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AEC RESEARCH AND DEVELOPMENT REPORT

LOS ALAMOS SCIENTIFIC LABORATORY

OF THE UNIVERSITY OF CALIFORNIA ○ LOS ALAMOS NEW MEXICO

WELDING OF PLUTONIUM

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LOS ALAMOS SCIENTIFIC LABORATORY
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WELDING OF PLUTONIUM

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ABSTRACT

Delta-stabilized plutonium can be welded to itself or almost any other metal using the inert-gas metal-arc process. Equipment and procedures suitable for the welding of delta-stabilized plutonium under various conditions are described.

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INTRODUCTION

Plutonium melts at a relatively low temperature, 640°C, and it is a very reactive metal, particularly near its melting point. The film of surface oxidation which protects many metals from subsequent oxidation will not prevent pure plutonium from completely oxidizing at a temperature as low as 75°C in moist air. Delta-stabilized material does not oxidize as rapidly; however, it is still quite active and will burn at elevated temperatures in the presence of air.

Inert-gas metal-arc welding is a gas-arc process which uses an inert gas to protect the weld zone from the atmosphere. The necessary heat for welding is provided by a very intense electric arc which is struck between a virtually non-consumable tungsten electrode and the metal work piece. This process has the following inherent desirable features:

1. Provides inert gas at weld area.
2. Requires no flux.
3. Minimizes spatter and sparks.
4. Produces good welds on various combinations of dissimilar metals.
5. Uses a virtually non-consumable tungsten electrode.
6. Produces welds which are stronger, more ductile and more corrosion resistant than those made with ordinary metal-arc welding processes.

Since plutonium is handled in enclosures for control of the alpha activity associated with it, the inert gas from the torch can be used to inert an isolated welding box. This then serves to protect all surfaces from oxidation.

WELDING

Welding Machines

A welding machine having the following features is desirable for research, development, and general service work:

1. Effective amperage control and response in the range of 1 to 100 amp.
2. Both AC and DC output.
3. Both straight and reverse polarity.
4. Automatic high frequency supply.
5. Reproducible operation on a program control cycle.
6. Adjustable timer for automatic spot welding.

A General Electric Co. type WD-33-C, 300 amp. DC motor-generator set was used for most of the initial plutonium welding. A Harnischfeger Corp. P and H Model DA300HFSG welder was used in the later work. This unit has a 10 to 396 amp. AC, 7 to 300 amp. DC output, automatic high frequency starter, and a spot gun attachment. This machine has all of the desirable features outlined above except 1 to 10 amp. control. Stable currents in the 1 to 10 amp. range are obtained by operating the machine at 30 amp. AC or DC, where it exhibits good stability, and reducing the output to the desired value by means of a heavy duty variable resistor in series in the output line.

The following Linde Air Product Co. welding torches were used:

a. Type HW-9 (gas cooled)
b. Type HW-12 (water cooled)
c. Type HW-8 (spot welding)

Gas Mixer and Proportioner

The gas control unit used to regulate the flow of helium, argon, or a mixture of the two gases to the welding torch is shown schematically in Fig. 1. A bypass line, operated by a foot switch, provides a pure argon supply at the torch for striking an arc at very low amperages.

