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TECHNICAL REPORT NO. 11891

REFERENCE RADIOGRAPHS FOR FULL
PENETRATION ALUMINUM WELDMENTS

JUNE 1974



by MELVIN V. PYHTILA, WALTER F. WULF

TACOM

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VEHICULAR COMPONENTS & MATERIALS LABORATORY

U.S. ARMY TANK AUTOMOTIVE COMMAND Warren, Michigan

20031219004

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REFERENCE RADIOGRAPHS FOR FULL
PENETRATION ALUMINUM WELDMENTS

BY
WALTER F. WULF
MELVIN V. PYHTILA

JUNE 1974

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ARMOR, MATERIALS & COMPONENTS DIVISION

ABSTRACT

Standard reference radiographs were selected from weld flaw specimens fabricated from aluminum plate of various thicknesses to establish a military document containing reference radiographs for quality control of full penetration aluminum weldments. The various types of flaws known to occur in full penetration aluminum welds were prepared with production reproducible welding procedures, and were radiographically graded according to pre-established severity levels.

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Section A - Reference Radiographs for Full Penetration Aluminum Welds (1/16" to 1/4" Thickness Range)	
Section B - Reference Radiographs for Full Penetration Aluminum Welds (3/16" to 1/2" Thickness Range)	
Section C - Reference Radiographs for Full Penetration Aluminum Welds (Over 1/2" to 1" Thickness Range)	
Section D - Reference Radiographs for Full Penetration Aluminum Welds (Over 1" to 2" Thickness Range)	
Section E - Illustrations of Ungraded Flaws	

ACKNOWLEDGEMENT

Appreciation is expressed for the excellent welding service furnished by personnel of the Armor Function and Experimental Division. Through their technical proficiency, the difficult task of achieving the designated weld flaw types and quality levels was accomplished at an unprecedented 50% efficiency factor.

This project has been accomplished as part of the US Army Materials Testing Technology Program, which has for its objective the timely establishment of testing techniques, procedures or prototype equipment (in mechanical, chemical, or nondestructive testing) to insure efficient inspection methods for materiel/material procured or maintained by AMC.

INTRODUCTION

The increasing use of aluminum in the fabrication of military hardware has brought into focus the need for a document to provide universal quality control for full penetration aluminum weldments.

In accordance with project authorization from Army Materials and Mechanics Research Center, this task was established under the Materials Testing Technology Program. The effort was determined necessary since there are no standard reference radiographs presently available for full penetration aluminum welds in the thickness ranges required for Army application.

OBJECTIVE

Establish standard reference radiographs for full penetration aluminum weldments ranging in thickness from 1/16 inch to ²/₁ inches.

SUMMARY AND CONCLUSIONS

Standard reference radiographs displaying graded and ungraded illustrations of flaws found in full penetration aluminum weldments were established. Completion of the document provides the means for establishing universal quality assurance standards for military hardware containing full penetration aluminum welds.

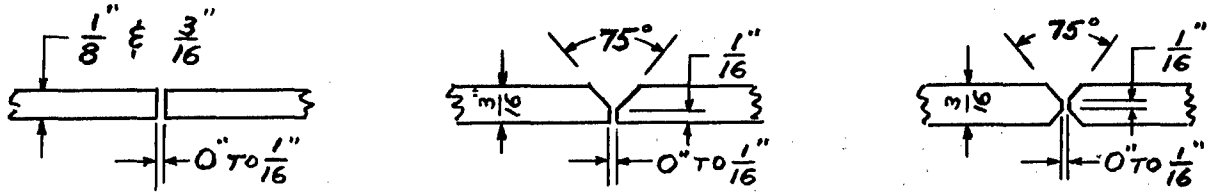
TEST MATERIAL

1. Wrought aluminum alloy plates, types 6061 and 5083, 1/8", 3/16", 3/8", 3/4" and 1-1/2" thick.
2. Electrode wire of varying sizes for the MIG and TIG welding process of aluminum.
3. Argon shielding gas, welding grade, 99% pure (TIG).
4. Argon shielding gas, welding grade with 1% oxygen added (MIG).
5. Industrial X-ray film, size 4-1/2 x 17", fine grain.
6. Commercial photographic copy film, size 4 x 5".
7. Photographic projection print paper.

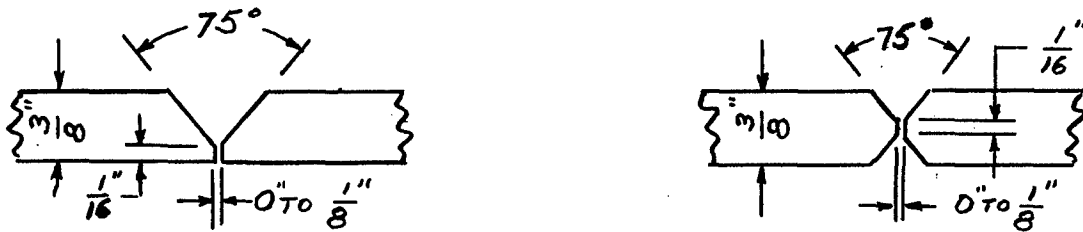
TEST EQUIPMENT

1. Constant-arc voltage rectifier power source, 500 ampere capacity, for the inert gas consumable electrode welding process.
2. An AC-DC, 300 amp, power source for the inert gas tungsten arc welding process.
3. Industrial X-ray machine, 250 KVP, 10 MA capacity.
4. Commercial, 4 x 5", view camera.
5. Commercial, 4 x 5", condenser type photographic enlarger.

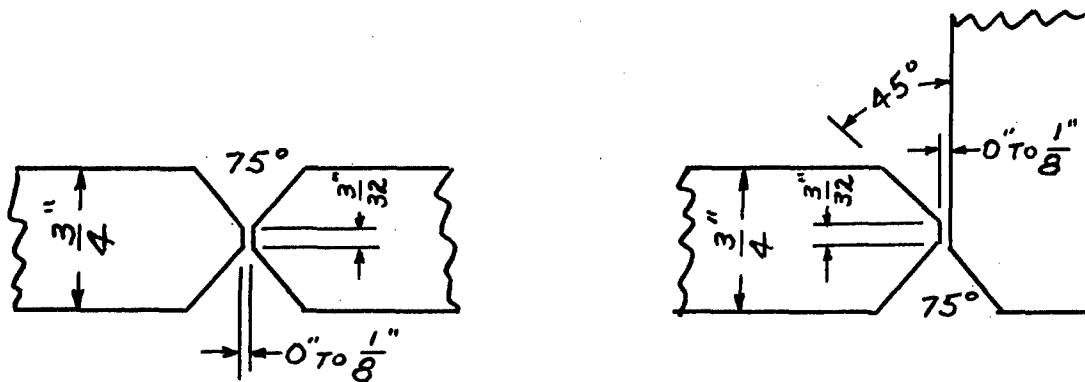
Section A (1/16" to 1/4" Thickness Range)



Section B (3/16" to 1/2" Thickness Range)



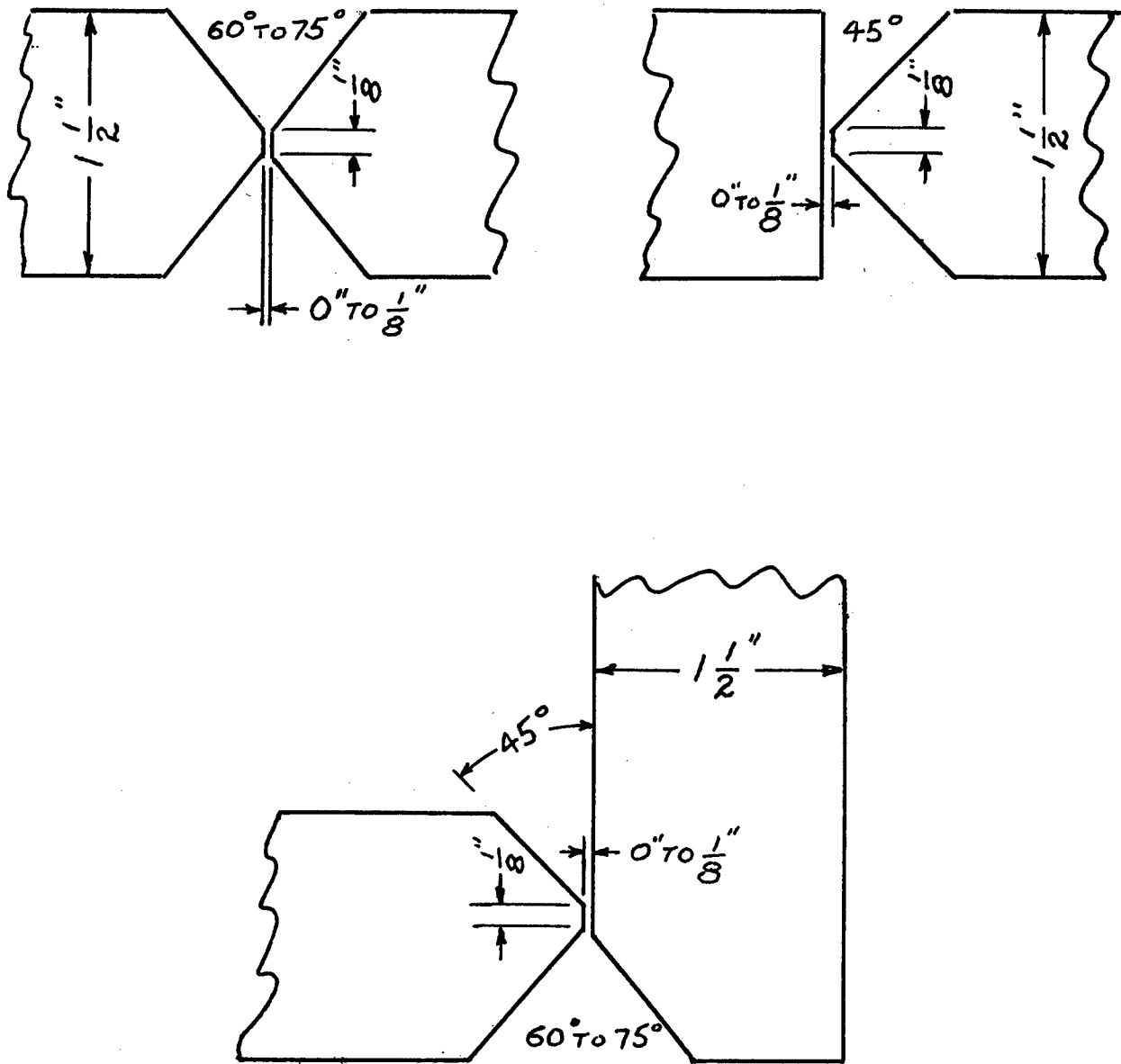
Section C (Over 1/2" to 1" Thickness Range)



WELD JOINT DESIGNS USED ON FLAW SPECIMEN PLATES

Figure 1

Section D (Over 1" to 2" Thickness Range)



WELD JOINT DESIGNS USED ON FLAW SPECIMEN PLATES

Figure 2

TEST PROCEDURE

1. Weld Plate Preparation:

Plate size and thickness used for each of the four thickness ranges are as follows:

	<u>Thickness Range</u>	<u>Master Plate Thickness</u>	<u>Plate Size</u>
Section A	1/16" to 1/4"	1/8" & 3/16"	6" x 15"
Section B	3/16" to 1/2"	3/8"	6" X 24"
Section C	Over 1/2" to 1"	3/4"	8" x 30"
Section D	Over 1" to 2"	1-1/2"	10" x 30"

Edge preparation for the weld groove was accomplished by sawing and hand grinding. A few plates requiring a more precise fit were machined. Joint designs used for each weld thickness range are illustrated on Figures 1 and 2.

2. Welding Procedure:

Two welding processes were employed. The gas tungsten arc (TIG) process was used on the 1/8" and 3/16" plates comprising Section A. These plates cover the thickness range from 1/16 to 1/4 inch. The gas Metal Arc (MIG) process was used on the remaining plates.

3. Radiographic Examination

Radiography of the weld plates was performed in accordance with MIL-STD-453. A minimum quality level of 2 - 1T, representing 1.4% sensitivity was maintained for all exposures. The following radiographic technique was employed for the various size plates.

Plate Thick- ness	KV	MAS	FFD	SCREENS	Approx. Film DENSITY
1/8 in	80	150	36 in.	None	2.0
3/16 in.	80	180	36 in.	None	2.0
3/8 in.	80	325	36 in.	None	2.0
3/4 in.	100	700	48 in.	None	2.0
1-1/2 in.	150	550	48 in.	.005"	2.0

4. Metallographic Evaluation:

Weld cross sections were extracted from selected weld specimens for verification of radiographic findings. Photomicrographs were also made of typical flaw conditions for correlation with the reference radiographs.

5. Selection of Reference Radiographs:

Selection and grading of the radiographs was based on; (a) correlation of current USATACOM standards for partial penetration weldments (ATAC - STD-113 and 114), (b) Weld research programs conducted at USATACOM, and (c) Production welding problems experienced by government contractors.

6. Reproduction of Radiographs:

The original radiographs were photographically reproduced, utilizing a 4 x 5 inch view camera to copy the radiographic image as viewed with a fluorescent illuminator. Projection prints were then made from the copy negatives and assembled into a photo composite for each page of the document. Final lithographic reproductions were then made from the photographic composites.

RESULTS AND DISCUSSION

1. The primary objective of this effort was production of the standard reference radiographs. These are included as part of the report in five separately bound sections. Separate binding was performed to provide greater flexibility, and to accommodate later conversion of the document to either a TACOM or Military Standard.

2. Lithograph reproductions were selected for the final printing rather than film transparencies or photographic prints. This was done primarily to reduce cost and provide ease of application. When proper controls are exercised, lithographs will display 90% or more of the original print detail which is adequate for reference radiographs. The capability of viewing the radiographs with reflected light also permits wider use of the document by concerned engineering personnel that do not have X-ray viewing equipment.

3. Welding procedures used to produce the various flaws were for the most part those that could accidentally be performed in production. Following are the procedures found most effective for the flaws illustrated:

a. Scattered Porosity:

Water contamination of the shielding gas using the MIG process proved most successful on the 3/4" and 1-1/2" thick weld specimens. On the 1/8", 3/16" and 3/8", contamination of the joint face proved successful.

b. Linear Porosity:

This type of flaw occurs in full penetration aluminum plates as a result of entrapped gas emanating from the root area. The severity level varies depending on the cleanliness of joint interfaces and joint fit. The method used to produce the reference radiographs was by contaminating the root area of the joint.

c. Clustered Porosity:

On the 3/4 in. and 1-1/2 in. thick weld specimens, this flaw was achieved by intermittently disturbing the shielding gas with an air draft. On the 1/8 in., 3/16 in. and 3/8 in. thick weld specimens, the condition was obtained by contaminating selected areas on the joint interface with small amounts of oil and paint.

d. Tungsten Inclusions:

This condition occurs only with the TIG welding process. It usually happens when the tungsten electrode is accidentally inserted into the molten weld puddle during the welding operation.

e. Incomplete Penetration:

Most of the illustrations shown were achieved by reducing the welding current. This condition can also result from an improper gun position during the weld operation.

f. Lack of Fusion:

Most frequently this flaw is associated with incomplete penetration on aluminum weldments. It results from molten metal flowing beyond the point of penetration and filling most of the weld groove without fusing with the side walls. Unfortunately, however, it is often difficult to detect radiographically due to radiation angle problems. It is, therefore, considered as an integral part of incomplete penetration, and judged accordingly.

APPLICATION OF REFERENCE RADIOGRAPHS

1. The reference standards are a collection of radiographs illustrating types and degrees of weld flaws experienced in full penetration aluminum weldments. They are not quality level acceptance requirements; designation of required acceptable quality level should be made from the reference radiographs by the design agency.
2. The standards are intended to cover a weld thickness range from 1/16 to 2 inches. This may be extended to 3 inches, if applicable, at the discretion of the design agency.
3. Grading of the standards was based on correlation of existing specifications, welding research programs, and liaison with private industry. Standard 1 represents the highest quality normally expected in production welding which contains a few flaws to reserve a rating of "sound" for special applications. Standard 5 is designated as the lowest quality welds ever accepted in production welding. The intermediate standards are divided proportionally between 1 and 5.
4. Acceptance standards may be selected directly from one of five reference radiographs for all flaws illustrated except clustered porosity and incomplete penetration. Rules governing the standards for these flaws are specified on the appropriate illustrations in each section.
5. When only one type of flaw is present in the radiograph and is less severe than the specified quality level, the weld shall be regarded as radiographically acceptable. If the radiograph shows a flaw of greater severity than specified, the weld shall be rejected unless repair is permitted.
6. When two or more types of flaws are present in the same radiograph, the predominating flaw, if unacceptable, shall govern without regard to the other types of flaws.
7. When two or more types of flaws are present to an extent equal to that of the specified standard, the weld shall be judged unacceptable unless repair is permitted.

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13. ABSTRACT Standard reference radiographs were selected from weld flaw specimens fabricated from aluminum plate of various thicknesses to establish a military document containing reference radiographs for quality control of full penetration aluminum weldments. The various types of flaws known to occur in full penetration aluminum welds were prepared with production reproducible welding procedures, and were radiographically graded according to pre-established severity levels.			

