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AEC RESEARCH AND DEVELOPMENT REPORT

LOS ALAMOS SCIENTIFIC LABORATORY

OF THE UNIVERSITY OF CALIFORNIA ○ LOS ALAMOS NEW MEXICO

PREPARATION OF PLUTONIUM SHEET BY EXTRUSION

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LOS ALAMOS SCIENTIFIC LABORATORY
OF THE UNIVERSITY OF CALIFORNIA LOS ALAMOS NEW MEXICO

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PREPARATION OF PLUTONIUM SHEET BY EXTRUSION

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ABSTRACT

Plutonium sheet of uniform thickness and good surface can be made by the extrusion of a tube which is then split and flattened. This report describes the equipment and the operating conditions for making sheet 0.005 to 0.055 in. thick with areas up to 24 in. square.

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INTRODUCTION

Plutonium metal is very plastic at elevated temperatures, making it possible to extrude thin-walled tubes which can then be split and flattened into sheet stock.

In order to avoid the difficulties involved in the design and operation of the usual feed slug-piercing step employed in conventional extrusion units, the extrusion unit for plutonium was simplified by the use of a ring-shaped charge which was pre-formed by casting and machining.

The first unit constructed and tested was a conventional tube-extrusion die using the so-called Hooker process. This process employs a unit consisting of a cylindrical housing containing a fixed ring die and a hydraulic ram. The ram forces the feed ring against the face of the die and extrudes the tube through the orifice created by the die and a cylindrical projection on the nose of the ram.

The use of this design was discontinued because tests showed severe galling between the tube and the cylindrical projection on the ram which formed the inside of the extruded tube. This galling resulted in wrinkled and torn tubes.

As a result of the above tests and information obtained from F. Schonfeld and L. Levinson of LASL, a die has been designed in which the tube is formed by extruding the feed through an orifice formed by inner and outer die rings. This method consistently produces sheet stock of uniform thickness and good surface.

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For certain alloys a method has been developed for flattening the split tube, and annealing cycles have been established to improve the working properties of the sheet.

EXTRUSION DIE

The unit developed for making thin-walled tubing is a direct-extrusion type; that is, the orifice section is stationary and the feed is moved under pressure through the orifice, forming the tube. The conventional unit for this purpose forms the tube by extruding the material through an outside ring die and around an inside guide mandrel. It was found that, when plutonium was extruded with this type of die, it would gall on contact with the inner guide mandrel and the resulting tube would be wrinkled and torn.

The unit was modified as shown in Fig. 1, so that there is an inner and an outer die ring. The two die rings form a circular orifice through which the material is extruded. The outer die ring is contained in the unit housing and the inner die ring is supported on a column which is attached to the base of the unit. That portion of the column above the die ring is centered by the inside of a tubular push mandrel.

The face of the die is flat and at right angles to the line of extrusion. The edge of the orifice is sharp with no radius and is supported by a straight section for 0.066 in. and then undercut to provide clearance for the extruded tube. The feed ring is forced against the flat face of the die by the tubular push mandrel. The edges of the die section around the orifice are sharp so that the tube will be sheared from the ring as the metal is forced through the orifice.

The uniformity of wall thickness of the extruded tube and the thickness variation of the finished sheet are dependent on the concentricity of the inner and outer die rings. This is attained by maintaining a close fit between the outside of the push mandrel and the unit housing, and between the inside of the mandrel and the outside of the inner-die column.

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As the push mandrel advances, it will extrude a constant volume of material through all sections of the orifice. If the cross section of the orifice varies, where it is least the same volume of feed will extrude a longer tube section than where it is greater. This produces a bent tube which is shorter and thicker on one side and longer and thinner on the other side. If this variation in wall thickness is greater than 5 to 10 percent, the tube will be so bent that it cannot be flattened into good sheet stock. It is apparent that it is much easier to build dies to form good thick tubes than good thin ones. A wall thickness of 0.015 in. seems to be the practical lower limit. Most of the extruded tubes 0.005 in. thick were too wrinkled to flatten.

The extrusion-unit feed chamber must be designed so that equal volumes of feed material are contained on each side of an imaginary right cylinder extending upward from the average orifice diameter. When the orifice is located outside of this imaginary cylinder, the extrusion produces a tube that is bell-shaped and which splits lengthwise from the forward end.

Different tube thicknesses can be made by changing the size of the outer ring die. The length of the tube is determined by the quantity of material in the feed ring.

