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INDUSTRIAL PLANT HARDNESS

Phase II

(12) LEVEL III

Boeing Aerospace Company
P.O. Box 3999
Seattle, Washington 98124

30 April 1978

Final Report for Period 25 May 1977—30 April 1978

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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

This work is part of a larger effort to determine whether simple hardening techniques will allow protection of industrial equipment in a nuclear attack. Previous work included hardening tests of buried equipment in two DNA sponsored 5 ton HE tests and in the DICE THROW 500 ton test. In addition Boeing conducted static hardening tests and analytical studies on general hardening techniques, earth arching, thermal pulse and debris survivability. over

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20. ABSTRACT (Continued)

In this report a list of industries is developed which would be critical for U.S. industrial recovery. Two sample industry surveys are also included. The first is a summary of previous Boeing hardening and recovery studies on the Auburn machine shop. The second involves a small plastics industry. A proposed test plan is presented which suggests standard HE tests, impulse tests, and continued expedient shelter wall stabilization tests.

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1.0 INTRODUCTION

The present work is a part of a larger effort to determine whether simple and inexpensive hardening techniques will allow protection of industrial equipment in a nuclear attack so that rapid post attack repair/rebuild/recovery is possible. In Phase I some of the hardening techniques were successfully tested in Event DICE THROW, a 500 ton TNT equivalent event which took place 6 Oct. 1976 (Ref. 1). Boeing participated in additional hardening tests in two DNA sponsored 5 ton TNT events, 25 August 1976 (Ref. 2) and 10 August 1977 (Ref. 3). In addition, Boeing conducted static hardening tests and analytical studies on general hardening techniques, earth arching, thermal pulse and debris survivability and on recovery of Boeing's key machine shop, the Auburn facility, after a nuclear attack.

In the present report a list of industries is developed which would be critical for U. S. industrial recovery. Two sample industries were surveyed in some detail to develop insight on hardening and recovery procedures. The first survey is a summary of the previous Boeing Auburn hardening and recovery study. It serves as a model for large industries. The second survey involves a small plastics industry (Reynolds Industries, Inc.) in the Los Angeles area. It serves as a model for smaller subcontracting plants.

A proposed test plan is included for FY 1978. It includes model factory and model Soviet basement shelter tests in an event such as MISERS BLUFF, high impulse machine hardening tests in AFWL advanced HEST tests (to simulate megaton impulses) and continued expedient shelter wall stabilization tests.

2.0 INDUSTRIAL SURVIVAL AND RECOVERY-- ESSENTIAL FUNCTIONS AND FACILITIES

The economy of the United States is complex, diversified, and rapidly changing. To the knowledge of the authors no studies or models of the U. S. economy yet exist that correctly interpret the functioning of the U. S. economy and its response to major perturbations. An examination of some major perturbations of the U. S. economy such as the depression of the 1930's, the great expansion during World War II, the technological changes and expansion of the 1950's and 1960's, the reaction to environmental and pollution control legislation, and the reaction to the OPEC oil embargo and increased oil prices show there are strong relationships among government social legislation, fiscal policy and the industrial economy. The U. S. economy has demonstrated great resiliency in many situations and considerable confusion in other situations. The difference between resiliency and confusion is closely associated with the presence or absence of clear cut national priorities and with fiscal policies which permit or hinder implementation of the priorities. Existing studies and models of the U. S. economy are unable to correlate all the interactions of production, distribution, and consumption or to include the interactions of government policies/ priorities and fiscal policies. In the absence of correct correlations, there is no yardstick to properly assess the importance of one segment of industry compared to another. This is especially true since the desire is to determine the importance of post attack industry in a situation expected to produce an ecomomy of scarcity while the present U. S. economy is an economy of abundance. In an economy of abundance industry can produce more of almost every product than can be consumed. Several alternate products compete for the same customer so substitution is quite easy. In an economy of scarcity demand greatly exceeds production capability, all goods produced are consumed regardless of quality and if a product fails or disappears, there are no immediate substitutes. Selection of priorities is therefore much more important in an economy of scarcity than in an economy of abundance. In current U. S. industry there is little training of managers to operate efficiently in an economy of scarcity. Establishment of priorities and the availability and assignment of skilled workers will therefore be of much more importance in post attack recovery than at present.

In reference 4, the authors point out there has been little agreement among civil defense authors on which industries are essential. They felt that without an exhaustive study of the entire U. S. economy that any list of essential industries will be quite judgemental. Despite the reservations stated by Sachs and Leavitt, we feel that the industrial priority list they developed is the best available. However, since they tied their priority list directly to the SIC* code system without estimating individual industrial importance, we feel their list is not completely satisfactory. For example, on their list (Appendix B of the reference) it appears that paper bags and lampbulbs have the same priority as petroleum refining or railroads.

Since use of the SIC code system is not essential to the purposes of the present study it is felt that descriptive/functional titles give a better understanding of the essential functions and facilities list. Most of the items on this list correspond roughly with those on the referenced list but will be grouped in functionally related categories. It is important to recognize that many essential items should be available through salvage from facilities which have been put out of operation but not totally destroyed. Examples are tools and structural steel. Furthermore, if war fatalities are high production pressure on food, potable water, and pharmaceutical industries might be reduced. Such items where the supply (through salvage) and the demand (number of people surviving) are dependent on nature and severity of attack are tagged by an asterisk in the list.

The approach used in developing a list of industries essential for post attack recovery was first to define very broad categories of the essential functions to rebuild society, narrow the list of industrial survival/recovery requirements, and then to group the essential functions and facilities into functionally related categories. The criteria used in selecting essential industries include: (1) bulk tonnage of input raw materials (2) number of workers in the industry (3) ranking in corporate/business worth (4) gross sales value of product (5) engineering estimates of the number of other industries dependent on recovery of this industry and (6) engineering judgements on the likely post attack overall economic/industrial situation.

*Standard Industrial Classification code in which industries are identified by 4 digit numeric codes.

The broad essential functions (not in priority of relative importance) to sustain and rebuild a technical society are:

Table 1. Essential functions to rebuild society.

I	People to sustain and rebuild. This requires people to be released from subsistance drudgery.
II	Energy
III	Raw materials
IV	Water supply for people, agriculture and industry
V	Communications
VI	Transportation for people, products, and raw materials
VII	Construction industry
VIII	First tier (end product) manufacturing
IX	Second tier (materials such as steel or chemicals) manufacturing
X	Maintenance facilities, utilities, and repair capabilities
XI	Education (long term recovery)
XII	Centralized (government) control for priority allocations

The restoration of the educational system and government control are outside the scope of this study. However, our system of checks and balances in government and a division of responsibility and authority among federal, state, county, city school district, and various regional agencies mandates that all levels of government must regain functional capability if industry is to recover in a short time. Industry is dependent on utilities, communication, transportation, housing for workers, police and fire protection and medical facilities which are funded, directed and regulated by an interlocking network of government entities. Without functioning governments at all levels industrial recovery would be greatly delayed. Restoration of communication and of transportation (for people) will be essential for retaining or rebuilding functioning governments.

For labor requirements industrial recovery is directly concerned only with the availability and assignment of skilled industrial workers, repair/rebuild workers and trainees. These workers will not be available if failure of food, clothing, and housing forces everyone into a fulltime desperate struggle for survival. Recovery of society is completely dependent on keeping a skilled labor force free of the daily struggle for subsistance living. This means that production and distribution of food, clothing and shelter are prerequisities for industrial recovery. With these considerations in mind, the list for general recovery of society is subdivided into functionally similar categories. An asterisk indicates some relief is possible through salvage or through reduced population levels. Parenthetical item references indicate interrelationships in the list. Order in the list is not necessarily a measure of importance or priority.

Table 2 Essential functions for industrial recovery

I People to rebuild industry
1. Skilled survivors moved where needed
2. Water (Item IV)
3. Shelter
   a. Materials (Item VIII)
   b. Transportation (Item VI)
4. Food
   a. Storage*
   b. Transportation (Item VI)
   c. Seed Stocks
   d. Fertilizer (Item VII)*
   e. Agrichemicals (Item VII)*
   f. Farm machinery (Item VII)*
   g. Fishing Boats

II Energy*
   a. Power Plants*
   b. Transmission and Distribution*
   c. Fuel Supplies (oil, natural gas, jet fuel, gasoline, coal, uranium)

III Raw Materials
   a. Crude oil (petrochemical industries)
   b. Barite
   c. Fluorspar
   d. Potash
   e. Soda
   f. Borates
   g. Phosphate rock
   h. Rock salt
   i. Wood pulp
   j. Alkalies
   k. Metal ores
   l. Sulfur
   m. Coal (fuel and coke)
   n. Crushed rock, gravel, sand

Table 2 Essential functions for industrial recovery (continued)

IV Water supplies (people and industry)

1. Sources (wells, pumps, etc.)
2. Treatment (Items VI and VII)
3. Distribution*

V Communications

1. Transmit stations (TV, telephone, telegraph, radio)*
2. Lines (telephone, telegraph)*
3. Receive stations*
4. Energy (Item II)

VI Transportation

1. Vehicles (trucks, trains, ships, tugs, barges, waterways, docks, ports, locks, aircraft maintenance vehicles)
2. Roads*
3. Railroad tracks*
4. Airfields
5. Energy (Item II)

VII First tier (end product) manufacturing

1. Fertilizer*
2. Agrichemicals*
3. Farm machinery*
4. Steel pipes and tubes*
5. Cars, trucks*
6. Paper products
7. Containers (bags, bottles, cans, boxes)
8. Sanitary paper products
9. Batteries
10. Pharmaceutical, medical, botanical products
11. Soaps, detergents and sanitary agents
12. Tires and inner tubes
13. Rubber and plastic hose and belting
14. Hand tools (powered and unpowered*)
15. Construction machinery*
16. Welding apparatus
17. Electric lamps

Table 2 Essential Functions for Industrial Recovery (Continued)

VIII Second Tier Manufacturing

1. Petroleum derivatives (asphalt, etc.)*
2. Steel
3. Nonferrous metals
4. Paper
5. Synthetic rubber
6. Plastics
7. Intermediate chemicals (sulphuric acid, etc.)
8. Lumber, wood products
9. Cement

IX Maintenance Facilities (Including Construction)

1. Skilled people (Item I)
2. Vehicles (Item VI)*
3. Tools and welding apparatus (Item VII)*
4. Parts and Materials
5. Energy (Item II)

Several points can be made concerning some major topics on this list: The availability of an adequate number of trained people is necessary for industrial recovery. Industrial survival/recovery cannot be divorced from population protection. The construction and provisioning of shelters for workers can readily be a part of industrial protection, but protection of workers will have little value unless their families, neighbors and friends are protected. This requires a national commitment on population protection activities.

Oil refineries, which are crucial to energy needs, are very vulnerable and difficult to harden. A large number are concentrated in Louisiana. Many others are constructed near oil tanker port facilities. Most of the vulnerable catalytic cracking towers and distillation towers are primarily utilized to obtain high fractions of specific fuels. Simpler distillation equipment could be constructed from salvaged or stockpiled materials and could produce lower grade fuels at reduced efficiency. It is felt the recovery scheme for oil refineries should include plans to first rebuild simple distillation equipment to provide emergency fuels for transportation (and some power plants).

There are unique supply problems for some raw materials which are now essential. An example is vanadium used in some high quality steels. The only U. S. supplier is the U.S.S.R. The only recourses to interruption of this supply are stockpiling or substitution of other steel alloys.

Pharmaceutical manufacturing which is crucial to population health is concentrated in the New York - New Jersey area. Stockpiling and plans for dispersal of manufacturing appear necessary.

Some second tier products are utilized in a large fraction of first tier industries. An example is sulfuric acid which is used in large quantities by many industries. Since much of the U. S. manufacture of sulfuric acid is co-located with major users in heavy industrial areas it could be vulnerable to attack.

Fortunately the production of sulfuric acid is extremely simple and could be done with very crude equipment. Rather than protect the large acid towers now utilized, it would appear better to plan to begin post attack production with simple (low efficiency) burning and spraying towers built from stockpiled or salvaged materials. Stockpiling acid resistant materials (sheet lead) would be necessary.

3.0 SAMPLE INDUSTRY SURVEYS

3.1 BOEING AUBURN PLANT

Hardening and recovery studies were carried out in 1975 and 1976 on the Boeing Auburn plant. Some of the results are summarized here to illustrate the methodology of such studies. The overall purpose of this work was to examine the effectiveness of Soviet industrial hardening techniques against U. S. warheads. A "mirror image" approach was adopted. The Auburn plant (along with the entire Puget Sound industrial area) was treated as a part of Soviet industry. A portion of the U. S. retaliatory warhead inventory was then targeted against the Puget Sound area. Two attack scenarios were considered:

1. A direct attack (one 100 kt warhead) was made on the hardened Auburn plant, and
2. A "collateral" attack was made on the unhardened Auburn plant (i.e. the plant was not an aim point, but was subjected to 10 psi blast overpressure as a result of an attack on a nearby target).

Recovery times were estimated only for the collateral attack case.

Since the purpose of this contract is to study industrial hardening the direct attack case will be summarized. However, recovery time is also of interest. Even though the Auburn plant recovery times were for an unhardened plant, the procedure used to obtain these times is typical.

The Boeing Auburn plant is the primary machine shop/fabrication facility for the Boeing aircraft production program (see Fig. 1). The following topics were addressed:

1. What key items must be hardened, dispersed or stockpiled (hardening in this study means prevention of irreparable damage),
2. Methods of protection,
3. What materials, emplacement times and resources are required for protection,
4. Post-attack recovery time, recovery methods and resource estimates, and
5. Critical subcontract industries.

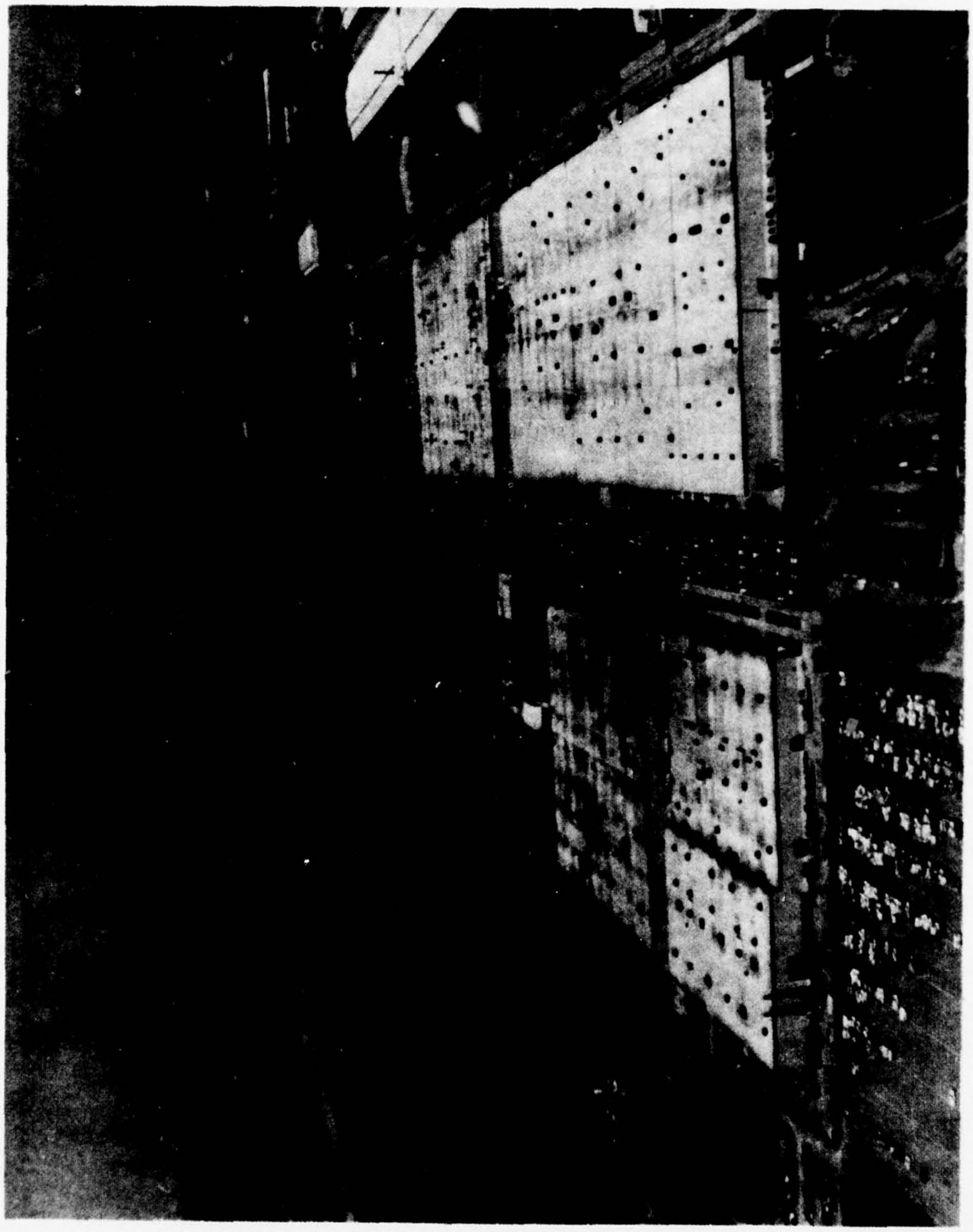


Figure 1 Aerial view of Boeing Auburn facility

The results of this study were used to help evaluate the effectiveness of industrial protection and aided in initial planning for field tests.

Boeing Auburn is one of the largest machine shops in the world. The most important items are located in four large buildings shown in Fig. 1 (540 ft. wide and up to 1260 ft. long). Key items were chosen as those which are unique to Boeing in the local (Puget Sound) industrial area and which are essential to normal commercial production. Six key item types were singled out:

1. Autoclaves (Fig. 2) used to bond composite structures at high pressure and temperature,
2. Heat treat facility (Fig. 3),
3. Spar mills (Fig. 4) used to machine wing spars,
4. Skin mills (Fig. 5) and
5. Process tank lines (Fig. 6) - large tanks in which aircraft parts are dipped for various chemical treatments,
6. Five-axis milling machines (Fig. 7).

Many other items would also be protected to assure rapid recovery, but many of them could be obtained from non-critical surviving industries in the local area.

Of the protection alternatives (hardening, dispersal, stockpiling entire machines or a combination) only hardening was studied in detail for the six key item types. Dispersal, unless carried out as part of a long range program would disrupt production unduly while stockpiling duplicates of key machines would be very expensive. Cheap and effective hardening techniques were developed and tested in high explosive events. As noted earlier, simple hardening may not be feasible for key items in some industries such as petroleum and steel industries.

Hardening techniques developed for the six key items are illustrated in Figures 8 through 13. Heat treat furnaces would be filled with sand, laid on their sides and buried or would be lowered into holes and buried. Quench tanks would be submerged in water. Spare firebricks, firebrick mortar, and nichrome wire would be stockpiled at a remote site.

The spar mills and five-axis mills would be replaced on stiff but crushable bases. In the hardening exercise they would be covered with sheet plastic, surrounded by a layer of crushable material for rattle space and buried in soil. At Boeing