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT

SECTION A

REFERENCE RADIOGRAPHS FOR FULL PENETRATION ALUMINUM WELDS

(TIG WELDING PROCESS)

THICKNESS RANGE
1/16" TO 1/4"

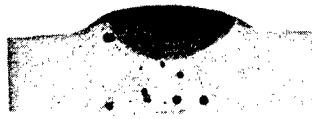


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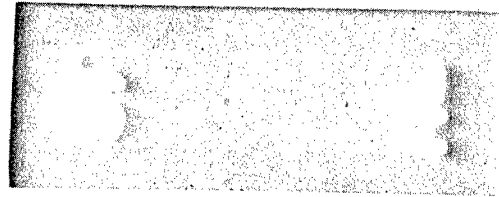
<u>Reference Radiographs</u>	<u>Page No.</u>
Fine Scattered Porosity	1A – 2A
Coarse Scattered Porosity	3A – 4A
Linear Porosity	5A – 6A
Clustered Porosity	7A
Tungsten Inclusions	8A – 9A
Incomplete Penetration	10A

FINE SCATTERED POROSITY

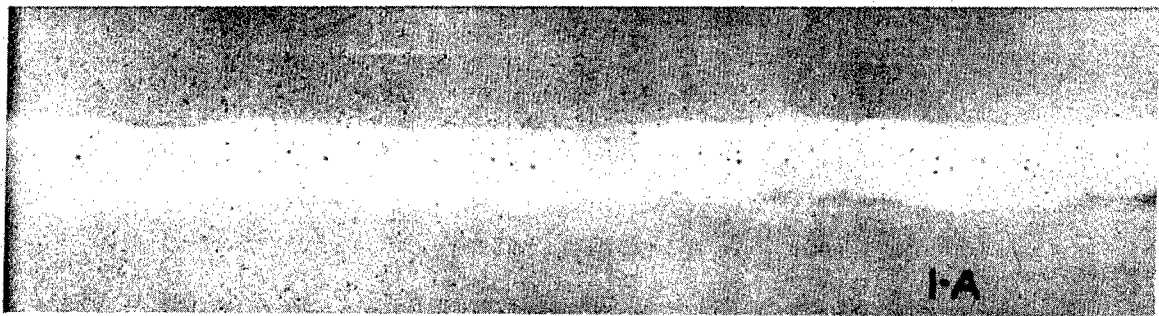
(1/16" to 1/4" Thickness Range)



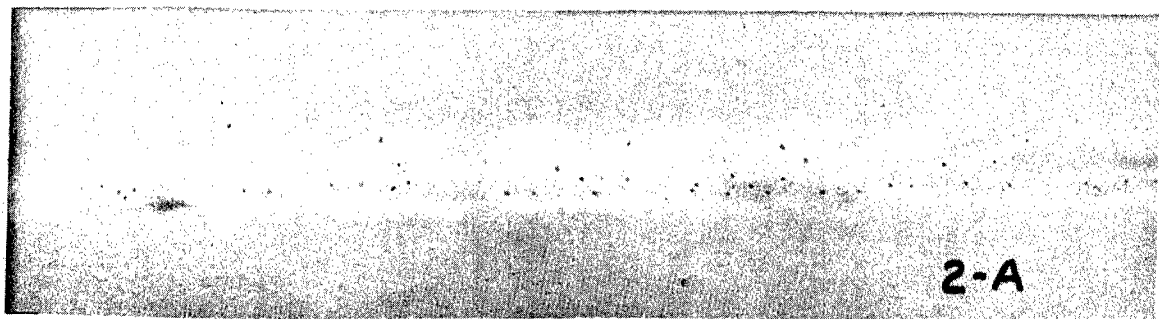
**Cross Section of
Fine Scattered Porosity
2X - Mag.**



**2-IT Radiographic
Quality Level**



STD. 1 (Approx. 6 Pores Per Sq. Inch)



STD. 2 (Approx. 12 Pores Per Sq. Inch)

1A

FINE SCATTERED POROSITY

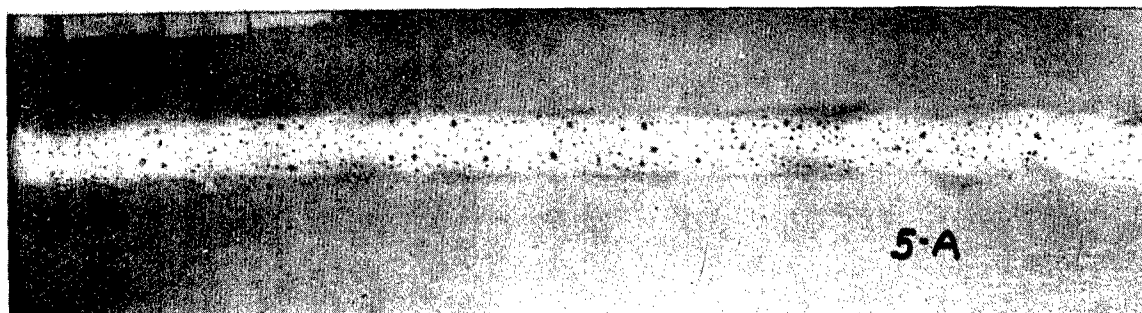
(1/16 to 1/4" Thickness Range)



STD. 3 (Approx. 25 Pores Per Sq. Inch)



STD. 4 (Approx. 50 Pores Per Sq. Inch)



STD. 5 (Approx. 100 Pores Per Sq. Inch)

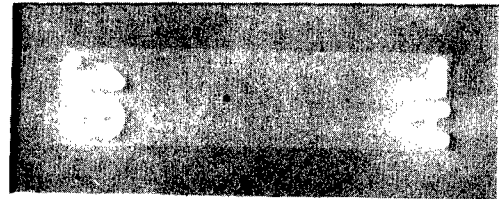
2A

COARSE SCATTERED POROSITY

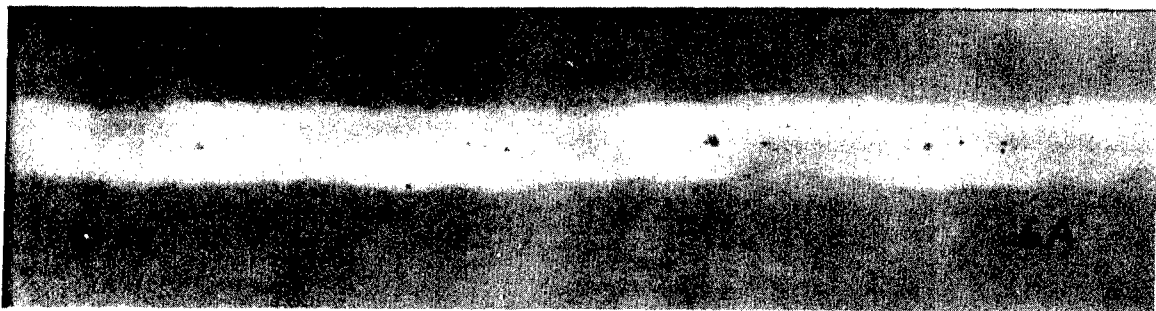
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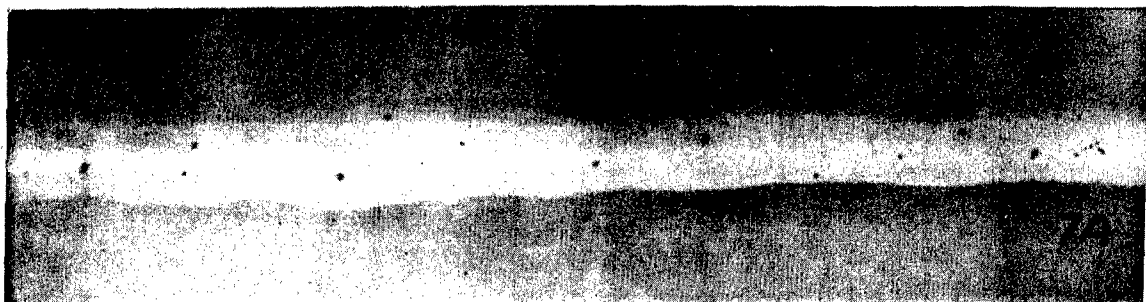
Cross Section of
Course Scattered Porosity
2X - Mag.



2-IT Radiographic
Quality Level



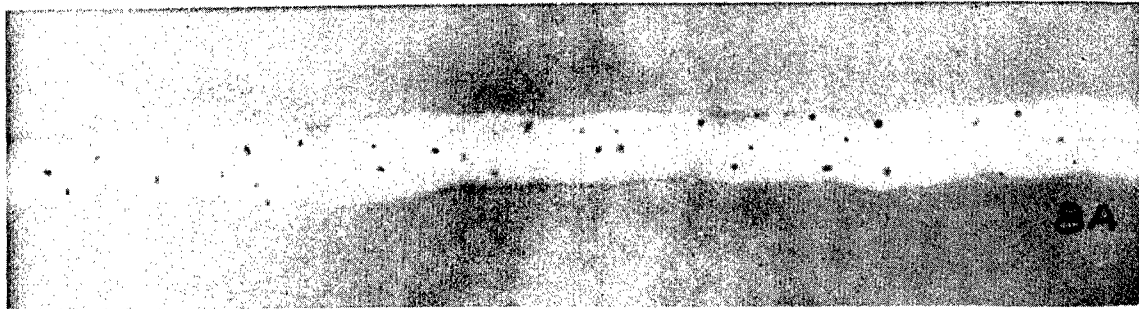
STD. 1 (Approx. 2 Pores Per Sq. Inch)



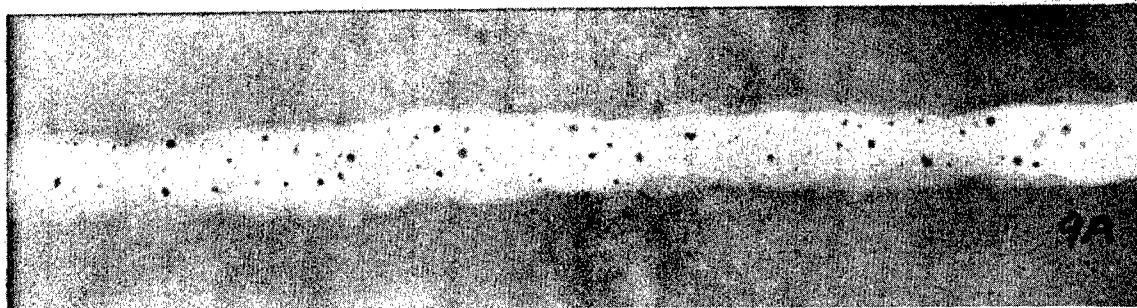
STD. 2 (Approx. 4 Pores Per Sq. Inch)

COARSE SCATTERED POROSITY

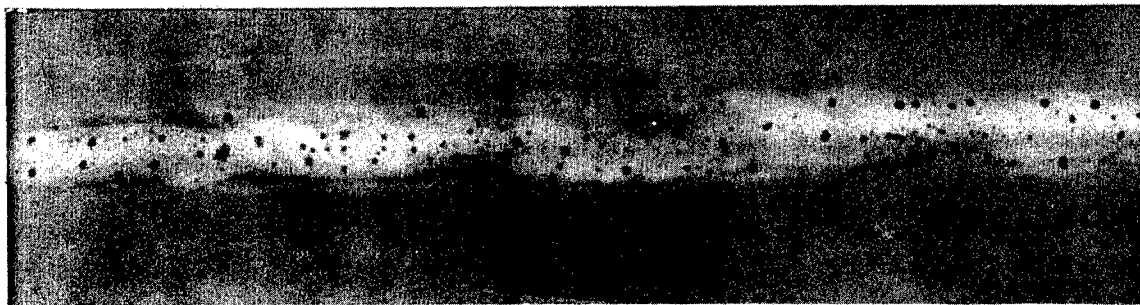
(1/16 to 1/4" Thickness Range)



STD. 3 (Approx. 8 Pores Per Sq. Inch)



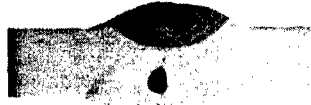
STD. 4 (Approx. 16 Pores Per Sq. Inch)



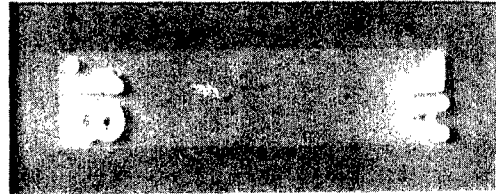
STD. 5 (Approx. 32 Pores Per Sq. Inch)

LINEAR POROSITY

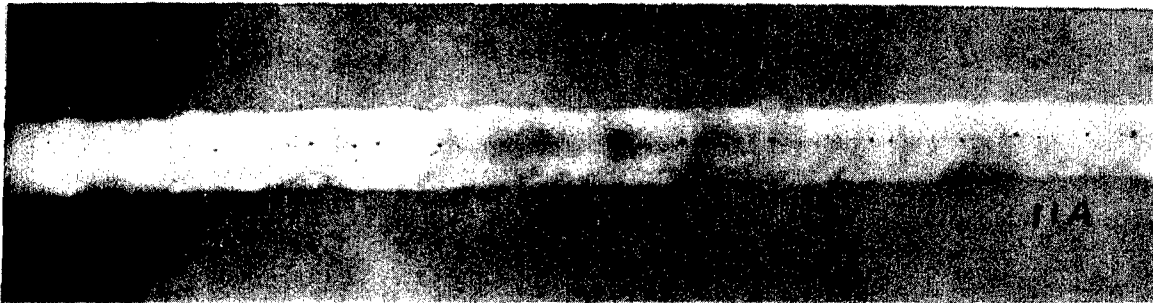
(1/16" to 1/4" Thickness Range)



**Cross Section of
Linear Porosity - 2X-Mag.**



**2-IT Radiographic
Quality Level**



STD. 1

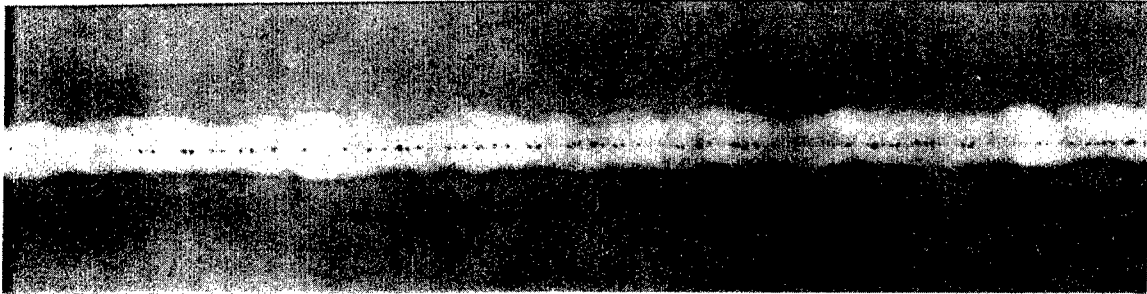


STD. 2

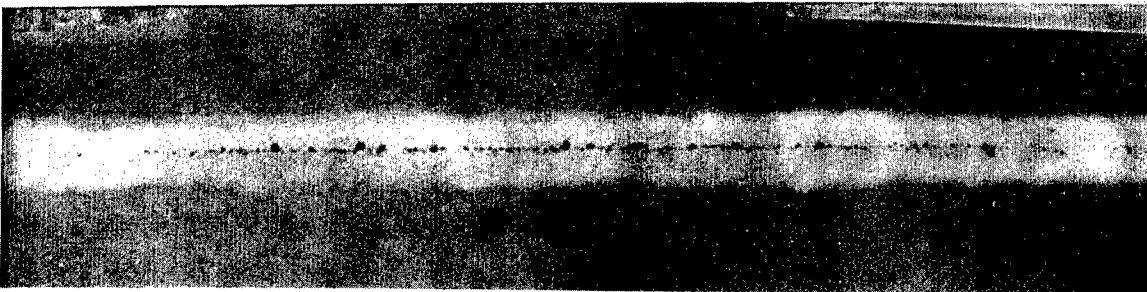
5A

LINEAR POROSITY

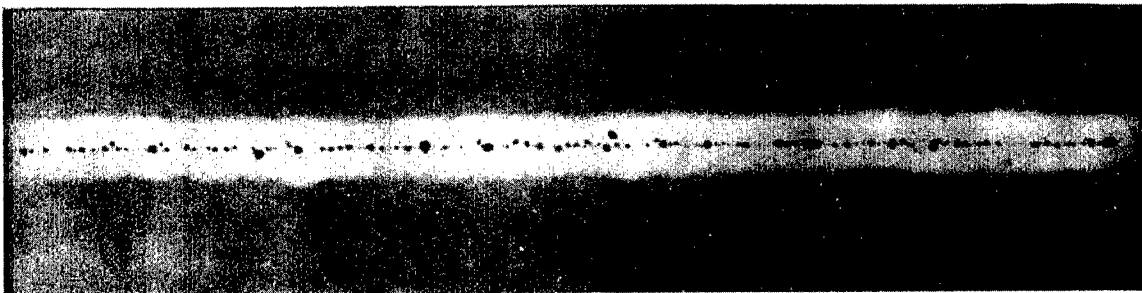
(1/16" to 1/4" Thickness Range)



STD. 3



STD. 4



STD. 5

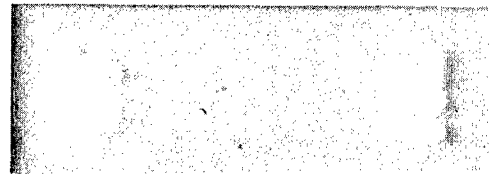
6A

CLUSTERED POROSITY

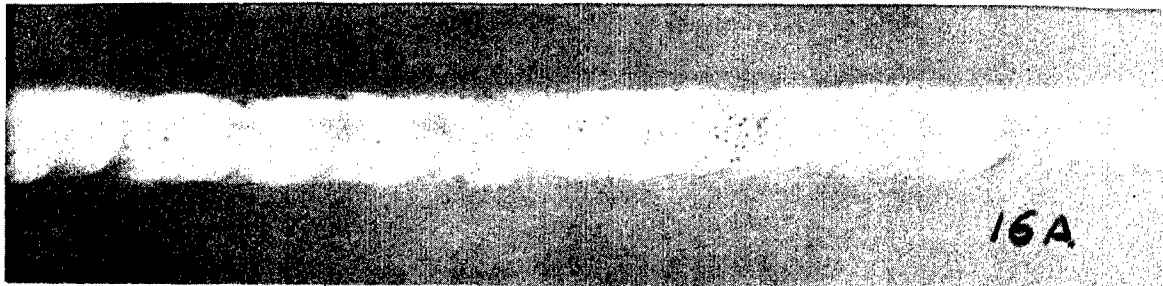
(1/16 to 1/4" Thickness Range)



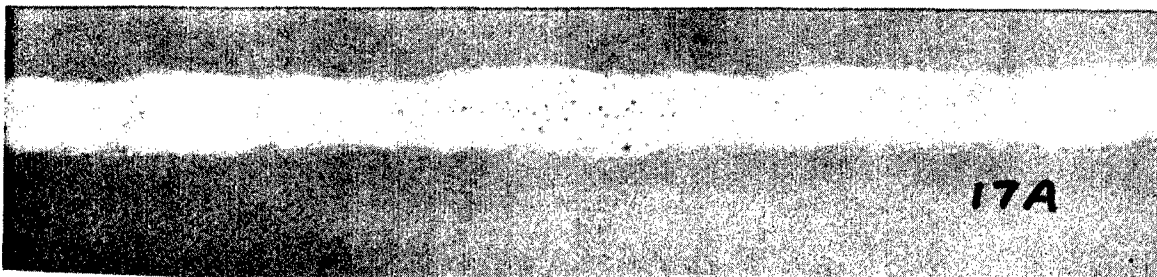
Cross Section of
Clustered Porosity - 2X-Mag.



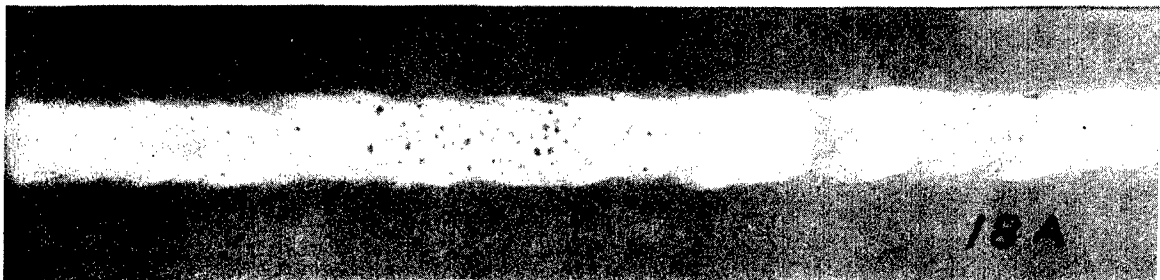
2-IT Radiographic
Quality Level



STD. 1



STD. 2



STD. 3

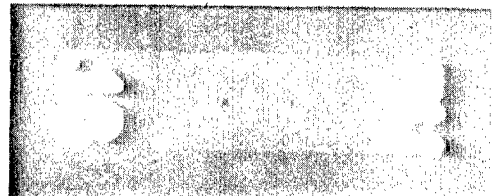
NOTE: Any condition more severe than Std. 3 shall be judged as scattered porosity.

