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INTRODUCTION

3 pages

HANFORD ENGINEER WORKS TECHNICAL MANUAL

SECTION A - METAL PREPARATION

Metal is used in the Hanford process in the form of short cylinders, or slugs, which are bonded to aluminum jackets. The jackets are necessary to prevent corrosion and the escape of radioactive materials. The bonding is required to provide adequate heat transfer. This section of the manual deals with the preparation of the jacketed slugs.

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SECTION A - METAL PREPARATION

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PROCESS SUMMARY

Metal is received at Hanford from various suppliers as billets that have been analyzed and inspected, and are ready for extrusion. These are preheated as needed in a rotary furnace to the extrusion temperature of about 1625°F (885°C) in an atmosphere of argon. As quickly as possible the billet is then placed in a hydraulic press and extruded into a long rod. This is partially straightened by hand working and rolling before quenching in water. Imperfect ends of the rod are then cropped off by an abrasive cutter, if necessary, and the usable rod is straightened thoroughly in a bar straightening machine. The rod is then "out-gassed" to remove dissolved hydrogen by heating for 11 hours to 1150°F (621°C) in a sealed steel cylinder through which argon gas is passed at 6 cu.ft./hr.; the cylinder is placed in an electrically heated car-bottom type furnace. The rod is machined on turret lathes into 8-inch long slugs suitable for canning.

The primary requirements for a canned slug are firm and complete bonding of slug to can, high melting-point of bonding medium, and mechanical strength of the assembly, to withstand thermal shocks encountered in service. The aluminum-silicon bonded slug meets these conditions. Oxide on the surface of the slug is removed in a bath of nitric acid in the first step of this process. The slug is then dried and dipped into a bath of molten copper-tin alloy. This forms a blocking layer on the surface of the metal that prevents it from alloying with the bonding material during the canning operation. The bronzed slug is dipped into a bath of molten tin to remove the excess bronze from its surface. The excess tin is then removed from the slug by centrifuging. Following this, the slug is dipped into a molten aluminum-silicon bath and manually pressed into the can, which has previously had its surface prepared and has been preheated in the Al-Si canning bath and filled with the molten metal. An aluminum cap previously cleaned and etched is inserted into the open end of the can above the slug after having been preheated and coated with aluminum-silicon. The assembly is then removed from the canning fixture and quenched in cool water. Following this, the cap end of the canned piece is machined to the proper thickness as measured by X-ray methods, and the end closure is completed by welding the cap to the can using an electric arc in an atmosphere of argon.

The general layout of buildings in the metal preparation area is shown in Figure 1.

PHYSICAL AND CHEMICAL PROPERTIES

Metal

Metal is very dense and has a bright finish that assumes a golden appearance after a few hours' exposure to air at room temperatures. This color changes to a dark brown after several days' exposure. It is very reactive chemically, and in many of its properties resembles iron. At elevated temperatures it is attacked by hydrogen, water vapor, carbon dioxide and hydrocarbons.

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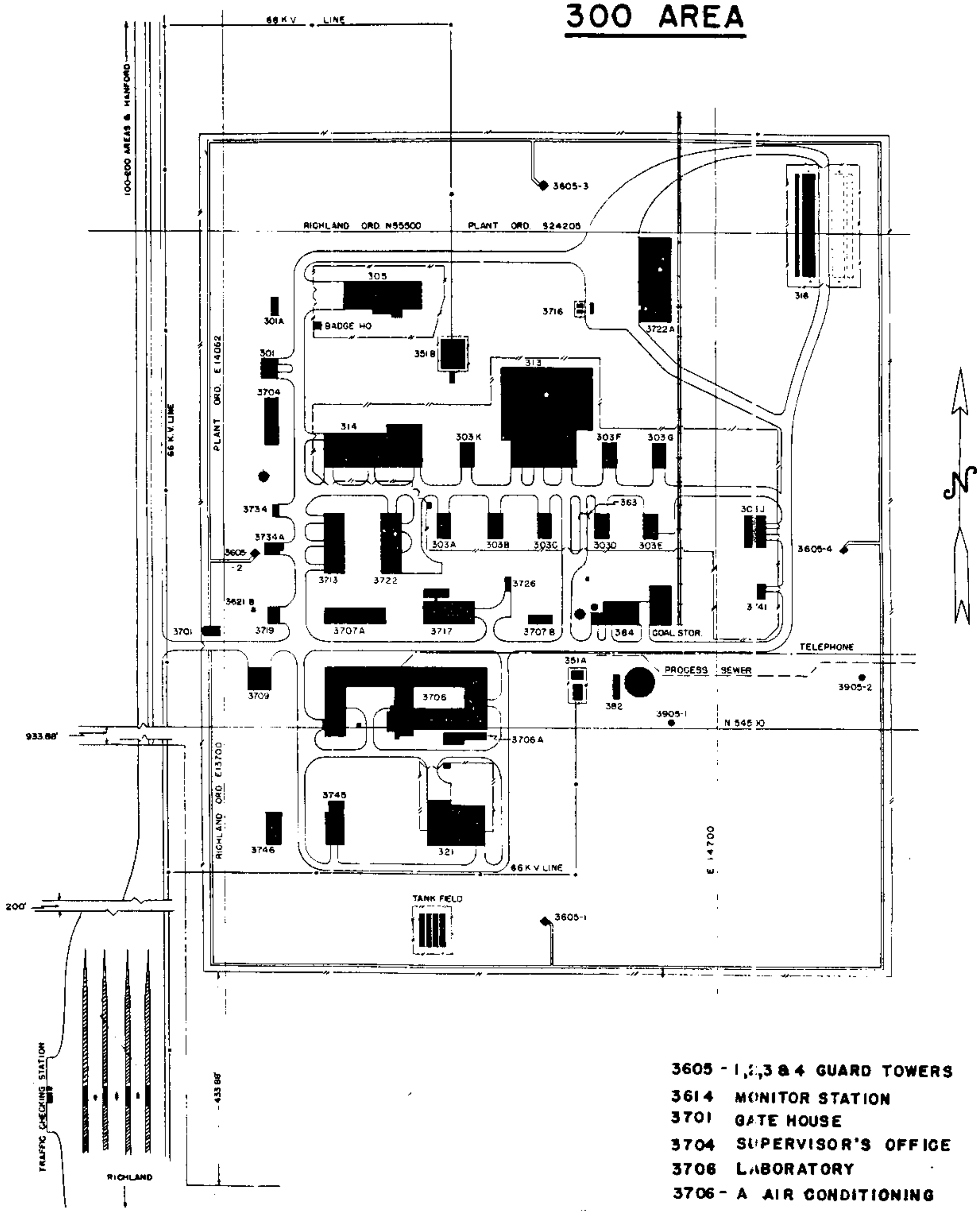
FIGURE I

300 AREA



301 STORAGE-GRAPHITE
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305 TEST PILE
313 SLUG MACHINING AND CANNING
314 ROD EXTRUSION
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3741 BOX STORAGE
3905 - 1, 2 WELLS