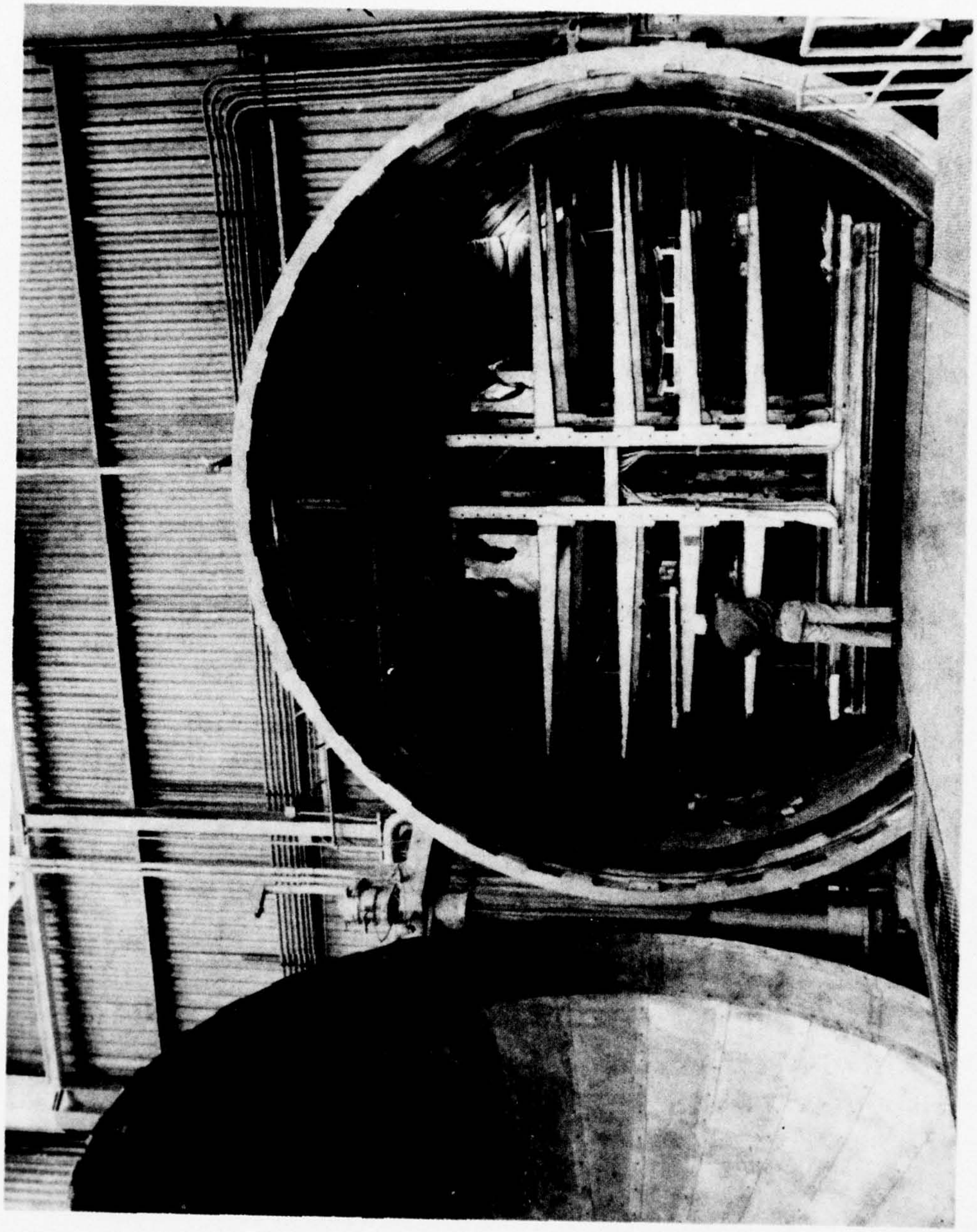


Figure 2 Autoclave

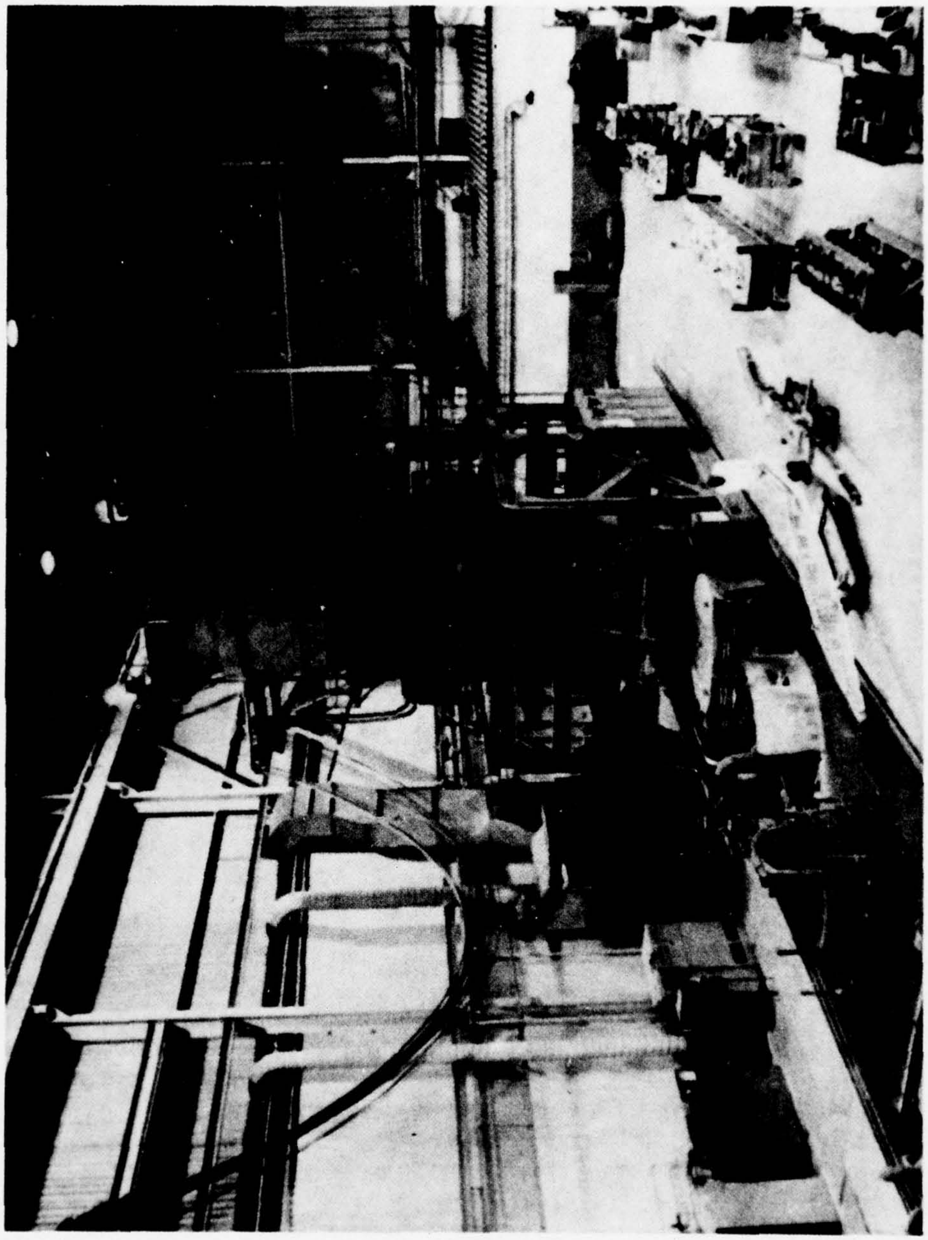


Figure 3 Heat treat facility

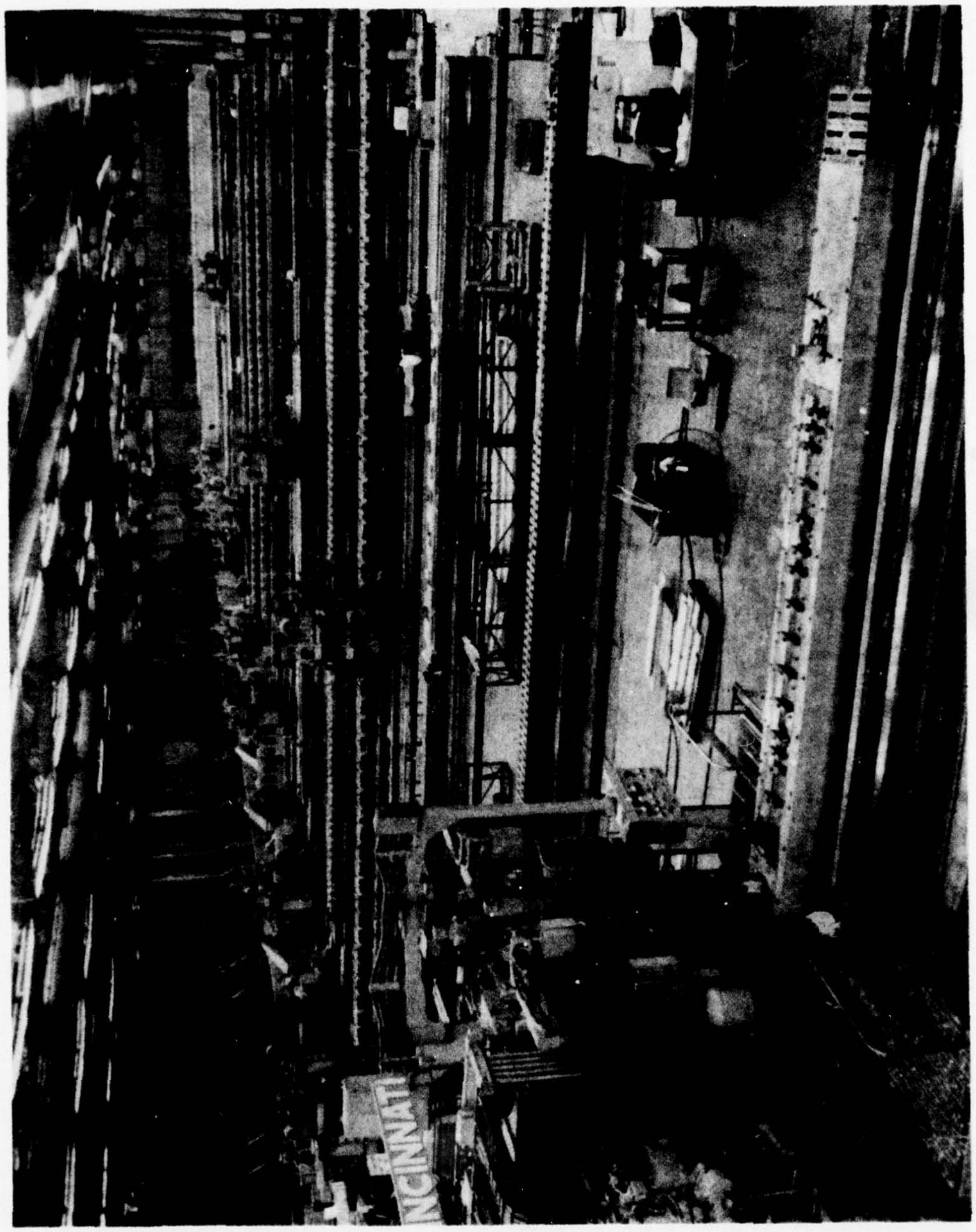


Figure 4 Spar mills

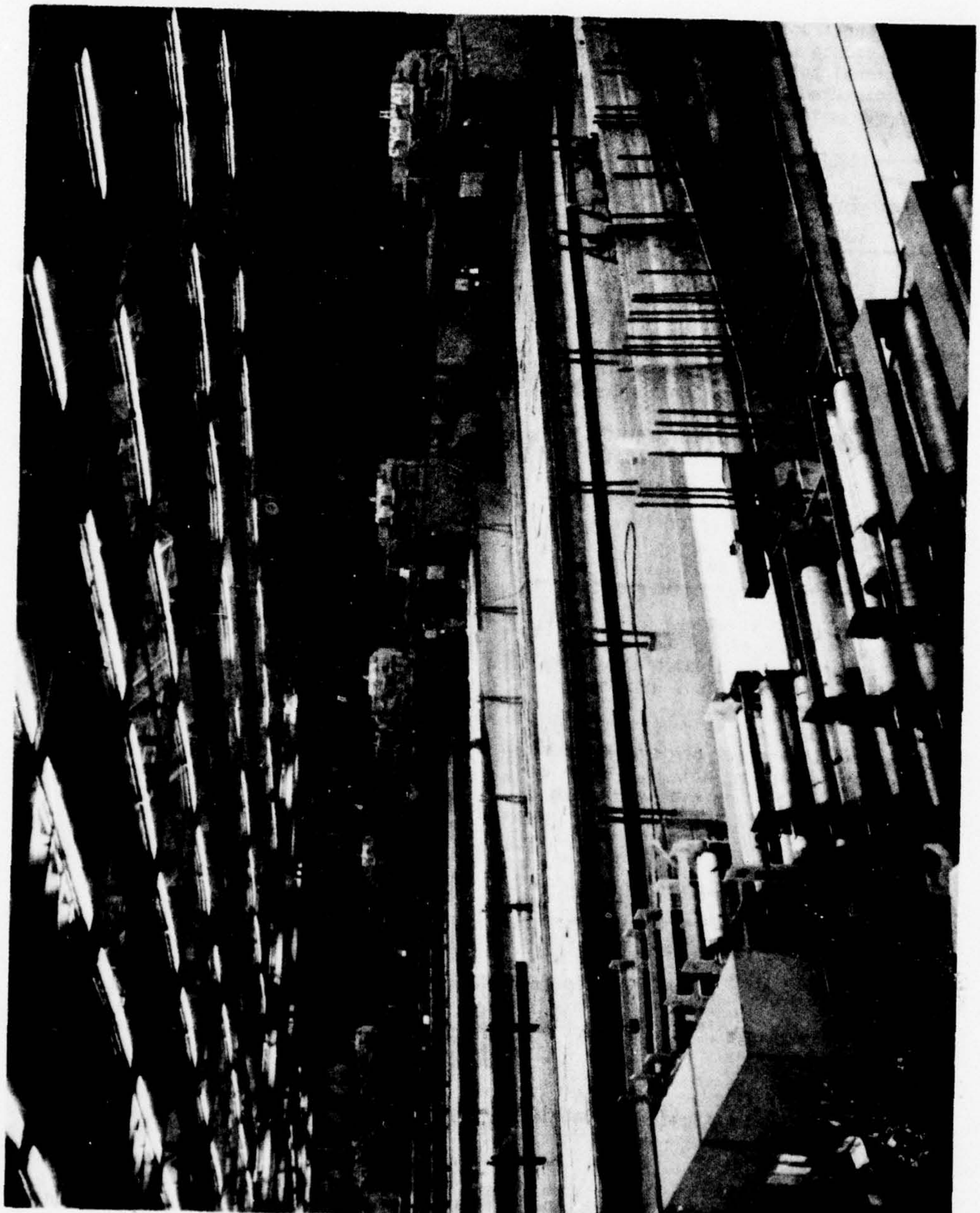


Figure 5 Skin Mills

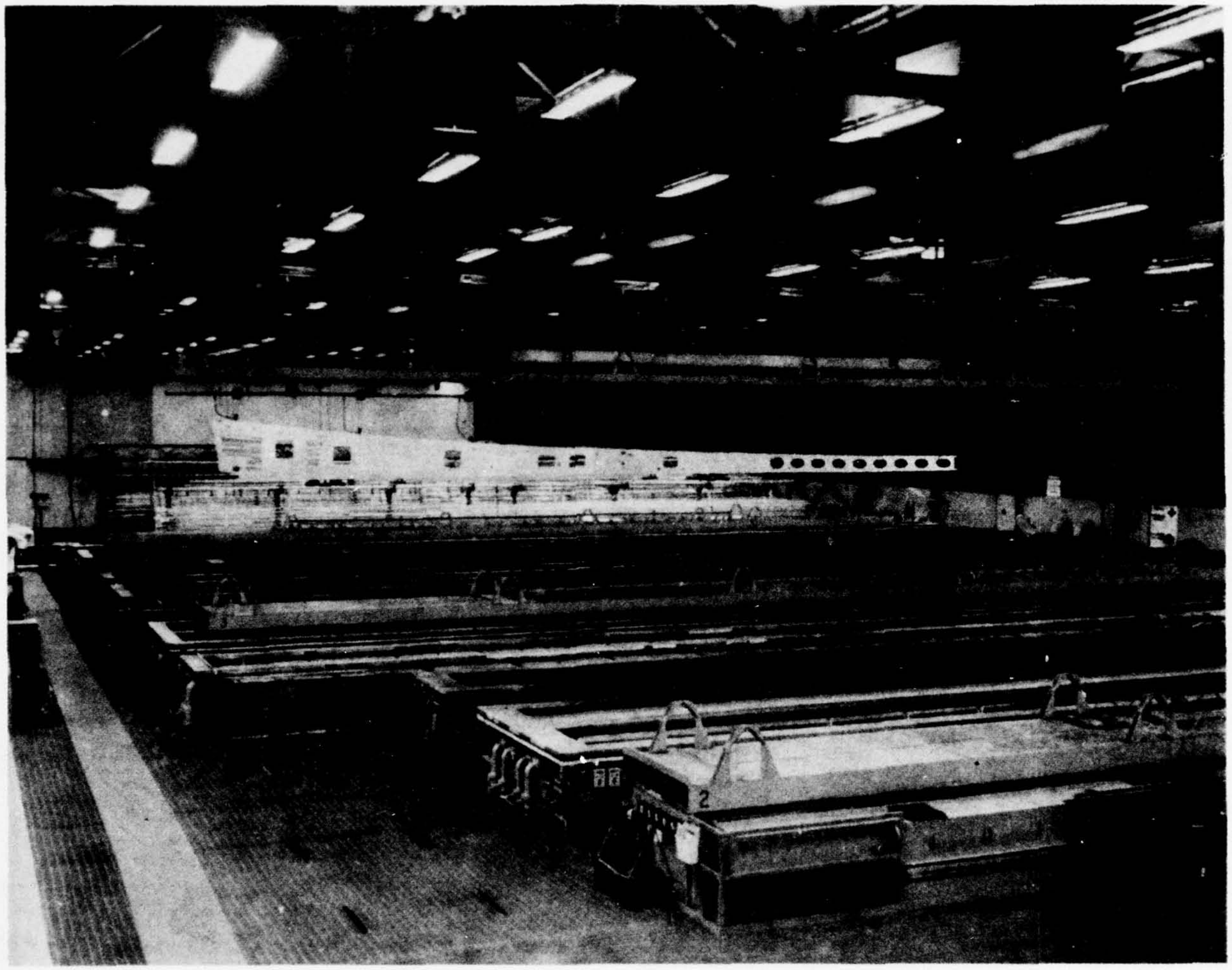


Figure 6 Process tank lines

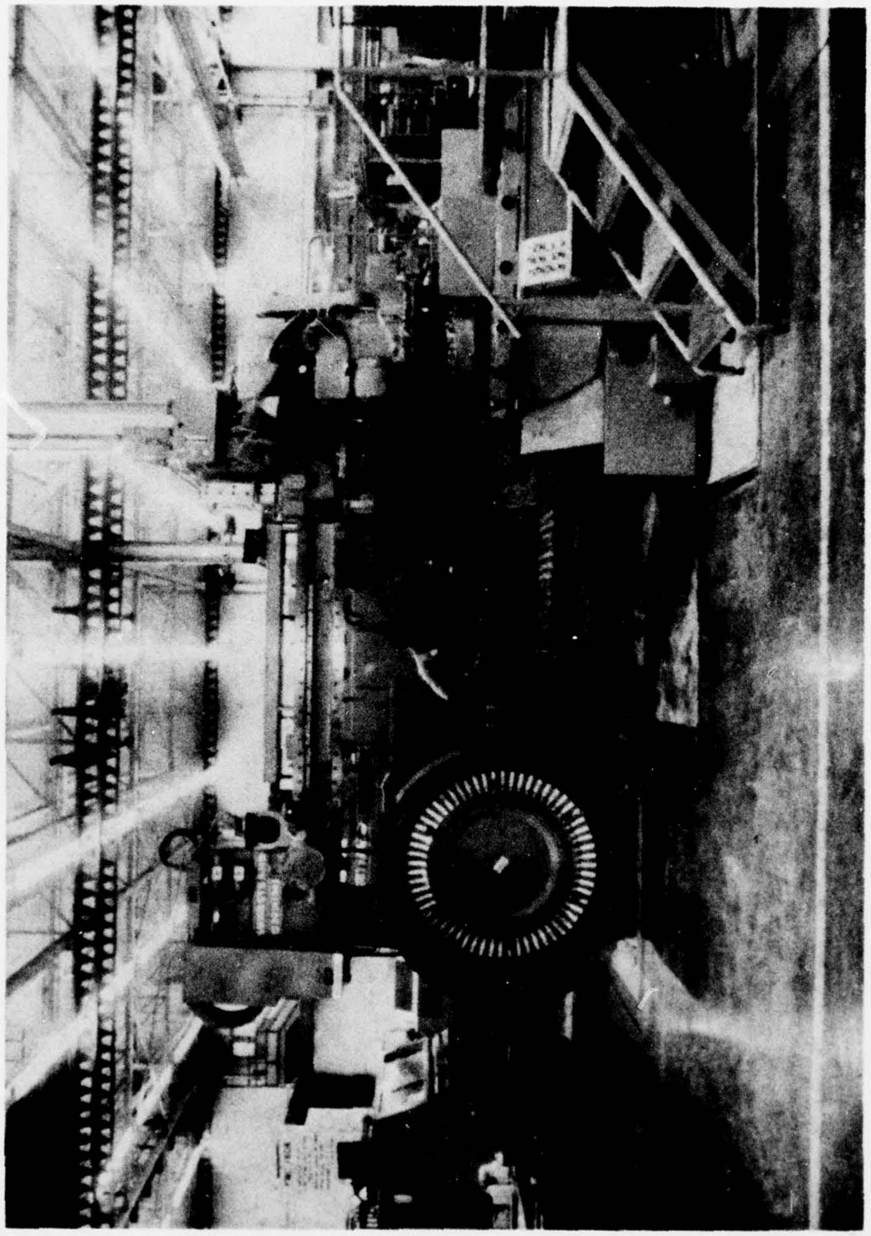


Figure 7 Five-axis milling machine

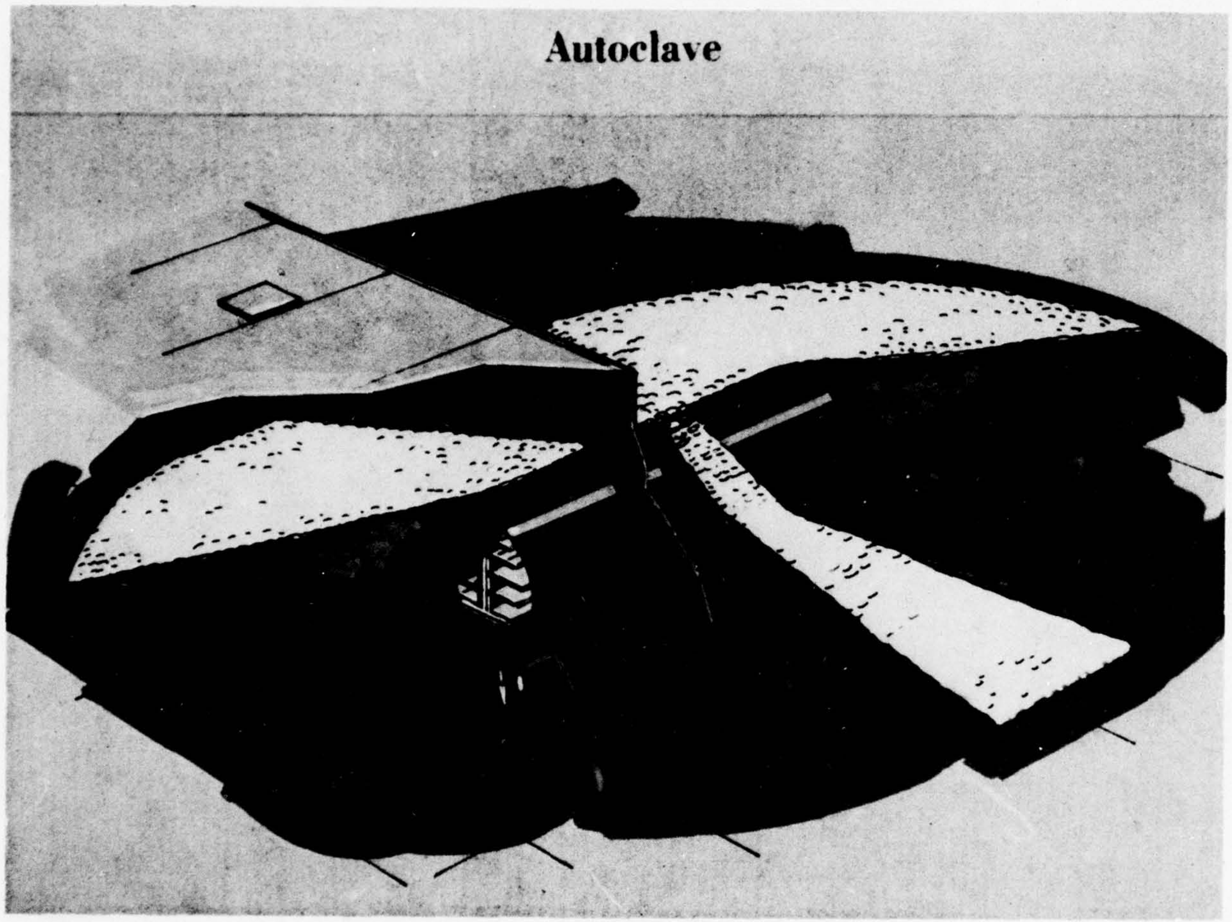


Figure 8 Hardened autoclave

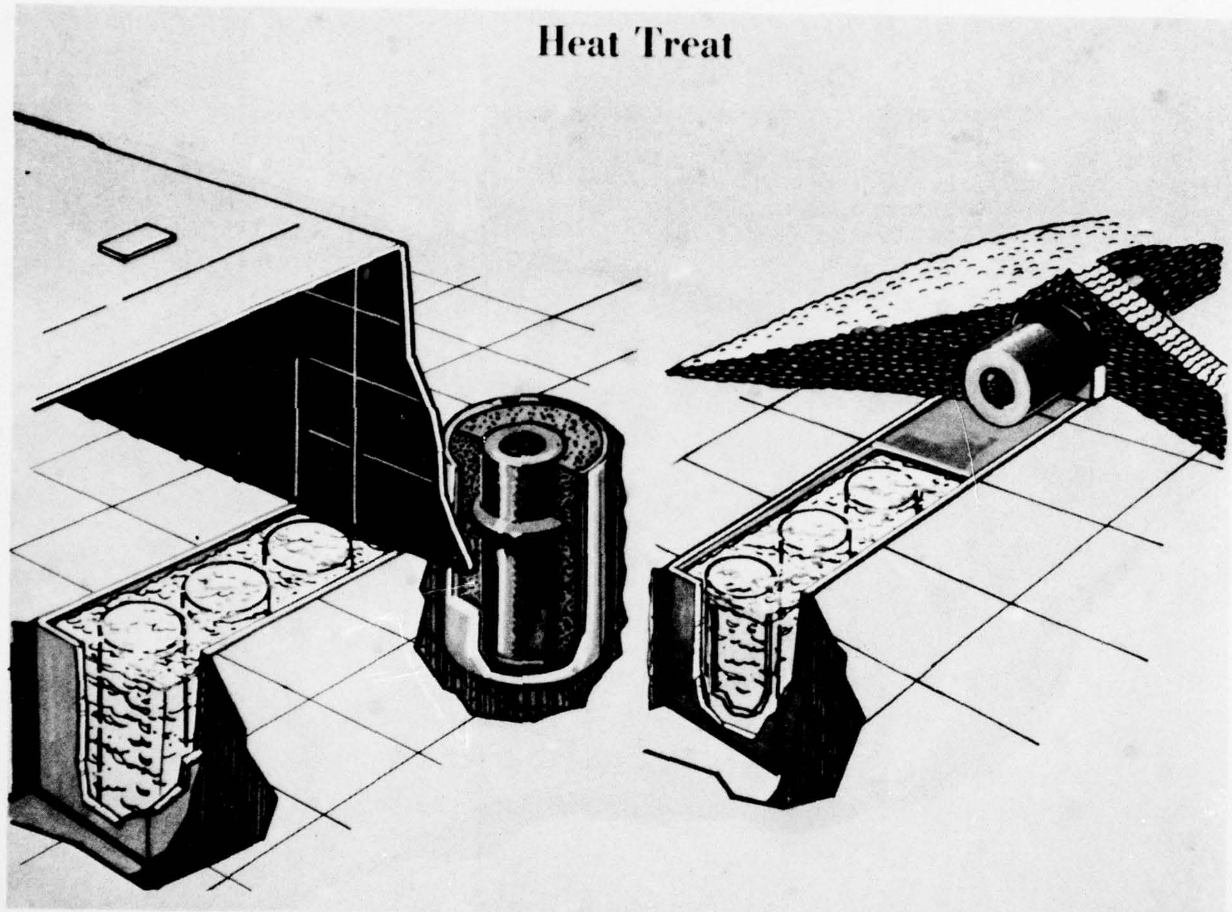


Figure 9 Hardened heat treat facility

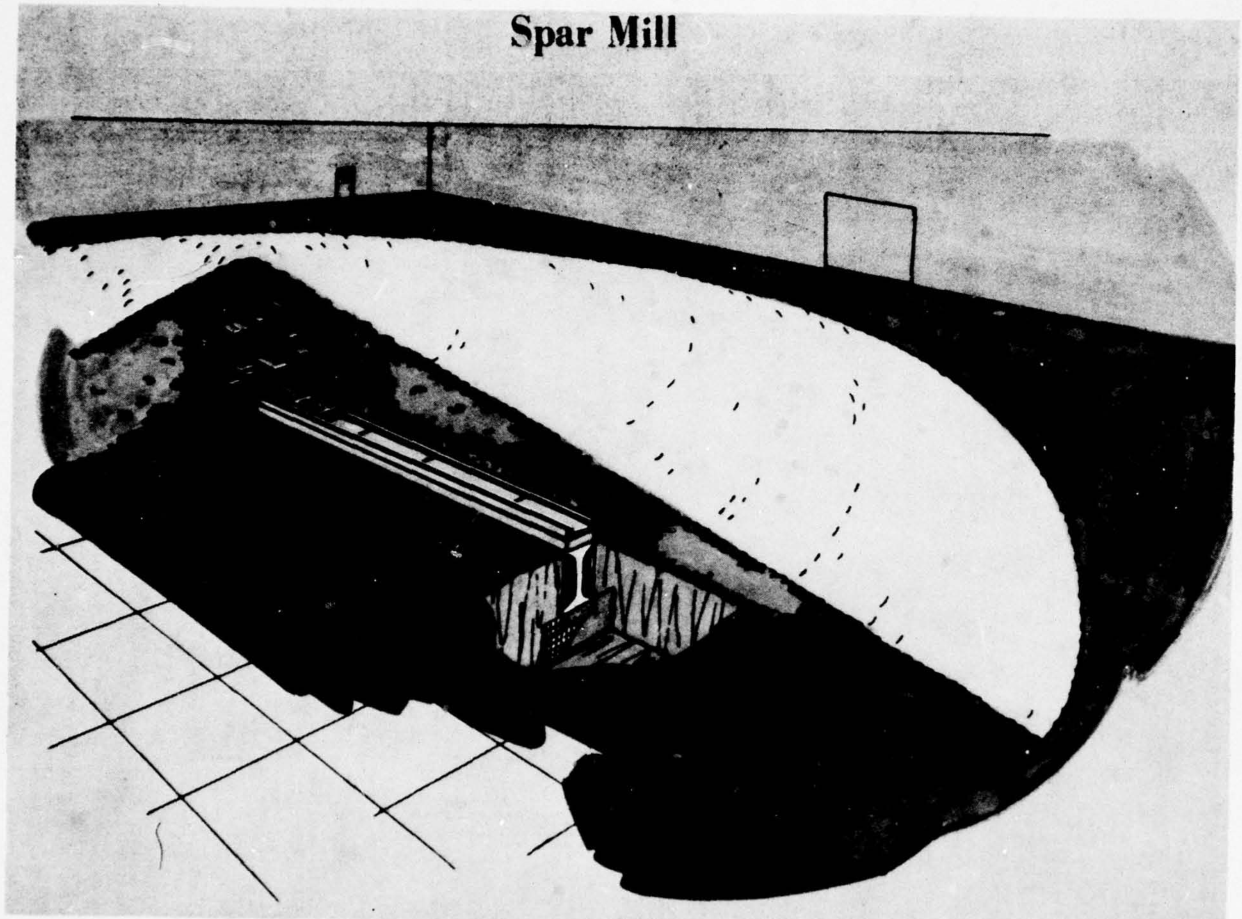


Figure 10 Hardened spar mill

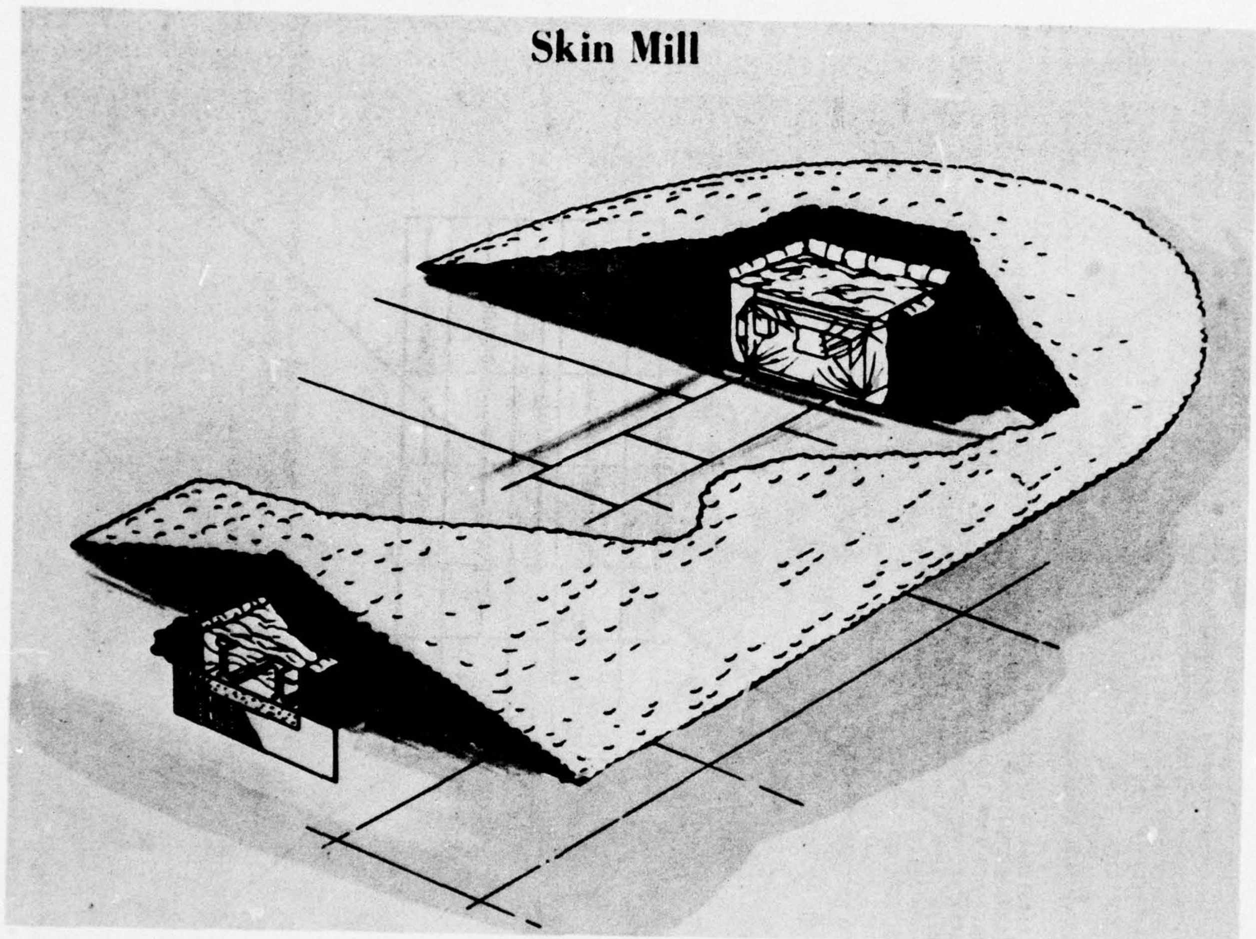


Figure 11 Hardened skin mill

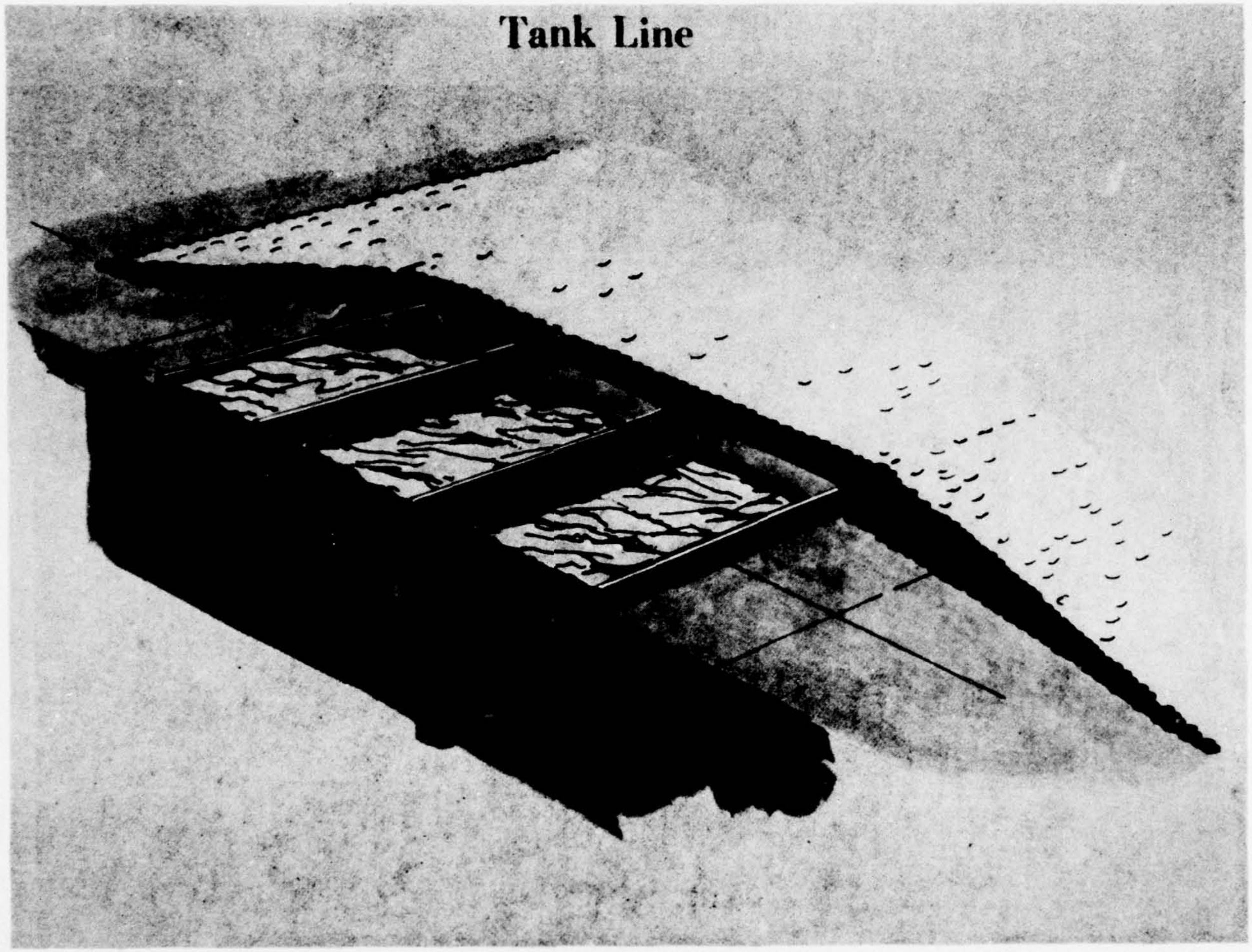


Figure 12 Hardened tank line

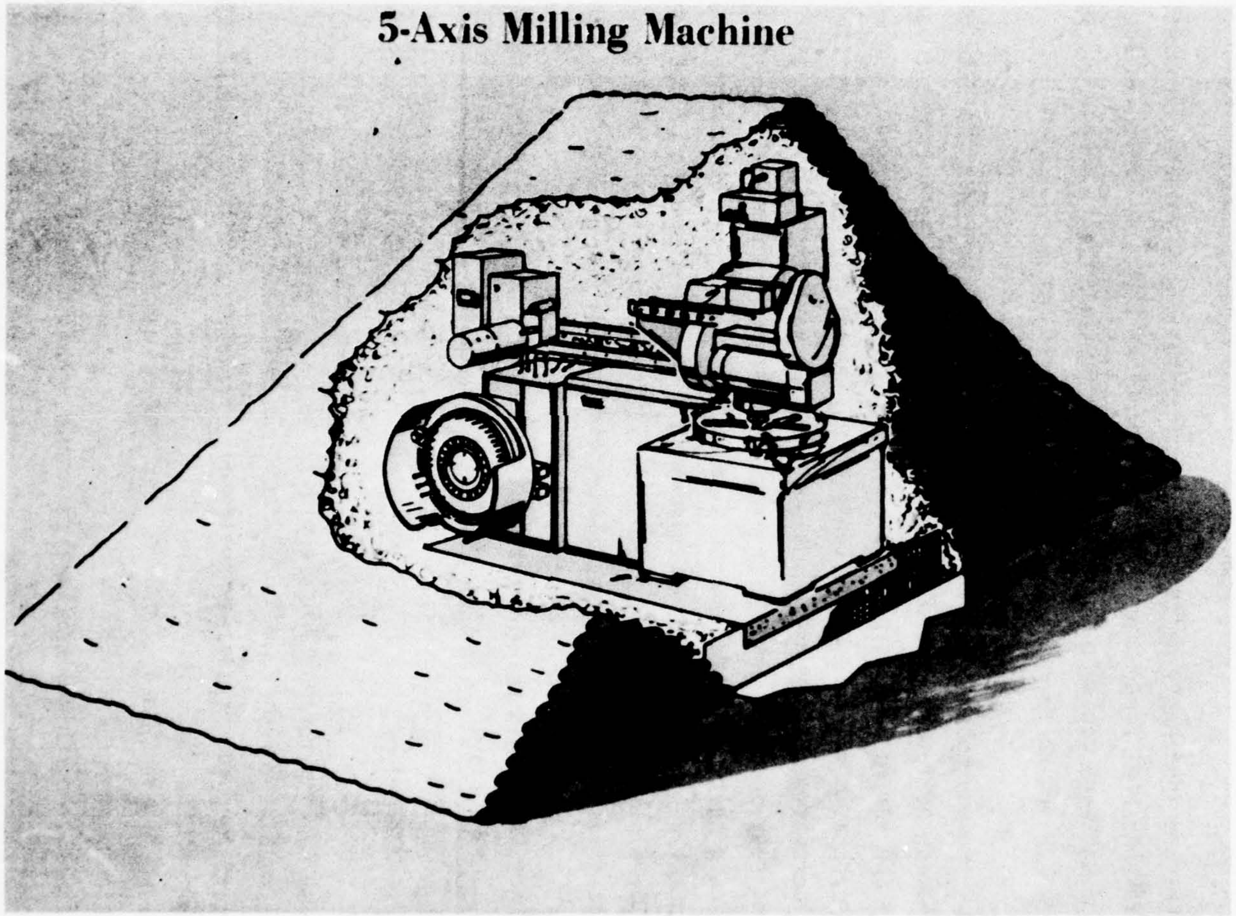


Figure 13 Hardened five-axis mill

the crushable material would be aluminum chips which are produced in large quantities. Some spares (depending on the machine) would be remotely stockpiled.

The autoclaves are inherently quite hard, particularyif they are kept pressurized by a small (expendable) compressor. Delicate machines could be stored inside in chips. The autoclaves would be buried in soil to prevent debris damage and to avoid turnover by nuclear weapon produced dynamic pressure.

The hardening proceduresshown in Figs. 11 and 12 for process tanks and skin mills involve emplacing cofferams around the item, flooding to the bottom of a cover over the dam and burying the cover in the soil to avoid debris damage. The water transmits hydrostatic pressure with little energy deposition in the item itself. A simpler alternative for the process tanks would be to fill the pit and tank with soil and rely on earth arching to protect the tank. (High explosive test results indicate that crushable materials and earth arching may be advantageous for the skin mills.) For either tank hardening scheme some bending of the tanks would be tolerable. However, teflon and plastic lining materials should be remotely stockpiled, since these specialized linings are not readily available.

The following items should be stockpiled in hardened, dispersed storage areas:

Food
Drinking water
Basic tools
Cutting/welding torches and acetylene
Small machine parts
Vehicles (perhaps dispersed--bulldozers, cranes, forklifts, trucks, etc.)
Firebricks and firebrick mortar
Nichrome wire
Selected structural steel
Duplicate electronics, rectifier elements, transformers
Air compressors
Motor generators and 600 to 750 hp motors
Key overhead crane components
Emergency motor/generator plant and fuel
Cement and cement mixers

Process tank liners

Wheelbarrows and shovels

Sheet plastic for weather protection

Several calculations were made using different assumptions concerning the time required to harden the four Boeing Auburn machine shop buildings. Machines were assumed to be preplaced on stiff, crushable bases to provide ground shock protection. On notification of an impending attack all available personnel would be divided into three shifts and assigned the following tasks:

1. Disconnect all machine wiring to avoid EMP damage,
2. Disconnect delicate items such as machine control panels and milling machine cutting heads for special hardening attention (such as emplacement in chips in the autoclaves),
3. Apply anticorrosion treatment (grease, paint or cosmoline) to machines,
4. Cover all machines with sheet plastic,
5. Emplace prebagged crushable materials,
6. Cover all machines with enough soil to provide earth arching.

The last item would be most time-consuming. It was found that important machines tended to be clustered closely enough that near-flush burial of large numbers of machines was needed rather than provision of single mounds around individual machines. (This is an advantage because less soil is required.) Soil depth is dependent on machine size (actually on minimum horizontal dimension across the machine), but is generally many feet (about 20 ft. for a large mill bed and 8 ft. for smaller machines). There would be some mounds (4 to 1 slope) above this flush cover over some very tall items.

Although an admittedly huge amount of soil is needed (about half a million cubic yards) it was found that the time to harden the majority of machines in the four main buildings would be about 2 days under the following assumptions:

1. Preplaced (weather protected) earth mounds and bagged chips near the buildings,
2. Full use of all overhead cranes and earth moving equipment to move soil,

3. Movement of 10 cubic yards per day of soil by wheelbarrow by all personnel not engaged in other activities (total work force of 12,000 assumed). (This would imply stockpiling 4,000 wheelbarrows and shovels which should be dispersed after hardening for use in recovery).

There are other more minor assumptions such as the need to extend overhead crane rails outside the buildings to the earth mounds. The important point is that vast amounts of soil can be moved in rather short times if adequate planning and preparation is carried out.

A second study was made assuming no advance preparations were made except stockpiling of sheet plastic and plastic bags, shovels, and hydraulic jacks. In this case one crew would be assigned to jacking up machines, so aluminum chips could be placed under them as a crushable base. All dirt was moved by pickup trucks and automobiles belonging to the workers. In this case from 4 to 7 days were required to protect all key equipment. One-third of all key equipment could be protected quite readily in three days.

Post attack recovery time strongly depends on a number of factors:

1. The severity of the attack,
2. The availability of local support industries, materials, and utilities after the attack,
3. Survival of needed personnel,
4. Degree of double or triple shifting on surviving machines,
5. Fraction of recovery which is acceptable

It was assumed that a 100 kt surface burst occurred on one of the four main buildings (direct attack case) and that little survived in this building. Some machine dispersal would be highly desirable. For example, the large mills and autoclaves are clustered in small areas in one building. If that building is hit all these machines could be lost. If they were dispersed in several buildings no one hit could destroy all of them. An assessment was then made of damage to be expected in the other three buildings.

In this assessment it was found that the building walls and roof would be damaged beyond repair. The floor would be buckled several inches over horizontal distances of the order of 100 ft. Utilities buried in soil would survive, but those in the open would be destroyed.

The following types of damage are expected for the six key items. All items were protected as shown in Figures 8 thru 13.

Expected Damage to Heat Treat Facility

Foundation under the quench tank pit will be displaced up to 3 inches vertically, up to 1-1/2 inches horizontally, and tilted up to 5 degrees.

Walls of the quench tank pit will be cracked and tilted up to 5 degrees from vertical.

Valves and piping under quench tanks - cast iron pipes or valves will have cracked joints due to bending or shear. Malleable steel pipes or valves will have some bending but should not break.

Quench tanks - very little damage.