TUNGSTEN INCLUSIONS

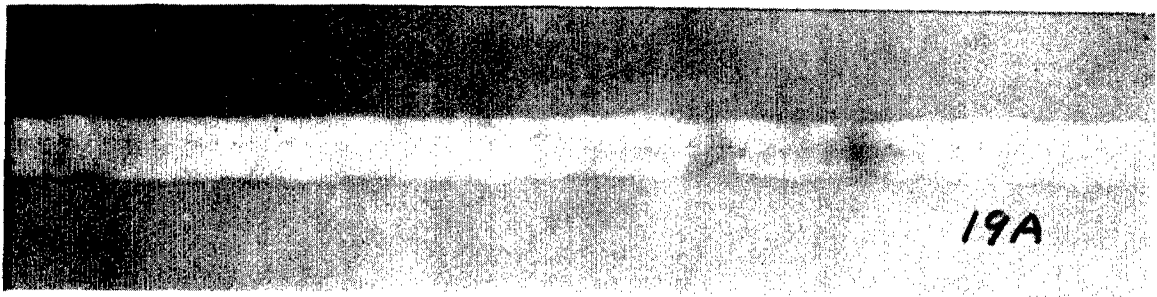
(1/16 to 1/4" Thickness Range)



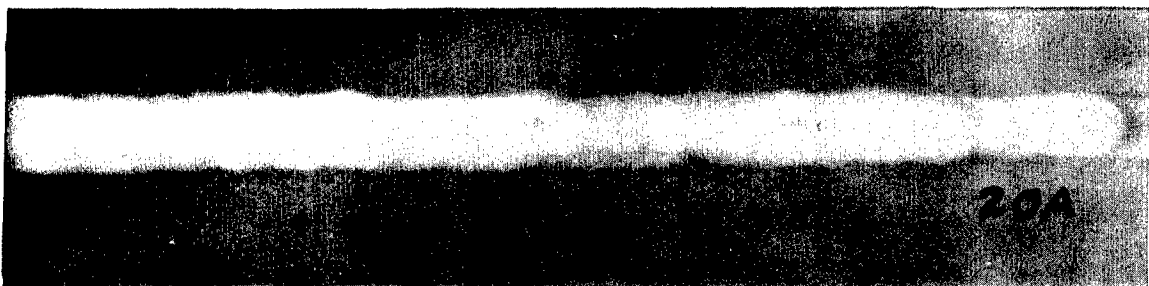
Cross Section of
Tungsten Inclusions - 2X-Mag.



2-IT Radiographic
Quality Level



STD. 1

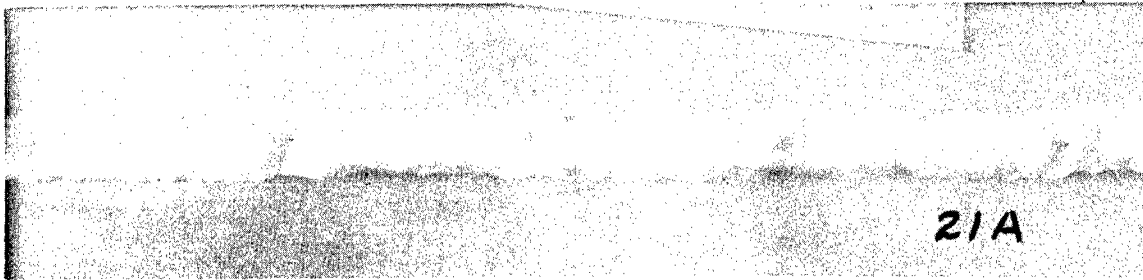


STD. 2

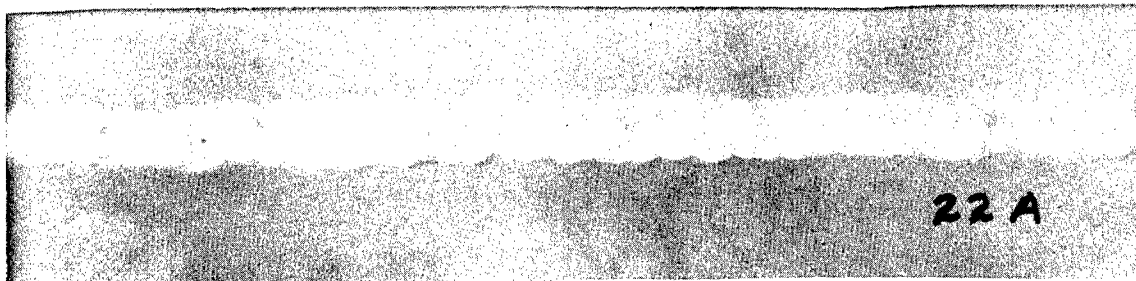
8A

TUNGSTEN INCLUSIONS

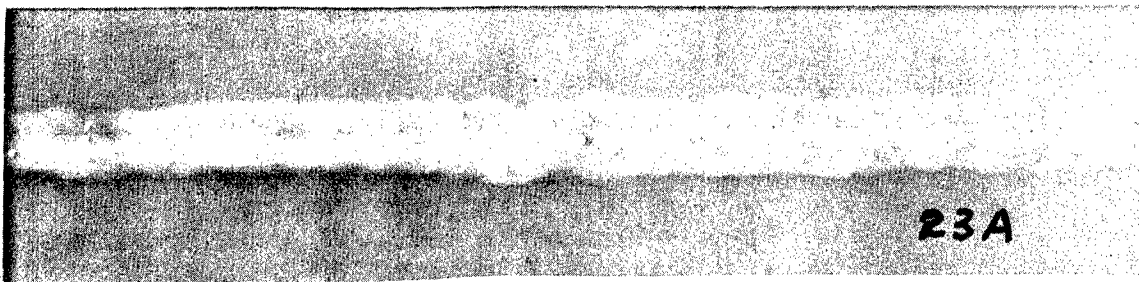
(1/16" to 1/4" Thickness Range)



STD. 3



STD. 4

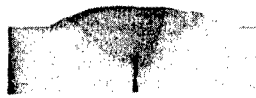
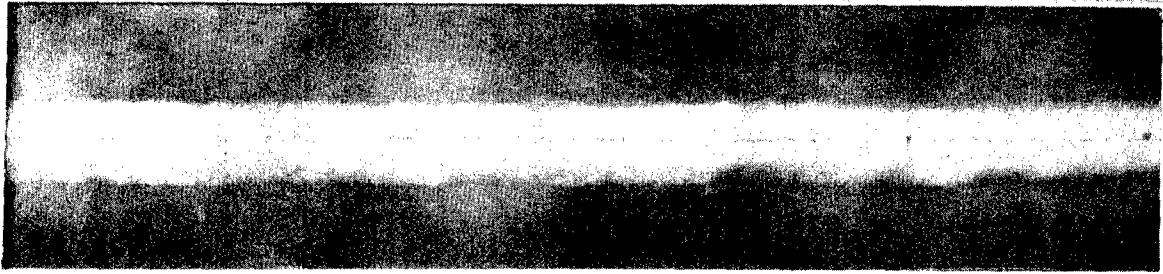


STD. 5

9A

INCOMPLETE PENETRATION

(1/16 to 1/4" Thickness Range)



2X - Mag.

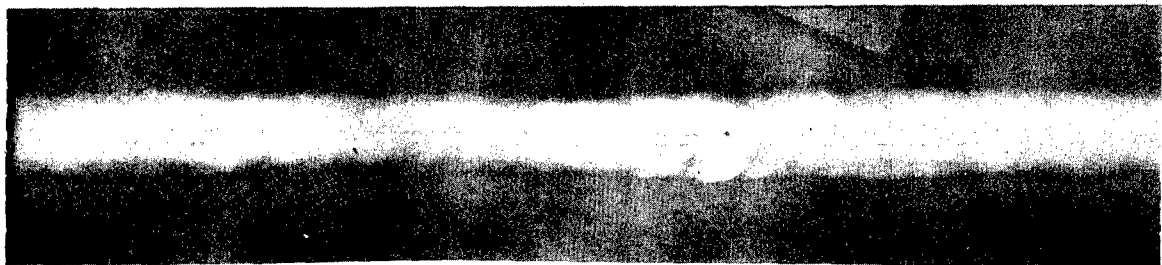


ABOVE - Cross section of two conditions that produce a single line image on the radiograph as shown.

BELOW - Cross section of two conditions that produce a double line image as shown.



2X - Mag.



ILLUSTRATIONS OF INCOMPLETE PENETRATION - Std. 1 - 1/2"
Reference standards are based on flaw length as follows: The accumulated length of flaw shall not exceed the limit stated for each standard in any 6 inch weld length.

Std. 2 - 1"
Std. 3 - 2"
Std. 4 - 4"
Std. 5 - 6"

SECTION B

REFERENCE RADIOGRAPHS FOR FULL PENETRATION ALUMINUM WELDS

(MIG WELDING PROCESS)

**THICKNESS RANGE
3/16" TO 1/2"**

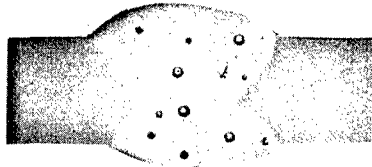


CONTENTS

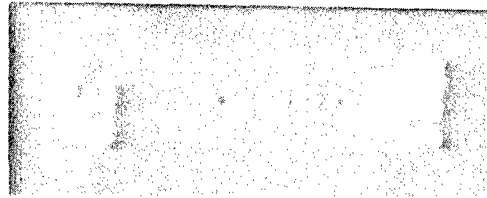
<u>Reference Radiographs</u>	<u>Page No.</u>
Fine Scattered Porosity	1B – 2B
Coarse Scattered Porosity	3B – 4B
Linear Porosity	5B – 6B
Clustered Porosity	7B
Incomplete Penetration	8B

FINE SCATTERED POROSITY

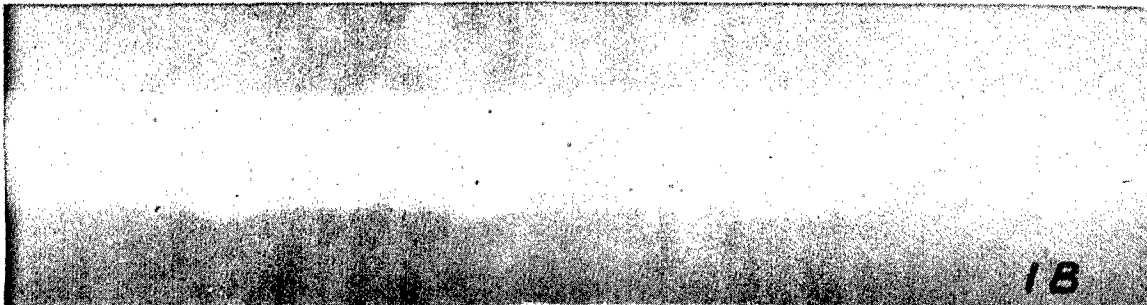
(3/16" to 1/2" Thickness Range)



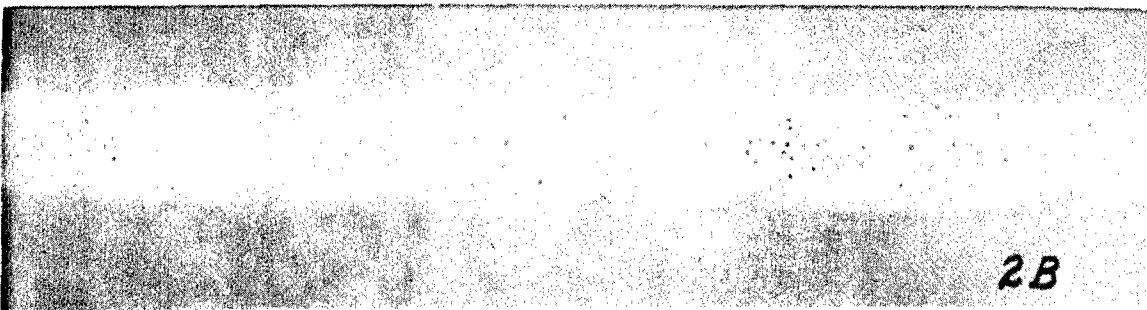
Cross Section of
Fine Scattered Porosity
1.5X - Mag.



2-IT Radiographic
Quality Level



STD. 1 (Approx. 6 Pores Per Sq. Inch)

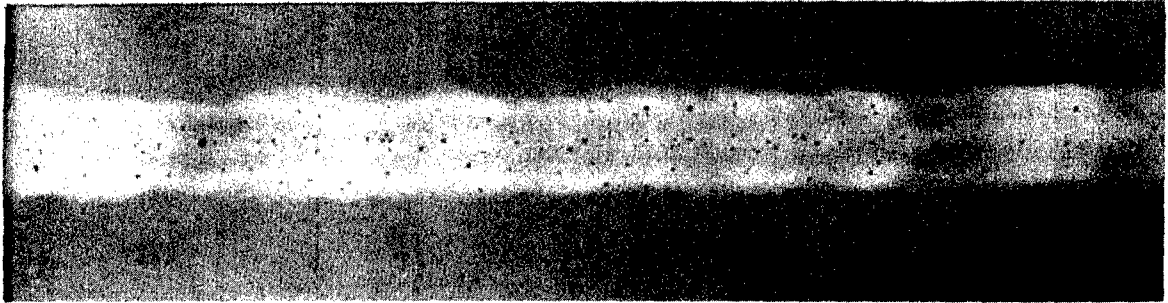


STD. 2 (Approx. 12 Pores Per Sq. Inch)

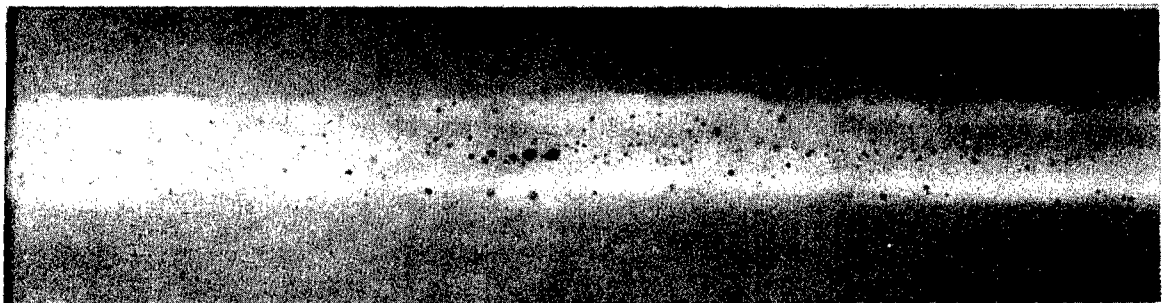
1B

FINE SCATTERED POROSITY

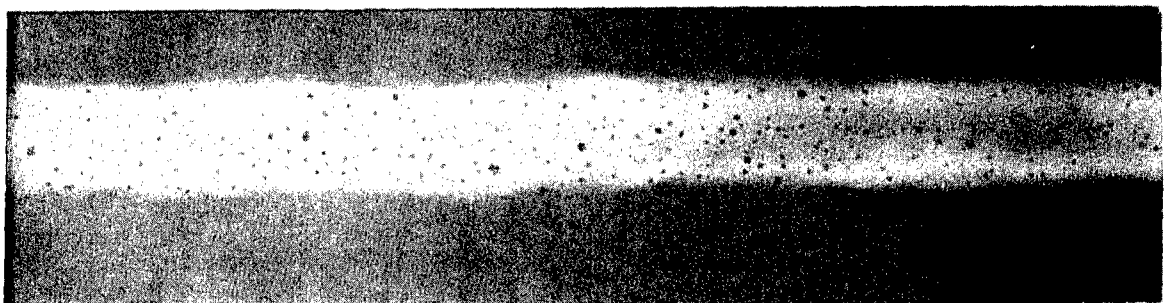
(3/16" to 1/2" Thickness Range)



STD. 3 (Approx. 25 Pores Per Sq. Inch)



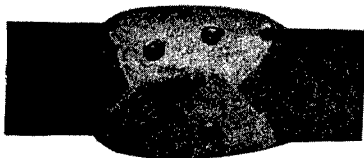
STD. 4 (Approx. 50 Pores Per Sq. Inch)



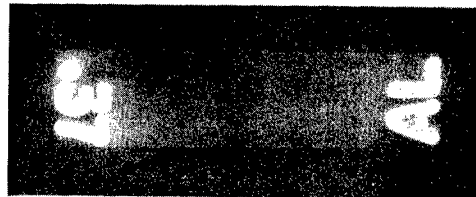
STD. 5 (Approx. 100 Pores Per Sq. Inch)

COARSE SCATTERED POROSITY

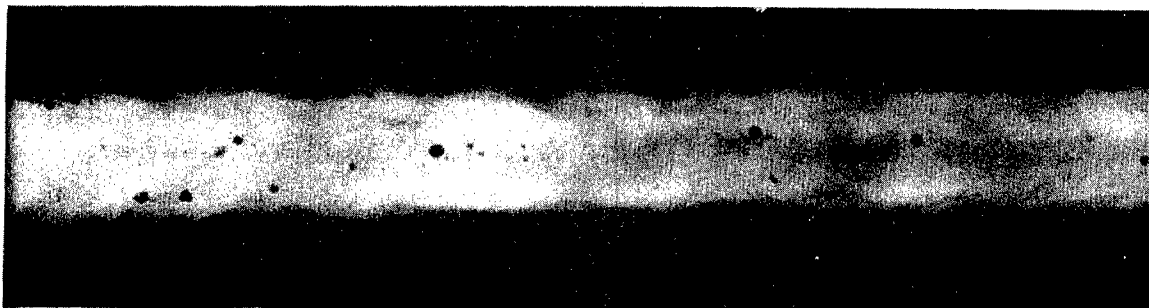
(3/16" to 1/2" Thickness Range)



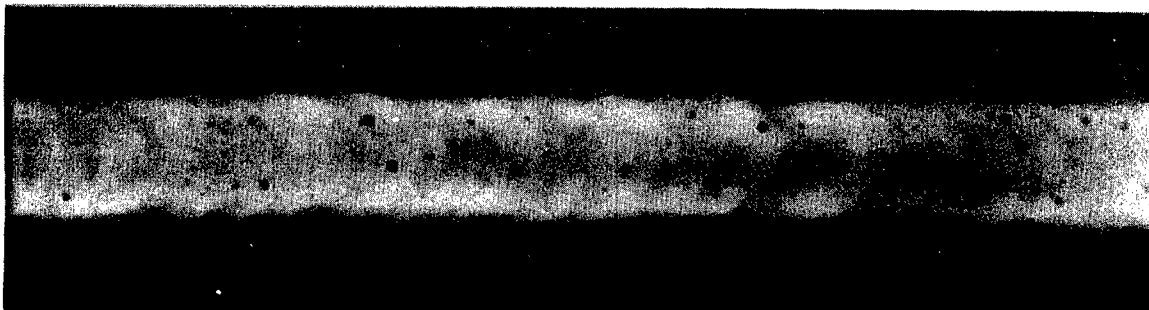
Cross Section of
Coarse Scattered Porosity
1.5X - Mag.