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HW-10475-SEC. A-DEL

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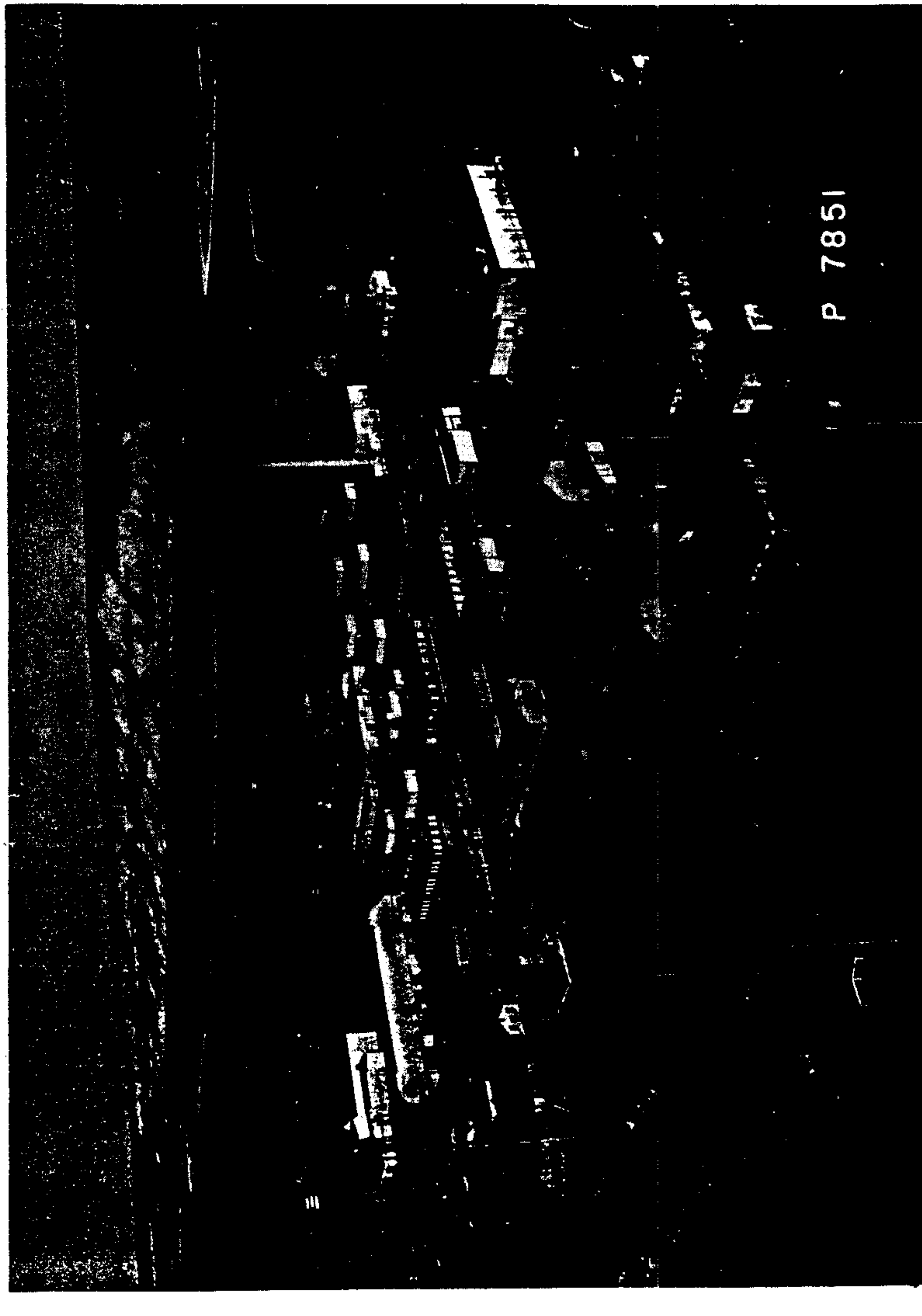
FIGURE 1A



200 AREA

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DECLASSIFIED

When heated in an atmosphere of hydrogen at 480-580°F (249-304°C) the metal breaks down into a gray granular powder. The solubility of hydrogen in metal is appreciable at all temperatures, being at a maximum at 570°F (299°C) and at a minimum between 840-1160°F (449-627°C). Its ignition temperature in air is between 300-340°F (149-171°C), depending upon the subdivision of the metal.

The crystalline structure of metal is dependent on its temperature. At room temperature, in the alpha phase, the crystals are orthorhombic. When heated to 1229°F (665°C) there is a transformation to the beta phase, which has a cubic structure. Further heating to 1429°F (776°C) causes transition to the gamma phase.

In the alpha phase, the metal is moderately hard like steel or cast iron. In the beta phase it is very hard and brittle. In the gamma phase it it increasingly malleable.

Fabrication can be done in the gamma or high alpha phases by extruding, rolling, or forging; in the high alpha phase relatively high pressures in the metal are required compared with gamma phase fabrication. For example, extrusion from 4-inch diameter billets to 1 1/2-inch diameter rods requires about 80 tons/sq.in. pressure at 1000°F and about 7 1/2 tons/sq.in. pressure at 1700°F.

The upper limit of fabrication temperature depends on the melting point of the metal and the degree of oxidation that can be tolerated.

Metal can be welded by use of the atomic hydrogen torch, the helium shielded tungsten arc, or the oxyacetylene torch.

Hardness range of the metal is from about 90 Rockwell B when annealed to about 112 Rockwell B after severe cold-working.

Other physical data are listed below:

Solid Phases	°F	°C
Transition Temperatures (heating)		
Alpha to Beta	1229	665
Beta to Gamma	1429	776
Note - in effect, somewhat lower when cooling		
Melting Point	2010	1100
Boiling Point	7770	4300
Heat of Transformation		
Alpha to Beta Transition	5.0 BTU/Lb	665 Cal/Mol
Beta to Gamma Transition	8.9 BTU/Lb	1165 Cal/Mol

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PHYSICAL AND CHEMICAL PROPERTIES

Heat Transfer Coefficient

Metal to Aluminum 0.258 BTU/Hr/Sq Ft/°F 0.035 Cal/Sec/Sq Cm/°C

Coefficient of Thermal Expansion (Linear)

6×10^{-6} per °F	70-250° F	=	20-160° C	10.8×10^{-6} per °C
8×10^{-6} per °F	250-460° F	=	160-240° C	14.4×10^{-6} per °C
9.5×10^{-6} per °F	460-930° F	=	240-500° C	17.2×10^{-6} per °C

Density at Room Temperature

1185 Lb/Cu Ft = 19.0 g/cc

Tensile Strength

Annealed	60,000 - 80,000 Lbs/Sq In
Cold Rolled	80,000 - 190,000 Lbs/Sq In

Aluminum

The surface of aluminum is covered with a very thin film of oxide. This forms instantaneously after the metal has been cut or scratched. The chemical properties of aluminum surfaces are a function of this film. Before any chemical attack can be made on the aluminum itself, the film must be pierced or dissolved. Aluminum can be readily dissolved in basic solutions and also in acid solutions in the presence of mercury salts. Aluminum is very ductile and malleable. It is a good conductor of heat and electricity. The crystals of the metal are arranged in a face-centered cubic-lattice. It readily forms alloys with other metals and, when molten, certain gasses and non-metals are quite soluble in it. Other physical data are listed below:

Density 168.6 Lb/Cu Ft = 2.702 g/cc

Melting Point 1216° F = 658.7° C

Boiling Point 3272° F = 1800° C

Expansion Coefficients

°F		°C
68- 212	24.0×10^{-6}	20-100
68- 392	25.9×10^{-6}	20-200
68- 572	26.7×10^{-6}	20-300
68- 752	27.2×10^{-6}	20-400
68- 932	27.9×10^{-6}	20-500
68-1112	28.6×10^{-6}	20-600

[redacted]

Increase in Volume in Melting 6.6%

Recrystallization Temperature 302° F = 150° C

Ultimate Tensile Strength of Annealed Aluminum 14,000 Lbs/Sq In

EXTRUDING METAL RODS

General

Regular and consistent cycles of operation are important for successful results, as temperatures and operating conditions in several parts of the equipment are dependent on material going through. The metal being handled is more difficult in many respects than most materials commonly extruded, e.g., ready oxidation, poor heat transmission, and unworkable characteristics in the beta phase. Greater care and closer control are therefore necessary than in the usual commercial extrusion. For the purpose in question, extrusion is not an ideal method of fabrication; it has been selected as the least objectionable, all things considered, in preference to rolling, drawing, forging, etc.

Preheating Billets

A rotary furnace with six electrical resistance unit heated zones, all separately pyrometer-controlled, is used for billet heating. The rotating hearth is provided with 72 saddles, each holding one billet; of these 66 can be filled at a time, the idle ones being between the charging and discharging doors. Billets are raised to the charging level by a hydraulic lift, and pushed into the furnace and onto the saddles by a hydraulic plunger. An indexing dial is provided, connected to the hearth drive, to show which saddle is in the charging position.

Inert atmosphere, to reduce billet oxidation, is provided within the furnace by a supply of 99.6% argon, fed at a rate sufficient to hold not over 2% oxygen content of the furnace atmosphere. Instruments are provided to indicate argon supply and oxygen content of the furnace atmosphere.

Furnace temperatures are controlled (at about 1700°F) to heat billets to a uniform temperature of 1600-1625°F in 60-65 minutes. Thorough and consistent heating is desirable for satisfactory flow of metal in extrusion. Minimum feasible time and temperature, with reasonably inert atmosphere, reduces billet oxidation, which wastes metal and (unless removed) impairs the extruded rod.

