimate strength. The endura                      | ance limit of 17-7PH steel sheet   |
|           | ksi in axial tension-tension f                     | ondition, was determinéd as, 106   |
|           | The TH AVER CONSTOLL OCTOBUTIN                     | · · · · · · · · · · · · · · · · · · ·                                    |
|           | The dimensional changes of 17.                     | -7PH steel sheet specimens on heat                                       |
| 1         | treatment were measured. All                       | the spegimens grew somewhat dur-   |
| ]         | ing heat treatment through the                     | e transformation step.; They con-  |
|           | tracted ja lattle on aging. Th                     | he final result was growth. With   |
| ł         | increasing temperature of agin                     | ng the amount of contraction   |
| ·         | increased. For some reason th                      | he overall growth of the .005"   |
| <b>1</b>  |  | · · · · · · · · · · · · · · · · · · ·                                    |
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|---------------|---------------------------------------|-----------------------|----------------------------|---|--|---------------------------------------|---------------|--------|
|               |                                       | 1                     |                            |   |  |                                       |               |        |
|               | ,                                     |                       |                            |   | n multiple                                       |                                       |               | į      |
| · · ·         | thick shows or .020"                  | eet was r<br>materia  | predominant                | ly greater<br>instances,                    | than that  | of the .00                            | 08"           |        |
|               |                                       | ly small.             |                            | instances,                                  | S COTAL  | growth was                            | 5             |        |
|               | TTEM B -                              | COMPARTS              | ON OF BRAZ                 | ING CYCLES                                  |  |                                       | a 107 177 mu  |        |
|               | <u>A</u>                              | STEEL SI              | EET BRAZED                 | WITH 85:15                                  | SILVER M   | NGANESE A                             | LLOY.         |        |
|               | Several                               | basic pro             | cedures of                 | heat treat                                  | ment with  | variation                             | were          |        |
|               | investig                              | ated in c             | onnection                  | with develo                                 | bing a sat                                       | tisfactory                            | braz-         | • •    |
|               | tests we                              | re made c             | n 17-7PH a                 | 5:15 silve<br>teel specim                   | ana mosti  | r in three                            | Tensile       | -<br>- |
| . 1           | thickness<br>heat trea                | Ses, viz.             | <b>,</b> .005",,           | 08", and                                    | 020", afte                                       | r the var                             | lous          | in     |
|               |                                       | • •                   | -                          |   | •  | -                                     |               | ÷      |
|               | Practical cycles                      | lly all t             | he treatme                 | ts tried,<br>ile proper                     | as simulat                                       | ed brazing                            | 5             | •      |
|               | were ageo                             | d at 1050             | ) or 1060 F                | Specific                                    | treatment  | s gave high                           | th            | i      |
|               | yield and<br>Other tre                | d ultimat<br>satments | e strength                 | with sati<br>longation                      | sfactory e                                       | longation                             | -<br>         | •      |
|               | Thus, a c                             | choice of             | procedure                  | was made                                    | available.                                       | CANTA BCL                             | ingths.       |        |
|               | The elong                             | ation ge              | nerally in                 | reased und                                  | for the fol                                      | lowing cor                            | ditions       |        |
|               | With incl                             | cease in              | the thickne                | iss of spec                                 | imen: with                                       | increase.                             | in            |        |
|               | aging. I                              | for a giv             | mperature;<br>en heat tre  | and with i atment, th                       | norcasing<br>e elongati                          | temperatur                            | e of          |        |
|               | increase.                             | ,with dec             | rease in t                 | me at the                                   | transforma                                       | tion, temps                           | rature        | i      |
|               | of -100 f                             |                       | •                          |   | )<br>•   | 3                                     |               | •      |
|               | Usually, strengths                    | when the              | elongátion                 | increased                                   | , the yield                                      | andjultim                             | ate           | •      |
|               | -                                     |                       | •                          |   | )  | * *                                   |               |        |
|               | With only                             | one exc               | eption; the                | .008" thi<br>than the                       | 6k sheet h                                       | ad higher                             |               | ŗ      |
| 1             | ror all a                             | leat trea             | tments. T                  | e elongati                                  | on of the  | .020, mate                            | riais<br>k    | -      |
|               | sheet was                             | highest               | for these                  | treatments                                  | •  | 3 6                                   |               | Y<br>N |
|               | ITEM C -                              |                       | Ц.<br>-                    |   | 3<br>1   | 9<br>8                                |               | ŗ      |
|               | Changing                              | brazing               | allovs nec                 | ssitated f                                  | 1<br>H<br>arther wor                             | i<br>k toideteir                      | mine          |        |
|               | the effe                              | t of dif              | ferent, hea                | This was                                    | on the t   | ensile pro                            | per-          | τ,     |
|               | paring B                              | mulated               | brazing cy                 | les for us                                  | for the pu<br>with the                           | rpose of c<br>sterling                | om-<br>silver | ŧ.     |
|               | plus .2%                              | 11thium               | alloy in bi                | azing sand                                  | <b>vich</b> panel                                | s. In par                             | ticu-         |        |
|               | iar, the investige                    | ted.                  | or chailerol               | mation and                                  | aging tem  | peratures,                            | were          |        |
|               |                                       | ł                     |                            |   |  |                                       |               | 8      |
|               | · · · · · · · · · · · · · · · · · · · | 7                     | 3                          |   | ·<br>· · · · · · · · · · · · · · · · · · ·       | 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 |               | i I    |
|               | Į                                     | ł                     |                            | •   |  | म्                                    | • ,           | 8      |
|               | 7                                     | 1<br>1<br>1           | E E                        |   |  |                                       |               | Į.     |
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For the .010" thick sheet, when the 1400 F step was incorporated in the cycle, the tensile strength tended to increase with lower transformation temperatures. Without the 1400 F step there was a marked loss of strength with transformation temperature of -100 F. For the .005" sheet, with the 1400 F step, the strength was appreciably decreased by transforming at -60 and -100 F. Without the 1400 I step the strength tended to decrease noticeably with decreasing temperature of transformation, with a marked loss for -100 F; there was a considerable increase for -20 F. The values for various tests on specimens cut from brazed sandwich panels were mostly acceptable. However, tension-tension fatigue specimens failed considerably below the specified minimum, and skin specimens from one panel showed low elongation, ITEM D The investigation summarized as Item D led to the following conclusions: The 1400 F ponditioning step is not necessary when a brazing temperature of 1650 F is used for 17-7PH steel sandwich panels. For some heats of 17-7PH steel sheet an aging temperature of 1050 F can give low elongation. An aging temperature of 1060 -1070 F may be better for production. The percent elongation of thin 17-7PH steel sheet increases with increasing width of test specimen. With increasing gage length the measured elongation increases. Also, with depreasing gage length the scatter in value decreases. ITEM E As to Item E, the following conclusions were drawn: The texture developed by rolling 17-72H steel sheet in light gages exhibits pronounced directionality. The degree of grain orientation varies from heat to heat. The (211) reflection of ferrite and martensite and the (200) reflection of austenity are least affected by the grain prientation.

| R | 0 | N | V        | Å | l | D    |
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The percentages of retained austenite found in 17-7PH steel sheet by the X-ray diffraction method were in the range to be expected on the basis of prior work on martensitic steels. No means was found to validate the results.

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#### CORE PROBLEMS

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Three investigations on problems relating to honeycomb core were carried out in 1956-1957. The results were reported in memoranda. Summaries of these investigations are given as Items F, G, and H.

#### ITEM F - ELEVON RIB CORE, 472615:

Early in 1956, a peculiar appearance of honeycomb corfe was noticed in production after pickling for cleaning and before layup of panels. The core had been supplied by the John J. Foster-Mfg. Company, Costa Mesa, California. Cleaning produced a series of bright and doll bands, alternating to suggest zebra stripes. The appearance is shown in the photograph of Figure IF-1. More of the core was bright than dull.

Tests were made to determine the cause of the banding. These disclosed that the elevon rib core (4T2615, S/N 1811, IR 33234) was not fabricated entirely in 17-7PH steel but rather largely in type 321 stainless steel. The smaller amount of the core was 17-7PH steel.

Knoop hardness tests showed some difference between the dull and bright bands. Converted to Rockwell hardness numbers, the values were: Dull, RB 98.5; bright RB 90-92. Metallographic examination showed a pronounced difference in structure of the dull and bright core. Figure IF-2 is a photomicrograph of a dull section. This is typical of annealed 17-7EH steel. Figure IF-3 is a photomicrograph of a bright section. This is an austenitic structure similar to that of 18-8 stainless steel. Chemical analysis of the bright core gave results corresponding to the nominal composition of 321 stainless steel,

This investigation indicated that 321 steel foil had lost identification in the plant of the core manufacturer and had become mixed there with 17-7PH steel foil.

When the investigation was dompleted, recommendation was made that all honeycomp core then at Convair-FW be examined and tested for composition. Recommendation was also made that procedures of quality dontrol be established for all core received at Convair to prevent a recurrence of the situation described.

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### ITEM G - GERRO-ALLOY ATTACK ON 17-7PH STEEL:

A preliminary investigation was carried out about the middle of 1956 to determine the effect of Cerro alloys on the tensile properties of 17-7PH steel foil. The so-called Cerro alloys are supplied in a variety of analyses and are compositions which melt at relatively low temperatures, e.g., 100 to 200 F.

This preliminary work indicated that the alloy Cerrobend in contact with the steel diffuses into it when the temperature is raised for brazing or heat treatment. The diffusion is quite detrimental to the steel, causing a loss in tensile strength of up to (75%, and mostly or wholly destroying the elongation.

In performing the experimental work, tensile test specimens of 17-7PH steel foil, .002" thick, were subjected to a dondition much more severe than would normally be encountered in the production brazing of honeycomb sandwich panels. Cerrobend was cast around each specimen before heat treatment. The specimens were then exposed to a simulated production brazing cycle and subsequently, heat treated in accordance with the schedule of Table IGTI. Cerrobend melts at about 158 F. When the tensile specimens were heated in the simulated brazing cycle, the resulting liquid alloy diffused into the steel.

Table IG-I gives the results of the tensile tests on the specimens as heat treated. The tensile properties of 17-7PH steel foil, .0015-.002" thick, heat treated as indicated may be taken as: Tensile yield strength, upwards of 150 ksi; ultimate strength, upwards of 180 ksi; and minimum elongation in 2", 3%. The values may be compared with the test results in the Table. Figure IG-1 is a photomicrograph which shows the intergranular diffusion of the Cerrobend in the steel.

Additional work was done, on selected samples of honeycomb, core represented as typical of vendor fabrication in which one of the Cerrolow alloys was used to aid in the milling operation. The particular Cerrolow composition was not identified. The core samples were heat treated at Convair, using a production cycle. Metallographic examination was made to determine whether the vendor's cleaning process had removed all the Cerrolow. Numerous samples were examined, and in two sections areas were found where slight intergranular diffusion had occurred. X-ray fluorescent analysis indicated that small amounts of bismuth, estensively originating in the Cerrolow, were present in core as received and in ore after heat treatment at Convair.

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### ITEM H - INVESTIGATION OF LOW STRENGTH HONEYCOMB CORE:

An investigation was completed early in 1957 on the cause for low strength of honeycomb cores in brazed sandwich panels as detected by the flash test. These panels were produced in 17-7PH steel and were brazed with the 85:15 silver-manganese alloy. Metallographic examination, chemical analyses for carbon and nitrogen, and microhardness tests were made on the core of the panels. Flatwise compression tests were performed on samples from the panels.\*

The panels involved in this investigation were production parts from vendors and from Convair as well as experimental items brazed in production facilities. Type 3-10 core was used in some panels. These were tested to determine the structural integrity of the type 3-10 core.

Early in this work, two conditions which affect the strength of core were observed. One was the degree of response to heat treatment and the other was intergranular penetration of the core steel.

The data obtained in testing samples from a number of panels are given in Table IH-I.

A comparative measure of the response to heat treatment of various core samples was obtained from knoop hardness determinations on dross-sections of the core foil. The values converted to Rockwell Cinumbers are listed in Table IH-I. These values are considered to be comparable as among core samples but are not convertible to tensile strength. In addition, core hardness is not indicative of panel strength.

The initial work on panels brazed with 3-10 core developed the following observations:

1. The hardness of cores varies among panels.

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2. Nearly all carbon determinations were higher than the .09% maximum specified in Mil-S-25043. All nitrogen determinations were above the .03% maximum specified by the Armco Steel Corporation, producer of 1747PH steel.

\*See Supplemental Sheet S-1

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3. Core hardness was significantly lower than skin hardness on all panels tested.

4. The lowest core hardness corresponded to exceptionally high contents of both carbon and nitrogen.

5. Core material containing high carbon and nitrogen was heat treated in the laboratory to hardness higher than that of many core samples from panels.

6. Variance in core hardness among panel samples did not correlate consistently with flatwise compression values.

Referring to the chemical analyses noted in item 2 above, the results of a study on the effects of carbon and nitrogen on the response of 17-7PH steel foil to heat treatment has been reported in FGT-2452. Correlation was not established.

Intergranular, penetration has been mentioned. This condition was found in the core of panels where the flash test and mechanical tests indicated low strength. The penetration appeared to be an oxidation or corrosion effect associated with the braging atmosphere. Figure IH-I is a photomicrograph which shows this type of penetration. Its occurrence is not related to the presence of the brazing alloy. Grain-boundary penetration by oxidation or corrosion diminishes the section of the core and reduces the panel strength. A microstructure regarded as normal for 17-7FH steel core in a brazed panel is shown in Figure IH-2.

During brazing, the conditions which cause the type of penetration just described are not known. However, a penetration of similar appearance can be produced by heat treating in an atmosphere of argon having a high content of water. In examining intergranular penetration, the object was to determine whether it reflected a susceptibility of some core to oxidation or other attack under certain brazing conditions.

Testing was discontinued because the type 3-10 core proved inadequate under marginal processing conditions. Although variations in chemistry, microstructure and response of core to heat treatment did exist, the performance of the core in a panel was not definitely related to these items. Rather, control of the brazing process and the quality of the resulting brazement appeared to be more important. In general, the response of the core to heat treatment was inferior to that of the skin material. Still, the core did respond well enough to impart adequate strength to the panel.

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| CONCLUSIONS:       ITEMS - F, G, H         ITEM F - ELEVON RIB CORE       ITEMS - F, G, H         The investigation of a banded appearance of honeycomb core supplied by a vendor showed that the two steels had been fabricated partly from 17-7TH steel foll and partly from 321 stainless steel foll. The conclusion was drawn that the two steels had become mixed in the fabricated partly from 321 stainless steel foll. The conclusion was drawn that the two steels had become mixed in the fabricated partly from 321 stainless steel foll. The conclusion was drawn that the two steels had become mixed in the fabricated of that a recurrence of this situation showed that the two steels had become mixed in the fabrication of the effect of Cerro alloys on the tensile procedures of quality control.         THEM G - CERRÓ ALLOY ATTACK ON 17-7TH STEEL       Image: State of the s  |              |  |                   | PA             | GE         | 114        |
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|            | gran        | ular per      | netratio               | n of the                              | core, and t                           | he extent o                | f feil     | buckling              |
|            | deve        | loped i       | n fabric               | ation of                              | the core.                             | κ.                         | 3          | *                     |
|            | Thte        | nanon         | or nonet               | nation du                             | to oridet                             | ion or corr                | outon w    | 40 <sup>-</sup> 9     |
|            | ' evid      | lently, a     | ssociate               | d with a                              | ontaminant                            | in the bra                 | zing at    | mosphere.             |
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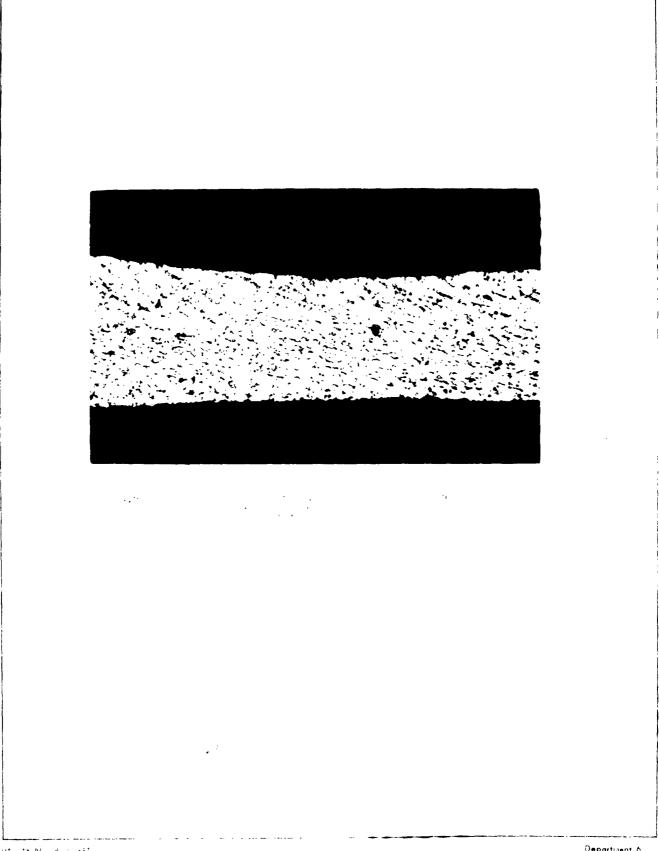
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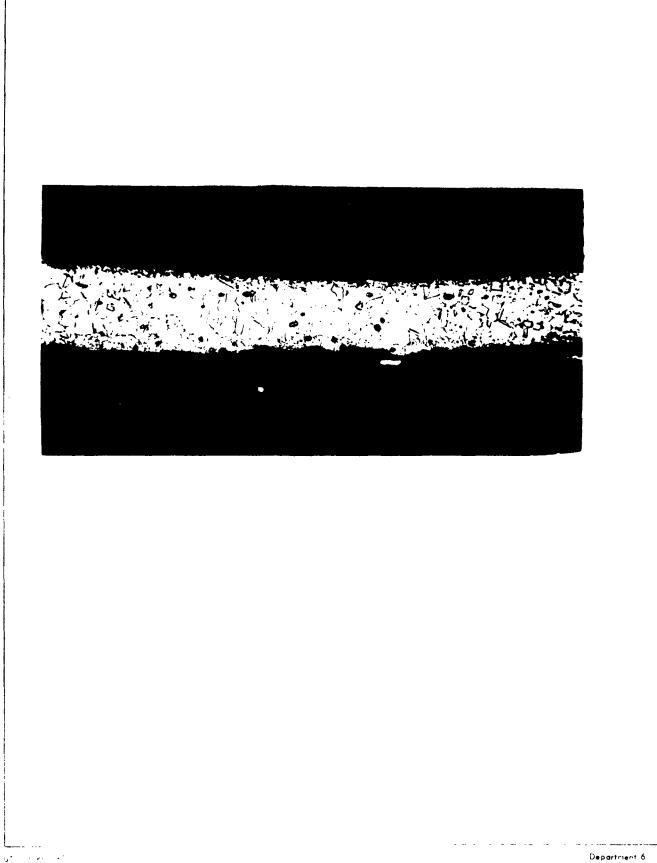




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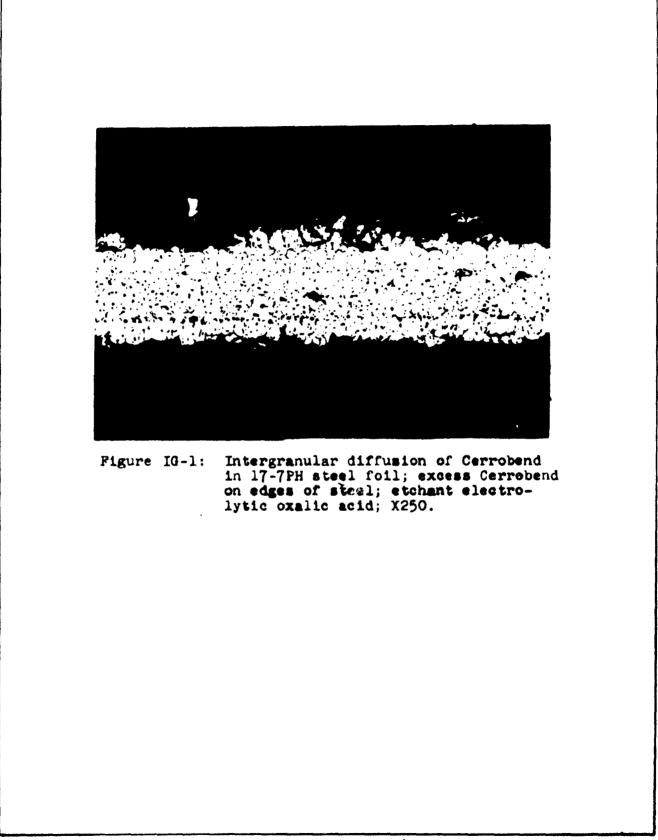
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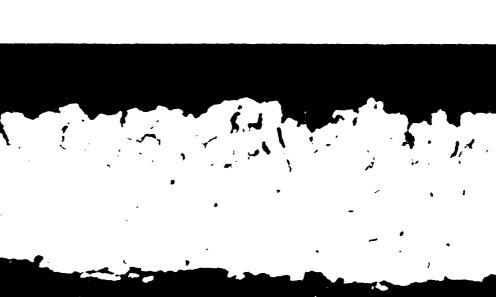


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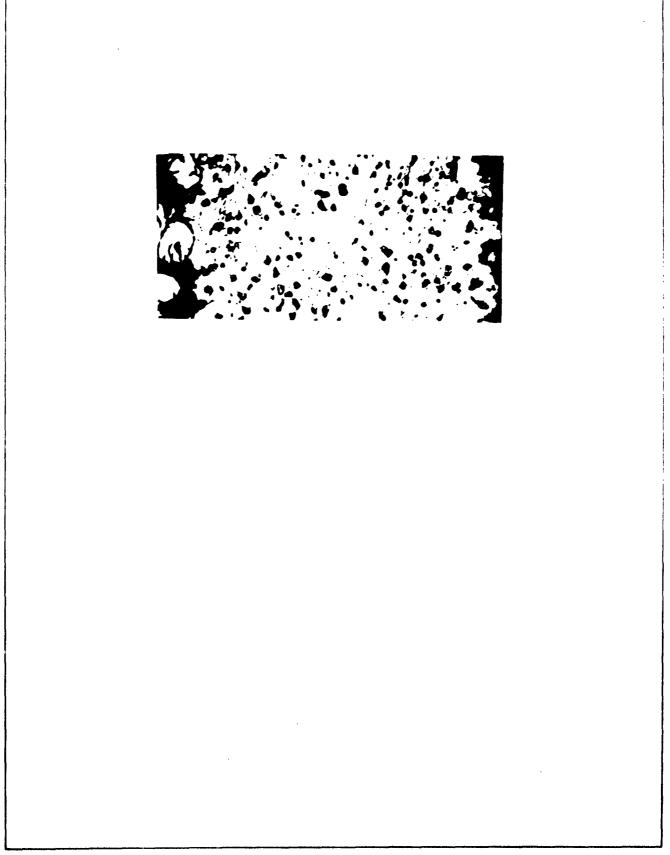
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|            |                                       | -                  | ABLE IG-I              |  |
|            |                                       |                    | ND ON THE TENSILE PROP | ERTIES   |
|            |                                       | <u>OF 17-71</u>    | H FOIL, .002" THICK    |  |
|            |                                       | :                  | ·                      | · · · ·  |
|            | : ·····                               | Yield              | Ultimate               |  |
| v          | , , , , , , , , , , , , , , , , , , , | " Strength,        | Strength,              | <sup>b</sup> Percent   |
|            | Specimen '                            | ksi                | <u>ks1</u>             | Elongation   |
| • •        | 2                                     | None '             | 73.5<br>47.0           | None<br>None   |
|            | 3                                     | None<br>None       | 79.0<br>139.6<br>44.1  | None<br>0.5  |
|            | 5                                     | None<br>None       | 44.1<br>143.4          | 0.5<br>None  |
|            | 7                                     | 158.9<br>F None I  | 162.8<br>114.9         | None   |
|            | 8<br>9                                | None               | 95.7                   | - None   |
|            |                                       |                    |                        |  |
|            | Heat treat                            | ment cycle:        | 1                      | с.   |
| ,          | 1. Held a                             | t 1815 F for 15 m  | nutes                  |  |
|            | <b>)</b>                              | b booled to 1400 H | •                      |  |
|            | ■ <b>■</b>                            | t 1400 F for 90 mi |                        |  |
|            |                                       | ₽.'                | emperature in 4-1/2 ho |  |
|            |                                       | ed to -20 F        |                        |  |
|            |                                       | b 1050 F for 90 m  |                        |  |
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|--------------------------|----------|--|---------------------|-------------------------------|------|---------------------------------|------------------------------------|------------------------------------|
|                          |          |  |                     | ON PANEI                      |      | ED: 17-7PH<br>Manganese         |                                    |                                    |
|                          | 2.<br>2. | Panel<br>Identificăți                                    | Core<br>Lon Type    | Flatri<br>Compres<br>Strength | sive | .Core<br>Hardness,<br>ogkwell C | Core Con<br>Carbon                 | Nitrogen                           |
| an<br>An Iona<br>An Iona | -        | S/N 40,00 <b>3*</b><br>1324-45<br>S/N 4911               | <b>3-10</b><br>3-10 | <b>3</b> 55 <b>-6</b> 4       |      | 15<br>24-29                     | .27-                               | .25                                |
|                          |          | 1275-8<br>S/N 21001                                      | 3-10                | 157-24                        |      | 31                              | .17                                | .24                                |
|                          | *        | 1295-43-2<br>S/N 51002*<br>4P 1326-5 <b>9</b><br>S/N 119 | 3-10<br>3-10        | 125-30<br>121+ <b>3</b> 4     | · ·  | 31<br>36                        | .23 <mark>[</mark><br>.09          | .08                                |
| н<br>                    |          | 4P 1326-60<br>S/N 306-38                                 | 3-10                |                               |      | 25.                             | .10                                | .11                                |
|                          |          | 4T 14004<br>S/N 2409<br>4P 1271-101<br>S/N 10,016        | 3-10<br>3-10        | 172+39<br>131-80              | • •  | 27<br>29                        | .12                                | • •07                              |
|                          |          | 4P 1661-13<br>3/N RO 3601-                               | <b>k</b> .          | 716-11                        | .16  | . 44                            | .14                                | .22                                |
|                          | 「「「「     | 4T 015-2<br>S/N 5000<br>4. FTP 356                       | 3-15<br>3-15        | 170-68                        | 88   | 32<br>36                        | .12                                | .12                                |
|                          | 184      | S/N 3037<br>4T 2234-4<br>S/N 3274                        | 3-15<br><b>3-15</b> |                               |      | 27                              | .10                                | .13                                |
|                          |          | + Flash Test   | t Failure           |                               |      |                                 |                                    |                                    |

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## C O N V A J R A DIVISION OF GENERAL DYNAMICS CORPORATION

(FORT WORTH)

24 PAGE. FGT-272 REPORT NO. B-58 MODEL 1/19/61 DATE.

### EFFECT OF CARBON:

Two investigations concerning the effect of carbon in the brazing operation on 17-7PH steel were carried out. The results of one of these were reported in a memorandum. The results of the other were communicated verbally. Summaries of these investigations are given in the following items I and J.

ITEM I - EFFECT OF GRAPHITE ON 17-7PH STEEL DURING BRAZING AT 1850F.

An investigation was made to determine the amount of Carbon absorbed by the steelifrom the graphite block or from the atmosphere in brazing 17-7PH steel panels. Also, the effect of the absorbed carbon on some mechanical properties was determined.

According to the specification of the Armco Steel Corporation the maximum carbon allowed in 17-7PH steel is .09%.

Specimens from 17-7PH sheet which had been put through the standard brazing cycle, used at the time (1955) with the 85:15 silver-mangapese alloy, were analyzed for carbon. The arrangement in the brazing was as shown in Figure I-II. Here, TL and Bl were top and bottom shim sheets in contact with the skins of the panel, and B2 and B2a were sheets in contact with the traphite form. These lettered sheets were all 17-7PH steel.

Table I-I-I gives the results of the chemical analyses for carbon. The samples identified as 6" x 6" x .008" were assochated with a small test panel. It was not brazed but was laid up and put through the standard brazing cycle in the laboratory. The other samples identified as 049- etc. were associated with panels brazed in production. As may be noted, the carbon pick-up by the sheets in contact with the graphite was considerable. The carbon pick-up by the top and bottom shim sheets of the production panels brazed in argon was slight. These shims were shielded from the graphite. The much larger increase in carbon of the B2 and B2a sheets of the small test panel, as compared with the increase of the production panels, is attributed to the hydrogen atmosphere.

Specimens for the mechanical tests were cut from the top and bottom shim sheets and also from the sheets in contact with the graphite, used in the brazing of production panels. Tensfle and axial tension-tension fatigue tests were made. The actual test data have been reported as no longer available. In the following two paragraphs, are statements concerning these tests as given in the covering memorandum. The term 'shielded' means TI and Bl shim sheets, and the term 'unshielded' means B2 and B2a

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| • · · ·                               |  |   |                                     |   |
|                                       |  |   |                                     |   |
|                                       | sheets. The term 'skin' mea  | ns shim sheet.  |                                     |   |
| · · · · · · · · · · · · · · · · · · · | "The minimum ultimate and y<br>met by both the shielded and<br>with 4.3 to 4.9% elongation<br>843#1 skins had higher ultim<br>3.8% elongation. The shield<br>design allowables with 4.5% | unshielded 17-7PH stat<br>for the 049-837-T4 skir<br>ate and yield strength<br>ed skin from 049-841-7 | inless s<br>ns. The<br>with 2       | teel<br>049-<br>.8 to   |
|                                       | "The results from the tension<br>and unshielded 17-7PH stain<br>slight effect due to carbon<br>The endumance limit for the<br>approximately 5000 psi lower<br>17-7PH."                   | ess steel appeared to s<br>pick-up for the skins i<br>unshielded 17-7PH were                          | show only<br>from 049<br>(sic) -    | y a<br>-837-T4.   |
| F                                     |  |   |                                     |   |
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|                               | ITEM J - INVESTIGATION OF EMBRITTLEMENT IN THE COL   | INER REGION                             | <u>s</u>       |
| · · · ·                       | OF 17-7 STEEJ, SANDWICH PANELS   |   |                |
|                               | An investigation was undertaken as a result of the   | metaction                               | of i b         |
| •                             | several brazed 17-7PH steel sandwich panels because  |   | called         |
|                               | corner condition. The term "corner condition" was  | s meant to                              |                |
|                               | indicate that the panel showed evidence of contamination of contamination in the panel showed evidence of contamination of the panel showed evidence of contamination of the panel showed evidence of contamination of the panel showed evidence of contamination of the panel showed evidence of contamination of the panel showed evidence of contamination of the panel showed evidence of contamination of the panel showed evidence of contamination of the panel showed evidence of contamination of the panel showed evidence of contamination of the panel showed evidence of contamination of the panel showed evidence of contamination of the panel showed evidence | ination at                              | the 👘 🖓 👘      |
|                               | corners. Testing usually showed that such contam   | inated pane                             | 1              |
| ų, ų                          | regions failed in a brittle manner.  | · · · · ·                               |                |
|                               | The contamination was first attributed to air leal   | ke in the                               |                |
|                               | incoming argon gas lines. Since several structure  | al members                              | of 👫           |
|                               | a sandwich panel join at the corners, these region   |   |                |
| 1                             | that serve as openings for circulation of the pure   | ging gases                              | into           |
|                               | and out of the core during brazing. Air leaking  | into the ar                             | gon 🧯 🚽        |
| • . •                         | line was eliminated by maintaining the pressure in   | n the incom                             | ing j          |
|                               | gas line above atmospheric pressure.   |   | 5              |
| · · ·                         | Although excluding air from the argon undoubtedly  | afforded h                              | etter          |
|                               | panels, the corner condition was still found in so   | ome. Anoth                              | er             |
|                               | possible cause of the contamination was thought to   |   |                |
|                               | pick-up from the graphite brazing form. Test date  | a were obta                             | ined 💦         |
|                               | to determine the validity of this idea.  |   | 1              |
|                               | Nine panels exhibiting contaminated corners were   | arontnod du                             | с <sup>1</sup> |
|                               | this investigation. The data presented for panels  | s 1. 3. 7.                              | and the second |
|                               | 9 are representative of the results obtained. Me   | tallographi                             | C ·            |
|                               | sections were taken from contaminated areas in each  | ch panel, a                             | nd 🕺           |
| , ÷                           | chemical analyses for carbon and nitrogen were run   | n on adjaces                            | nt 👔           |
|                               | regions.   | el A                                    |                |
| •                             | Figures AJ-I through IJ-4 are diagrams showing the   | martona a                               | mpled 5        |
|                               | and listing the carbon and hitrogen contents found   | i in variou                             | ambred         |
| 4                             | panel sections. Figures IJ-5 through IJ-9 are pho  | otomicrogra                             | ph <b>s</b>    |
|                               | of specimens removed from various locations in the   | panels.                                 | •              |
|                               |  |   | _              |
|                               | The chemical analyses showed that the carbon contends in almost every instance exceeded the max.   |   |                |
|                               | .09%, specified for 17-7PH steel. This excess car  | chon in the                             | 7              |
|                               | members was concentrated at the outer edge and mon   | e exposed                               | upper          |
|                               | members was concentrated at the outer edge and mor<br>surface, as shown in Figure IJ-2. In one panel, a  | a high cont                             | ent of         |
| : · · ·                       | carbon was found on the outer side of a bottom ski<br>gen contents, although high in several analyses, o<br>any definite pattern of location.  | In. The ni                              | tro-           |
|                               | gen contents, although high in several analyses, o   | 110 not isug                            | gest           |
|                               | any definite pattern of location.  | •<br>•                                  |                |
| <u>*</u> •                    | The metallographic examinations confirmed the resu   | ilts of the                             | chem-          |
|                               | ical analysis for carbon. Excessive amounts of ca  | arbides wer                             | 8              |
|                               | present in the former austenite grain boundaries   | of the Z-mer                            | nber           |
|                               |  | · 호 토 :                                 |                |
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27 PAGE FOT-272 REPORT NO. **B-58** MODEL A DIVISION OF GENERAL DYNAMICS CORPORATION 1/10/6 DATE. (FORT WORTH) specimens. This carbide contentration was heaviest toward the surfaces of these parts. Figure IJ-5 shows the difference in carbide content of a Z member and a panel skin. Figure IJ-6 shows the difference in carbide content of a Z member and a panel doubler. Figures IJ-7 IJ-8, and IJ-9 show the presence of intergranular oxidation on the more exposed surfaces of Z members and doublers. This condition is definitely indicated in the photomicrographs in which the grain boundaries are evident when no etchant was used. The oxidation can be inferred, from the photomicrographs of the same sections after etching, by the extent of the attack on the surface layers. CONCLUSIONS: A ITEMS I, J The investigation on the effect of graphite on 17-7PH steel during brazing at 1850 F showed that carbon is absorbed in considerable amount when the steel is in contact with the 1 :graphite. The test results indicated that graphite forms can be used successfully in brazing sandwich panels provided that a protection sheet is laid between the graphite and the panel skin. The study on corner embrittlement disclosed that this condition is due to carbon absorption by the steel. Carbon contamination was found in the Z members of nine panels examined. The contamination was most severe in regions of maximum exposure to the circulating gases during brazing. Superficial intergranular oxidation was observed on the more exposed surfaces. Ъr,

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# Table I-I-I - Indicated Carbon Pickup