Furnace - If furnace is in separate silo, filled with sand and surrounded by 20 inches of crushable backfill no damage is expected except fire bricks will be shaken loose from their mortar and nichrome wire broken.

If furnace is covered horizontally, the damage will be greater. Firebricks are expected to be dislodged and will cause extensive denting of furnace shell. Portions of the furnace shell, perhaps 10% to 20% of total area, will be dished in up to 6 inches.

Expected Damage to Spar Mill

Foundation - vertical displacement up to 6 inches, horizontal displacement up to 3 inches, tilt up to 10 degrees.

Main foundation beam - up to 3 inch horizontal displacement on foundation.

Machine Bed - up to 3 inch lateral displacement on beam. Alignment bolts sheared if not removed or loosened.

Working Machine - if removed from track and placed on crushable material very little damage except for bending of secondary support members - unsupported end of cable braces, tool holders, etc. bent 3 inches.

If remaining on track, warping or twisting of main arbor and track wheels, 2^o twist or warp.

Expected Damage to Autoclave

Dents in shell up to 6 inches deep over main saddle supports.

Main door is expected to rotate up to 2 degrees compared to cylindrical shell. This will cause warping of the main hinges and warping or breaking of latches, stops or dogs. (Soil cover would prevent internal pressure from blowing door open).

Foundations under the support saddles may be displaced up to 3 inches vertically, 1-1/2 inches horizontally and tilted up to 5 degrees.

Heating elements will be broken if not removed.

Control cabinets will be dished in up to 3 inches. Internal wire connections will be broken.

Expected Damage to Tank Lines

Foundations may be displaced up to 6 inches vertically, 3 inches horizontally and tilted up to 10 degrees.

Sides of tanks may be dented inward or outward up to 6 inches.

Protective liner materials will be spalled loose from the tank walls and cracked into pieces about 1 foot square.

Some tank walls will be perforated by roof girders. Perforations about one foot in diameter going though two walls of each tank can be expected.

Piping and valves - any brittle cast iron piping joints will be cracked. Malleable steel piping - some bending but no breaks.

Expected Damage to Skin Mills

All parts exposed to corrosion as a result of immersion in water.

Foundation - vertical displacement up to 6 inches, horizontal displacement up to 3 inches, tilt up to 10 degrees.

Main foundation beams - up to 3 inch horizontal displacement on foundation.

Machine bed - up to 3 inch lateral displacement on beams, alignment bolts sheared if not loosened preshot, up to 6 inches of warping or twisting of bed along 100 foot length. Two or three perforations by roof girders penetrating the sand bag layer end on - perforations about 1 foot in diameter.

Working machine - bellows torn off by water velocity. Any sheet metal panel - dished in or "oil-canned" by water velocity.

Machine "warped" from one side to other by 2^{0} twist.

Major load bearing arbor and supports - no damage except 2^{0} warp or twist.

Secondary structures, supporting cables, control panels, etc. - unsupported end bent 3 inches.

Expected Damage to Five-Axis Milling Machine

Foundations may be displaced up to 6 inches vertically, up to 3 inches horizontally and tilted up to 10 degrees. Sheet metal cabinet sides will be dented in up to 3 inches.

Main support frame or arbor will be warped or twisted up to 5 degrees.

Secondary support structures such as cable supports or motor mounts will be bent up to 3 inches.

A large number of machines besides the key items are involved in the hardening scheme. Taking small lathes as typical of these machines, the following level of damage may be taken as representative.

Expected Damage to Small Lathes

Cast iron support legs - about half will be cracked or broken.

Malleable support legs - bent up to 3 inches

Lathe bed - bent up to 1/2 inch or warped up to 2 degrees.

Gear drives - random damage by debris impact. About 25% of gear trains will have one or more damaged gears or bearings.

In all cases some corrosion damage can be expected despite the anti-corrosion films and sheet plastic covers.

The external appearance of the plant would be one of devastation--three of the key buildings flattened and the fourth cratered. However, test data from high explosive events indicate that large numbers of machines would be repairable. Furthermore, in a study in which the Puget Sound area's "proportion" of warheads were targeted on key industries and military facilities, it was found that a large fraction of supporting industry also would survive. Finally, it was found that insufficient weapons were available to seriously cripple the electrical supply and distribution system. Assuming Soviet-type population protection measures were taken as part of the overall civil defense drill, recovery would be possible.

There is a continuous range of possible recovery levels. At one extreme the Auburn plant could be more or less duplicated on an adjacent site and the surviving machines moved over. This would take an amount of time comparable to the time it took to build the present plant, i.e. a period of years. At the other extreme is the Soviet experience in the second World War. In moving industry east of the Urals there were cases in which production continued on machines which were out in the open in subzero weather. The Messerschmidt plant in Augsburg demonstrated an intermediate case. After a raid which appeared to destroy the main factory, production was resumed in a few weeks.

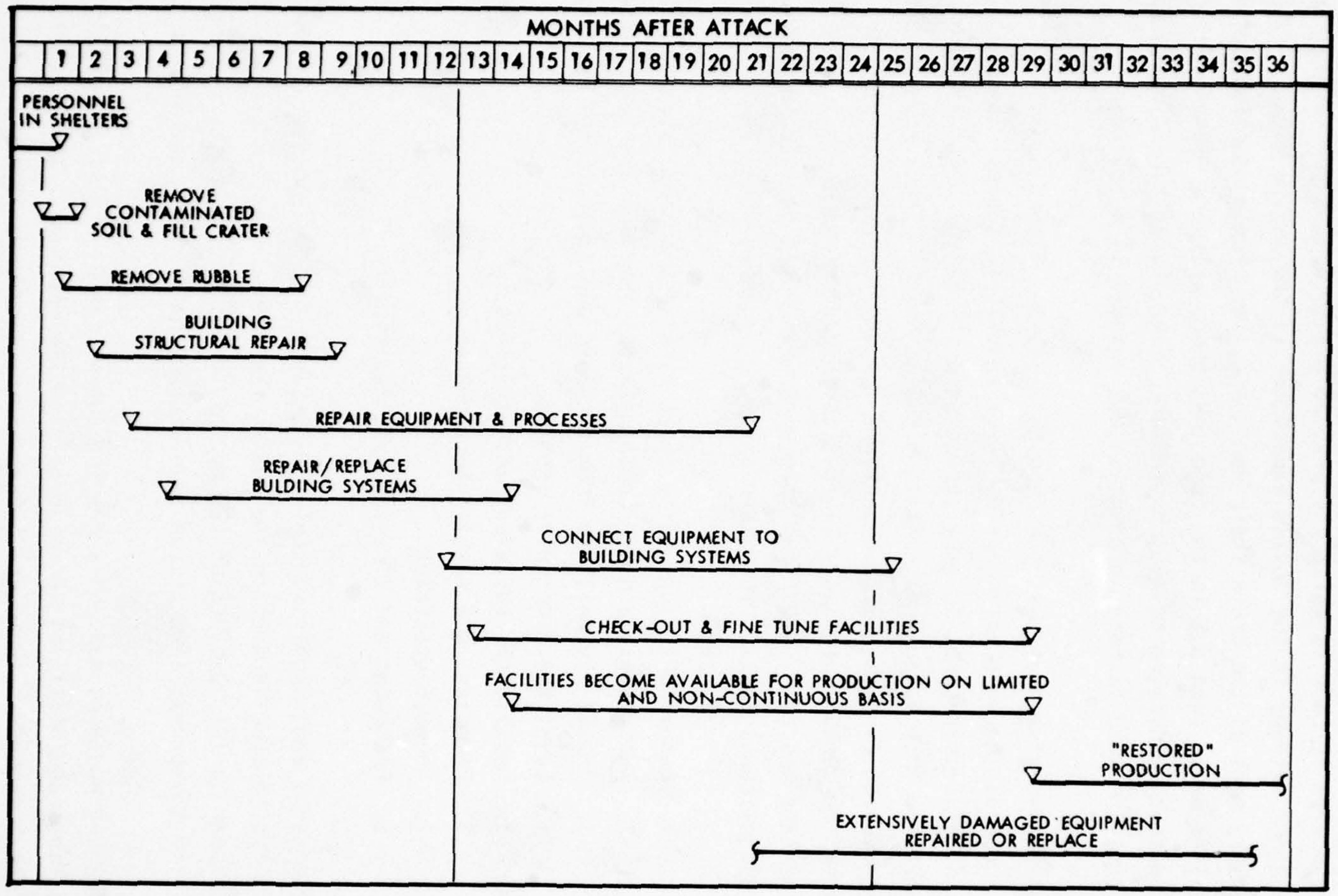
In the case of recovery at the Auburn plant, the floors would still be usable so three of the four buildings could be rebuilt in place. The timing sequence would be for personnel to stay sheltered until fallout activity dropped to levels permitting 2 to 4 hour work shifts (about a week). Then properly clothed and instrumented parties would be sent out for short periods to fill the crater and remove the contaminated soil layer from the buildings to be reconstructed. After this was done (about two more weeks) it would be safe to work full shifts on a continuous basis. Then the following sequence would be followed:

1. Remove building debris (both machine and hand labor),
2. Remove soil and crushable material (machine and hand labor),
3. Remove any moisture from machines and protect them from weather,
4. Level the floor with asphalt,
5. Rebuild the buildings and utilities,
6. Reemplace and repair the machines,
7. Connect utilities
8. Check-out and fine-tune all facilities

These tasks are roughly scheduled in Table 3 for the collateral damage case. Note that production returns to 10% of the prewar level in about 17 months. To return to full production (30 months) more factory shifts would be needed than in the prewar time period to overcome the loss of some machines.

Heavy use would be made of surviving subcontractor skills in rebuilding the buildings and utilities and in repairing the machines. These skills would be in great demand in the overall Puget Sound Recovery. The schedule takes the scarcity of these skills into account. It was assumed that the Boeing plant would have priority access to 25% of the surviving Puget Sound machine shop capability and 10% of the surviving electrical generating capability.

Table 3 Recovery time for collateral attack (No hardening)



Although the recovery time for the direct attack case was not computed, it should be noted that in some cases the damage to unhardened machinery at 10 psi (collateral attack) would be greater than the damage to the same machines hardened for the direct attack. Tank lines and heat treat facilities are examples since these were heavily damaged by 10 psi air blast. Because of this it is expected that the direct attack recovery times would be comparable to those in Table 3.

3.2 REYNOLDS INDUSTRIES, INC.

The Boeing Auburn plant represents a large first tier industry with hundreds of key manufacturing items. Sweeping generalizations were made by necessity in the Auburn plant hardening and recovery considerations. A second hardening/recovery study was undertaken on a small second tier industry partly in order to deal explicitly with all of the personnel and items needed for post-war recovery. Reynolds Industries, Inc., a small second-tier cable and connector manufacturer located in the Los Angeles area, agreed to participate in this work.

The approach was to give key Reynolds personnel a briefing on the methods and goals of the hardening/recovery program and supply them with a suggested outline to follow. Reynolds personnel then carried out the program internally and prepared the report attached as the Appendix. Although this report has some deficiencies resulting from the lack of a detailed scenario and personnel trained in hardening techniques, it demonstrates:

1. That hardening and recovery of industries does indeed appear to be feasible if a massive national civil defense effort were undertaken, and
2. That a dedicated team of industrial personnel can develop their own hardening and recovery plan with little outside direction.

4.0 TEST PLANS

This section covers proposed tests for FY 1978 which would extend the work reported in References 1 through 3. The section is organized around a briefing given to DNA in the fall of 1977. The proposed tests are not prioritized and are quite comprehensive. Fiscal constraints are expected to necessitate both simplification in and elimination of some of the tests.

Tables 4 and 5 give the reasons for extending previous tests to high (nuclear burst simulating) impulses, carrying out debris impact tests on model factories and carrying out expedient shelter, model Soviet basement shelter and mound scouring tests. Approaches to these tests recommended and recommended test beds are covered in Table 6. Test details, estimated costs and preferred test beds are covered in Figures 14 through 17 and Tables 7 through 9. Advanced HEST ("Foam HEST") charges under development at AFWL are recommended for high impulse tests, for instrumentation to understand hardening mechanisms and for the expedient shelter test (Fig. 14 and Table 7). Model factories, Soviet basement shelter models and mound scouring would be tested in one of the DNA sponsored 120 ton ANFO tests at MISERS BLUFF (Fig. 15 and Table 8). Very high impulse tests and hardening mechanism tests could be carried out in the AFWL GRABS facility (Fig. 16 and Table 9). A simple expedient shelter test is recommended for DIABLO HAWK to determine wall displacements under non-earth arching conditions (Fig. 17 and Table 10). Costs for the recommended tests are summarized in Table 11, and program milestones are given in Table 12.

Figures 18 through 21 and Tables 13 through 16 cover backup test beds. The T-5 HEST test at Yuma would be suitable for high impulse tests, although impulse is less than desired (Fig. 18 and Table 13). Figure 19 is a sketch of a large hammer which would give well controlled and repeatable high impulse tests. Table 14 lists some problems with such a facility. (Reportedly such a system is being considered by WES). The DABS S-4 and S-5 tests (Fig. 20 and Table 15) could give both high impulse inside the structure and MISERS BLUFF type environments in the muzzle region. There could be economies in performing all tests at one test bed. However, impulse is less than desired and the muzzle area environments are not well known. The WES Large Blast Load

Generator (Fig. 21 and Table 16) is not only a good backup for GRABS, but could also replace the HEST or DABS tests if test items were not too large. Both overpressure and impulse can be simulated well. (In other test beds, overpressure is generally higher than desired).

Table 4 Program rationale

RATIONALE

- U. S. THROW WEIGHT BECOMES INADEQUATE AS SOVIET EQUIPMENT HARDNESS APPROACHES 40 PSI (IMPULSES IN 4 TO 12 PSI-SEC RANGE).
- IN MIRROR IMAGE CASE S. U. THROW WEIGHT BECOMES INADEQUATE FOR U. S. HARDNESS OF 150 PSI (26 PSI-SEC IMPULSE).
- RANGES OF INTEREST ARE THUS 40 TO 150 PSI OVERPRESSURE AND 4 TO 26 PSI-SEC.
- PREVIOUS TESTS HAVE DEMONSTRATED EQUIPMENT PROTECTION FROM 20 TO 1500 PSI, BUT LARGEST IMPULSE WAS 1.8 PSI-SEC.
- HIGHER IMPULSE *EQUIPMENT TESTS AND HARDNESS MECHANISM TESTS ARE NEEDED.*
- BESIDES SURVIVING BLAST RELATED EFFECTS, EQUIPMENT MUST SURVIVE STRUCTURAL DEBRIS IMPACT. MODEL FACTORY TESTS ARE RECOMMENDED.
- AT DICE THROW EXPEDIENT SHELTER WALLS COLLAPSED IN SOME CASES. WALL STABILIZATION TESTS ARE RECOMMENDED.
- SOVIET BUILDING CODES REQUIRE BASEMENT SHELTERS IN NEW APARTMENT BUILDINGS. SCALE MODELS OF THESE SHELTERS ARE PROPOSED.

Table 5 Program objectives

OBJECTIVES

- SIMULATE NUCLEAR IMPULSES FOR EQUIPMENT SURVIVAL TESTS.
- OBTAIN PRESSURE AND ACCELERATION MEASUREMENTS TO PROVIDE UNDERSTANDING OF PROTECTION MECHANISMS.
- TEST MODEL FACTORIES TO DEMONSTRATE DEBRIS IMPACT HARDNESS OF EQUIPMENT.
- DEVELOP SIMPLE WALL STABILIZATION TECHNIQUES FOR EXPEDIENT SHELTERS.
- TEST BLAST CAPABILITY OF SOVIET APARTMENT BASEMENT SHELTER.

Table 6 Program approach

APPROACH

- HIGH IMPULSE TESTS ON EQUIPMENT AND HARDENING MECHANISMS ON THREE ADVANCED HEST DEVELOPMENT TESTS. FOLLOWED BY VERY HIGH IMPULSE "PROOF OF CONCEPT" TEST AT GRABS.
- EMPLACE HARDENED AND UNHARDENED MODEL FACTORIES AND SOVIET BASEMENT SHELTER MODELS AT THREE OVERPRESSURES AT MISERS BLUFF (DABS MUZZLE BLAST AREA AS BACKUP).
- DETERMINE MOUND SCOURING FOR MOUNDS OF THREE DIFFERENT SLOPES.
- TEST EXPEDIENT SHELTER WALL STABILIZATION CONCEPTS ON TWO ADVANCED HEST DEVELOPMENT TESTS AND IN DIABLO HAWK UGT.

ADVANCED HEST DEVELOPMENT

SMALLER SIZE

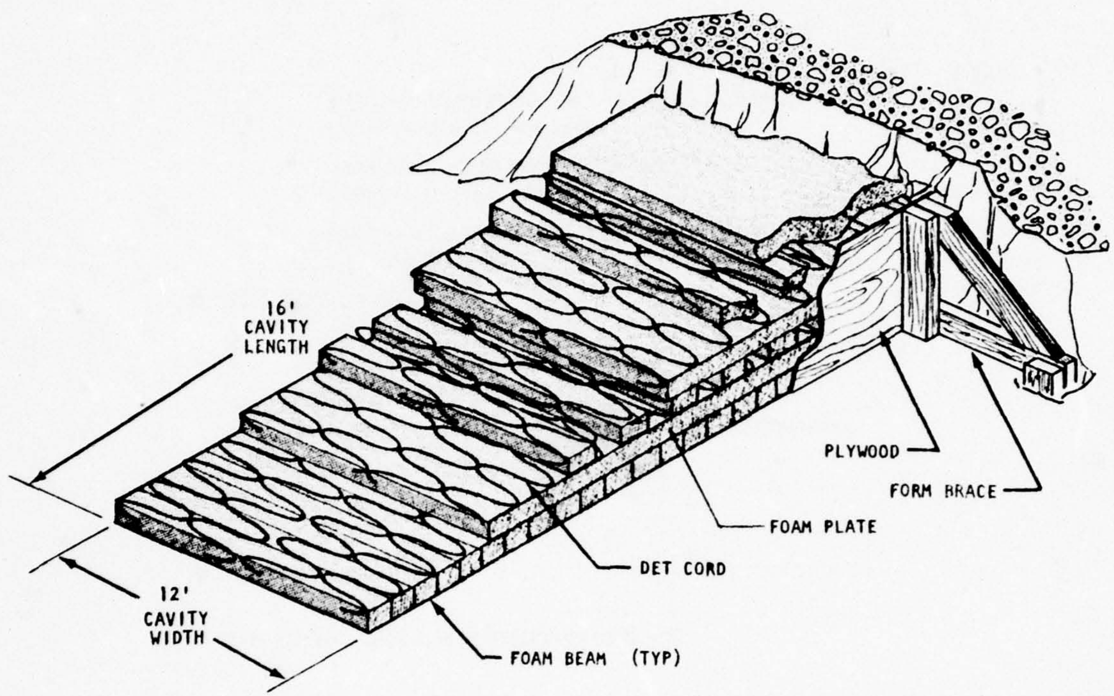


Figure 14 Advanced HEST development

Table 7 Advanced HEST development

ADVANCED HEST DEVELOPMENT

- LOCATION: CERF (NEAR KIRTLAND AFB)
- AGENCY: AFWL
- TEST OBJECTIVES:
  1. HIGH IMPULSE EQUIPMENT TESTS
  2. INSTRUMENTATION FOR HARDENING MECHANISM UNDERSTANDING.
  3. SIMPLE EXPEDIENT SHELTER TESTS
- TEST DETAIL AND COSTS

	COST
1. "PIGGYBACK" ON SCHEDULED AFWL TEST, JAN 1978 600 PSI AND 10 PSI-SEC (12 x 18 FT CAVITY)	$ 15 k
2. DEDICATED TEST, FEB 1978 ~1000 PSI AND 20 PSI-SEC (30 x 30 FT CAVITY)	$ 25 k
3. DEDICATED TEST, APR 1978 ~1500 PSI AND 30 PSI-SEC (30 x 30 FT CAVITY)	$ 25 k
TOTAL	$ 65 k

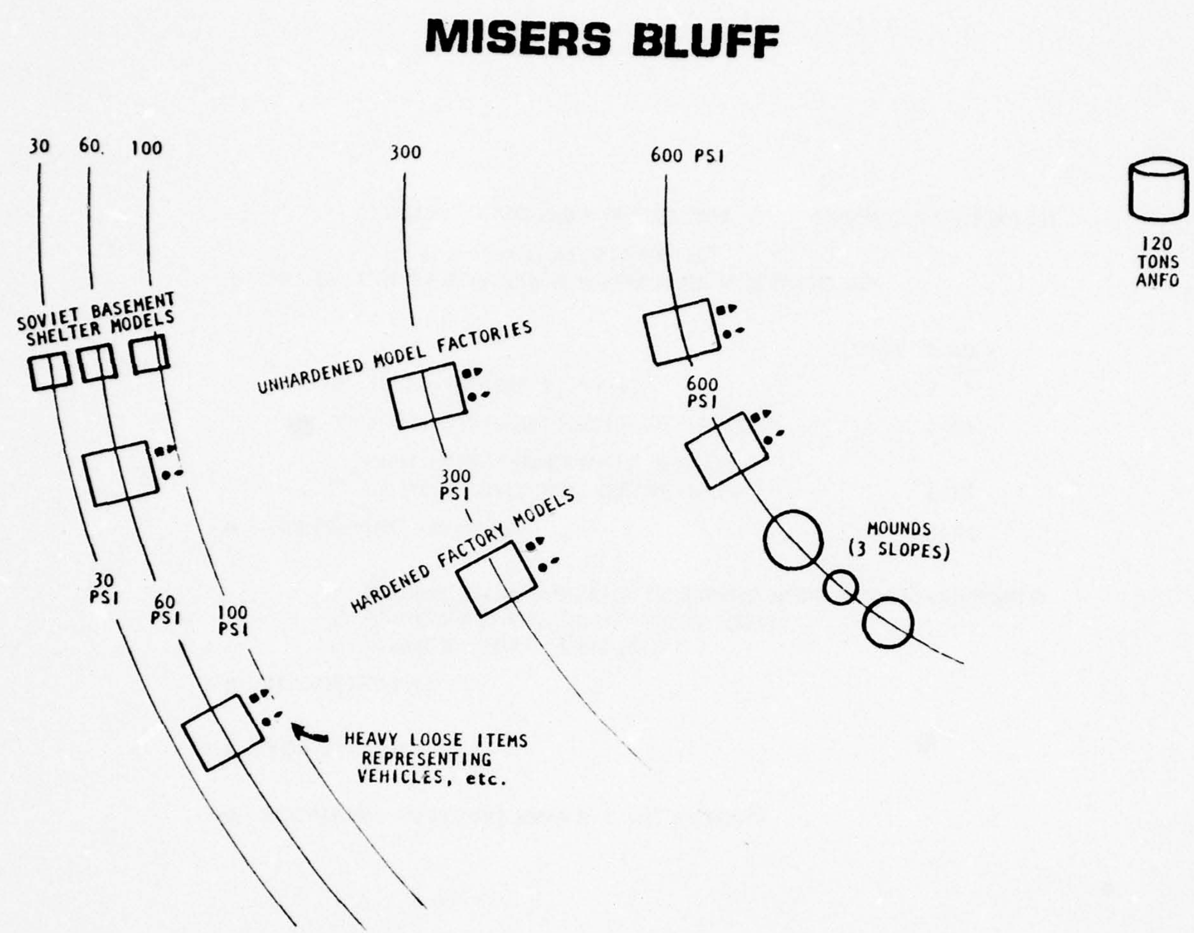


Figure 15 Miser's Bluff

Table 8 Miser's Bluff

MISERS BLUFF

- LOCATION: NEAR LAKE HAVASU CITY, ARIZONA
- AGENCY: DNA
- TEST OBJECTIVES:
  1. MODEL FACTORY DEBRIS TESTS
  2. SOVIET BASEMENT SHELTER MODEL TESTS
  3. MOUND SCOURING TESTS (DETERMINE WHAT SLOPE IS PREFERABLE)
- TEST DETAILS AND COSTS

TEST DETAILS AND COSTS	COST
1. SIX MODEL FACTORIES EMPLACED ON NON-INTERFERENCE BASIS, JULY 1978	$ 150
2. SOVIET BASEMENT SHELTER MODEL TESTS	$ 100
3. THREE MOUNDS AT 600 PSI	$ 2
TOTAL	$ 252 K

- NOTES: 1. DABS IS BACKUP IF MISERS BLUFF NOT APPROVED (DABS S-5, NOT YET SCHEDULED)
  2. SPECIAL PERMISSION NEEDED FOR EMPLACEMENTS INSIDE 300 PSI

GRABS

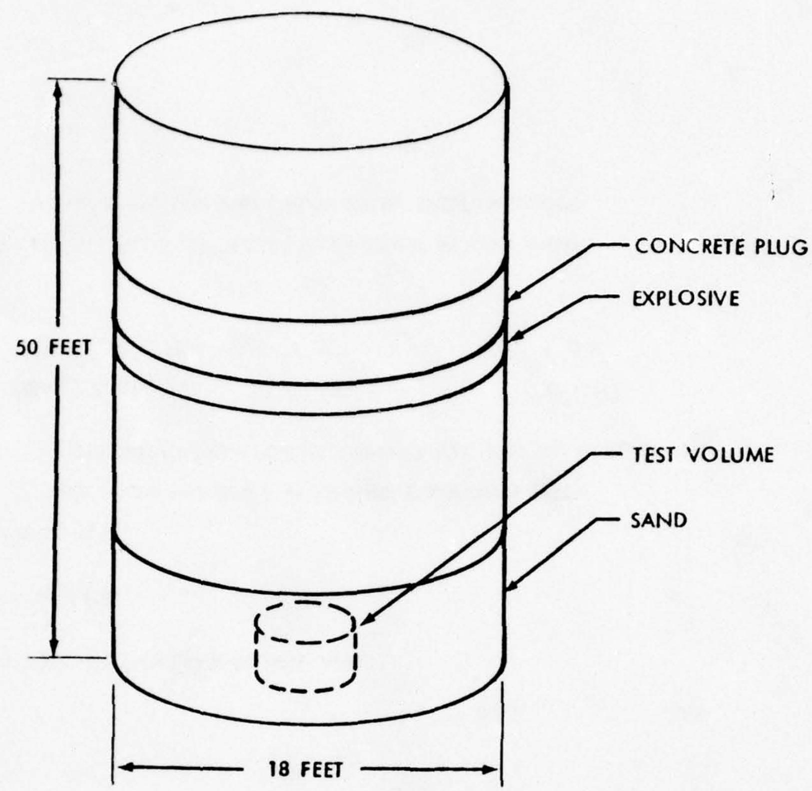


Figure 16 GRABS

Table 9 GRABS

GRABS

- LOCATION: CERF (NEAR KIRTLAND AFB)
- AGENCY: AFWL
- TEST OBJECTIVES:
  1. VERY HIGH IMPULSE (~55 PSI-SEC) EQUIPMENT TESTS
  2. INSTRUMENTATION FOR HARDENING MECHANISM UNDERSTANDING
- TEST DETAILS AND COST

TEST DETAILS AND COST	COST
DEDICATED TEST IN FALL OF 1978	$ 50 K

- NOTE: SINGLE SHOT TO OBTAIN DATA POINT AT VERY HIGH IMPULSE (PRELIMINARY CALIBRATION SHOT INCLUDED IN COST)

DIABLO HAWK

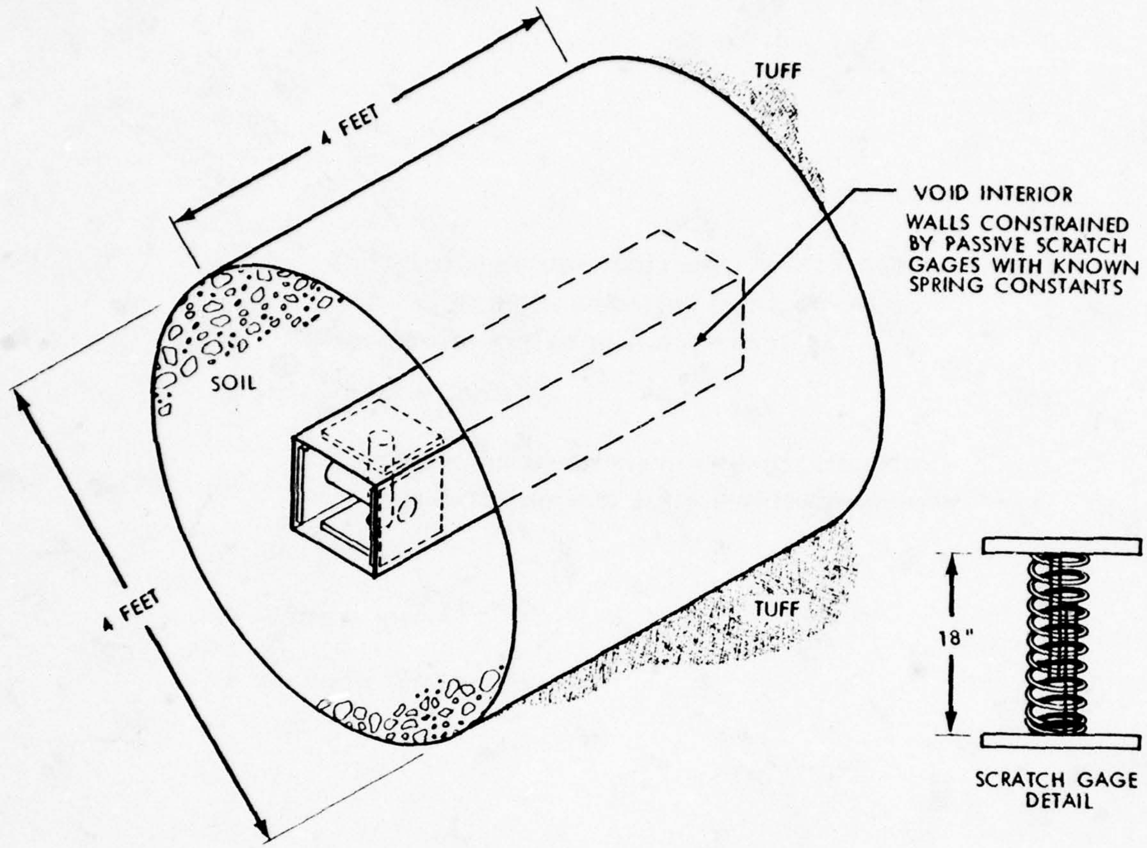


Figure 17 Diablo Hawk

Table 10 Diablo Hawk

DIABLO HAWK

- LOCATION: NEVADA TEST SITE
- AGENCY: DNA
- TEST OBJECTIVE:

  TO DETERMINE CAVITY WALL DISPLACEMENTS WITH MINIMUM CONSTRAINT UNDER NON-EARTH- ARCHING CONDITIONS

- TEST DETAILS AND COST

	COST
PREPACKAGED TEST CELL TO BE EMPLACED UNDER NON-INTERFERENCE CONDITIONS. STATION LOCATION TO BE DETERMINED. TENTATIVE DATE IS OCTOBER, 1978	$ 5 K

Table 11 Estimated cost summary for recommended test series

COST SUMMARY FOR RECOMMENDED TEST SERIES

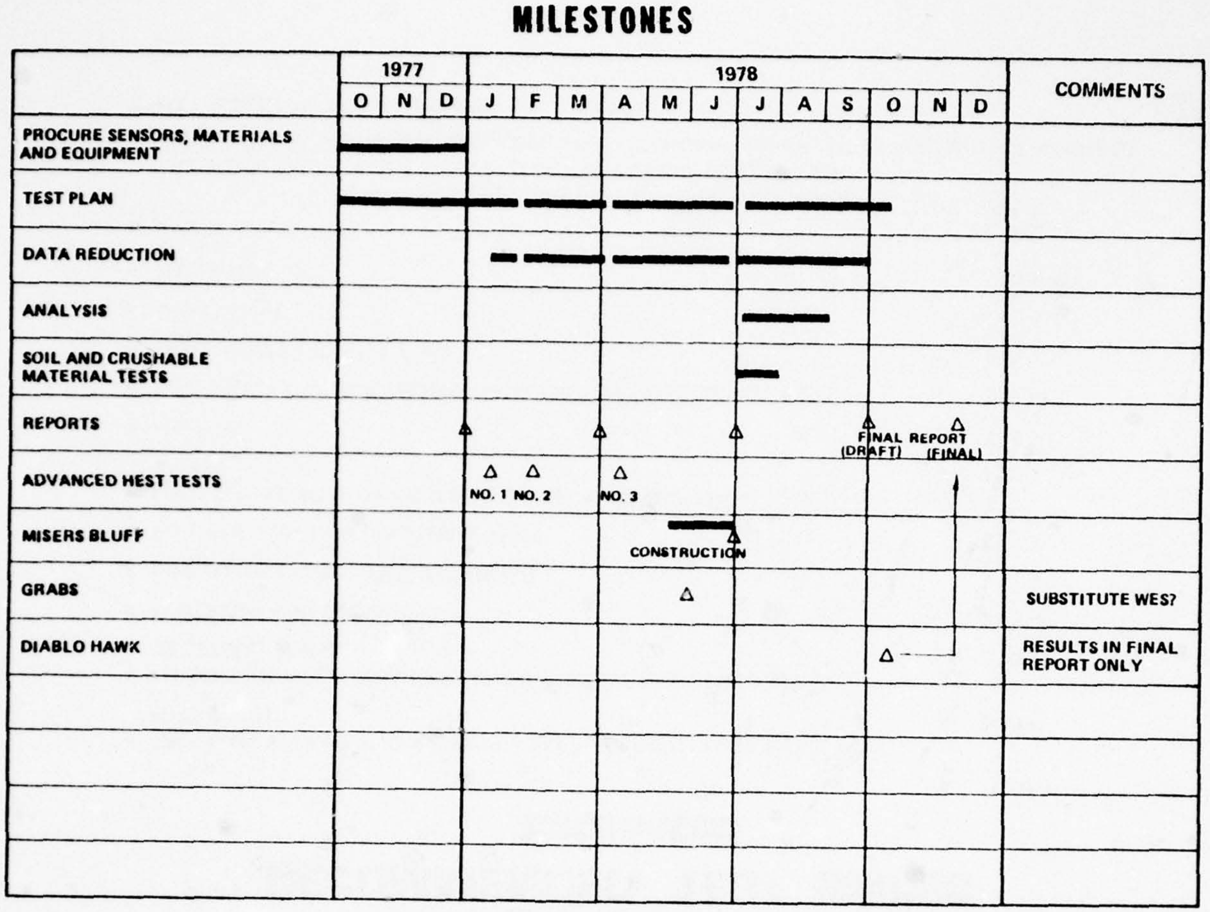
Estimated

	COST
• ONE MAN YEAR OF ENGINEERING (TEST PLANNING, DATA REDUCTION, REPORTING)	$ 60 K
• SENSORS* (6 ACCELEROMETERS AND 4 PRESSURE GAUGES TO BE USED IN SEVERAL TESTS)	$ 8 K
• MATERIALS AND EQUIPMENT *	$ 5 K
• DIGITAL RECORDER * MODIFICATIONS	$ 5 K
• SOIL AND CRUSHABLE MATERIAL TESTS	$ 5 K
• FIELD TEST PERSONNEL COSTS (~$ 5 K PER SHOT FOR TRAVEL, PER DIEM, SALARY, ETC.)	$ 30 K
• SHIPPING	$ 5 K
• TWO MAN MONTHS HARDNESS ANALYSIS (EARTH ARCHING, ETC.)	$ 10 K
• THREE ADVANCED HEST TESTS	$ 65 K
• MISERS BLUFF TEST	$ 252 K
• GRABS TEST	$ 50 K **
• DIABLO HAWK TEST	$ 5 K
TOTAL	$ 500 K

*MUCH EQUIPMENT WILL BE SUPPLIED FREE BY BOEING RECLAMATION.
ALSO, BOEING WILL USE EXISTING DIGITAL RECORDERS WHICH, HOWEVER, MUST BE MODIFIED.