The portions of the extrusion die and that part of the die housing subjected to wear are made of a "red-hard" tool steel, usually Star Zenith, heat-treated to a hardness of Rockwell C-60 and ground to dimension.

One of the units has been used for more than fifty extrusions without noticeable wear on any of the parts.

A photograph of the unit used to make 8 in. diameter tubing is shown in Fig. 2. A tube and the 3 in. extrusion die are pictured in Fig. 3.

FEED

Feed for the extrusion die is a machined ring. The desired alloy is cast into an oversized ring and then all surfaces are machined for surface clean-up and for proper dimensions and weight. The feed ring may fit loosely in the extrusion unit, since the push mandrel deforms the charge to fit the feed chamber before extrusion commences. The cast and machined feed rings as well as the produced tube and sheet stock are shown in Fig. 4.

LUBRICANT

The extrusion temperature, 300 to 400°C, is such that most lubricants cannot be considered. A mixture of 50-50 Aquadag and Molykote has been found to give satisfactory lubrication and die protection.

Before a new extrusion unit is used, all contact surfaces are treated in this manner:

1. All parts are degreased with an organic solvent.
2. A heavy coating of the lubricant is applied.
3. The parts are heated to 350°C, then cooled to room temperature.
4. The surfaces are brushed with a fine-wire brush in a high-speed hand grinder.
5. Steps 2, 3 and 4 are repeated at least three times.

Each time the die is used, all plutonium contact surfaces and guide surfaces are brushed clean with a wire brush in a hand grinder; an additional coating of the lubricant is applied and allowed to dry. Before it is loaded into the die, the feed ring is coated with the lubricant and allowed to dry. No lubricant is evident on the extruded tube.

OPERATING CONDITIONS

When the plutonium is extruded through the die, it is very hot and the surface is devoid of any protective coating. Severe oxidation will occur if the tube is not extruded into an oxygen-free atmosphere. Since the work area of the presses used in experiments was not dry-boxed, it was necessary to enclose the extrusion units in vacuum-tight pressing cans. These cans contained the alpha contamination and made it possible to establish an inert atmosphere around the die by repeated purging with vacuum and helium.

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The extrusion units were heated by induction. The heating coil was located outside the pressing can.

Temperature measurements were made with a chromel-alumel thermocouple located in the extrusion-unit housing. Calibration runs gave the relation between this temperature and that of the feed ring.

Two different presses were used. The 1.5 and 3 in. diameter extrusions were made with a 200 ton Clearing press. The 4.5 and 8 in. diameter extrusions were made with a 5,000 ton Erie press. The precalibrated Bourdon-tube gauges in the hydraulic systems of the presses were used to indicate pressure.

A dial indicator attached to the moving platen of the press was used to determine the progress of the extrusion.

Data obtained for various extrusion runs using pure plutonium and 1 w/o gallium alloys are given in Table 1.

TABLE 1

Extrusion Temperatures and Pressures

Tubing Diameter, in.	Material	Wall Thickness, in.	Temperature, °C	Pressure, ton gauge[a]	Feed Ring Pressure, psi
1.5	1 w/o Ga	0.005	320-330	40	79,000
3	Pure Pu	0.030	320-330	100	34,000
3	1 w/o Ga	0.015	320-330	140	47,000
3	1 w/o Ga	0.030	320-330	120	40,000
3	1 w/o Ga	0.060	320-330	100	34,000
4.5	1 w/o Ga	0.045	320-330	360	47,000
4.5	1 w/o Ga	0.055	320-330	220	28,000
8	1 w/o Ga	0.030	320-330	700	62,000
8	1 w/o Ga	0.050	320-330	600	53,000

[a]Extrusion pressure is that pressure indicated during the extrusion when a reasonable rate was attained. The feed thickness-diameter ratio, and the temperature, lubricant and extrusion rates influence the extrusion pressure.

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SHEET SIZES AND ALLOYS

Extrusion units have been built to make tubing of four different diameters, 1.5, 3, 4.5 and 8 in. The desired sheet thickness in a tube size is attained by changing the size of the outer die ring. Tube length is varied by the quantity of material in the feed ring.

Tube extrusions have been made of pure plutonium and various alloys including delta-stabilized plutonium. In general, the pressure required for extrusion increases with an increase in percentage of alloying material. Plutonium stabilized in the delta phase by gallium required less pressure for extrusion than aluminum delta-stabilized alloy. Sheet sizes made by extrusion and flattening are shown in Table 2.