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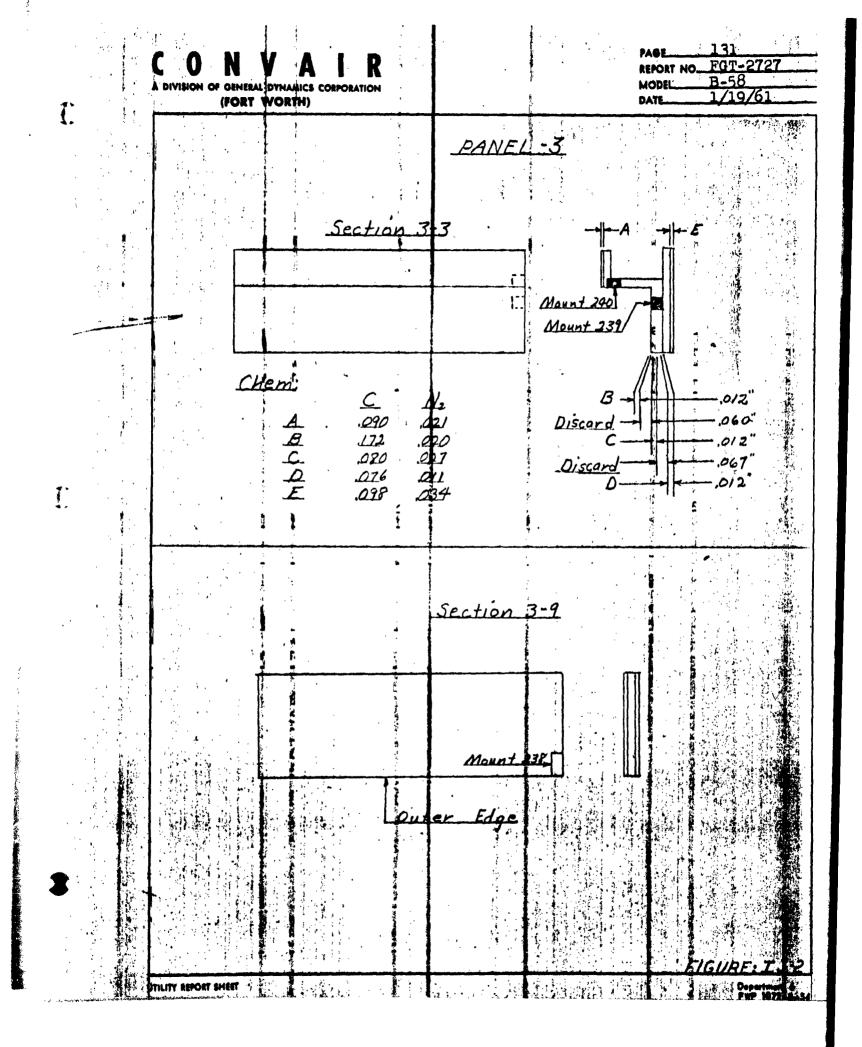
in Brazing 17-7PH Steel

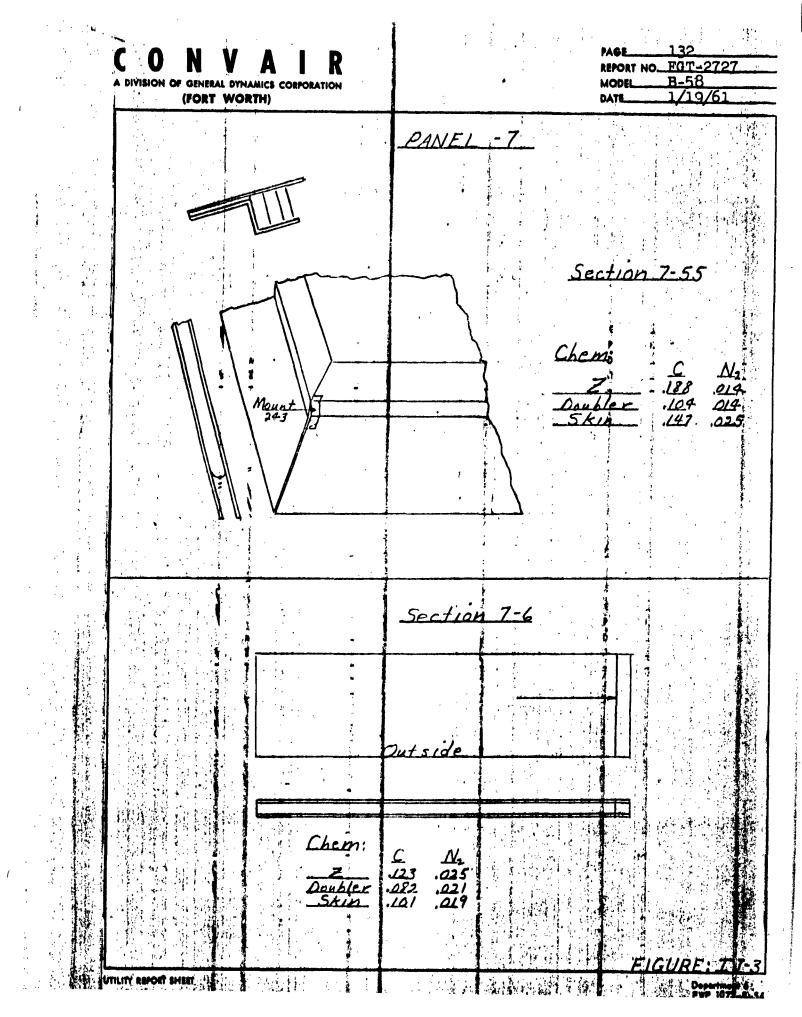
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|     | Sample          | Location        | Brazing<br>Atmosphere | Carbon<br>\$                       | Amount C<br>excess of<br>Specifica | Armco<br>tion      |
|-----|-----------------|-----------------|-----------------------|------------------------------------|------------------------------------|--------------------|
|     | As received     |                 |                       | .062                               | £                                  |                    |
| .:  | 6 x 6 x .008    | " Tl -          | Hydrogen              | 128                                | 038                                |                    |
|     | Ħ               | B2              | н                     | .424                               | • 334                              |                    |
|     | 11              | B2a             | 17                    | .570                               | .480                               |                    |
|     | 049-841-7       | Tl              |                       | .074                               |                                    |                    |
|     | 049-837-т4      | 71 <sup>1</sup> | <sup>1</sup> Argon    | .072                               |                                    |                    |
|     | n               | <b>B1</b>       | 11                    | .084                               | i                                  | 4<br>4<br>4        |
|     |                 | B2              | - H                   | .126                               | 036                                |                    |
|     | 049-843-1       | Tl              | II                    | .07                                |                                    |                    |
|     | u i             | B1              |                       | .076                               |                                    |                    |
|     | n               | B2              | n                     | .136                               | :046                               |                    |
|     |                 |                 |                       |                                    |                                    |                    |
|     |                 |                 |                       |                                    |                                    |                    |
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120 FOT\_272 REPORT NO B-58 MODEL HON OF GENERAL DYNAMICS CORPORATION 1/19/61 (FORT WORTH) DATE Diagram of Test Panel Layup Graphite Pane 1 2-8 T.1 - Top shim sheet B-1-Bottom ship sheet 7 î B-2 - Barrier sheet B-2a - Bottom sheet, some as bottom of retort G REPORT

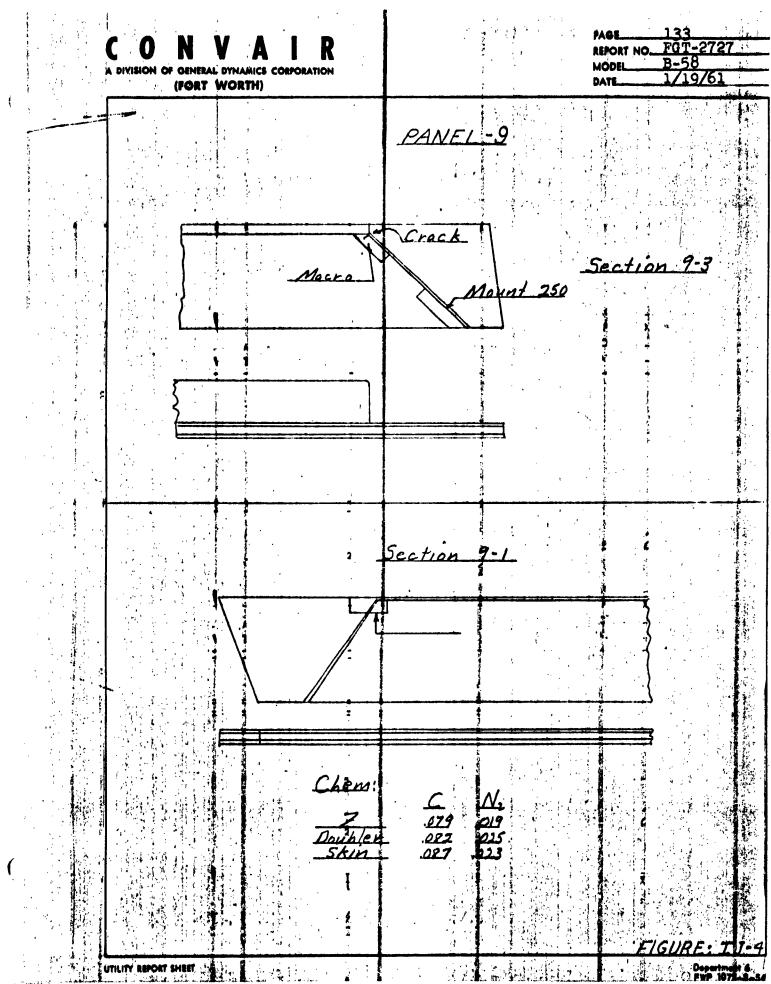
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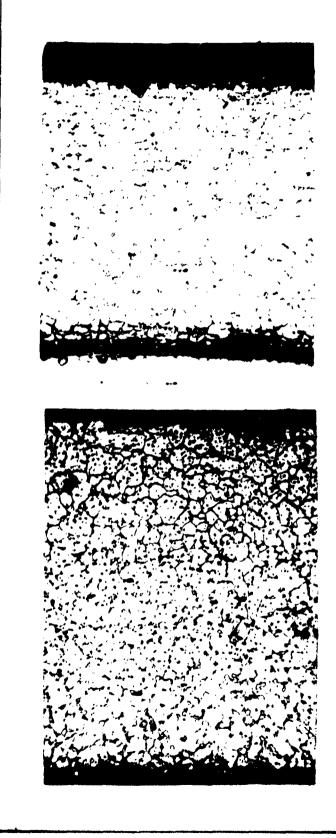
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Top of skin

Fanel 1, Section 1-54

Jiella's etclant; **X500** 

This section of skin is normal. No contamination is present.

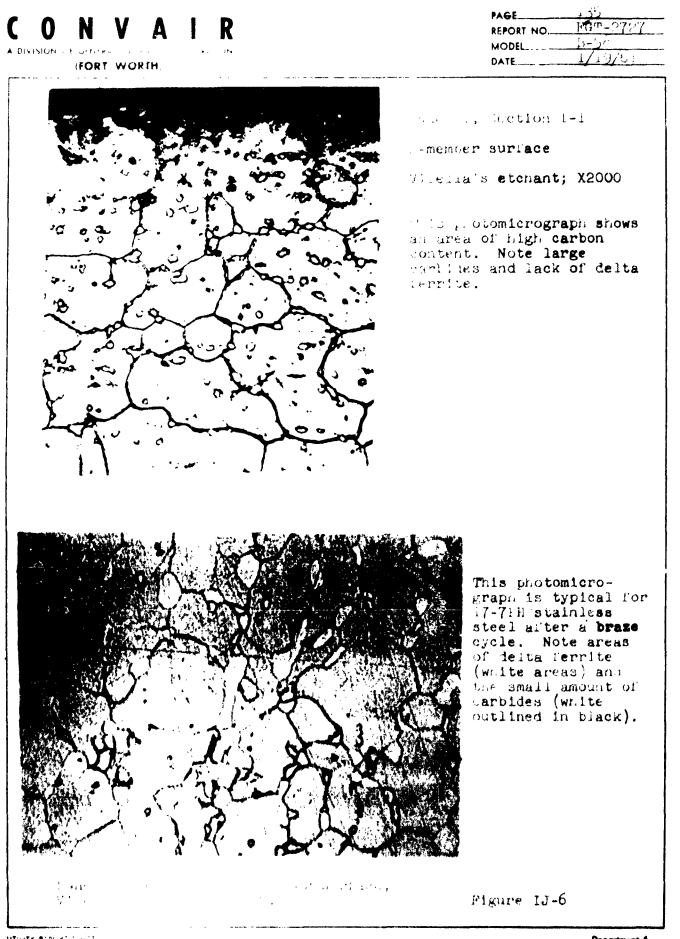
Brazing Alloy

Top of edge member Panel 1, Section 1-10 Vibila's etchant; X250 The top surface of this

edge member shows severe carburisation.

Figure 13-5

UTILITY REPORT SHEET



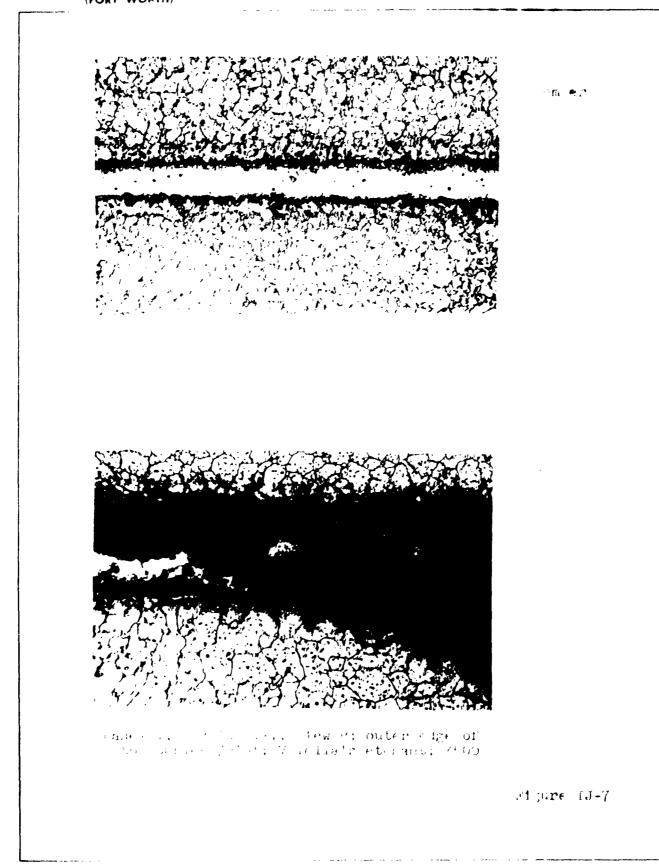
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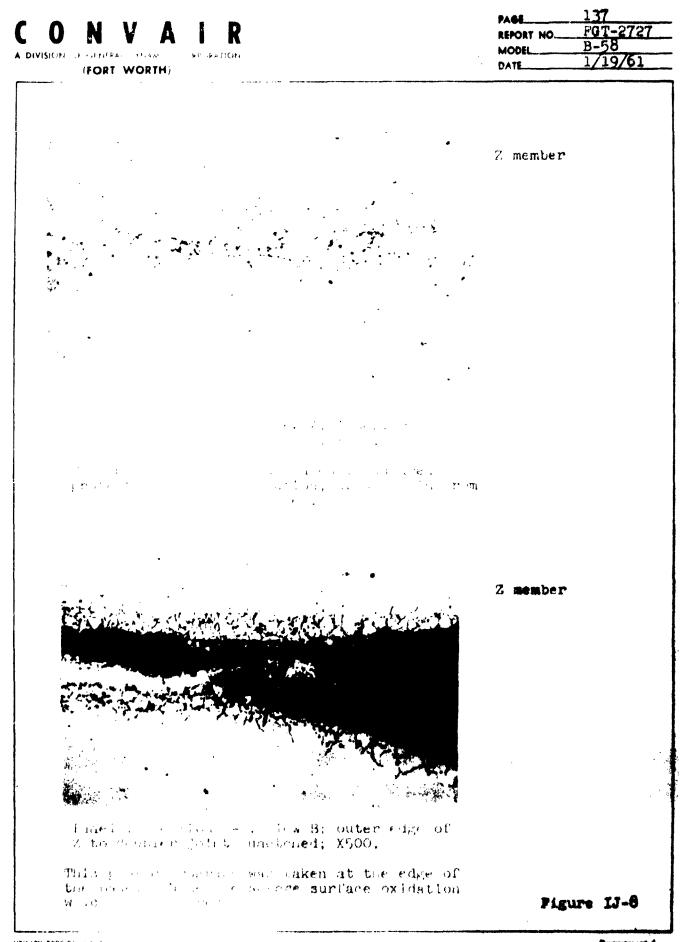
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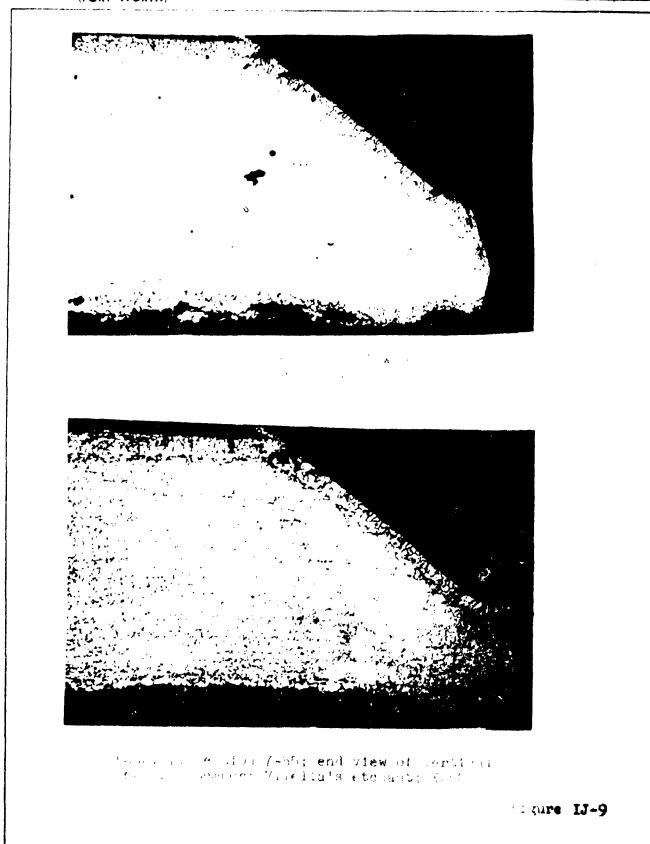


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### EFFECT OF ELEVATED TEMPERATURES:

Two investigations on the effects of elevated temperatures on 17-7PH stainless steel were recently carried out, the results of which were not published. They were made available by memoranda. In addition, some information on these effects has appeared in two published reports (reference FTDM-1415 and FGT-1362-1). The first gives some values as to the effect of repeated exposures to 1000 F and subsequent cooling to room temperature on the tensile strength and dimensions of 17-7PH steel and two other stainless steels. The second contains some data on the shear strengths of brazements of 17-7PH steel. The results of the two unpublished investigations are given below.

#### ITEM K - ELEVATED TEMPERATURE PROPERTIES OF 17-7PH STEEL

When the sterling silver lithium alloy was adopted, the brazing temperature was lowered from 1825 to 1650 F. With these changes, the number of edge-member voids increased in 17-7PH steel sandwich panels. One possible dause for this condition was suggested, viz., the higher mechanical properties of the steel at the reduced brazing temperature.

Late in 1957, as connected with the problem of voids, tests were performed to determine the tensile properties and shorttime creep strength of 17-7PH steel at elevated temperatures. The data were obtained for use as a manufacturing aid in deciding the amount of mismatch and danning, of the edge-member components of panels, that could be corrected by the pressure applied during brazing.

The tests were made on sheet with nominal thicknesses of .040" and .063". The following properties were determined; Modulus of elasticity in tension and short-time creep strength at 1600, 1650, 1700, and 1825 F; tensile yield and ultimate strength, and elongation in 2", at 1650, 1700, 1750, 1800; and 1850 F. Most of the data are the results of single tests.

The values optained are given in Tables IK-I to IK-III. The data of Table IK-I and IK-II are plotted in the graphs of Figures IK-I and IK-2, respectively. 'In Figures IK-3 to IK-6 the data' of Table IK-III' are plotted. Higure IK-7 is a composite which shows the stress required to deform 17-7PH steel sheet, either elastically or plastically, at temperatures from 1600 to 1825 F on the basis of modulus of elasticity, yield strength, and creep.

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### ITEM L - EFFECT OF EXPOSURE AT 700 F ON BUTT-WELDED 17-7PH STEEL

In the early months of 1959, an investigation was carried out to determine whether prolonged exposure in air at 700 F would adversely affect the tensile properties of 17-7PH steel sheet as butt-welded and unwelded.

Two lots of sheet stock were tested. One was .005" thick, and the other was .010" thick. Part of the specimens for test were butt-welded by the Heliarc method. The weld seam ranctransversely across the middle of the gage section. The rest were not welded. Conjecture had been made that the weld zones might be affected differently than the parent metal as a result of prolonged. exposure at 700 F.

The material for test was heat treated in simulation of a production brazing cycle (1650, 1400, -20, 1050 F). Tensile specimens were heated in air at 700 F for 100 and 300 hours. The tests were performed at room temperature after the exposures at the elevated temperature.

The results of the tensile tests are given in Tables IL-I to IL-VI. The specimens referred to as Control had not been welded. Figure IL-I shows the effect of the exposures on the tensile strength and elongation of the welded specimens. As is evident, the strength of both the .005" and .010" sheet, plain and welded, was increased substantially by the exposures. The precise effect of the hesting on the elongation was indeterminate.

As shown in the tables, more weld-zone breaks occurred in specimens which had been heated to 700 F than in those not so heated. However, the tensile strength of hearly all the welded-and-heated specimens was substantially in excess of 200 ksi. Also, as a rule, specimens which failed in the weld zone exhibited appreciably lower elongation than those which broke elsewhere in the parent metal. Weld-area breaks here are not to be construed as having occurred in the weld but rather occurred, in the heat-affected zone close to it.

In general, the values for the tensile yield and ultimate strength of the unvelded specimens were in rather good agreement with the values of the corresponding welded specimens. Figures for the elongation of some unwelded specimens, 010" thick, are doubtful due to damage caused by clamping them in contact with welded specimens, for machining. The elongation values for the unwelded specimens, .005" thick, are in reasonable agreement with those of the welded specimens.

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| - | CONCLUSI   | ONS: ITEN   | 1 <u>5 K, L</u>   |   |   |  |
|   | modulus<br>psi at 1<br>strength<br>the ulti<br>ksi, res<br>The exte  | of elastic<br>600 F to 7<br>fell from<br>mate strer<br>pectively;<br>nsions unc | city in ter<br>7.6 millior<br>n about 10.<br>ngths at the<br>and the e<br>der loading | vated temperatures<br>sion decreases fro<br>psi at 1825 F. T<br>9 ksi at 1650 F to<br>ese temperatures w<br>longations were 76<br>in short-time cre<br>es IK-3 to IK-6. | m about 14<br>he tensile<br>6.1 ksi at<br>ere 17,1 an<br>and 44 per   | million<br>yield<br>1850 F;<br>d 10.5<br>cent. |
|   | strength<br>substant<br>This app<br>and .010<br>fairly w<br>The valu | iof 17-7P<br>fally by f<br>lies to bo<br>thick.<br>ell with t<br>ts for the     | i steel in<br>heating for<br>th unwelde<br>The result<br>those for the<br>elongation  | the tensile yield<br>the TH 1050 condit<br>100 and 300 hours<br>d and butt-welded<br>s for the unwelded<br>he corresponding w<br>n were not suffici<br>ite conclusions. | ion are inc<br>in air at<br>specimens,<br>specimens<br>elded speci  | reased<br>700 F.<br>005" -<br>agreed<br>mens.  |
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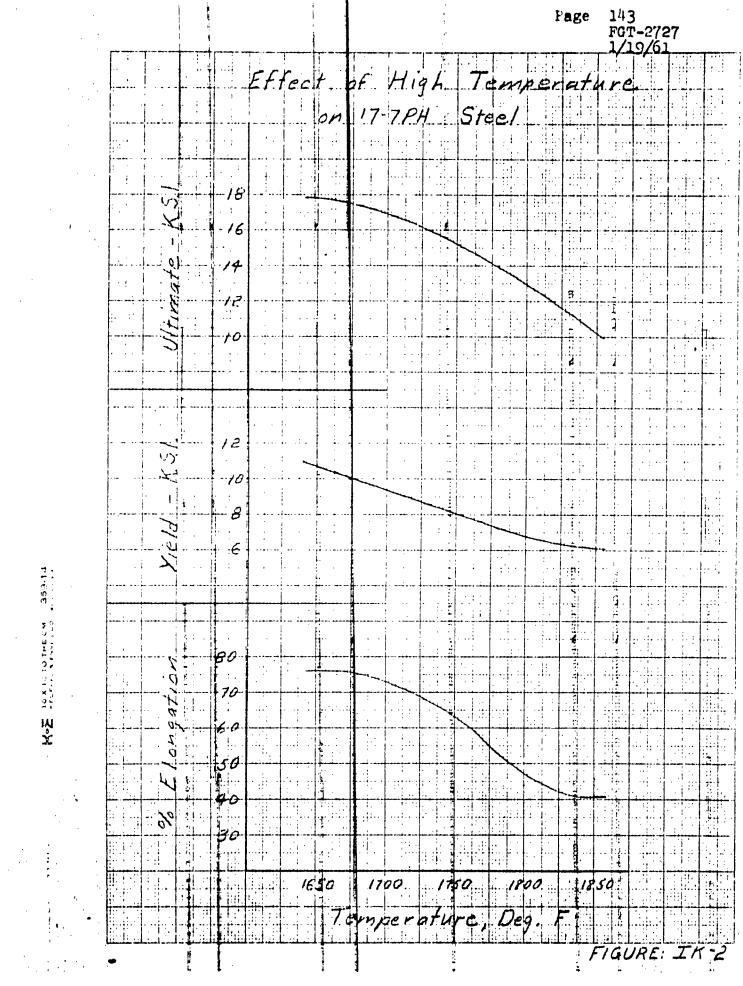
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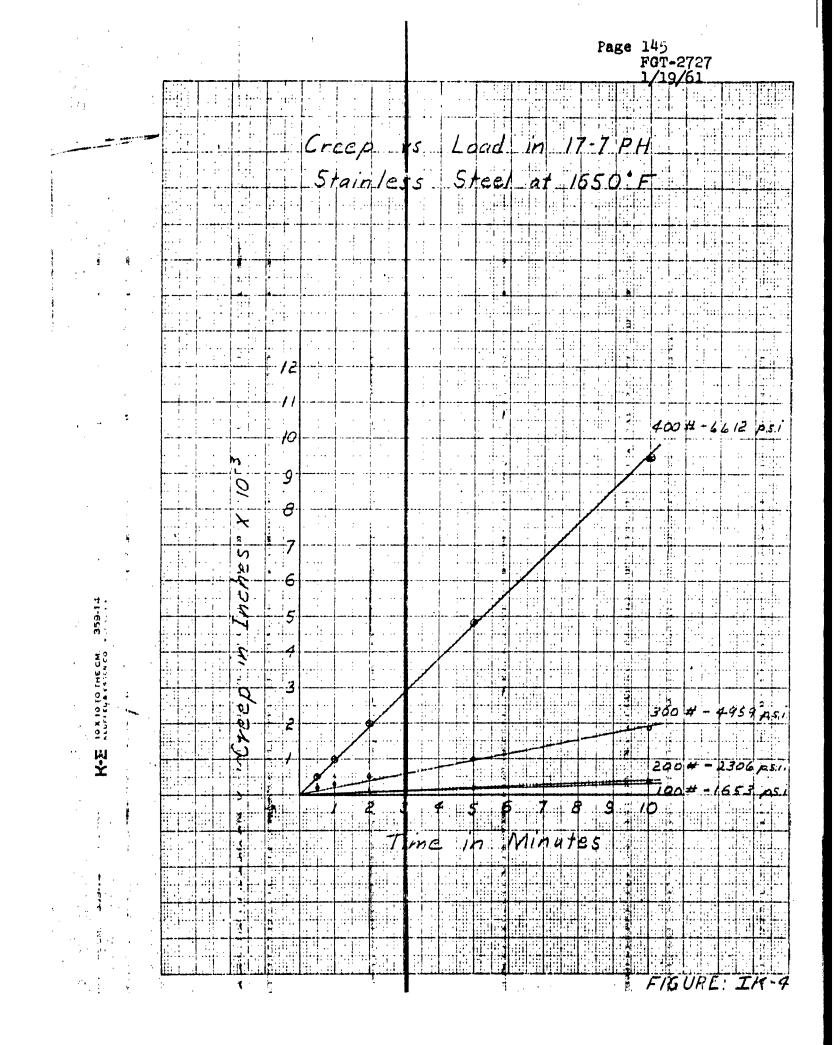
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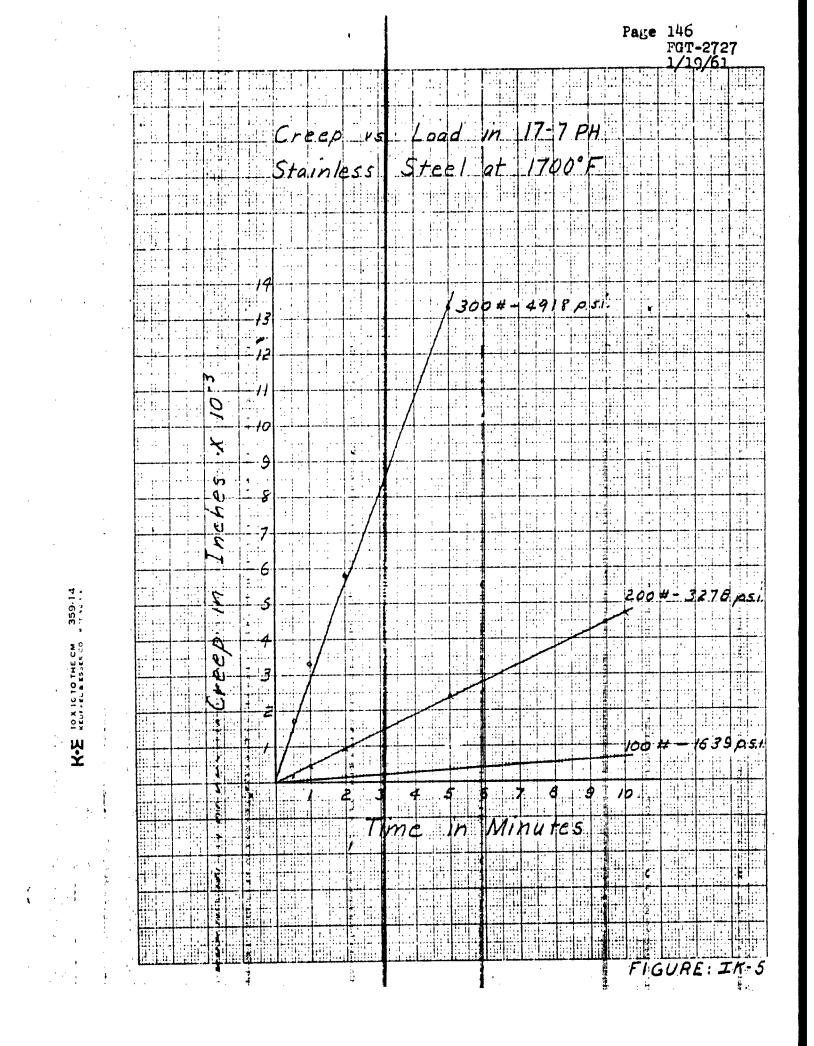
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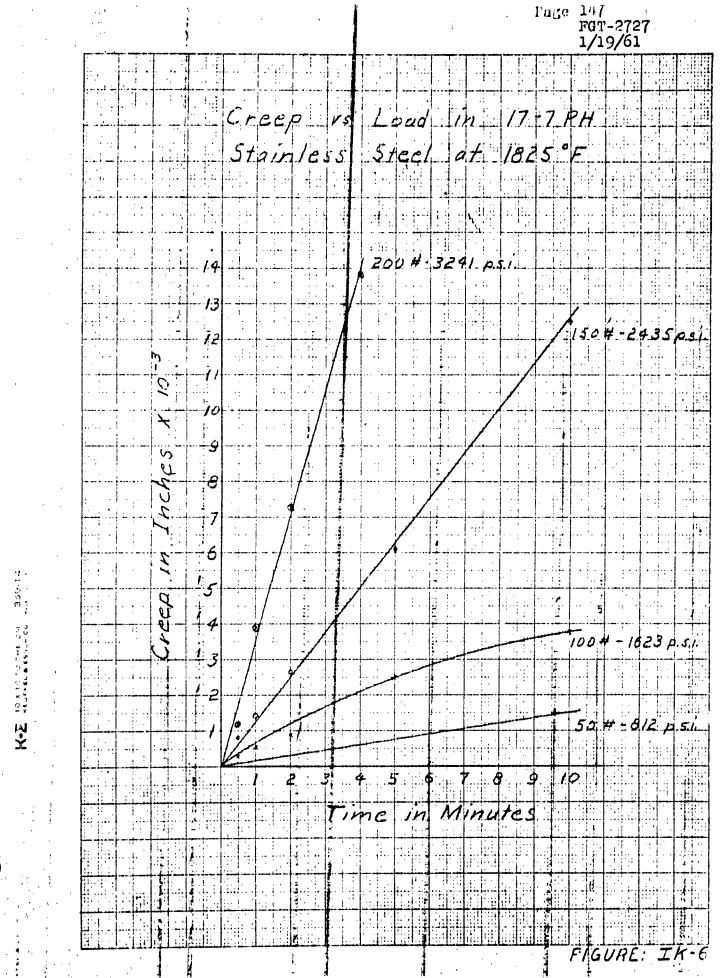
142 FGT-2727 1/19/61 Fage Modulus of Elasticity of 1.1 1. 17-7 PH Stainless Steel at • • Temperatures . .: Elevated 1:11:1: ..... :..<sup>1</sup> 11. • ;  $\frac{1}{1}$ ц**е**, ١. . .: hi i 4 4 ÷ :: i... . . 1.1 **L** .: Codei ÷ ţ . . 11 Ň Max - average. Varlu 14 1 Ν ł Ø a lu e overage ... Aug. Ŀ .1. i  $\mathbf{\lambda}$ Y. ..... 40/48 12 averago Min. 1 4 1 5 i 0 1 **N** į ÷, ...; Ξ. X . : 44 .... ••• . 1 4 +0 1. ž į T ; · i Ī i ũ ł ٠, · · · · i < : ÷ Ð X Ĩ 1 es. •••• ۰. ţ. X L. 1 .: : 'n: . ...d: i...  $\frac{1}{2} = \frac{1}{2}$ .. . \* 6 2 14.5 .... ...**.** . :.... ·••• 359-14 4 d 1 11 • • ł j: i., ģFli v 1 ÷Ť 1 4 4 10 X 10 TO THE CM XEUFIEL & ESHER CO : . 4 7 Ā ··i.i.i.i 19 ł .;::.. ; ; ; 1 414. \_\_\_\_\_\_  $\sim 1$ ...... -+-.. ...... , |:. ...0 • 9., 1 1 2 :111 . . . 1. Ч Т ų, 111 i. : ħ. 1800 . 1900 1700 1600 'i. (<u>å</u> 1 -ded ... 13 11 .l: 1:. emperature - Deg. ΗĘ: 4 ::1 ••• ÷ ÷ ä -1. . i •::!• ļ H tr 1 -ijo :1: FIGURE: IK-1 1



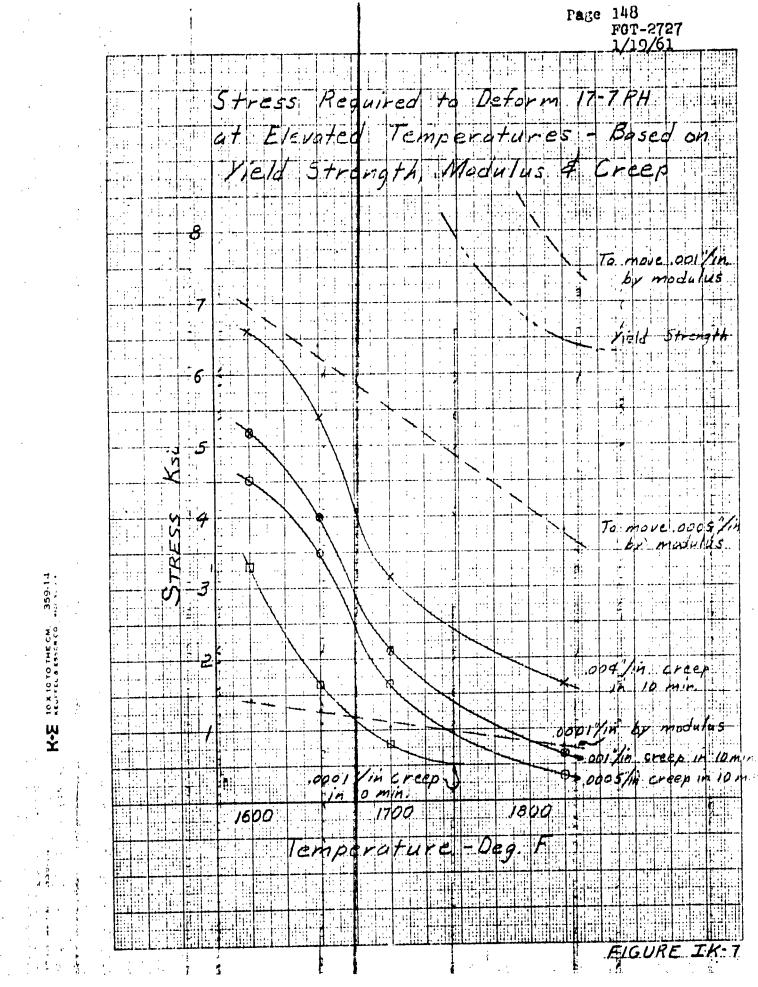
144 Fot-2727 1/19/61 Fage **:**. . i İ 5 Load in 17-7 PH Steel at 1600° F Greep Stainless 1 : •] ;÷. ؛ . .. . **1** -· · · · · · · 11 · |---::: . **|.**. ÷ 1::1 1 . .1 .<u>|</u>:. j, •••‡ . . ::: -12 . : . 11 12 14 ŀ. 44 ..... ï 2 ŧŰ •1• ••• · · · 2 1. 9 1.10 ..... ..... HE. 1 1 θ ÷Ĵ. ..... - } trj · 7 . . i inte :1 Ð -Y.J. Y.J ;6 7.5 359-14 -5 T.M. Z. ÷ 6568 psi 400 # -4 Kor IOX 10 THE CM <u>\_</u>z, ÷į, . 1. A. . . . . de Propo . | ! <u>----</u> : :: --2 100 4 i - -· į · 300 # - 4926 ASI 1.1 200#-3284 05 1 . : 5 7 8 Minutes 9 4 11 11 10: 1 in. i. Time . •14 1.4 21 1111 ĥ 1 шİ (**F**) 5 :11 ÷ į --신에 학생이 : **T** FIGURE: IK.3 