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Extruding the Billets

The billet, after removal from the furnace, is moved quickly by mechanical handling into the extrusion container; during this billet exposure any necessary brushing or flattening of rough or swollen spots is done, to facilitate prompt entering into the press container, and reduce the oxide or scale on the billet. A "dummy block" is inserted back of the billet, the die carriage locked to the container, and the press ram advanced to extrude the billet metal through the die, forming a rod.

The extrusion press is rated at 1000 tons, having a 33-inch stroke with a 4 1/4-inch ram, operating at speeds of 145 inches/min. below 500 tons and 23 inches/min. with 500-1000 tons pressure.

The extrusion die, mounted on a movable carriage, is 1-inch thick and 4 1/2 to 5 inches diameter, with a tapered throat and a "bearing" or active forming area 3/32 inches wide. The material is hot die steel of 10-15% W content, hardened to about 40 Rockwell C, and coated on face and bearing with a 1/16-inch veneer of Stoodite No. 54, which is ground and polished to proper smoothness and size (about 1.500 inches for 1.465-inch diameter rods). Dimensional accuracy and surface smoothness are essential for proper rod diameter and surface which in turn are required for economical machining. Die marks may cause surface cracking during quenching, by stress concentration. The Stoodite surface resists wear and alloying with the extruded metal.

The extrusion container is a hot die steel spool of 4 1/2-inch inside diameter and 26-inch length, including a replaceable inner liner, set in a cradle or housing containing electric resistance heating elements automatically controlled to hold an operating temperature of 1000°F. This temperature is kept as high as possible without softening the steel container, to avoid chilling the billet below optimum extrusion temperature. Before each extrusion the container bore is cleaned and lubricated with a graphite-oil mixture. Periodically, reboring is necessary to maintain close clearances.

Dummy blocks are used in sets of three to six to permit cleaning and assure stable temperature. They are cylinders of hot die steel, closely fitting the container (about 0.010-inch total clearance, cold), with one end and flank coated with a veneer of No. 6 Stoodite, for the same reason as the dies. Dummy blocks are also cleaned and lubricated with graphite and oil, to reduce adhesion and wear, and to aid metal flow.

Under normal conditions, 15000-25000 lbs./sq.in. pressure in the container is required for extrusion. A 20-inch long 200-lb. billet requires about 10 seconds for extrusion, and makes a rod about 14 feet long.

At the end of extrusion, the rod and die carriage are withdrawn from the press container; about 1/2-inch of the original billet is not extruded, but left at the back end of the rod with dummy block adhering. This "butt" is cut off the rod by a hydraulic shear at the end of the press. There are two reasons for leaving the butt, which is about 3-7% of the original billet; further extrusion would involve extreme increase of pressure, and the metal remaining in the butt is contaminated with oxide and scale. The butt is removed from the dummy block (which is then cleaned and reused), quenched in water, and handled as scrap metal to be reclaimed, segregated from other scrap. Figure 2 shows a normal billet, rod and butt.

Preliminary Straightening and Quenching Rods

The sheared rod is withdrawn from the die, straightened while still in gamma phase, air-cooled to about 900-1200°F, and water-quenched uniformly. Air-cooling reduces likelihood of cracking and surface hardening of rods. Water-quenching (within, say, 5-8 min. after extrusion) reduces oxidation loss due to holding the rod at high temperature.

Marking and Cropping Rods

Each rod is stamped with the billet number from which it was extruded for identification through machining. Rods showing external imperfections preventing machining to good slugs (oxide inclusions, ragged ends, etc.) are cropped by an abrasive cutter to remove the defective portions; the resulting solid scrap is segregated for reclaiming.

Final Rod Straightening

The rods are then passed through a Medart roll straightener, to prepare them for machining in turret lathes.

Outgassing Rods

To remove dissolved, combined, or included gases in the metal (particularly hydrogen), the straightened rods are placed in a closed cylindrical container (90 rods capacity), through which argon gas is passed; this container is placed in an electrical resistance heated car-bottom furnace and heated to 1150-1220°F (621-600°C) for a period of about 11 hours. At this temperature, hydrogen solubility in the metal is minimum. The rods are cooled in the container with argon atmosphere retained, and must test less than 2 ppm of hydrogen to be acceptable.

Rods which warp during outgassing to an amount not acceptable for machining are restraightened and reannealed.

MACHINING SLUGS FROM METAL RODS

Machinability of Metal

Machining properties of metal somewhat resemble those of mild steel. Because of lower heat conductivity the chips become much hotter when they

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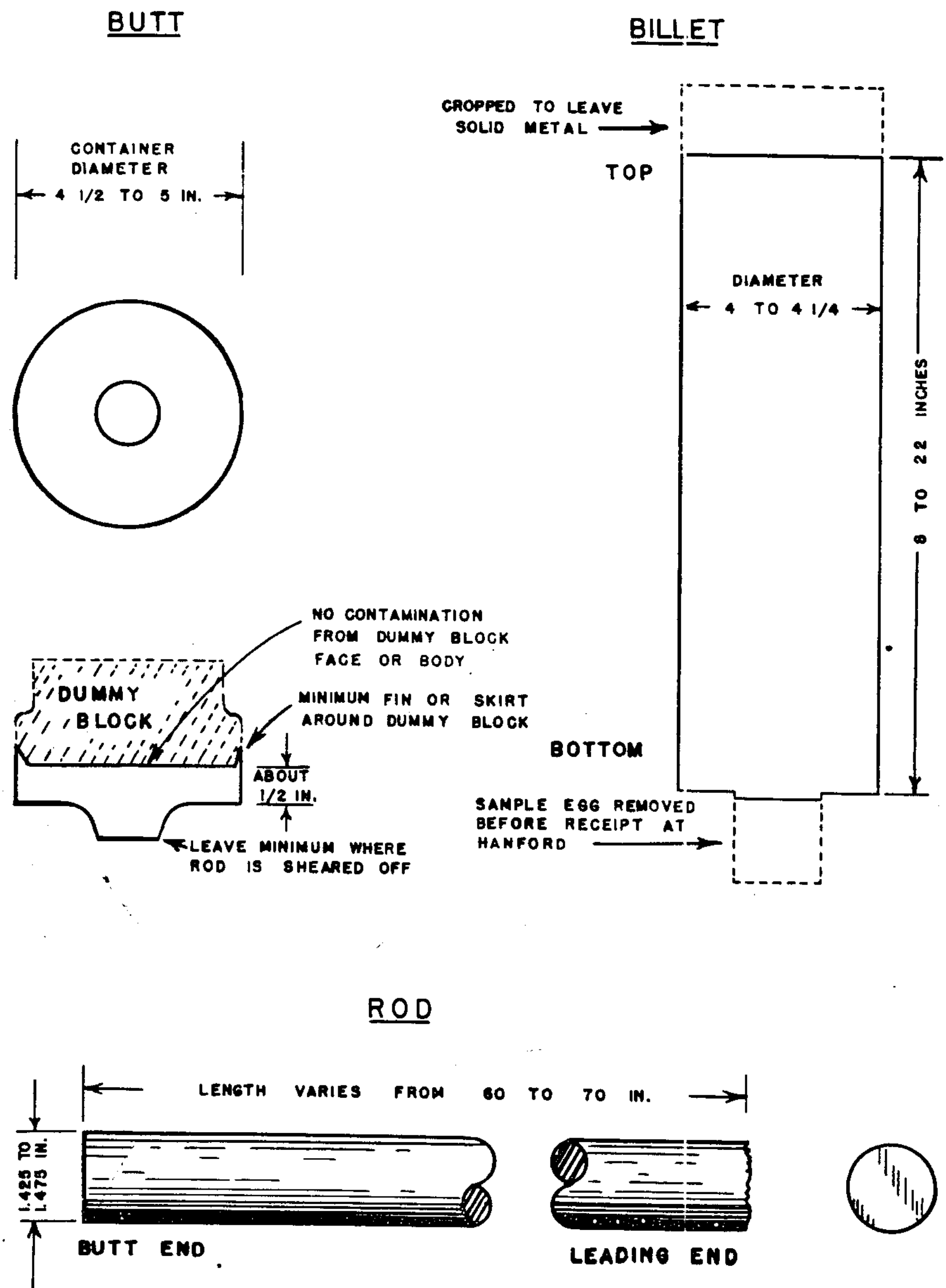
FIGURE 2



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are removed from the stock. These oxidize at temperatures above 340 °F (171 °C) and may cause a serious fire if not properly guarded. To prevent this it is necessary to supply a large flow of coolant (20 parts of water to 1 part of soluble oil) to the tool bit. The catch pan on any machine on which metal is worked should be filled with 3 to 4 inches of coolant in which the hot chips may fall and be quenched. During the process of oxidation some of the metal oxide is given off into the air. All machines on which metal is to be worked should be provided with adequate individual suction air vents.