TABLE 2

Sheet Sizes Made by the Extrusion Process

Tube Diameter, in.	Flattened Width, in.	Length, in.	Thickness, in.	Thickness Variation, in.
1.5	4.7	3	0.005	±0.0002
3	9.4	10	0.020, 0.030 0.035, 0.055	±0.0005
4.5	14.1	15	0.045, 0.055	±0.0005
8	25.1	27	0.030, 0.055	±0.0005

SUMMARY

Plutonium sheet stock of uniform thickness has been produced by the extrusion of a tube which is then split and flattened. Sheets up to 24 in. square and of a thickness range of from 0.005 to 0.055 in. were made of pure and delta-stabilized plutonium.

The tube is produced by direct extrusion of a ring-shaped feed through a die which has a flat face and a sharp-edged orifice. Die surfaces are lubricated and protected with a 50-50 mixture of Aquadag and Molykote. The extrusion is made at 300 to 400°C in an inert atmosphere. High pressures are required.

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The tube is manually split and is flattened by compressing between dural plates at 200°C.

The working qualities of delta-stabilized plutonium are improved by solution-annealing at 450°C followed by quick cooling.

This process is now routinely used to produce plutonium sheet stock.

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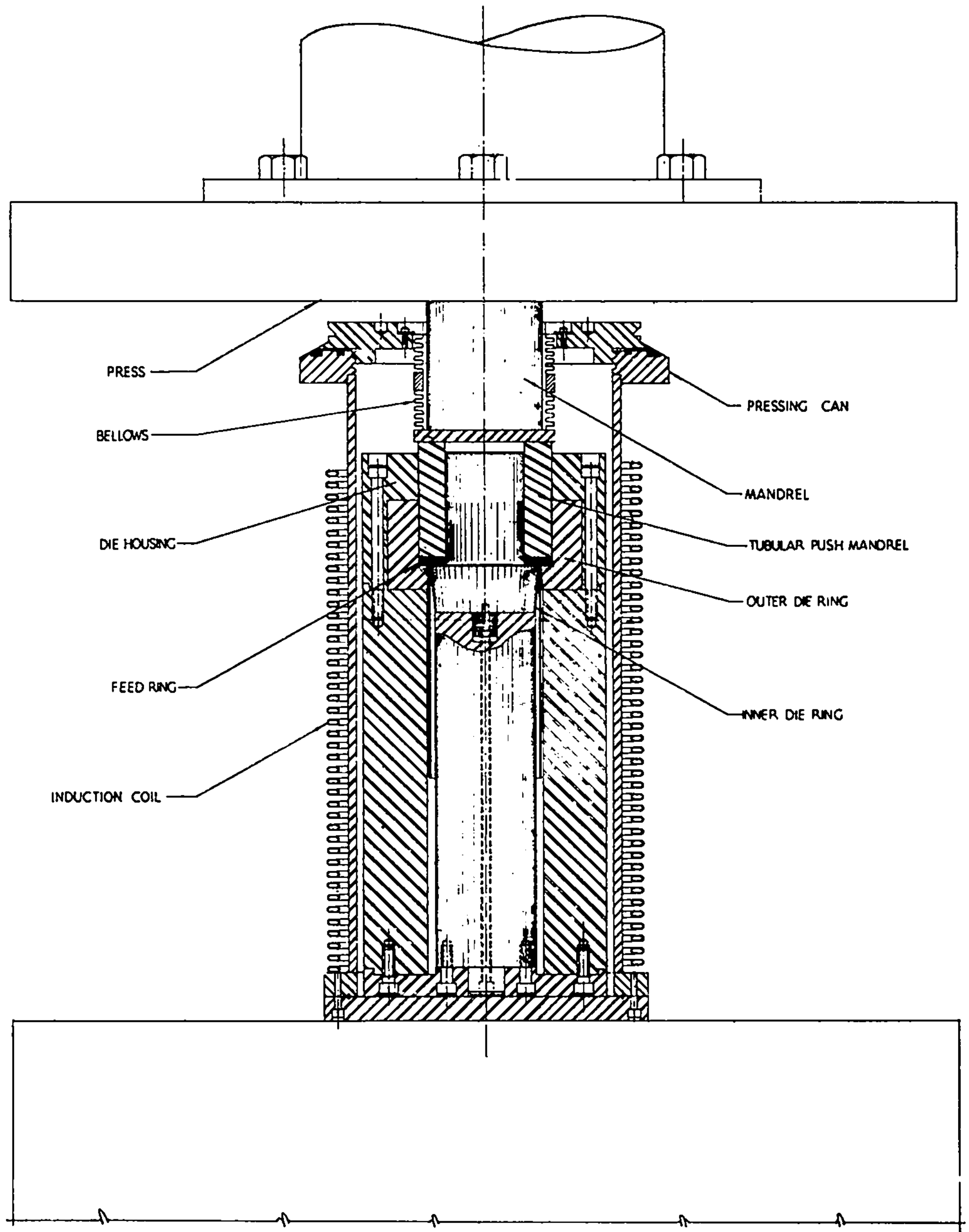