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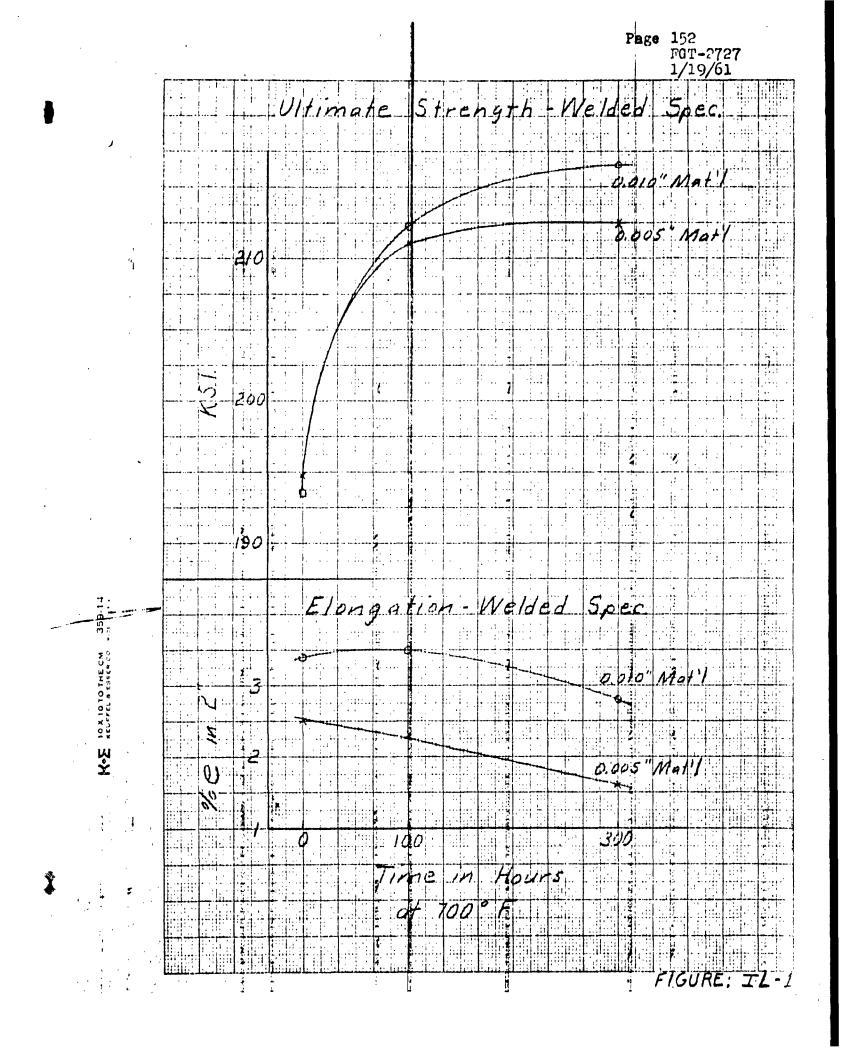


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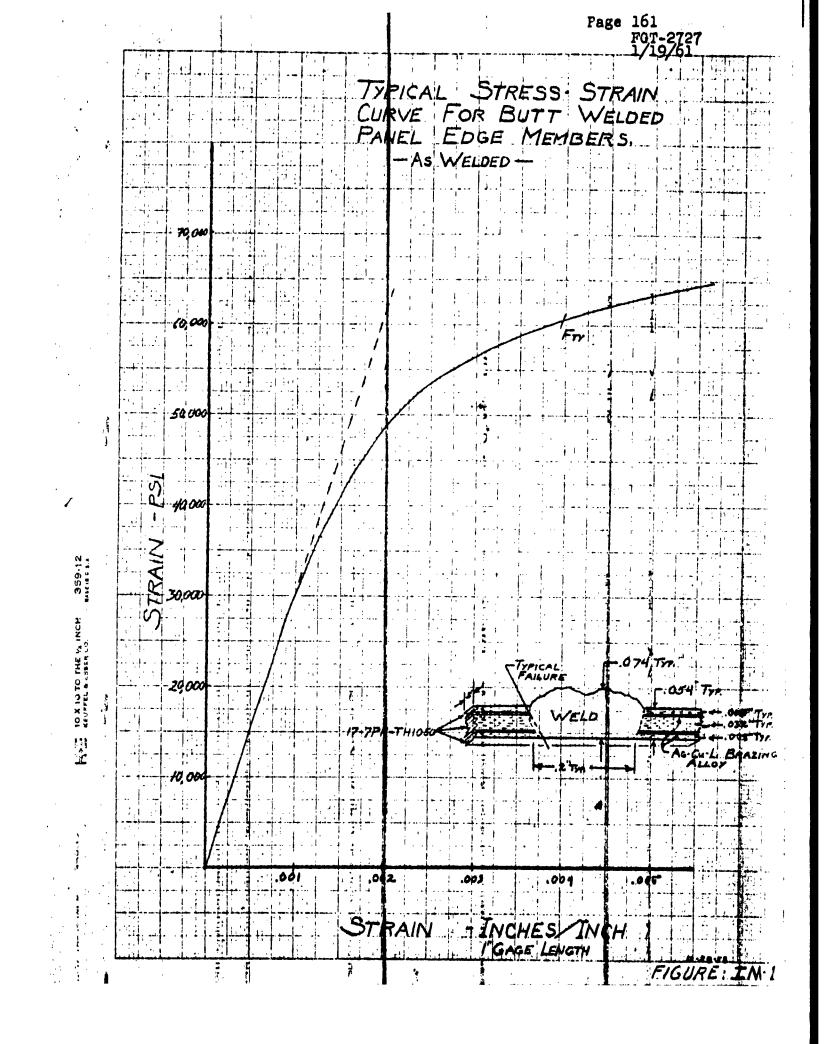
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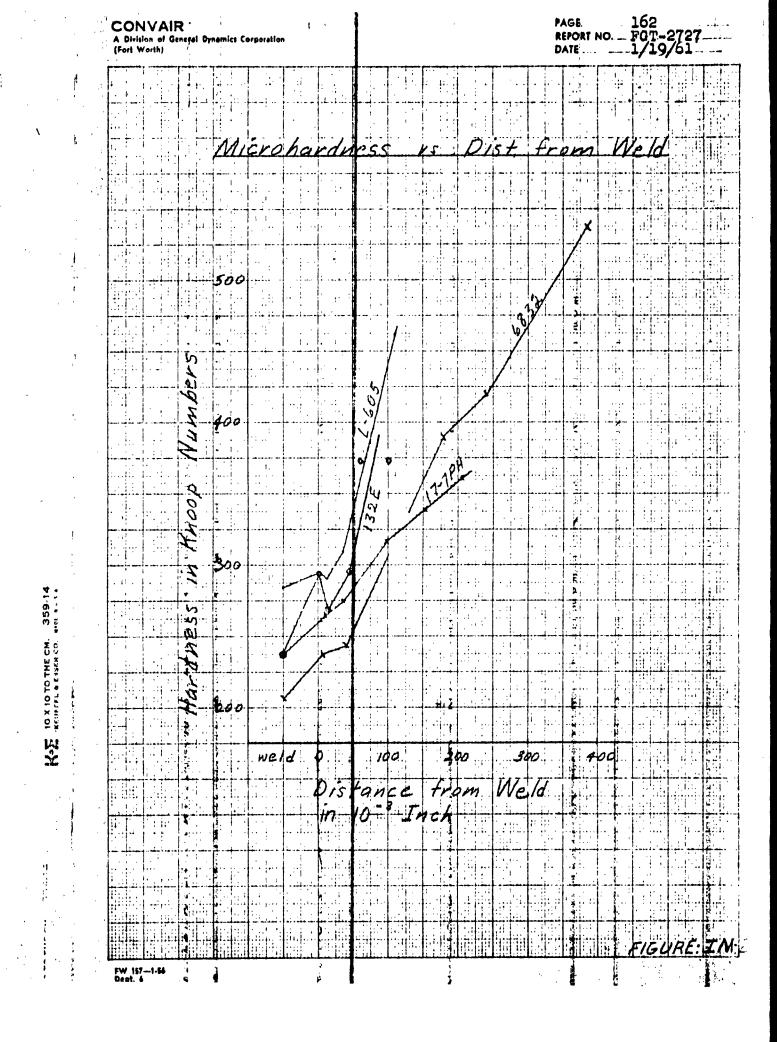
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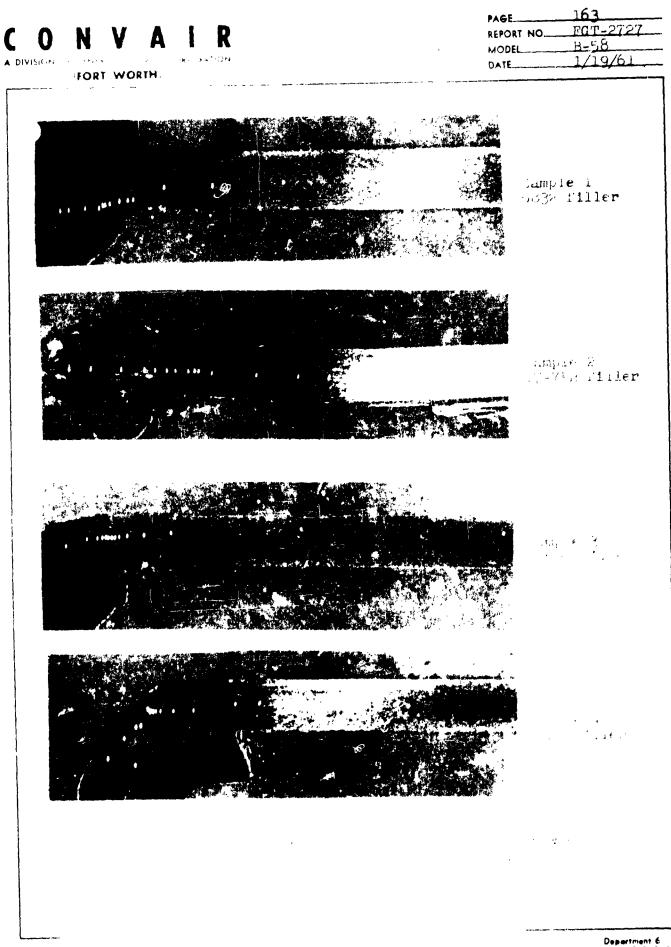
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|          | WELDING   | i i i i i i i i i i i i i i i i i i i  |
| . 1      | the second |  |
|          | ITEM M - WELDED EDGE MEMBERS OF PANELS IN 17-   | <u>PH STEEL</u>  |
|          | Two investigations were carried out to determ<br>welding on the strength of 17-7PH steel in th<br>This work was done in the latter part of 1958<br>of 1959. The investigation of 1958 comprised<br>of butt-welded joints on the basis of tensile<br>In the work of 1959, the purpose was to appra<br>of welding as a method of sealing the corner<br>wich panels.   | e TH 1050 condition.<br>and in the spring<br>the evaluation<br>and fatigue tests.<br>tise the feasibility  |
|          | Referring first to the investigation of 1958,<br>edge-member assemblies were butt welded as sh<br>sketch of Figure IM-1. The results of tensil<br>tension fatigue tests on specimens of such we<br>Table IM-I. These results show that the weld<br>strength equivalent to 17-7PH steel in the an<br>The elongation of the welded specimens was sl<br>that of the steel in the TH 1050 condition.<br>a typical stress-strain curve for the butt-we<br>The number of fatigue specimens tested were to<br>to establish an S-N curve, but did indicate a<br>strength when compared to the yield strength  | own in the inset<br>e and axial tension-<br>lds are given in<br>s have tensile<br>mealed condition.<br>ightly higher than<br>Figure IM-1 shows<br>lded specimens.<br>o few in, number<br>relatively high |
|          | For the investigation of 1959, four welded Z<br>by the Solar Aircraft Company. The vertical<br>members had been welded by the tungsten, inert<br>materials the commercial alloys 6832, 17-7PH,<br>were used. The nominal composition of the fi<br>Following are the compositions of the other t   | sections of these<br>gas method. As filler<br>L-605, and I32E<br>rst is not known.   |
|          |   | sition %   |
|          |   |  |
| · · ·    | 17-7PH 1 16-18 Cr, 6.5-7<br>.09 C max.  | .5 N1, .75-1.5 A1,   |
|          |   |  |
| · .      | $L-605$ $50 C_0, 20 Cr, 1$  | 5 W, 10 N1, 1.51 Fe,   |
| <b>.</b> |   |  |
|          | 132E 68 Mn, 16, Co, 1   | <u>6 N1</u>  |
|          | For the purpose of evaluating the welded join<br>hardness was measured in the welds and butwar<br>into the parent metal. Tables IM-II and IM-I<br>obtained. The data are plotted in Figure IM-<br>of the four samples are shown in Figure IM-3.<br>indicates that the sample welded with the L-   | d for a distance<br>II list the values<br>2. Photomicrographs<br>Figure IM-2   |
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| u -   | the hundret is had the blahast strength mis  |                | <b>.</b>      |                           |                      |
|       | the hardest, i.e., had the highest strength. This to the weld, and the parent material was affected f      | or th          | he            | . • •                     | • •                  |
|       | shortest distance away from the weld. Joints made  | with           | the           |                           |                      |
| •     | 132E and 17-7PH alloys had equivalent strength in t<br>In the sample where 17-7PH steel was used as the fi | ne we<br>ller  | eids.<br>met: | •<br>al.                  | •                    |
| t.    | the heat affected zone extended a greater distance   | from           | the           |                           |                      |
| ,     | weld. The 6832 alloy as filler material gave still<br>strengths both in and adjacent to the welded joint.  | . lowe         | er            |                           |                      |
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| CONVAIR FORT WORTH<br>TABULATION SHEET | SPEC. NO.                    | 1   | SPECIMEN<br>NUMBER<br>2<br>2<br>4<br>4   |

| CON                       | CONVAIR Fort WORTH<br>TABULATION SHEET ////CEDAGEAGESS | H<br>ET Micko                | hardne |          | Values on   | E IM- IL<br>n Welded | <u></u><br>Н <u>Т-7РН</u> | H Stee    | 1721  | Members    | STO        | ĩ   | <i>`</i> . |
|---------------------------|--|------------------------------|--------|----------|-------------|----------------------|---------------------------|-----------|-------|------------|------------|-----|------------|
|                           | SAMP NO ME   | Filler Dit hom<br>Metal Weld |        | Kuszy2   | Zone        | SAMP.                | SAMP NJ Metal             | Dist from |       | 4000       | Zone       |     | ۰.         |
|                           | THREE L-6  | L-LOS NONE                   |        | 270      | Weld        | FOUR                 | 2-22-E                    | None      |       | 215        | Nell       |     |            |
|                           |  |                              |        | 301      |             |                      |                           |           |       | 241        |            |     |            |
|                           |  |                              |        | 100      |             |                      |                           |           |       | 226-       | - <b>b</b> |     | ŧ          |
|                           |  |                              |        | 276.     |             |                      |                           | - 5%      |       | 250        |            | ;   | ł          |
|                           |  |                              | AVA    | 294      |             |                      |                           |           | ALG   | 236        |            |     |            |
|                           |  | 100                          |        | 377      | 45          |                      |                           | 100       | •     | 286        | HE         |     |            |
|                           |  | .003                         |        | 274      | ,<br>,<br>, | 1<br>1               |                           | 602       |       | 307        |            |     |            |
|                           |  | 1 .005                       | -      | 299      |             |                      |                           | .003      |       | 288        |            |     |            |
|                           |  |                              | AV3.   | * V 0 CV |             |                      |                           |           | Ava   | \$ 394     |            |     |            |
|                           |  | 600                          | • • •  | 1:222    | Brent.      | • <del>•</del>       |                           | 700       |       | 572        | Parent     |     |            |
|                           |  | 5/0                          |        | 000      | - Taby      |                      |                           | 5/2       |       | 272        |            |     | 1          |
|                           |  | .021                         | • ···  | 196      | ÷           | -                    |                           | .024      |       | -          |            |     |            |
|                           |  | ,                            | A43    | 7902     | • •         |                      | -                         |           | AVa   | 268        |            |     |            |
|                           |  |                              |        | ····‡    |             | ++                   |                           |           | •     |            |            |     |            |
|                           |  | 780.                         | +      | 310      |             |                      |                           | 670-      |       | 295        | -          |     |            |
|                           |  | 1 -122                       | 1.<br> | 42.2     |             |                      | +-<br>+-<br>              | 190       |       | 373        |            |     | 1          |
|                           |  |                              |        |          |             |                      | *                         | 101       |       | 323        |            |     | ****       |
|                           |  |                              |        |          |             |                      | -                         |           |       |            |            |     |            |
|                           |  | * These                      |        | values h | Were        | used in              | platt                     | ng E      |       | N-2.       |            |     |            |
|                           |  | HIVER.                       |        | 4        | c avp       | roge yalu            | es a                      | pedia     | dist  | ance       |            |     | Ē          |
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| And a state of the second | 1  | • • • • • • • • •            |        | •        |             |                      | -                         | r r       |       |            |            |     |            |
|                           |  | HE.                          | - Heat | eff.     | cted =      | ZONE IN              | Which                     | Struc     | tural |            |            | FO  | 16         |
|                           |  |                              | 6604   | 1251     | 105         | Reparen              | tIND                      | 250       | retal |            |            | ŕ-2 | 5          |
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|                           |  |                              |        |          | _           |                      |                           |           |       |            |            | 27  | · · ·      |
| *                         |  |                              |        |          | _           |                      |                           |           |       |            |            |     |            |
|                           |  |                              | -      | -        |             |                      |                           |           |       | - <u> </u> |            |     | •<br>•     |
|                           | - Let Mer 141  | an an an Anna M              |        |          | -           |                      |                           | •         |       |            |            |     | T          |
|                           |  | <b></b>                      |        |          |             |                      |                           |           |       |            |            |     |            |
|                           |  |                              |        |          |             |                      |                           |           |       |            |            |     |            |

| Members                            | Knasp Zone                | 244 Weld | 246 | 250 | 229  | 37* | 140 HE              |      | 257  | 1 012 | 266* | Luzier Voc   | 278 120 431 | 266  | 275   |      | 316         | 235  | 3174  |     | 339* | 26/ |   | 2       | ace -    |        | 9        |         |
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|                                    | ₹                         |          |     |     |      | Arg |                     |      |      |       | 6.4  |              |             |      | Ara . | -+-  |             |      | Ave . |     |      | 1-  |   | e IN-2  | distance |        | 6 60 40  |         |
| I.M.II.<br>Welded, 12-7PH Steel, Z | Ditter<br>Weld            | NONE     |     |     | - 94 |     | .003                | 300. | 210  | 610.  |      | 020          | .028        | .053 |       |      | 076         | 6/1  | ,     |     | .153 | C02 |   | Flaure  | edian    | -+     | 1001     |         |
| - <i>III</i><br>4, 12-71           | SAMP, NO. Ment            | HdI-LI   |     |     |      |     |                     |      |      |       |      |              |             | 9    |       | -    |             |      |       |     |      |     | - | 100     | a r      |        | 41.11    | at a la |
| 1 I                                | SA NP. A                  | TWO      |     |     | -8-  |     |                     | +    |      |       | ,    |              |             |      |       |      |             |      |       |     |      |     | - | 240/0   | N        |        | 104 5    | 250     |
| TABLE.<br>Wes on                   | •                         |          |     |     | 4    |     |                     |      |      |       |      |              |             |      |       |      |             |      |       |     |      |     | - | 11 20   | ere.     | 11,60  | hi ula   | q = 77  |
| V.a.                               | P ZONE                    | held.    |     |     |      |     |                     | HE   |      |       | -    | 0            | Metal       |      |       |      |             |      | *     | ~   |      |     | - | e 450   | OHONO.   | 507    | SHEE     | . r     |
| 55au p                             | Kneep<br>No.              | 212      | 202 | 210 | 105. | 196 | $\left\{ -\right\}$ | 238  | 246  | 2 2   | -235 | - <b>-</b> - | 246         | 251  | 248   | 224  | 5<br>7<br>1 | 3294 | 420   | 531 |      |     | - | wer     |          | 10-10  | K        | 2       |
| 101101                             | <b>X</b>                  | •        |     |     | •    | 410 |                     |      |      |       |      |              |             |      |       | 4.10 |             | ~    |       | *   |      |     |   | values  | the c    | 2      | offecter | 20,00   |
| Taldro                             | ter Dist from<br>tel Weld | 32 None  |     |     |      | •   |                     | 100. | 200. | 600   | -0/4 |              | .016        | .039 | 190   | .100 |             | .127 | .241  | 38  |      |     | - | 2       | Whare    | trow   | took.    | 1225    |
| dri worth                          | NO Nº tal                 | 6832     |     |     |      |     |                     |      |      |       |      |              |             | -+   |       |      |             |      | -+    |     |      |     |   | ra<br>L |          | H<br>+ | - 717    | _       |
| CONVAIR-FORT WORTH                 | SAMP                      | DNE      |     |     | 1    |     |                     |      | -    |       |      |              |             |      | -     |      |             |      |       |     |      |     |   |         |          |        |          |         |

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#### MISCELLANEOUS:

Investigations were carried put to determine the tensile properties of two steels of the stainless, precipitation hardening type. These were: AM 350, produced by the Allegheny Ludlum Steel Corporation, and Stainless W, produced by the United States Steel Corporation. The results of these investigations are given below, under Items N and O.

#### ITEM N - EVALUATION STUDY OF AM 350 STEEL

Tensile tests and measurements of changes in dimensions were made on specimens of AM 350 steel, heat treated according to different procedures. The specimens were in the form of sheet 1005" thick.

This work was performed in 1956. The object was to provide data for the preliminary evaluation of the steel with regard to its possible use as an alternate structural material for brazed sandwich panels.

The test results are given in Tables IN-I and IN-II together with the heat treatments employed. In Table, IN-I, three basic heattreating procedures are shown with certain variations for each. The temperature of 1850 F in all three corresponds to a brazing temperature for some filler alloys. Table IN-II shows the effects of three treatments on the tensile properties. Referring to the material in the as-received condition, designated as 0, the tensile properties suggest that the steel had been annealed at about 1600 F. Table IN-II includes figures for the dimensional changes caused by the various treatments, as measured after holding at -100 F and after subsequent aging.

Table IN-I shows that the variation of tensile properties was slight with heat treatments I and III. Likewise, the effect of the holding time at 1750 F was small. (H.T. - III). These two similar treatments gave desirable tensile properties. Heat treatment II gave values for the tensile yield and ultimate strength which were marginal with respect to Convair Specification FZS-4-046.

Figure IN-1 shows a graphical comparison of the tensile yield and ultimate strengths together with the elongations resulting from the various preatments. The values for the type II heat treatment of Table IN-I were omitted in plotting the figure because the strengths were low. In this treatment the aging temperature was 850 F as contrasted with 750 F for types I and III. In Figure IN-1, items 4 and 5 are indicated as averages. Because of the small differences in values as affected by variations in heat

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|        | k                           | 4                  |   |                      |
|        | treatments                  | [ and III. average | es of the average resul   | ts were plotted      |
|        | £                           |                    | showed that the AM 350  |                      |
|        | , mens exhibit              | ted growth after   | treatment through the -   | 100 F step follow-   |
|        | was growth.                 | This may be not    | ed by comparing the figures of Table IN-II. For   | ures in the          |
|        | specimens                   | lated, there were  | two exceptions. Specir  | men 10 did not       |
|        | all average                 | growth for the A   | cimen 11 grew a little<br>1 350 steel was 49% that  | t of 17-7PH          |
|        | steel. This<br>sheet with a | variety of heat    | parison of results for treatments for both ste  | .005" thick -        |
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| · · · | CONVAIR  | PAGE<br>REPORT NO<br>MODEL | 169<br>FGT-2727<br>B-58 |
|-------|--|----------------------------|-------------------------|
|       | DIVISION OF GENERAL DYNAMICS CORPORATION<br>(FORT WORTH)   | DATE                       | 1/19/61                 |
|       |  |                            |                         |
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|       |  |                            |                         |
|       |  |                            |                         |
|       | ITEM D - EVALUATION STUDY OF STAINLESS W STEEL   | ٦                          |                         |
|       | In the spring of 1958 a preliminary investigation w  | es corri                   | ieđ                     |
|       | out on Stainless W steel. Part of the resulting te   | st data                    |                         |
|       | was reported by memorandum. The object of the work determine whether this steel might be used in place   |                            | איז א                   |
| •     | steel for the fabrication of brazed sandwich panels  |                            |                         |
|       | Tensile tests were performed on specimens of Stainl  | ess Wat                    | eel -                   |
|       | sheet after various heat treatments. Three thickne   | SSPA WAT                   | ים י                    |
|       | tested, viz., .005", .008", and .014". All the mat<br>from Heat No. 7X2117. The composition of this heat | erial we                   | 18                      |
|       | by certified analysis supplied by the producer was   | as follo                   | DWS1                    |
|       | C.08%, Mn.79, P025, S.014, Si.64, Ni 6.72, Cr  | 16.82,                     |                         |
|       | T1.72, and Al.20%.   |                            |                         |
|       | The variations in heat treatment for the material t  | ested ar                   | e                       |
|       | given below:   |                            | 1                       |
|       | Simulated Brazing Step: Heated to 1650 F in 3  | 0 minute                   | 38                      |
| ł     | and held 10 minutes.   | •                          | -                       |
|       | Conditioning Step:   | 1<br>12 F                  | 5<br>5                  |
|       | a. Cooled to 1400 F in 60 minutes, held 90   | minutes                    | 3.                      |
| 1     | and cooled to room temperature in 3 hou  |                            | 1                       |
|       | b. Furnace cooled from 1650 F to room temp   | erature                    | in -                    |
|       | 3 hours. {   | j fi                       | ₹<br>■4, 4<br>3<br>2.   |
|       | c. Air cooled from 1650 F to room temperat   | ure in                     | <b>*</b><br>F           |
|       | approximately 30 minutes.  | 1                          |                         |
|       | Transformation or Chill Step:  | 4<br>2                     |                         |
|       |  |                            |                         |
|       | a. OF for 30 minutes   | 1 64<br>1<br>2<br>2        |                         |
|       | d. 20 F for 30 minutes   | 1 2                        | ·                       |
|       | d. 50 F for 30 minutes   | 1                          |                         |
|       |  |                            |                         |
|       | d60 F for 30 minutes   |                            |                         |
|       | e. 100 F for 30 minutes  | 1 12<br>14                 | ∳*`<br>} -              |
|       |  |                            |                         |
|       | Aging Step:  | 1                          |                         |
|       | a. 1900 F for 90 minutes   |                            | рн<br>, Э               |
| 1     |  |                            |                         |
|       |  | 1                          |                         |

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| L L             | UNV   |   |  | 1   | REPORT NO  | FGT-2727   |  |
| AD              | VISION OF GENERAL DYNA  | MICS CORPORATION  |  | 1   | MODEL  | <u>B-58</u>  |  |
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| <u> </u>        | 1   | f   |  | \$<br>1   |  |  | م <b>و</b> يشيون   |
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|                 |   | ł ,   | 1  |   |  |  |  |
|                 |   | 4   | 1  |   |  |  |  |
|                 |   |   | •  | 1   |  |  |  |
|                 | b.  | 950 F for 90 mi   | nute <b>s</b>  | •<br>,  |  |  | ;  |
| n<br>S<br>S     | с.  | 1000 F for 90 m   | inutes   |   | •  | ,  |  |
|                 | d.  | 1050 F for 90 m   | inutes   | •   |  | ,  |  |
|                 | е.  | 1100 F for 90 m   | inutes   |   |  |  |  |
| •               | ·   | 1   |  |   | Ε.   |  | -  |
|                 |   | a heat treatment  | nts used are   | shown in the  | tables   | ÷ .  | -  |
| ,<br>,          | of test data  | • IC ·  | ŧ.   |   | E .  | •  | -  |
| .               | Table IO-I-g  | ives the result   | s of tensile   | tests on .00  | 5 <sup>"</sup> and   | .008"  | -  |
|                 | thick sheet   | with and withou   | t the 1400 F   | step, stabil  | ized at  | three  |  |
|                 |   | mperatures, and   |  |   |  |  |  |
|                 |   | ormation for .0   |  |   |  |  |  |
|                 |   | of tensile test<br>1400 F step, st  |  |   |  |  |  |
|                 | On the whole  | , the transform   | ation tempers  | ature gave no   | Invont   | able   |  |
|                 | pattern of e  | ffects on the t   | ensile proper  | rties. Howey  | er. for  | the  |  |
|                 | .005" sheet   | with the 1400 F   | step, the te   | ensile yield  | and ult  | imate  |  |
|                 | strengths in  | creased noticea   | bly as this t  | temperature w   | as lowe  | red  |  |
|                 | From U to -5  | OF. Also, for ongation decreas  | the .014" sr   | neet, with th   | e Bame   | treat-   |  |
|                 | the use of the  | he 1400 F step  | increased bot  | th strengths  | to some  | anu,<br>extent   |  |
| •               | in nearly al  | 1 instances and   | reduced the  | elongation.   | t .  |  | •  |
| <u> </u> '      |   |   | \$   | -   | 2  | r  | đ  |
|                 |   | s aged at 950"F   |  |   | cooled   | from   |  |
| 14              |   |   |  | Comma 2 - L   |  |  |  |
|                 |   |   |  | nsformed at -   | 20F. A   | s compare  | ed -   |
|                 | with specime  | ns aged at 1050   | F which othe   | erwise had th   | 20F. A<br>eusame   | s compare<br>treat-  | ed.  |
|                 | with specime<br>ment, those   |   | F which othe<br>ad somewhat h  | erwise had th<br>higher tensil  | 20F. A<br>eusame   | s compare<br>treat-  | ed.  |
|                 | with specime<br>ment, those<br>ultimate str   | ns aged at 1050<br>aged at 950 F, hi<br>engths but lower  | F, which othe<br>ad somewhat h<br>r elongation.  | erwise had th<br>higher tensil  | 20 F. Á<br>e same<br>e yield   | s compare<br>treat-<br>and   | ed.  |
| A<br>F          | with specime<br>ment, those<br>ultimate stre<br>Table IO-III  | ns aged at 1050<br>aged at 950 F ha<br>engths but lower<br>gives the result   | F which othe<br>ad somewhat h<br>r elongation.<br>Its of tensil  | erwise had th<br>higher tensil  | 20F. A<br>e same<br>e yield<br>014" sh   | s compare<br>treat-<br>and<br>eet,   | be   |
| <b>ا</b> م<br>: | with specime<br>ment, those<br>ultimate stru-<br>Table IO-III<br>transformed  | ns aged at 1050<br>aged at 950 F, hi<br>engths but lower  | F which othe<br>ad somewhat h<br>r elongation.<br>Its of tensil<br>o temperature   | erwise had th<br>higher tensil<br>te tests on .<br>as and aged a  | 20F. A<br>e same<br>e yield<br>014" sh<br>t 900,   | s compare<br>treat-<br>and<br>eet,<br>1000,  | ed.  |
|                 | with specime<br>ment, those<br>ultimate str<br>Table IO-III<br>transformed<br>and 1100 F.<br>room tempera   | ng aged at 1050<br>aged at 950 F hi<br>engths but lower<br>gives the resul<br>at three subzer<br>All the specime<br>ture before trai  | F which othe<br>ad somewhat h<br>r elongation.<br>Its of tensil<br>o temperature<br>ens were air<br>nsforming. F   | erwise had th<br>ligher tensil<br>te tests on .<br>s and aged a<br>cooled from<br>ligure IO-1 1   | 20F. A<br>e same<br>e yield<br>014" sh<br>t 990,<br>1650 F<br>s a bar  | eet,<br>1000,  | ed. to come and a second second  |
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| EPORT NO. | FOT-2 | 727                |   |
| ODEL      | B-58  | 1                  | _ |
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|           |       |                    |   |

#### CONCLUSIONS: ITEMS N, O

The conclusions drawn from the evaluation studies of the AM 350 and Stainless W steels are given below:

Two similar heat treatments imparted desirable properties to AM 350 steel sheet. For example, this steel conditioned at 1750 F, transformed at -100 F, and aged at 750 F had tensile yield and ultimate strengths comparable to those of 17-7PH steel in the TH 1050 condition.

With corresponding strength, the elongation of AM 350 steel was appreciably higher than that usually found for 17-7PH material in thickness of .005".

The growth of AM 350 steel on heat treatment was about half that of 17-7PH steel.

With suitable heat treatment: Stainless W steel gave satisfactory tensile properties. For equivalent acceptable strength its  $\frac{1}{17}$  elongation tended to be considerably higher than that of  $\frac{17}{17}$ -7PH steel.

For certain heat treatments, Stainless W steel gave acceptable tensile properties with transformation temperatures in the range of 0 to -100 F.

For a given prior treatment, maximum tensile properties were obtained by aging at 900 F. Aging at 1100 F gave low strength.