**MAY SUBSTITUTE WES IF CHEAPER

Table 12 Program schedule



HEST (YUMA) T-5

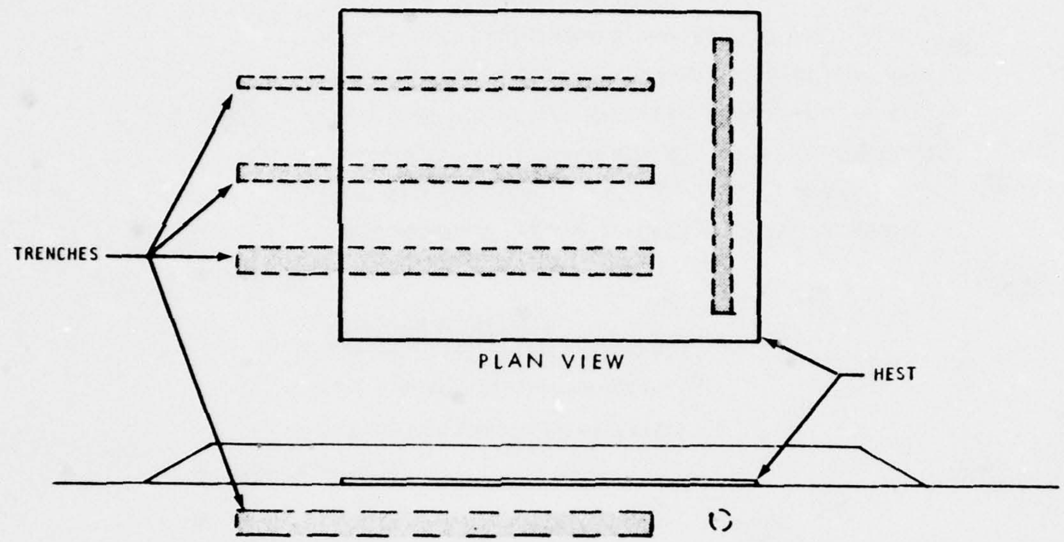


Figure 18 Yuma HEST T-5 layout

Table 13 Yuma HEST T-5

HEST (YUMA) T-5

- LOCATION: NEAR YUMA, ARIZONA
- AGENCY: AFWL
- TEST OBJECTIVES:

  BACKUP FOR ADVANCED HEST TESTS.

  PEAK T-5 IMPULSE (~ 9 PSI-SEC)

  SOMEWHAT LESS THAN DESIRED BUT WOULD BE ACCEPTABLE.

- COMMENTS:

  LARGE AREAS ARE AVAILABLE NEAR THE EDGES. HOWEVER, EDGE EFFECTS COULD BE A PROBLEM. ALSO, DRIVER CHARGES WHICH DETONATE BEFORE THE HEST CHARGE COULD PREINITIATE THE DIGITAL RECORDERS. DABS S-4 or S-5 ARE PREFERRABLE BACKUPS, PARTICULARLY SINCE FACTORY AND MOUND TESTS COULD ALSO BE EMPLACED AT DABS. HEST T-5 MAY BE SPLIT INTO TWO TESTS.

DROP TEST

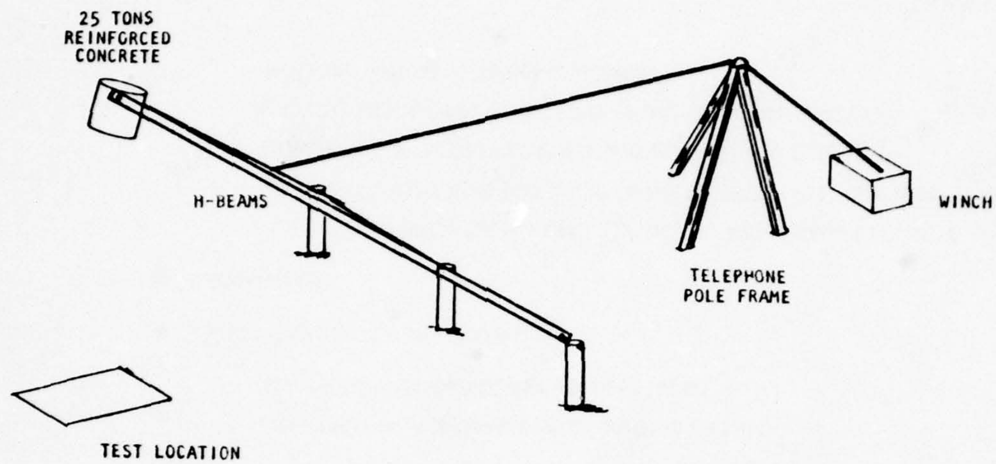


Figure 19 Drop test

Table 14 Drop test

DROP TESTS

- LOCATION: SEATTLE AREA (POTENTIALLY)
- AGENCY: DNA-SPONSORED (POTENTIALLY)
- TEST OBJECTIVES:

  REPEATABLE AND VARIABLE HIGH IMPULSE TESTING (SEE OBJECTIVES OF ADVANCED HEST TESTS)
- COST OF FACILITY: UNKNOWN
- COMMENTS:

  TEST RESULTS FROM SUCH A FACILITY WOULD BE VALUABLE BECAUSE OF REPEATABILITY AND IMPULSE CONTROL. HOWEVER, CANNOT EXACTLY MATCH DESIRED BLAST WAVE SHAPE AND DOES NOT INCLUDE SECONDARY BLAST EFFECTS (HORIZONTAL GROUND MOTIONS, WIND SCOURING, DEBRIS)

DABS

S-4 & S-5

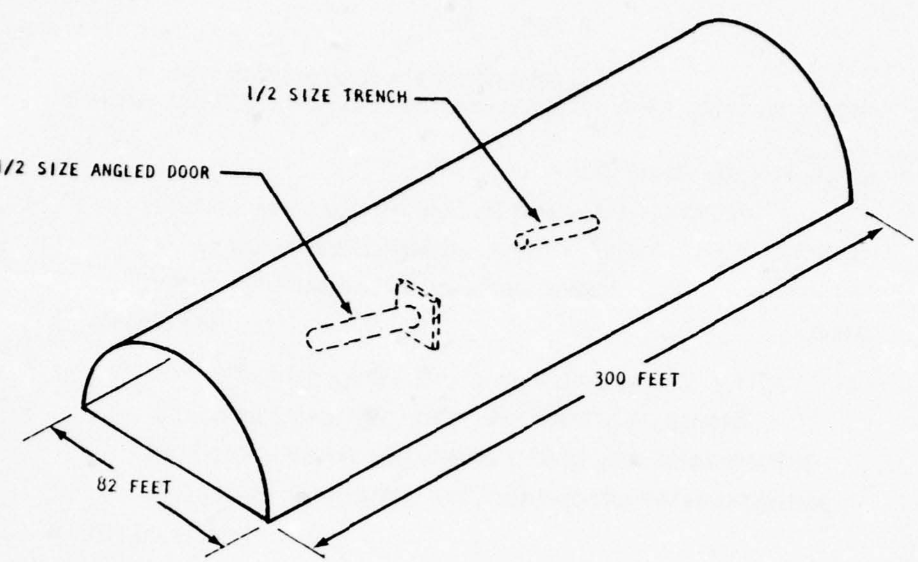


Figure 20 DABS S-4 & S-5

Table 15 DABS S-4 & S-5

DABS S-4 AND S-5

- LOCATION: NEAR YUMA, ARIZONA
- AGENCY: AFWL
- TEST OBJECTIVES:

  BACKUP FOR MISERS BLUFF (FACTORY AND MOUND TESTS OUTSIDE DABS FACILITY) AND FOR ADVANCED HEST TESTS (HIGH IMPULSE TESTS INSIDE FACILITY). DABS PEAK IMPULSE (~9 PSI-SEC). SOMEWHAT LESS THAN DESIRED BUT WOULD BE ACCEPTABLE.

- TEST DETAILS

TEST DETAILS	COST
MISERS BLUFF TEST (SEE MISERS BLUFF CHARTS)	
ADVANCED HEST TESTS (SEE MISERS BLUFF CHARTS)	$ 25 K

  DATE FOR S-4 IS MARCH, 1978. S-5 IS NOT YET SCHEDULED.

  (COSTS NOT NECESSARILY ADDITIVE)

- NOTE: ENVIRONMENTS OUTSIDE DABS (FACTORY AND MOUND TESTS) LESS WELL KNOWN THAN FOR MISERS BLUFF.

WES TEST BED

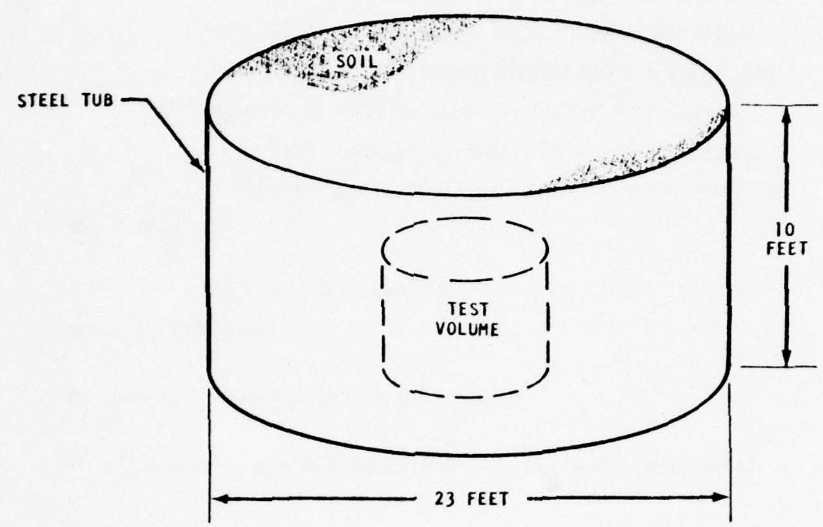


Figure 21 WES Test bed

Table 16 WES test

WES

- LOCATION: WATERWAYS EXPERIMENT STATION, MISSISSIPPI
- AGENCY: ARMY CORPS OF ENGINEERS
- TEST OBJECTIVE:

  BACKUP FOR GRABS TEST
- COMMENTS:

  THE WES BLAST FACILITY CAN GIVE VERY HIGH IMPULSES (TENS AND PERHAPS, HUNDREDS OF PSI-SEC). THE TEST VOLUME IS GREATER THAN IN THE GRABS FACILITY. VERY PRELIMINARY COST ESTIMATES ARE $ 17 K FOR THE FIRST SHOT AND $ 10 K FOR EACH ADDITIONAL SHOT. IT IS PROBABLY SUPERIOR TO AND LESS EXPENSIVE THAN THE GRABS FACILITY. WHEN FURTHER DATA ARE AVAILABLE ON WES (PARTICULARLY SCHEDULE DATA) IT MAY BE DESIRABLE TO SWITCH THE GRABS TEST TO WES.

5.0 CONCLUSIONS

1. There is little agreement in the civil defense community concerning which industries are essential. Such a list was developed in this report starting from broad categories of the essential functions to rebuild society.

2. Sample industry surveys on a large plant (Boeing Auburn machine shops) and on a small second-tier plant (Reynolds Industries, Inc.) indicate that industrial recovery is possible in a reasonable time if adequate steps are taken to protect the plant and its key personnel. However, it would be useful to carry out such surveys on a wider spectrum of industries.

3. The following tests are the most promising candidates for future high explosive events: industrial equipment hardening to simulate nuclear impulses, debris tests of model factories, overpressure tests of Soviet basement shelter models and expedient shelter models and mound scouring tests.

6.0 RECOMMENDATIONS

1. Discontinue work on critical industrial surveys at this time. Definition of post-attack priorities would require a vast economic study dealing with preattack, transattack and postattack scenarios.

2. Carry out an industry survey on one of the more vulnerable critical industries (e.g. oil refining or steel production).

3. Prioritize industrial hardening/recovery tests and schedule dedicated tests and/or participation using existing test beds. Include passive and/or active instrumentation schemes to determine hardening mechanisms.

7.0 REFERENCES

1. Holze, D. H. and York, E. N., "Industrial Equipment Hardening Study", Boeing Document D180-20450-1, 14 January 1977 (U)

2. Holze, D. H. and York, E. N., "Industrial Equipment Survival/Recovery Feasibility Program During Event DICE THROW", DNA report DNA 4192F. 31 December 1976 (U)

3. Holze, D. H. and York, E. N., "Industrial Equipment Hardening Program 1977 5-Ton HE Test Results", Boeing Document D180-22878-1, In Preparation (U)

4. Sachs, A. and Leavitt, J., "Analysis and Identification of Nationally Essential Industries, Volume 2: Methodology and Results", DCPA Paper P-972, IDA Log. No. HQ 74-16770, September 1974 (U)

APPENDIX

SAMPLE INDUSTRIAL SURVEY
REYNOLDS INDUSTRIES, INC.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (Continued)

1.0 INTRODUCTION

Blast overpressure damage resulting from major nuclear detonations in industrial areas will prevent resumption of significant industrial production for an extended period. This report addresses the necessary planning and preparation for the rapid production recovery of a small industrial facility in the Los Angeles, California area following such a detonation. Its purpose is to investigate the methods which are feasible and might be used by facility personnel to hasten a return to production.

This report has been prepared by personnel of Reynolds Industries, Inc., a production facility chosen at random, and represents their view of the necessary preparations and recovery activities leading to the most rapid resumption of production of several key products.

One specific scenario has been selected as the background for the report. This scenario is as follows: (No attempt has been made to establish or justify the validity of the sequence of events before or after the attack).

1. At least two years prior to the attack, the necessary capital and motivation will be available to enable the completion of all long range preparations including planning, facility preparation, material stockpiling and personnel training.

2. All personnel protection up to the post attack period will be provided by civil defense efforts. Necessary facility employees will be available up to one day prior to and after the attack.

3. Effects of the attack other than blast effects, such as nuclear radiation, may be ignored.

4. Outside assistance will not be available immediately following the attack nor up to the time when production has been restored. As a consequence, all power and raw materials must be provided within the facility.

5. A two week pre-attack warning will be given, thus permitting final preparation of the facility and equipment in accordance with the previously planned

facility survival plan. Following the attack, additional war activities and civil disturbances may be ignored.

6. The size and location of the blast in relation to the Reynolds facility will be such that blast over-pressures in the 18 psi range will occur. The Reynolds building, typical of many housing light industrial companies, is not expected to survive this over-pressure. As a consequence this report assumes a total building collapse with only the intentionally reinforced basement surviving.

2.0 SUMMARY

This survey illustrates the feasibility of providing a significant shortening of the time span necessary for a small industrial facility to resume production following the blast effects of a nuclear explosion.

With adequate preparation and with two weeks forwarning of an attack limited production could be resumed within a time span of 5 weeks at a direct cost of approximately $370,000.

One to two years preparation would be necessary to provide this rapid post-attack recovery. A considerable portion of this preparation time would be required for the purchase and delivery of necessary survival materials and supplies and for the selection and training of the post-attack work force.

Production would be confined to only those limited products selected as most desirable in a post-attack economy. This production would not be self-sustaining and its continuation would depend on a resumption in the delivery of critical raw materials and on a new source of outside energy several months following the attack.

Three significant conclusions are apparent in this survey. First, blast hardening for future production in an organization such as Reynolds requires a high degree of effort at the individual company level due to the specific adaptability of the building, the choice of post-attack products and the necessary knowledge of the manufacturing procedures.

Second, two specific preparation lead times are necessary. A long term preparation period, in excess of a year, is required for planning, stockpiling and making basic facility modification. A final one to two weeks warning is also necessary to cease normal production, relocate and cover equipment.

Finally, high technology companies such as Reynolds Industries are highly dependent upon outside suppliers for sub-product level components, which are necessary to produce the final product. This necessary by-product of the free enterprise system requires extensive stockpiling of these sub-product level components to assure a supply of necessary parts in the post-attack production period. Alternate efforts to acquire the necessary technology and tooling to provide a high degree of self-sufficiency appear to be impractical unless funded from outside sources.

3.0 DESCRIPTION OF REYNOLDS INDUSTRIES, INC.

Reynolds Industries, the company whose facility has been selected for this survey, is representative of the network of small production facilities within the United States producing a variety of industrial products of relatively high technical content.

The Reynolds main facility is located in Marina Del Rey, California, within the Los Angeles basin. Figures 3-1 and 3-2 illustrate the Reynolds building and its location. A second smaller Reynolds facility is located in San Ramon, California where several specialty explosive products are manufactured. Only the main facility in Los Angeles has been considered in this report.

Reynolds employs approximately 100 people at its Los Angeles facility and enjoys an annual sales volume of between three and five million dollars. Several distinct product lines contribute to this sales volume, including high voltage and speciality connectors, exploding bridgewire detonator systems, and electrical transient protection devices.

Reynolds products are marketed primarily in the Military-Aerospace sector and reflect the technical and quality requirements of this specialized market area. Figures 3-3 and 3-4 illustrate a portion of the high voltage connector assemblies manufactured by Reynolds. These connectors and various assemblies of these connectors with high voltage cables represent the primary Reynolds product line.

Three distinct technical skills are the foundation for the majority of Reynolds products. These are 1) mechanical design and fabrication, 2) precise physical assembly labor, and 3) electrical skill in both design and product test areas.

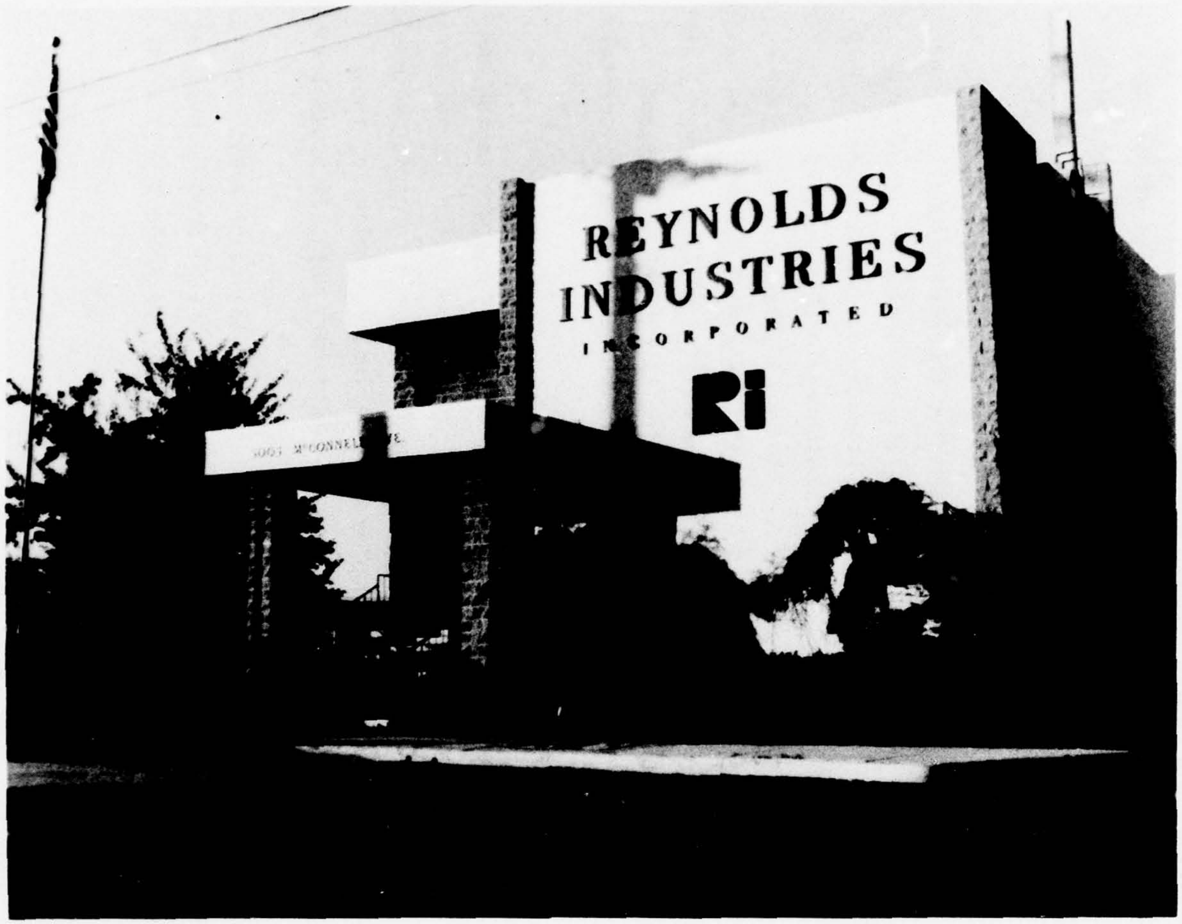


Figure 3-1 Reynolds Los Angeles facility

LOS ANGELES OPERATIONS

REYNOLDS INDUSTRIES INCORPORATED
5005 McCONNELL AVENUE
LOS ANGELES, CALIFORNIA 90066
(213) 823-5491 TELEX: 65-2424

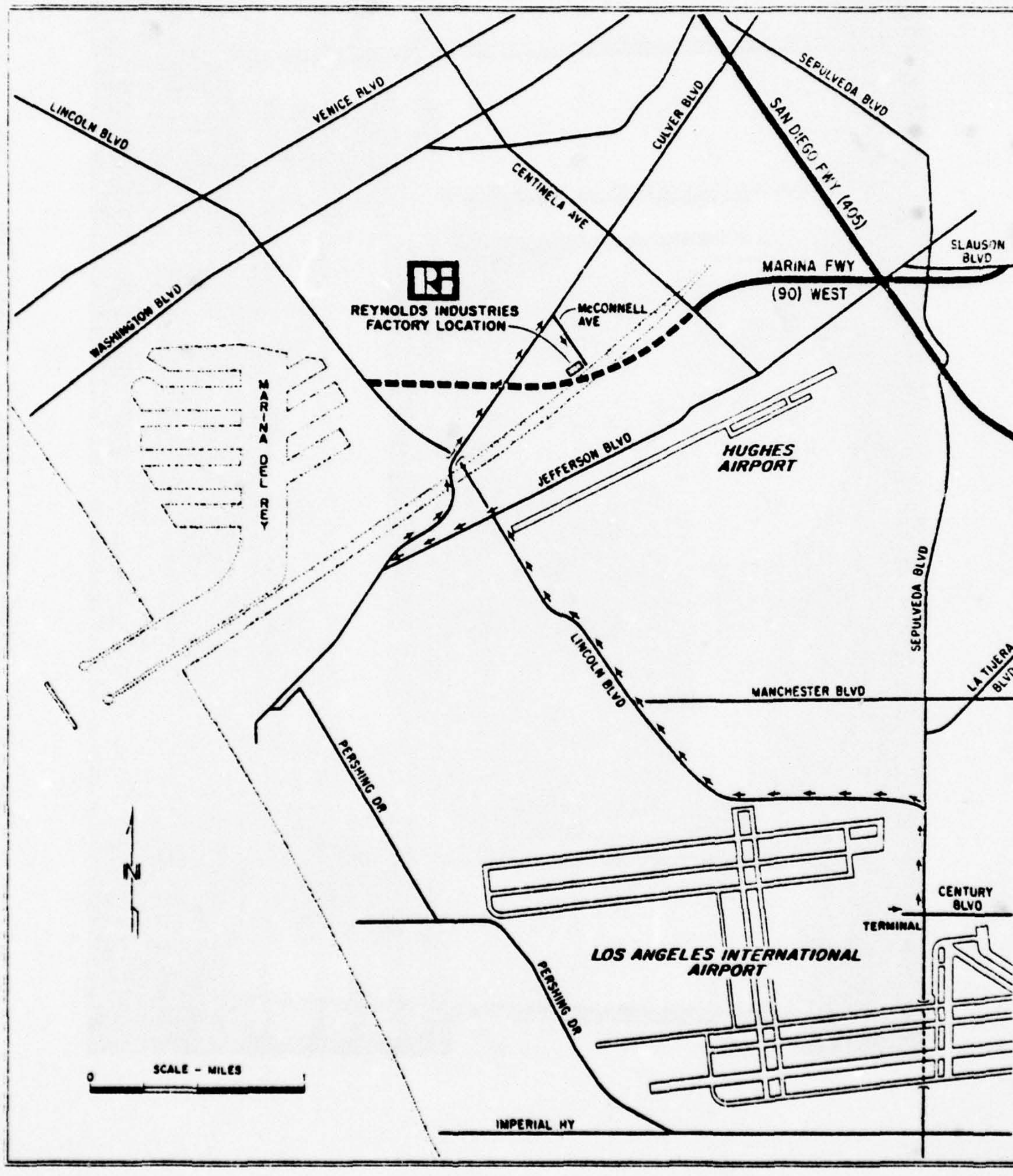


Figure 3-2 Plant location, Los Angeles, Ca.

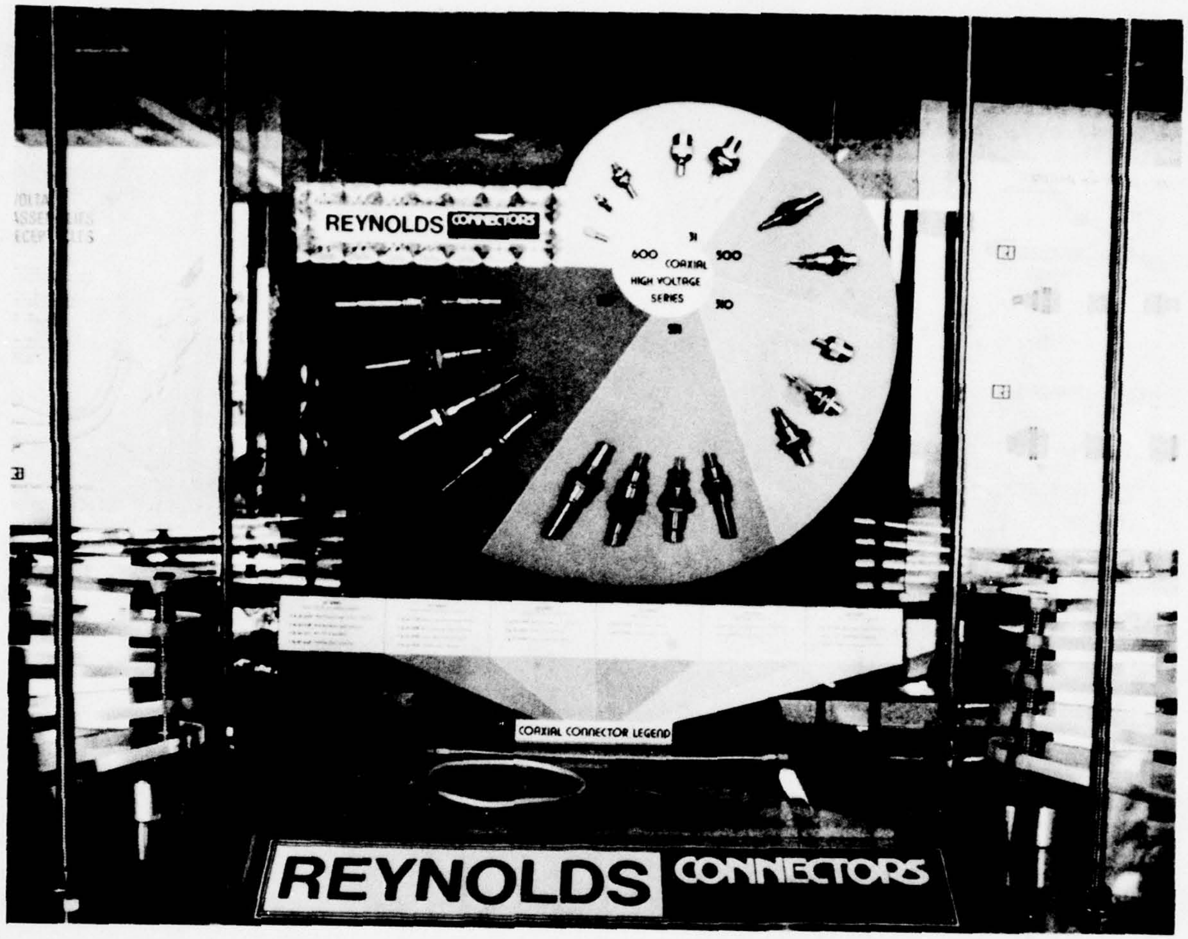


Figure 3-3 High voltage connector product line

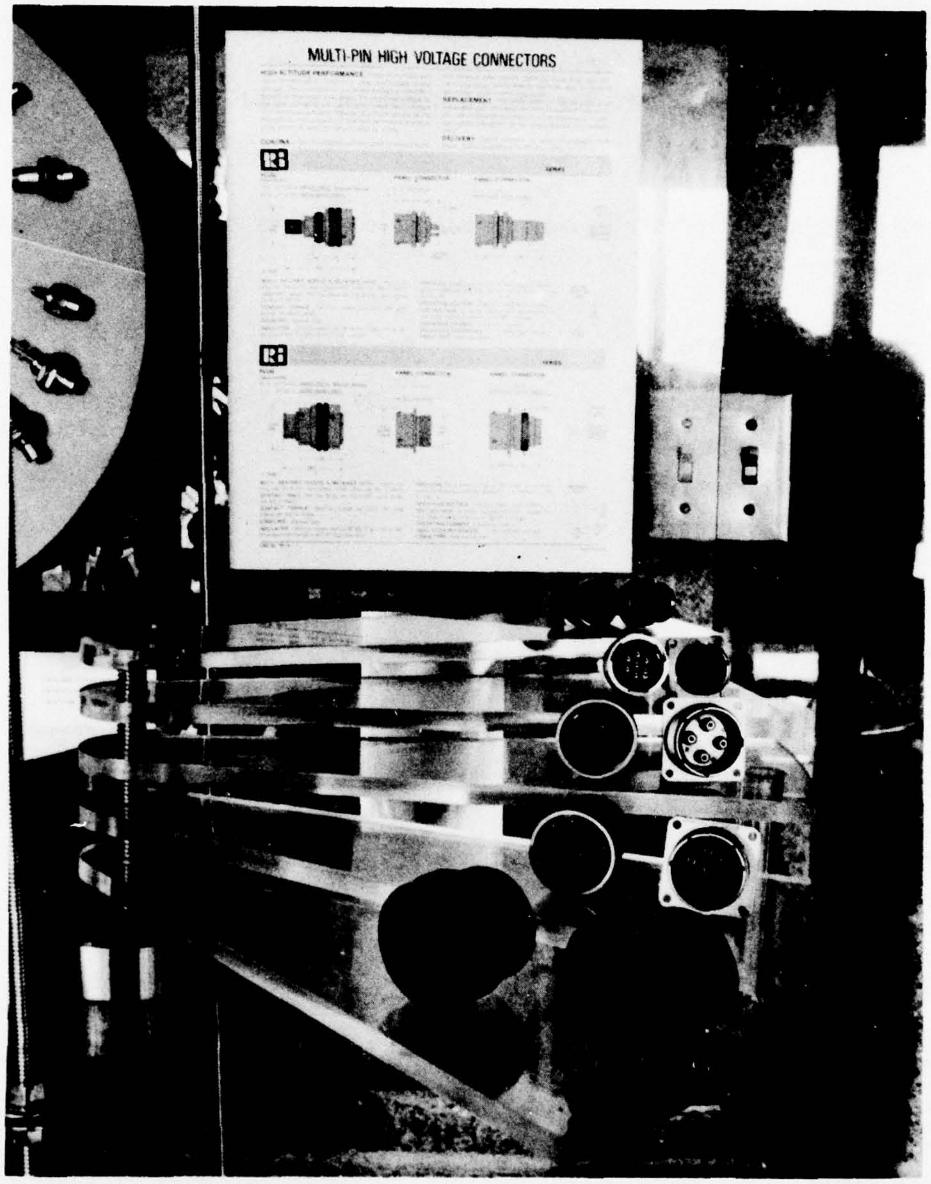


Figure 3-4 Mulit-pin high voltage connector

Personnel

Reynolds' Los Angeles facility presently employs 101 people in a combination of indirect and direct labor functions and is non-union. Figure 3-5 illustrates the current organization chart for the corporation including the San Ramon, California explosives group.