Fig. 1. Schematic of die for forming thin-walled tubing.

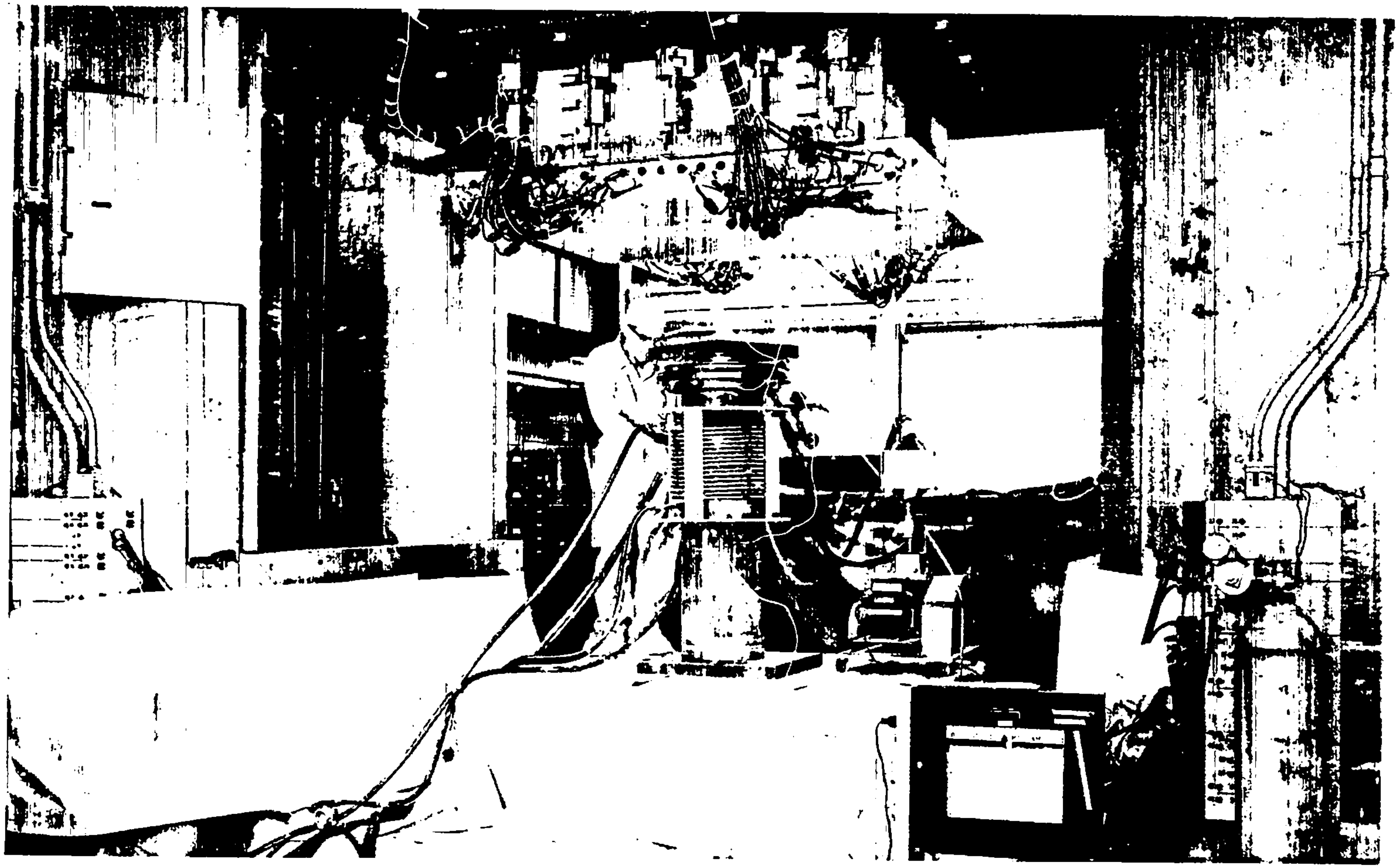

Fig. 2. Eight in. diameter extrusion die assembly in the 5,000 ton Erie press.