When machining metal, the tool bit must be kept extremely sharp. Hard tungsten-carbide tool bits are used for this work. Should the bit chip or become rounded and drag on the work, the metal becomes work hardened to such an extent that any following machining operations are extremely difficult. Experience indicates that the best rake and clearance angles on a tool are between 6 and 7 degrees. The surface speed of the work should be kept between 125 and 150 feet/minute. The depth of cut should not exceed 0.050 inches nor the carriage feed exceed 0.015 inches/revolution. Increasing the size of chip or cutting speed damages the tool bit. Metal chips from machining operations are most safely stored in steel cans under water.

The Machining Process

The machining process is as follows:

1) The rod is chucked in the lathe so that a slug's length extends out of the jaws, with enough extra to permit working the cut-off tool for cutting a slug of proper length.

2) The outer end of the rod is faced smooth and square.

3) The cylindrical surface is machined to 1.359 + 0.001 - 0.002 inches diameter.

4) The slug is cut off about 8 1/16 - 8 3/32 inches long.

5) The slug is then reversed and re-chucked.

6) The cut off end is machined smooth and flat so that the slug is 8 inches long.

7) The corners are rounded with a radius cutting tool.

During the machining process a large flow of coolant is required to keep the chips below the ignition temperature. The chips must be frequently removed from the catch pan in order to prevent burning. The liquid level maintained in the catch pan must be such that all chips falling into it are completely submerged. Should a fire result from this operation the only satisfactory method of extinguishing is to cool the chips below their ignition temperature by submerging them in water.

During the machining operation the surface of the slug must be kept free of smeared metal caused by dull tools or improper feed. It has been found that this type of surface causes a poor heat transfer that would hamper the normal operation of the slug.

Inspection

After the slugs have been machined they are inspected for dimensions, soundness of metal, surface finish, and weight.

THE CANNING PROCESS

Process Control

Figure 3 is a flow sheet of the assembly operation. The various parts used in the assembly operation are shown in Figure 4. Figure 5 shows the assembly of a finished slug.

The prime requisites in the production of a finished metal slug are: the slug shall be completely bonded to the aluminum can and cap at every point; the cap shall be firmly and voidlessly bonded to the walls of the can above the slug proper; and the aluminum envelope thus placed about the slug shall be absolutely free from ruptured or penetrated regions to the end that the canned piece shall be able to withstand prolonged exposure to steam or water at high temperature without the slightest trace of water coming in contact with the base metal.

The bonding medium used in the process is an aluminum-silicon alloy

In order to insure complete bonding between the metal slug and the aluminum can and cap, it is essential that the surface of all the component parts be completely wet by the bonding medium and that they be assembled in the presence of an excess of the bonding medium in a fluid state.

Wetting of the slug surface with the bonding medium is accomplished by first degreasing and pickling the slug, and then passing it through a series of molten metal baths of suitable temperature and composition.

Several factors must be considered in establishing a technique for wetting aluminum cans and caps with the bonding medium:

1) The surface must be chemically clean.

2) The surface must be free from areas of fine irregularities or matte condition.

3) The surface must be treated to remove most of the film of aluminum oxide normally existing on aluminum surfaces exposed to air, and to inhibit further formation of such film. This treatment must not be drastic enough to produce a matte surface.