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) Department 6 EWP 1072-8-5

| . <b>.</b>                            | CONVAIR<br>A DIVISION OF GENERAL DYNAMICS CORPORATION<br>(FORT WORTH)  | PAGE 173<br>REPORT NO_ FQT-2727<br>MODEL B-58<br>DATE 1/19/61 |
|---------------------------------------|--|---|
| ļ                                     | Heat Treat Kes   | pouse of AM 350   |
|                                       | 1. As Reed Mat'l   | Ultimate  |
|                                       | 2 -100°F, 2 hrs  |   |
|                                       | 3100°F, 2hrs + 750°F, 2hrs.  |   |
|                                       | 4. Avg. of H.T. T., Table  |   |
| x                                     | 5. Aug of H.T. III, Table  |   |
|                                       | - 1 <u>2</u> (   |   |
| , , , , , , , , , , , , , , , , , , , | · - 2  | Yield   |
|                                       |  |   |
|                                       | - 4  |   |
| :                                     | 5  |   |
|                                       | , K5.1-  | 80 100 120 : 140 160  |
|                                       | 1  |   |
|                                       |  | Elongation  |
|                                       | 3  |   |
|                                       | 4  |   |
|                                       | 5<br>PERCEN  | 17-16 7 8 9 - 10 11   |
|                                       | TEACEN   |   |
|                                       | LITY REPORT SHEET  | FIGURE TA   |
|                                       | And the second s | Department 6<br>FWP 1072-8-5                                  |

| <u></u> | CONVAIR FORT            | -FORT WORTH    | 0.005 Gage | <u>9</u> e       | TABL             | L.       | H             | ŀ              |                     |                      |                   |            |            |
|---------|-------------------------|----------------|------------|------------------|------------------|----------|---------------|----------------|---------------------|----------------------|-------------------|------------|------------|
| SPEC    | SPEC GRAIN THEIL CHARGE | L L            | 151        | 0 ULT<br>ASI     | 2%               |          | 27661         | GRAIN<br>DIR 1 | 1 - 1               | 1910<br>11ELD<br>151 | 17/ 07/           | 2%         | ,<br>d I a |
| 10%     | Leng                    | 1472           | 162.9      | 9 1925           | 0.8              |          | 252 /         |                | 14+2                | - 1// 4              | 2007              |            |            |
| 11×     |                         |                | 150.5      | † <b>†</b>       |                  |          | $\rightarrow$ |                | ] ]                 | 1643                 |                   | 7 60       |            |
| AVERAGE | -                       |                | 1520       | 7 1925           | 70               |          | 275           |                |                     | 1626                 | <u>}</u> <b>k</b> | <b> </b>   |            |
|         | -                       |                | -          |                  |                  |          |               |                |                     |                      |                   |            |            |
| 121     |                         | 1922           | 16.22      |                  |                  |          | 281           | 7              | 18+2                | 166.6                | 6 2050            |            |            |
| AVERASE | -                       | •              | 1642       | 22250            | 000              |          | 30%           |                | -+-                 | 1649                 |                   |            | ł          |
|         |                         |                |            |                  |                  | <i>V</i> | AVERAGE       | ┿╼┿<br>┥       | <br> <br> <br> <br> | 1550                 | 1-1               | 2 70       | , .        |
|         | 7                       | Heat Yo        | 2.0521 2   | 40 14 15         | 1                |          |               | -              | 6+)                 | 67711                | 6325 67           |            |            |
|         |                         | 103            |            |                  |                  |          | 32 x          |                |                     | 1677                 | <u> </u>          | 10         | ,          |
| H H     |                         |                | :          | 60 m             | 14               |          | 33.1          | ->             |                     | 163                  |                   | <b>L</b> . | 1          |
|         | n<br>                   | -100-1         | 8          | ere a            |                  | 8        | AVERAGE       |                |                     | 165.0                | 1                 |            | <b>.</b>   |
|         | •                       | 1200027        | r 750 F    | 4                | 415              |          | 702           | - `            | - r<br>1<br>C       |                      |                   | _          |            |
| SPEC    | GRAIN                   |                | VIELD      | D 117            |                  |          | 35,           | ¥<br> <br>     | 272                 | 10/1                 | 0707 0            |            | 1          |
| Ъ       | DIR                     | $H\mathcal{I}$ | -<br>-<br> | £                | 20               |          | 361           |                |                     |                      | · .               | 101        |            |
|         |                         |                |            | 1                | L                | '1<br>   |               |                |                     | 152                  | ħ                 |            |            |
| 141     | -6407                   | 1/4            | 1970       | 177.             | 1                |          |               |                |                     |                      |                   |            | :<br>• •   |
| 21×     |                         |                | 1001       | 1                | 200              |          |               |                |                     |                      |                   |            |            |
| AUFRAGE |                         |                | 1430       | 1.80             | $\left  \right $ |          |               | 1              | Heat to             | 200321               | 1.1.1             |            |            |
|         |                         |                |            |                  |                  |          |               | 7              |                     | 105010               | Ìt.               | 20-11      |            |
| 22X     |                         | 16             | 1542       | 183              | \$ 5.8           |          |               | 9              | ;                   |                      | *                 |            |            |
| 234     |                         | -+             | -}         |                  | Y                |          | HT-TH         |                | :                   |                      |                   | 40 M I     |            |
| 111     |                         |                | 157.2      | + 1/2            | ;]               | -        |               | 2              | 11                  | -                    | ٤                 | 120 20     | ag         |
| AVERAGE | 6                       |                | 155        | 5 120.3          | 1                |          |               | - 7            | 2000                | 5                    | Lrs &             |            | я          |
|         |                         |                |            |                  |                  |          |               | N              |                     | N                    | 8                 | 2 hes      | 174<br>FG4 |
|         | ×                       | H=a+ +a        | 1850%      | h= 14 /          | in in            |          |               | +              | -                   |                      | -                 |            | -2         |
|         |                         | + /0           | 1350 %     | 10 90            | 1_               | •        |               |                |                     | -                    |                   |            | 72'        |
| HTH     | H<br>H                  | 6/2/           | 2          | Pimi 06          | - Cool R         | RT<br>Z  |               |                |                     |                      |                   |            | 7          |
|         |                         | a. Temper (    | per @ 250  | 2 250 F Sr Lhour | LAUR             |          |               |                |                     |                      |                   |            |            |
| ]       |                         | 1001-1         | STANT      | 2000 1001 1      | 1 2 1            | -        | •             |                |                     | -                    |                   |            |            |

| <i>trauth</i>          | 477                                  | 2022     | 0200   | 0031   | 2030  | 0500  | 22   | 26       |          |        |      |         |   |       |       |         | ALMA   | ו<br> : | 'a[]<br>*     | ;e<br>: | 175<br>PGT | -27              | 27      | 1     |
|------------------------|--------------------------------------|----------|--------|--------|-------|-------|------|----------|----------|--------|------|---------|---|-------|-------|---------|--------|---------|---------------|---------|------------|------------------|---------|-------|
| EXC                    |                                      | +-+-     | 44-4   |        |       | 4-4   | 90   | 20010    | +        |        |      | 15 1111 |   | 2 2 2 | 11 90 | ta 2    | 30     | 20      | 0             | 07-     | 2 4 5      | ט<br>1<br>2<br>2 | 4       |       |
| ~ ~                    | 2 0                                  | 101      |        | 12 + 0 |       | 17    |      | +11      |          |        |      | -4      |   | 6     |       | V       | heh    | =       | •             |         |            | -4               | 1       | 5     |
|                        | 11/11                                | 1024     | 100.   | 0032   | 0032  | 0200  | 0030 | 0500     |          |        |      | 505-    | PT in                                   |       | 5/3   | 2 min,  | 1750F  | :       | •             | 2       | OF.        | - 100-           |         | 7 4 6 |
| Misc.                  | 7 <del>1</del> 1<br>1 <del>1</del> 1 | +-1      | 1875   | 10+0   | 1atC  | 13+C  | 11   | 210      |          |        | mat  | 18      | 2                                       | +     | 7     | he 12 9 | led to |         | •             | :       | 70 - 1     |                  | 9       |       |
| 1                      |                                      |          |        |        |       |       | +    | <b>-</b> | <b>-</b> | -apo-  | 20,9 | ed 70   | pel co                                  | = 1   | Q     | min, bu | 000    | :       | : :           | •       | 1 2 2      | 4                | 1 - U - | 1 T   |
| Steel.                 |                                      | <u>k</u> |        |        |       |       |      |          |          | 207    | 2    | Hatca   | U<br>V                                  |       | 9 FEC | 8       | AFO    |         | י י<br>על     |         | [pa]       | 2000             | aud     | R     |
|                        | Alla<br>Alla                         |          |        | •      |       |       |      |          |          | R      | 0    | - /     |   |       |       |         |        |         | :             |         | ij         | י<br>2           |         |       |
|                        | 010                                  | Ma       | 5      | gr     | 00    | 01    | 1:   | -        |          | 1      |      |         |   |       |       |         |        |         | -             |         | ۲.         |                  |         |       |
| ~                      |                                      |          |        |        |       |       |      |          |          |        |      |         | }<br>  <br>  <br>                       |       |       |         |        |         | ₹ <u></u><br> |         | T<br>      |                  |         |       |
|                        | ) (<br>)                             | 120      |        | 20     | 202   | 6.4   | 25   | 15,4     | 9        | M      | -    |         | -  F                                    |       |       |         |        | -       |               |         | 54         |                  |         |       |
| 7.12.L                 | 1                                    |          |        | ++     |       | 556   | 0    |          |          |        |      | +       | -                                       |       |       |         |        | _       |               | 2       | 2          |                  |         |       |
|                        | 177                                  | 171      | 527    | 6/     | 196.  | 132   | 000  | 200      | 200      | 2007   |      |         | 1                                       |       |       | 0110    | 191    |         |               | 24      | 12         |                  |         |       |
| Eage<br>Sage           | 72.9                                 | 72.6     | .113   | 1174   | 111.6 |       | 1705 | 126.8    | 122.2    | 1100   |      |         | -                                       |       | mai   | han     | 1001-  | 1       |               |         | 505        |                  |         |       |
| 2005                   |                                      |          | i<br>i |        |       | ┞╌╌╀┈ | -    | -        |          |        |      | ++      |   |       | recd  | recid   | - c/   |         | 1001          | 205 -   | 6          |                  |         |       |
| E E                    |                                      |          | •      |        |       |       |      | •        |          |        | +    |         |   |       |       |         | palo   | 445     |               |         | 000        | +                |         | +-+   |
| PORT WORTH             | 1                                    |          |        |        |       |       |      | }        | -        |        | ++-  | ┥┥      |   |       | 28-62 | 5H-     | 000    |         | 2H - 0        | 2       | 0          |                  |         |       |
|                        | Lono.                                |          |        | <br>   |       |       | -    | 1<br>7   | -        |        |      |         | H.T. 1                                  |       | 9     |         |        |         | 2             |         |            |                  |         |       |
| CONVAIR –<br>TABULATIO |                                      |          | *      | ┢┼     |       |       |      | 1        |          | €<br>⊈ | ┥┥╸  | ┼╍┠     | - u - u - u - u - u - u - u - u - u - u |       |       | +       |        | +       | ·<br>         |         | 4          |                  |         |       |
| CON<br>TAB<br>TAB      | 2                                    | 86       | AVG    | m      | 4 N   | AVG   |      | Ñ.       | 9        | 511 F  |      |         |   |       |       |         |        |         |               |         | 1          |                  |         |       |

176 PAGE ... N 0 FGT-2727 R REPORT NO. ſ B-58 1/19/61 MODE GENERAL DYNAMICS CORPORATION DATE (FORT WORTH) Effect of Chill & Ade Town on CON Goac Stainless W 5.1% 900 E Ayc 22%c Å ٦ 1.3%.C 10005 Age -20E Chill 12%C 11.1%C 1100FAge 13.5%C L. . 2005 Aye L ł 1.0% C 9.0%c 42%e -60F IDCOF AGE ł Chill 1 8,8%0 11.8%-C 1100F Ane -12.5% C YOOF\_Age 8.3%C i i 9.0 %ee L ł 1 4 5.0%e • 1 1000E Age -100F Chill \$7%e ۱ 1. 18%0 1100F Age 13.7% e. 140 160 1803 200 ULT - K.S.I. 1 **4** 7 FIGURES ΖO Department 6 FWP 1072-8-54 UTILITY REPORT SHEET ĥ ، بو . \* 5

Luge 178 FGT 2727 RI 50 4 5 50 90 0 M 3 7 5.5 8 V 05 40 U Ň 9 1923 199.2 1375 222 2104 1002 2023 2005 2227 205.9 5 761 215 1221 14002 TABULATION SHEET 0,000 & 0014 Gage, Stainless M, Tensiles -- Heat: 1X2117 2002 194.0 1302 1334 GAGY VIELD 191.0 1955 1997 1912 1903 192.7 1931 7777 1650For -20°F 950 F 0.005 2.00.2 2014 HVG2112 AVG. AVG. : \* 2 STEP TEWR TEMP trow 1 12 : 20/000 650 • ŝ τ (  $N_{O}$ . t Thiskelow 0 ĩ • 27.12 201000 ۲ ۲ ; , 5 . 7.8.4 KU C C C 20: N CEL 0.10/2 10.5 25 25 20 0 3 60 12.0 50 45 25 45 05 20 S 20 4 7 0 6.0 Ø 02 5.7 % 190.6 1928 1-13.5 191.2 1723 1328 1920 AVG-1824 1941 192.0 1893 . 179.0 1713 1234 1946 1963 193.7 accumens. 1341 1723 1313 194.7 1550 ULT KSI 123.1 1226 1341 1741 DECIMENS 1723 1777 1243 122.51 1779 3 100 - 5. YIELD 7261 1843 203 1730 123 1790 179.7 1725 179.0 1243 1012 しょう 176.1 1.0 K.51 1231 Ų GAGE 40 0.014 426 AVG. AVG. エンら The 411 ب آ لا -7. TEMP 10505 . H 1 a id \$ 13700 4 . . ---, SPACIMENS ITED CHILL 7.05-R be lang itudinal -٢ - -\$ vection -20'F 1.0 1 MACH ç i, 2 15 050 51 - I WONLL -9K- ----- All and Annual State ž. , z , ž No Yes Ser Yes 00 01 No Grain • 

| IIIK     Temp     FF.I.GF.2     K       Trans     200F     1731     2032     55       Tans     2014     25     2703     57       Tans     1935     2103     57       Vic     1734     2114     55       Tans     1935     2103     57       Vic     1735     2103     57       Vic     1914     2033     20       Vic     17914     2105     57       Lang     17914     2105     57       Lang     1757     1794     2105       Lang     1757     1794     2105       Lang     1757     1779     1757       Lang     1755     1751     115       Lang     1755     1751     115       Lang     1755     1751     115       Lang     1256     1521     157       Lang     1255     1575     157       Lang     1255     1555     1555  |       | 524 6411           |               | <u> -104</u> | 10 -104 - Ch | $\frac{1}{7}$        |          |
|--|-------|--------------------|---------------|--------------|--------------|----------------------|----------|
| 9005 1731 2032 5<br>1744 2114 5<br>1744 2103 5<br>1935 2116 7<br>1935 2116 7<br>1935 2116 7<br>1914 205 7<br>1914 205 7<br>1914 205 7<br>1914 205 7<br>1914 205 7<br>1914 205 7<br>1914 205 7<br>1914 205 7<br>1914 205 7<br>1914 205 7<br>1914 205 7<br>1914 205 7<br>1914 205 7<br>1914 205 7<br>1914 205 7<br>1917 7<br>1925 153 7<br>100F 1256 1537 12<br>1100F 1256 1537 12<br>1255 153 12<br>1255 153 12<br>1375 12<br>1375 153 12<br>1375 12<br>1375 153 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12<br>1375 12   |       | -KS1 5-K21 80      | <u>v</u>      | 5-451        | 154-7        | 0.<br>V              |          |
| 1844     2114     5       1001     135     2112     5       10005     1914     2165     5       11006     1813     1914     2165       11006     1813     1914     2165       11006     1813     1914     2165       11006     1813     1914     2165       11006     1813     1914     2165       11006     1813     1914     2165       11255     1716     17       1256     1531     11       1255     1521     11       1255     1521     11       1256     1551     12       1255     1551     12       1255     1551     12       1255     1551       1255     1551       1255     1551       1255     1551       1255     1551       1255     1552       1255     1552       1255     1552       1255     1552       1255     1552       1255     1552       1255     1552       1255     1552       1255     1552       1255     1552       1255     1552 </td <td></td> <td>6 0516 7961</td> <td><i>c</i>,</td> <td>13.61</td> <td>2210</td> <td></td> <td></td>  |       | 6 0516 7961        | <i>c</i> ,    | 13.61        | 2210         |                      |          |
|  |       | 2145               |               | 6251         | 2716         | 10                   |          |
|  |       | 210.3              | 0             | 1261         | 15           | 000                  |          |
| 1000F 1925 2126 7<br>1935 2116 7<br>1925 2016 7<br>1914 2106 7<br>1914 2106 7<br>1914 2106 7<br>1914 2106 7<br>1914 2106 7<br>1914 2106 7<br>1757 1537 8<br>1755 1537 8<br>1755 1537 8<br>1755 1537 15<br>1100F 1566 1557 15<br>1266 1556 1537 15<br>1265 1555 15<br>1266 1555 15<br>1266 15<br>1265 15<br>1265 15<br>1265 15<br>1275 15<br>1265 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>1275 15<br>127   | -     | 57 -12.3 "         | . 05          | N            | 2155         |                      |          |
| 1000F 1914 2016 7<br>1909F 1914 2066 7<br>1914 206 2033 9<br>1914 206 7<br>1757 1537 4<br>1755 1711 2<br>1755 1711 2<br>1755 1711 2<br>1453 1716 11<br>1455 1716 11<br>1455 1716 11<br>1455 1537 12<br>1455 1537 12<br>1455 1537 12<br>1100F 1266 1537 12<br>1455 1537 12<br>1265 1537 13<br>1268 13<br>1268 13<br>1275 1537 13<br>1275 1537 13<br>1275 1537 13<br>1275 1537 13<br>1275 1537 13<br>1275 1537 13<br>1275 1537 13<br>1275 1537 13<br>1275 1537 13<br>1275 1537 13<br>1275 1537 13<br>1275 1537 13<br>1275 1537 13<br>1275 1537 13<br>1275 1537 13<br>1275 1537 13<br>1375 1537 13<br>1375 1537 13<br>1375 1537 13<br>1375 1537 13<br>1375 1537 13<br>1375 1537 13<br>1375 1537 13<br>1375 1537 13<br>1375 1537 13<br>1375 1537 13<br>1375 1537 13<br>1375 1537 13<br>1375 1537 13<br>1375 1537 13<br>1375 1537 13<br>1375 1375 13<br>1375 1375 13<br>1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 13<br>1375 1375 1375 13<br>1375 1375 1375 1375 1375 1375 1375 1375   |       | 6000               | ()<br>()      |              |              |                      |          |
| 1000F 1819 1994 4<br>1000F 1819 1994 4<br>1200F 1819 1994 4<br>1252 1831 2<br>1255 1831 2<br>1255 1831 2<br>1255 1831 2<br>1255 1831 2<br>1255 1831 2<br>1255 1831 1<br>1255 1831 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1   |       |                    |               |              | 1.277        | 1010                 |          |
| 1914 2106 1914 4<br>1000 1819 1944 4<br>1000 1819 1944 4<br>1224 1925 4<br>1251 1251 121 1<br>1252 1251 1<br>1100 11256 1231 2<br>1255 1251 1<br>1100 1256 1251 1<br>1100 1256 1257 1<br>1100 1256 1257 1<br>1255 1537 1<br>1100 1256 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1537 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>125   |       | 2000               | 2.0           | 1256         | 2000         | 00                   |          |
| 1000F 1819 1819 1894 4<br>1000F 1819 1894 4<br>1757 1831 2<br>1757 1831 2<br>1755 181 2<br>1755 181 2<br>1955 181 2<br>1955 181 2<br>1000F 1956 1831 2<br>1955 181 2<br>1100F 1855 1837 1<br>1436 1837 1<br>1100F 1855 1837 1<br>1256 1837 1<br>1256 1837 1<br>1256 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1255 1837 1<br>1   |       | 2 206.2            | 0             |              | 2057         | 00                   |          |
| 10001<br>12011<br>1224 1925<br>1252 1924<br>1299 1831<br>1299 1831<br>1299 1831<br>1299 1831<br>1299 1831<br>1299 1831<br>1299 1831<br>1299 1831<br>1200<br>1255 1531<br>1200<br>1255 1537<br>12<br>12<br>12<br>12<br>12<br>12<br>12<br>12<br>12<br>12   |       |                    |               |              |              |                      |          |
| 1252 1524 132.7 4<br>1254 132.7 4<br>1255 1531 2<br>1255 1531 2<br>1255 1531 2<br>1255 1531 1<br>1100F 1256 1551 1<br>1455 1551 1<br>1455 1551 1<br>1455 1551 1<br>1455 1551 1<br>1455 1551 1<br>1455 1551 1<br>1455 1551 1<br>1100F 1<br>1255 1551 1<br>1255 1551 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1<br>1255 1 |       |                    | 0             | 1831         | 196.3        | 60                   |          |
| 17524 1928 2<br>1757 1224 1928 2<br>1757 1237 2<br>1755 1716 11<br>100F 1256 1521 1<br>1455 1716 11<br>1455 1716 11<br>1455 1716 11<br>1455 1716 11<br>1455 1716 11<br>1255 1537 12<br>1100F 1256 1537 12<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1537 13<br>1255 1557 1557 1557 1557 1557 1557 1557   | •     | 19                 | 5             | 1230         | 1930         | 4.0.4                |          |
| 1757 1537 7<br>1757 1537 2<br>1757 1537 2<br>1755 1711 2<br>1453 1716 11<br>1455 1521 12<br>1455 1521 12<br>1455 1521 12<br>1455 1527 12<br>1455 1527 12<br>1100F 1266 1537 12<br>1255 1577 11<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1257 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1255 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 1577 12<br>1257 12<br>1257 1577 12<br>1257  |       | 12201925 6         | 0             | 1.221        | 1975         | 50                   |          |
| 1757     1757     1751     1751     2       1757     1757     1631     2       1757     1757     1631     2       1757     1755     1716     1       1755     1716     1     1       1755     1716     1       1755     1716     1       1755     1716     1       1755     1716     1       1755     1716     1       1755     1716     1       1755     1716     1       1755     1716     1       1755     1557     1       1755     1557     1       1755     1557     1       1755     1557     1       1755     1557     1       1755     1557     1   | *     | with a set and the | Same marine & | 7.2.7        | 197.9        | 20                   |          |
| 1     1 <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>  |       |                    |               |              |              |                      |          |
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| <pre></pre>  |       | 1221 12            | 30            | 172.7        | 1221         | 00                   |          |
| <ul> <li>x 1100F</li> <li>x 1100F</li> <li>x 1255</li> <li>x 1256</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1255</li> <li>x 1</li></ul>   |       |                    | 25            | 172.5        |              | 07                   |          |
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### C O N V A I R A DIVISION OF GENERAL DYNAMICS CORPORATION

(FORT WORTH)

| PAGE  | 180      |
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|       | FGT-2727 |
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#### SECTION II

#### CORROSION AND OXIDATION:

Several investigations relating to the corrosion or exidation of brazed sandwich panels in 17-7PH stainless steel have been carried out. Two reports (FTDM-2270 and FTDM-2355) on oxidation have been published. Abstracts of these are given in the Bibliography. The unpublished results of investigations in this general field have been reported either by memorandator verbally. Summaries of these are presented here.

#### ITEM A -- IDENTIFICATION OF CORROSION PRODUCT ON PANELS BRAZED WITH SILVER-MANGANESE ALLOY

Some time after 17-7PH steel panels brazed with the 85:15 silver-manganese alloy had been placed in service on the B-58 airplane, routine inspection revealed isolated localities in the panels where corrosion had occurred. These localities were subject to failure during flash testing at 600 - .650 F.\*

An investigation was made early in 1957 with the object of identifying the corrosion products in the panels. This comprized metallographic examination and the use of X-ray, methods. As a result, regions of high manganese; were found on the steel surfaces,

Figure IIA-1 shows a dark etching constituent at the core alloy and steel-alloy interfaces. The constituent was identified as manganese or a manganese compound by X-ray fluorescence. This technique also showed that the manganese indication on the exterior side of the manel skin was much lower than that on the brazed side. The significance of this is emphasized by the fact that all the brazing alloy was dissolved off the skin specimen before the X-ray fluorescence run. Conjointly, the metallographic and X-ray fluorescence examination showed that manganese from the brazing alloy had diffused into the steel during brazing.

X-ray diffraction patterns obtained from the corrosion product found in the panels indicated the presence of Ag, MngO4, and Cr203.

#### \*See Supplemental Sheet - S-1

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UTILITY REPORT SHEET

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| ITEM D -<br>A memorar<br>backgrour<br>panels br<br>of metall<br>panels fr<br>The 85:15<br>on its re<br>steel par   | METALLOGRA<br>IN SILVER-<br>ndum issued<br>nd of the c<br>razed with<br>lographic e:<br>rom B-58 ai:<br>5 silver-man   | MANCANESE BRA<br>in April 195<br>revice corros<br>the 85:15 sil<br>xamination of   | 22ED PANELS F<br>9 gave a sum<br>ion problem<br>ver-manganes<br>86 specimen  | VICE CORROSION<br>ROM A/P #4.<br>mary concernin<br>in 17-7PH stee<br>e alloy. The<br>s representing   | g the<br>l<br>results  |
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|  | humidity<br>brazing a<br>The ster<br>the silve<br>brazed w<br>service.<br>object of<br>ability<br>graphic<br>panels t<br>in accor<br>five show<br>were four<br>no evide<br>classifie<br>Attention<br>tion of<br>though c<br>corrosion<br>can cause<br>the oppo | humidity. All the<br>brazing alloy from<br>The sterling silver<br>the silver-manganes<br>brazed with the lat<br>service. A metallo<br>object of providing<br>ability of these pa<br>graphic examination<br>panels taken from a<br>in accordance with<br>five showed definit<br>were found with les<br>no evidence. Five<br>classified.<br>Attention is invite<br>tion of a small sam<br>though corrosion is<br>corrosion may occur<br>can cause failure of<br>the opposite skin. | humidity. All the failures occubrazing alloy from the steel at<br>The sterling silver 0.2% lithium<br>the silver-manganese composition<br>brazed with the latter alloy bef<br>service. A metallographic test<br>object of providing additional in<br>ability of these panels, together<br>graphic examination was made of<br>panels taken from airplane #4.<br>in accordance with the degree of<br>five showed definite indications<br>were found with less evidence of<br>no evidence. Five specimens had<br>classified.<br>Attention is invited to the fact<br>though corrosion is not found.<br>corrosion may occur can not be p<br>can cause failure on one skin of<br>the opposite skin.<br>1<br>*See Supplemental Sheet S-I. | humidity. All the failures occurred by sepa<br>brazing alloy from the steel at the interfac<br>The sterling silver 0.2% lithium alloy was a<br>the silver-manganese composition. However,<br>brazed with the latter alloy before the chan<br>service. A metallographic test program was<br>object of providing additional information a<br>ability of these panels together with flash<br>graphic examination was made of plug specime<br>panels taken from airplane #4. Each specime<br>in accordance with the degree of corrosion.<br>five showed definite indications of crevice down<br>were found with less evidence of crevice corr<br>no evidence. Five specimens had no fillet,<br>classified.<br>Attention is invited to the fact that the me<br>tion of a small sample does not insure that a<br>though corrosion is not found. Also, the loc<br>corrosion may occur can not be predicted. Cr<br>can cause failure on one skin of a panel and<br>the opposite skin. | Attention is invited to the fact that the metallographic entition of a small sample does not insure that a panel is good though corrosion is not found. Also, the location of where corrosion may occur can not be predicted. Crevice corrosion can cause failure on one skin of a panel and not be present the opposite skin. |

| •<br>•<br>• | CONVAIR<br>A DIVISION OF GENERAL DYNAMICS CORPORATION<br>(FORT WORTH)   |   | PAGE 184<br>REPORT NO. FGT-272<br>MODEL B-58<br>DATE 1/19/61 |
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| · · ·       | ITEM E - <u>OXIDATION OF SILVER</u><br><u>AT ELEVATED TEMPER</u><br>In the summer of 1958, oxida<br>copper-lithium alloy in braz<br>after the parts had been exp<br>550 F. The presence of cupp<br>diffraction patterns of fill | TURES<br>tion of fillets of th<br>ed 17-7PH steel panel<br>osed in air at temper<br>ic oxide was determin | e standard silver.<br>s was observed<br>atures above         |
|             | In 1959, specimens cut from<br>in air for different times u<br>compression and shear beam   | p to 300 hours at 700<br>ests were performed o  | F.E Edge<br>n these specimens.                               |

These tests showed that, given adequate fillets, the oxidation does not significantly decrease the strength for exposures up to 300 hours at 700 F. The results of this investigation have been published (Reference FTDM-2355).

Metallographic examination was made of fillets oxidized in air for various times at temperatures up to 800 F after aging in air for 90 minutes at 1050 F. This examination indicated that the extent of oxidation increased with both time and temperature of exposure., Also, porgsity in the fillet caused the depth of attack to be uneven in many specimens.

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Figure IfE-1, is a photomicrograph of a sample which had been exposed for 100 hours in air at 700 F after aging.

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|                                       | ITEM F - CONCLUSIONS FOR ITEMS A, B, C, D, E  |   |
|                                       |   |   |
|                                       | The conclusions drawn from the investigations oxidation of brazed sandwich panels are given                               |   |
|                                       | The 85:15 silver-manganese alloy is not suital  | ole for brazing   |
|                                       | 17-7PH steel panels. Crevice corrosion occurs   |   |
|                                       | alloy-steel interface and causes separation.  | The corrosion   |
|                                       | product is a mixture of manganese oxide, Mn <sub>3</sub> O <sub>2</sub>   | i, and chromium   |
|                                       | oxide, Cn <sub>2</sub> O <sub>3</sub> . On test, 17-7PH steel panels bi<br>alloy were found to fail in less than 50 hours | in standard salt  |
|                                       | spray. Failures also occurred on exposure of  |   |
|                                       | air atmospheres of high humidity.   |   |
|                                       | Metallographic examination of numerous specime  | ens removed from  |
|                                       | 17-7PH steel panels brazed with the 85:15 silv  | ver-manganese   |
|                                       | alloy has disclosed the presence of crevice co  |   |
|                                       | tent ranged from slight to severe. Metallogra   |   |
|                                       | does not insure that a panel is free from corn<br>no evidence is found. The location of where of                          | corrosion may   |
|                                       | occur can not be predicted.   |   |
|                                       |   |   |
|                                       | The sterling silver 0.2% lithium alloy was add<br>in place of the silver-manganese alloy, Braze                           |   |
|                                       | former alloy have not been deserved to develop  | crevice corrosion.  |
|                                       | However, they undergo oxidation in air at temp  | peraturés abóve 👘 👘   |
|                                       | 550 F. Tests have shown that the oxidation do   |   |
|                                       | impair the strength in edge compression or she<br>after exposures in air at 700 F up to 300 hour                          |   |
| 1                                     | FTDM-2355).   |   |
|                                       |   |   |
|                                       | On the basis of tests, sandwich panels brazed copper-lithium alloy incorporated in iron spor                              | with the silver-  |
|                                       | factory resistance to salt apray and to elevat  | ed temperature  |
|                                       | in air (Reference FTDM-2270).   |   |
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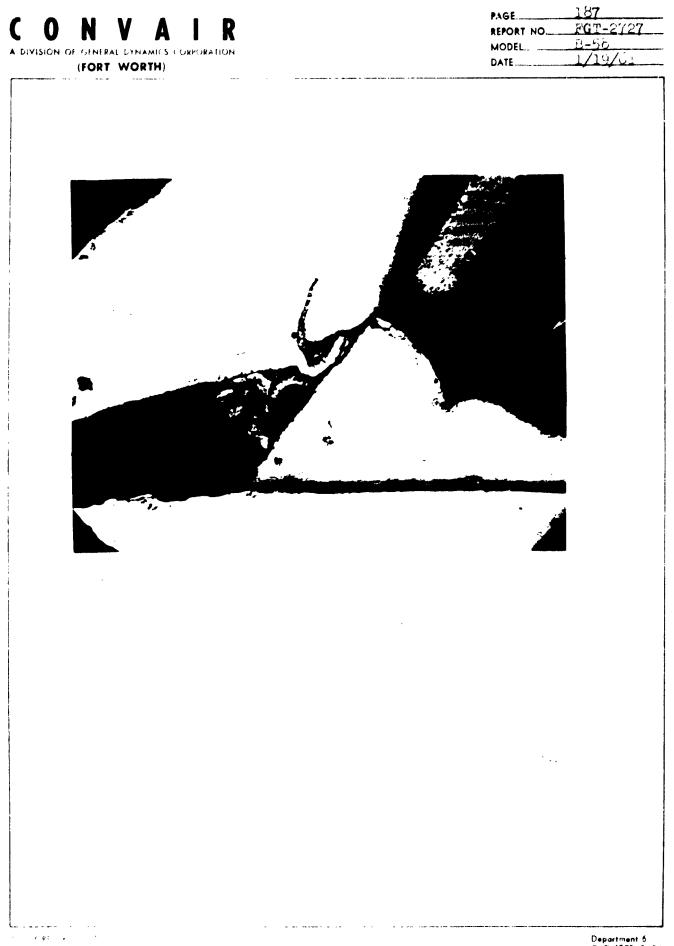
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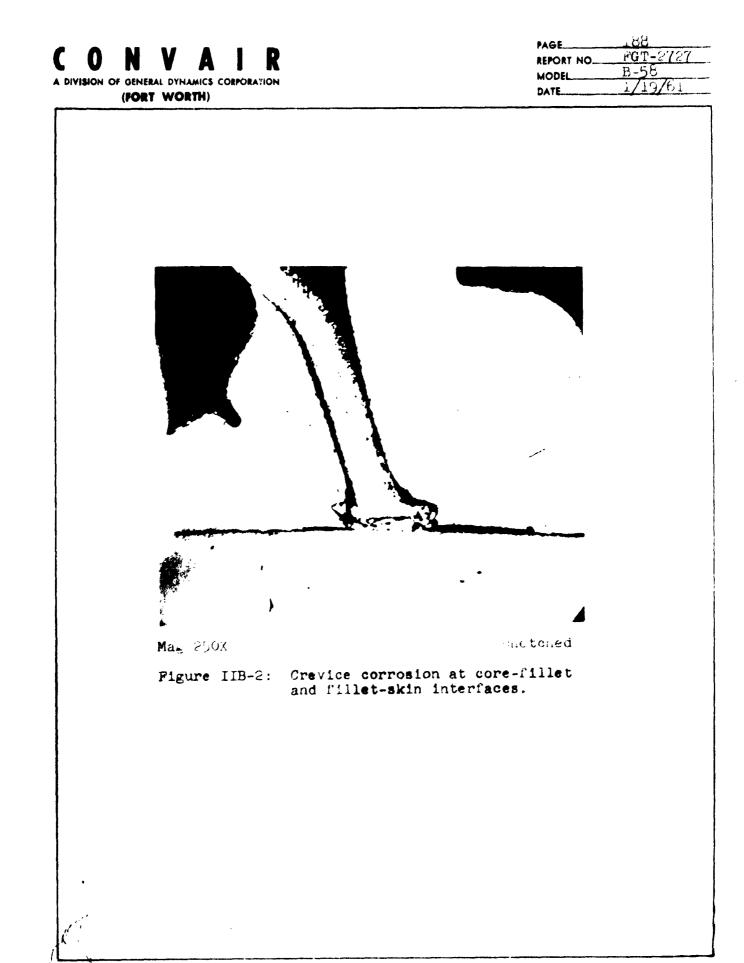
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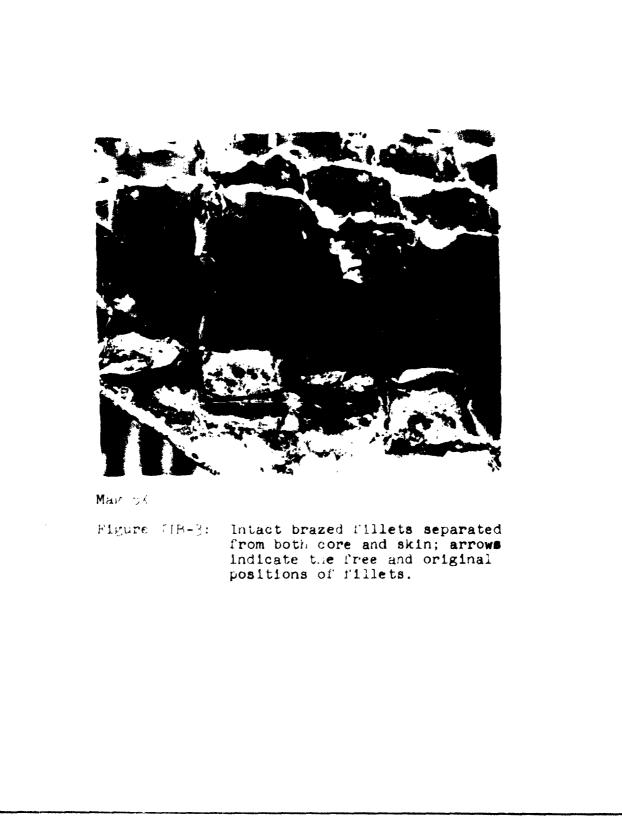
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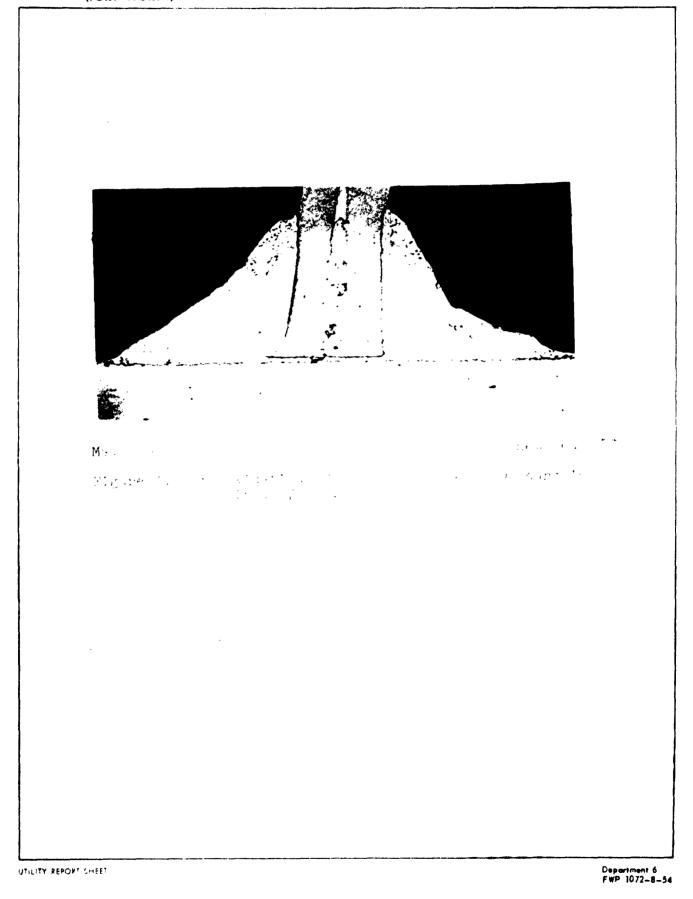
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#### BRAZING ALLOYS:

A number of investigations on the evaluation of alloys for brazing 17-7PH steel sandwich panels has been carried out. Most of the results have been published in a spries of reports. These are listed in the Bibliography (references FGT-1153, MR 54-5, FGT-1363, FGT-1362-1, FGT-2088, FTDM-2270, and FTDM-2355).