2-IT Radiographic
Quality Level



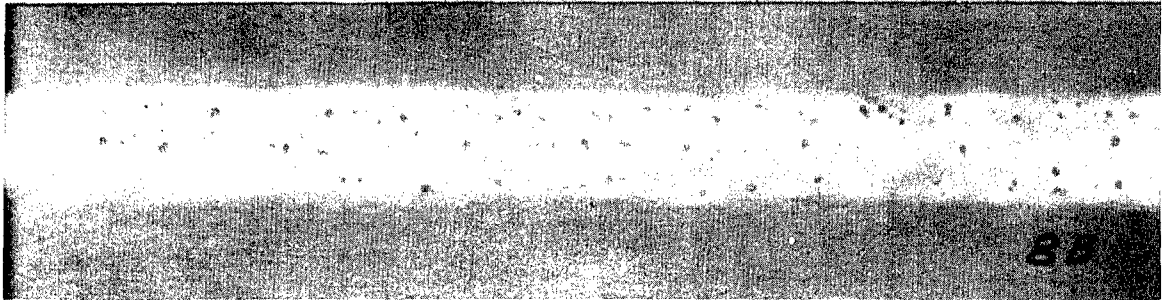
STD. 1 (Approx. 2 Pores Per Sq. Inch)



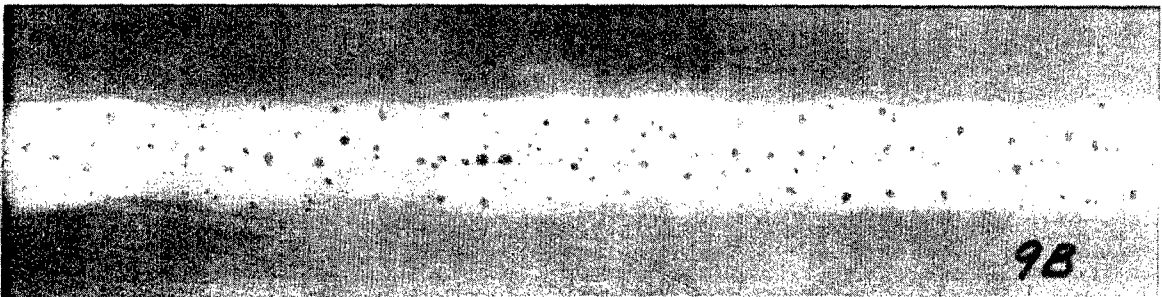
STD. 2 (Approx. 4 Pores Per Sq. Inch)

COARSE SCATTERED POROSITY

(3/16" to 1/2" Thickness Range)



STD. 3 (Approx. 8 Pores Per Sq. Inch)



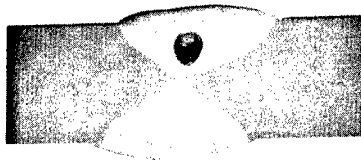
STD. 4 (Approx. 16 Pores Per Sq. Inch)



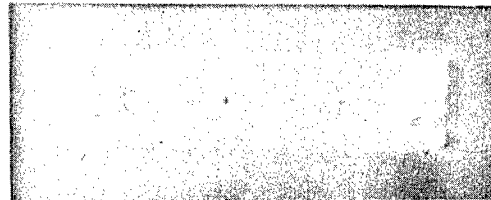
STD. 5 (Approx. 32 Pores Per Sq. Inch)

LINEAR POROSITY

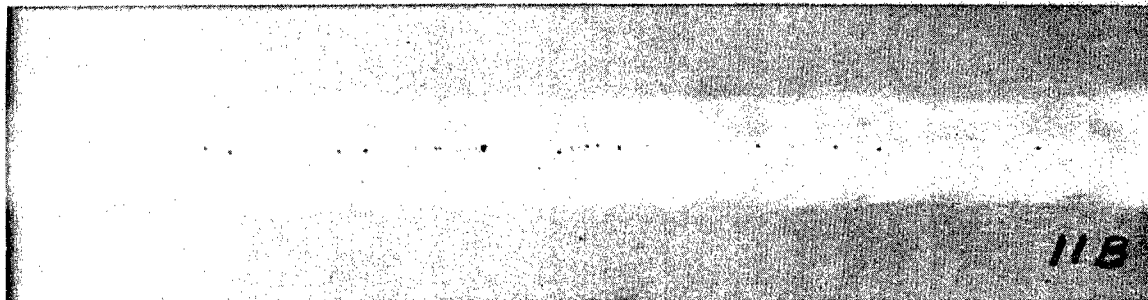
(3/16" to 1/2" Thickness Range)



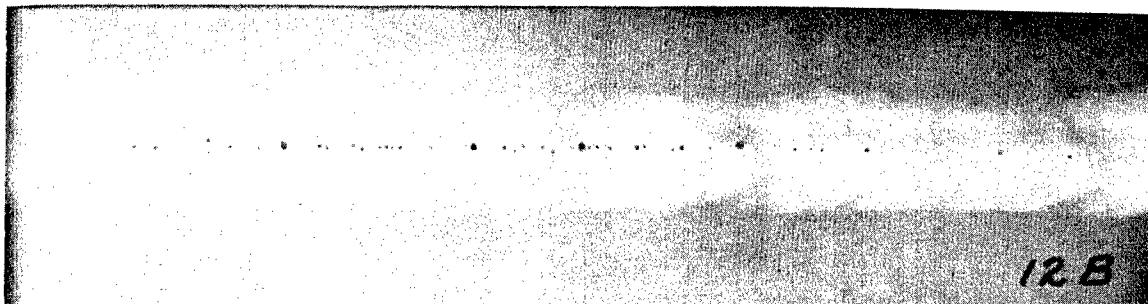
Cross Section of
Linear Porosity - 1.5X Mag.



2-IT Radiographic
Quality Level



STD. 1

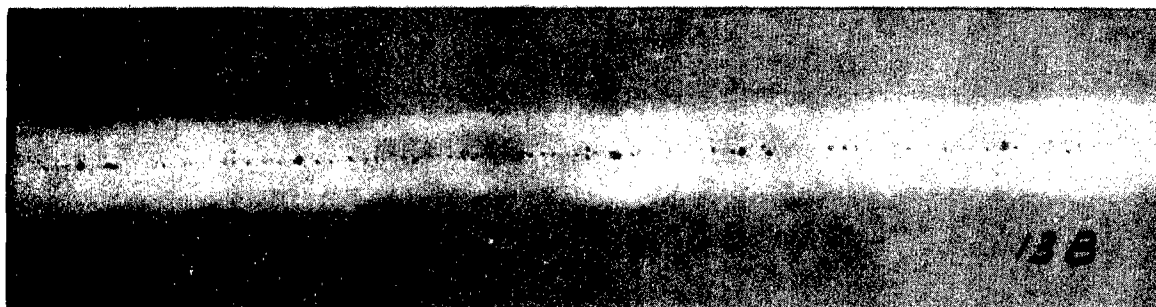


STD. 2

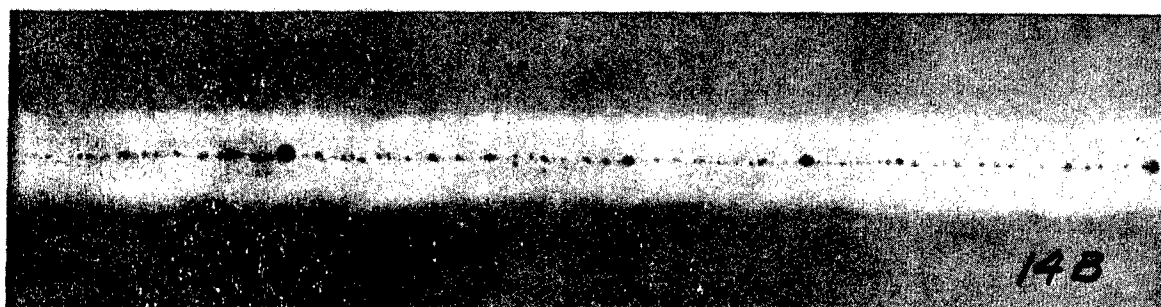
5B

LINEAR POROSITY

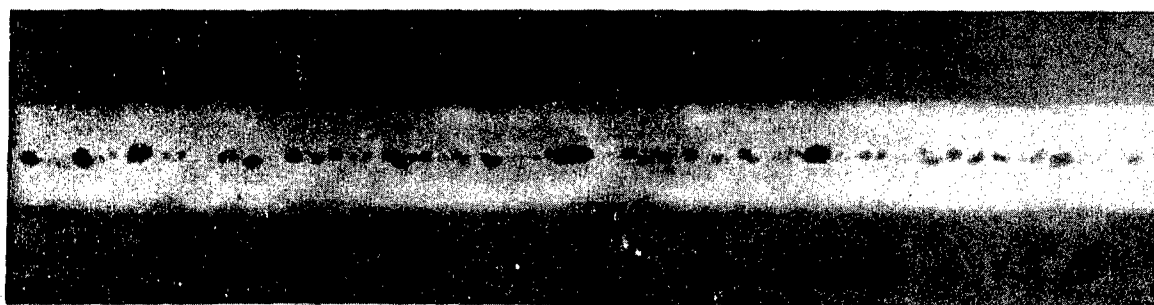
(3/16" to 1/2" Thickness Range)



STD. 3



STD. 4

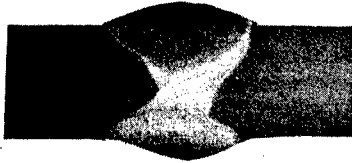


STD. 5

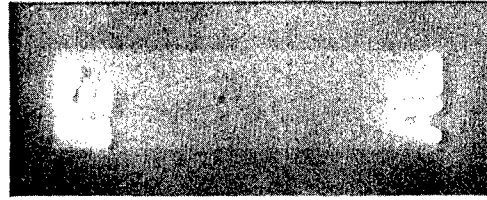
6B

CLUSTERED POROSITY

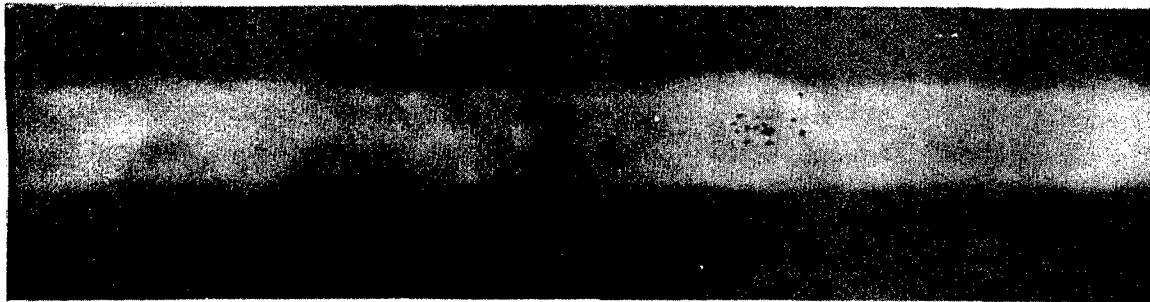
(3/16" to 1/2" Thickness Range)



Cross Section of
Clustered Porosity - 1.5 Mag.



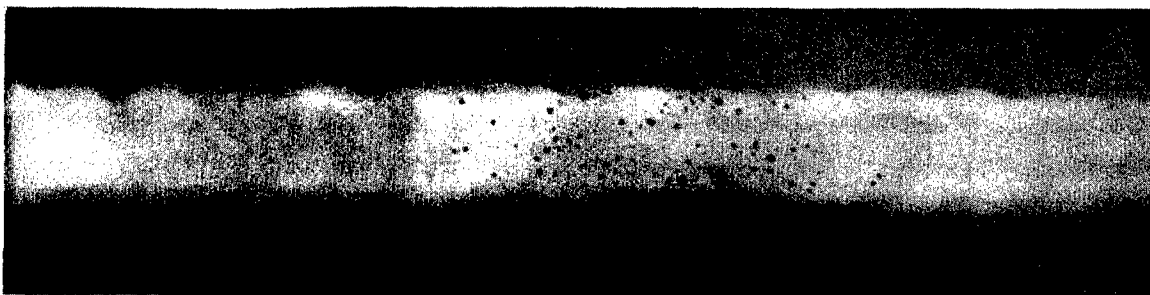
2-IT Radiographic
Quality Level



STD. 1



STD. 2



STD. 3

NOTE: Any condition more
severe than Std. 3 shall
be judged as scattered
porosity.

INCOMPLETE PENETRATION

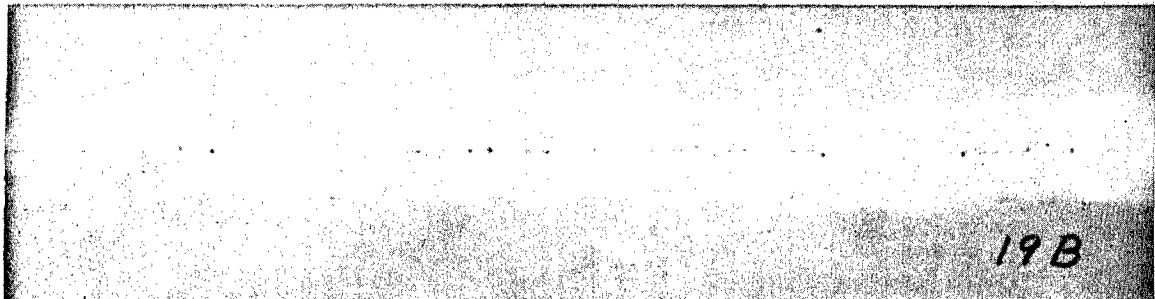
(3/16" to 1/2" Thickness Range)



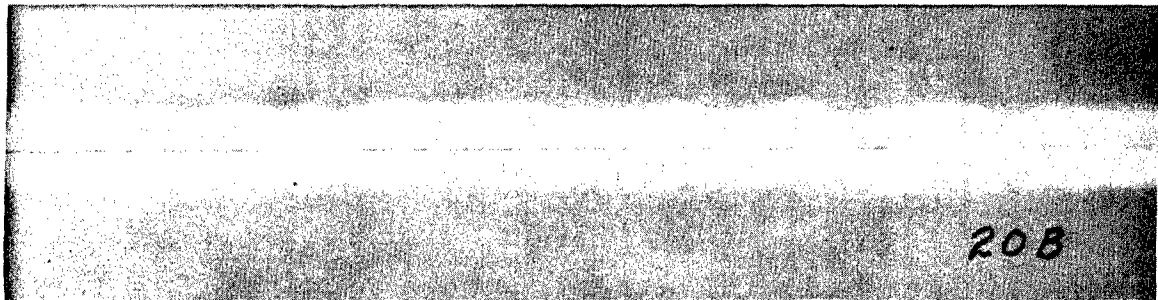
Cross Section of
Plate 19B - 1.5X - Mag.



Cross Section of
Plate 20B - 1.5X - Mag.



Linear Porosity frequently accompanies incomplete penetration when the plates are fit tightly together.



ILLUSTRATIONS OF INCOMPLETE PENETRATION - Std. 1 - $\frac{3}{4}$ "
Reference standards are based on flaw length as follows: The accumulated length of flaw shall not exceed the limit stated for each standard in any 8 inch weld length.

Std. 2 - $1\frac{1}{2}$ "
Std. 3 - 3"
Std. 4 - $5\frac{1}{2}$ "
Std. 5 - 8"

SECTION C

REFERENCE RADIOGRAPHS FOR FULL PENETRATION ALUMINUM WELDS

(MIG WELDING PROCESS)

THICKNESS RANGE
OVER 1/2" TO 1"

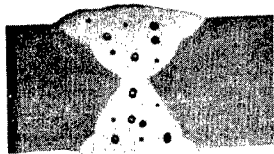


CONTENTS

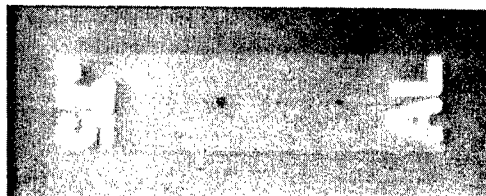
<u>Reference Radiographs</u>	<u>Page No.</u>
Fine Scattered Porosity	1C – 2C
Coarse Scattered Porosity	3C – 4C
Linear Porosity	5C – 6C
Clustered Porosity	7C
Incomplete Penetration	8C

FINE SCATTERED POROSITY

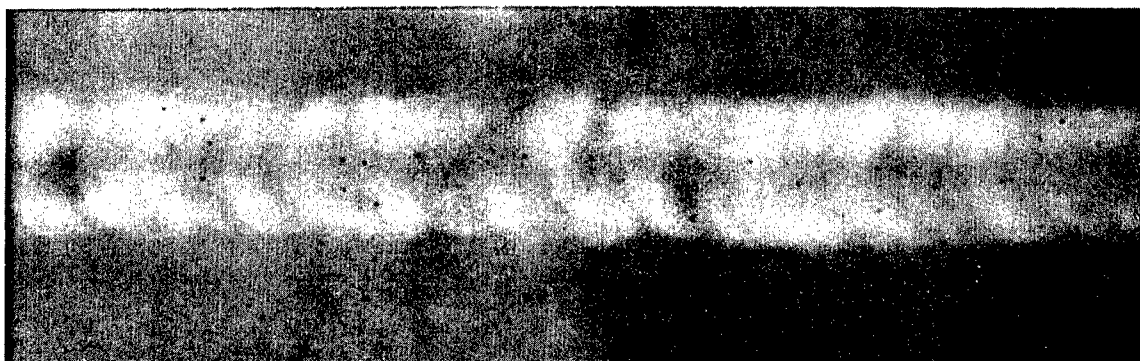
(Over 1/2" to 1" Thickness Range)



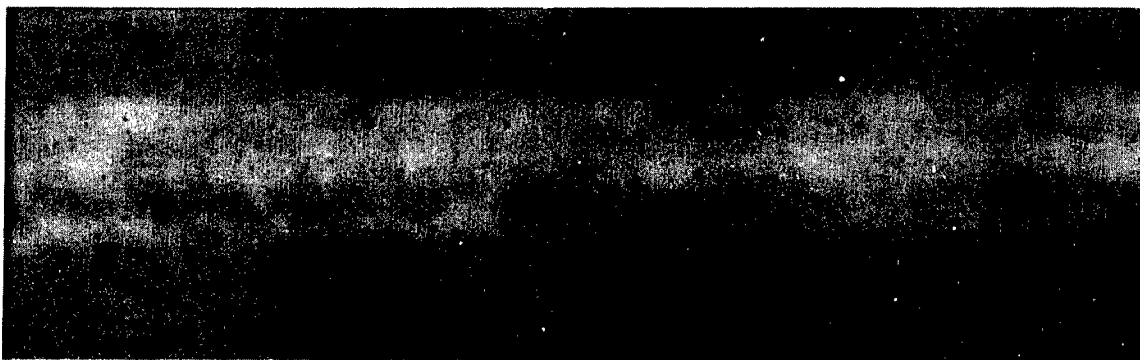
**Cross Section of
Fine Scattered Porosity
Actual Size**