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FIGURE 3

ASSEMBLY FLOW SHEET
TRIPLE DIP - SUBMERSION CANNING METHOD

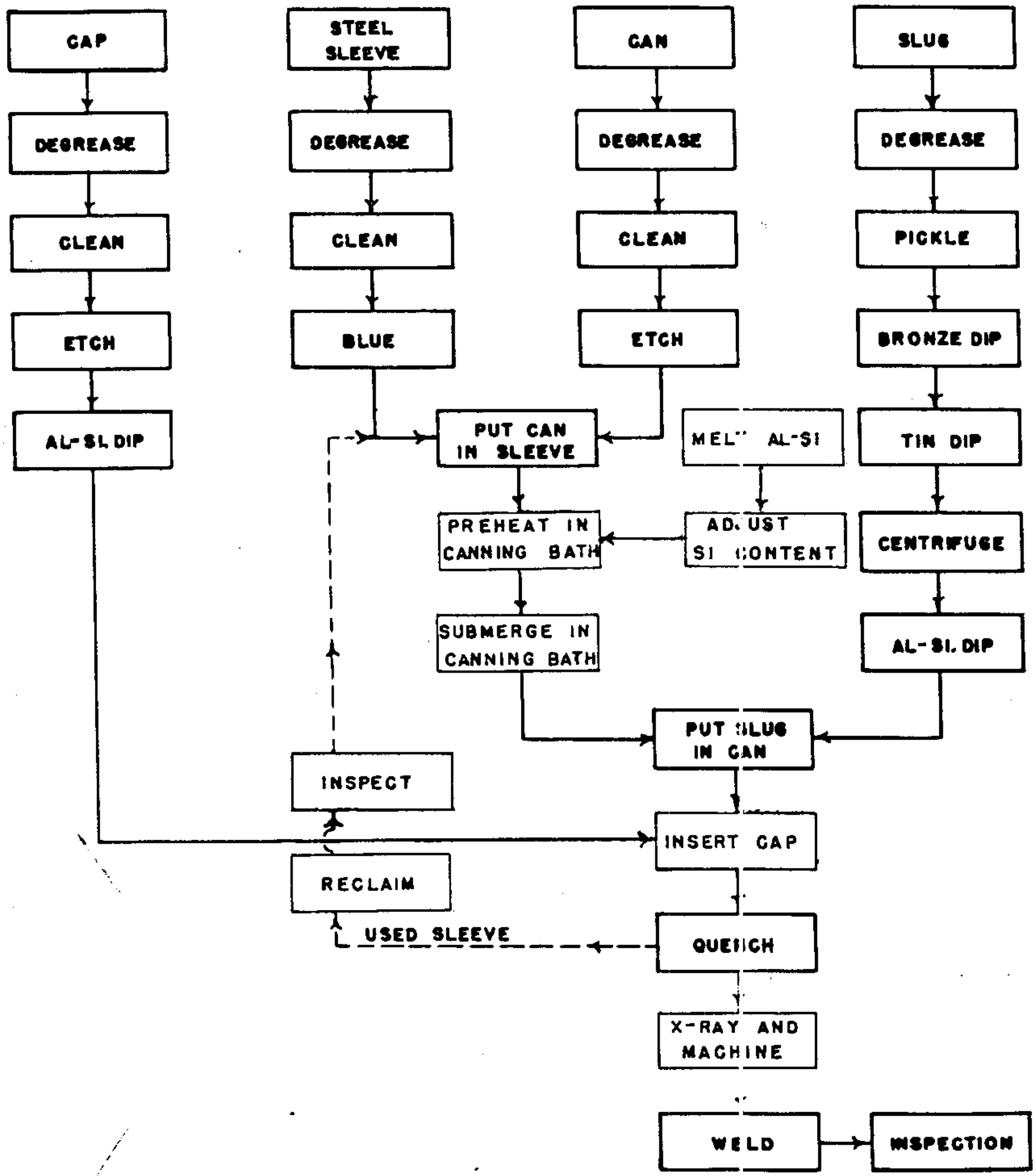

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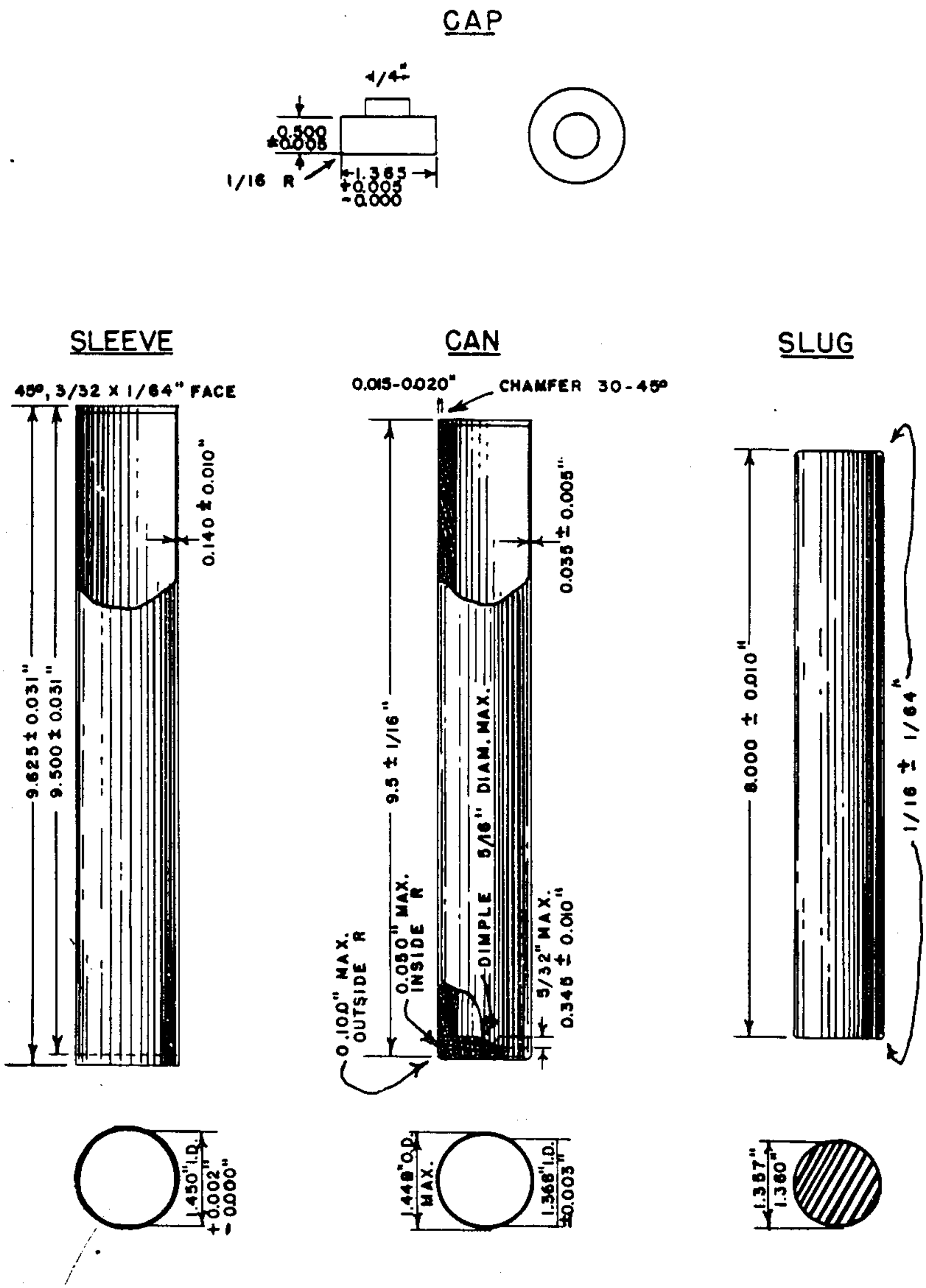
FIGURE 4



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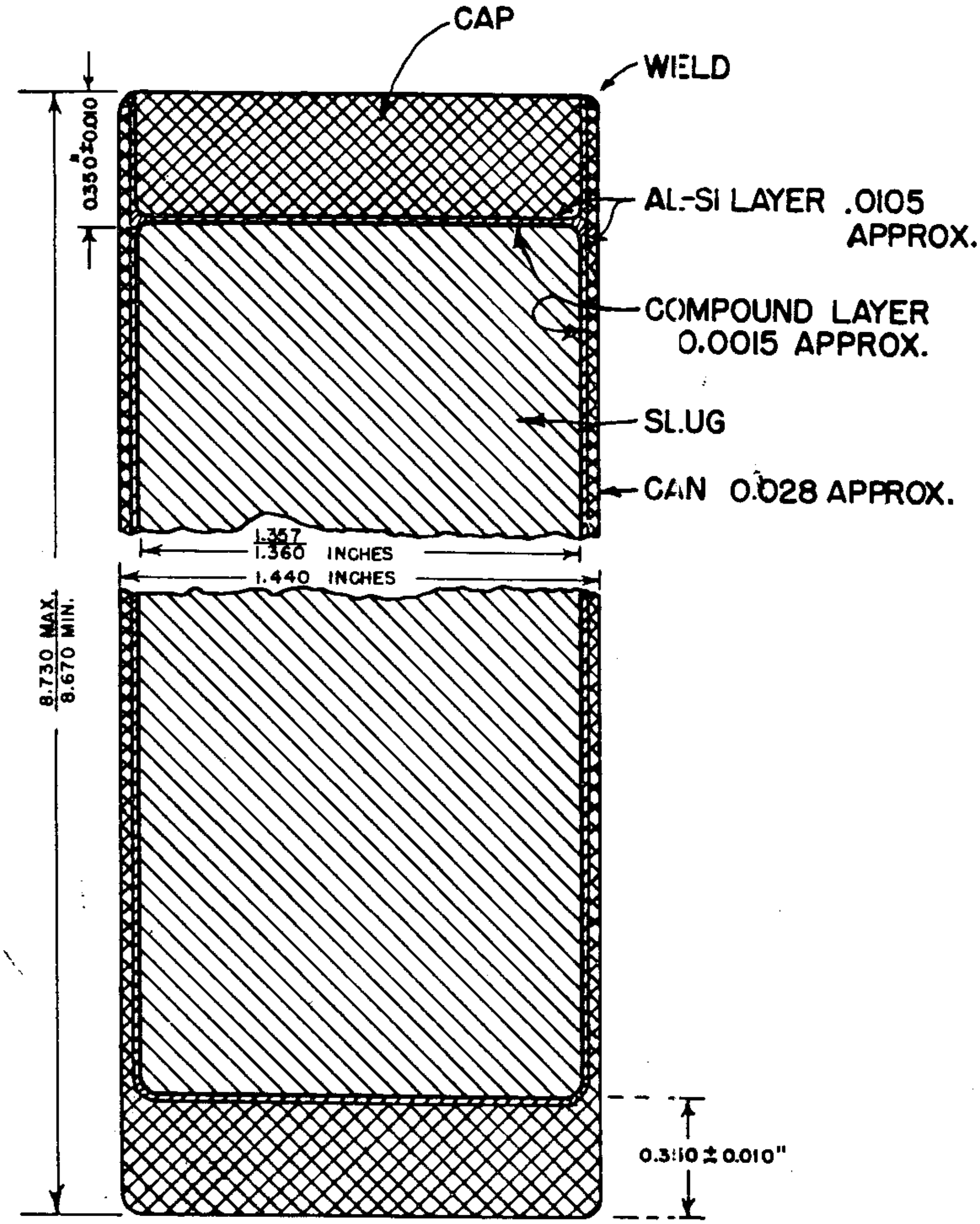
ASSEMBLED SLUG



ASSEMBLY MUST PASS THROUGH A FULL LENGTH TUBE GAUGE 1.455" DIAMETER

[redacted]

4) Adsorbed moisture tends to react with the aluminum to produce a surface not conducive to wetting.

5) Abrasion of the aluminum surface at a temperature above the melting point of the Al-Si, while in intimate contact with the molten alloy in conducive to the wetting of the surface.

In addition, it is necessary to control the length of time in the baths and handling time between them accurately. Excessive handling time results in the formation of a thick compound layer between the slug and the can or in excessive lowering of the slug temperature.

Equipment

Slug Machining

For slug machining No. 4 Gisholt Lathes are used. These are equipped with hexagonal turrets and carbolloy-tipped cutting tools ground to suitable shape. Each lathe is covered by a vented hood to prevent scattering of chips, and to draw off finely divided oxide and fumes from the coolant. Snap-gages and length gages with dial indicators are used to insure proper dimensions of the turned slug.

Slug Pickle

The tanks containing the nitric acid bath used for removing oxide film from slugs prior to canning, as well as the rinse-water tanks, are made of stainless steel (Cr 18, Ni 8, Mo 1) with welded seams. These tanks are fitted with stainless steel steam coils and dial type thermometers to permit maintaining proper temperature. Exhaust hoods are provided to draw off fumes from the nitric acid.