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Fig. 3. Tube and 3 in. diameter extrusion die.

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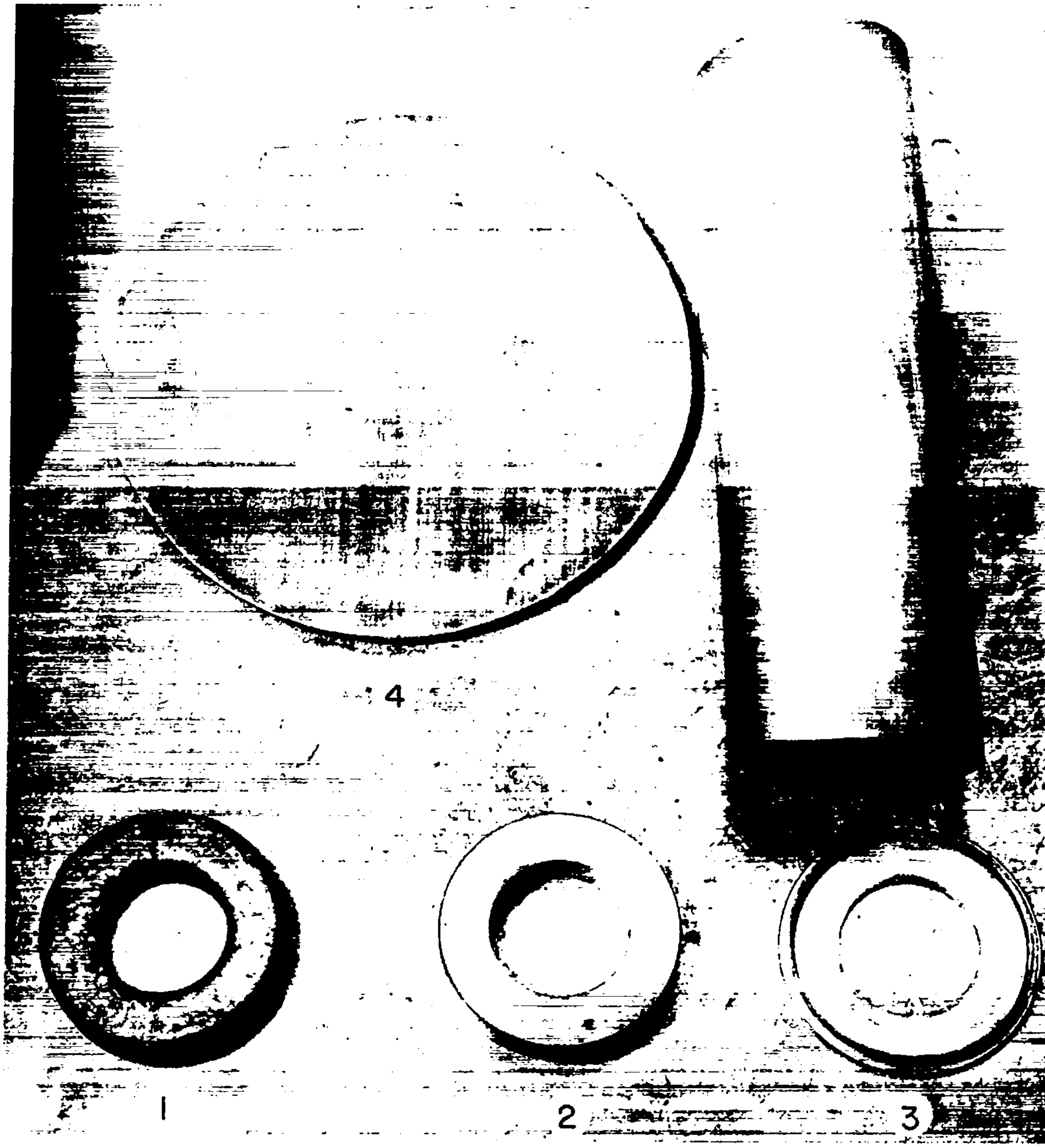

Fig. 4. Metal forms associated with tube extrusion die.

1. Cast feed ring
2. Machined feed ring
3. Extruded tube and heel
4. Flattened sheet stock

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