The results of several other studies on brazing alloys have not been published but have been reported in memoranda or otherwise. Summaries of these are given here.

#### ITEM G - EVALUATION OF SILVER-COPPER-LITHIUM ALLOY: »

In the Spring of 1957, the fact was recognized that the 85:15 silver-manganese alloy was unsuitable for use in brazing 17-7PH steel sandwich panels because of its poor resistance to corrosion. Preliminary tests were made with a silver-copper alloy (sterling silver) containing a small amount of lithium. The results were promising. The Engineering Metallurgical Laboratory was then asked to conduct an investigation for the purpose of evaluating silver-copper-lithium brazing alloys. Tests were carried out to determine the following: Resistance to salt spray, effect of lithium content, strength of lap-shear joints, and optimum brazing temperature. Also, general metallographic examination of brazements was made. The results of this work are presented here.

The nominal composition of sterling silver is 92.5:7.5 silvercopper. Brazing and other tests were performed with this alloy to which 0.1, 0.2, and 0.5% lithium had been added. Brazements of 17-7PH steel with these three compositions were satisfactory and had similar characteristics. The alloy containing 0.2% lithium was recommended in place of the 85:15 silver-manganese alloy for use in brazing production panels. The sterling silver composition containing 0.2% lithium seemed a little more likely to give consistent wetting than the 0.1% alloy. A content of 0.5% lithium appeared to be unnecessarily high.

Figures IIG 1 and IIG-2 are photomicrographs at fillets made by brazing 17-7PH steel with the sterling silver 0.2% lithium alloy. The first shows an as-brazel joint, and the second shows a joint after exposure of 69 hours to salt spray. As may be noted, there is no evidence of corrosion by the salt spray. By contrast, similar joints brazed with the 85:15 silver-manganese alloy fell apart after 50 hours exposure.

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A few experiments were made on the use of borax as a flux with sterling silver as the trazing alloy. This combination wet 17-7PH steel poorly and formed uneven fillets. Figure IIG-3 is a photograph of a core-to-skin joint in this steel brazed with sterling silver fluxed with borax.

Figure IIG-4 shows double lab-shear strengths of brazements as affected by temperature. For the test specimens, 17-7PH steel sheet stock was brazed with three different alloys. These were sterling silver plus 0.5% lithium, fluxed with borax; 85:15 silver-manganese alloy fluxed with borax; and 85:15 silver-manganese alloy plus 0.5% lithium. The sterling silver base alloy had higher shear strength at room temperature than the other two. However, it had lower strength than the silver-manganese compositions at temperatures in the range of about 300 to 900 F.

Tests were made to determine whether copper in the sterling silver 0.2% lithium alloy would diffuse into 17-7PH steel at the recommended brazing temperature. Figure IIG-5 may be noted in this connection. It is a photomicrograph which shows an area of a Tee joint in 17-7PH steel brazed with the sterling silver alloy. Knoop hardness determinations were made in the joint area. These values were converted to Rockwell numbers. The hardness in the steel sections of the Tee was 38.3 RC. It was 47.5 Bp in the brazing alloy not close to a steel interface, and near an interface it was 65.5 Rp. In the steel close to an interface with the brazing alloy, the hardness was 43.7 RC. This showed a small increase over the value 38.3 RC. No definite evidence indicated that copper had diffused from the brazing alloy into the sceel. The converted hardness values are given at the right of Figure IIG-5.

Figure IIG-6 shows the microstructure of the sterling silver 0.2% lithium alloy as brazed in a small panel. This structure is the result of slow cooling where the silver-rich phases freezefirst followed by dopper-rich phases, with the latter surrounding the silver areas

Voids can be formed by the shrinkage of the brazing alloy on freezing.1 An example of shrinkage cavities is shown in Figure IIG-7. The relatively long solidification range of the alloyr contributes to the mottled appearance shown in Figure IIG-8. Work on the 85:15 silver-manganese alloy showed that lithium additions are the major cause of these voids when slow cooling rates are encountered. The amount of contamination present inside the panel backage apparently influences the degree of the mottled condition.

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| ،<br>به<br>به در ا |             |                | HOP  | T SHE | ET ;        | · .           |             |            |            |             |      |            |     | •.  |     |     |        | 7.         |            | • , | •••••••••••••••••••••••••••••••••••••• |       |        |                 |         | а<br>Э.          |            | De              | partm<br>VP 10 | nit A     |

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| A DIVISION OF GENERAL DYNAMICS CORPORATION<br>(FORT WORTH)   |   | MODEL <u>B-58</u><br>DATE <u>1/19/61</u>  |
|  | TEMPERATURE OF NICKEL SPO   | ONGE ALLOY.   |
| The material referred to<br>position developed by th<br>excessive brazing alloy<br>17-7PH steel during braz<br>contained approximately   | as nickel sponge alloy is<br>a landy and Harman Corpora<br>flow in curved sandwich pa<br>ing. A composition suppli<br>506 nickel sponge and 50%<br>Other ratios may be pre  | s a special com-<br>ation to reduce<br>anels in<br>ied for test<br>sterling                             |
| for brazing 17-7PH steel<br>sandwich panel 1/2" x 3"<br>was brazed in a stainles<br>retort was used to maint<br>top and bottom skins of<br>couples were spaced at 2<br>panel. By leaving the f | b determine the optimum te<br>with the nickel sponge ma<br>x 12" was used for this r<br>steel retort without fir<br>ain an even temperature be<br>the panel during brazing.<br>" Intervals along the long<br>irrace door partly open, a<br>to F was obtained along the<br>( | aterial. A<br>purpose. It<br>xtures. The<br>etween the<br>Six thermo-<br>g axis of the<br>a temperature |
| obtained below 1700 F, w<br>to produce small top fil<br>fillets obtained, the bp<br>1725 to 1775 F. Figure<br>brazing at 1725 F. Figu<br>nickel in a joint brazed                              | i panel showed that poor h<br>hile temperatures above 18<br>lets. Based on the size of<br>timum brazing, range appear<br>IIH-I shows top fillets for<br>re IIH-2 shows the distrib<br>at the same temperature.<br>S formed. The effect of r<br>teel is given in Section 1   | 800 F seemed<br>of the top<br>red to be<br>ormed on<br>bution of<br>A continuous                        |
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|            | A DIVI!    | ON OF GENERAL DYNAMICS CORPORATION | 1  | MODEL        | <u>B-58</u>   |
| •          |            | (FORT WORTH)                       |  | DATE         | 1/19/61   |
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|            |            | THE T ODUTNIN DDATTN               |  | ATTOVS       |   |
|            | · ·        | TTEM I - OFTIMUM BRAZING           | TEMPERATURES OF TRI-METAL                                  | ADDOID       |   |
|            | · ·        | The co-colled tri-metal            | brazing alloys consist of a                                | 0 00000      | ailwan  |
|            |            |                                    | between layers of the stan                                 |              |   |
| - * * [    |            |                                    | by. Perhaps, tri-layer is                                  |              | 14 14 14 14 14 14 14 14 14 14 14 14 14 1  |
| }          |            | enpropriate term. The              | ri-metal brazing materials                                 | were d       | evised  |
| •          |            | with the object of decre           | asing alloy flow in contou                                 | red nen      | ola   |
| 5 <b>•</b> |            |                                    |  | ica pan      | c.o.  |
| · ·        | <u>н.</u>  | About mid-1958, tests w            | ere made on three tri-metal                                | allova       | th deter-   |
| · · · [    | l .        | mine their minimum braz            | ing temperatures. The spec                                 | ific de      | signa-  |
|            | 1 ·        | tions of the allovs tes            | ed were 1-3-1, 1-4-1, and                                  | 1-6-1        | These   |
| 1          | Ι.         |                                    | e relative thicknesses of                                  |              |   |
| 1          |            | layers in each foil sand           |  |              | · ·   |
| Į          | l · .      | .p                                 |  | 4            | 4   |
|            | · interior | order to determine t               | e prazing temperatures, the                                | rëe pan      | els "   |
|            |            | 1/2 X 12" were bri                 | ze <b>¢</b> , each with one of the                         | tri-meta     | al  |
|            | l          | materials. The tempera             | ure was varied over the pai                                | nel len      | gth 👘 📜   |
|            |            | by leaving the furnace (           | loor partly open, as descri                                | bed in       | Item H.   |
|            | 1          | • > 1                              |  |              |   |
|            |            |                                    | brazing with the 1-3-1 for                                 | TT MOON      | and the second se |
|            |            |                                    | 'illets were formed at 1650                                |              | еве   |
|            |            | increased in size with;            | increasing temperature to 1                                | 690 F.       |   |
|            | ĺ          | Temperatures above 1690            | F produced no apparent chan                                | nge in a     | size.   |
|            |            | The minimum suitable bra           | zing temperature was 1680 ]                                | Fy i         |   |
| · ]        | ĺ          |                                    |  |              |   |
|            |            | The temperature range in           | brazing with the 1-4-1 for                                 | il was i     | from  |
|            |            | 1590 to 1800 F. Figure             | II-I-I and II-I-2 are pho-                                 | tograph      | 5   |
|            |            | or the panel. Figure 1.            | -II shows the top skin af                                  | cer 10,1     | was .   |
|            | 1          | peeled from the core.              | s can be seen from this pho                                | otograpi     | n, ?  |
|            |            | the flifets formed at 1            | 00 F and above retained pie                                |              | -   |
| · ·        | Í          | core. The minimum suits            | ble brazing temperature was                                | a, TLOOP 1   | tan an an an an an an an an an an an an a   |
|            |            | F                                  | brazing with; the 1-6-1 for                                |              | Cara di la  |
| · · · ·    |            | 1640 to 1850 F Good                | lists wore obtained at 176                                 | Le Was, I    | highen (  |
|            |            | The minimum suitable br            | llets were obtained at 1760<br>zing temperature was 1760 1 |              | TTTRICT .   |
|            | ĺ          | The manifestion paragraph of       |  | . <b>n</b> j | F.  |
| 4          |            | 1                                  |  |              |   |
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|            |  |   |
|            | ITEM J - <u>METALLOGRAPHIC EVA</u><br>ON SPONGE-TYPE BRA   | LUATION OF ENVIRONMENTAL CONDITIONS   |
|            | A metallographic study was                                 | made during the first half of 1959 of   |
|            | A commercial brazing alloy                                 | ed with various so-called sponge alloys.<br>called T-50 was included. The T-50                                  |
| •          | alloy is basically 72:28 si<br>plus 5% nickel. It was of   | lver-copper (the eutectic of the system)  |
|            | to oxidation at elevated te                                | mperatures.   |
|            | The sponge-type alloys were<br>flow in contoured sandwich  | developed to control brazing-alloy<br>panels. Such alloys consist of a  |
| • •        | sponge or skeleton of metal                                | having a melting point above the<br>sed. This sponge is impregnated with  |
|            | the actual brazing alloy.                                  | The opinion has been expressed that   |
|            | ing alloy to low regions of                                | nge inhibits gravity flow of the braz-<br>the sandwich-panel package during<br>stainless steel, and cobalt have |
|            | been tested as sponge metal                                | s impregnated with the sterling   |
|            | silver 0.2% lithium brazing<br>sponge metal ranged from 25 | alloy. Variations in the amount of to 50% by weight.  |
|            | For the investigation summa                                | rized here, small Tee sections in 17-7PH  |
| •          | Manufacturing Research & De                                | various sponge-alloy materials by the velopment Dept. Environmental tests                                       |
|            | Metallurgical Laboratories.                                | ons were conducted by the Engineering<br>The environmental testing comprised                                    |
|            | exposure for 50 hours to sa<br>of 700 or 1000 F for variou | It spray and also in air at temperatures  |
| · ·        | Figures IIJ-1, IIJ-2, and I                                | IJ-3 show the microstructures of the  |
| ÷          | 50:50 nickel, iron, and 430                                | stainless steel sponges, respectively,<br>They exhibit differing fibrous  |
| <u>'</u> ! | structures. The fibers are<br>to the required thickness.   | developed by deformation on rolling   |
| 1.11       |  | ostructure of a joint in 17-7PH   |
| • :        | steel brazed at 1725 F with                                | 25:75 nickel sponge. The nickel<br>teel sections may be noted. The  |
| ' ;        | dispersed particles in the                                 | prazing alloy (light) are nickel from   |
|            | 1675, 1700, 1725, and 1750                                 | examination of joints brazed at<br>showed that the depth of the diffusion                                       |
|            | increased appreciably with                                 | ligher temperature. The diffusion of  |
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nickel in 17-7PH steel impairs the response to heat treatment and measurably reduces the strength. Joints brazed with the nickel sponge compositions had good resistance to salt spray but were susceptible to oxidation at elevated temperatures.

Iron-sponge brazements were found to etch in air, that is, they were quickly attacked by the moisture present in air. Figure IIJ-5 shows a joint in 17-7PH steel, brazed with 40:60 iron sponge, after 50 hours in salt spray. The corrosion along the iron of the alloy-depleted sponge, between the fillet above and the skin below, is marked. Figure IIJ-6 illustrates the appearance of a joint after oxidation in air at 700 F for 100 hours. The advance of the iron oxide formed is indicated by the unsound borders at the right and left of the photomicrograph. These unsound areas are darker in coloration than the unoxidized brazing alloy. Brazements made with iron sponge are unsatisfactory as concerns resistance to both salt spray and oxidation. Data on the edge compression and shear strengths of specimens from a sandwich panel brazed with iron sponge and exposed to the conditions just mentioned are given in FTDM-2270.

Joints brazed with 50:50 430 stainless steel sponge were outstandingly good as compared with those brazed with the other sponge compositions. The former exhibited neither corrosion nor diffusion, but they did not resist oxidation at elevated temperatures. However, brazements made with the other sponge materials or with sterling silver 0.2% lithium alloy are also subject to oxidation at elevated temperatures.

Figure IIJ-7 shows the structure at a Tee joint in 17-7PH steel as brazed with 50:50 430 stainless steel sponge. Figure IIJ-8 shows the structure after 50 hours in palt spray. The small fillets may be noted. These are more or less typical of the fillets observed when sponge compositions are used for brazing. Since the sterling silver 0.2% lithium alloy is oxidized in air at elevated temperatures, fillet size is important in relation to the service life of a brazed panel. In the use of stainless steel sponge, fillet size might be increased by several means. These include varying the sponge metal-brazing alloy ratio, varying the size of the sponge fibers or particles, and utilizing the optimum brazing temperature.

Joints in 17-7PH steel brazed with 50:50 cobalt sponge had good resistance to salt spray. Slight diffusion of cobalt in the steel was apparent.; The oxidation of the brazed fillet in

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198 PAGE\_ FGT-2727 0 R N REPORT NO. **B-58** A DIVISION OF GENERAL DYNAMICS CORPORATION 1/19/61 DATE (FORT WORTH) air at 700 F was evidently accelerated by the presence of cobalt. As to this, comparison may be made of the photomicrographs of Figures IIJ-9 and IIJ-10. The former shows the extent of oxidation at a honeycomb core-skin joint of a panel after exposure in air for 300 hours at 700 F. This joint was backed with the sterling silver 0,2% lithium alloy. The latter photomicrograph shows the oxidation at a Tee joint after the same exposure. This joint was brazed with 40:60 cobalt sponge. Joints brazed with the T-50 alloy appeared to be about equal to those brazed with the sterling silver 0.2% lithium allow as concerns susceptibility to oxidation at elevated temperatures. Nickel diffused from the alloy into 17-7PH steel to an appreciable. extent on brazing. Ċ ſ Ē Ē ŝ ε e f Ł 1 Ľ ٦ Ē E 2 y ٢ UTILITY REPORT SHEET Department 6

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### ITEM K - CONCLUSIONS FOR ITEMS G, H, I, J

The conclusions drawn from the studies on brazing alloys are given below.

Tests carried out to evaluate silver-copper-lithium alloys for brazing 17-7PH steel showed that satisfactory results could be obtained with several compositions. The alloy consisting of sterling silver plus 0.2% lithium was recommended for replacing the 85:15 silver-manganese alloy. The former has since been used as the standard for brazing sandwich panels in production.

Brazements in the sterling silver 0.2% lithium alloy exhibit good resistance to corrosion in salt spray and have moderate strength in lap shear at temperatures up to about 600 F. Tests indicated that copper does not diffuse from this alloy into 17-7FH steel at the recommended brazing temperature. This temperature was determined as 1650 F. This alloy apparently has a tendency to form shrink cavities under the slow cooling conditions of brazing.

For bonding 17-7PH steel with a nickel-sponge alloy, the optimum brazing range was determined by test to be 1725 to 1775 F. This alloy contained about 50% nickel sponge and 50% sterling silver plus 0.2% lithium.

The minimum temperatures suitable for brazing 17-7PH steel with three tri-metal alloys were determined. These alloys were made up as foll with pure silver as the center layer and sterling silver plus 0.2% lithium as two outer layers. In the composite foil, the relative thicknesses of the layers corresponded to 1-3-1, 1-4-1, and 1-6-1. Tests with small 17-7PH steel panels indicated that suitable brazing temperatures were 1680, 1700, and 1760 F, respectively.

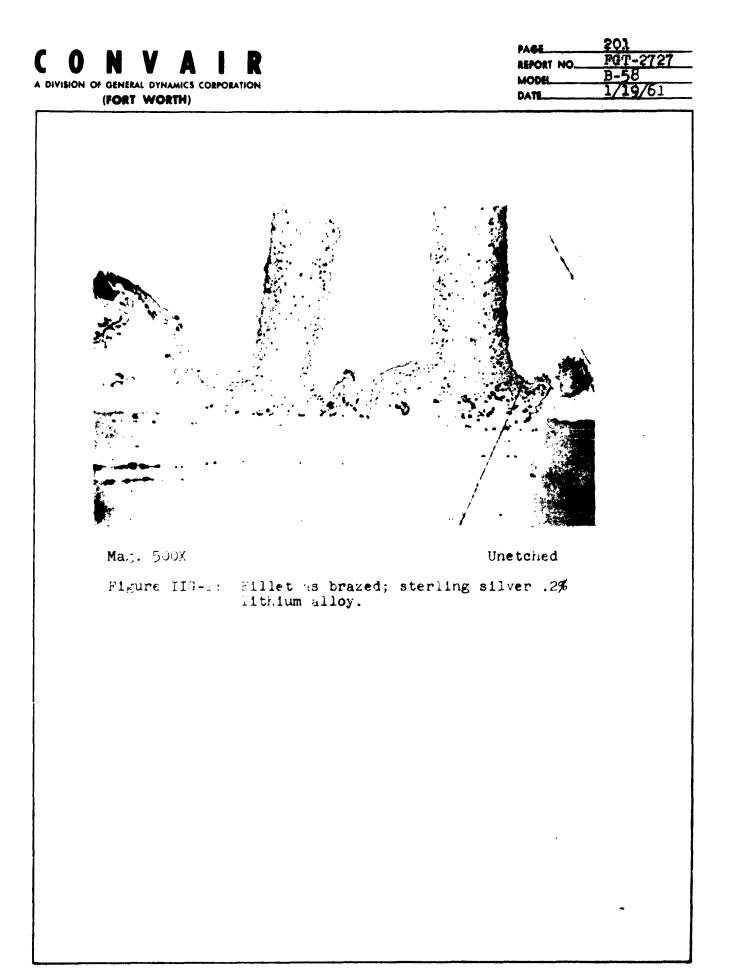
Metallographic study of joints in 17-7PH steel brazed with various sponge alloys showed the effects of certain environmental conditions. The sponge metals were nickel, iron, 430 stainless steel, and cobalt. These were impregnated with sterling silver 0.2% lithium. The amount of sponge metal in the composites ranged from 25 to 50%. The environmental conditions were exposure for 50 hours to salt spray and also in air at 700 or 1000 F for various periods of time.

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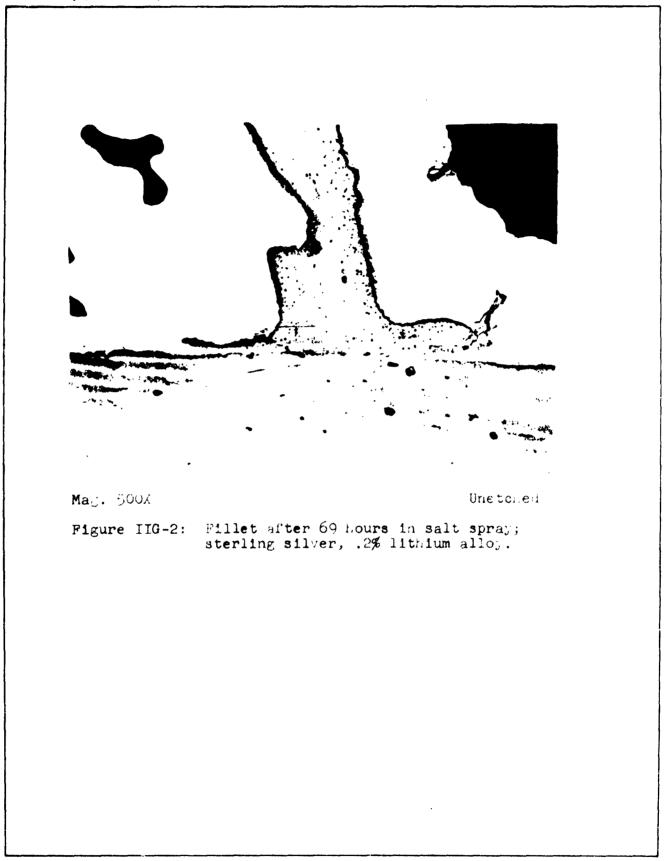
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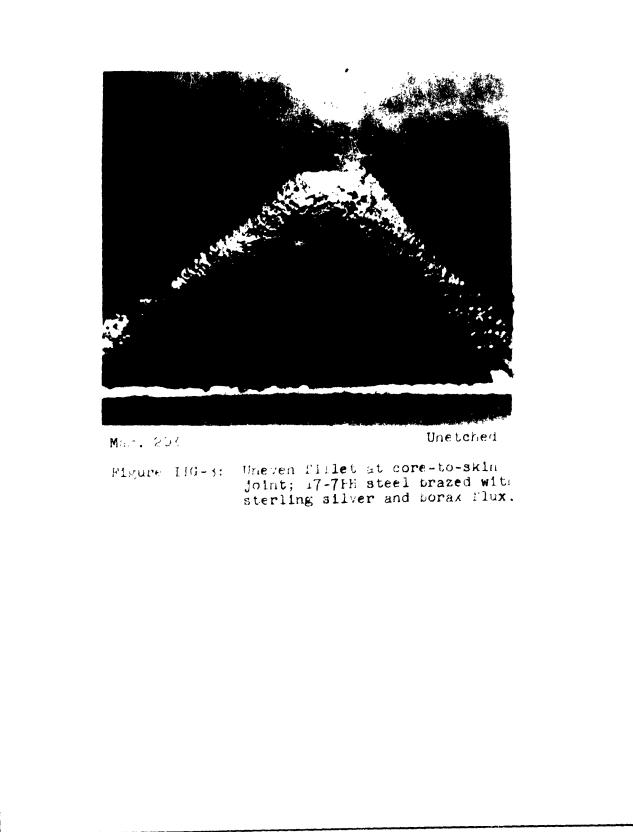
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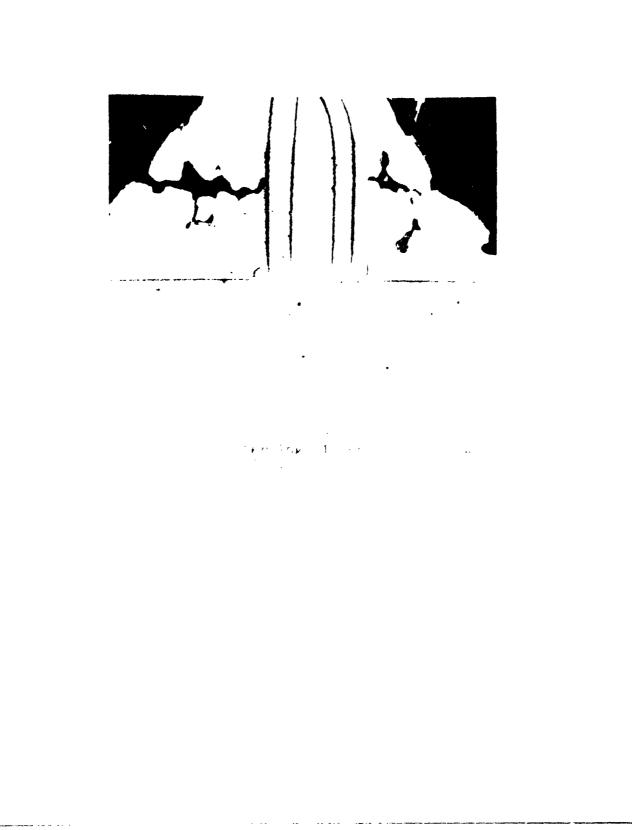
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Figure IlG-6: Structure of sterling silver .2% lithium alloy, as brazed.

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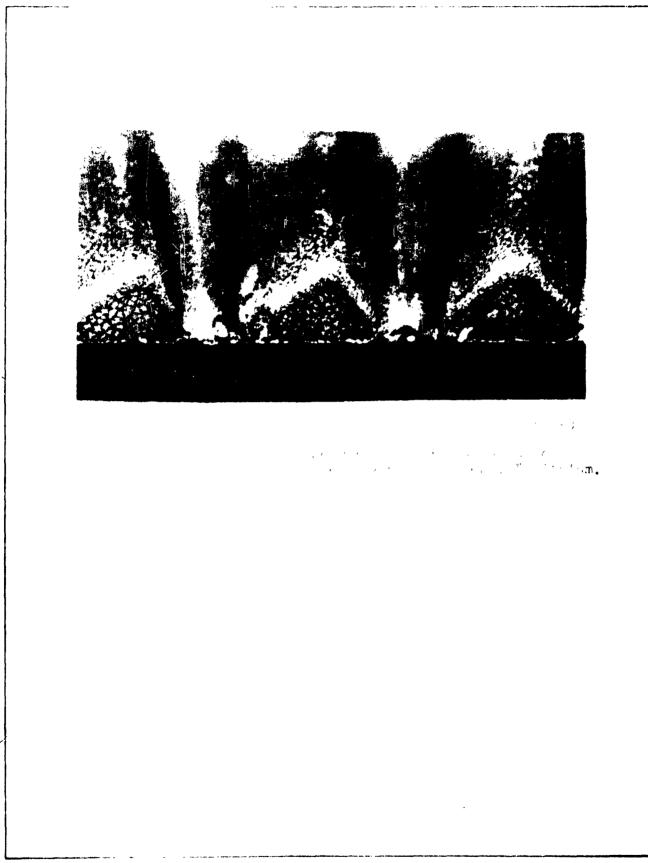
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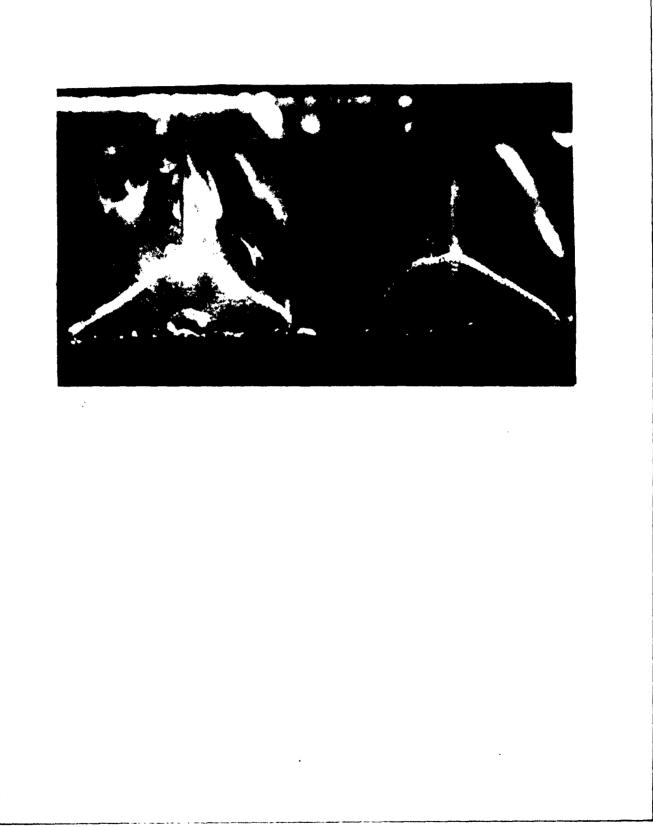


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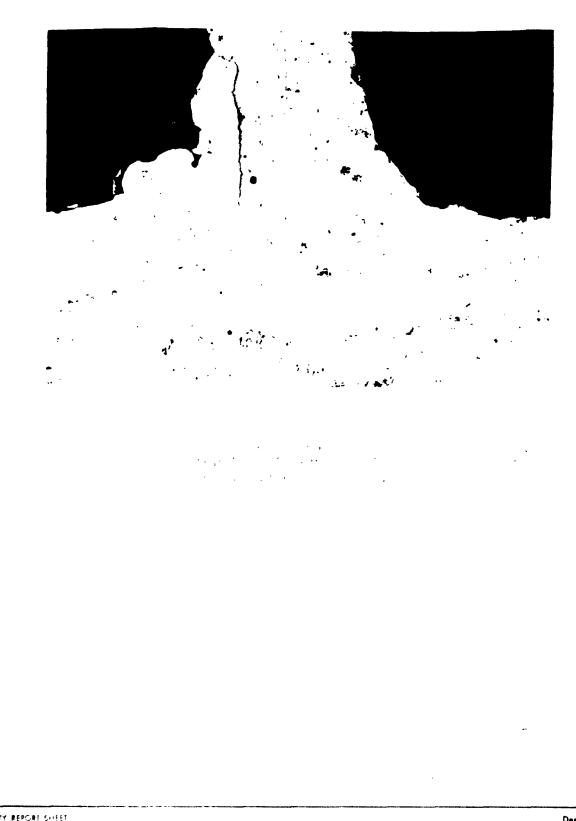
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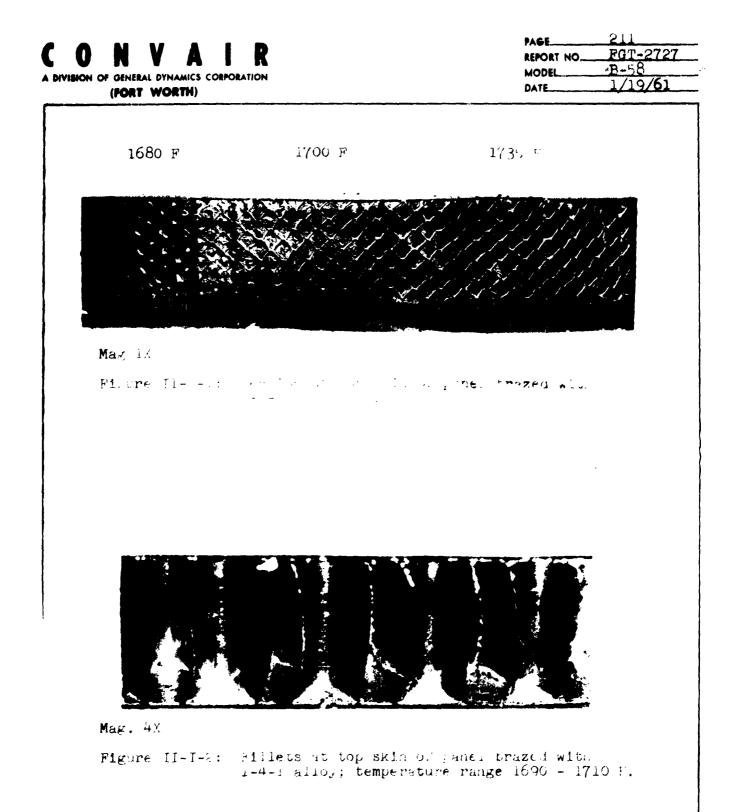


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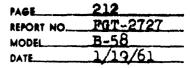


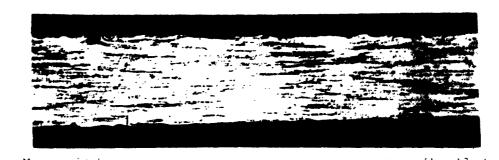
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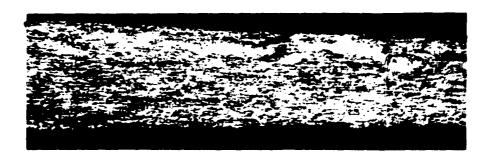






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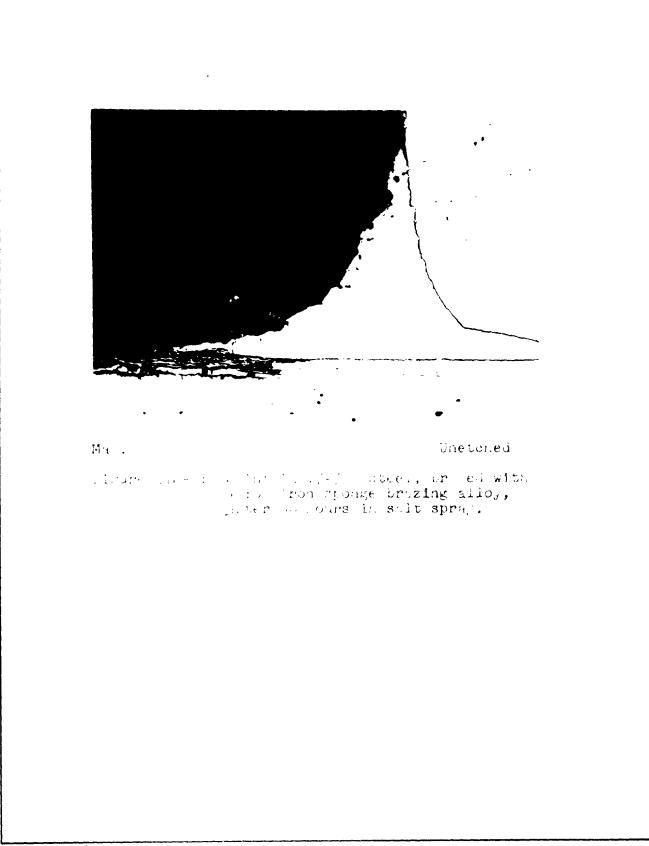
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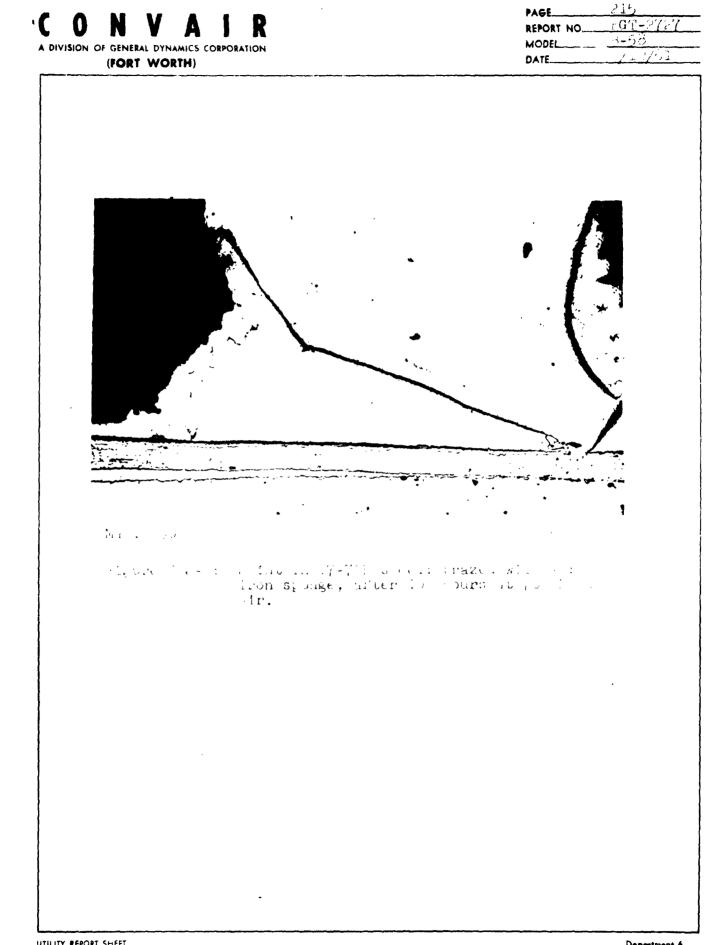
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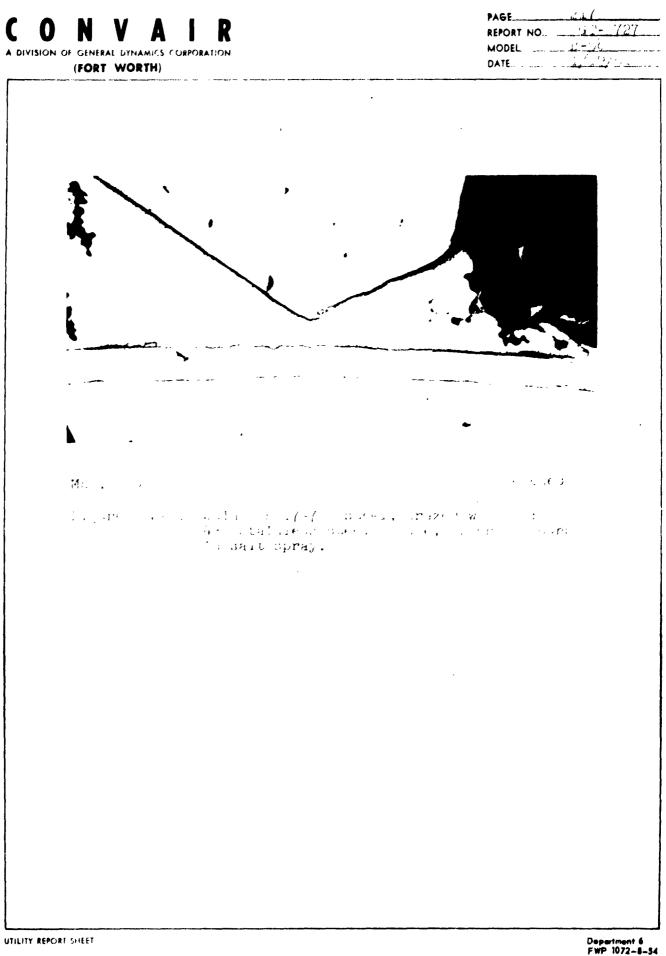
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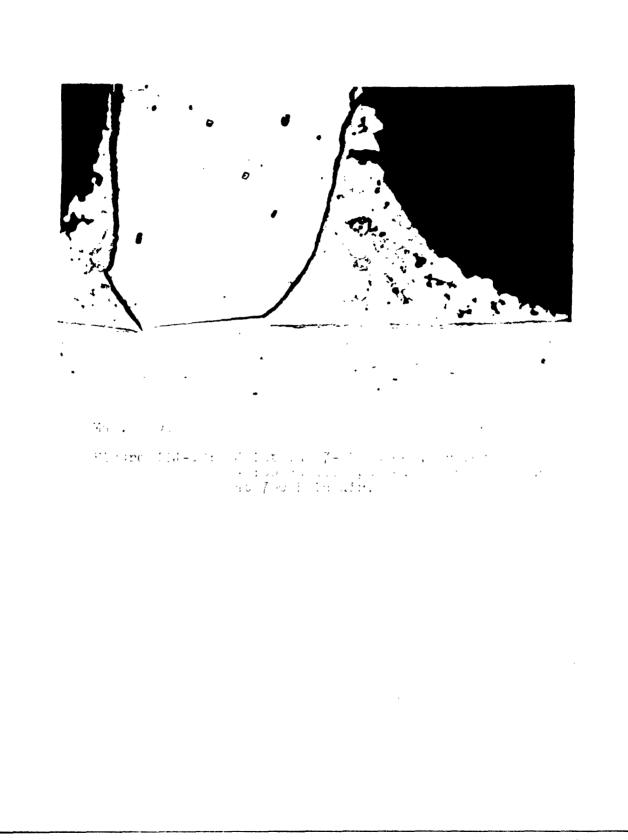
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### BRAZING ALLOY FLOW:

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Several investigations were carried out, mostly in 1958, on the flow of liquid brazing alloys during the operation of brazing, but the results were not published. Memoranda were issued on three of the investigations. Summaries of all are given here.