Metal Bath Furnaces

The furnaces used for melting and keeping molten the various coating metals employed in the canning process are Hevi-Duty nichrome element type furnaces of the proper size to hold 24-inch by 24-inch graphite or Tercod crucibles. The crucibles holding the bronze and aluminum-silicon baths are supported within the furnaces on pedestals each made up of three 120° segments of Tercod cylinder. The tin crucibles are encased in a metal sheath for protection, but such a sheath retards heat transfer too greatly in the other furnaces.

The furnace temperatures are controlled by adjusting heat input to rate of flow of material through the baths. Micromax automatic controls and recorders are adjusted in the light of experience to furnish proper heat input to maintain the temperature desired in the bath within a close temperature range.

Centrifuges

The centrifuges used for removing excess molten tin from the slugs prior to dipping them in the Al-Si bath are of the heavy-duty type, permitting attainment of maximum speed of rotation within 5 seconds after starting. They are each fitted with a brake which will stop rotation in an additional second or two, thus making it possible to remove most of the excess tin from the slug without unduly cooling the latter.

Canning Fixtures

The removable baskets used to hold the sleeve-can assembly in the canning bath, as well as all tongs and spatulas which are in frequent contact with molten metal are made of 18-8 stainless steel in order to resist solution in the baths and corrosion by the atmosphere. The baskets are supported by a two-position camjack with a level adjusting clamp, permitting the sleeve-can assembly to be lowered into and raised from the canning bath with facility.

Quench Tanks

The tanks used for quenching the assembled canned pieces are rectangular in shape and of about 30-gallon capacity. Each is fitted with a 1/2-inch cold water inlet and a weir with catch basin and drain for maintaining proper water level as the cold water flows through it. Accessory to the quench tank are receiving baskets into which the hot slug-can-sleeve assembly is placed after removal from the canning basket.

Slug Preparation

Degreasing

As the slug comes to the canning area from machining, it is covered with a film of cutting oil to which adhere particles of various kinds of foreign matter. A preliminary step in the preparation of the slug for canning is the removal of this surface dirt and oil. This is easily and effectively accomplished in a solvent-vapor degreaser. The oily slugs are suspended in suitable baskets in trichlorethylene vapors for a period of 2 1/2 minutes during which time the vapors condense on the surface and run off, carrying away the oil and dirt particles.

Pickling

The dark film of oxide adhering to the slug is insoluble in the solvent used in degreasing. It is removed by immersing the slugs batchwise in a bath of 50 ± 5% nitric acid at 60 - 70 °C for 4 1/2 minutes followed by a rinse and a 1/2 minute repickle.

The slugs are rinsed acid free in cold running water and dried in a blast of warm dry air. The water evaporates from the slugs before they are heated to a temperature high enough to cause formation of oxide through reaction with the water. Slugs should be put through the canning process as soon as possible after pickling to prevent re-formation of the oxide film. Pickled slugs which have become tarnished from exposure to air may be reconditioned by a few seconds repickling in the acid bath. No attempt should be made to can tarnished slugs.

[redacted]

After pickling and drying, the slugs are handled only with clean, dry gloves and are placed directly from the drying operation onto the dispensing rack.

Bronze Dip

In order to wet the surface of the slug with the bonding medium it is necessary to raise the temperature of the slug above that of the melting point of the bonding medium. This can be accomplished by heating the slug directly in the Al-Si bath, but the long exposure of the slug to the aluminum at high temperature results in alloying of the two metals, forming an excessively heavy compound layer that is extremely brittle on cooling, and can not satisfactorily withstand mechanical or thermal shock.

It has been found that this difficulty is not encountered if the slug is brought up to canning temperature in a bronze bath. Lead has also been found satisfactory for this purpose.

Tin Dip

The tin dip serves as an intermediate bath between the bronze and the aluminum-silicon. It removes practically all copper from the slug and applies a surface to it that the aluminum-silicon will readily wet.

It also serves to cool the surface of the slug sufficiently to prevent its oxidation when carried from this bath to the aluminum-silicon bath.

Flux, carried from the bronze bath, floats on the surface of the tin bath after slug immersion. This is carefully skimmed off before the slug is removed from the bath. In this manner, no flux is carried from the tin bath into the aluminum-silicon bath.

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[redacted]

The aluminum slowly forms a compound with some of the copper which is carried over the bron e bath. This compound floats on top of the bath and is skimmed off after each slug is placed in it. When the surface of the bath shows signs of excessiv oxidation, it indicates that the aluminum content should be increased. An excess of aluminum, however, does not seem to aid in this function

Higher temperatures are not necessary and serve only to produce excessive oxide formation on the bath and the slug. Lower temperatures cool the slug so that there is danger of Al-Si freezing on it before the canning operation is complete.

As the slug is released from the bronze-dipping basket, it drops onto a stainless steel tray which is suspended about 4 inches below the surface of the tin bath.

The surface of the bath is then skimmed and the slug grasped in stainless steel tongs and removed to the centrifuging operation.

Centrifuging

As the slug is removed from the bath a large excess of tin clings to its surface. This must be removed before the slug is dipped into the aluminum-silicon bath so that the latter will not be rapidly contaminated with tin.

In addition, the tin layer contains a relatively high percentage of dissolved heavy metal received from the bronze bath. This metal, when alloyed with aluminum-silicon, forms a brittle compound which is undesirable in the final assembly.

When the slug is removed from the tin bath it is placed in a container on the circumference of the rotating basket. The opposite side of the basket is counterbalanced in order to prevent vibration. The slug retains sufficient heat in itself so that it is not necessary to heat the basket in the centrifuge.

Aluminum-Silicon Dip

Aluminum-silicon is used as a bonding medium since it has a lower melting point than aluminum and virtually the same corrosion resistance.

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Preparation of Parts

Sleeve Preparation

During the process of assembling the slug and cap in the aluminum can, the latter is enclosed in a heavy walled steel sleeve open at the top end. This sleeve serves the four-fold function of holding the can in position in the molten Al-Si bath for slug insertion, of preventing the Al-Si from fouling the outside surface of the can, of supporting the can rigidly to prevent its deformation during slug insertion, and of transferring heat from the molten bath to the can. Differential contraction of the steel and assembled slug permits easy removal of the latter after quenching provided the sleeve has the shape of a right circular cylinder without distortion.

The steel protective sleeve, as received, have no coating over the bare metal. If they are submerged in this condition in Al-Si at the canning-bath temperature and allowed to remain until temperature equilibrium is reached, especially if the surface is subjected to abrasion while in contact with the alloy, the latter solders itself to the steel and is very difficult to remove. For this reason, it is necessary to bake the sleeves at a high temperature in an oxidizing atmosphere until they become coated with a heavy blue oxide film which resists attack by the aluminum-silicon bath during the assembly operation.

Sleeves may be re-used repeatedly as long as their dimensions are not distorted. It is only necessary to dissolve off adhering Al-Si in a strong caustic solution, rinse, and dry them thoroughly. They are given a final rinse in soapy water before drying to cover them with a rust-preventing film.

Can Preparation

In order to insure a good bond between slug and can, the latter must have a chemically clean, dry surface on the inside, free from matte areas. After a great deal of experimentation, the following preparative procedure has been adopted as conducive to best bonding results.

1) Inspect out cans having interior surface stains, matte areas, and other surface imperfections

2) Degrease in clean solvent

3) Soak 6 minutes in a solution of 0.1% tetrasodium pyrophosphate, 0.1% at 55-65 °C, followed by thorough rinse, first in hot water, then in cold water

4) Etch by complete immersion in 20 ± 1% phosphoric acid at room temperature (20-30 °C) for 4 min. ± 15 sec. This etch must be very mild to prevent forming a matte surface

5) Rinse thoroughly in cold water and drain

6) Rinse in C.P. methanol

7) Dry at least 15 minutes on forced air dryer at 60-70 °C

Cap Preparation

The reason for careful preparation of aluminum caps are the same as those given for cans. The treatment is also the same except that etching is done in a 1% solution of fluosilicic acid for 8 minutes at room temperature instead of in phosphoric acid.

Assembly

Assembling Can and Sleeve

Immediately following the final step of can preparation, the cans are inspected for internal flaws, following which they are inserted in pre-inspected sleeves. It is necessary to flare slightly the mouth of the can to seal it against the sleeve in order to prevent the molten Al-Si from running down between the sleeve and can. According to present procedure, this flaring is accomplished in two steps: a 2-inch steel ball is pressed into the protruding end of the can after its insertion into the sleeve, and later, after the can-sleeve assembly has been heated by partial immersion in the molten canning bath until the can has become annealed, a similar ball is again tapped into its mouth to readjust the contour of the can to that of the sleeve.