**2-IT Radiographic
Quality Level**



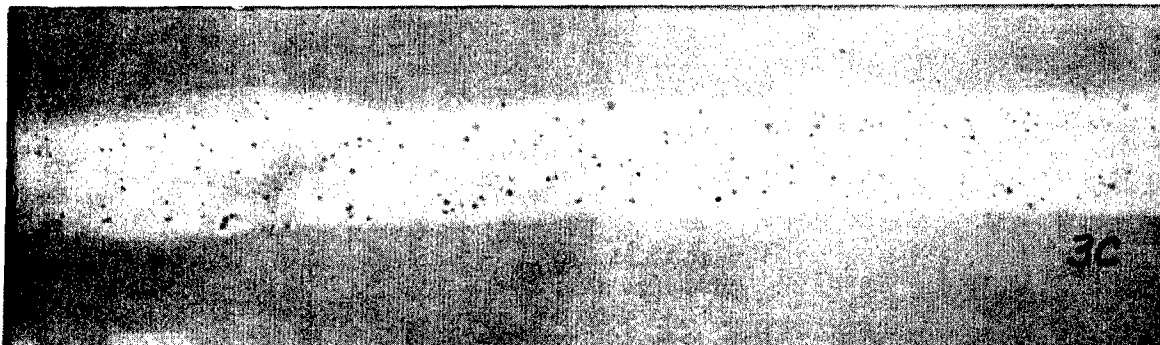
STD. 1 (Approx. 6 Pores Per Sq. Inch)



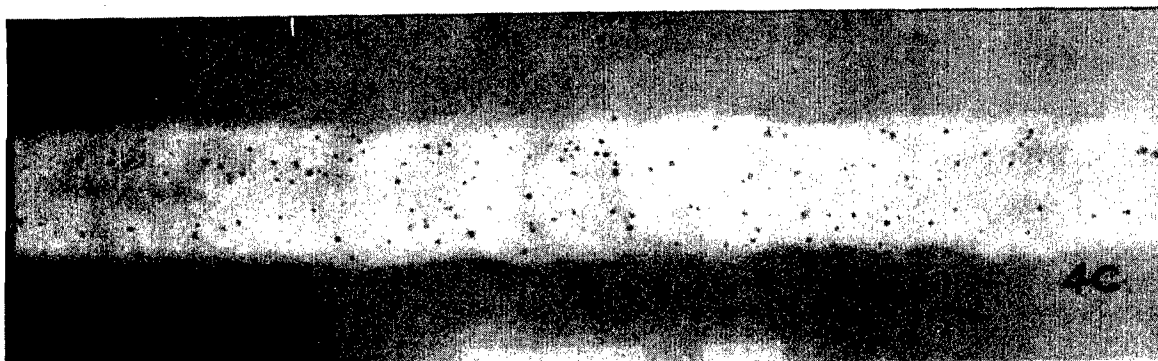
STD. 2 (Approx. 12 Pores Per Sq. Inch)

FINE SCATTERED POROSITY

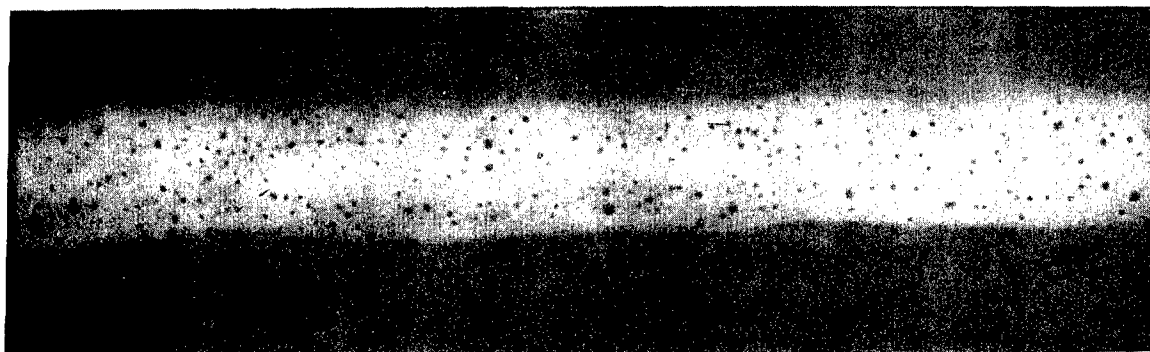
(Over 1/2" to 1" Thickness Range)



STD. 3 (Approx. 25 Pores Per Sq. Inch)



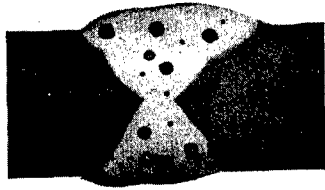
STD. 4 (Approx. 50 Pores Per Sq. Inch)



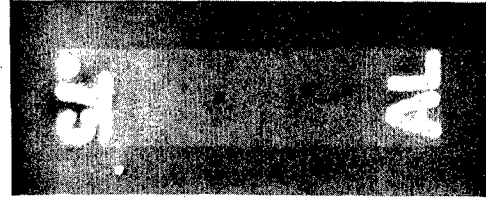
STD. 5 (Approx. 100 Pores Per Sq. Inch)

COARSE SCATTERED POROSITY

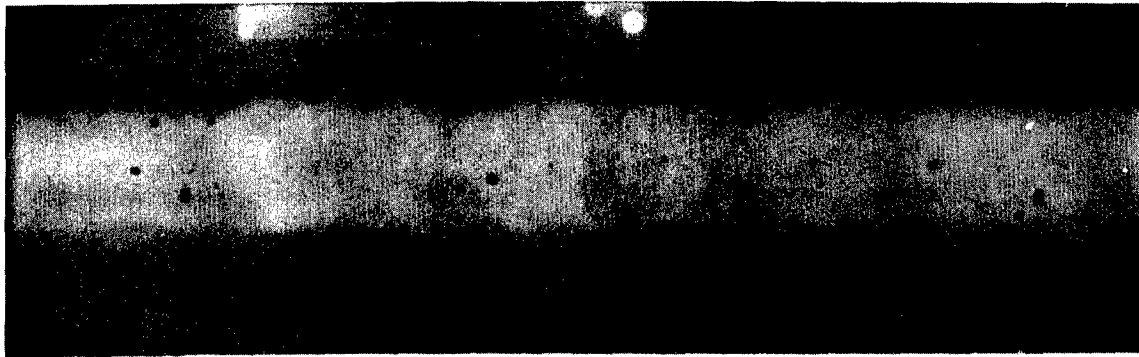
(Over 1/2" to 1" Thickness Range)



**Cross Section of
Coarse Scattered Porosity
Actual Size**



**2-IT Radiographic
Quality Level**



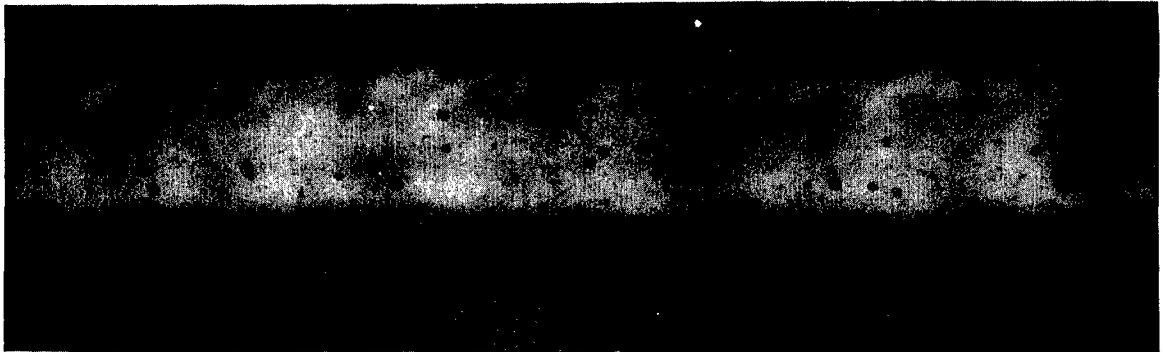
STD. 1 (Approx. 2 Pores Per Sq. Inch)



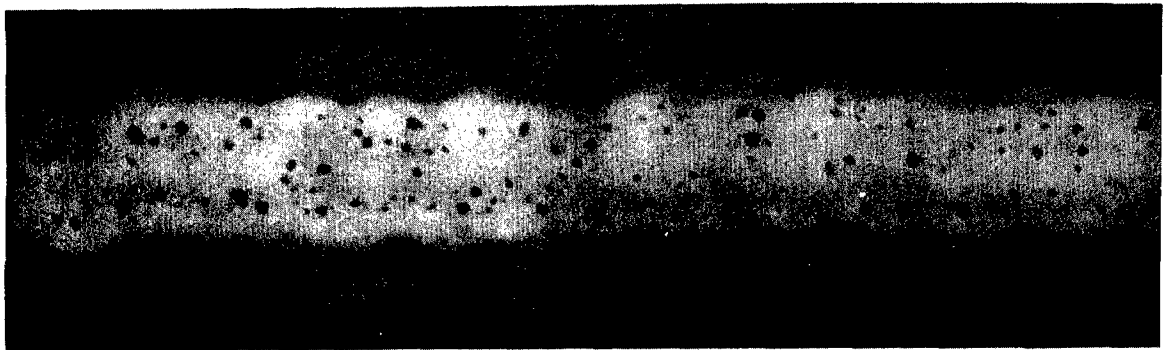
STD. 2 (Approx. 4 Pores Per Sq. Inch)

COARSE SCATTERED POROSITY

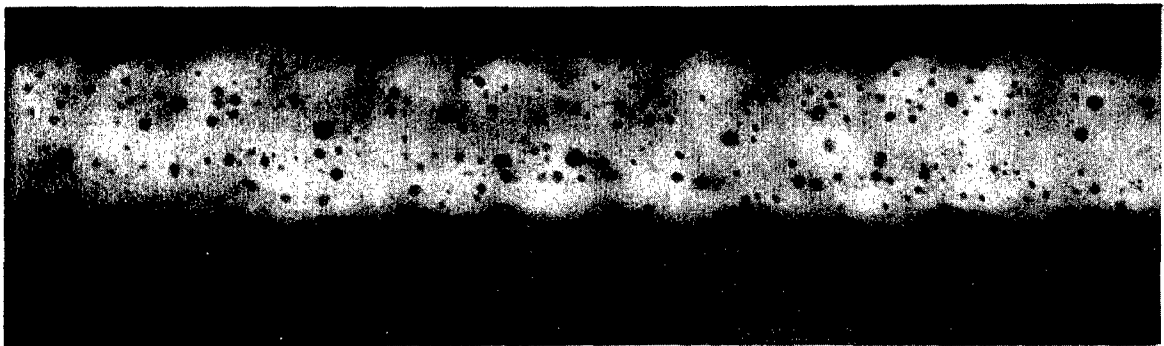
(Over 1/2" to 1" Thickness Range)



STD. 3 (Approx. 8 Pores Per Sq. Inch)



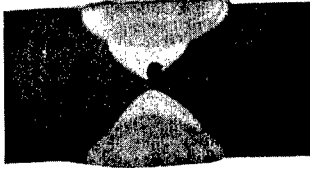
STD. 4 (Approx. 16 Pores Per Sq. Inch)



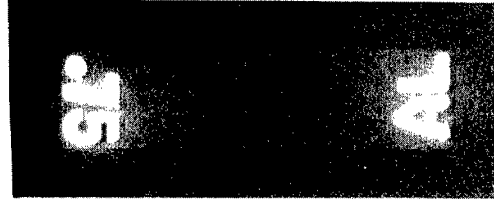
STD. 5 (Approx. 32 Pores Per Sq. Inch)

LINEAR POROSITY

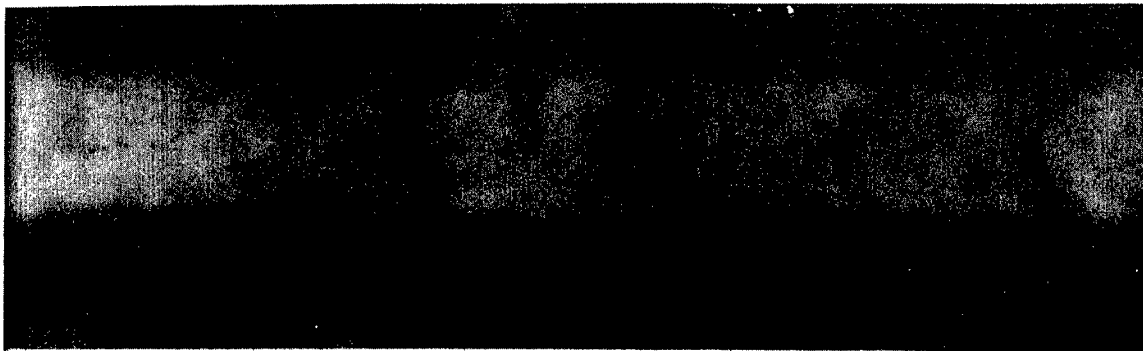
(Over 1/2" to 1" Thickness Range)



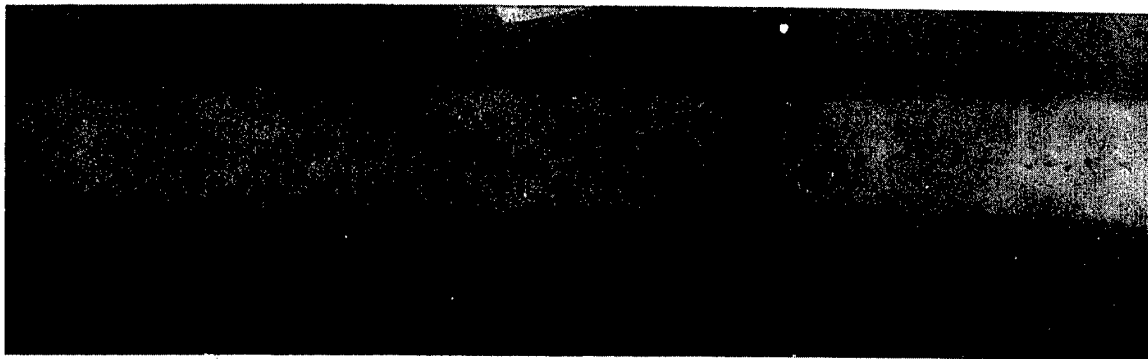
Cross Section of
Linear Porosity-Actual Size



2-IT Radiographic
Quality Level



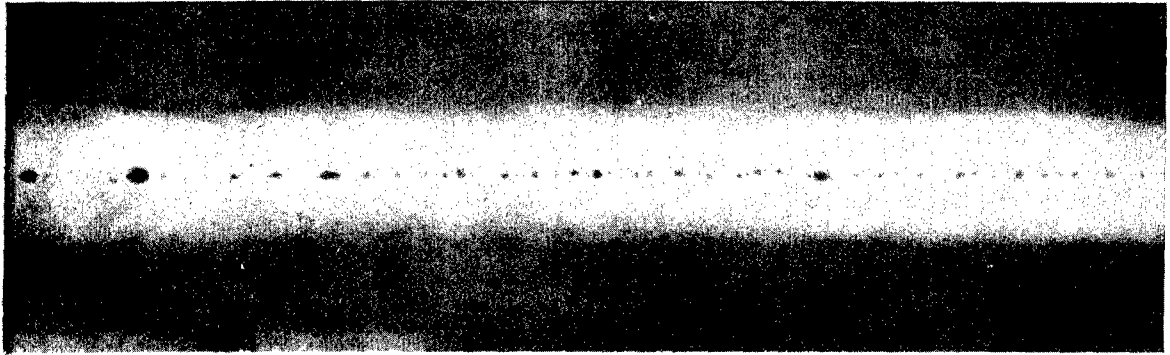
STD. 1



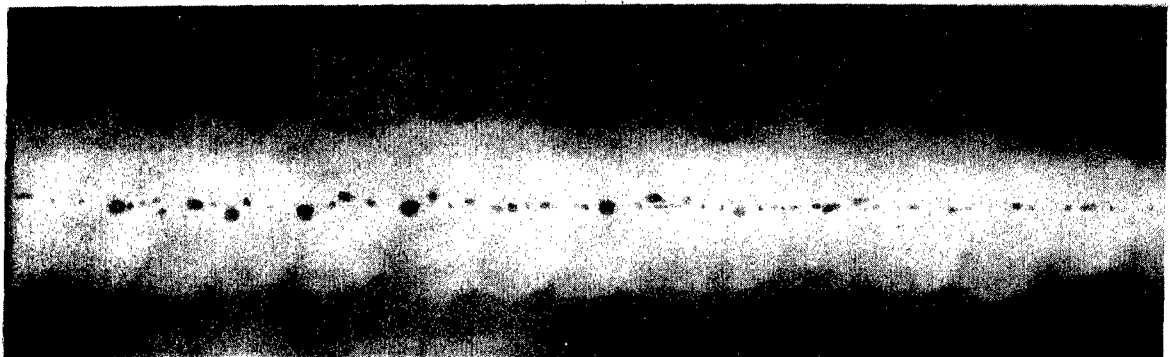
STD. 2

LINEAR POROSITY

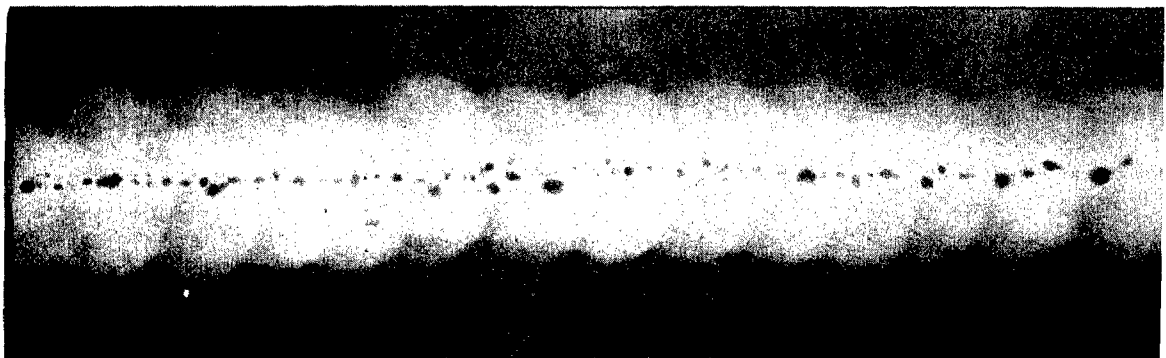
(Over 1/2 to 1" Thickness Range)