One method advocated to control brazing alloy flow consists in plating one or both surfaces of the components to be joined. Another is to plate the brazing foil. If 17-7PH steel were plated with silver and brazed with the sterling silver 0.2% lithium alloy, additional silver would be made available to the brasing alloy. Thus, its meiting point would be raised and its rate or extent of flow reduced: However, tests have shown that this expedient is largely useless except for occreasing node flow in thick core sections of sandwich panels.

In one published report (reference FGT-2510) a description is given of the sandwich type test for measuring brazing alloy flow under controlled conditions. This gives reproducible values.

## ITEM L - EDGE-MEMBER VOIDS:

Increasing numbers of vold areas were observed in the edge-member joints of brazed sandwich panels after the adoption of the sterling silver 0.2% lithium alloy.

Prior to the investigation summarized here, the MR&D Department carried out a study on the effect of joint gap or spacing on the occurrence of voids in brazements. Subsequantly, the Metallurgical Section, ETL investigated the effect of nickel plating the brazing surfaces of edge members. The results of this latter work are summarized in Item M of this section. In the present Item L, general observations concerning the causes of edge-member voids are given together with photographs of typical void areas.

Voids have been ascribed to a variety of causes including badly mating parts or wide joint gaps, low brazing temperatures, foreign included matter, gas evolution, oxide films or oxidized areas on the brazing surfaces, alloy shrinkage of freezing, and stop-off. Of these, there seems little doubt but that wide gaps and oxidized brazing surfaces are the most important. In passing, note may be made that inadequate flow of the brazing alloy is closely related to oxidized surfaces which cause poor wettability and to low brazing temperatures.

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FOT-272 REPORT NO. **D-58** A DIVISION OF GENERAL DYNAMICS CORPORATION MODEL 1/19/61 (FORT WORTH) DATE. Ø Figure IIL-1 is a radiograph of panel 5N6255C. This panel was rejected because of edge-member voids and lack of vertical ties. The light areas at the top and left indicate voids which are typical of those observed in the joints of edge members. The spacing, clearance, or gap between the detail parts in sandwich panels to be brazed demends upon the dimensional quality of the parts and upon the quality maintained in the components of the fixtures. The fixtures transmit contact pressure to the panel details during brazing. Figure IIL-2 is a radiograph showing the size of void areas in brazed joints of definite spacing. The light areas are void and the dark are brazed. Obviously, the percentage of void area increases with increasing joint spacing. Additional information on this subject is available in MR&D Brazing Memorandum No. 18, dated August 7, 1957. In brazing, some foreign matter is likely to be present in a joint. The foreign substances may be solids or gases. Successful proce-dures for brazing sandwich panels are duite complicated, and the presence, of foreign matter in the joints can be troublesome. How-ever, foreign solids and gases evidently have little effect on the over-all quality of the joints provided that proper brazing procedures are followed. Foreign substances in brazes joints may be classified as follows: (a)i Oxide and other non-metallic films on the Burface of the parts to be brazed: (b)<sup>3</sup> Non-metallic inclusions in the brazing alloy; • 1 (0); Gases dissolved in, or mechanically held by, the brazing alloy. Figures IIL-3 to IIL-6 are photographs at low magnification showing interior locations at brazel joints of edge members after the panel skin had been peeled off. The joints were brazed in 17-7PH steel, using the sterling sliver 0.2% lithium alloy. All show 7 discontinuities, that is, while or inclusions or both.

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Samples for the tensile tests were prepared from thin sheet material of 17-7FH speel in nominal thicknesses of .005", .008", and .010". Nickel electroplates designated as flash, .0001", .0002"; and .0005" thick were applied to the tensile specimens. After plating, they were subjected to a typical production brazing cycle. Two unplated , .0002"; and .0005" samples were included for each thickness of nickel plate.

were tested to determine the effect of nickel plating the 17-7PH

The tensile yield and ultimate strength together with the elongation were determined for the various specimens. For brevity, the actual tensile data are not included here. Figure IIM-1 shows the decrease \* in strength plotted against the thickness of nickel plate. The unplated nominal thickness was used in calculating the tensile Figure IIM-1, indicates decreases in tensile strength strength. in the three thickness of sheet as the initial diffusion of nickel lowers the strength of the 17-7PH steel. The loss in strength is greatest in the thinnest material. As is apparent, the strength of the three materials increases as the thickness of the nickel plate becomés appreciable.

The double lap-shear specimens were prepared to obtain some measuro of the braze strength when nickel plate was present on the brazing surface of the steel. Nickel was applied by both dipping and electroplating. Nickel plate applied by dipping is referred to as electroless. Specimens, with plates in both electro and electro-less nickel, were prepared as flash, .0001", .0002", and .0005" thick.

The plated lap-shear specimens were tested at room temperature, 400, 600, 800, and 900 F. For previty, the actual shear test data are omitted here. Figure IIM-2 shows the shear strength plotted against temperature for the flash and .0001" thicknesses in both electro-plated and electroless hickel. The figure shows that considerably higher values were obtained by electroplating than by dipping. 승 A DIVISION OF GENERAL DYNAMICS CORPORATION (FORT 'WORTH)

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For either method of application, the effect of the plate thickness was seemingly unimportant. The shear-strength values obtained in these tests are within the range usually given by specimens brazed with the sterling silver 0.3% lithium alloy.

Ten test sandwich panels in 17-7PH steel were brazed to evaluate the effect of nickel plating and other treatments on the quality of joints. These panels were 1/2" x 6" x 6" with Z edge members. The brazing operation was conditioned more or less to simulate production practice. Most of the work on test panels was directed toward trying to obtain improved brazes of edge members with a lessened number of voids. Nickel was applied to Z members by electroplating in flash, .0001", .0002", and .0005" thicknesses. On two panels, the skins as well as the edge members were nickel plated. Tests were also made in which the sterling silver 0.2% lithium alloy was nickel or silver plated. A few experiments were carried out to examine the effect of borax flux and of positioning the brazing alloy so as to direct flow. Panels were brazed where the surface of each edge member was given the same treatment and also where different treatments were applied.

The brazed test panels were X-rayed to determine the effect of plating or other treatment on the quality of the joints. Metallographic examination was made of a few selected sections. The results are summarized below.

Nickel plating the Z members had the effect of producing brazes with equal or better quality than those obtained by other treatments. As stated, the other treatments included using borax flux, silver plating the brazing alloy, and positioning the alloy. Insufficient tests were made with the latter two methods to define their effects. The addition of borax flux seemed to aid somewhat.

Comparisons of various methods of treatment can be obtained from the radiographs in Figures IIM-3 to IIM-5. The most noticeable improvement from nickel plating appeared along the edges and in the corner joints of Z member brazements. Here, the brazing alloy completely filled the areas that would have only partially filled if the nickel plate were not present. The thickness of the plate had no effect on the quality of the brazements.

On one pinel where the skin as well as the edge members were nickel plated, exceptionally large fillets were formed. Figure filled is a photomicrograph showning core-skin joint with the large fillets

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and Figure IIM-7 is a radio raph illustrating the core area. An attempt to reproduce the large fillet size by nickel plating the skins of another test panel was unsuccessful. The conditions necessary for the formation of unusually Targe fillets were not determined.

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| :                                    |               |  | -  |  |                                    | Line Artes                          |
|                                      |               |  |  |  |                                    |                                     |
| , <sup>1</sup> 14<br>4<br>5 <b>4</b> |               | ITEM N - NODE FLOW ON THICK  | CODE SECTION   | NO DV OTIVED                             | CODDED                             | T THUS TIM                          |
| e 14<br>- 4<br>1 1 1                 |               | BRAZING ALLOY  | COUR DEVIL   | NS DI SILVER                             | -COPPEA-                           | HIMION                              |
|                                      | <b>1</b>      | A few experiments were carr<br>difficulty in retaining suf<br>of deep sandwich panels to                                 | icient braz  | ing alloy in                             | reasons<br>the top                 | for the<br>skin                     |
| •                                    | n<br>N<br>V   | Four test panels, 3" x 6" x<br>standard sterling silver 0.2  | % lithium 🕯  | lloy was use                             | d for br                           | azing.                              |
|                                      | *             | Figure IIN-1 shows the array<br>junctions with the top and   |  |  |                                    |                                     |
|                                      |               | brazing were, as follows:  |  |  |                                    | 46 g                                |
|                                      | i.            | Panel 1 10 minutes at  | 1600 F   |  |                                    |                                     |
|                                      | •             | Panel 2 - 10 minutes a   | 1650 F   |  |                                    | ू ।<br>इन्हें के<br>1.1.74<br>संग्र |
|                                      |               | Panel 3 - 20 minutes at  | 1650 F   | . ``                                     |                                    |                                     |
|                                      |               | Panel 4 - 20 minutes at  | 1725 F   |  | ₽° ×                               | :<br>الم<br>- م                     |
| ,                                    | • •<br>•      | Figure IIN-2 shows sections  | of top and   | bottom skins                             | peeled                             | from the                            |
|                                      | ;             | Figure IIN-2 shows sections<br>core. The panel was brazed<br>the amount of brazing alloy<br>section and was deposited on | at 1000 F.<br>which flow<br>the opposi   | The photogra<br>d up or down<br>te skin. | the 3"                             | cates<br>core                       |
|                                      |               | Observations of the panels \$  |  | •  | 7<br>htazing                       | allov                               |
|                                      |               | into the core node region pr<br>simultaneously. It is the n  | oceeds from  | both top and                             | d, bottom                          | skins                               |
|                                      | •<br>•<br>• • | alloy to be present to form  | adequate fi  | llets in deep                            | p"sandwi                           | ch-                                 |
|                                      | · · · ·       | panel sections. The force of brazing alloy to the bot  | om skin. T   | hus, larger f                            | [i]lets :                          | are forméd                          |
|                                      | 1             | at the bottom than at the to<br>top is the result of capille   | p skin. F <b>l</b>   | ow from the 1                            | bottom <sup>t</sup>                | o the                               |
|                                      |               | Node flow takes place 30 to  | Ĩ  | •  |                                    |                                     |
| A                                    |               | to form satisfactory fillets   | . The vari   | ation in temp                            | perature                           | at which                            |
| '                                    |               | node flow occurs is probably present on the core. Anothe   |  |  |                                    |                                     |
|                                      |               | the time during which a pane<br>However, no pifect was noted   | l is held a  | t the brazing                            | temperi                            | ature.                              |
|                                      |               | 1650 F, as tried in these ex   | periments.   | The interval                             | l <b>\$</b> necès:                 | sary                                |
| •,                                   |               | to measure the time effect of used in this work.   | re propadit  | mugn Snortel                             | than th                            | HET                                 |
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|              | •          | THEN O TIMETING NODE BLOU TH MUTCH CODE GAVE  |  |
|              |            | ITEM O - LIMITING NODE FLOW IN THICK CORE SAND<br>BY SILVER PLATING!  | WICH PANEL SECTIONS  |
| · · ·        |            | A preliminary investigation was carried out wi<br>trying to control node flow, in brazing deep c<br>sandwich panels, by silver plating. The plati<br>make additional silver available to the sterli<br>lithium alloy during the brazing operation. W<br>silver provided for solution by the brazing al  | ore sections of<br>ng was intended to<br>ng silver 0.2%<br>ith additional<br>loy, the melting                            |
|              |            | - range should be raised and flow restricted. I<br>experiments, incorporating plating were promisi  |  |
|              |            | Five $2-1/2"$ x 5" x 5" sandwich panels were bra<br>identified as A-1 to A-5. The material was 17<br>IIO-1 shows the variations in positioning and<br>alloys together with the location of the silve<br>silver electroplate was applied wherever plati<br>The flash plates were about .0005" thick. On<br>silver plated on the core faces, the length of<br>the cell walls varied from $1/8"$ to $3/8"$ . | zed. These were<br>-7PH steel. Figure<br>amount of brazing<br>r plating. A flash<br>ng is indicated.<br>panels which had |
|              |            | In addition, to the usual cleaning procedure, a<br>acid pickle, was used on the core sections of p<br>prior to plating, to obtain good adherence of<br>steel. For panels A-3, A-4, and A-5, the pick<br>the core sections to be plated. There was no<br>omission changed any of the brazing characteri  | anels, A-1 and A-2,<br>the silver, to the<br>le was omitted on<br>evidence that this                                     |
|              |            | Large fillets were formed at both the top and<br>panels A-1, A-2, and A-3. The illustrations i<br>IIO-3 are typical of these joints. The use of<br>the brazing alloy or a silver plate on one-hal<br>and bottom skins, as with panel A-1, resulted<br>difference in the type of braze obtained. Nod<br>panels extended from 0 to /4" up or down the<br>brazed joints.                                     | n Figures IIO-2 and t<br>extra layers of<br>f of both the top<br>in no apparent<br>e flow in these three                 |
| · · ·        |            | Tests of three specimens taken from panel A-3   | gave average strength  |
|              | · • •      | of 1057 psi in flatwise core compression. This above the minimum strength of 875 psi specifie   | s is considerably  |
| •            |            | core material used in the panels brazed in this   | investigation.   |
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| ··· · · |   |   |   |
|         | An attempt was made with par  |   |   |
| 8       | the top fillets restrictedly<br>nodes by silver plating only<br>edge of the core was not ple<br>bottom was expected to devel<br>results were not attained.<br>wards from the top braze joi<br>the bottom joints in the hal<br>on the top edge of the core<br>brazing atmosphere inasmuch<br>plated on any surface showed<br>bottom joints. The reason<br>from the bottom in the panel<br>only the top core edge. The<br>panel A-4 were confirmed by | and prevent its flow<br>the top edge of the c<br>ted. Thus, the brazin<br>op some node flow upwa<br>Node flow extended 1/4<br>nts but was completely<br>f section having the s<br>This condition was n<br>as the panel half whic<br>definite node flow fr<br>s not known for the la<br>section having the si<br>foregoing observation | down the core<br>ore. The bottom<br>ag alloy on the<br>ords. The desired<br>" or less down-<br>absent above<br>tilver plate<br>tot caused by the<br>h was not silver<br>om both top and<br>ock of node flow<br>lver plate on<br>as concerning |

panel prepared in the same way.

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The 1-3-1 tri-metal alloy was used at the top of panel A-5. As explained in Item I under Brazing Alloys, this section above, the designation 1-3-1 indicates the relative thicknesses of the three layers in the foil sandwich In the present alloy, the outer 1 layers were sterling silver 0.2% lithium and the center 3 layer was pure silver. This tri-metal alloy did not flow at the brazing temperature used, viz., 1660 F.

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### ITEM P - CONCLUSIONS FOR ITENS L, M, N, AND O

A study of the causes for and methods of eliminating voids in edge members of brazed sandwich panels led to the following conclusions:

Edge member voids are of more frequent occurrence when the sterling silver 0.2% lithium alloy is used for brazing as contrasted with the 85:15 silver-manganese alloy

The observed causes of voids are large joint gaps, foreign matter in the joint, and brazing alloy shrinkage. Foreign matter includes oxide films on the surfaces to be joined, non-metallic inclusions in the brazing alloy, and gas evolved from the metal brazed or from the brazing alloy.

Close joint spacing is the most critical factor in eliminating or minimizing voids in brazed edge members. Foreign matter and shrinkage may be difficult or impossible to control.

Only relatively large vold areas are thought to impair seriously the over-all strength of a joint.

An investigation to determine the effect of nickel plating 17-7PH steel surfaces before brazing gave useful information. This investigation was carried out primarily with the object of decreasing the occurtence of edge-member voids by nickel plating.

Nickel plating was found to provide a surface more responsive to brazing on wetting by the brazing alloy: Brazements of equal or better quality were produced by nickel plating than by other methods tried for reducing the number of voids.

The tensile properties of 1777PH steel in light sheet were not appreciably changed by nickel plating. Also, the double lap-shear strength of specimens was but little affected by nickel plating. The effect of various thicknesses of nickel on the properties was relatively unimportant.

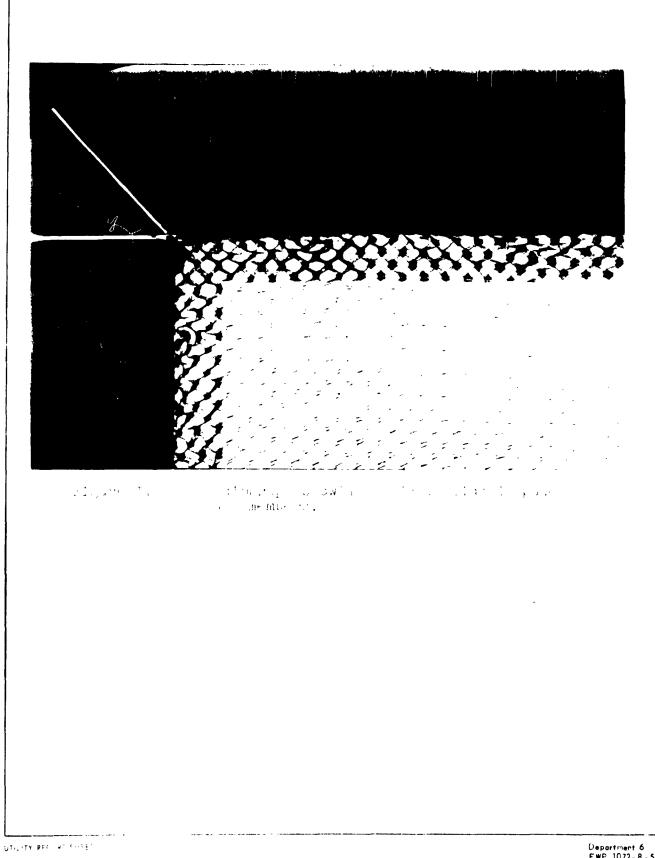
The least possible thickness of nickel plate is apparently as helpful as larger thicknesses on the result obtained in brazing.

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| ·                                     |              | few e             | xperim          | ents mad               | e to ol            | serve the               | node flo             | w of braz                | ing all | ov on                       |
| 1                                     | t 1 t        | hick c            | orte se         | ctions in              | n sandi            | ich panels              | s afforde            | d interes                | ting fa | ots.                        |
|                                       |              |                   |                 |                        |                    | g alloy f               |                      |                          |         | from                        |
|                                       |              |                   |                 |                        |                    | s. The f.<br>se observe |                      |                          |         | 'nv                         |
| · .                                   | 1            | nsuffi            | olent.          | alloy is               | retai              | ed at the               | top skin             | to form                  | large f | illets                      |
| 4                                     | 1 1          | They al           | so exp          | lain why               | large              | fillets an              | re formed            | at the b                 | ottom s | kin.                        |
|                                       |              | nother            | inves           | tigation               | carrie             | d out with              | n the obj            | ect of fin               | hibitin | g node                      |
|                                       |              |                   |                 |                        |                    | d that th:              |                      |                          |         |                             |
|                                       | t            | ne pla            | ting w          | as appli<br>The res    | ed vari            | ously to a owed that    | skins and            | core edg                 | es of t | nick                        |
|                                       | , ∴ <b>v</b> | ver, on           | the 'e          | dge and (              | extend             | ng along t              | the core             | about 1/8                | " from  | the [                       |
|                                       | e            | dge, e            | limina          | ted node               | flow a             | t 1660 F.               | The eff              | ect was b                | rought  | about                       |
|                                       |              | by the            | additi          | onal sil               | ver fro            | m the plat<br>alloy on  | te, this             | dissolvin                | g in th | e                           |
| r                                     |              |                   |                 | erature.               |                    | alloy on                | brazing              | and thus                 | raising |                             |
| •                                     |              |                   | -               |                        |                    | 2<br>2<br>4             |                      | ••                       |         |                             |
|                                       |              | in conn           | egtion          | with the               | e above            | investig                | ation on             | silverrpl                | ating,  |                             |
|                                       |              |                   |                 |                        |                    |                         |                      |                          |         |                             |
|                                       |              | ace com<br>anel b | razed           | in the la              | s were<br>aborato  | made on sa              | casults s            | howed tha                | t the c | olumn                       |
|                                       | P<br>S       | anel b<br>trengt  | razed<br>h of t | in the la<br>he core s | abórató<br>withoui | ry. The p<br>node flow  | results s<br>was con | howed tha                | t the c | olumn<br>the                |
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|                                       | P<br>S       | anel b<br>trengt  | razed<br>h of t | in the la<br>he core s | abórató<br>withoui | ry. The p<br>node flow  | results s<br>was con | howed tha                | t the c | olumn<br>the                |
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|                                       | P<br>S       | anel b<br>trengt  | razed<br>h of t | in the la<br>he core s | abórató<br>withoui | ry. The p<br>node flow  | results s<br>was con | howed tha                | t the c | olumn<br>the                |

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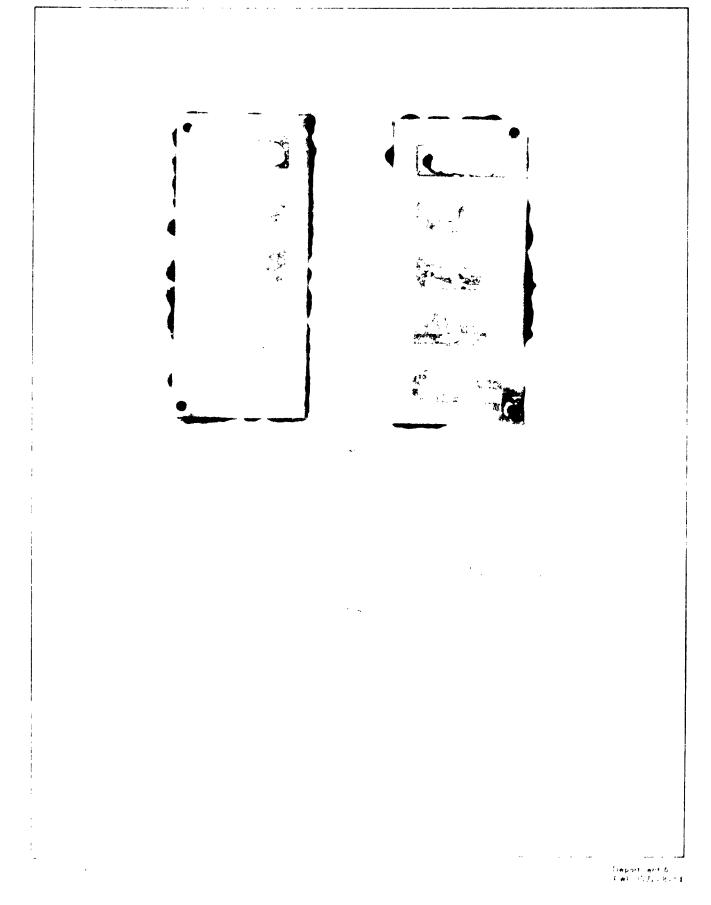


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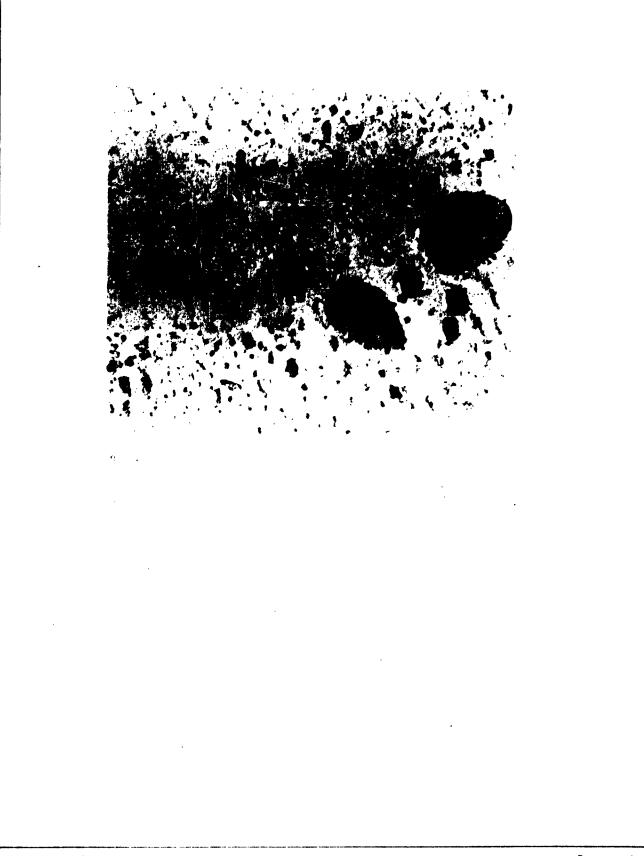
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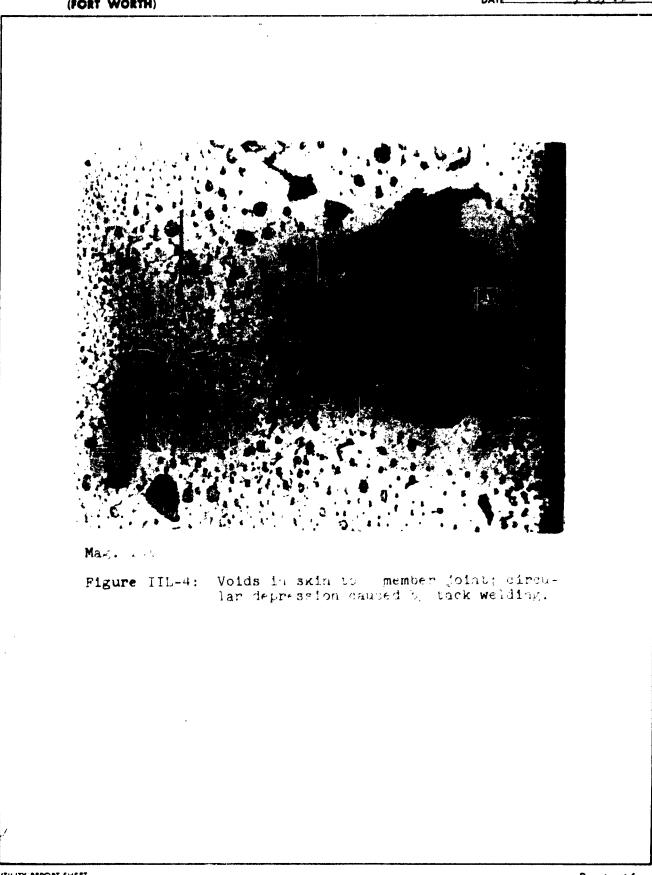


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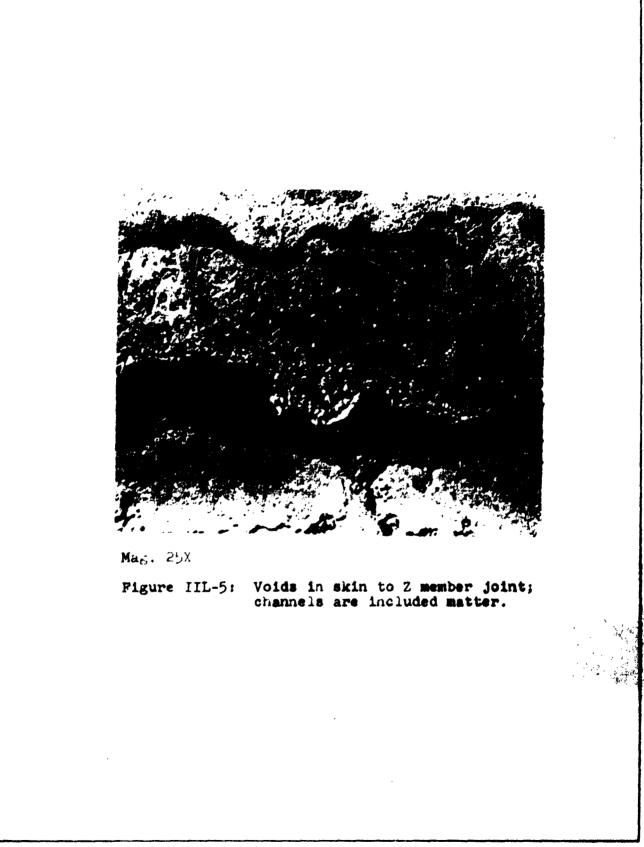
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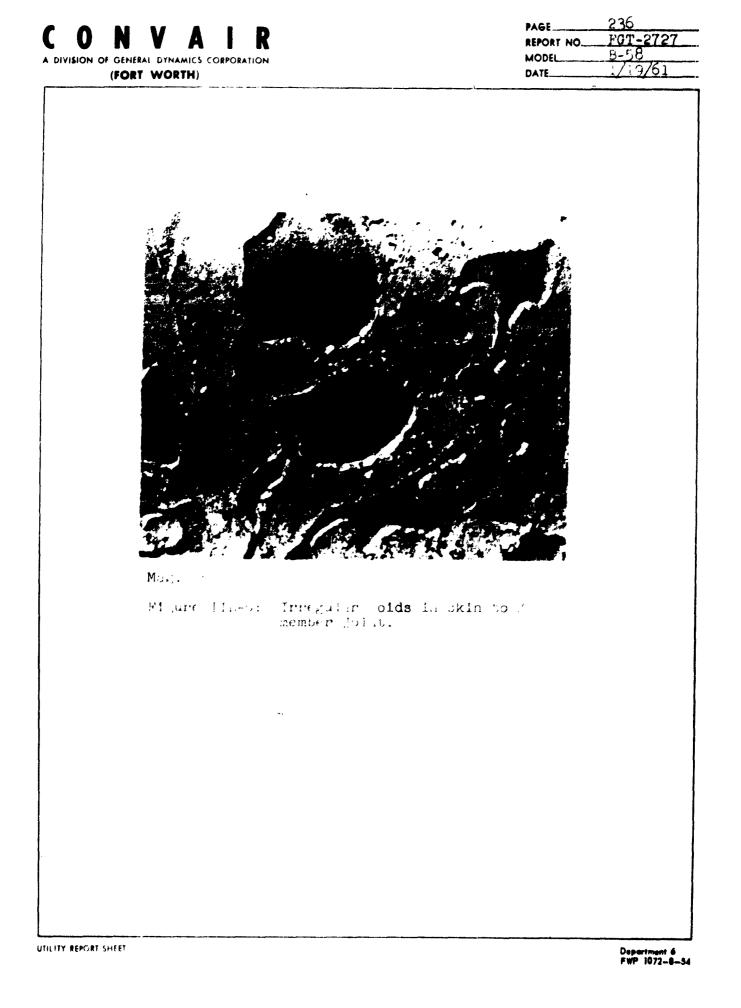
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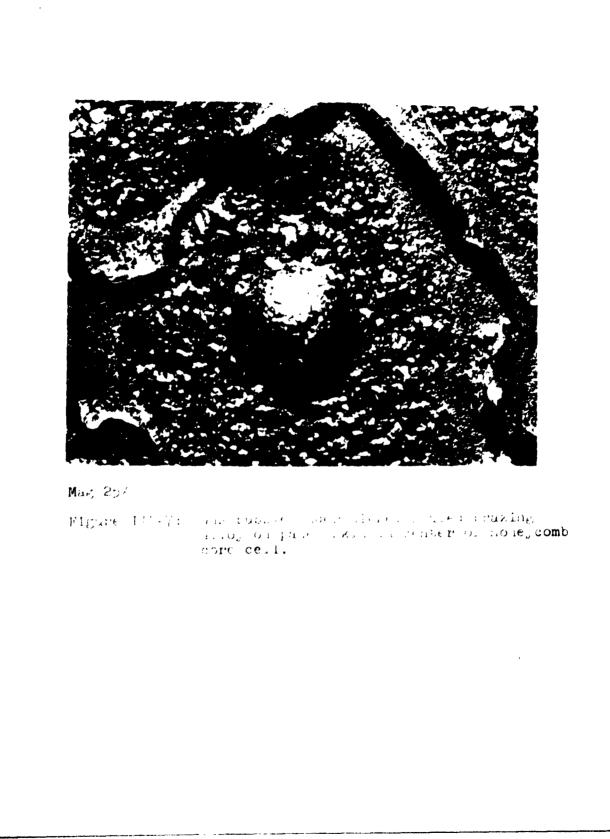