Employees of Reynolds Industries may be broken down into the following general classifications:

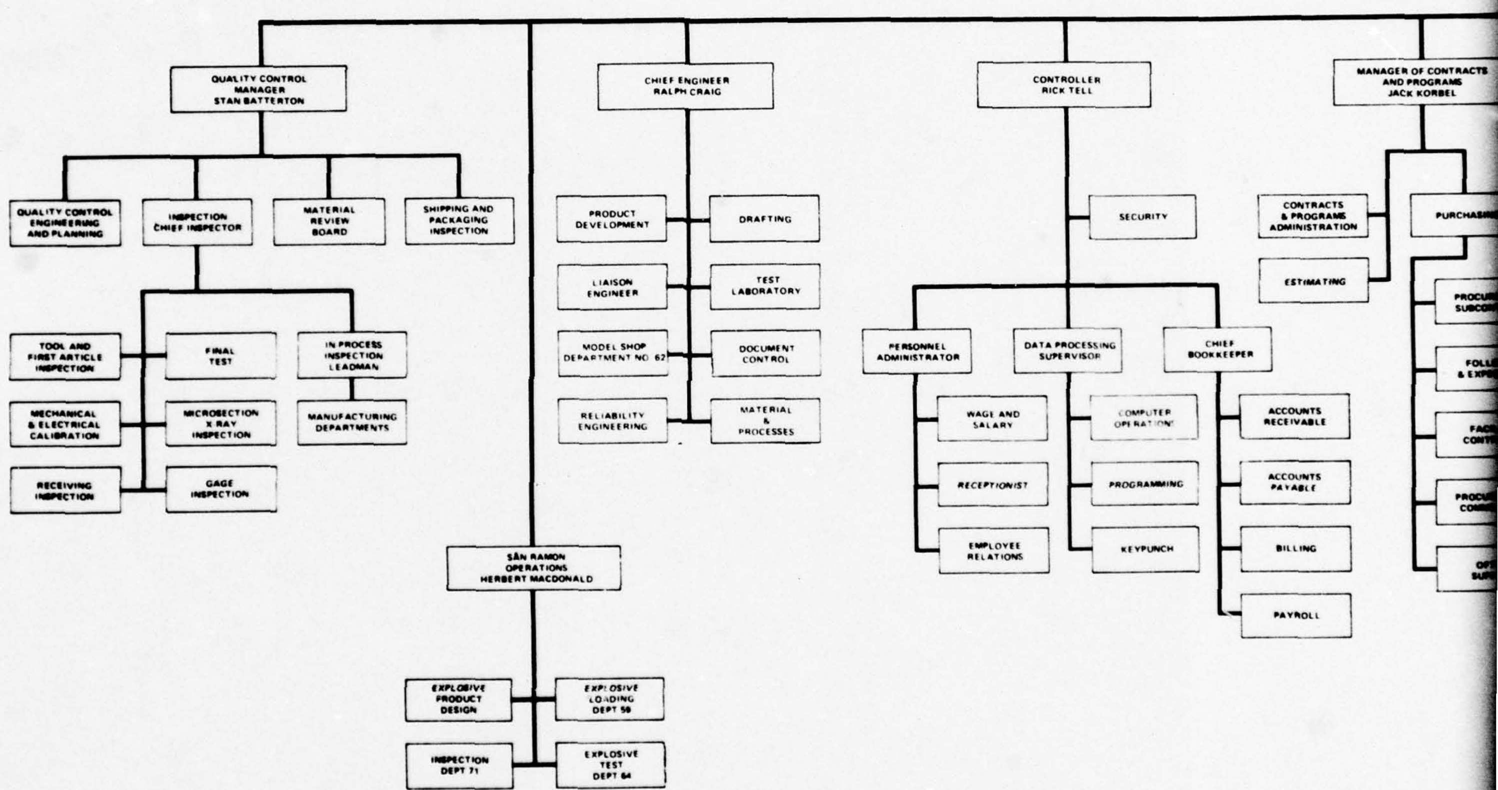
Job Function	Personnel
Administration	27
Engineering	13
Quality Control	11
Manufacturing	50

Within these general classifications, tasks performed by the Administration, Engineering and Quality Control groups are typical of those found for these type groups within the Aerospace industry.

Individual job descriptions within the manufacturing group are directly related to the somewhat unique Reynolds' product line. The following job descriptions illustrate several of the basic performance requirements within the production area.

Molding Department

Foreman: Supervisor of load and press operators. Responsible for the tooling and equipment set-up; verifying that in-process molding operations conform to drawings, specifications, and MP's; taking corrective action when molding anomalies occur, i.e., tooling modification, formulating and milling silicone/fluorosilicone rubber per specs. Individual is heavily experienced in the molding characteristics of rubbers and plastics and the tooling requirements. The processes and tooling for new products are verified and proven out by the foreman prior to production runs. Responsible for the department work load and the meeting of production control schedules.


QUALITY CONTROL MANAGER STAN BATTERTON
QUALITY CONTROL ENGINEERING AND PLANNING
INSPECTION CHIEF INSPECTOR
MATERIAL REVIEW BOARD
SHIPPING AND PACKAGING INSPECTION
TOOL AND FIRST ARTICLE INSPECTION
FINAL TEST
IN PROCESS INSPECTION LEADMAN
MECHANICAL & ELECTRICAL CALIBRATION
MICROSECTION X RAY INSPECTION
MANUFACTURING DEPARTMENTS
RECEIVING INSPECTION
GAGE INSPECTION
SAN RAMON OPERATIONS HERBERT MACDONALD
EXPLOSIVE PRODUCT DESIGN
EXPLOSIVE LOADING DEPT 59
INSPECTION DEPT 71
EXPLOSIVE TEST DEPT 64
CHIEF ENGINEER RALPH CRAIG
PRODUCT DEVELOPMENT
DRAFTING
LIAISON ENGINEER
TEST LABORATORY
MODEL SHOP DEPARTMENT NO. 62
DOCUMENT CONTROL
RELIABILITY ENGINEERING
MATERIAL & PROCESSES
CONTROLLER RICK TELL
SECURITY
PERSONNEL ADMINISTRATOR
DATA PROCESSING SUPERVISOR
CHIEF BOOKKEEPER
WAGE AND SALARY
RECEPTIONIST
EMPLOYEE RELATIONS
COMPUTER OPERATIONS
PROGRAMMING
KEYPUNCH
ACCOUNTS RECEIVABLE
ACCOUNTS PAYABLE
BILLING
PAYROLL
MANAGER OF CONTRACTS AND PROGRAMS JACK KORBEL
CONTRACTS & PROGRAMS ADMINISTRATION
ESTIMATING

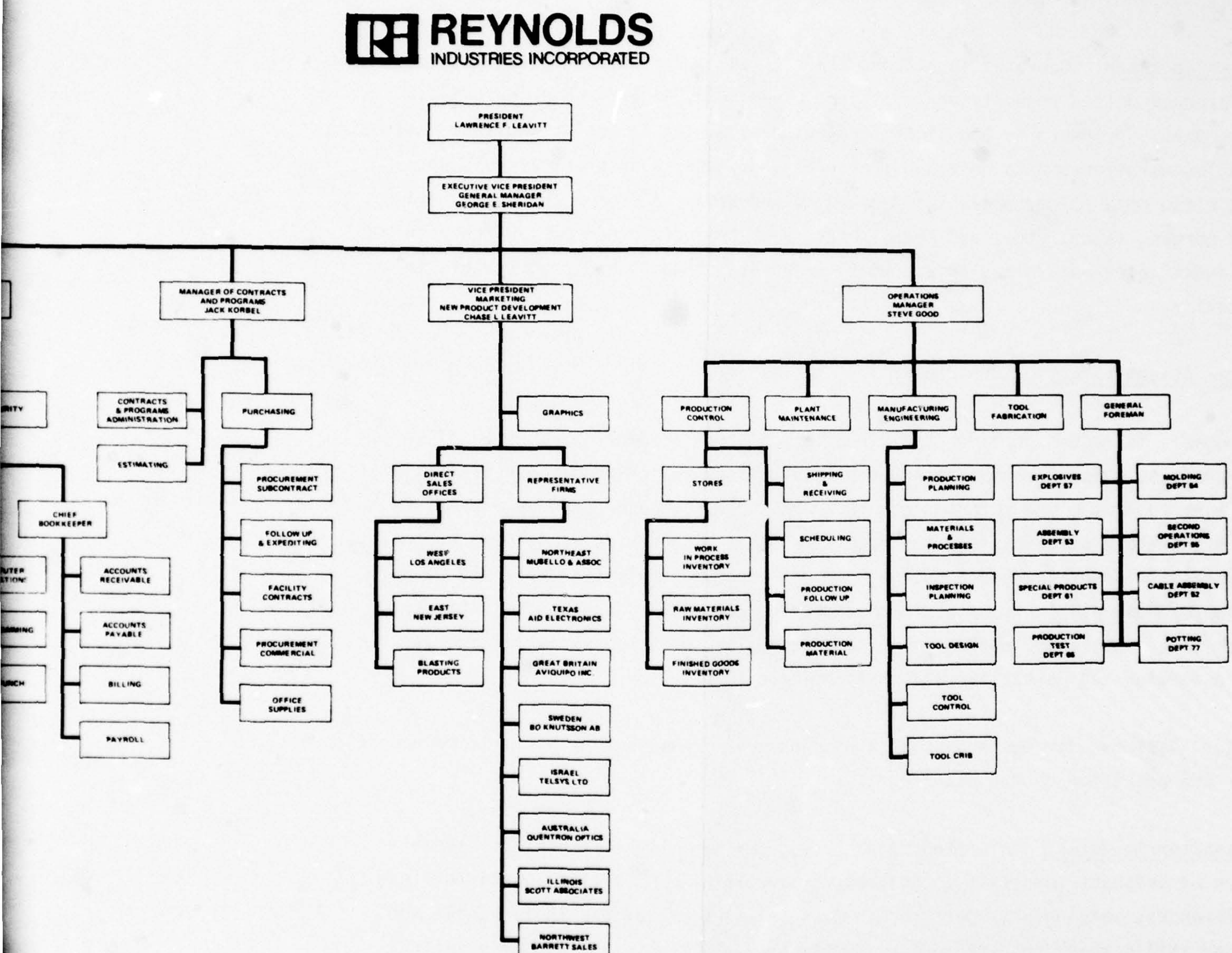


Figure 3-5 Organizational chart

Lead: will perform the duties of foreman in the foreman's absence. On a routine basis performs set-up for production products. Also is a press operator.

Press Operator: Operates injection, transfer and compression molding machines to produce molded products or parts from pre-mixed standard rubber or plastic compounds. Preheats to specified temperature and starts machine cycling. Maintains continuous attention to heat and pressure gauges and to ensure that mold does not close on a molded product. Removes molded products from machine, may trim off sprues, flash, etc., and keeps a record of products produced. Watches for malfunction of machine as evidenced by defective products and reports this to superior.

Final Assembly/Potting Department

Foreman: Is responsible for the direction of bench production assembly of units or products which are moderately or highly complex and which may require ability to work to very close tolerances. The work cycle in these assembly operations is either long or completely nonrepetitive, involving a wide variety of operations. Subordinate assemblers must have a high degree of manipulative skill and be able to work from detail blueprints, manufacturing procedures, and specifications. Must have a thorough knowledge of the function of the items assembled and be able to determine the workability of the completed item.

Lead: Performs foreman's duties in his absence. On a routine basis is responsible for the operation of the department.

Assembler/Solderer: On a production basis, performs light mechanical assembly work of moderate complexity. Assembly procedure involves fitting parts to close tolerances, working with parts or components which are difficult to handle and other skills which require good dexterity and facility in the use of a variety of hand tools. Work is not typically highly repetitive, but the cycle of repetition may be short enough to allow the development of some habit patterns. Must be able to work from detail blueprints, assembly sketches and other input documents of similar complexity.

Cable Shop Department

Foreman: Is responsible for the direction of bench production assembly of units or products which are moderately or highly complex and which may require ability to work to very close tolerances. The work cycle in these assembly operations is either long or completely nonrepetitive, involving a wide variety of operations. Subordinate assemblers must have a high degree of manipulative skill and be able to work from detail blueprints, manufacturing procedures, and specifications. Must have a thorough knowledge of the function of the items assembled and be able to determine the workability of the completed item.

Lead: Performs foreman's duties in his absence. On a routine basis is responsible for the operation of the department.

Assembler/Solderer: On a production basis, performs light mechanical assembly work of moderate complexity. Assembly procedures involve fitting parts to close tolerances, working with parts or components which are difficult to handle and other skills which require good dexterity and facility in the use of a variety of hand tools. Work is not typically highly repetitive, but the cycle of repetition may be short enough to allow the development of some habit patterns. Must be able to work from detail blueprints, assembly sketches or other input documents of similar complexity.

Machine Shop and Second Operation

Foreman: Is responsible for the supervision of employees who perform multiple setups and operations to produce metal parts on a production basis. Subordinates are typically journeyman machinists who are able to set up and operate a variety of machines, such as lathes, mills, precision grinders, etc., to perform diversified machining operations. They must be able to work from complex blueprints and drawings, perform standard shop computations relating to dimensions of work, tooling, speeds and feeds of machining, and use of a wide variety of precision measuring instruments.

Lead: Performs foreman's duties in his absence. On a routine basis is responsible for the operation of the department.

Machinist: Performs multiple setups and operations to produce metal parts and assemblies on a production basis. Sets up and operates a variety of machines such as lathes, mills, precision grinders, etc., to perform diversified machining operations. Must be able to work from complex blueprints and drawings, perform standard shop computations relating to dimensions of work, tooling, speeds and feeds of machining, and use a wide variety of precision measuring instruments. Includes only journeyman machinists who regularly use more than one type of machine in their work. Excludes maintenance machinists and experimental machinists.

Production Worker: Performs routine factory work requiring little job knowledge skill or discretion in selecting work methods. Covers such duties as performing simple repetitive bench operations such as burring, deflashing, abraiding, heat treating, parts numbering, replenishing process solutions, etc. Includes only light to medium physical effort.

INDUSTRIAL PLANT

The front portion of the Reynolds' building, as shown in front view in Figure 3-6, is a two story structure of standard rebar reinforced concrete block construction. This two story segment of the building houses the administration functions. Adjoining the front two story structure is a single story manufacturing area constructed of tilt-up concrete walls. All roofs are of plywood diaphram/glu-lam construction. Figure 3-7 shows the rear one-story section of the building and Figure 3-8 the roof.

A large basement, used as a parking facility for employees, lies under the entire structure. This basement has a 200 pound per square inch floor and overhead supported by an array of reinforced concrete columns.

Figure 3-9 illustrates the internal plant layout and reflects the production area peculiar to the Reynolds' product line.

Building power is all electric and is local utility supplied. Single phase 120/240 volt and three phase 120/208 volt power is used. Utility pole mounted transformers are visible in Figure 3-7. Two power service control rooms are located in the basement area. Air compressors and hydraulic pumps are co-located with the 120/240 volt control room.

Figure 3 - 6 Front view of facility across canal

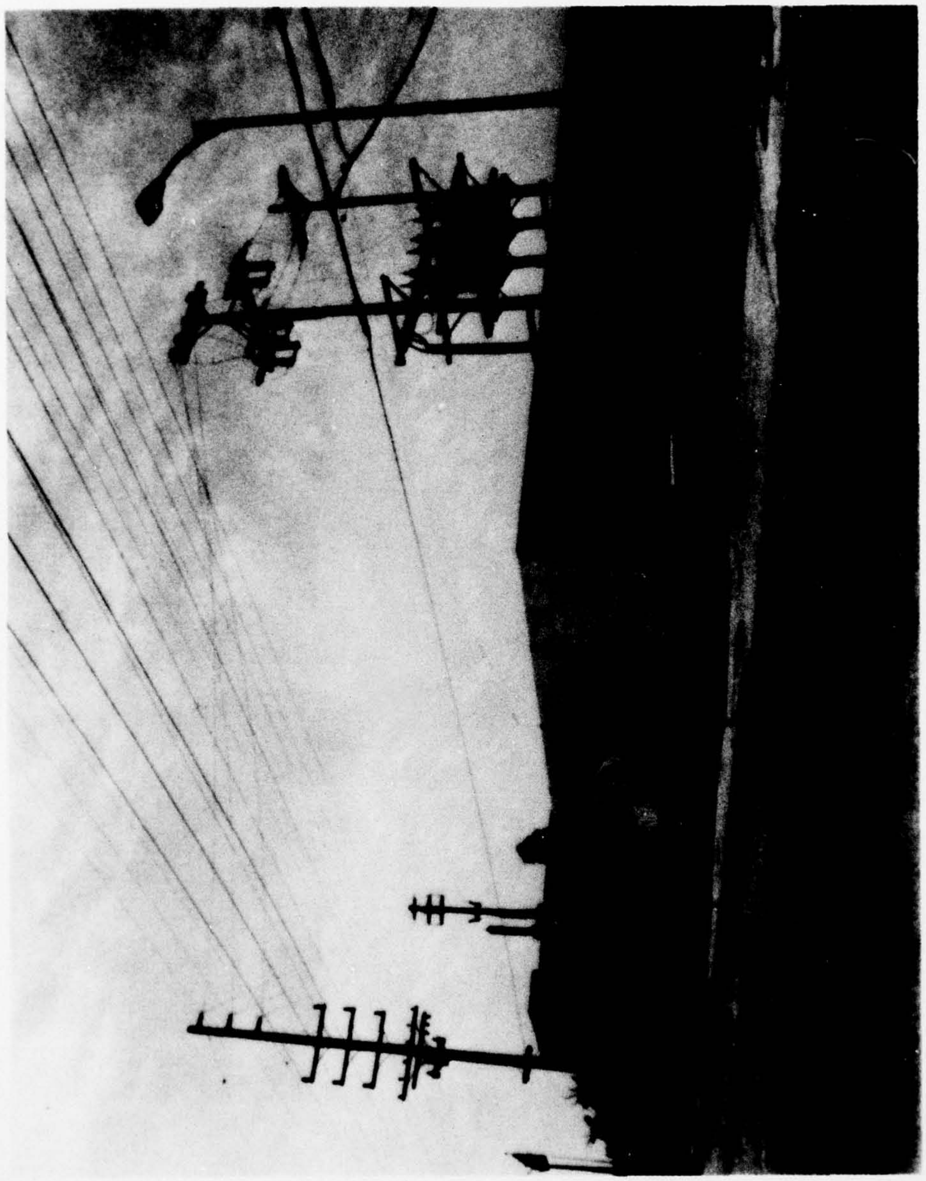


Figure 3-7 Rear view of facility

Figure 3-8 Facility roof

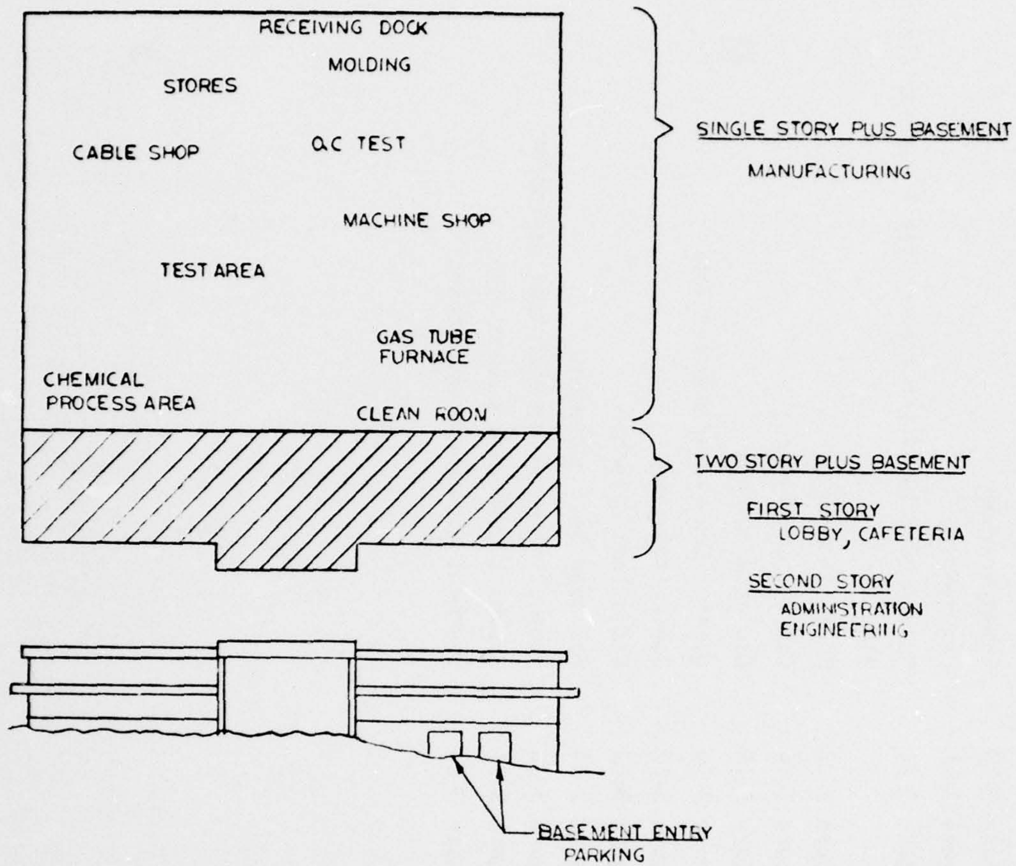


Figure 3-9 Plant layout

Photographs of portions of the facility and equipment within the building are as follows:

Figure 3-10	Computer room
Figure 3-11	Engineering
Figure 3-12	Main production floor viewed from lower administration floor
Figure 3-13	Milling machine
Figure 3-14	Cable assembly shop
Figure 3-15	Gas tube furnace
Figure 3-16	Quality Control inspection lab
Figure 3-17	Cable test shop
Figure 3-18	Veeco leak detector
Figure 3-19	Gas tube test equipment
Figure 3-20	Thermotron environmental test equipment
Figure 3-21	Basement hydraulic compressors
Figure 3-22	Basement electric power control

Figure 3-10 Computer room

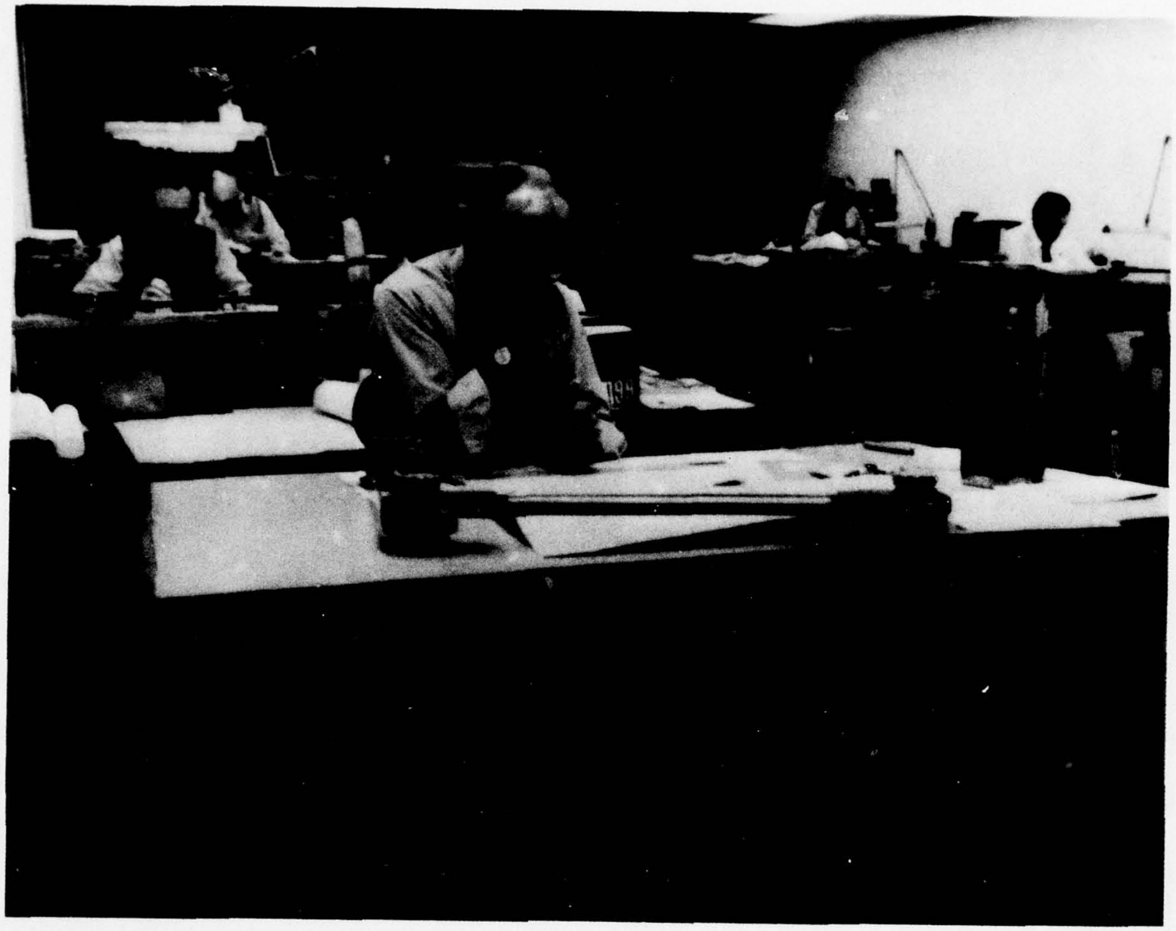


Figure 3-11 Engineering department

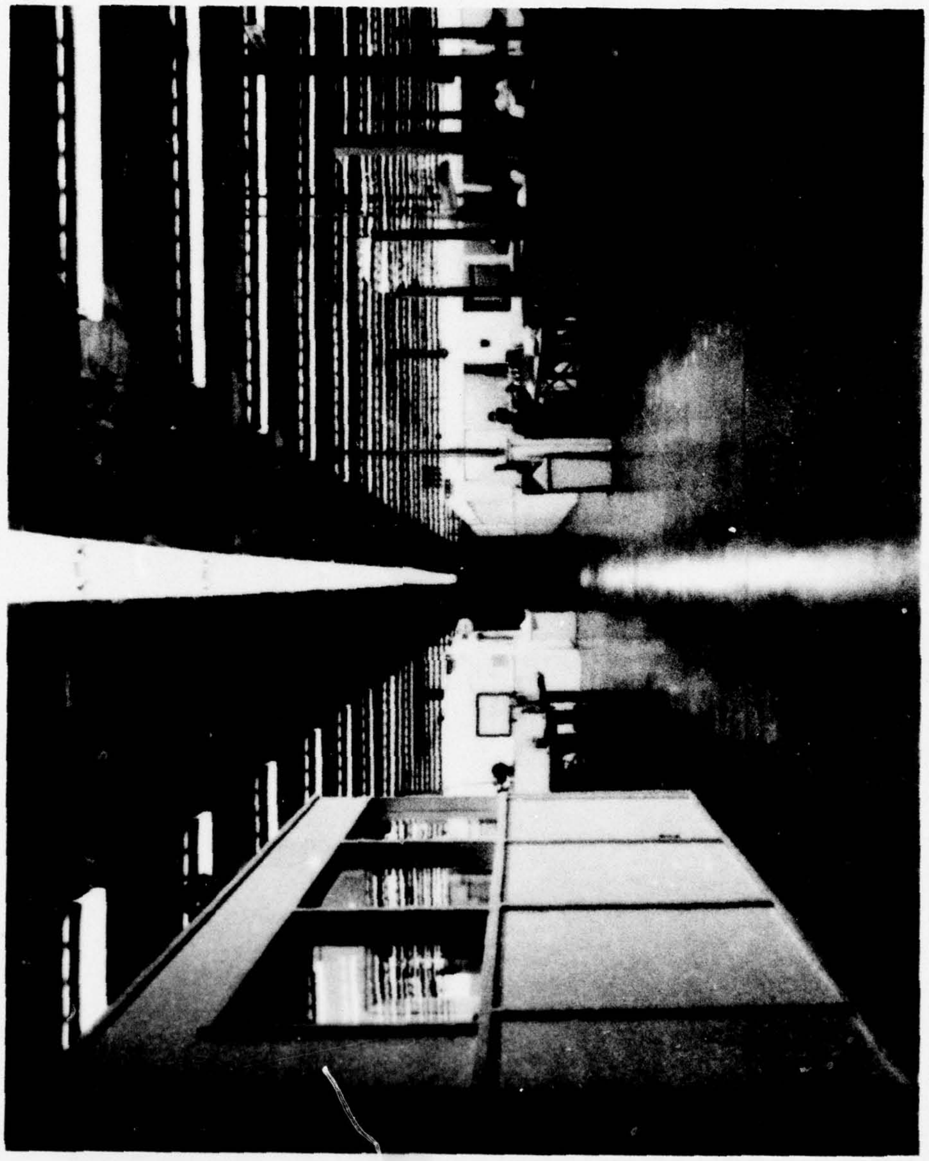


Figure 3-12 Main production floor

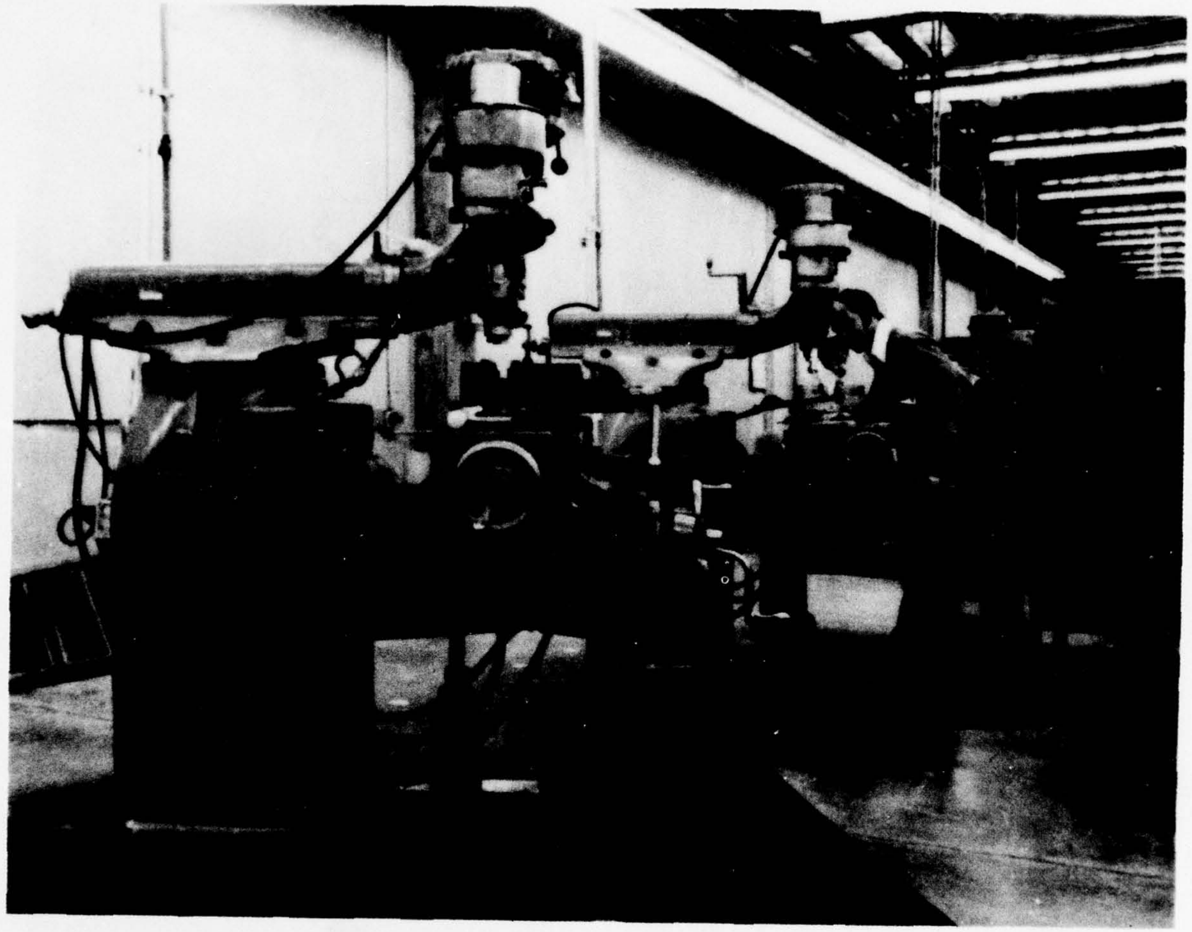


Figure 3-13 Milling machine

Figure 3 - 14   Cable assembly shop

AD-A066 399 BOEING AEROSPACE CO SEATTLE WASH F/G 18/3
INDUSTRIAL PLANT HARDNESS. PHASE II.(U)
APR 78 E N YORK, D H HOLZE, E MALONE DNA001-77-C-0256