Assembling Component Parts

The steps in the assembly process are as follows:

1) Place sleeve-can assembly in canning basket

2) Immerse sleeve-can assembly

3) Completely submerge sleeve-can assembly in canning bath allowing can to fill with molten metal.

4)

5) Dip slug brought over from Al-Si dip bath into canning bath. Immediately remove and insert lower end of slug in open end of can-sleeve assembly which has been rinsed to permit location. Align slug coaxial with can.

[redacted]

6) Allow slug to drop under its own weight into can at least half its length, displacing molten Al-Si as it settles. Keep slug aligned coaxial with can. Meanwhile, lower assembly again so that mouth of can is entirely submerged.

7) Press slug completely to bottom of can with push rod.

8) Remove cap from bath, scrape bottom vigorously across a rough surface (such as a transite board) to insure its wetting.

9) Re-dip cap in bath

10) Insert cap in open end of can above slug, using twisting motion, and press down tightly.

11) Remove assembled piece to quench.

Quenching

After removal from the canning basket, the assembled piece, still encased in the protective sleeve, is transferred with tongs to a quenching basket, similar in shape to the canning basket. The basket with its contents is then completely submerged in the cold flowing water of the quench tank until the molten Al-Si has solidified, after which the basket is suspended in the water with the top about 1/2 inch above the water level until the assembly is cool enough to handle comfortably. The slug is then removed from the sleeve by inverting and shaking, or in occasional stubbornly stuck pieces, by tapping the sides of the sleeve with a rawhide mallet.

Finishing Operations

Cut Off

After canning, the rough jagged end at the top of the slug is cut off on a band saw to give a piece about 1/4 inch longer than the finished length. The band saw is much faster for this rough cut than a lathe, and it lessens the danger of shattering the bond at the cap end.

Measuring and Marking Cap Thickness

Proper operation of the pile requires reasonably close tolerance in the thickness of the aluminum end pieces on the slug. The bottom of the cans are fabricated to the proper thickness (0.0345 ± 0.010 inches) and if the slug is completely seated, the thickness at the bottom is satisfactory. In order to insure proper cap thickness, however, in view of the fact that slug length tolerance is equivalent to cap thickness tolerance, it is necessary actually to measure the distance from the end of the slug to the end of the cap. This is accomplished by placing the canned piece in a beam of X-rays, indexing the end of the slug by viewing through a fluoroscope, and marking the wall of the aluminum can at the proper distance above the end of the slug to give a cap thickness of 0.0340 ± 0.010 inches.

Machining

After the slug has been marked to give the desired cap thickness, the sawed end of the piece is faced off in a lathe to the depth indicated by the mark on the side. A shoulder 0.030 ± 0.005 inches deep by 0.050 ± 0.010 inches wide is turned around the end of the slug to facilitate welding.

Welding

To insure complete closure of the cap end of the slug, the cap is welded to the can, using an electric arc in an atmosphere of argon. For this purpose a collet chuck capable of rotation of speeds varying from zero to about 30 rev./min. is used to hold the slug, and the torch is held in a sturdy jig capable of 3 inches lateral swing, and fitted with a micrometer screw for the vertical adjustment of the arc spacing.

In use, the slug to be welded is chucked in the collet and the tungsten electrode is adjusted to give the proper spacing (0.050 inches) from the machined end of the slug. The argon flow about the electrode is adjusted to the rate of 3 to 5 liters/min. The arc is struck by ionizing the gas with a high tension spark while the electrode and slug are at a potential difference of approximately 300 volts. After the arc is initiated, the current is adjusted to 70-75 amps, at which value the potential difference between electrode and slug drops to 11-15 volts. The arc is struck on the machined cap at a point approximately 3/8 inches away from the center of the slug, which is rotated in a counterclockwise direction for one full revolution, the speed being adjusted so that a well defined pool of molten aluminum exists under the arc for at least half of this revolution. The rate of rotation is then diminished or completely stopped while the electrode is moved slowly outward to a position just outside the machined shoulder of the slug. The rate of motion of the electrode must be such that the molten pool always stays ahead of the arc. As soon as a pool forms in the new arc location, rotation of the slug is continued at such rate that the molten pool stays ahead of the arc. One complete revolution is made with the arc in this position, plus about 1/4 inch overlap. The arc is then moved still further outward until it is such a position that it forms a smooth, rounded weld head. The rate of rotation is increased as much as possible, still keeping the pool ahead of the arc. After completing one revolution plus about 1/4 inch overlap, the arc is moved rapidly toward the center of the cap and the arc circuit is broken. The electrode is then moved aside and the slug removed from the collet with padded tongs and cooled in a water tank to permit handling.

INSPECTION AND TESTING

The inspections required for a completely assembled slug for the Hanford Plant may be divided into two main groups:

[redacted]

[redacted]

1) Inspection of materials

2) Inspection of completed assembly

The latter may be divided into four sub-groups which are: well soundness determination, extent of bonding present, gauging, and visual examination.

Materials Inspection

Inspections are made in the machine shop to see that the slugs meet the tolerance required before they are turned over to canning. No routine inspection in canning is made on the slugs. The aluminum cans and caps and steel sleeves are made by outside companies and shipped to Hanford. Samples are taken from the cans and caps received at Hanford periodically and analyzed chemically to see that the impurity tolerances allowed are not exceeded.

Cans, caps, and sleeves are completely inspected for the following items before they are turned over to production:

Cans: Length, outside diameter, wall thickness, bottom thickness, warp, interior and exterior surface condition. (Bottom radius, dimple dimensions, mouth chamfer and measurement of scratch depth are checked on representative samples rather than on all samples)

Caps: Diameter, body length, radius at bottom edge, boss, surface conditions.

Sleeves (new): Inside diameter, depth inside, length, wall thickness, chamfer, inside surface, weld bead inside, warp.

Sleeves (used): Inside diameter, warp, surface, adhering Al-Si.

Inspection of Canned Slugs

Fluoroscope Test

Prior to welding, the machined canned pieces are inspected by means of an X-ray machine with indexed fluoroscope for cap and bottom thickness. Those having thicknesses greater or less than the specified tolerances are rejected at this point, thus saving the time and labor involved in welding non-usable pieces.

It is also possible to pick out pieces having voided areas between slug and cap or bottom, which defects are not detected in the frost test. When such defective pieces are found, they are rejected. Pieces successfully passing the "Fluoroscope" test are sent on to the welding operation.

[redacted]

Frost Test

The slug to be tested is sprayed with a nearly saturated solution of acenaphthene in carbon tetrachloride until a smooth while film of the acenaphthene is obtained on the surface of the aluminum jacket. The slug is then passed during 30 minutes through a thermostatically controlled temperature equalizer which brings all slugs to a temperature of 25 ± 5 °C.

The slugs are then passed six at a time, at a definite velocity, through an induction coil which supplies approximately 25 kw of energy at 9600 cycles/second. This produces surface heating only. Acenaphthene melts between 93-95 °C. If the heat induced in the surface of the aluminum can passes through a good bonding medium to the slug, a temperature above 95 °C is not reached on the surface, hence the acenaphthene remains white and crystalline on all spots where the bonding between the can and the slug is sound. If there is a void in the bonding, or if the bonding is defective, the heat induced on the surface is sufficient to raise the temperature on the surface above 93 °C and the acenaphthene melts at that point. When the acenaphthene melts and then solidifies it forms rather large clear crystals and remains in this form. Acenaphthene slowly sublimes at room temperature, so that the slugs must be classified soon after passing through the testing machine or erroneous classifications may be made. Slugs are classified according to the size and location of melted areas developed in the frosty coating.

Pre-autoclave Inspection

Pieces successfully passing the frost test are de-frosted by trichlorethylene vapor degreasing, or by other suitable means, and are then etched 10 minutes in a 40-50% solution of nitric acid at 80-90 °C.

This treatment serves to darken any areas of exposed aluminum-silicon so that any regions in which the bonding medium may have penetrated through the aluminum can become black and may be easily observed by visual inspection and rejected.

Following this etching treatment, the canned slugs are inspected for diameter and warp by use of a full length tube gage of 1.455 inches inside diameter. They are then visually inspected for penetration, surface defects, weld quality, and presence of identification marks.