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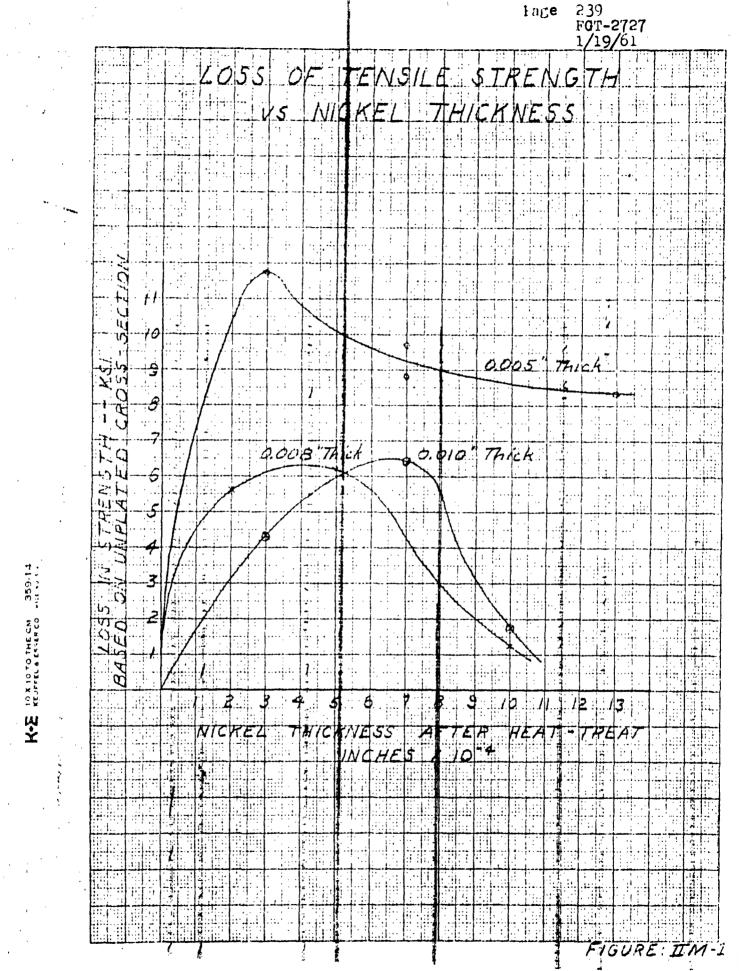
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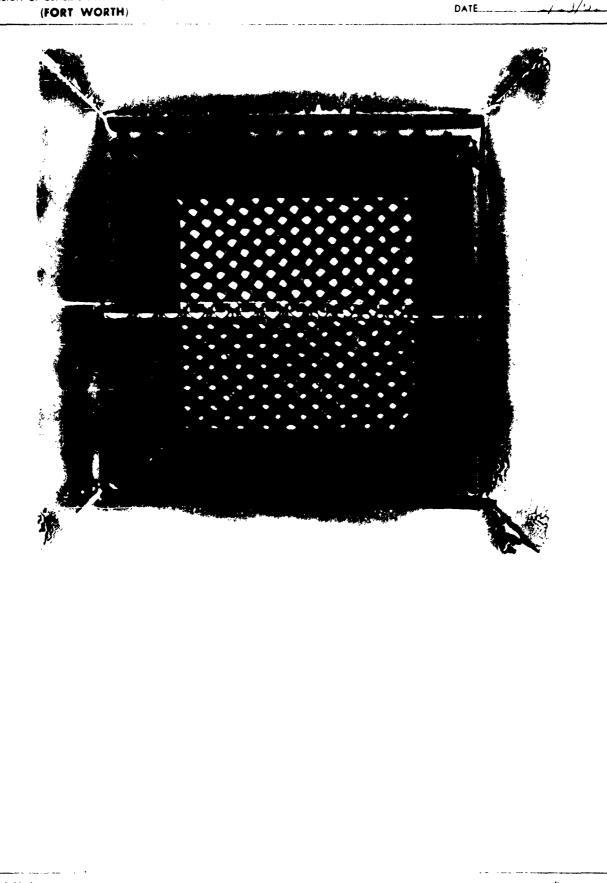
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FIGURE: I.M - ? 1



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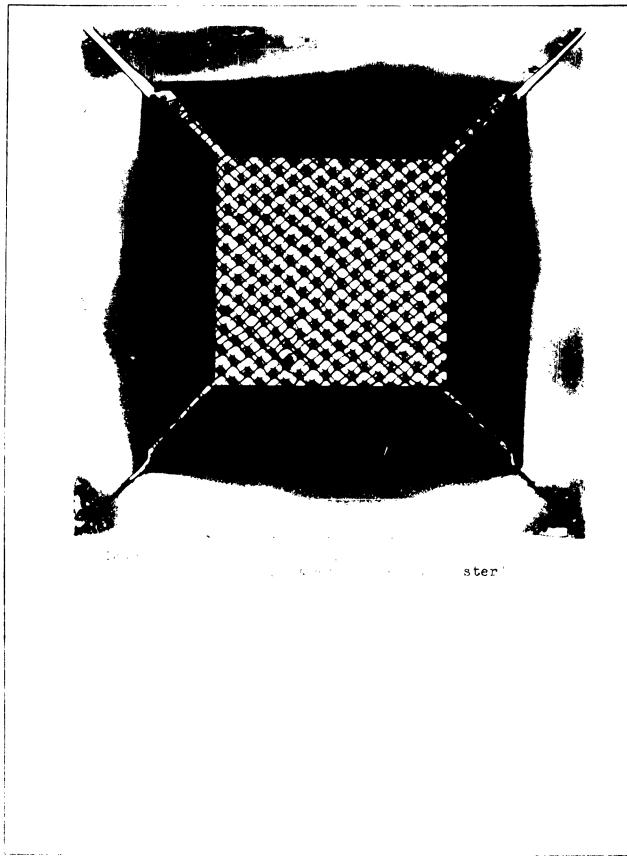


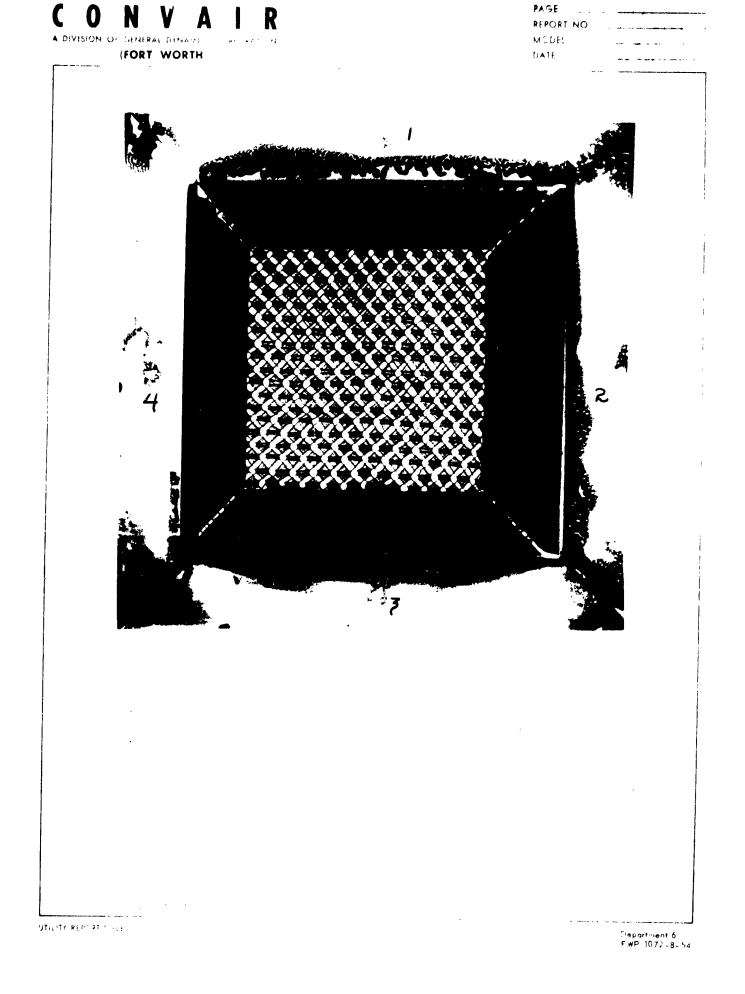
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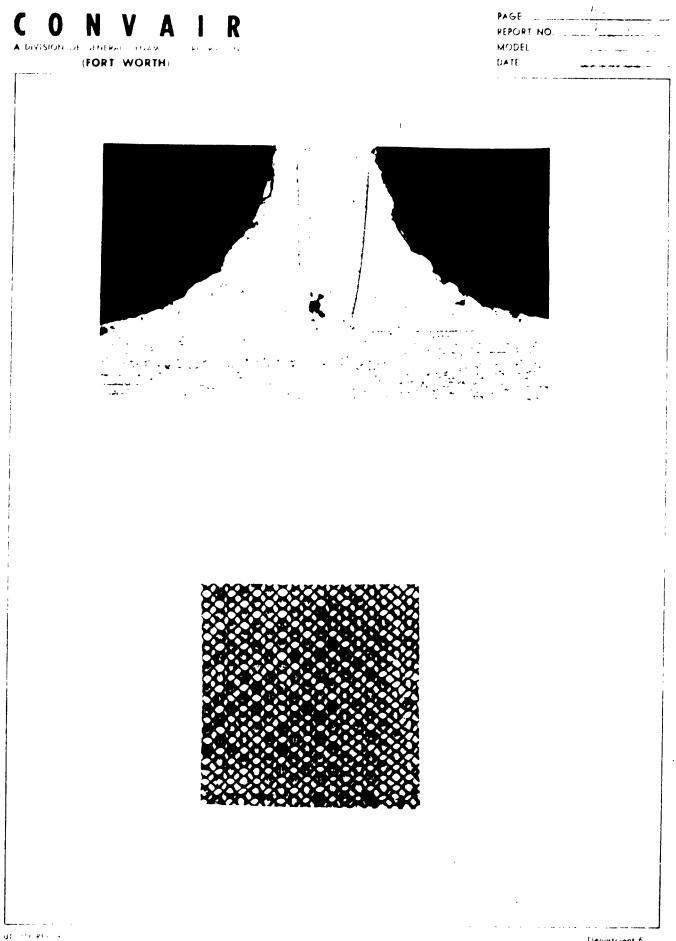
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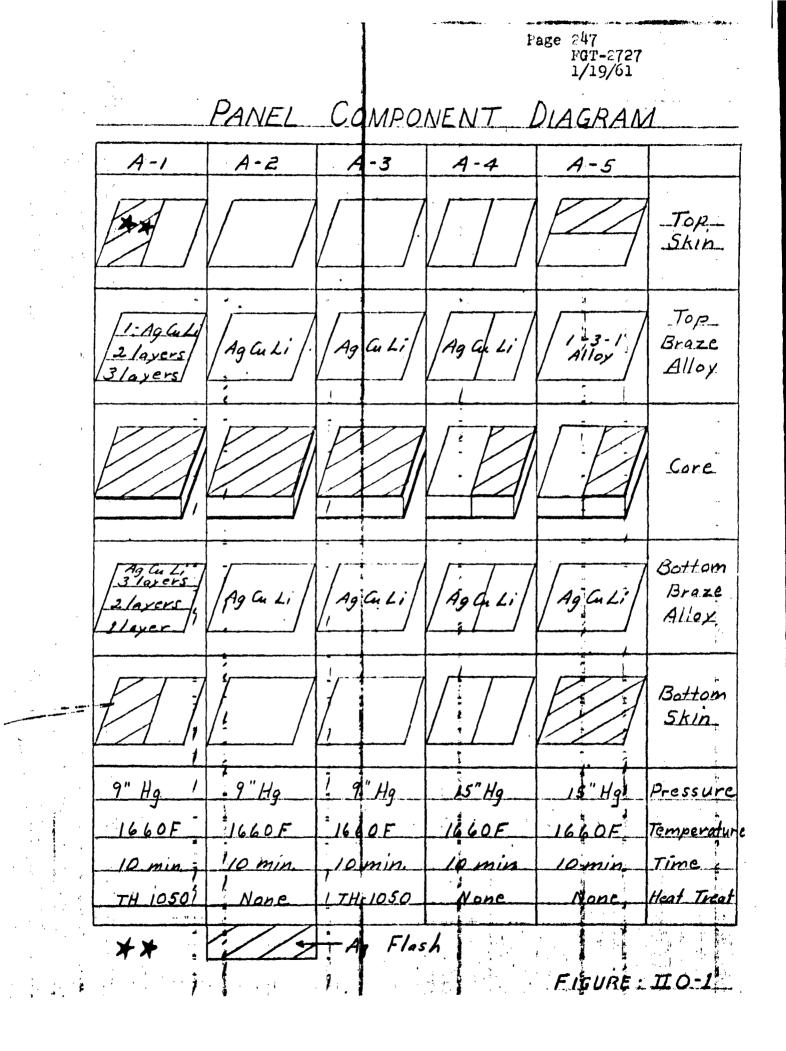
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Page 245 FGT-2727 1/19/61 PH - TOP SKIN ターブ 2 Layers Ao Cu Li. No Braze Alley ż 1 Loyer Ag Li Ġu PF CA -15 RF 17.1 PH - BOTTOM SKIN. L Layer Ag Cu Li No Braze Aller 2 Loxers Agar Li 50 ,Ú \*\*

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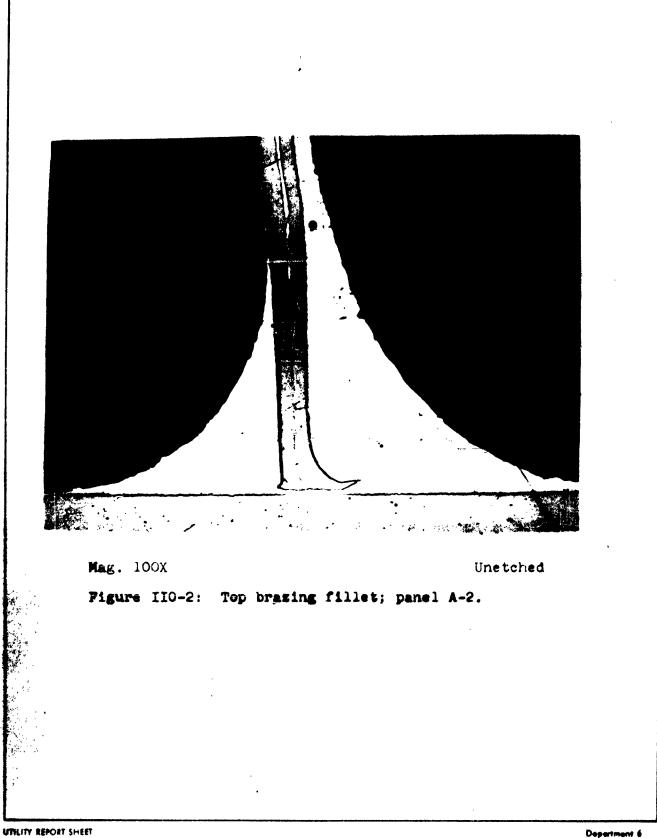
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|   |   |                                 |                   |
|   | The and bottom skins<br>at 100 F.                                   | s of test pane                  | l b <b>raze</b> d |
| placed on totto   | tions snow flow from<br>m skin of a 3° core<br>no alloy was origina | panel section                   | to                |
|   | sections show flow :  | From brazing a lel section to   | 1109              |

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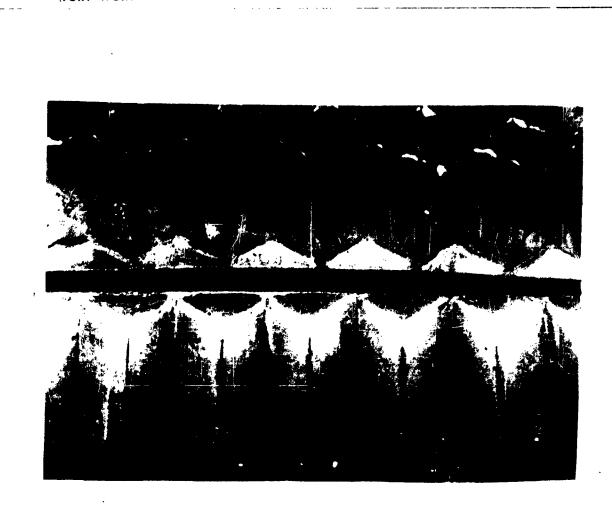
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### INDUCTION BRAZING OF STAINLESS STEEL SANDWICH PANELS

### INTRODUCTION

In September 1955 a detailed manufacturing research proposal was approved which included several research programs on problems associated with the fabrication of stainless steel sandwich panels. The purpose of these programs was to investigate various methods of sandwich panel joining, such as resistance brazing and welding, ultrasonic welding, and induction brazing. The problems were studied simultaneously at convair and by certain other companies under contract agreements. The preliminary results of the investigations indicated that the induction brazing approach showed considemable promise.

Battelle Memorial Institute conducted research on induction brazing from March 1956 through August 1958. Summary reports covering their work were issued in February 1957 and August 1958. Convair Report MR 55-14 summarizes their work from March 1956 to January 1957.

Induction brazing studies conducted at Convair, Ft. Worth were similar to those pursued by Battelle during the early stages of the investigation, but were more limited in scope. From March 1958 to February, 1959 an effort, was made at Convair to adapt induction heating to contoured sandwich panel, brazing.

Induction brazing of sandwich panel structures offers two advantages over the conventional furnace brazing methods. The time during which the brazing alloy is molten can be materially reduced by the induction method. Diffusion of a brazing alloy into the base metal is a function of time at temperature. Thus, induction brazing could afford a means of control over the diffusion problem in sandwich panel brazing. Induction brazing also affords a means of controlling brazing alloy flow in curved sandwich panels through its application to a zone brazing technique.

This memorandum is issued to summarize the basic conclusions regarding brazing by an induction heating process. Additionally, it describes the work procontoured sandwich panel brazing done at Convair, in the later stages of the program.

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| 4<br>7     | * · · · · ·        |  | . • '                                    |
| SUMMARY    | •                  |  | ·  |
|            | ,<br>,             |  |  |
|            |                    | zing flat or contour                       |  |
| noneycom   | b sandwich panels  | has been proven to<br>he larger portion of | De l'easible on                          |
| flat pan   | els was accomplis  | hed at Battelle Memo                       | orial Institute.                         |
| The cont   | oured sandwich par | nel brazing was done                       | in the Engineering                       |
| Metallur   | gical Laboratory   | at Convair, Fort Wor                       | th, flat test<br>anels 1/2" x,10" x 15"  |
| panels 1   | /2" x 10" x 20" a  | nd 180° contoured pa                       | nels $1/2$ " x 10" x 15"                 |
| were bra   | zed satisfactoril; | y by induction heat:                       |  |
| The foll   | owing statements   | will serve to summar                       | ize the basic                            |
| requirem   | ents and limitati  | ons determined durin                       | ng this investiga-                       |
| tion for   | the use of induc   | tion heating in sand                       | wich panel brazing.                      |
|            | ,                  |  |  |
| 1.         |                    | idally feasible to h                       |  |
|            |                    | ch panel by induction                      |  |
|            |                    | wer requirements.                          |  |
| ,          | of a narrow braz   |  |  |
|            | 1                  |  | · · ·                                    |
| 2.         | It was found tha   | t to maintain a spec                       | cified panel contour                     |
|            | a reference form   | was necessary. Th                          | is need was accentu-                     |
|            | ated by the use    | nackage similar to "                       | technique indicated that used at Convair |
|            | for furnace braz   | ing proved satisfact                       | tory for the                             |
|            | induction-heatin   |  |  |
|            |                    |  |  |
| 3.         | . It was necessary | to maintain the over                       | er-all panel temper-                     |
|            | athre within 200   | DO JUU FOI THE DEE                         | rces caused sarpage.                     |
| 1          | By inclosing the   | entire brazing oper                        | ation inside a                           |
|            | resistance-type    | electric furnace thi                       | ls requirement was                       |
|            | fulfilled.         |  | -<br>. <b>4</b>                          |
|            | r . L              | 1  |  |
| 4.         | Wrinkling proble   | ms were solved by th                       | barrier was inserted                     |
|            | wrinkle barrier    | panel skin and the                         | acuum cover sheet                        |
| · ·        | of the panel pac   | kage. It protected                         | the panel skin                           |
| - <b>H</b> | from wrinkles th   | at sometimes develop                       | ed in the vacuum                         |
|            |                    |  |  |
|            | cover sheet.       |  |  |
|            | cover sheet.       |  |  |
|            | cover sheet.       |  |  |
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5. There was a slight tendency for the panel core to bridge away from the bottom panel skin in the lower section of 180° contour panels. This condition extended less than 1" into the panel from the panel edge on each side. It was thought that this was caused by poor mating of the detail parts of the panel package rather than by the brazing method itself.

6. A two to four turn, flattened, loop-type induction coil seemed to provide the best configuration for transforming the electrical power into heat in the panel package. The use of induction heating
\* frequencies in the 4 to 10 Kc range proved satisfactory
\* for this application. These Trequencies gave greater depth of heating, had less tendency to arc, and made the coil-to-work spacing less critical as compared with much higher frequencies.

7. Little or nothing was gained by attempting to heat from both sides of the panel package when a brazing form was included. The brazing form shielded the bottom panel skin from any induction heating effect and thus made attempts to heat the panel from this side of the panel package useless. Sandwich panels up to 0.75" thick have been brazed by heating from only one side of the package with a temperature gradient of tless than 50 F between the top and bottom skins.

Although all important variations of the above factors have not been examined, these tests are sufficient to provide a sound background for adapting induction - heating to the production brazing of honeycomb sandwich panels.

### PROCEDURE: t

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> This section describes the method used by Convair to braze contoured sandwich papels by induction heating. The procedure used by Battelle in brazing flat panels is not covered here. It, is mentioned briefly in the discussion section. Details of their method are given in Convair Report MR 55-14.

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|            |   |  |
|            |   |  |
|            | Figure IIQ-1 illustrates the experimental   | brazing setup. The                           |
|            | equipment shown is a two loop, induction-h  | neating coil inside                          |
|            | a Temperite, resistance-heated furnace.   | A device for rotating                        |
|            | the packaged, sandwich panel assembly is n  | nounted inside the re-                       |
|            | sistance furnace. This apparatus was rota<br>of the furnace by means of a hand crank, r | atable from the rear                         |
|            | picture. The panel assembly is attached f   | to the potative device                       |
|            | by slotted steel tabs welded to each corne  | or of the penel package                      |
| 1          | These tabs were bent around the 1/2" stair  | less steel prongs of                         |
| 1          | the rotative device. The panel assembly w   | vas centered in the                          |
| 1          | induction coil by means of lock nuts on the   | e prongs of the rota-                        |
|            | tive device"  | • •  |
|            | · · · · · · · · · · · · · · · · · · ·   |  |
|            | The cavity of the resistance furnace serve  | d for both preheating                        |
|            | and postheating. An inert atmosphere was  | obtained inside the                          |
|            | panel package by alternately pumping out a gas through a stainless steel tube welded    |  |
|            | end of the panel package.   | THEO CHE UPper Tere                          |
|            |   |  |
|            | After the panel had been properly purged,   | the resistance fur-                          |
| 1          | nace was set at 1000 F for heating overnig  | tht while the interior                       |
|            | of the panel package was held at less than  | 1 200 microns pressure.                      |
| 1          | The following morning the furnace temperat  | ure was raised to                            |
| 1 .        | 1550 F, and the differential pressure on t  | the panel reduced to                         |
|            | 12" of mercury. As soon as the panel temp<br>1500 to 1550 F, the induction heating unit | erature reached                              |
| ľ          | panel assembly was rotated through the hot  | zone under the                               |
|            | induction coil. The package was then cool   | ed, and the panel was                        |
| Į –        | cut out for examination.  | ieu, and eile paner nae                      |
|            |   | ₹  |
|            | Induction heating frequencies of 450 and 4  | .2 Kc were used for                          |
|            | the testing as listed in Table IIQ-I., The  | 450 Kc frequency                             |
|            | was obtained from a Westinghouse 10 KVA va  | cuum tube oscillator                         |
|            | type unit. The 4.2 Kc frequency was obtain motor generator unit.                        | ned from a 30 KVA                            |
|            | motor generator ante.   | Ę  |
|            | Panels for experimental brazing were packa  | ged according to the                         |
|            | types of assembly illustrated in Figure II  | Q-2.   |
|            |   |  |
| 1          | Twelve 17-7PH 180° contoured sandwich pane  | is were prepared for                         |
|            | brazing during this investigation. These<br>in Table, IIQ-I. Panels, 1 to 5 were heated | by pageing on indus                          |
|            | tion heating coil completely around the as  | sembly as shown in                           |
| · ·        | tion nearing corr compressed around one as  | bemory ab bliowig th                         |
| 1.0        |   |  |
| 1.12       |   | i i i i i i i i i i i i i i i i i i i        |
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|     |  |   |  |        |
|     | Position 1 of Figure IIQ-<br>placing the induction con<br>Position 2 of Figure IIQ-  | 1 on top of the packag  |  | ,      |
|     | Two methods of temperatur<br>Either thermocouples or a<br>dependable method of plac<br>heating coil was found.                                   | n optical pyrometer wa  | is used. No  |        |
|     | The experimental procedur<br>detail under the discuss  |   | .bed <u>kin</u> more                                       | 121    |
| · . | DISCUSSION   |   | C  | ^<br>* |
|     | This section is divided in<br>the basic problems encour<br>program and of the method<br>II describes the method of<br>brazing; of contoured sand | tered during the induc<br>s used to solve these<br>eveloped to apply indu | problems. Part   |        |
|     | PARTI  | •.<br>*   | 3 N  |        |

In order to produce satisfactory stainless steel sandwich panels three conditions must be satisfied. First, at brazing temperatures of silver-base brazing alloys a nonoxidizing atmosphere is necessary.; Second, some sort of brazing form is needed to produce panels having the shape required and quality desired in aircraft structures. Third, some method of maintaining contact of the various panel parts during the brazing cycle is necessary. In furnace brazing these conditions are satisfied by encasing the sandwich panel in a welded braze box containing a graphite brazing form, purging with argon gas, and brazing under a partial vacuum. Meeting these requirements in induction brazing is complicated by the relative position of the brazing form and panel package to the induction heating coil. Considerable experimentation was necessary to determine a satisfactory brazing procedure.

One of the<sup>f</sup> first decisions was that it would be impracticable to heat more than a narrow zone of the packaged sandwich panel to brazing temperature at one time because of power considerations. Such a conclusion necessitated movement of either the panel past the induction coil or movement of the coil past the panel package. All work throughout this investigation was accomplished by movement of the panel past the induction coil. This, involved a minimum of problems, at least for relatively small panels.

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|              |   |              |                    |             |  |                          |                        |
| •            | The ede   | ntion of a   | nerrow h           | eting zone  | necessita                                | ted preheat              | 100                    |
|              | and nos   | thesting t   | he work to         | reduce th   | armal grad                               | ients in th              |                        |
| 1            |   |              |                    |             |  | preheating               |                        |
|              |   |              |                    |             |  |                          |                        |
| ,            | postnee   | ting zones   | were two           | separate I  | urnace reg                               | ions with t              | ne                     |
|              |   |              |                    |             |  | toured pane              |                        |
| •            |   |              |                    |             |  | ed for both              |                        |
| . 1          |   |              |                    |             |  | Attempts t               |                        |
| 1.2          |   |              |                    |             |  | der was not              |                        |
|              | heated  | were compl   | etely uns🏟         | ccessful.   | It was for                               | und that pr              | eheat- 🛓               |
| •            | ing to  | 150 - 200    | F below th         | e brazing   | temperatur                               | e produced               | panels .               |
|              | which s   | atisfied t   | he flatne          | s specific  | ations for                               | Convair pr               | oduc -                 |
|              |   |              |                    |             |  | ostheat tem              |                        |
|              | ature   | s much as    | 300 F held         | w the braz  | ing temper                               | ature witho              | ut i                   |
|              |   | ; permanent  |                    |             |  |                          |                        |
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|              |   |              |                    |             |  | ock or subs              |                        |
|              |   |              |                    |             |  | An example               |                        |
|              | the use   | of Vycor     | plateş by.         | Battelle i  | n brazing (                              | 6" х <sub>2</sub> 6" fla | t                      |
|              | test pa   | nels. Tes    | ts with Vy         | cor were a  | bandoned b                               | ecause plat              | es were 👘              |
|              | unavai1   | able in la   | rger sizes         | . The pan   | el package                               | adopted wa               | s essen-               |
|              | tially  | the 'same a  | s that usé         | d by Conva  | lr in furna                              | ace brazing              | •                      |
|              | Three v   | ariations    | of this pa         | ckage are   | shown in F.                              | igure IIQ-2              | •                      |
|              | •   | , , ,        |                    | <b>J</b>    | L  |                          |                        |
|              | The col   | J configur   | ation four         | d to be as  | tisfactory                               | was a heli               | cally -                |
|              |   |              |                    |             |  | sed complet              |                        |
|              |   |              |                    |             |  |                          |                        |
|              | Poet+t-   | me packag    | $C$ IN TTO $2^{T}$ | tau panet   | tion heres                               | ogram as in              | r of <sup>2</sup>      |
|              | LOSTOTO   | dr T OT LTR  | une Ife -Ju        | ALL LILUUC  | Proved                                   | ng frequenc              | y UI                   |
|              | 450 KG  | was used o   | uring all          |             | -paner and                               | i part of t              | ne                     |
|              | contour   | ed-panei b   | razing pro         | grams. Th   | is irequend                              | cy was sele              | cted _                 |
|              | in an e   | front to o   | otain maxi         | num errici  | ency for th                              | ransformati              | on or                  |
|              |   | cal energy   |                    |             |  |                          | *                      |
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|              | package   | . Éfficie    | ncy was ap         | proximatel  | y equal and                              | i ease of o              | pera- 🦙                |
|              |   | ch better    |                    |             |  |                          | 1                      |
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|              | and ITO   | -3 that th   | e bottom a         | andwich pa  | nel skin m                               | st be furt               | ner                    |
| •            | away fr   | tom the coi  | 1 winding          | than the    | top panel s                              | skin in a p              | ackage                 |
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| 1.<br>       | of the  | rurnace wa   | s neared to        | 0 15/5 F 8  | na the pane                              | l was braze              | ed t                   |
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drawn through the heating coil at a rate of 3" per minute at a power setting of 4 KVA. The temperature was read with an optical pyrometer. The postheat zone was operated at 1400 F to coincide with the conditioning step temperature in the heat treatment of 17-7PH stainless steel.

### PART II:

UTILITY REPORT SHEET

The use of the zone technique in induction brazing flat sandwich panels led to the attempt to adapt this procedure to controlling brazing alloy flow in severely contoured panels. Brazing alloy flow occurs under the influence of gravity while the alloy is molten and causes a buildup of the brazing alloy in low portions of the sandwich panel at the expense of the higher regions. If the brazing alloy were molten only in the lowest portion of the panel, no flow could occur. This can be accomplished by the use of a narrow brazing zone.

In order to try zone brazing a contoured panel, a stainless steel rotating device or hanger was mounted inside a resistance furnace, as shown in Figure IIQ-1. Hooks were welded onto each corner of a 180° simply contoured panel brazing retort so that it could be fastened onto the hanger. The induction heating coil was mounted so that it encircled the panel package.

A vacuum line was welded into one end of the package to permit control of the atmosphere and pressure. During brazing, the panel was rotated 90° from the position shown in Figure IIQ-1, and the induction power was turned on. The panel was then slowly passed through the heating coil until the entire panel area had been brazed.

The first five panels were test brazed using a 10 KVA Westinghouse vacuum tube oscillator unit. The frequency of this unit was 450 Kc per second. These panels were packaged as shown in Type 1, Figure IIQ-2. The results as given in Table IIQ-1 were quite unsatisfactory. To obtain the required brazing temperature the induction coil-to-panel spacing was held at 0.25" or less. This made the alinement of the panel on the rotative device quite critical. Also, the heat on the inner panel skin was inadequate, although the best measurements obtained showed the temperature gradient from top to bottom skin was less than 50 F. The temperature difference between top and bottom panel skins is a function of the speed at which the panel is passed through the heating coil. A speed of 1 to 2"

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| ·       |  |  |  |           |
|         | After the first five panels                | had been brazed, it wa   | as decided to                          |           |
|         | try lowering the induction                 | eating frequency. A  | RO KVA motor                           |           |
|         | generator was available; th                |  |  |           |
|         | decided to heat from only the              |  |  |           |
|         | package. Because of the pr                 |  |  |           |
|         | form, it was obvious that f                |  |  |           |
|         | very little heat could be the              |  |  |           |
|         | from the bottom section of                 |  |  |           |
| •       | the same coil configuration                |  |  |           |
|         | in Position 2 of Figure IIQ                |  | · ···································· |           |
|         |  |  | C                                      |           |
|         | It was thought that the gray               | bhite form might be sar  | buing heat from                        | a         |
|         | the bottom planel skin. Con                | equently. A laver of F   | lberfrax insul                         | -<br>La   |
|         | tion was introduced as show                | in Type 2 of Figure 1  | [10-2. After                           | . <b></b> |
| •       | the Fiberfrax was added, no                | further trouble was ex   | perienced in                           |           |
|         | heating lower panel skins.                 | On panels 8 to 17 the  | barrier sheets                         | 5         |
|         | were placed as shown in the                |  |  |           |
|         | The bottom 0.032" barrier p                |  |  |           |
|         | from imperfections in the F                |  |  |           |
|         | protected the panel from wr                | inkles formed in the va  | cuum diaphragm                         | 1         |
|         | sheet of the brazing retort                |  | +                                      |           |
|         |  | 1  | с<br>о г                               |           |
|         | A problem which caused some                | trouble was that of in   | sulating the                           |           |
|         | water cooled induction coil                |  |  |           |
|         | methods shown as Types a, b                | c and d in Figure IIG  | 2-4 were?                              |           |
|         | successively tried. It was                 | found that Type d was  | best from                              |           |
|         | the standpoint of thermally                |  |  |           |
|         | wich panel itself.                         |  |  |           |
|         |  | 2  | <b>(</b>                               |           |
|         | 📜 🔄 Accurate temperature measure           | ment of the brazing zo   | ne Iwas 🧧                              |           |
|         | difficult. Several methods                 | of introducing thermoe   | ougles were                            |           |
|         | . tried. All the temperatures              | s shown in Table IIQ-I   | represent                              |           |
|         | surface temperatures on the                |  |  |           |
|         | ing retont. The only usable                | e thermocouple measurem  | iențs were                             |           |
|         | obtained by wiring the coup                | les underneath the cent  | er loop <sub>2</sub> of                |           |
|         | the induction heating coil                 |  |  |           |
|         | the Fiberfrax and the brazin               |  |  |           |
|         | dependable because the wire                | s sometimes burned off   | or the E                               |           |
| · · · · | thermocouple arced out on the              | ne brazing netort. Rea   | dings tåken                            |           |
|         | with an optical pyrometer w                | ere satisfactory althou  | igh <u>`</u> the                       |           |
|         | temperature read was usuall;               | y 30 to 50 K higher tha  | n that obtaine                         | d         |
|         | by thermocouples. The therm                | gocouple readings were   | considered                             |           |
|         | more accurate.                             | 1 1  | 24 N<br>19 S                           |           |
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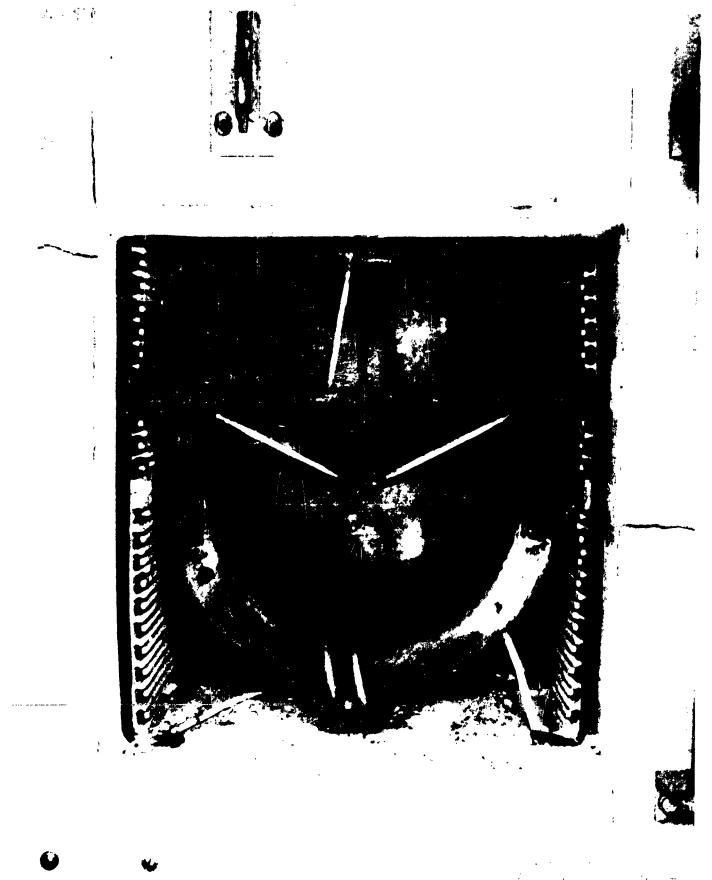
Test panels 9 to 12, listed in Table IIQ-1, were regarded as satisfactory from an experimental standpoint. Items such as cleaning, atmosphere conditions, and fit of detail parts were not as closely controlled in this investigation as they would be in production brazing. Panels 9 and 10 consisted of  $180^{\circ}$ panels  $1/2" \times 10" \times 15"$ . A photograph of panel 9 is shown in Figure IIQ-5. The uneven fillets were caused by poor wetting of the 92.3% Ag 7.5% Cu plus 0.2% Li brazing alloy on the 17-7PH stainless steel surfaces. This was caused by inadequate cleaning of the pinel parts.