UNCLASSIFIED DNA-4549F NL

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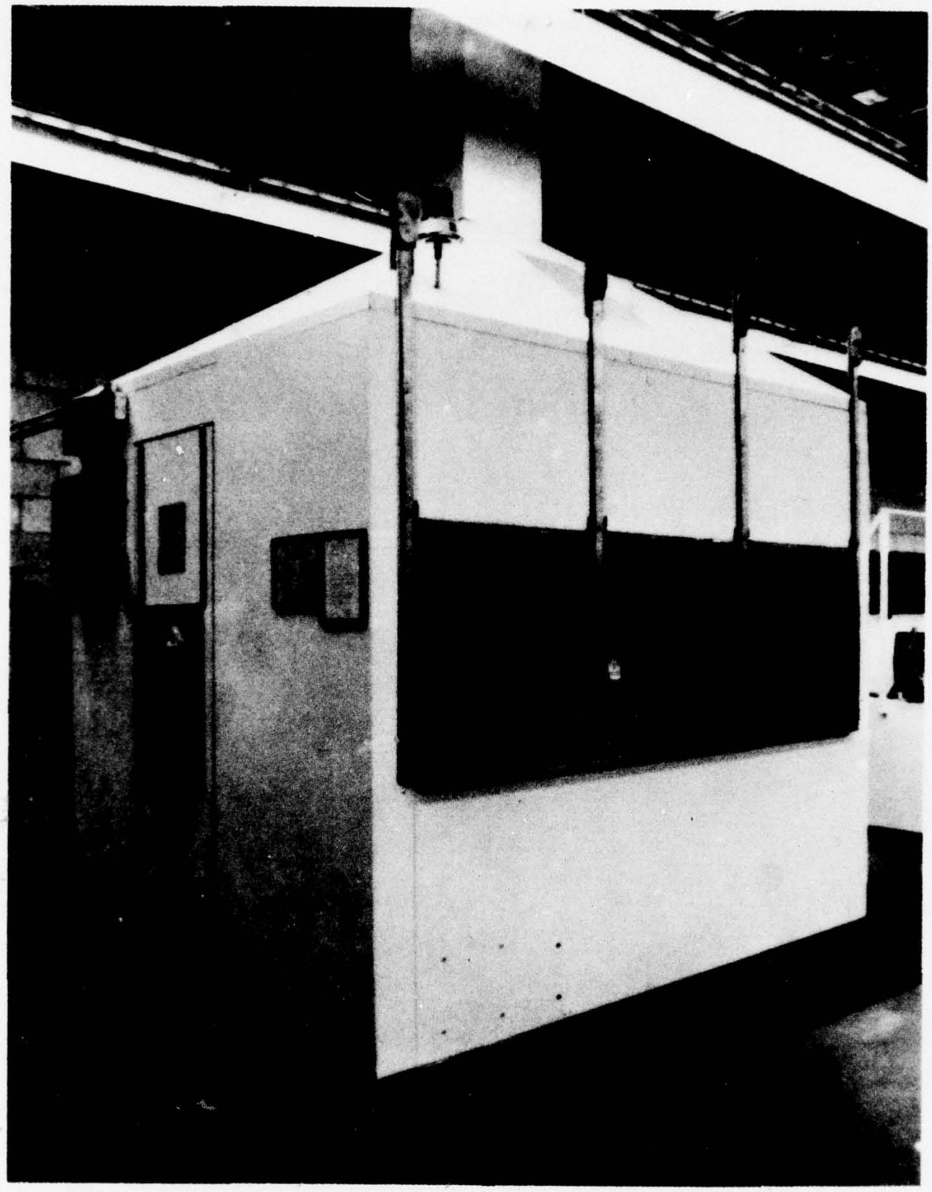


Figure 3-15 Gas tube furnace

Figure 3-16 Quality control inspection labratory

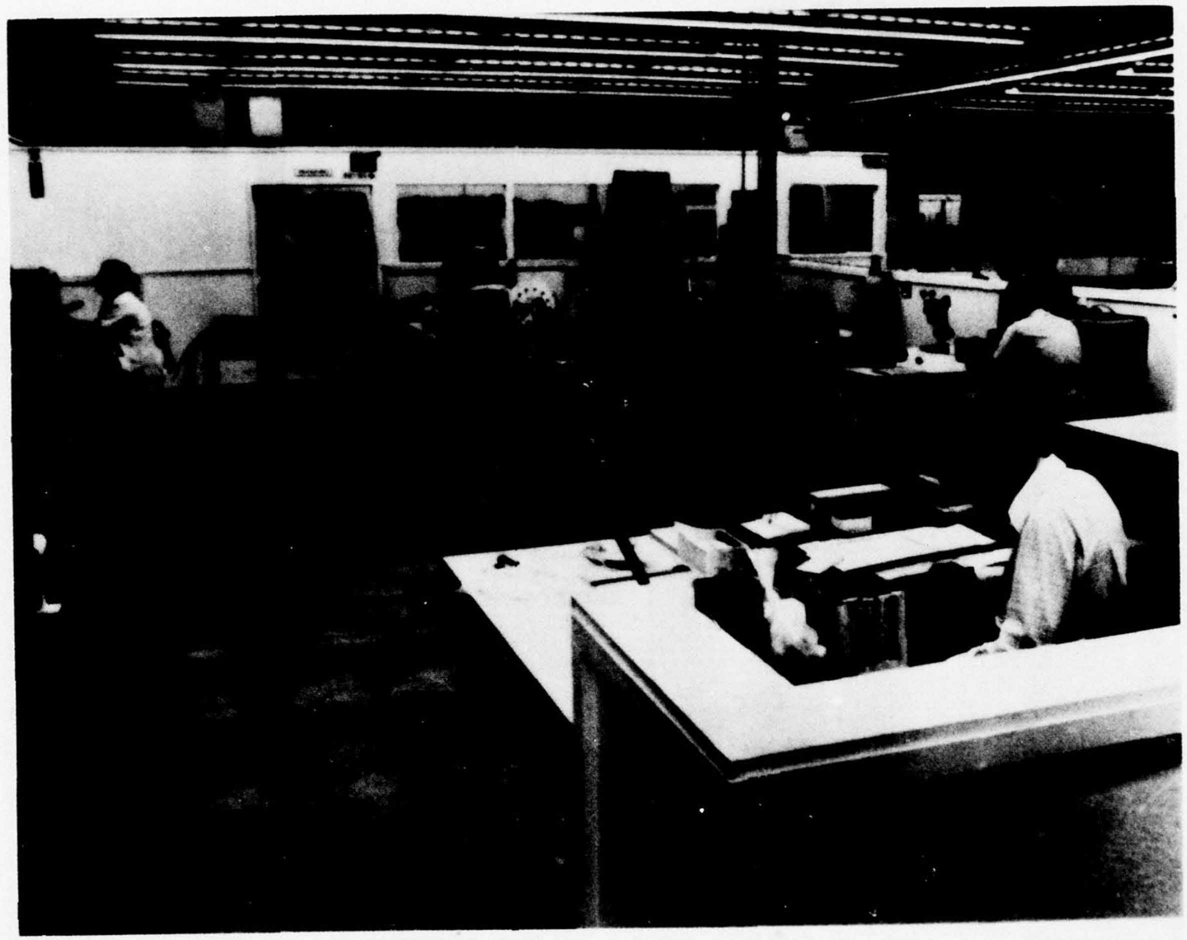


Figure 3-17 Cable test shop

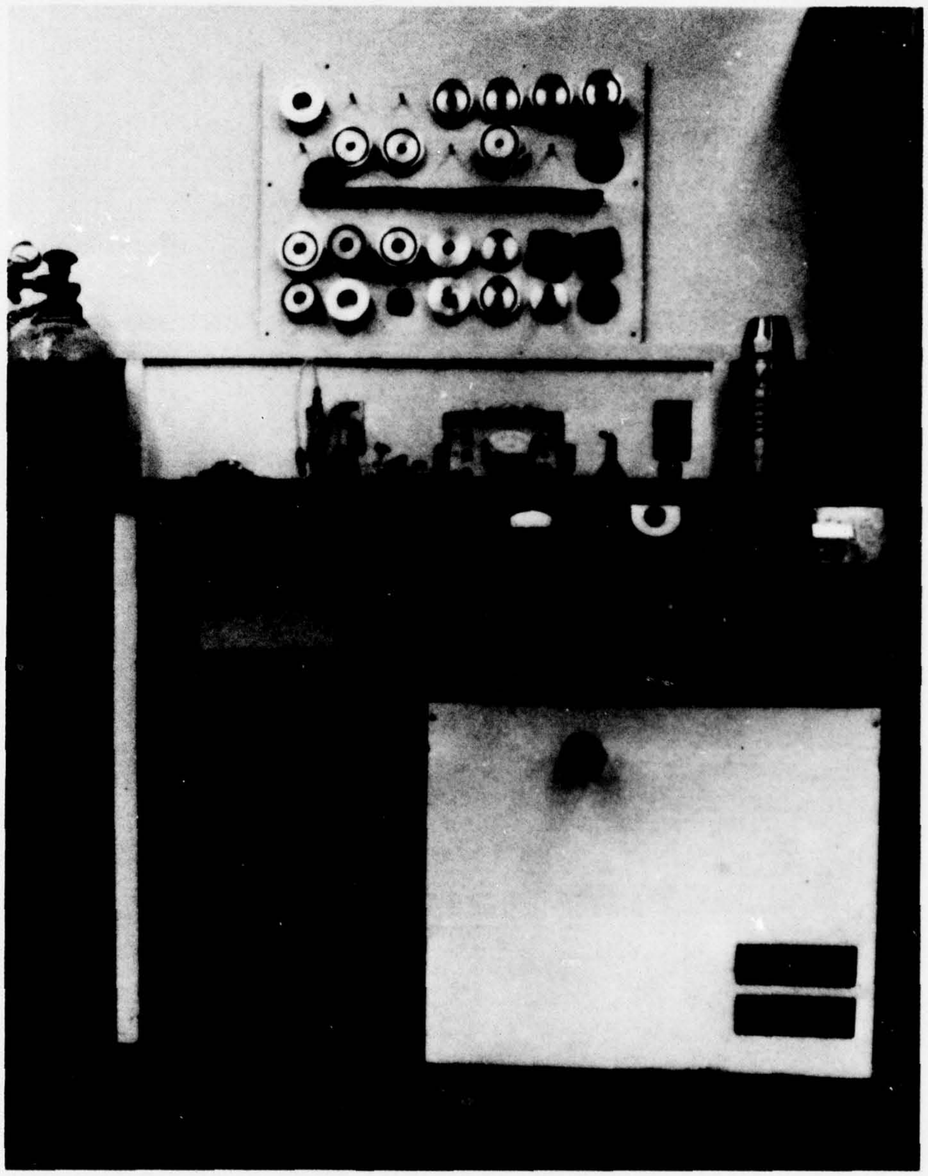


Figure 3 - 18   Vaeco leak detector

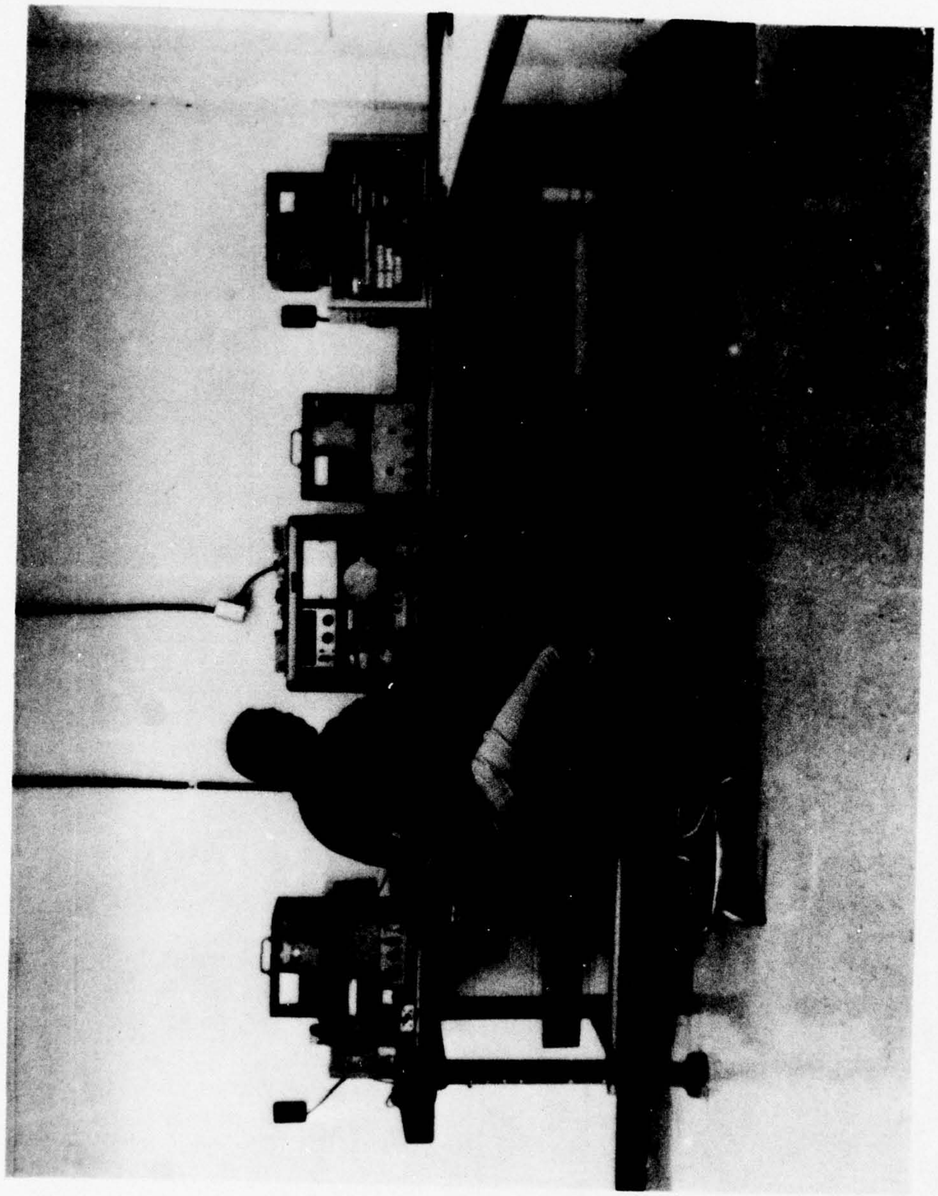


Figure 3-19 Gas tube test equipment

Figure 3 - 20 Thermotron environmental test equipment

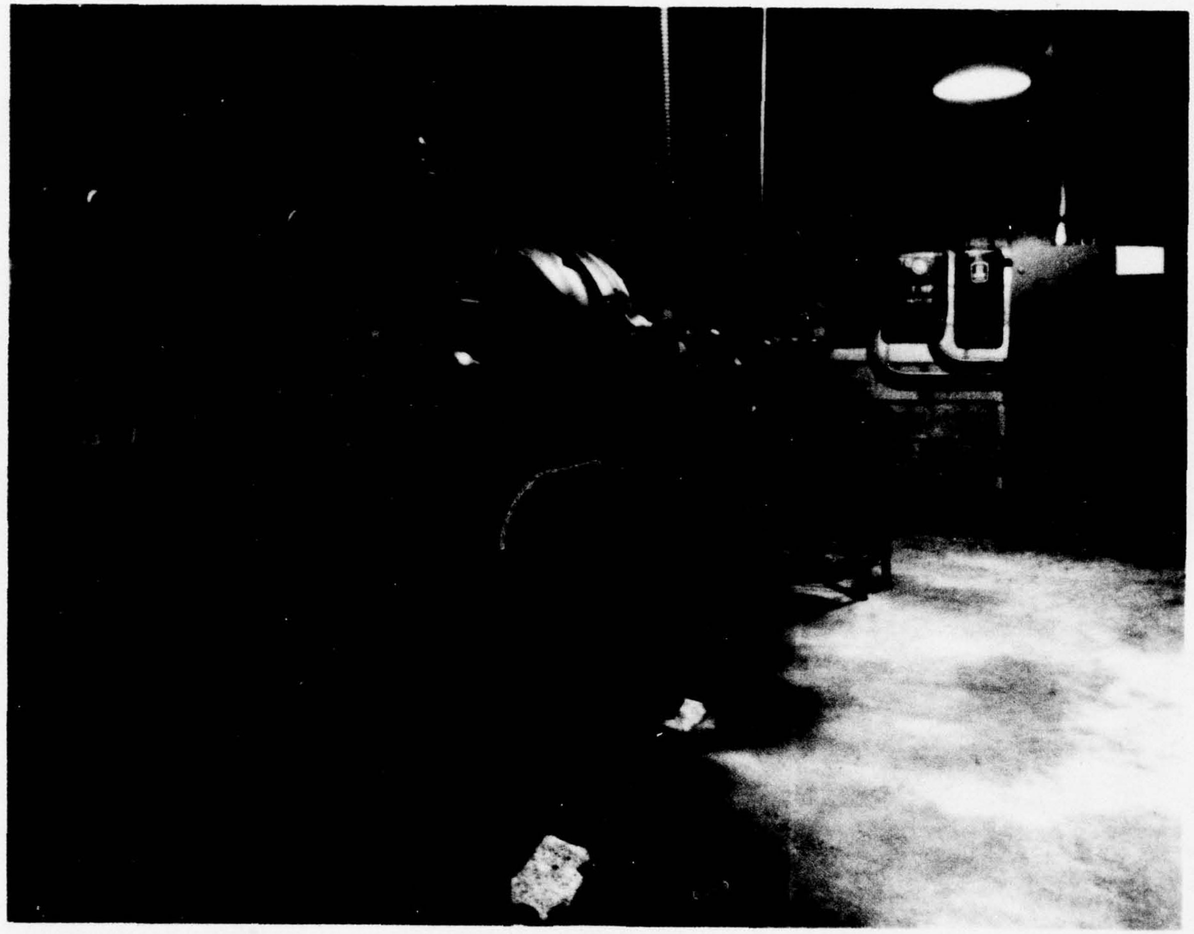


Figure 3 - 21   Basement hydraulic compressors

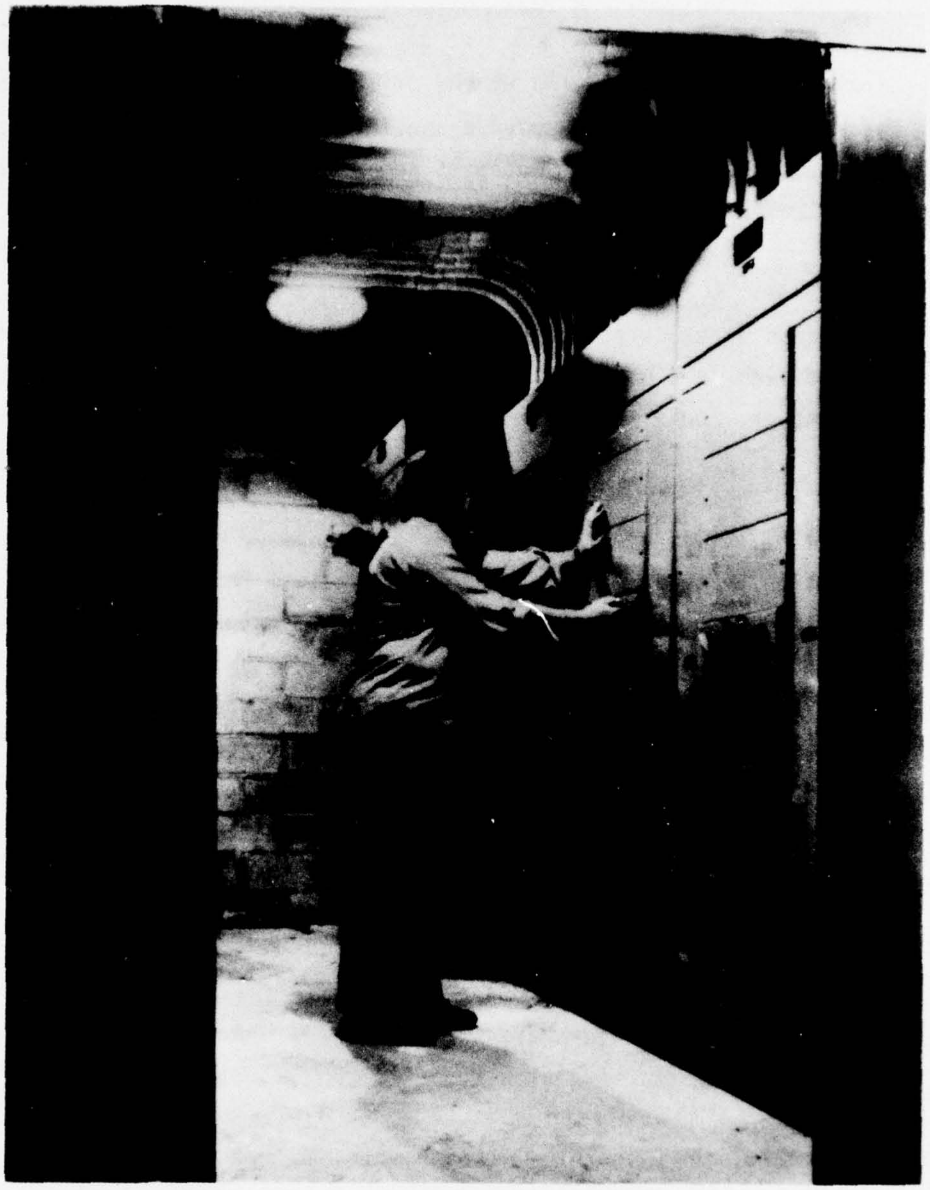


Figure 3-22 Basement electric power control

4.0 SELECTIONS FOR POST-CONFLICT SURVIVAL

This report presents a subjective view of the efforts and processes undertaken by a small industrial facility to survive a specified war time scenario. This section of the report describes the processes and reasoning followed in the selection of the surviving products, personnel, industrial tools, materials and records.

The selection process is essentially governed by the products selected as desirable post-attack commodities in a war damaged economy. Once the product is chosen, the necessary manpower, tools and materials follow automatically in the selection process.

A. The dependence of this choice of materials and manpower necessary for Post-attack production on the products chosen for survival leads to the conclusion that an on-going procedure must be established to continuously update the product choice for post-attack production as industry and Reynolds product priorities change. These on-going procedures should include the mechanisms to revise and update survival plans as necessary when new survival products are added to the facility plan and others are deleted.

For this report, product selection was undertaken by upper management within Reynolds Industries. Of the many product possibilities, the high voltage connector product line was selected for several reasons.

1. Reynolds high voltage connectors are sufficiently unique within the electrical industry to be a necessary post attack commodity.

2. Within the Reynolds organization, the high voltage connectors are produced only in the Los Angeles facility thus enabling the study to be confined to the one plant.

3. The high voltage connectors are the primary product within the Los Angeles facility.

PRODUCTS

A single product within the connector product area was chosen as a vehicle to illustrate the steps associated with the selection of personnel, materials and tools for survival of the high voltage connector manufacturing capability. This product is a connector/cable assembly used to interconnect a high voltage power supply to a traveling wave tube within an electronic countermeasures system.

This cable assembly is illustrated in Figure 4-1 and is composed of a section of high voltage cable terminated at each end with different Reynolds high voltage connectors. These cables may be seen installed in the users ECM system. See Figure 4-2.

The cable assembly is composed of a length of special high voltage cable terminated at each end with two different high voltage connectors of Reynolds proprietary design. Figure 4-3 breaks the complete assembly into its component parts.

Each connector contains several machined and plated components which are purchased by Reynolds as machined parts and subsequently sent to an outside plating shop for precision plating. These components are assembled by Reynolds in accordance with an exacting series of process procedures to mate with Reynolds molded rubber insulators and the precut and processed cable. Strict conformance to the precision process procedures assures the necessary high voltage tolerances required of the finished cable assembly.

Prior to shipment each finished cable assembly is tested at environmental extremes for the specified high voltage holdoff characteristics.

The cable assembly selected for the survey is typical of the production requirements imposed on both the high voltage connectors and connector/cable assemblies produced within the Reynolds Los Angeles facility.

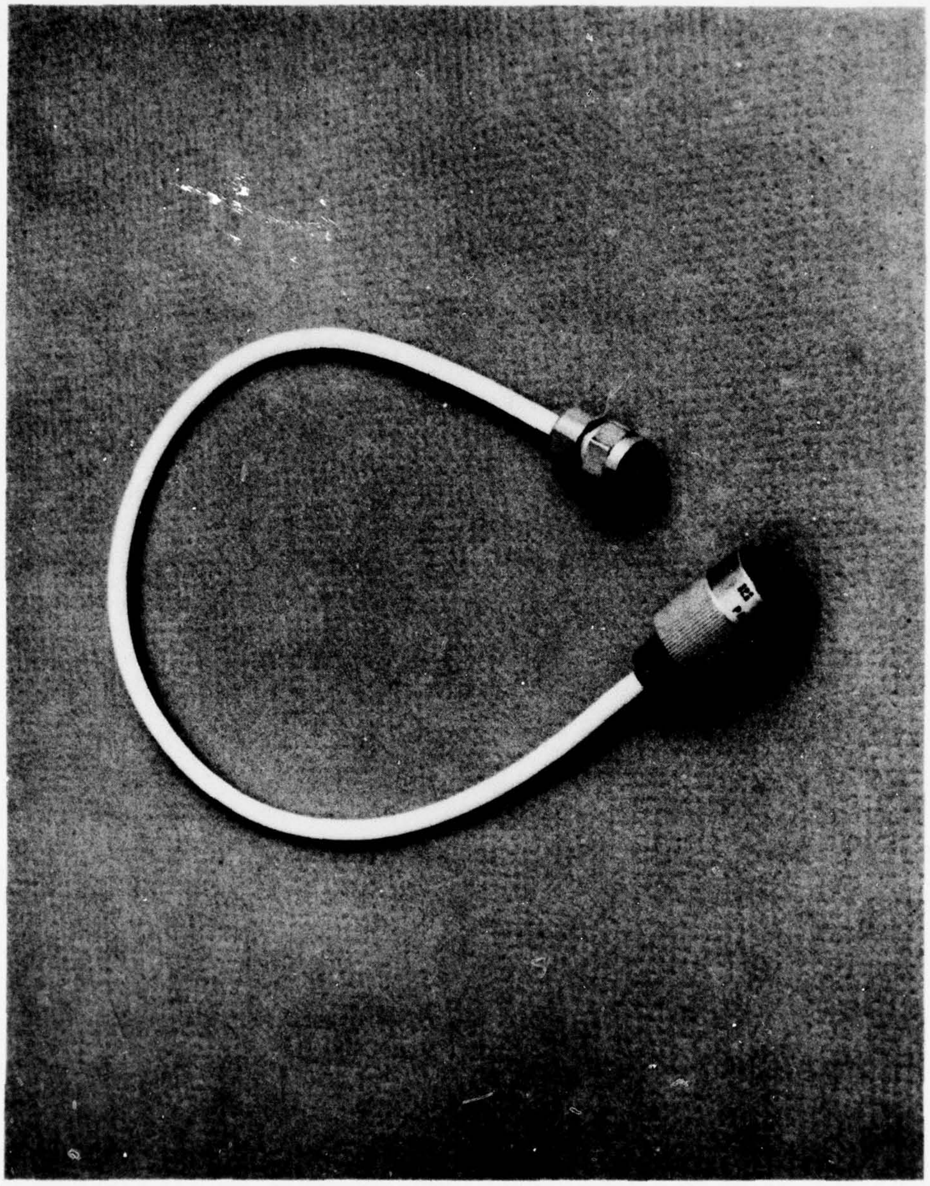


Figure 4-1 High voltage connector /cable assembly

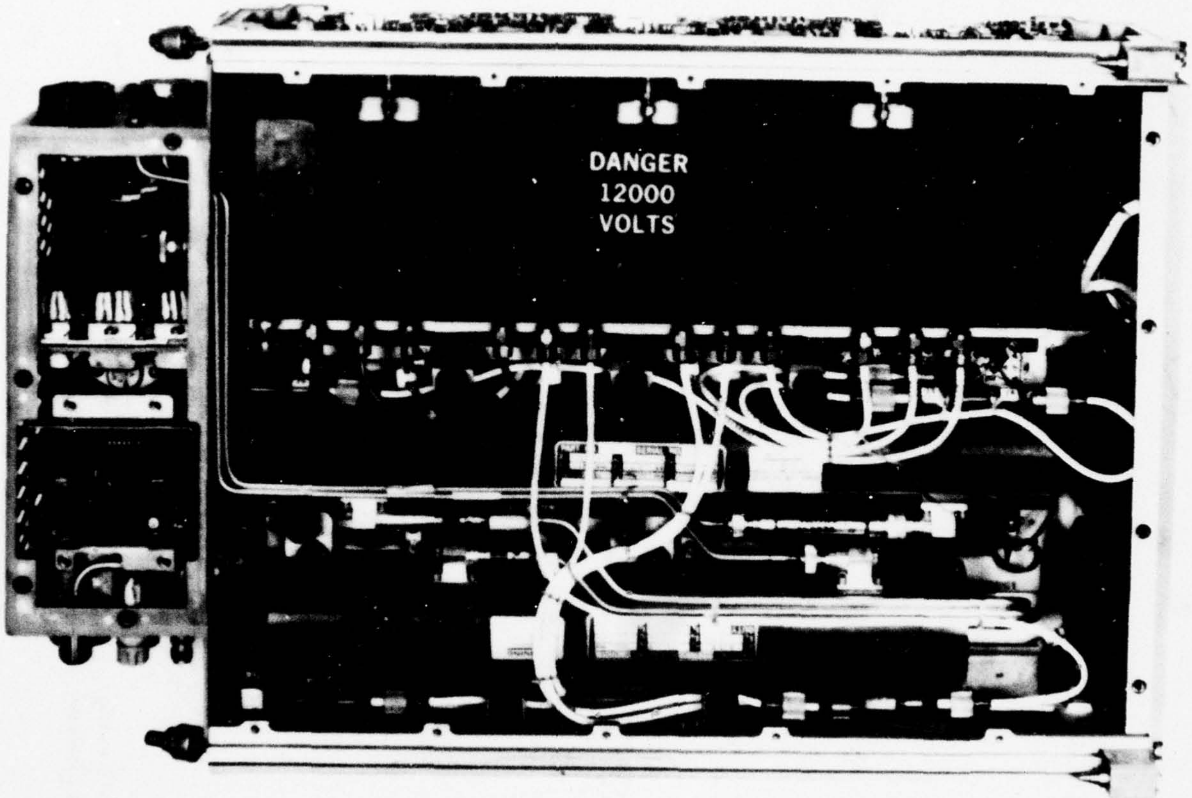


Figure 4 - 2 Connector/cable assembly installed in users TWT power supply

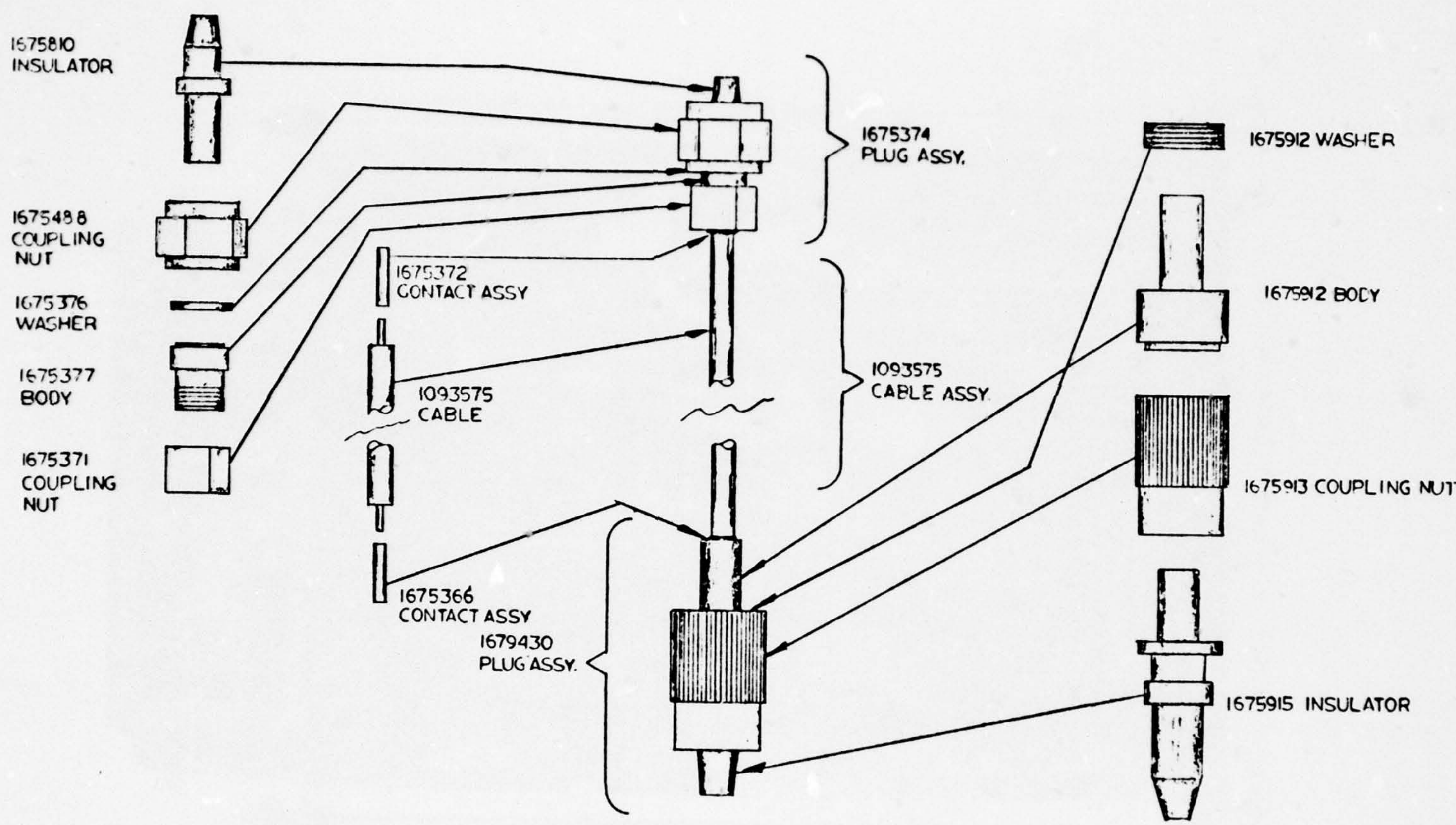


Figure 4-3 High voltage connector/cable assembly components

PERSONNEL

During the long term pre-attack preparation period the manpower resources of the entire Reynolds facility will be available. Following the attack a post attack production force of eleven people is planned and is considered adequate for production limited to the high voltage cable/connector assembly.

All personnel presently associated with financial and marketing functions within the organization were eliminated from post-attack consideration, and only those individuals within the engineering, manufacturing and quality control areas possessing broad capabilities have been selected for post attack work force consideration.

Reynolds strong program of promotion from within has resulted in a middle management staff possessing the capability to substitute where necessary in all production tasks associated with the high voltage cable/connector assembly. For this reason a considerable portion of the post-attack work force has been chosen from this middle management staff.

The post-attack choice of personnel is as follows:

	Present Assignment	Post Attack Work Force Assigned
1.	General Manager	Work Force Manager
2.	Chief Engineer	Product & Facility Engineer
3.	Lead Engineer	Manufacturing & Records Engineer
4.	Production Manager	Production Manager
5.	Quality Control Manager	Stores Management & Quality Control
6.	Quality Control Engineer	Quality Control Test
7.	Machinist	Machinist, Product & Facility Requirements
8.	Production Assembler	Production Assembly
9.	Production Leadman	Production & Parts Liaison
10.	Cable Shop Supervisor	Cable Assembly
11.	Facility Engineer	Facility Maintenance

Personnel selection for the post-attack work force was also based on the ability of the chosen individuals to work both independently and creatively. Second to direct knowledge of the surviving product production procedures, the ability to maintain a flexible attitude toward a variety of problems is considered highly desirable in the individuals chosen to function in the environment of the post-attack period.