STD. 3



STD. 4

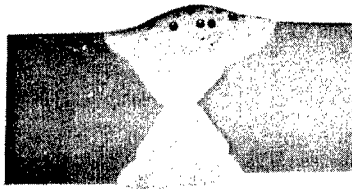


STD. 5

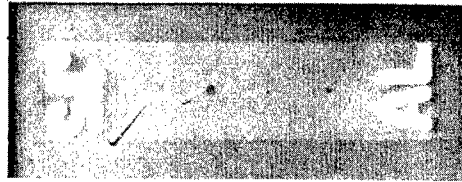
6C

CLUSTERED POROSITY

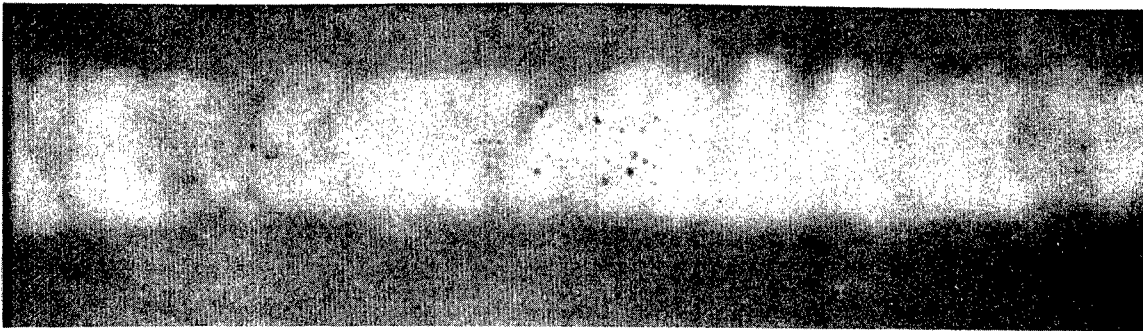
(Over 1/2" to 1" Thickness Range)



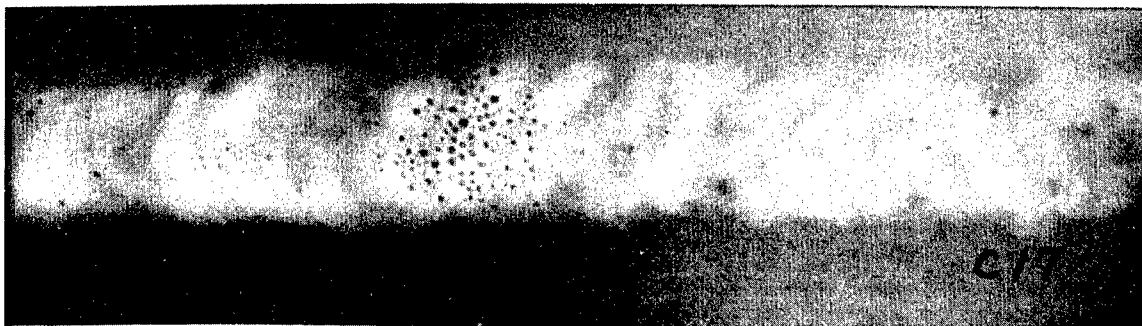
Cross Section of
Clustered Porosity-Actual Size



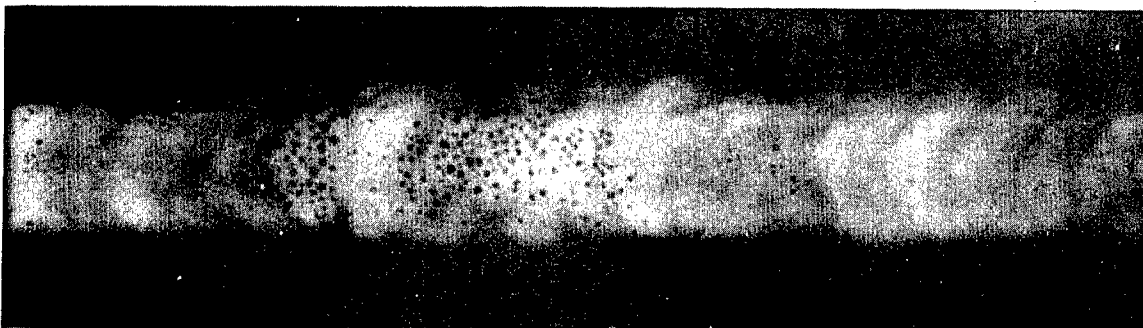
2-IT Radiographic
Quality Level



STD. 1



STD. 2

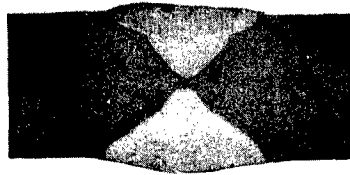


STD. 3

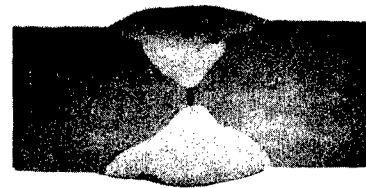
NOTE: Any condition more
severe than Std. 3 shall
be judged as scattered porosity.

INCOMPLETE PENETRATION

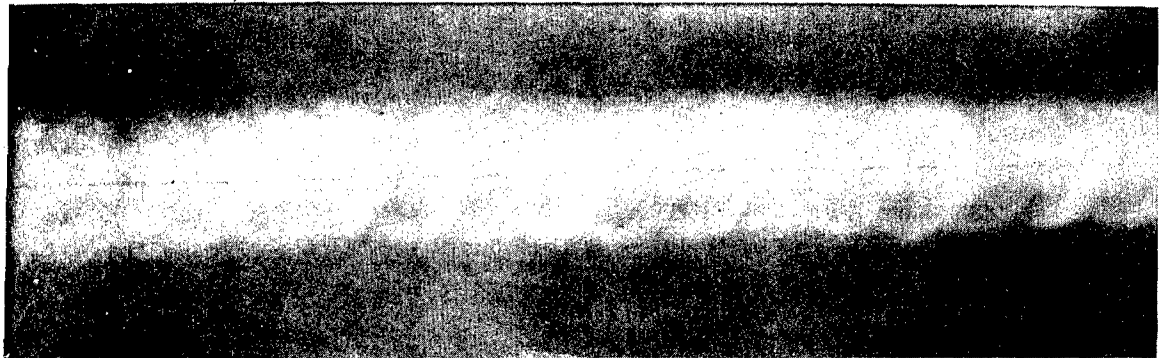
(Over 1/2 to 1" Thickness Range)



Cross Section of
Plate C-19-Actual Size

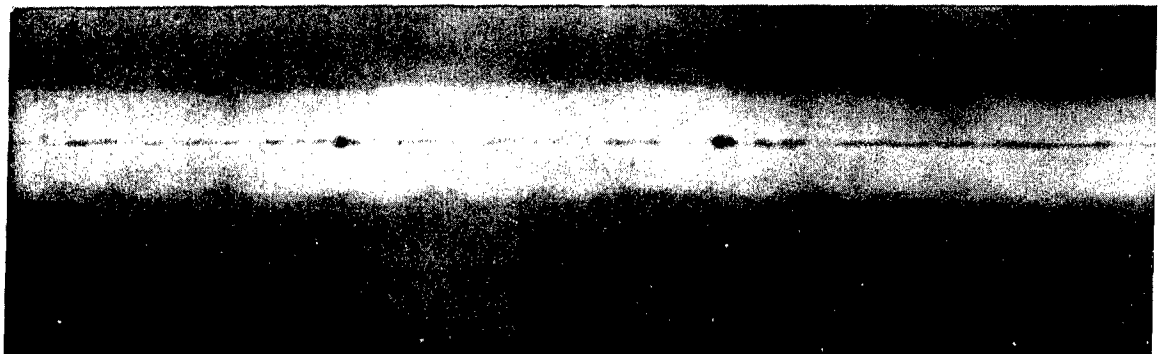


Cross Section of
Plate C-20-Actual Size



ABOVE - Faint image due to tight fit of plates.

BELOW - Heavy image due to plate separation.



ILLUSTRATIONS OF INCOMPLETE PENETRATION - Std. 1 - 1"
Reference standards are based on flaw length as Std. 2 - 2"
follows: The accumulated length of flaw shall not Std. 3 - 4"
exceed the limit stated for each standard in any Std. 4 - 7"
10 inch weld length. Std. 5 - 10"

SECTION D

REFERENCE RADIOGRAPHS FOR FULL PENETRATION ALUMINUM WELDS

(MIG WELDING PROCESS)

**THICKNESS RANGE
OVER 1" TO 2"**

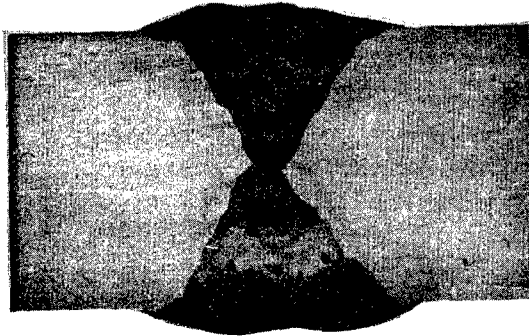


CONTENTS

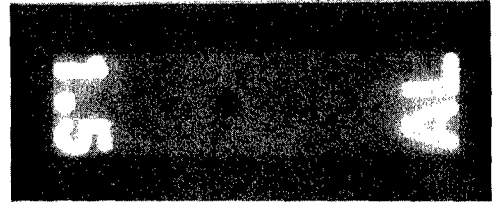
<u>Reference Radiographs</u>	<u>Page No.</u>
Fine Scattered Porosity	1D – 2D
Coarse Scattered Porosity	3D – 4D
Linear Porosity	5D – 6D
Clustered Porosity	7D
Incomplete Penetration	8D – 9D

FINE SCATTERED POROSITY

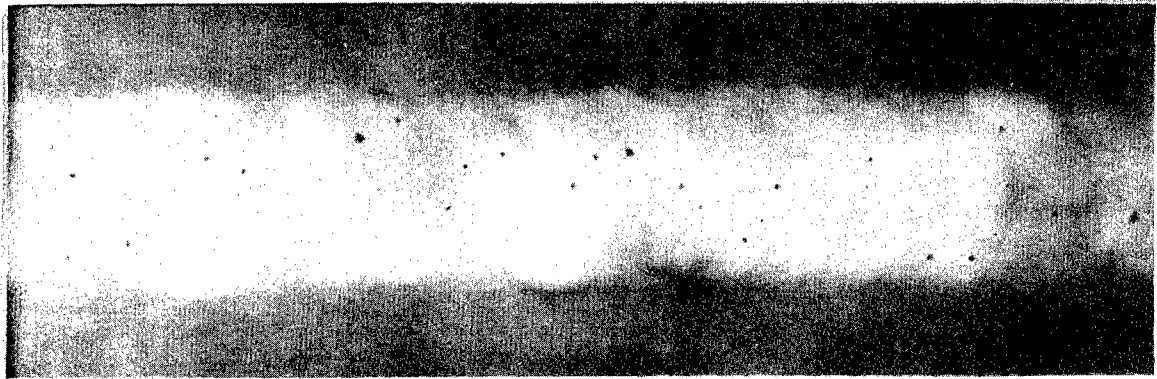
(Over 1" to 2" Thickness Range)



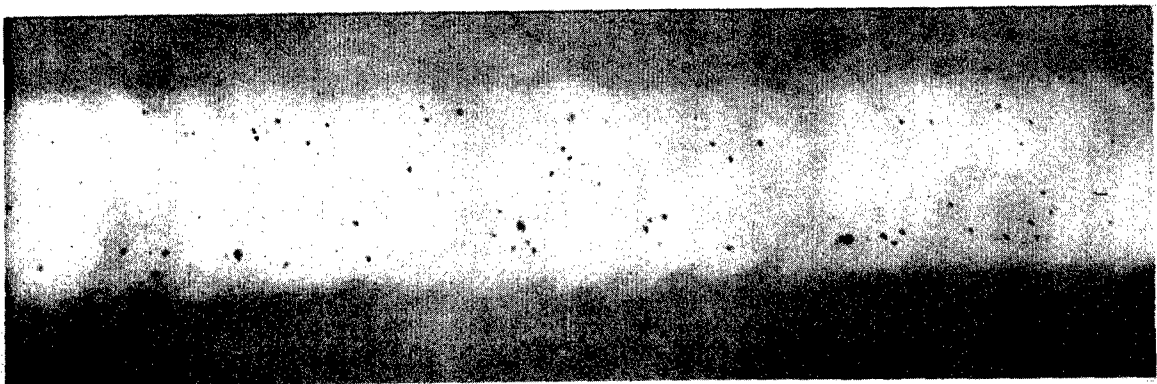
**Cross Section of
Fine Scattered Porosity
Actual Size**



**2-IT Radiographic
Quality Level**



STD. 1 (Approx. 6 Pores Per Sq. Inch)

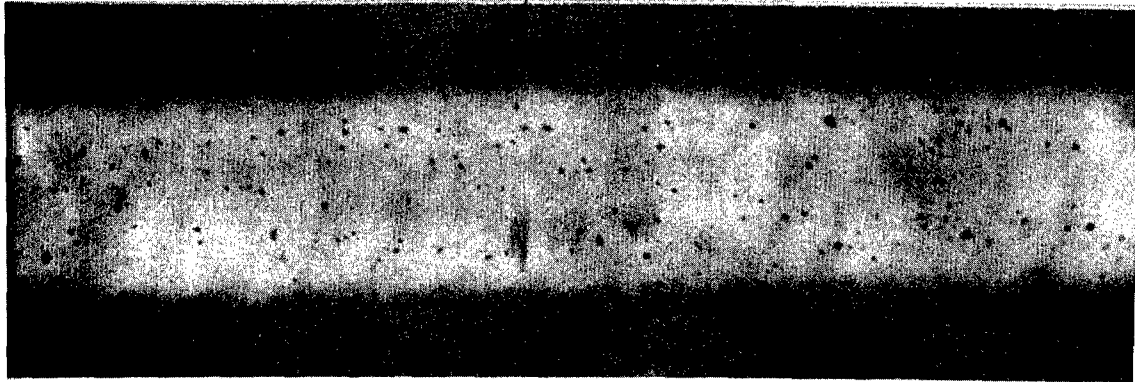


STD. 2 (Approx. 12 Pores Per Sq. Inch)

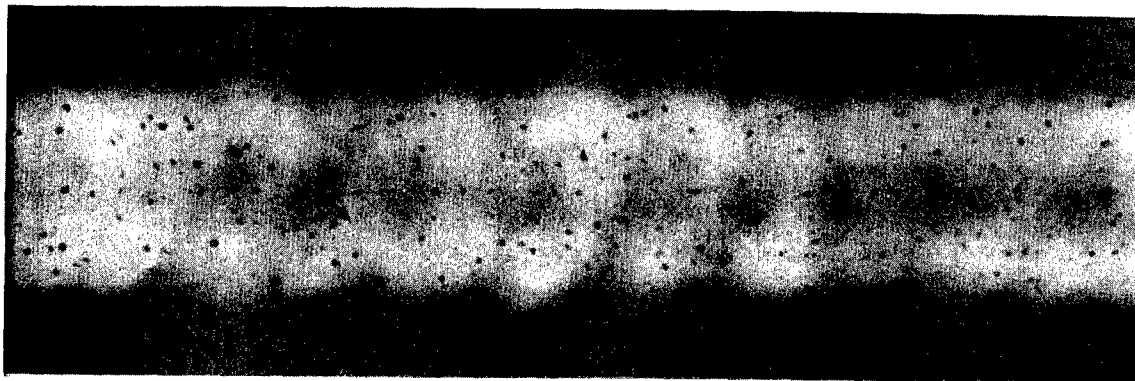
ID

FINE SCATTERED POROSITY

(Over 1" to 2" Thickness Range)



STD. 3 (Approx. 25 Pores Per Sq. Inch)



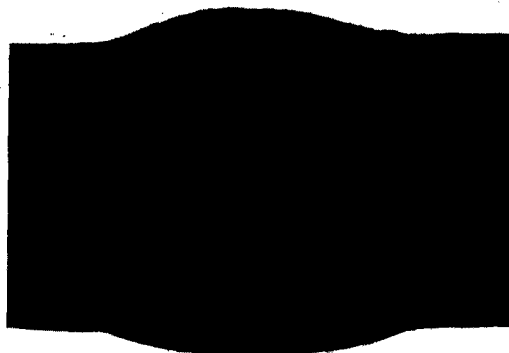
STD. 4 (Approx. 50 Pores Per Sq. Inch)



STD. 5 (Approx. 100 Pores Per Sq. Inch)

COARSE SCATTERED POROSITY

(Over 1" to 2" Thickness Range)



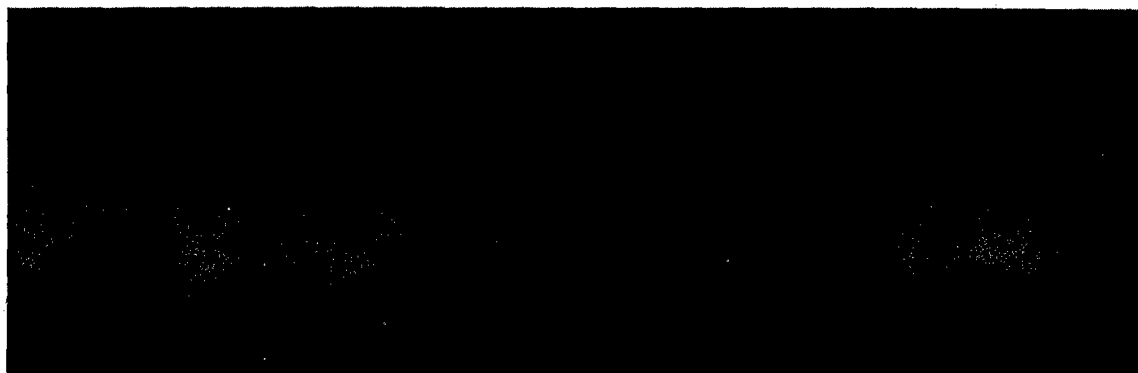
**Cross Section of
Coarse Scattered Porosity
Actual Size**



**2-IT Radiographic
Quality Level**



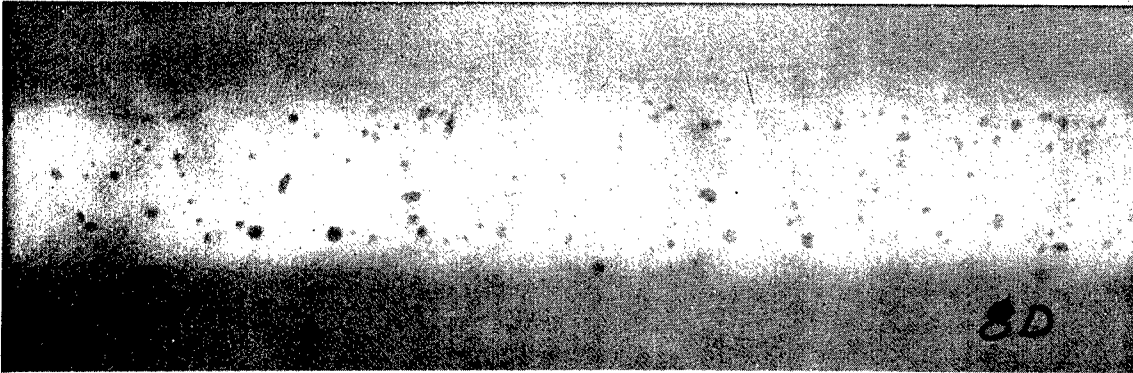
STD. 1 (Approx. 2 Pores Per Sq. Inch.)