The bridging or separation of the core and skins in the center section of the edges of panel 10 was the result of poor fit of the braze block in the brazing retort. Panel 11 was brazed with 0.125" stiffeners around the edges of three sides of the panel. This arrangement was for the purpose of checking the heat transfer through the greater mass. The braze on this panel was excellent although the mismatch of the panel parts caused inferior over-all panel, quality.

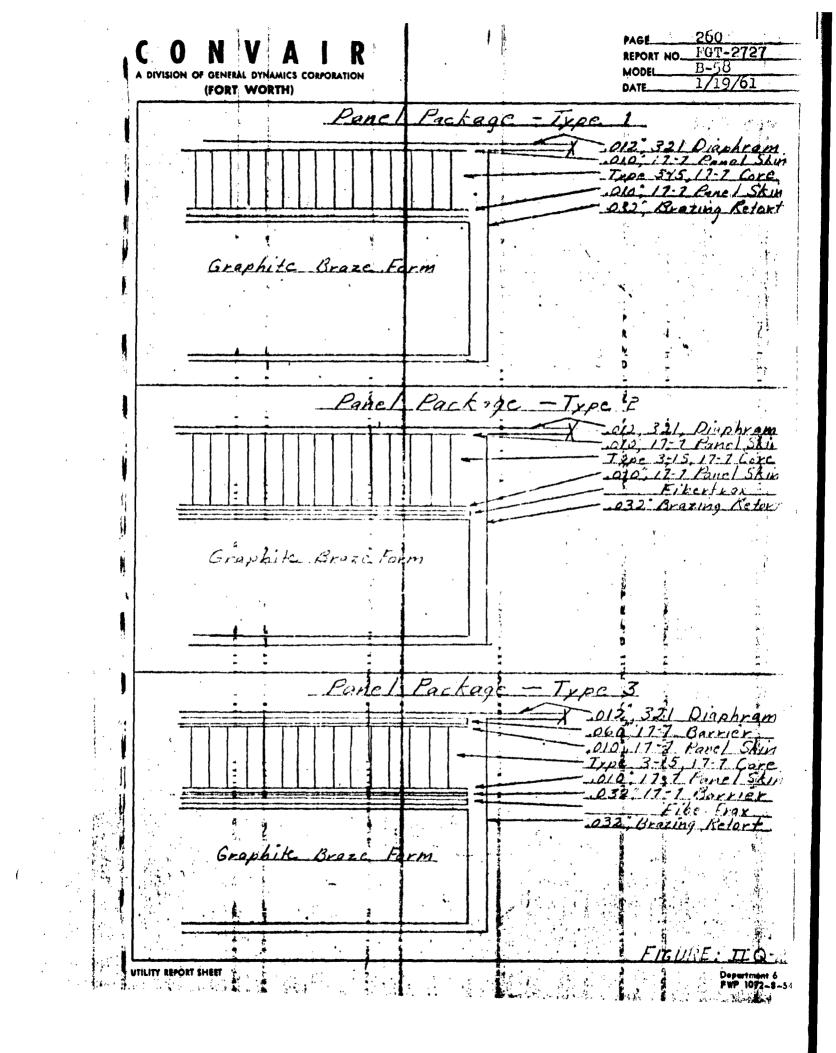
Panel 12 was brazed with 0.75" thick honeycomb core. When heat is applied to only one side of a sandwich panel there must be a maximum thickness over which the inner panel skin can not be brazed. This panel showed that 0.75" is within the limiting thickness which can be brazed by such a method. None of the 180° contoured panels listed in Table IIQ-I exhibited any brazing alloy flow.

## CONCLUSIONS

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|                      |   | 3                              | L                           |                        | i<br>V           | ٢                               | * **                          |
| 5.                   | Sandwich  | panel struct                   | tures up to<br>om only one  | 0.75" th<br>side of    | ick ca<br>the pa | n be<br>nel.                    |                               |
| 4.                   | Inductio  | n heating fre<br>able for sand | equencies in<br>iwich panel | n the 4 -<br>applicat  | 10 Ko<br>101.    | r <sup>i</sup> ange             |                               |
| 3.                   | Inductio<br>alloy fl  | n heating off<br>ow in contour | fers a methored sandwich    | od of elf<br>n panel b | minati<br>razing | lng -                           |                               |
| 2.                   | $\epsilon^{1}$ A major the braz   | asset of this<br>ing can be ad | s method is<br>complished   | the spee               | d at w           | nțch<br>!                       |                               |
| 1.                   | Inductio<br>E honeycom  | n heating is<br>b sandwich pa  | a feasible<br>anels.        | method o               | f braz           | ing                             |                               |
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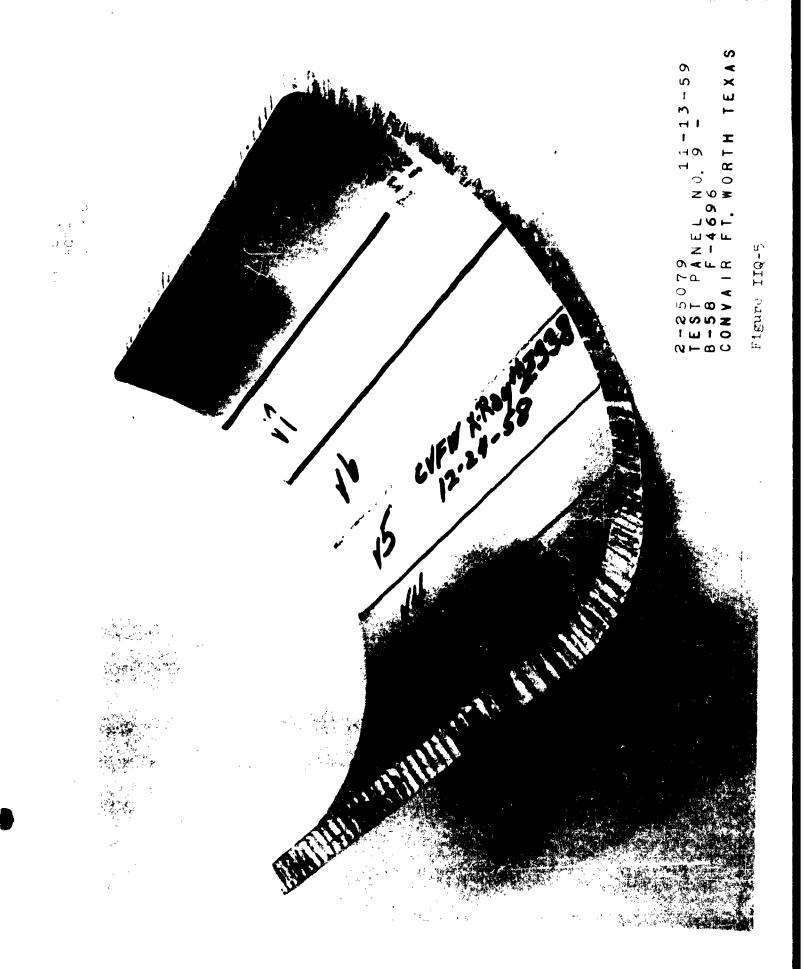






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| •     | SECTION III - BIBLIOGRAPHY:   |                 |                      |
|       | The results of some investigations on brazi   | ng 17-7PH ates  | 1 and 334            |
|       | related subjects, carried but by members of   | the Engineeri   | ng                   |
|       | Metallurgical Laboratory, have been describ   | ed in publishe  | d                    |
|       | Convair reports. These are listed below to  |                 |                      |
|       | of each. The abstracts are mostly verbatim  |                 |                      |
|       | the individual reports, giving the purpose<br>the various investigations.                   | and a summary   | UI I                 |
| r     |   |                 |                      |
|       | The results of the experimental work not pr   |                 |                      |
|       | by Convair are given in the present report.   |                 |                      |
|       | the unpublished data have been made availab<br>as memoranda, tables of test values, graphs  | Le Irom "time-t | o CIMe               |
|       | and other information to a limited number o   | f interested i  | ndivi-               |
| 1     | duals.  |                 |                      |
|       |   |                 | ·····                |
|       | 1. Z. R. Wolanski, 'Material - High T   | emperature Hon  | evcomt -             |
| · · · | Methods of Bonding - Determination  | of -", FGT-11   | 53,                  |
|       | November 5, 1953 26 pp. (F-4182).   | · · ,           |                      |
|       |   | · · · ·         |                      |
|       | ABSTRACT:   | ,<br>L 1        | 5.<br>1              |
|       | One purpose of this investigation was to de   | velop methoda   | of                   |
|       | bonding stainless steel skins to honeycomb  | core using hig  | h 🧃                  |
|       | temperature brazing alloys. Another purpos  | e was to deter  | mine                 |
|       | the optimum heat treatment for 17-7PH steel cold worked conditions.                         | in the anneal   | ea and               |
| · •   | cora narrege conarorons.  | r E             |                      |
| 1     | Six commercial brazing alloys were tested.  | These had flo   |                      |
| · ·   | points in the range of 1145 to 2100 F. Typ  | e 321 stainles  | s steel              |
|       | was used for skin material, and 17-7PH stee   | I was used for  | core.                |
|       | Microscopic examination of brazed panels sh   | owed that good  | fillets              |
|       | between the core and skins and good bond be   | tween the core  | ribbons              |
|       | at the spot welds were essential for satisf   | actory results  | •                    |
|       | Furnace brazing was found to be feasible for  | r both flat an  | d ourved             |
|       | panels After application of the brazing a   |                 |                      |
|       | assembled in a holding fitture and sealed in  | n an atmospher  | e ĝ                  |
|       | envelop of chamber. Resistance blanket bras<br>ities of practical application.              | zing presented  | possibil             |
| 1     | TOTED AT BUGOTCAT ADDITCHOTONS  | E E             |                      |
|       | For annealed ("A" condition) 17-7PH steel,  | the maximum te  | nsile 🕺              |
| ¥)    | yield and ultimate strength, together with  | relatively hig  | h 🤤                  |
|       | elongation, was obtained by the following he<br>tioned at 1400 F, quenched in water at 60 F |                 |                      |
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|       |                   | and ag      | ed at    | 900            | F for     | 2 hou                                   | rs. Hi                   | gh valu   | les wer  | e also                                | obte      | ined            |
|       |                   | by agi      | ng at    | 950            | F for     | 1/2 h                                   | bur to                   | 1-1/2 1   | hours.   |                                       |           | . · · ·         |
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|       |                   | elonga      | tion,    | was            | obtai     | ned by                                  | aging                    | at 900  | F for    | 1-1/2                                 | hours     | •               |
| · · · |                   | Highv       | alues    | were           | also      | obtai                                   | hed by                   | aging :   | for 1 h  | iour an                               | 1d 2 h    | ours.           |
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|       |                   |             | 22       | tpp.           | (F-46     | 96, Su                                  | pp1. 1)                  | -5.09   | <u>.</u> | در ـــ ر .<br>۱۱                      |           |                 |
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| ۰.    |                   |             |          |                |           |   | ed. The                  |   |          |                                       |           |                 |
| · • • | 1                 |             |          |                |           |   | bcedure:<br>h panel:     |   | orazing  | ; and n                               | eat t     | reat-           |
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| 1. Tu |                   | The re      | sults    | , of t         | his i     | nvesti                                  | gation :                 | Indica  | te that  | in br                                 | azing     | 17-7PH          |
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|     |             | 3/ S. D. Tannenbaum et al., "Manufacturing<br>Materials - High Temperature Brazing All<br>to Metal Sandwich Panel Construction - P<br>Evaluation of -", MR 54-5, April 20, 195<br>(F-4743).  | oy - Metal<br>reliminary              |
| • • | ۰.          | ABSTRACT:  | •                                     |
|     |             | The purpose of this investigation was to evaluate<br>cial brazing alloys for possible use in the manuf<br>comb sandwich panels in 17-7PH steel.  | several commer-<br>acture of honey-   |
|     |             | Each alloy was evaluated by brazing lap shear spe<br>sandwich pahels in a hydrogen atmosphere. The la<br>mens were tested in tension at room temperature a<br>Acceptable test panels were loaded as simple beam<br>at room temperature.              | p shear speci-<br>nd at 1000 F.       |
|     | ·           | Of five alloys tested, only one, a silver-base co<br>appeared to give satisfactory results. The other<br>tion and disintegration of the steel or quite def   | s showed penetra-                     |
|     |             | <ul> <li>4. P. F. Ghena, "Materials - 17-7PH, 302-3/<br/>321 Annealed - Strength and Size Effect<br/>Exposure to 1000 F - Determination of -"<br/>May 3, 1955, 21 pp. (F-4696, Suppl. 4)</li> </ul>  | on Repeated                           |
| •   |             | ABSTRACT:<br>The purpose of this investigation was to determin<br>of repeated exposure to 1000 F and subsequent coo<br>temperature on the tensile strength and dimension   | ling to room                          |
|     | •           | stainless steel alloys, including $17-7$ PH.   |                                       |
|     |             | The repeated exposures were made on specimens of<br>17-7 steel, aged at 1050 F. This material was in<br>sheet, .018" thick. The tests showed that exposu<br>seconds at 1000 F had no effect on the tensile st<br>dimensions of the 17-7PH specimens. | the form of<br>res for 30             |
| ÷   | •<br>•<br>• | <ol> <li>F. Ghena, "Empirical Data - Armco 17-<br/>Steel - Heat Treatment - Transformation<br/>tation Hardening - Effect of Time and Ter<br/>I FGT-1347, May 9, 1955, 77 pp. (F-4696).</li> </ol>  | and Precipi- 👘 🎉                      |
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| MODEL      | <u>FGT-2727</u><br>B-58 |
| DATE       | 1/19/61                 |

### ABSTRACT:

The purpose of this investigation was to examine various methods for the heat treatment of Armco 17-7PH steel and to determine the feasibility of combining the conditioning treatment with a low temperature brazing cycle for the production of sandwich panels. In addition, the effects of a conditioning treatment after a low temperature brazing cycle were studied.

Tensile and bend specimens were prepared from 17-7PH<sup>A</sup> steel sheet in thicknesses of .008", .04", and .040". For the study of conditioning treatments, the effects of various temperatures for times of from 5 to 60 minutes were investigated.<sup>A</sup> After the heating, some specimens were immediately quenched in water at 60 F. Others were cooled in air to room temperature in 15 or 60 minutes and then cooled at once to 0 or 60 F. Precipitation hardening was effected at several temperatures from 850 to 1050 F for periods of 10 minutes to 24 hours.

The .008" and .014" thick sheets were found to be relatively insensitive to conditioning variables of time and temperature. However, the .040" material required longer times at the lower temperatures to produce strengths comparable to those obtained at higher temperatures. The quench at 0 F was quite beneficial to the strength of specimens slowly cobled from the conditioning temperature.

The precipitation hardening temperatures of 950 F and below gave increased strength with increasing time at temperature up to 24 hours. By contrast, the temperatures 1000 and 1050 F gave decreased strength as the time was increased. A conditioning treatment of 90 minutes at 1400 F gave more uniform strength values, when the precipitation hardening was carried out at 1050 F, than the conditioning treatments for 30 or 60 minutes.

A correlation between Rockwell "C" and "D" hardness values and tensile strength was established for the .040" thick sheet. No correlation, could be established for the .008" and .014" .materials

| 6.                   | Re       | 'R. Wolanski<br>dwich Panel<br>Search - Tes<br>4696). | 8 - | npirical Da<br>Low Tempera<br>C -", FGT-1 | ture  | Brazed - | General |                        |  |
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| · ·   | ABSTRACT   |   | it in                              |
|       |  | Lation was to determine   | ·4 ·                               |
|       | The purpose of this invest<br>remelting temperature of se  |   |                                    |
| · ·   | relatively low melting point                               | hts. would increase subst   | tantially due                      |
|       | to loss of constituents on                                 | brazing. If the remelt  | Ing temperature                    |
|       | increased sufficiently, a 🤅                                | conditioning treatment at   | : 1200 F                           |
| · ·   | for 17-7PH steel might be                                  | carried out.  |                                    |
| ,     |  |   | No and hand and                    |
|       | Four brazing alloys were to<br>their remelting temperature | epice by several methods<br>by The neglite showed t                                     | that the                           |
|       | remelting temperatures of                                  | three allovs increased a  | njau une<br>poreciábly             |
| •     | from the original melting                                  |   |                                    |
|       | were not sufficient so that                                |   |                                    |
| · ·   | allovs could be heat treat                                 | ed after the brazing open   | ation. Heat                        |
|       | treating of sandwich panel                                 | s brazed with this alloy  | might be                           |
|       | accomplished provided that                                 | the heat treating proced  | lures are                          |
|       | suitably combined with the                                 | brazing to produce the I  | required                           |
|       | properties in sandwich pane                                | an a .  | ; ·                                |
|       | wich Panels - Low  | t the conditioning temper<br>i<br>Empirical Data - Stainles<br>Temperature Brazed - Ger | ss Steel Sand-<br>heral Research - |
|       | Tests of", FGT-13  | 52, July 15, 1955, 39 pp.   | (F-4696).                          |
| :     |  | 4   |                                    |
|       | ABSTRACTI:   | 1   |                                    |
|       | The purpose of this invest                                 | Agation was to determine  | whether the                        |
|       | conditioning treatment for                                 | landwich nonels in 17-71  | o¥isteói 👫                         |
| · ·   | the rate of cooling from the transformation could be ob    | , could be accomplished   | by controlling                     |
|       | the rate of cooling from the                               | e brazing temperature.  | If complete                        |
|       | transformation could be ob                                 | tained in the brazing pro   | ocess by                           |
|       | controlling, the cooling, ra                               | e, the usual conditionir  | ng treatment                       |
| 1     | could be eliminated.                                       |   | -<br>10                            |
|       | The results of this invest                                 | i<br>Ngation showed that when   | 17-7PH steel                       |
|       | sandwich panels are brazed                                 | at approximately 1800 F.  | complete                           |
|       | transformation will occur                                  | if the time of cooling fr   | om 1800 to                         |
|       | 1100 F is 1 hour or more.                                  | Thus, the conditioning t  | treatment at                       |
|       | He approximately 1400 F, could                             | d be eliminated provided  | that the                           |
|       | cooling time between 1800                                  | and 1100 F 18 1 nour or 1   | nore and the second                |
|       | panels are subsequently co                                 | qied to -20 F. increased  | 1700011ng                          |
|       | time beyond 1 hour slightl;                                | y decreased the ductifity   |                                    |
|       | sheet.   |   |                                    |
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|   | Panels brazed at 1900 F to 2200 F did not of<br>unless the cooling time to 1100 F was incre<br>10 hours and the panels were subsequently of<br>the ductility was reduced with increasing of | eased to approximately cooled to -20 F. Again, |
|   | A precipitation hardening treatment at 1050<br>should be used in processing 17-7PH steel a<br>strength is a critical design factor. A tr<br>for 90 minutes should be used when ductilit     | sandwich panels when<br>reatment at 1075 F     |
|   | 8. F. C. Nordquist, "Sendwich Panels<br>Production Brazed - Structural Eve<br>FTDM-1826, January 3, 1958, 5 pp.   | aluation - Tests of -", 7                      |
|   | ABSTRACT:   |  |
|   | The purpose of this investigation was to de<br>the service failure of two wing trailing ec<br>and 4T013-2, in 17-7PH steel brazed with 85<br>alloy.   | ige panels, 4T012-2                            |
|   | Examination showed that delamination of the occurred on both panels. The delamination corrosion at the braze alloy steel interiad   | was caused by crevice                          |
|   | 9. W. M. Pratt, "Materials - Brazing<br>pf -", FGT-1362-1, March 3, 1958,   |  |
|   | ABSTRACT:   |  |
| • | The purpose of this investigation was to find that would have all the characteristics des of sandwich panels in 17-7PH steel.   | ind a brazing alloy<br>sired for the brazing   |
|   | Twenty-one commercial brazing alloys, thoug<br>characteristics for brazing sandwich panels<br>tested. The most promising of these alloys<br>with the object of eliminating the undesire     | , were selected and<br>were nickel plated,     |
|   | and again tested.<br>Tests were carried out to determine the flo  | ) 11 <b>X</b>                                  |
|   | filleting of the alloy on 17-7PH steel. The<br>of the brazements was also determined. Lar<br>shear tests on brazed specimens were run fo  | e corrosion resistance                         |
|   | range -100 to + 900 F.  |  |
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The results of these tests showed that the nickel-base brazing alloys had the highest shear strengths at room temperature and elevated temperature. However, the elements added to reduce the melting points of the alloys had detrimental effects on the 17-7PH steel. Most of the silver-base brazing alloys were susceptible to corrosion in salt spray. An exception was sterling silver containing lithium, which held up very well. This composition exhibited the best combination of brazing qualities, on 17-7PH steel, of all the alloys tested. Nickel plating on the silver-base alloys improved their wetting on the steel-and also their resistance to corrosion. - However, the plating caused a slight reduction in the shear strength of the brazements at room temperature. No alloy was found that would fulfill all the requirements of an ideal brazing composition for 17-7PH steel sandwich ganels. W. M. Fratt, "Control Surfaces - Low Temperature Braze Material - Evaluation of -", FGT-2088, 10. 1 December 18, 1958, 36 pp. (F-7545). ABSTRACT: ' The purpose of this investigation was to select a brazing alloy for use in the repair brazing of 17-7PH steel sandwich panels. The extent of damage to the strength of the heat treated panels, caused by the localized temperature of the repair brazing, was also to be determined. To evaluate a brazing alloy for panel repair, a method for making brazed repairs on panels had to be first developed. Briefly, the adopted method consisted of brazing circular patches of 17-7PH steel, condition TH 1050, so as to cover a hole or tear in the panel, skin. The 97:3 silver-lithium alloy, nickel plated, was found to give the most satisfactory brazed repairs. A suitable brazing temperature was about 1250 F. The use of this brazing alloy, with the repair method developed, enabled reproducible repairs to be made on 17-7PH honeyognb sandwich panels. This brasing 11 procedure should be readily adaptable for field repairs.

|          | CON                 | VA                     |                                       |  |                           | PAGE <u>273</u><br>REPORT NO <u>FGT-2727</u>  |         |
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|          |                     |                        |                                       |  |                           |   | •       |
|          | The ten             | aile vie               | ld strength                           | of heat tre                                    | ated 17-7PH               | steel in  |         |
| •        | the area            | a of the               | braze was                             | of heat treat<br>reduced to an<br>lue, and the | oproximately              | y 40 to 45%   | ;       |
|          | of the o            | original               | TH 1050 Va                            | lue, and the                                   | ultimate st               | trength was   |         |
| · · · ·  | deorease            | ed. to <sub>2</sub> 65 | to 75%. I                             | he elongation                                  | n <sub>#</sub> was almost | t doubled.  |         |
|          | The land            | raat yor               | oin ottom                             | tal during th                                  | nte invocti               | gation, comprised   |         |
|          | a hole              | 2-1/2" 1               | n diameter                            | in one skin                                    | of a panel.               | gauron, computed  | 4       |
|          |                     |                        |                                       |  |                           | an a standar and the second second second second second second second second second second second second second |         |
|          | 11.                 | . Н. В.                | Farner, "M                            | aterials - I                                   | ron Sponge I              | Brazing   | -       |
| 1        |                     |                        |                                       | ental Evalua                                   |                           | FTDM-2270,  | -       |
|          |                     | imay 2                 | 2, 1999, 5                            | pp. (F-8619)                                   | •                         | 14<br>T   | -       |
|          | ABSTRACT            | T:                     | -                                     |  | -                         |   | -       |
|          |                     | -                      |                                       |  |                           |   |         |
|          |                     |                        |                                       |  |                           | e the effects   |         |
|          |                     |                        |                                       | and to 700 F<br>1 Bandwich pa                  |                           | an iron-sponge  | ,       |
|          |                     |                        | • •                                   | · · ·  |                           |   | •       |
|          | • A small           | test,pa                | nel was bra                           | zep with 92.                                   | B#7:0.2 Ag-0              | Cu-L1 alloy<br>i shear beam<br>de on these  |         |
|          | incorpoi            | rated in               | <b>iro</b> n spong                    | e. Edge com                                    | pression and              | d shear beam  |         |
|          | specimer            | ns were                | cut from th                           | e panel. Te                                    | sts were mad              | de on these   |         |
|          | specimer            | ns with                | and without                           | environment                                    | al exposure.              | . The results   |         |
|          |                     |                        |                                       | 0 hours to si<br>quite advers                  |                           |   |         |
|          |                     |                        |                                       | ngth. The 1                                    |                           |   | ٠       |
|          | unsatis             | factory                | for brazeme                           | nts to withs                                   | tand the cor              | nditions given.   |         |
| ,        |                     |                        |                                       |  |                           |   |         |
| •        | 12.                 | H.B.                   | Farner, "M                            | aterials - S:                                  | llver-Copper              | r-Lithium   | Ĺ       |
|          |                     | Fffec                  | ng Alloy -                            | ten Temperati                                  | ire On - Str              | Brazed With -   | •       |
| • .      |                     | Evalu                  | ation of -"                           | , FTDM-2355,                                   | October 12                | , 1959, 6 pp.   | *       |
|          |                     | <b>(</b> F-87          |                                       |  | •                         |   |         |
| . • .    |                     | . : )                  | 3                                     | ł  | <                         | .1 ''   | ,       |
|          | ABSTRACT            |                        | ý                                     |  | •                         | .x' 1   | $\cdot$ |
|          | The nur             | pose of                | this invest                           | igation was                                    | to determine              | the effect of   | å       |
| •        | oxidatio            | on in ai               | r at 700 F                            | on brazements<br>steel sandw:                  | s made with               | 92.8:7:0.2  |         |
|          | Ag-Cu-L             | i allóy                | in a 17-7PH                           | steel sandw:                                   | lph panel.                |   |         |
|          |                     |                        | 3<br>                                 |  | E<br>In have been         | han Anna Anna   |         |
| ;        | Specimer            | ns ror e               | age compres                           | sion and she                                   | ET Deam test              | with and without  |         |
|          | the exp             | omire in               | dicated.                              | he time perio                                  | ds of expos               | sure were from  |         |
|          | 100 to              | 300 hour               | 8.                                    |  |                           | 1   |         |
| 1        |                     | - ] # "<br>(           | t<br>n                                |  | I                         | 19<br>1 - 5<br>84   |         |
|          |                     | - 1                    | 4                                     |  | a e e                     |   |         |
|          |                     | l L                    | י<br>ז                                |  | <b>,</b>                  |   |         |
| •        |                     |                        |                                       |  | C                         |   | •       |
|          |                     | - A - 5                | , , , , , , , , , , , , , , , , , , , | l.   |                           |   | 4       |
| 1. 1. 1. | н                   | . 7                    | •<br>•                                | 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1          | 4 y y                     |   | •       |
|          |                     |                        |                                       | · ·  | *                         | 1 <sup>1</sup>  |         |

### C N V A 0 R A DIVISION OF GENERAL DYNAMICS CORPORATION (FORT WORTH)

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| PAGE       | 274          |
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| REPORT NO. | FGT-2727     |
| MODEL      | <b>B-</b> 58 |
| DATE       | 1/19/61      |

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|    |   |  |
|    |   |  |
|    | The test negulate should the              |  |
| ۰. | The cest results showed that              | after exposure, specimens with   |
|    |   | hs equal to or greater than specimens  |
|    | in the unexposed, as-brazed               | condition.   |
|    | A new turbe of compositor of              |  |
|    |   | razed 17-7PH steel was observed  |
|    | during this investigation.<br>determined. | The mechanism of the attack was not  |
|    | de terminea.                              |  |
|    | 13 W M Pratt "Mat                         | rials - Brazed Stainless Steel   |
|    | Sandwich Panels                           | Butt-Welded Facings - Evaluation   |
|    | Test of -". FTDM-                         | Butt-Welded Facings - Evaluation<br>433, December 20, 1959,  |
|    | 12 pp. (F-8213).                          | E C  |
|    |   | K  |
|    | ABSTRACT: L                               | ł _  |
|    |   | • • •  |
|    |   | ation was to evaluate butt-welded  |
|    | facing material in 17-7PH s               | teel for sandwich panels, as supplied  |
|    | by the Airline Welding Comp               | iny, Solar Aircraft Company, and   |
|    | Rohr Aircraft Corporation.                | Convair requirements for this  |
|    |   | pecification FPS-0038, paragraphs  |
|    | 3.4 through, 3.5.2.                       | *  |
|    |   |  |
|    | The welded sheet material w               | as supplied, in various thicknesses.   |
|    |   | ated in simulation of a production   |
|    | ware run the wolds in the                 | axial tension-tension fatigue tests pecimens being at the center of the  |
|    | reduced section.                          | spectments pering at one califer of the  |
|    |   | 5  |
|    | All the welded specimens par              | used the Convair tensile specification.  |
|    | None met the fatigue requir               | ements. E c  |
|    |   |  |
|    |   | erials - Honeycomb Core R4bbon -   |
|    | - Relationship Betwe                      | en Flow Characteristics of Brazing   |
|    | Alloy and Oxide H                         | Im Formation of - Determination<br>February 2, 1960, 21 pp., (F-8225).   |
|    | $\varepsilon$ or -, rur-2540, t           | repruary 2, 1900, 21 pp., $(r-0.225)$ .  |
|    | ABSTRACT                                  |  |
|    | ADDITIAUT,                                |  |
|    | "Mottled braze" conditions                | and variable fillet formation and  |
|    |   | s of honeycomb sandwich panels in  |
|    | 17-7PH steel have been the                | ause of panel scrappage at both  |
|    | Convair and sub-contractors.              | Tests have established that the  |
| •  | difficulties are due to' the              | presence of oxide films on the   |
|    | honeycomb core. These oxide               | films are attributed to variations   |
|    | in the quality of the hydrog              | en atmosphere in the annealing   |
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|                |   |                                      | FGT-2727        |
|                | A DIVISION OF GENERAL DYNAMICS CORPORATION  | MODEL                                | B-58<br>1/19/61 |
|                | (FORT WORTH)  | DATE                                 | 1/12/01         |
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|                |   |                                      |                 |
|                | furnaces of the foil producers.   |                                      |                 |
| •              | Turnaces of the fort producers.   |                                      | •               |
| •              | The purpose of this investigation was to determine<br>relationship between the flow characteristics of a<br>and the oxide films found on 17-7PH foil, (2) the<br>tics and identity of the films, and (3) methods by<br>formation of films can be controlled during the re-<br>annealing of 17-7PH foil. | a brazing<br>character<br>v which th | 18- ·           |
|                |   |                                      |                 |
|                | Convair-HW and the Armco Steel Corporation collabo  | orated in                            |                 |
|                | carrying out the program of investigation.  | II -2                                |                 |
| •.             |   | < ~                                  |                 |
|                | 17-7PH foil, .0015" thick, representing two heats,  | was anne                             | aled            |
|                | by the Armco Research Laboratories by heating in h  | vdrogen" g                           | 'A <b>S</b>     |
|                | of different dew points. The presence of water ve   | apor in th                           | ne -            |
|                | hydrogen of high dew points caused the formation of   | of a unifo                           | rm              |
|                | oxide coating on the surfact of the foil. Specime   | ens of 17-                           | 7 PH            |
|                | foil, .0015" thick, representative of the inventor  | v of Johr                            | J.              |
|                | Foster Mfg. Company, honeycomb core manufacturer,   | Costa Mes                            |                 |
|                | Calif., were obtained. Three heats were included,   | and sned                             | 1_              |
|                | mens from each were forwarded to Armco.   | and spec                             |                 |
|                | mene 11 ch. eden were rerwarded to Armos  | ] "                                  |                 |
|                | Sandwich turne braging flow togta ware mus on same  | 1.2 0                                |                 |
|                | Sandwich, type, brazing flow; tests were run on samp  | les irom                             | all             |
|                | the above heats, using the \$2.8:7:0.2 Ag-Cu-Li bra   | izing allo                           | У.              |
|                | The results of the flow tests were compared with t  | he result                            | S               |
|                | of other tests, as listed below, in an attempt to   | find a co                            | rrela-          |
|                | tion. The object of this was to find a reliable t   | est by wh                            | ich             |
|                | acceptable brazing flow, response of 17,7PH foil co   | uld be de                            | termined-       |
|                | before manufacture into relatively expensive honey  | comb core                            | •               |
|                | The tests for comparison with brazing alloy flow w  | ere:                                 | ֥               |
|                |   | A P                                  | · _             |
|                | 1. Determination of polor and reflectance v   | alues of                             | ÷               |
|                | surface films as bbtained from spectroph  | othetric                             | •               |
|                | measurements. These values were determi   | ned by                               | , .             |
|                | The Derby Company, Inc. Lawrence, Massac  | husetts.                             | •               |
|                |   |                                      |                 |
|                | 2. Electron diffraction of surface films, p   | errormed                             | by              |
| . 1            | the Armco Steel Corporation, Research De  | partment.                            | J.              |
| · •            | , Middletown, Opio.   | •                                    |                 |
| . · · ·        |   | e a                                  |                 |
|                | 3. Ferric chloride etching. This was also   | carried h                            | ot              |
| 1              | by the Armco Research Department.   | 5                                    |                 |
|                |   | 5 . 5                                |                 |
|                |   | <u>i</u> r                           |                 |
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|-----------------------------|-----------------|--|---------------------|
| CONV                        | A I K '         | 1  | REPORT NO. FGT-2727 |
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|                             |                 |  |                     |
| An entertas 234             |                 |  | the broging flow    |
| AS OFIGINALLY               | planned, roll   | wing completion of                             | took at the         |
| John J. Roste               | r Mfg. Co h     | to be made from the s<br>lying the best and wo | rat flow            |
| characteristi               | cs. The core    | was to be processed                            | into honeycomb      |
| sandwich pane               | ls by Convair   | and tested. The pur                            | pose was to         |
| correlate bra               | zing alloy flo  | ow characteristics wi                          | th the properties   |
| of production               | sandwich pan    | s. However, when t                             | the flow tests      |
| had been fini               | shed, foil con  | responding to the sp                           | ecimens tested      |
| was no longer               | avalladie at    | the Foster Company.                            | N                   |
| With the deve               | lopment of a    | pactical brazing flo                           | ow test. experi-    |
| ments were un               | dertaken to de  | etermine the effect o                          | of cleaning         |
| methods on 17               | -7PH foil hav   | ing poor wetting qual                          | lities. The object  |
| was to determ               | ine whether the | ne flow on foil unsat                          | tisfactory for      |
| core producti               | on could be in  | nproved by cleaning.                           |                     |
|                             |                 | i has the Converte                             | meduation mothod    |
| Some tests of               | specimens cl    | eaned by the Convair<br>ras the effect on bra  | zing allov flow     |
| Were inconcil               | ted testing o   | fisnecimens having Do                          | or flow indicated   |
| a pronounced                | improvement 1   | f specimens having po<br>flow after ultrason   | nic cleaning of the |
| I had motal of              | · Convola ()n   | the other hand, some                           | s spectmens         |
| ultrasonical                | ly cleaned at 1 | Bendix Aviation Corpo                          | oration did not     |
| yield good f                | LOW.            | 1  | W C                 |
| No. a sugar de de           | n has been fo   | und between laborator                          | ry brezing flow     |
| No correlation              | on has been to  | ctance, electron diff                          | Fraction of         |
| surface films               | . ferric chlo   | ride etching, or the                           | chemical composi-   |
| tion of 17-7H               | PH foil.        |  |                     |
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|---|-------|------------------|--------------------------------------|---|---|---------------|
|   |       |                  |                                      | SUP   | PLEMENTAL INFORMATION   | •             |
|   | Thi   | .s re<br>A.<br>! | Spec<br>spec<br>hone<br>wich<br>in t | ificatio<br>imens an<br>ycomb sa<br>panel t<br>his repo | emented with the following information:<br>h FMS-0036 is referenced for<br>d test procedure for brazed<br>hdwich panels. The only sand-<br>est specimens tested and reported<br>rt are flatwise compression. This<br>h is prepared and tested as follows: | <b>;</b>      |
|   |       | ,<br>R<br>-      | 2.                                   | thicknes<br>All edge<br>sandèd s                        | size is 2.00" x 2.00" x panel-<br>s.<br>s of specimens are filed and -<br>nooth to remove nicks and saw cuts<br>ght induce premature failure.   | Biss P. State |
| 1 |       |                  | ~                                    | <b>m</b> l  |   |               |

- 3. The specimen is placed in a 60,000 pound Baldwin universal testing machine, and the loading head and platen checked for parallelism.
- 4. A compressive load is applied to the test specimen at a rate of 8,000 pounds per minute until failure.
- B. Flash testing as referred to in this report is a nondestructive test procedure for brazed steel sandwich panels. It consists of flash heating 4.0" dia, circular areas of the panels to a temperature up to 800°F within four seconds.
  This is accomplished with a radiant heating apparatus utilizing heating elements similar to the General Electric Type T-3 quartz envelope. The apparatus is equipped with an automatic timing and control device. U. S. Patent No. 3,008,029 dated 7 November 1961 has been issued covering such an apparatus.

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