In this survey this post-attack work force and their families will return to the area of the facility on the day following the attack. Figure 4-4 illustrates the residential area of these employees. It is assumed that civil defense protection will be provided for most of these people in the area of their homes. Several of the work force personnel who live a considerable distance from the facility may find civil defense protection at a location in the general area of the plant.

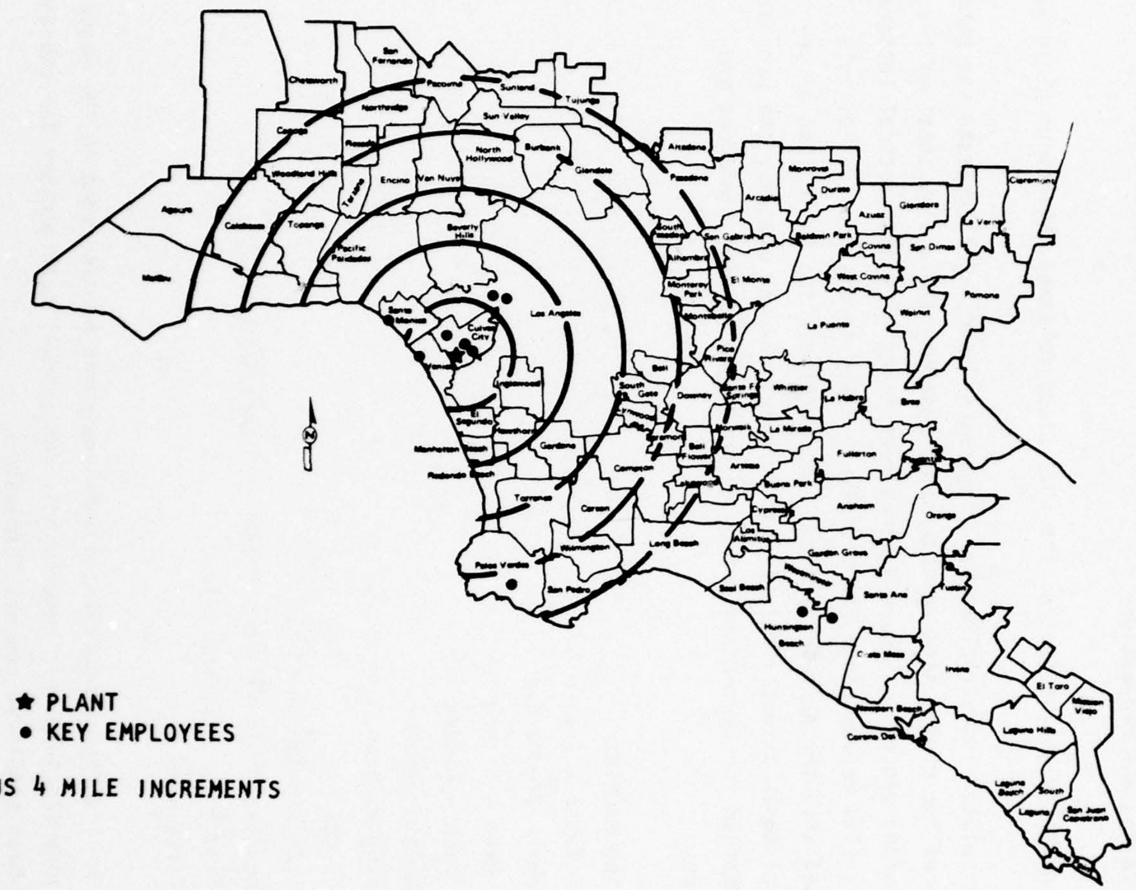
INDUSTRIAL TOOLS

Following selection of the desirable products for post-attack survival, key equipment necessary to support production following the attack has been classified and selected as follows:

A. Those industrial tools directly related to the manufacturing procedures established for the surviving product selected. These tools vary from large machine tools requiring external power sources to small hand operated tools critical to the individual manufacturing procedure.

B. Support equipment necessary to supply electrical power, water, air pressure and any other indirect requirements for the chosen industrial production process.

C. Tools and equipment necessary to provide production of those sub-level piece parts necessary for the production of the chosen post-attack products which are normally purchased from outside of plant sources. Selection of this equipment requires a series of detailed make or stockpile decisions because the necessary equipment and skills for the production of some product details are impractical to provide, even with adequate pre-attack planning.



★ PLANT

● KEY EMPLOYEES

RADIUS 4 MILE INCREMENTS

Figure 4-4 Emlopyee residences

D. Personnel support facilities and equipment. This category includes provision for board and lodging, sanitation facilities, medical care, transportation and recreation.

The key equipment selection process for this study followed these four classifications.

A. Directly related industrial tools: Figures 4-5 and 4-6 illustrate the detail assembly of the chosen high voltage cable assembly and a flow chart of the manufacturing process. Figure 4-6 has been keyed with alphabetical letters in the circles representing the individual steps to the industrial tools associated with the particular step. Listed belowis the basic list of key industrial tools directly related to the manufacturing process, and provides the foundation for the determination of necessary support equipment and facilities.

   a. Marking machine
   b. Speed lathe - Figure 4-7
   c. Abrader - Figure 4-8
   d. 100^0 oven - Figure 4-9
   e. 310^0 oven - Figure 4-9
   f. Ultrasonic cleaner
   g. Striping machine, air driven
   h. Solder pot
   i Resistance soldering iron
   j. Compounding Mill, silicone rubber - Figure 4-10
   k. Moulding Press - Figure 4-11
   l. Specialty wrench

Three pieces of indirect production support equipment not included in the above list are a hydraulic pump, air compressors, and a small refrigerator for storage of necessary heat sensitive process chemicals.

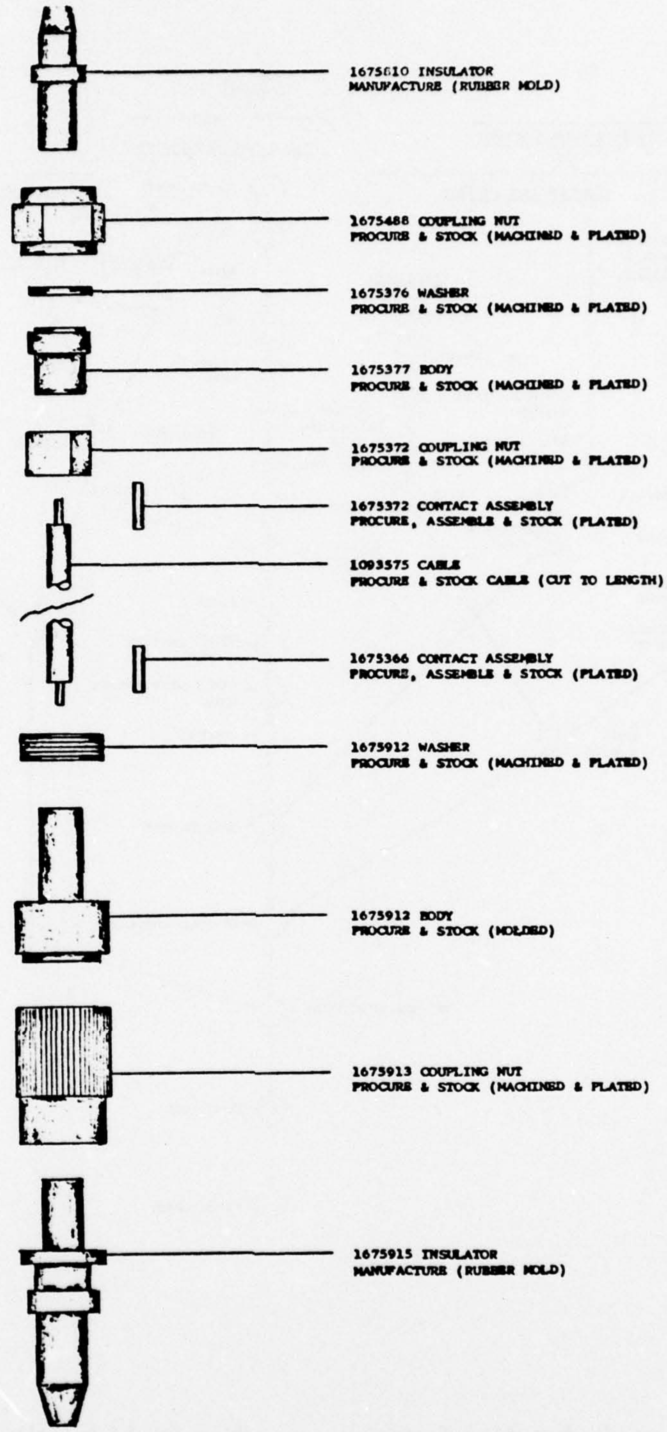


Figure 4-5 Sources of key materials

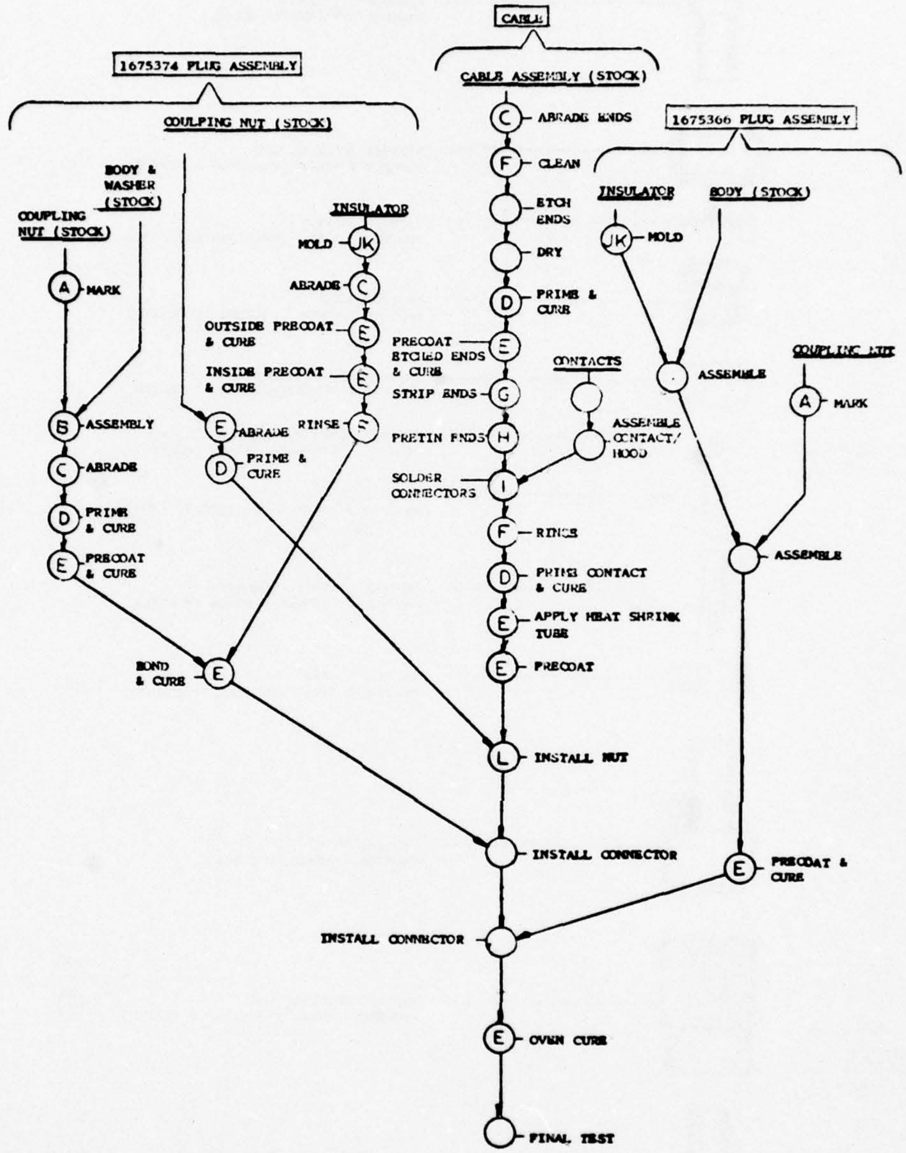


Figure 4-6 Manufacturing procedure for high voltage cable/connector assembly

Figure 4-7 Speed lathe

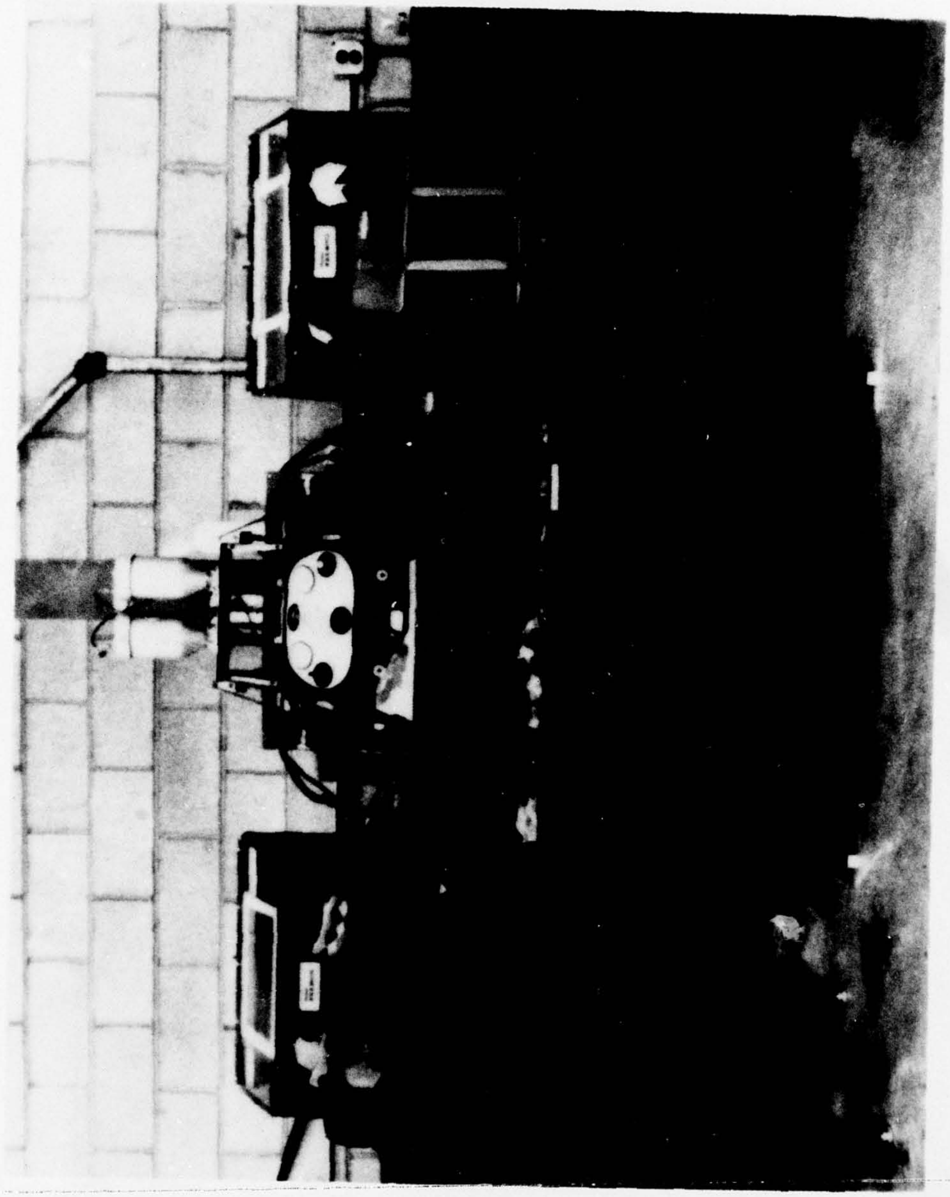


Figure 4-8 Abrader

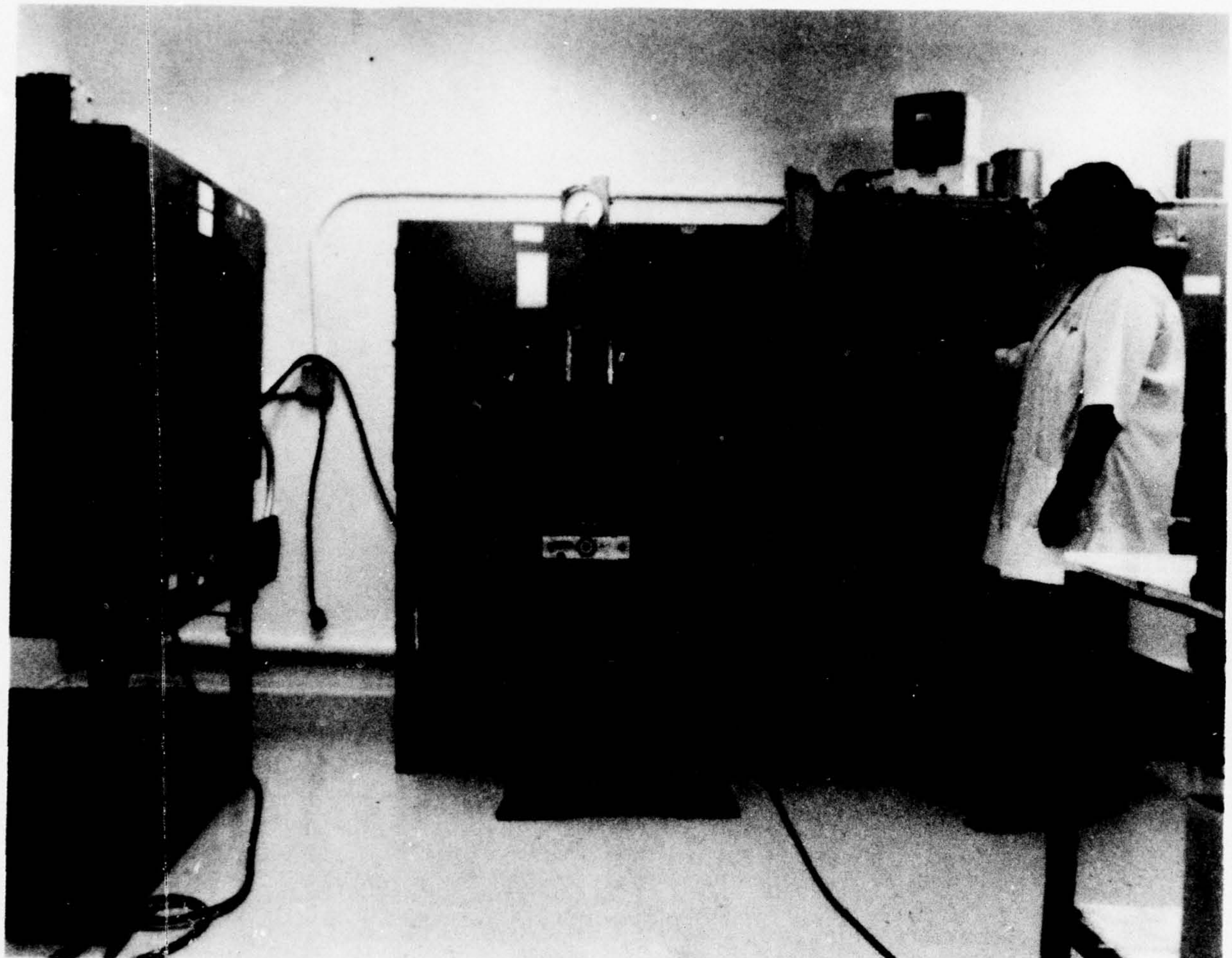


Figure 4-9 Ovens

Figure 4-10 Compounding mill

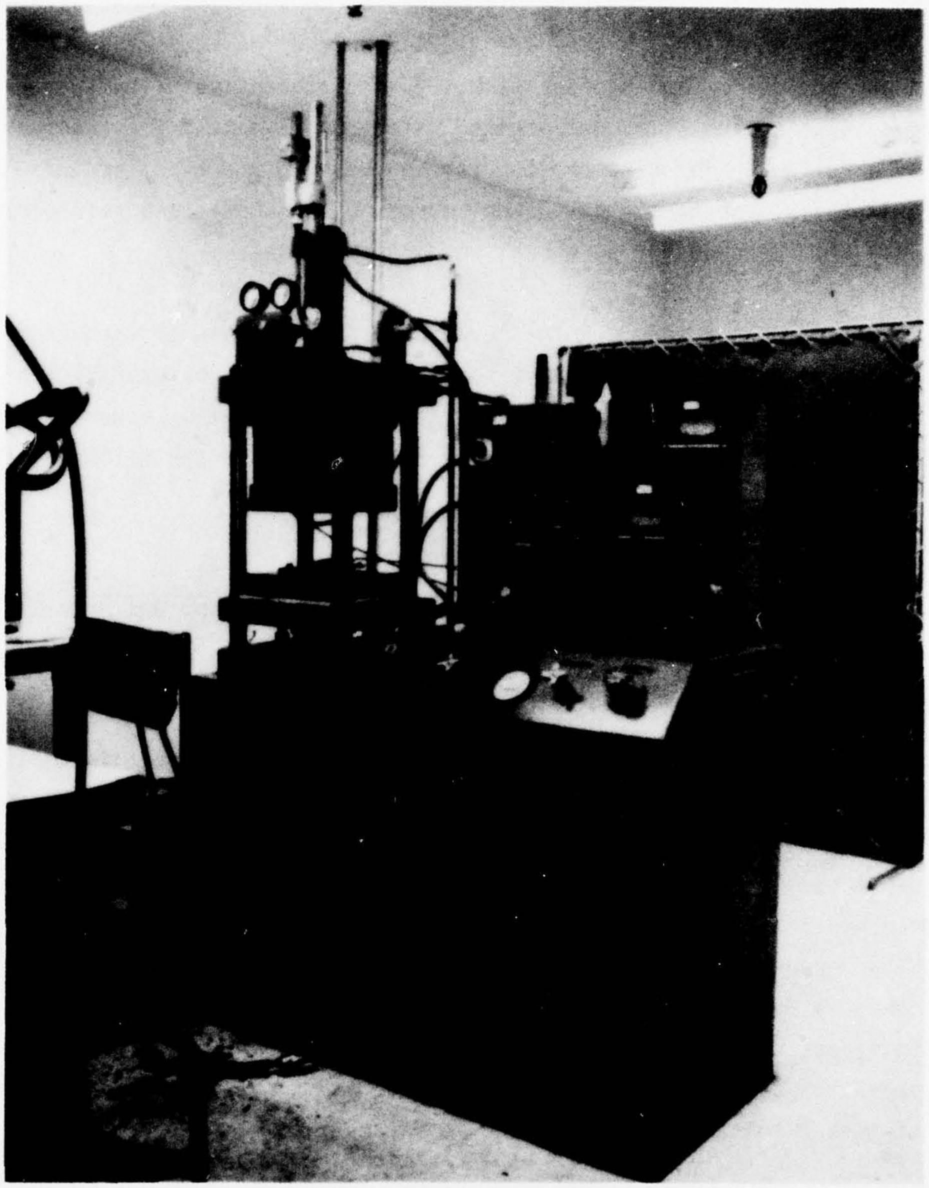


Figure 4-11 Moulding press

B. Support equipment necessary:

For the chosen surviving product six pieces of support equipment have been identified as necessary. These are 1) a source of electrical power, 2) an air compressor and storage tank, 3) a refrigeration unit for materials storage, 4) a source of uncontaminated water, 5) a vehicle for transportation, and 6) a bulldozer for clearing rubbish and opening the basement area. Three of these, the electrical power source, water supply and refrigeration unit may also be used for personnel support functions.

1. Electrical power source. The Reynolds facility presently requires one hundred thousand killowatt hours per month for the operation of the Los Angeles production facility. The average operation power consumption rate based on a thirty-day month is 568 KW based on the following calculation:

$$\text{Average Power} = \frac{\text{Monthly Usage}}{(\text{Total Days-Weekend Days})\ (\text{Production Hrs.})}$$

$$= \frac{100{,}000}{(30 - 8)\ (9)} = 568\ \text{KW}$$

This power is consumed for all direct production equipment in addition to the support function of lighting and cooling, various office machines and equipment such as the computer facility. In a post-attack environment where only a minor portion of the building and equipment survives, this consumption has been estimated to be reduced to ten percent of the pre-attack consumption, or 57 kilowatts. This estimate is considered conservative for the selected limited production because it provides in excess of one hundred percent of the load requirements of simultaneous operation of all surviving power consumation requirements. A summary of this simultaneous power usage is as follows:

Compressor	3730 watts
100^o oven	2940 watts
300^o oven	1600 watts
Abrader	240 watts
Lathe	1000 watts

Ultrasonic	300 watts
Refrigerator	300 watts
Lighting	5000 watts
Various office Equipment	2000 watts
Personnel heating	5000 watts
Water pump	1500 watts
TOTAL	23610 watts

For the post-attack period, where all utility power has been eliminated, a diesel motor generator will be used supplied with diesel fuel from an underground storage tank installed in the basement area prior to the attack.

Prior to the attack a 60 KW prime generator available from commercial sources will be purchased and installed. Continuous fuel consumption of 10 gallons of fuel per production hour has been anticipated requiring a diesel fuel storage capacity in excess of 2000 gallons per month. A 10,000 gallon storage tank has been selected.

Necessary facility voltage requirements will be provided by transformers supplemental to the motor generator. Power will be re-routed to the basement area through the existing basement control panels during the post-attack period to eliminate any damage to the re-routed cabling during the blast period.

2. Air compressor and storage tank. The existing basement compressors and storage facilities will be preserved for the post-attack period through the use of crushable backpacking materials and sandbags.

3. Refrigeration unit. A small portable electric powered refrigeration unit will be procured and stored in the basement area prior to the attack. Crushable material and sandbags will be used to provide blast protection of the unit.

4. Water. Potable water will be stored for both personnel and production usage in a 150,000 gallon underground storage tank installed beneath the basement floor in the long range pre-attack period.

5. Transportation. Two jeep type utility vehicles will be provided and stored in the basement area during the pre-attack period. One for personnel transportation and one of a truck configuration for materials transportation in the post-attack period. Both vehicles will be protected with crushable materials and sandbags.

All private personnel vehicles will be removed from the basement prior to the attack to provide additional storage space and to lessen the post-attack basement clean-up task.

6. A heavy diesel driven bulldozer will be procured during the pre-attack period to be used in the placement and removal of sandbags in the basement area. The bulldozer will also be used to clear the building debris after the attack and clear passages to the basement. This post attack refuse removal requires the bulldozer to be among the first equipment available after the attack, if for no other reason than to clear an entrance to the basement area. As a consequence of this immediate post-attack necessity, the bulldozer will be stored in a remotely located trench beyond the expected debris area. The bulldozer, a short term fuel supply, and hand tools such as picks, will be protected by crushable material in the excavation and then buried with shovels by the preparation crew. The necessary shovels for immediate post-attack recovery of the bulldozer will be placed in a shallow excavation prior to the attack.

C. Tools and equipment for producing sub-assembly level details in-house: For the chosen post-attack surviving product, the major capability not presently possessed by Reynolds Industries necessary for complete in-house production of the high voltage connector/cable assembly is that of precision plating.

Reynolds presently has the machine shop capability to machine the necessary connector details in-house. However, due to the subsequent precision plating requirement for these details, this post-attack machining option has not been included in this survey.

An alternate to the survival preparation plan presented would be to acquire the plating capability prior to the attack, thus lessening the stockpile requirement for these connector details. This alternate would require stockpiling and storage of the necessary chemicals and plating tanks. However, of more significance is the acquisition of the necessary plating technical skills.

D. Personnel support facility and equipment: A detailed analysis of the personnel support equipment for the post-attack work force is beyond the scope of this survey. Thought has been given to this problem with the conclusion that a realistic portion of any post-attack plan must include provisions for the maintenance of the post-attack production work force and their facility for approximately one month.

For this reason a partial list of those items to be stockpiled and stored within the facility basement is as follows:

1. Dried, canned food - 1 month supply
2. Medical supplies
3. Cots sufficient for work force and families
4. Materials to construct outside sanitation facility
5. Recreation exercise equipment, movies
6. Water to be jointly used with production requirements

A portion of the surviving basement production area will be set aside for lodging and boarding for the one month time span. It is assumed that during this time personnel will devote a portion of their efforts to securing permanent alternate sources of support in the Los Angeles area surrounding the facility location

MATERIALS

Two basic classes of materials are necessary to support a post attack production effort of the high voltage connector/cable assembly. The first class covers all the physical detail parts used directly in the produced part which are made outside of the facility and stockpiled, or alternately the materials to produce these parts in house during the post attack period.

The second class covers the expendable materials such as epoxy and cleaning fluids consumed as part of the production process.

Figure 4-12 illustrates the type of storage presently used in the Reynolds facility for storage of the first class of materials, and also for small tools such as precision molds.

Figure 4-5 lists the key materials directly associated with the high voltage cable assembly and the survey stockpile/manufacturing decision for these parts.

Pre-attack stockpiled parts are to be stored in the type of storage illustrated in Figure 4-12 until the immediate pre attack warning period, at which time all selected surviving product details will be transferred to boxes packed in crushable materials and soil for basement storage. Minimum inventory levels for all high voltage connector/cable assemblies will be increased in accordance with the anticipated post attack production requirements, and maintained at this level at all times in the pre attack period. Production during this pre attack period will draw from this single inventory source on a first in-first out basis.

The second class of materials, the expendable materials, are as follows:

Acetone
Nitrogen gas
Alcohol
Loctite
Ink
Freon
Methanol

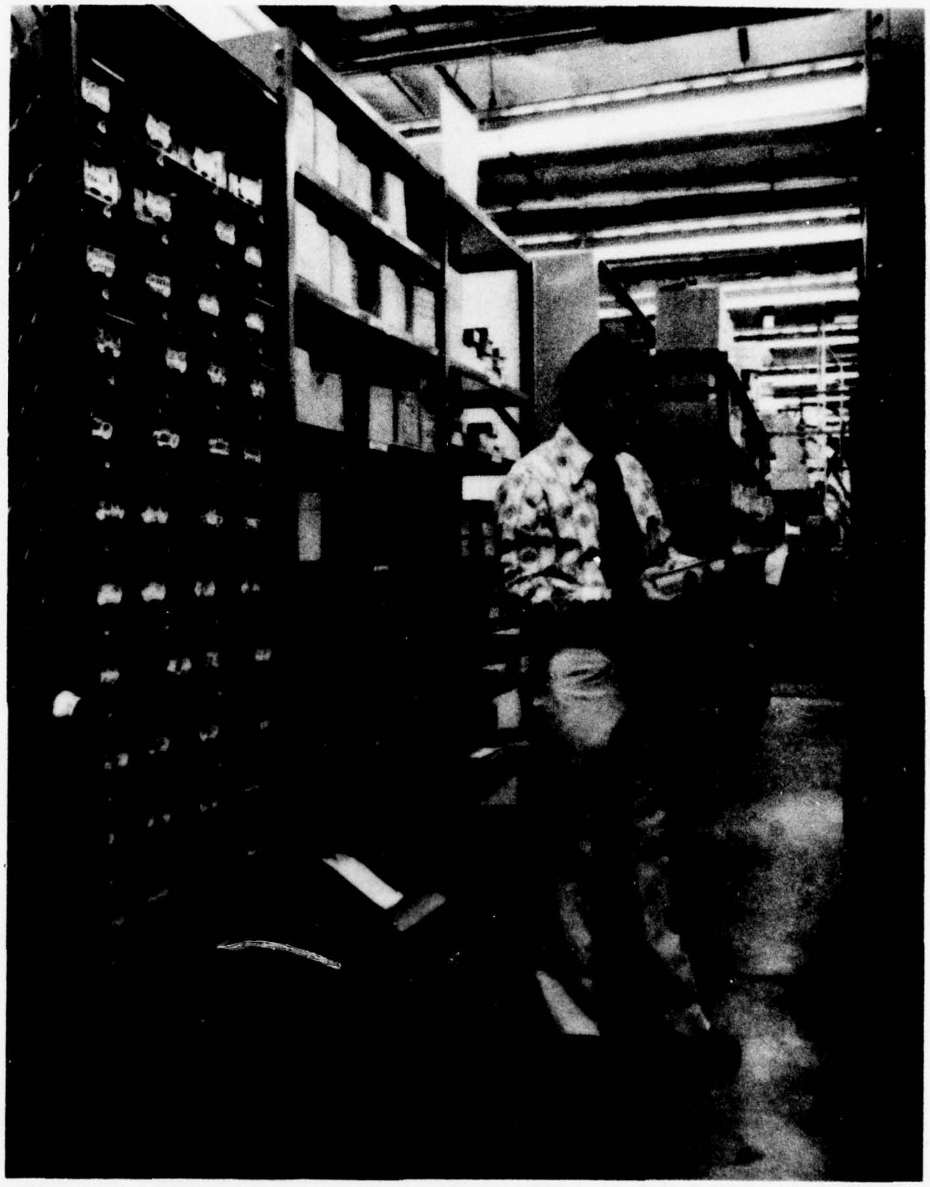


Figure 4-12 Typical materials and precision tòol storage

Primer

Sealant

Abrasive Sand

Adhesive

These materials will be either stored in permanent steel containers in the basement area prior to the attack, or where required, in the present facility cold storage locker for heat sensitive materials. This cold storage facility is illustrated in figure 4-13. During the imminent pre-attack period all material in cold storage will be transferred to the supplemental basement cold storage refrigeration unit. This basement unit will be disconnected from electrical power only on the last day prior to the attack and restarted as soon as possible after the attack when the diesel motor generator has been placed in service.