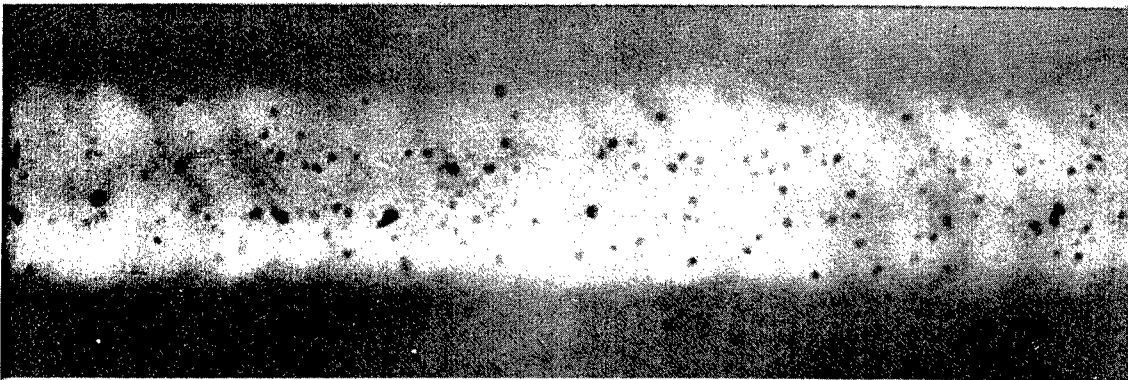
STD. 2 (Approx. 4 Pores Per Sq. Inch)

COARSE SCATTERED POROSITY

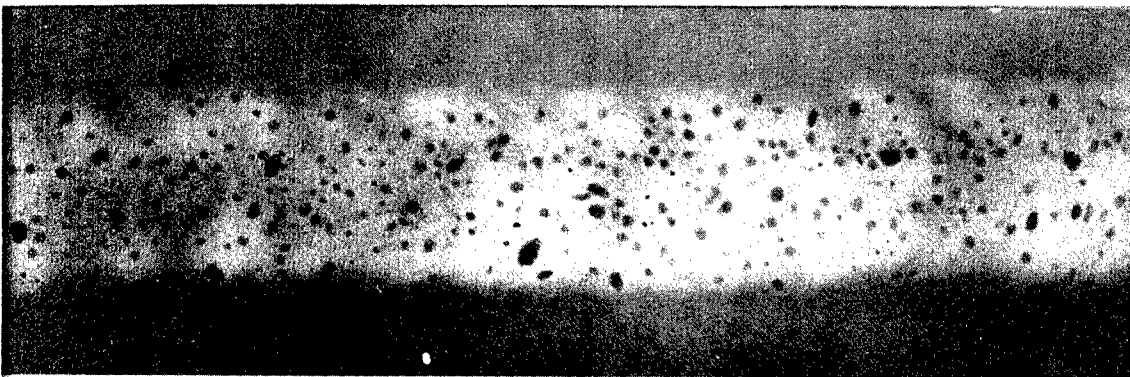
(Over 1" to 2" Thickness Range)



STD. 3 (Approx 8 Pores Per Sq. Inch)



STD. 4 (Approx. 16 Pores Per Sq. Inch)

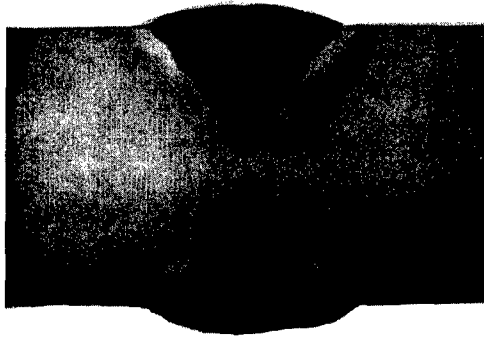


STD. 5 (Approx. 32 Pores Per Sq. Inch)

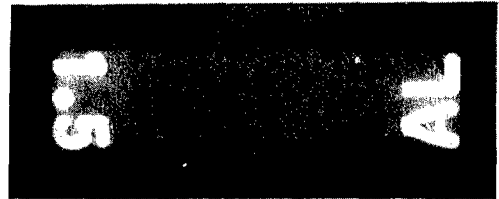
4D

LINEAR POROSITY

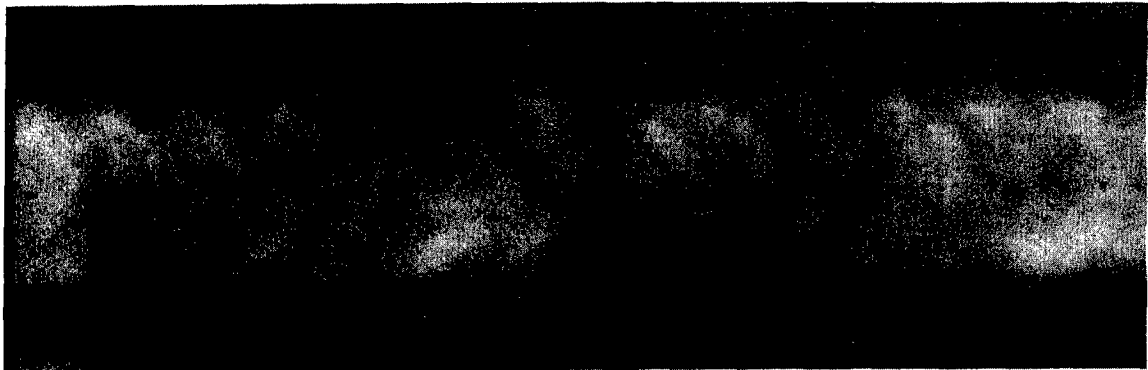
(Over 1" to 2" Thickness Range)



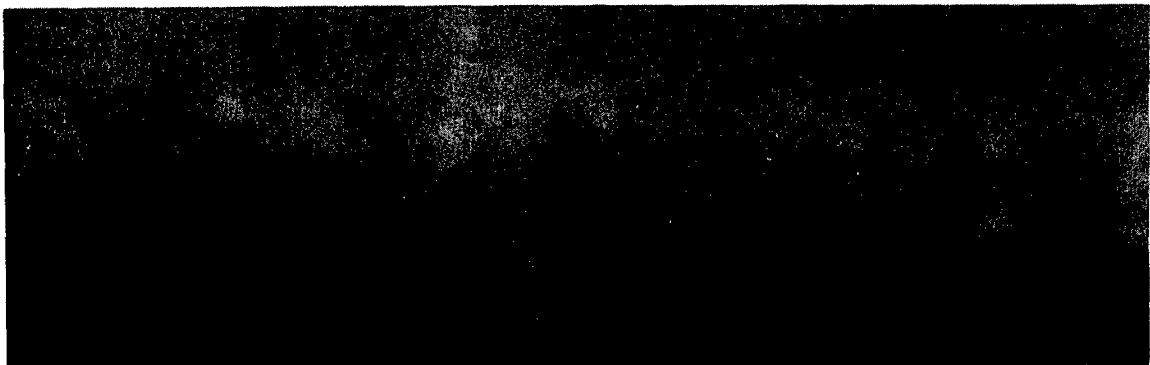
Cross Section of
Linear Porosity-Actual Size



2-IT Radiographic
Quality Level



STD. 1

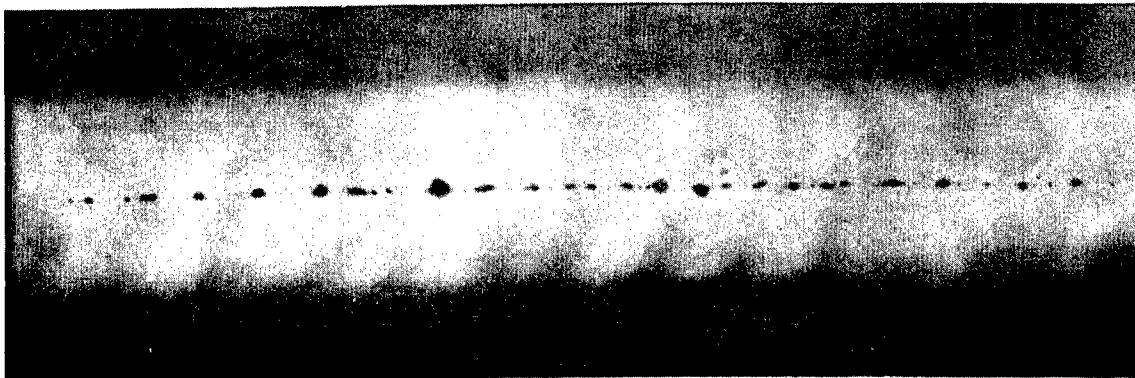


STD. 2

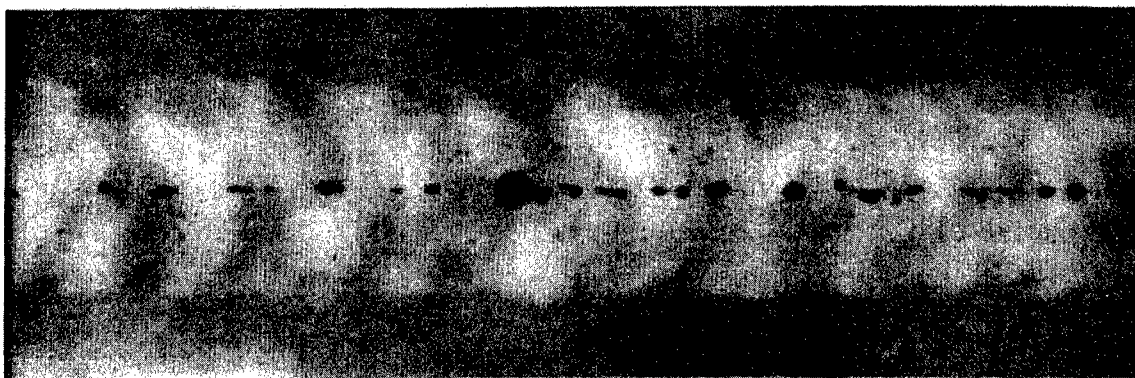
5D

LINEAR POROSITY

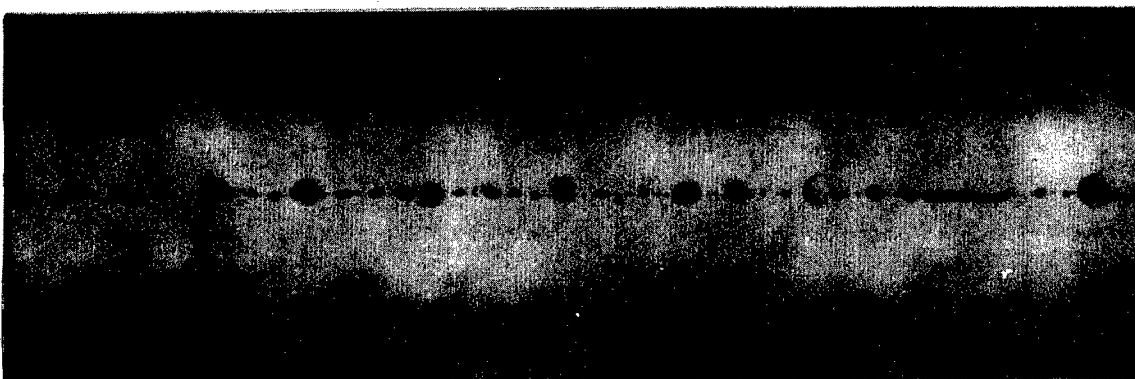
(Over 1" to 2" Thickness Range)



STD. 3



STD. 4

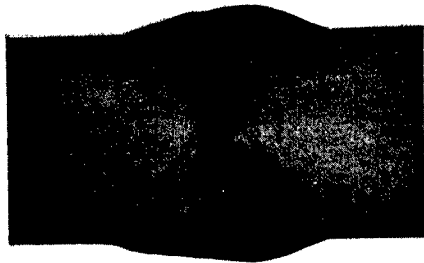


STD. 5

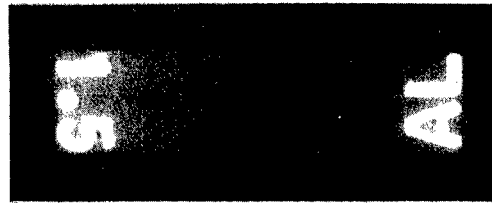
6D

CLUSTERED POROSITY

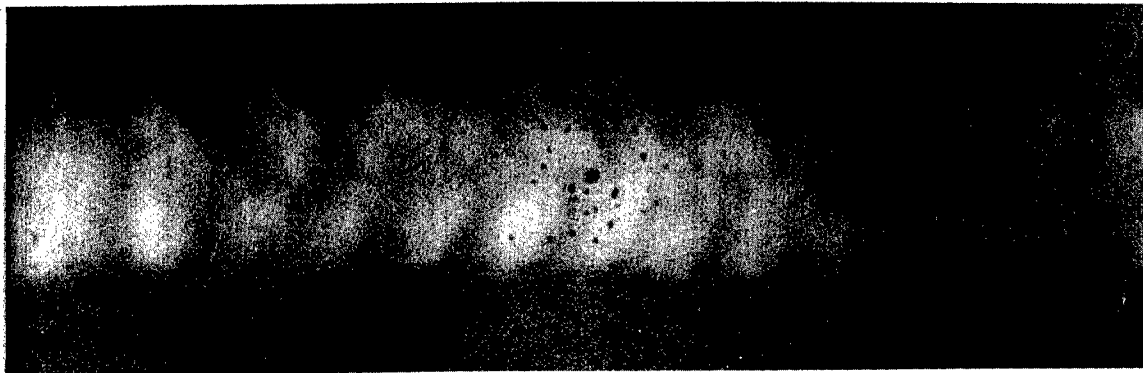
(Over 1" to 2" Thickness Range)



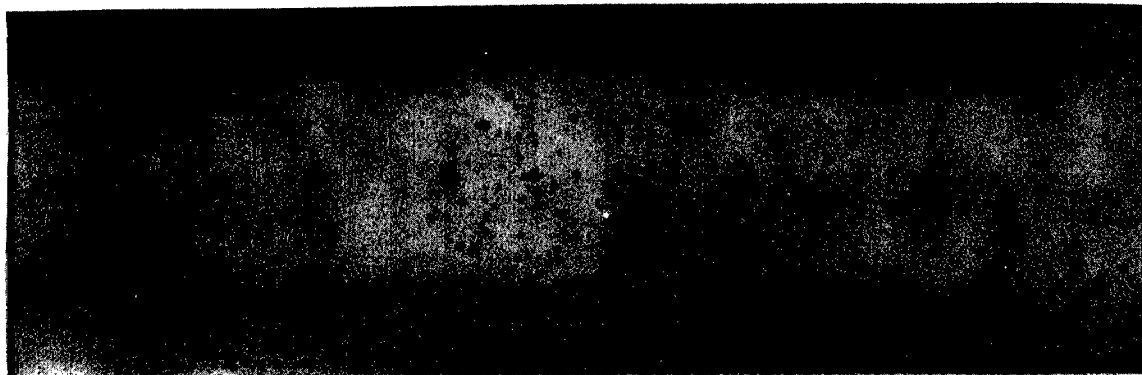
Cross Section of Clustered Porosity



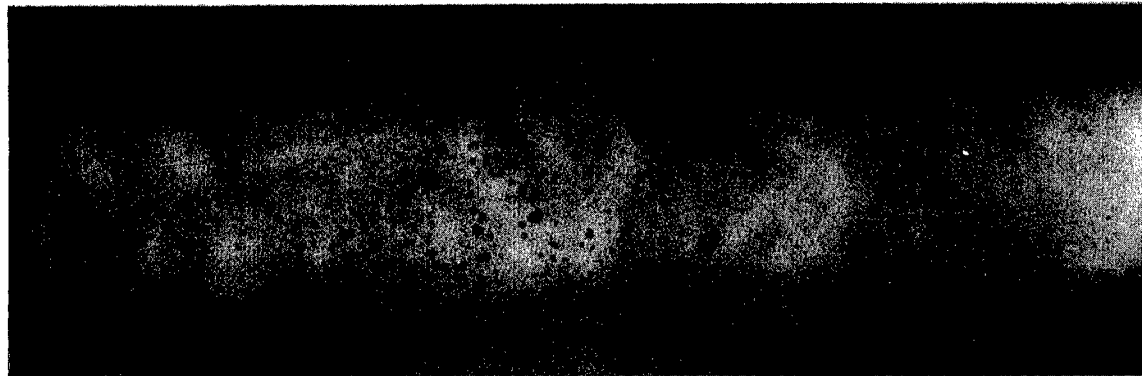
2-IT Radiographic
Quality Level



STD. 1



STD. 2



STD. 3

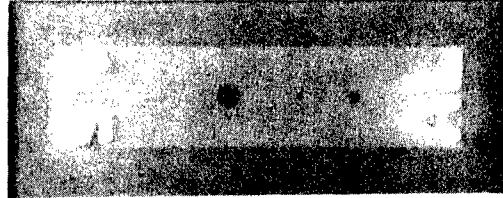
NOTE: Any condition more severe than Std. 3 shall be judged as scattered porosity.