Autoclave Test

All canned pieces are steam-autoclaved for 40 hours at 90 to 100 lbs./sq.in. steam pressure. In this treatment, 210 pieces per batch are loaded on suitable baskets and enclosed in a steel chamber into which steam is introduced. Under these conditions, any breaks in the aluminum envelope - even those of microscopic size - are permeated by the water or vapor and the metal slug is attacked and locally converted to the oxide which occupies several times the volume of the metal before oxidation. Thus warts or swellings are caused which betray defects in the continuity of the aluminum jacket. Pieces which have developed such swellings are culled out by means of a 1.455-inch tube gage similar to the one used in pre-autoclave inspection.

[redacted]

In addition to detecting and eliminating pieces with discontinuities in the aluminum jacket, the process of subjecting sound pieces to the action of steam builds up a heavier coating of aluminum oxide on their surfaces than is readily accomplished by other means. This oxide film serves to protect the aluminum jacket, making it more resistant to the corrosive action of the water with which the pieces are surrounded in the pile.

All canned pieces are given a final visual inspection after autoclaving in which those which have been marred in handling or have become warped or stained during autoclaving are rejected.

SAFETY

Machining and Handling Metal

During all operations involving the machining of metal a fume hazard is present. Toxic quantities of oxide liberated during these operations must be removed by adequate ventilation. The best method for removing this is individual exhaust hoods attached to each machine. By having an adequate supply of coolant applied to the tool bit the production of this oxide can be greatly reduced. Oxide is so concentrated in the air of the building where extrusion and straightening are carried out that operators are required to wear respirators.

The fire hazard in machining metal is always present. This can be minimized by using an adequate supply of coolant on the tool bit and by being sure that the chips are quenched in coolant when they drop into the catch pan below the lathe. It is necessary that they be removed frequently and stored in steel cans to prevent ignition from a hot chip.

Operators working with metal must be careful to wash their hands frequently and thoroughly in order to remove metal dust that may have collected on them. This metal is capable of destroying the skin tissue when in intimate contact with it. The degree of damage is determined by the length of time to which the tissues are exposed. For this reason, leather gloves must be worn when handling metal, either raw or canned. Operators must wear coveralls which are changed daily. Those whose work involves frequent handling of metal must take shower baths before resuming street clothes.

Handling Hot Equipment

In the extrusion and canning process much of the equipment is operated at dangerously high temperatures. It is necessary, therefore, that the operating personnel be properly and adequately clothed. This clothing should include heavy asbestos gloves, asbestos or leather apron, leggins, loose-fitting shoes, and complete face and head protection. The coveralls worn by the operating personnel are fireproofed. Only thoroughly dried tongs, lathes, etc., must be dipped into molten baths due to danger of

[redacted]

explosions of drops of moisture if introduced beneath the surface of the metal, with attendant hazards to the operators

Welding Precautions

Because of the electrical nature of the welding operation, adequate electrical insulation and protection of 11 equipment is required. Gloves should be worn when placing the pieces in the collet chucks and they should be removed with suitable padded tongs to prevent danger of burns. The light ilter shield which surrounds the arc must always be in place when welding is in progress. This provides adequate protection from the intense ultra-violet light generated by the arc.

Handling Acids

Operators who fill and empty the various acid bath tanks must wear rubber suits, hoods, boots and gloves at the time of handling the acid. The fumes generated in the hot nitric acid tanks are quite noxious and must be carried off by adequate exhaust hoods.

Solvent Degreasers

Active metals, such as those involved in the present process, promote the decomposition of the chlorinated hydrocarbon used as solvent in the vapor degreasers. Although the solvent employed in these units contains a basic stab lizer, the stabilizer may become exhausted and decomposition may proceed unabated. Since the decomposition products of chlorinated hydrocarbons include phosgene, chlorine and hydrochloric acid, it is necessary to test the solvent periodically and change it when evidence of decomposition is indicated.

In additions to the hazards occasioned by the decomposition of the trichlorethylene, the vapors themselves are toxic in concentration of a few hundred parts per million, so that it is necessary to operate these units in a well-ventilated location without drafts.

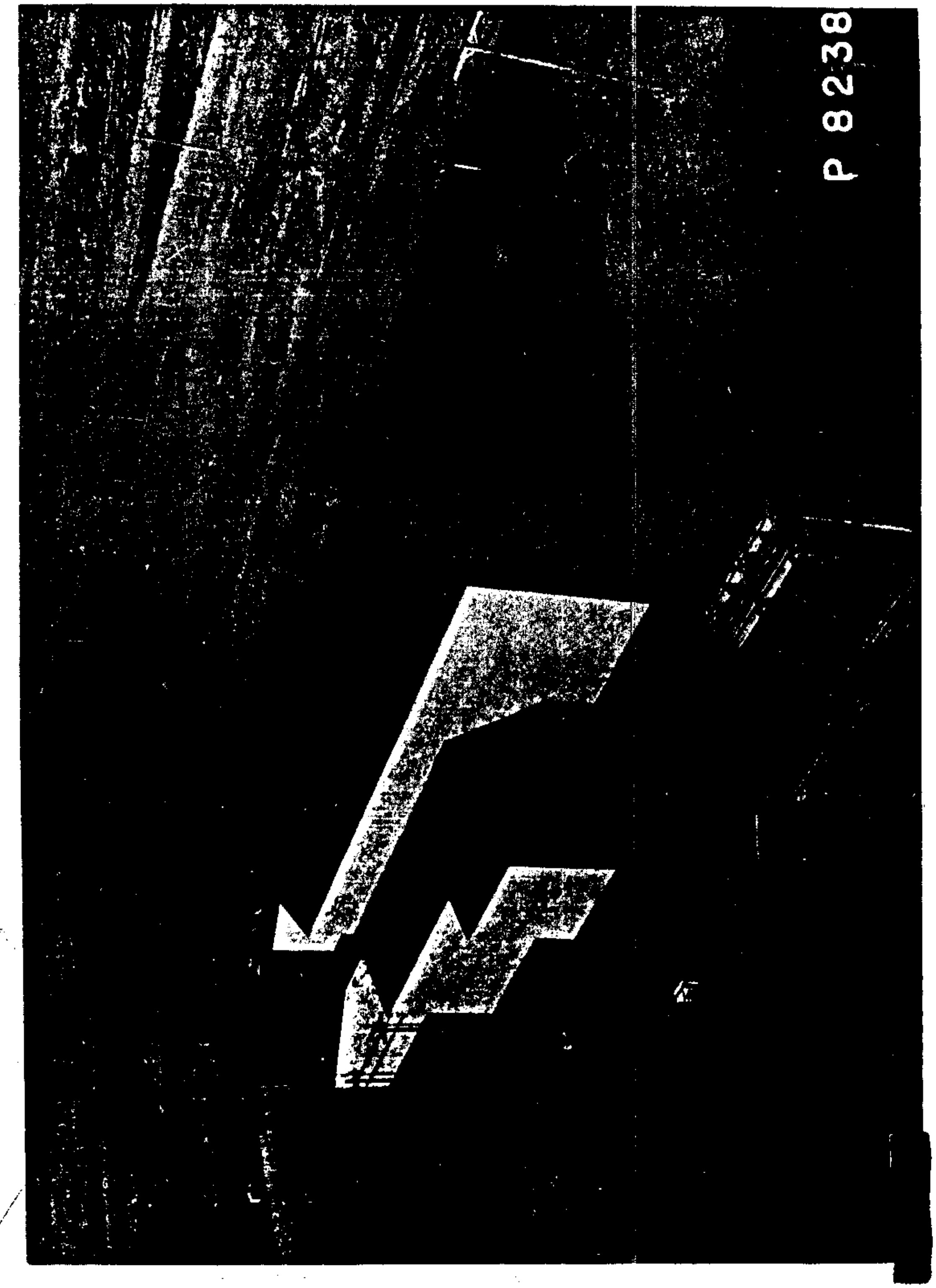
The solvent dissolves natural oils from the skin and is directly absorbed through the skin into the blood stream where it has adverse physiological effects. The hands must never be put into the solvent vapors.

General Safety Equipment

Because of the danger of fl ing chips, splashing acid, and other hazards to the eyes existing in the extruding, machining, and canning areas, all persons entering these areas are required to wear side shield safety glasses. Safety shoes are also recommended as a general safety precaution.

[redacted]

FIGURE 5A



TEST PILE BUILDING

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INDEX

SECTION A - METAL PREPARATION

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