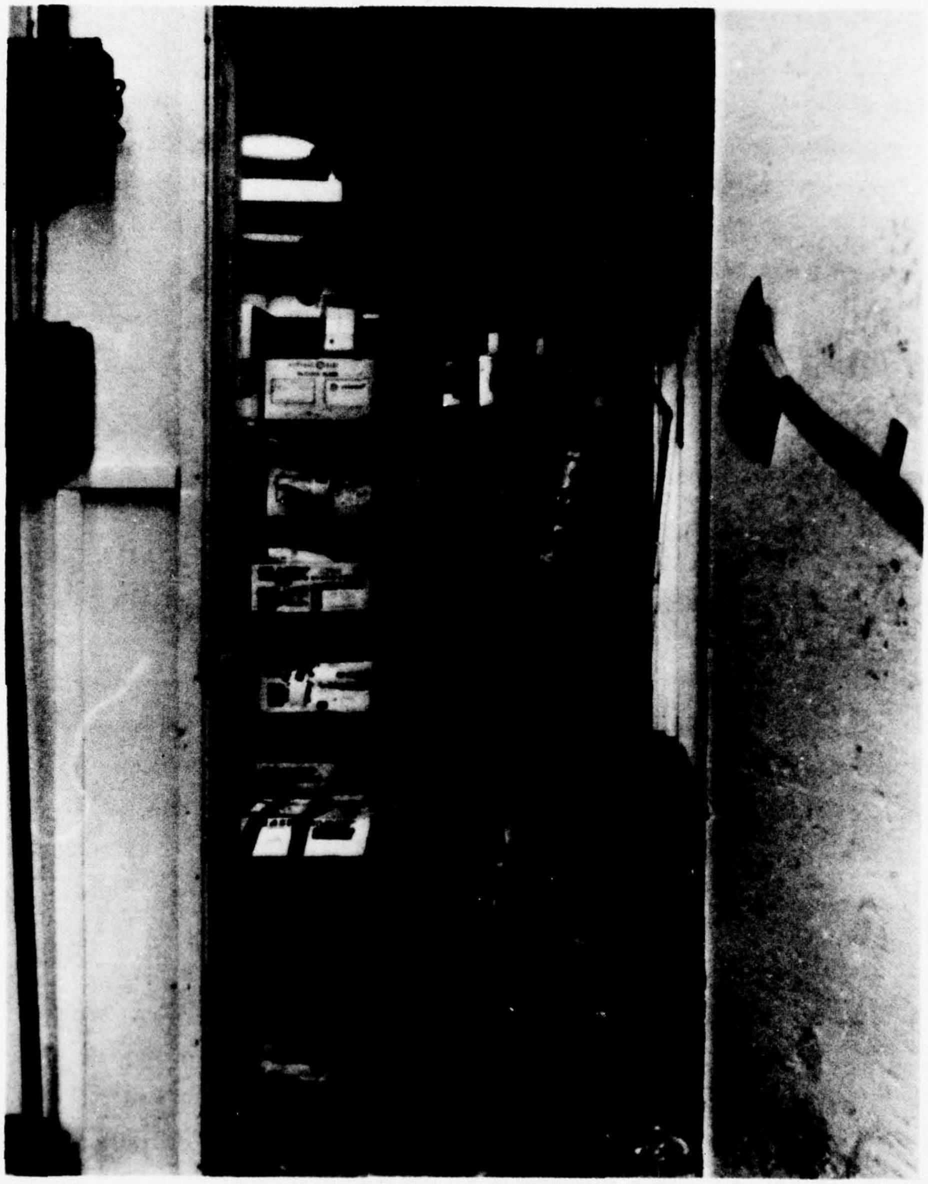


Figure 4-13 Cold storage facility

RECORDS

Reynolds presently provides two types of storage for industrial records. Alternate storage provisions for these records would be necessary for their survival to enable a post attack return to production. Drawings and microfilm records are stored and distributed from a central graphic service office located on the second floor of the building, while detail current production procedures and parts list are retained in the facility computer memory bank located in the computer room adjacent to the graphic services office. Prior to a production run current copies of all necessary manufacturing documents are obtained from both sources by manufacturing.

Figure 4-14 illustrates the standard metal file type storage used by graphic services. The computer room is illustrated in Section 3.0, Figure 3-9.

The scenario of this report provides that the entire Reynolds building will be destroyed, with the exception of portions of the basement, leading to the conclusion that pre-attack action must be taken to transfer current copies of all drawings and procedures for all post attack production products from present data storage facilities to a survivable pre-attack designated data storage area. This conclusion establishes the need for procedures which flag all records pertaining to the chosen surviving products and automatically causes a new copy of each record to be made and substituted for the old record in the survivable data storage area whenever a change is made to the product data record.

Examples of the records which are required for production of the high voltage connector/cable assembly, used as an example in this report, are the detail computer stored indentured parts list, manufacturing procedures, and cabinet stored engineering drawings related to the part. Figures 4-15 and 4-16 are examples of these types of records.

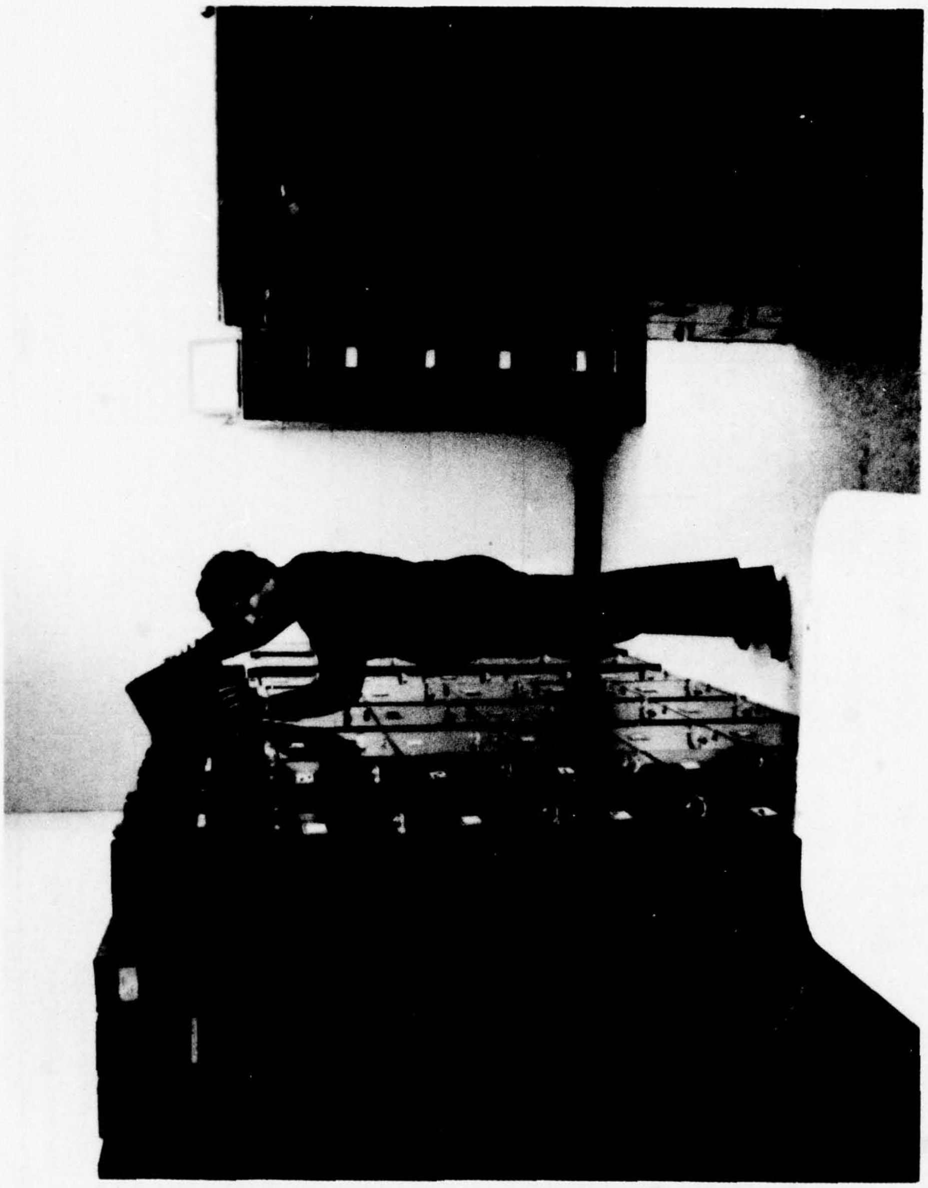


Figure 4-14 Graphics service record storage

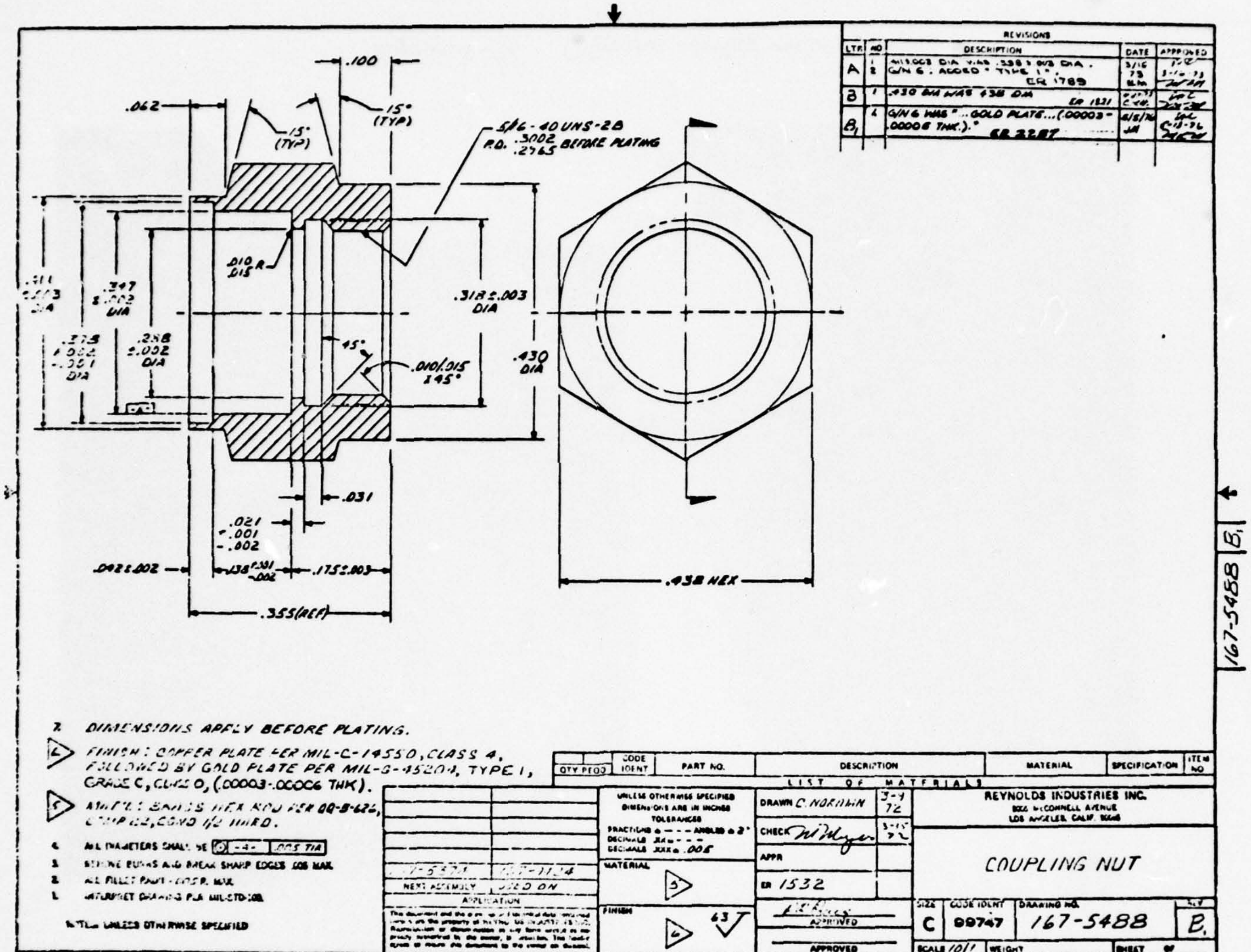


Figure 4-15 Typical drawing

```
1675915          0      REYNOLDS INDUSTRIES INC      MANUFACTURING PROCEDURE

LOT              SPLIT       MWO          QTY          RELEASE DATE 10/14/77

OPR  DEPT  LN  OPERATION PROCEDURE                               PAGE   1

000  00    01  PLANNED BY W.KAHLER-T.MURTAZA      DATE 12-03-73

00A  00    01  Q.A. APPROVAL S.BATTERTON          DATE 12-03-73

01A  00    01  SPECIAL TOOLING REQUIRED
           02  --1.1----1675915RUMO 14711RUMO (02A-54)

01B  00    01  INSP PLAN/MIL-STD-105/LEVEL II/NORMAL INSP

02A  54    01  SET-UP TOOL 1.1----MILL 100PBW SE5601 WITH
           02  2.2PBW TS-50-CADOA

02B  54    01  MOLD PART PER DRAWING AT 240 F FOR APPROX (5)
           02  MINUTES

02C  54    01  POST CURE FOR 16 HOURS AT 450 F PER DWG 7

02D  51    01  NOTE : TOOL CONTROLLED DIMENSIONS. COMPUTE        QTY   DATE   INSP.
           02  DIMENSIONS UTILIZING S.M.I----MAJOR 1.0

03A  55    01  REMOVE FLASH EXCEEDING PART TOLERANCE. INSIDE
           02  & OUTSIDE

03B  51    01  ASSURE COMPLETE DE-FLASHING----CRITICAL A 0.25    QTY   DATE   INSP.

04A  55    01  THOROUGHLY CLEAN WITH ALCOHOL & AIR DRY

04B  51    01  ASSURE THAT ALCOHOL CLEANING & AIR DRYING HAS     QTY   DATE   INSP.
           02  MADE THE PART FREE OF DIRT. LINT. FLASH. CHIPS
           03  OR OTHER FOREIGN MATTER & CONTAMINANTS----
           04  CRITICAL A 0.25

05A  51    01  FOR FINAL INSP VERIFY PREVIOUS OPERATIONS         QTY   DATE   INSP.

               **** END-OF-PLANNING ****
```

Figure 4-16   Example of operation procedure

5.0 PROTECTION PLAN

Figures 5-1 and 5-2 illustrate the automobile parking garage under the Reynolds building. The somewhat unique availability of a large basement in the Reynolds building provides the basis for the overall protection scheme.

Following notification of an expected attack, additional prestocked shoring will be installed in this basement area and previously identified industrial tools, materials and records will be moved to this basement. This equipment will be covered by tarpaulins and sandbagged for additional protection. Post-attack fuel and water will have been previously stocked within the basement area in addition to the necessary bulldozer required to move the equipment and sandbags.

Figure 5-3 illustrates planned basement modifications.

Personnel previously identified and trained as members of the post-attack production team will obtain protection during the attack in accordance with Civil Defense procedures established during pre-attack training. Those outside of plant protection efforts will cover the protection of personnel during the period immediately preceding the attack until just after the attack when they will return to clear the debris and set up for post-attack production.

A clearly defined post production organization will exist in accordance with pre-attack planning. Upon their return to the Reynolds' plant area, following the attack, the production staff will reside there with their families during the critical post-attack production period.

Once back in the facility area, first effort will be directed toward debris clearing to the extent necessary to gain access to the basement area where personnel shelter and food routines may be established. Following this, efforts directed toward the resumption of production will resume leading to the gradual return to an overall production capability.

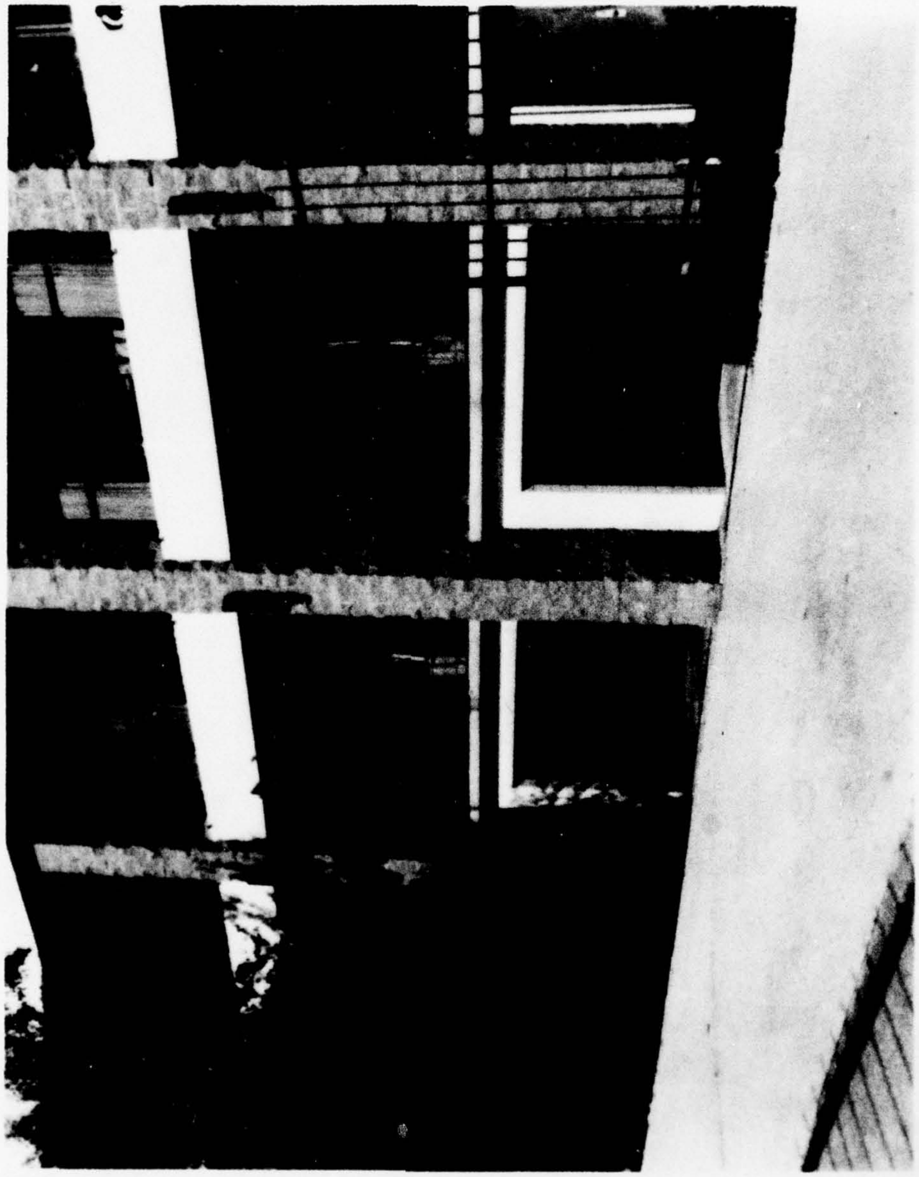


Figure 5-1 Basement enterance

Figure 5-2 Basement area

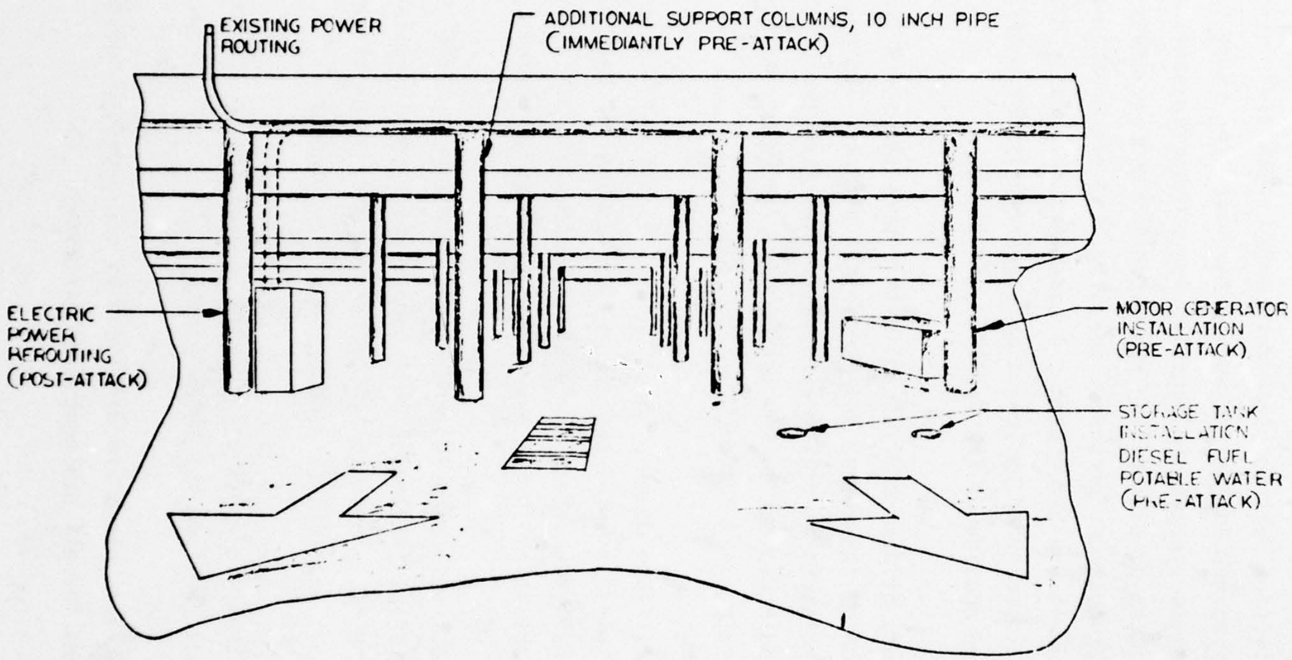


Figure 5 -3 Basement modifications

6.0 PRE-CONFLICT ACTIVITIES

Pre-conflict activities fall into two categories. The first category covers those tasks that are performed during the one to two year long range time span following the basic decision to prepare the facility for production survival. During this period the activities of stockpiling raw materials and equipment directly associated with production, personnel training, and preparation of the building and support equipment are undertaken. A considerable portion of this preparation time is absorbed by lead time requirements for materials and equipment procured outside of the facility.

The second category of pre-conflict activity covers the short time span between final notification of the attack and the actual attack. The two week time span provided by the scenario is filled with activities directed toward relocation of records, tools and equipment to the previously planned basement storage, and placement of coverings and sandbags.

The pre-attack milestone chart of Section 8.0, Figure 8-1, lists identifiable activities and their estimated time spans. Following the decision to prepare for an attack a management team is formed which then identifies and manages all subsequent activities in the pre-attack preparation period.

A surviving product selection is made based on analysis of the future product needs of a post-attack industrial environment which then permits detail plans to be laid for the type of facility stockpiling and personnel selection required to support post-attack production of the product.

Long lead time stockpile parts are ordered in addition to the necessary basement storage containers required for these parts.

Detail formal survival plans are developed by the survival management team which provide guidelines for all subsequent preparations.

With the assistance of outside construction specialists a study is made of the building to determine the most probable results of blast overpressures on the building and to recommend placement of supplemental support structures. Procurement of the materials necessary for the required building reinforcement is undertaken in addition to procurement of fluid storage tanks for the basement area.

The post attack work force is selected and brought into the management team to provide maximum transfer of all knowledge pertaining to the survival plans and preparations. Weekly training sessions are begun and continue up to the immediate pre-attack period. Each member of the work force is trained in all functions to the maximum extent possible to provide maximum flexibility during the post attack period.

As materials for the facility modifications are delivered they are installed using both contracted and overall plant labor.

Crushable materials and sand bags are procured and stored in the basement area following modifications to that portion of the building.

When delivered, the motor-generator and bulldozer are housed in the basement allowing operational instruction to be given to all members of the post-attack work force.

As the necessary heavy post-attack production tools are identified, plans are developed to allow their rapid removal to the basement area.

Upon notification of an imminent attack, all normal facility production is terminated. Basement fluid storage tanks are filled and shoring is installed. All planned production equipment is moved to the basement including stockpiled production parts and materials. Crushable materials are placed over the equipment followed by sandbags. All normal facility personnel assist in these last preparations.

Following all plant preparations the bulldozer is buried at a distance beyond the expected plant debris area.

7.0 POST ATTACK ACTIVITIES

Initial activities in the post attack period are directed toward re-entry into the basement area and provisions for the billeting of personnel. Figure 8-2 of Section 8.0 illustrates the milestone chart for the post attack period.

With the return of members of the post-attack work force and their families first efforts are to recover the bulldozer and open access to the basement. Once this access has been gained the motor generator is uncovered and started thus providing electrical power, and personnel are moved into the sheltered area.

All materials and production tools are uncovered and separate task forces set up to continue clearing debris, set up the production machinery and reroute electrical power.

Production is resumed in the fifth week. Concurrent with production, efforts are made to re-establish outside communication and locate materials and suppliers to enable the continuation of production as stockpiled materials are consumed.

Personnel are expected to become self supporting outside of the facility at the end of the first month.

With restocking of supplies and either a resupply of diesel fuel or a resumption of utility supplied power, the facility may continue production indefinitely.

8.0 TIME SCHEDULES

Figures 8-1 and 8-2 give estimated time schedules for pre-conflict and post-attack activities.

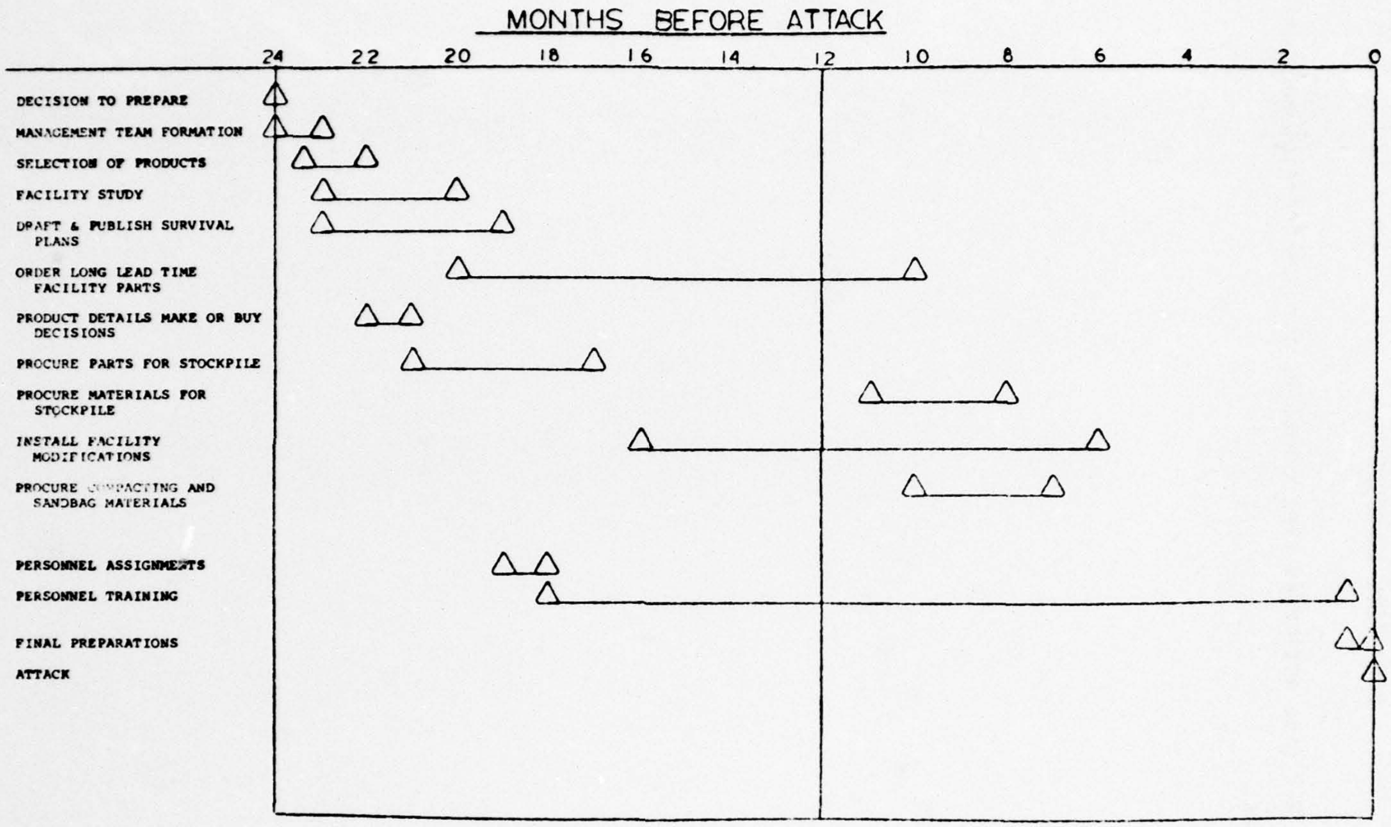


Figure 8-1 Pre-attack milestone chart

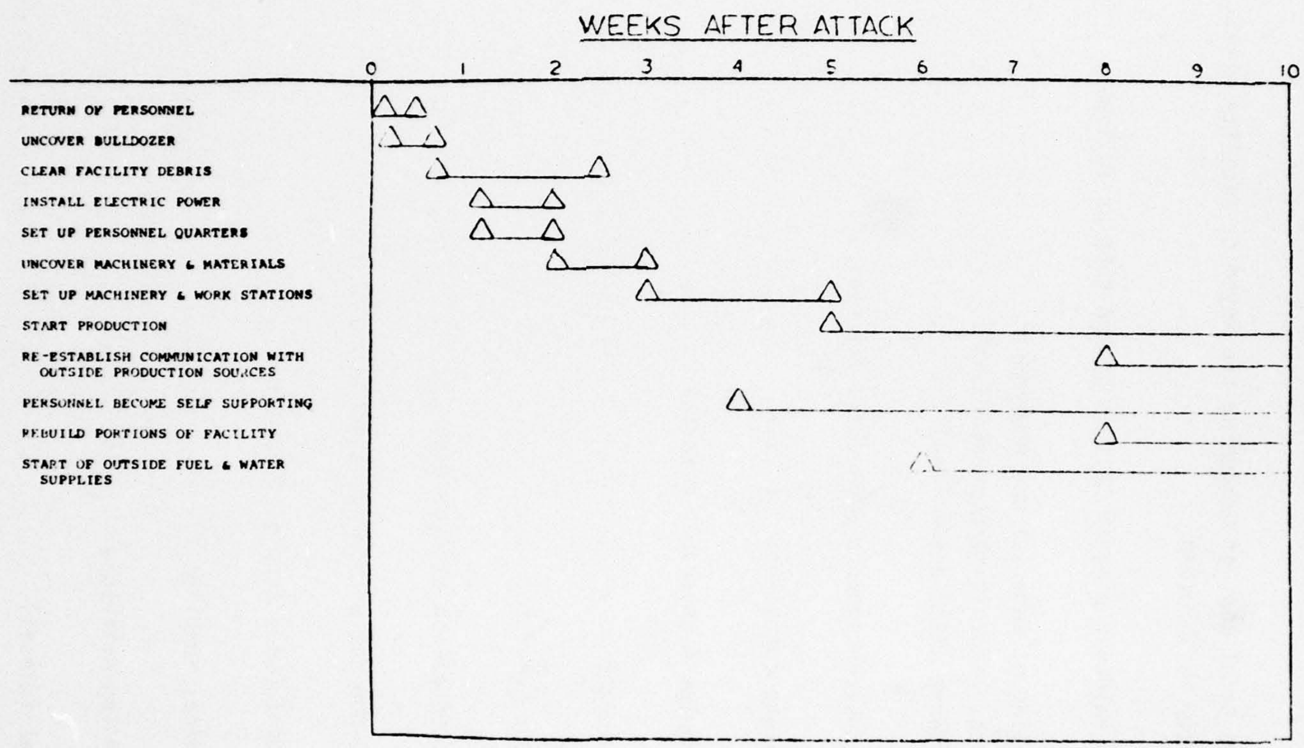


Figure 8-2 Post-attack milestone chart

9.0 HARDNESS PROGRAM COST

An estimated total cost of hardening the Reynolds facility within the guidelines of this survey is $370,000.

The overall hardness program cost is broken down as follows:

A. Stockpiling of material and equipment:

1.	Direct highvoltage connector/cable hardware (5000 assemblies)	$35,000
2.	Production support expendable material	5,000
3.	Storage containers	2,000
4.	Sandbags & crushable material	3,000
5.	Bulldozer	40,000
6.	Motor generator	15,000
7.	10,000 gallon storage tank	4,000
8.	150,000 gallon storage tank	50,000
9.	Food (30 day supply, 35 people)	6,000
10.	Medical supplies	3,000
11.	Lodging materials	1,000
12.	Fuel (diesel)	5,000

13. Miscellaneous tools . . . . $ 2,000

14. Shoring for basement 10,000

Total: $181,000

B. Building Preparation:

1. Installation of storage tanks . . . . $ 30,000

2. Footing for additional basement support 10,000

3. Motor generator installation 2,000

4. Relocation of equipment to basement during final pre-attack period and shoring of basement 10,000

Total: $ 52,000

C. Personnel training (11 people, 8 hours per week, 18 months) 137,000

Total Cost: $370,000

10.0 SURVEY PROCESS

The process followed in the preparation of this survey was not unlike one which might be followed in an actual blast hardening effort.

A survey team was established at the onset of the program by Reynolds management. The team was composed of one technical and one production/personnel member. Facility line managers were informed of the purpose and goals of the survey and requested to assist to the extent necessary for the report.

Initial survey team-management discussions were held to establish the boundaries of the report and the products to be chosen for the survey. Scenario guidelines were discussed.

Following the preliminary discussions, detail investigations were made into the best plan for use of the building capabilities as a shield against the blast and into the task of separating a specific product for survival from the many products manufactured in the facility.

The existance of a basement in the building led to its obvious choice as an area in which to place equipment for survival. The degree of reinforcing was determined through the use of outside assistance.

Separation of the surviving product materials and equipment requirements identified the need for storage provisions for certain raw materials, tools, to be transferred to the basement and protected, and for emergency power provisions.

Tasks associated with the product manufacturing procedures identified the minimum required post-attack technical and production manpower skills. Management knowledge of the capabilities of individual employees then identified those most appropriate for the post-attack production period and suitable for training for alternate job functions.

Following establishment of the necessary purchased equipment attributable only to a survival preparation program, price estimates were obtained.

As the report was prepared for the transfer of knowledge pertaining to the survey, rather than for subsequent action, extensive pictures of the facility were obtained to aid in establishing a background knowledge of the Reynolds plant for the user.

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