INCOMPLETE PENETRATION

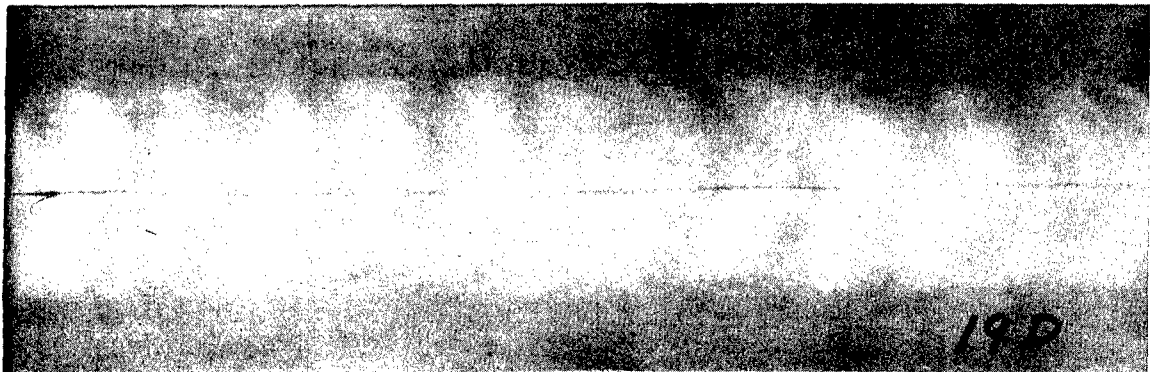
(Over 1" to 2" Thickness Range)



Cross Section of
Plate 19D-Actual Size

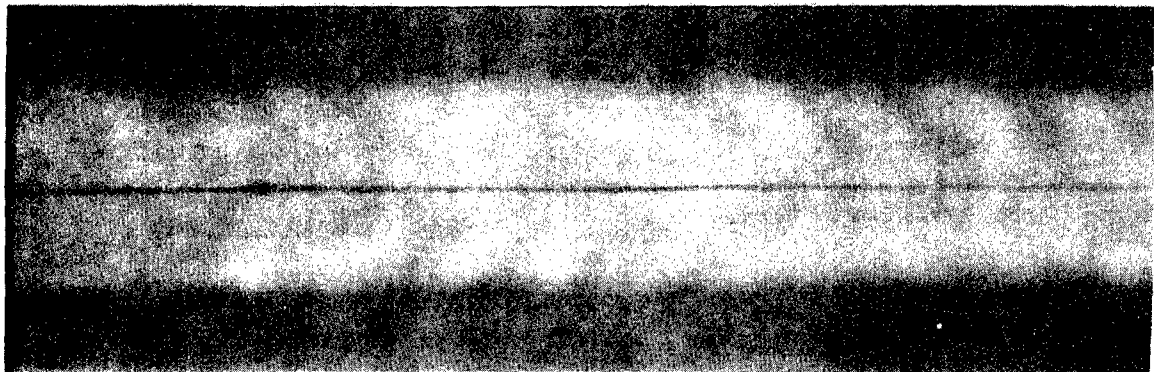


2-IT Radiographic
Quality Level



ABOVE - Faint image due to tight fit of plates.

BELOW - Heavy image due to plate separation.

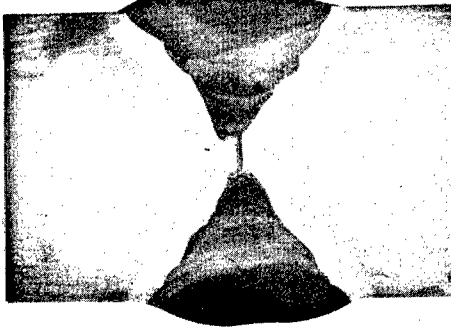


ILLUSTRATIONS OF INCOMPLETE PENETRATION

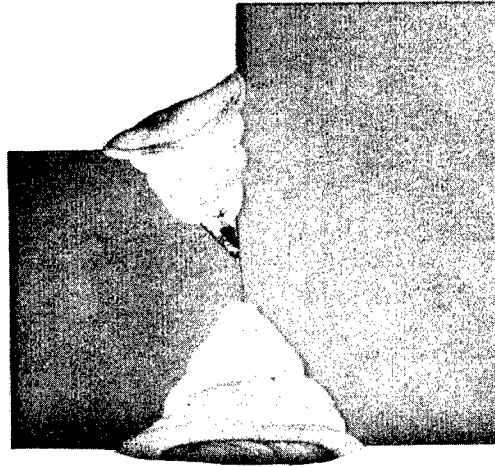
8D

INCOMPLETE PENETRATION

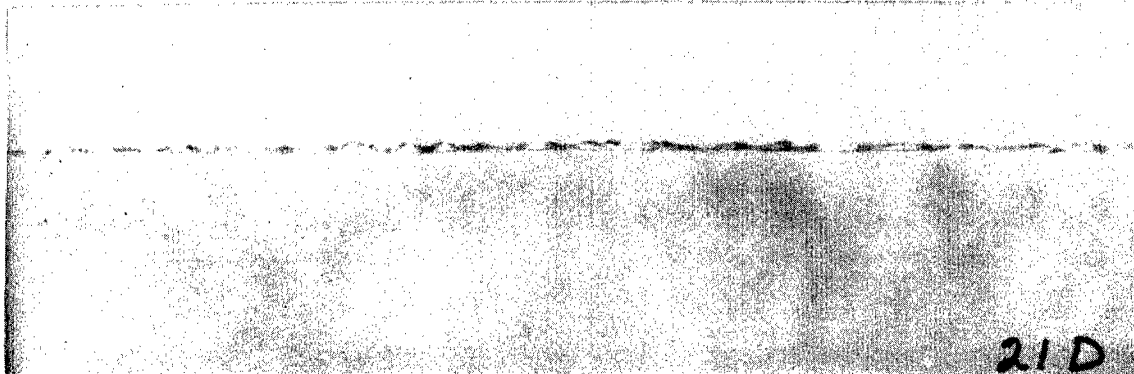
(Over 1" to 2" Thickness Range)



Cross Section of
Plate 20D-Actual Size



Cross Section of
Plate 21D-Actual Size



Incomplete Penetration and Lack of Fusion.

ILLUSTRATIONS OF INCOMPLETE PENETRATION -

Reference standards are based on flaw length as follows: The accumulated length of flaw shall not exceed the limit stated for each standard in any 12 inch weld length.

Std. 1 - 1½"
Std. 2 - 3"
Std. 3 - 6"
Std. 4 - 9"
Std. 5 - 12"

SECTION E

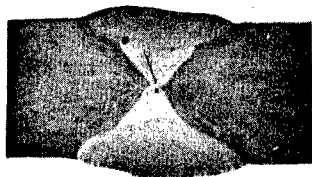
ILLUSTRATIONS OF UNGRADED FLAWS FOR FULL PENETRATION ALUMINUM WELDS



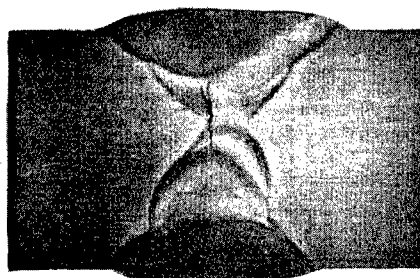
CONTENTS

<u>Ungraded Flaws</u>	<u>Page No.</u>
Longitudinal Cracks	1E
Transverse Cracks	2E
Plate Separation	2E
Oxide Inclusions	3E
Undercutting	4E
Incomplete Weld	4E

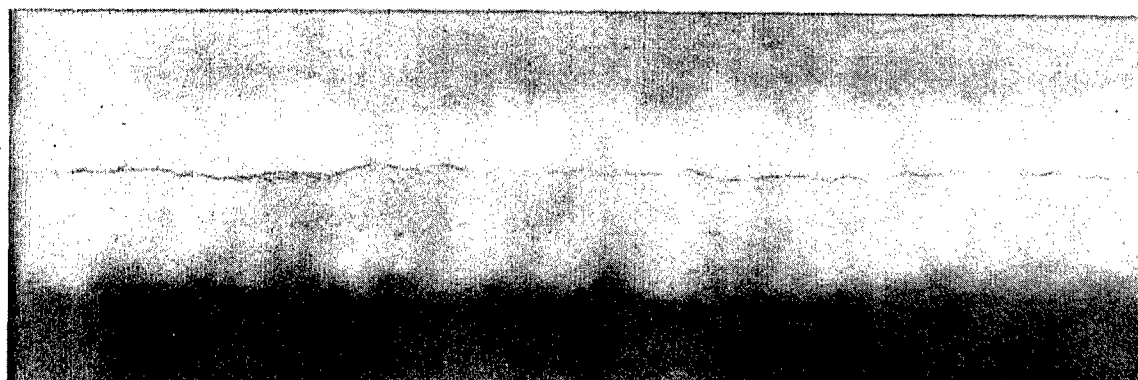
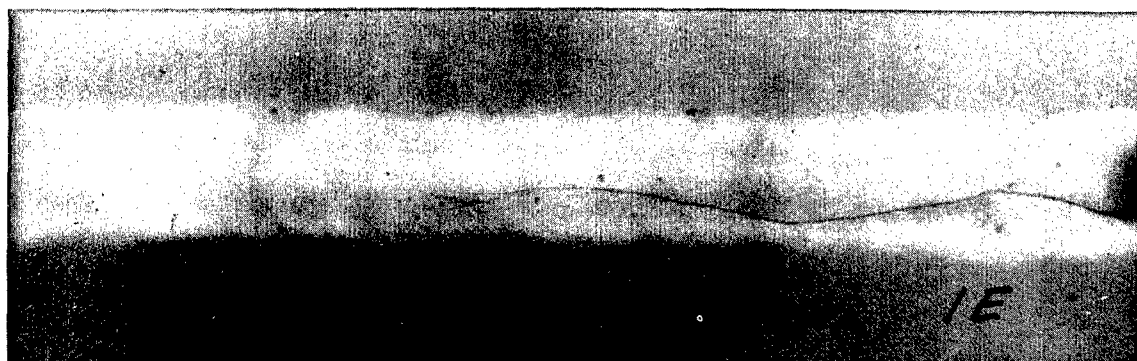
UNGRADED FLAWS



**Cross Section of
Plate 1E-Actual Size**



**Cross Section of
Plate 2E-Actual Size**



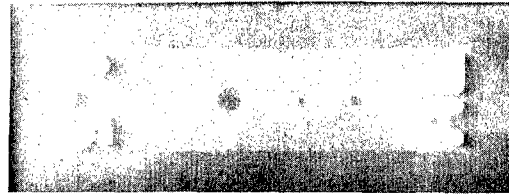
ILLUSTRATIONS OF LONGITUDINAL CRACKS
(All Cracks are unacceptable)

1E

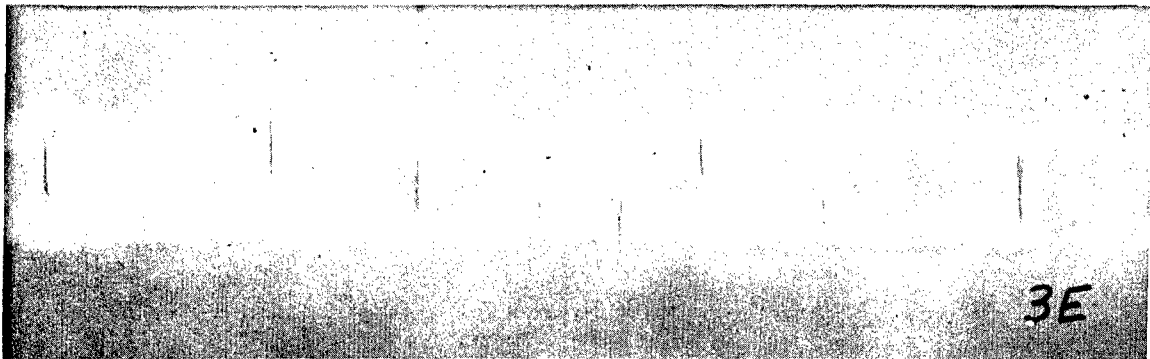
UNGRADED FLAWS



Cross Section of
Plate 4E-Actual Size



2-IT Radiographic
Quality Level



Transverse Cracks - 3/4 Weld

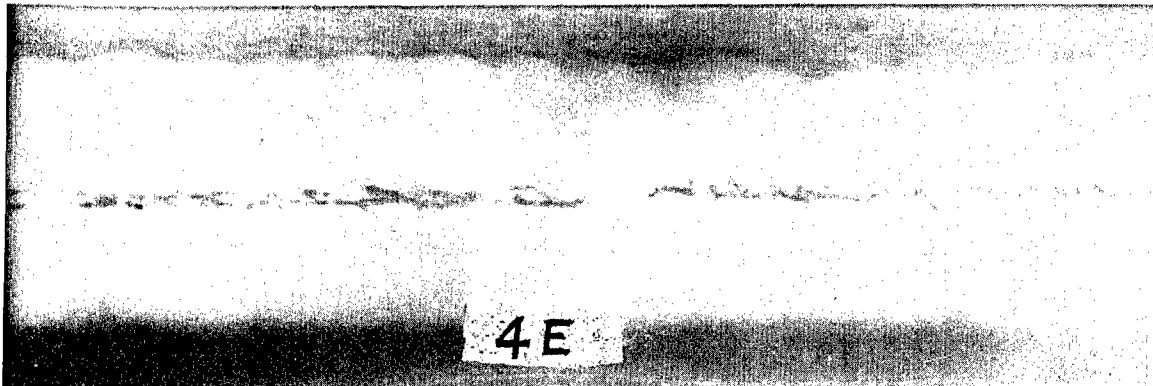
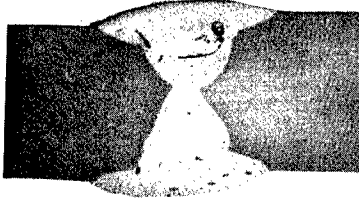


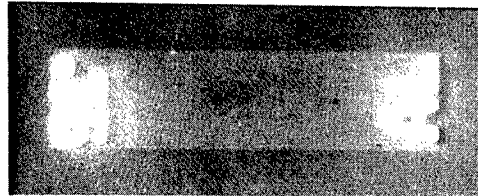
Plate Separation and Incomplete Penetration Due to
Improper Gun Alignment - 1 $\frac{1}{2}$ " Weld.

2E

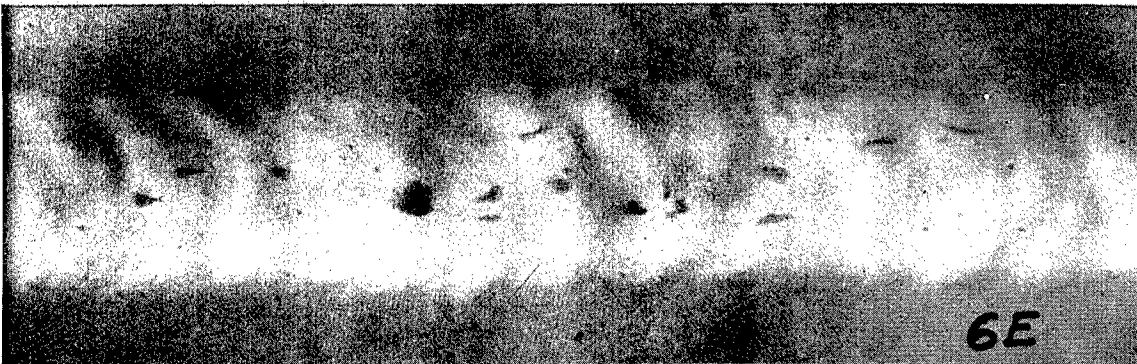
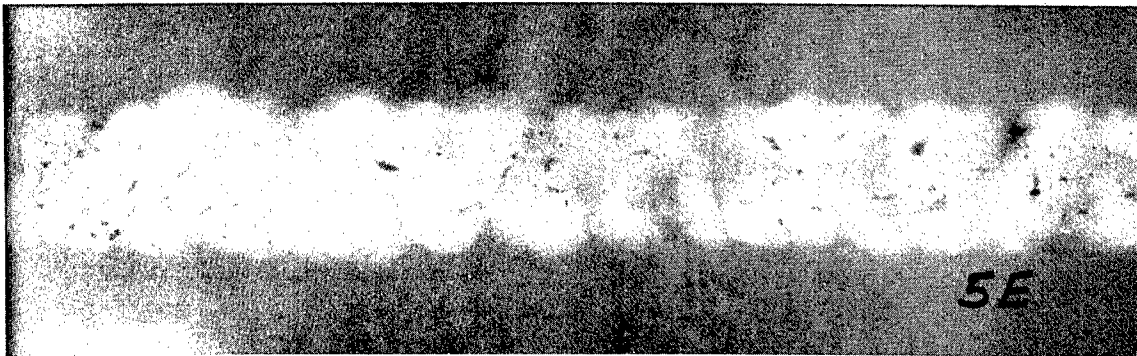
UNGRADED FLAWS



Cross Section of
Plate 5E-Actual Size



2-IT Radiographic
Quality Level



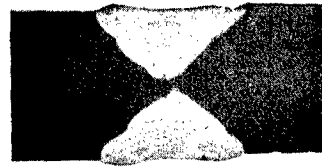
ILLUSTRATIONS OF OXIDE INCLUSIONS
(Judge severity according to scattered Porosity)

3E

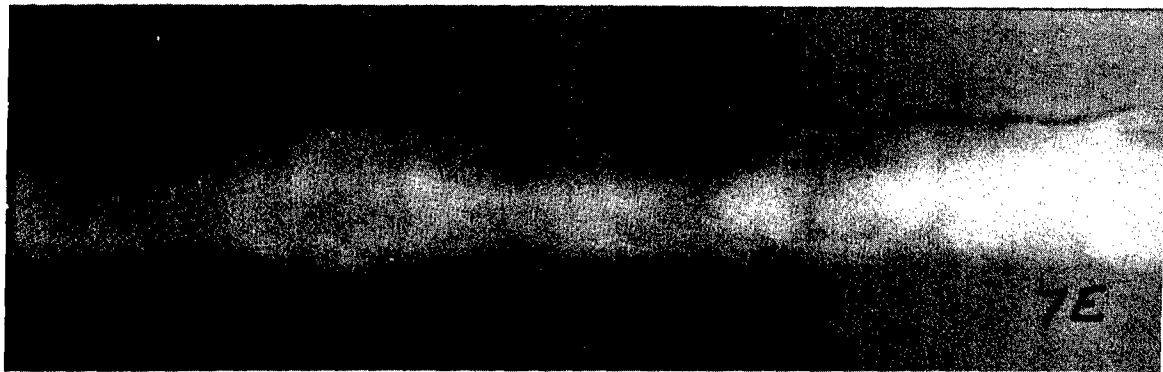
UNGRADED FLAWS



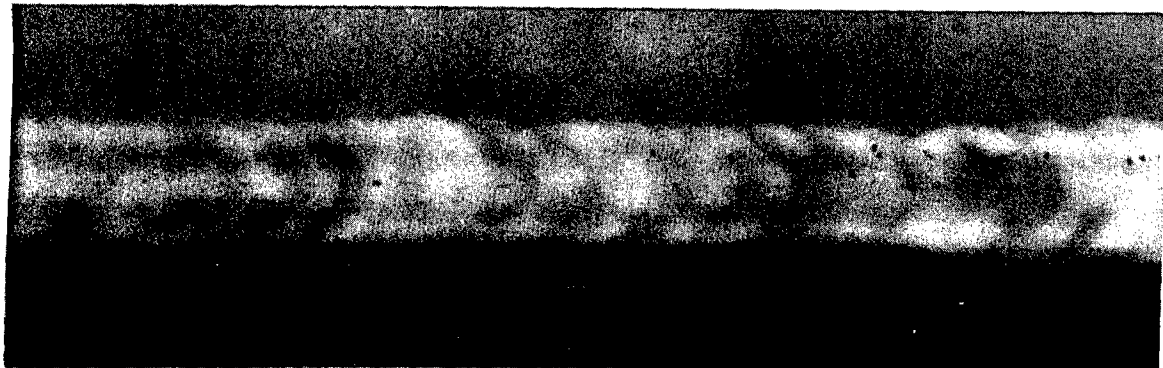
Cross Section of
Plate 7E-Actual Size



Cross Section of
Plate 8E-Actual Size



Undercutting



Incomplete Weld

ILLUSTRATIONS OF UNDERCUTTING AND INCOMPLETE WELD
(Both conditions are normally detected visually)