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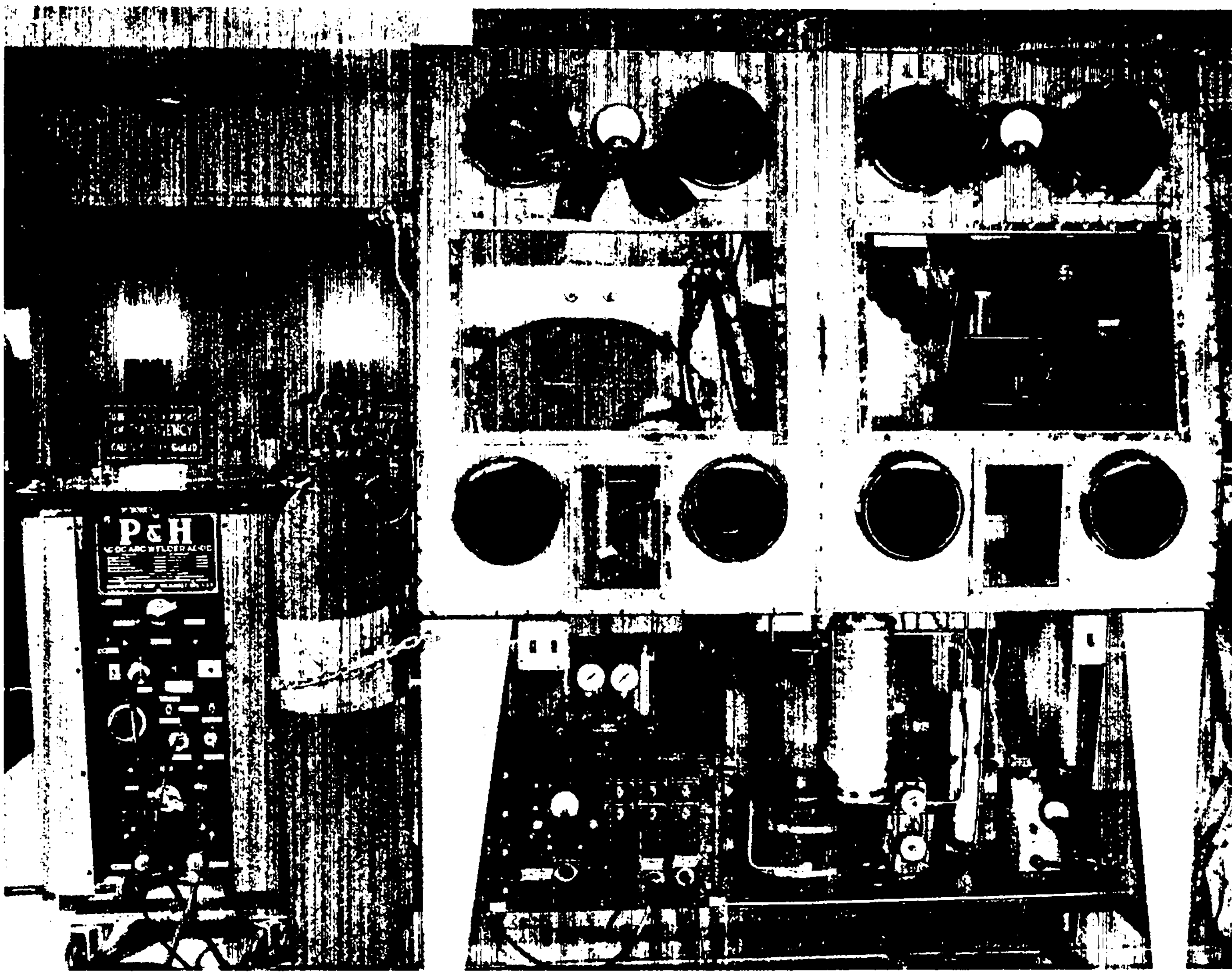

Fig. 1. Gas control unit for inert arc welding box.

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Welding Box

The welding box, shown in Fig. 2, consists of a two-section glove box with a partition in the center. The welding is performed in the box on the left, while the one on the right is used for introducing and removing materials through plastic bags and for storage space. The torch connections are made through an insulating plate located in the top.

The box is made of 12 gauge, type 316 stainless steel panels bolted together over neoprene gaskets. Windows are safety glass.

ATMOSPHERE AND VENTILATION

The entire welding box is inerted so that all surfaces are protected from oxidation. The gas system is shown in Fig. 3. Argon, helium, or a mixture of the two gases is introduced into the glove box through the torch. By starting the flow 1 hr. before welding, it is possible to obtain a 99 percent inert atmosphere, which is satisfactory for plutonium welding. To maintain this atmosphere and provide adequate flow at the torch during welding, a flow of 2 to 8 liters/min. is maintained at all times.

The gas flow sequence is from the cylinders, through a chemical dryer into the mixer and regulator box, and then through the torch into the box. The pressure in the welding box is maintained at 0.2 to 0.6 in. of water negative with respect to the operation area by removing the gas from the box through canister type filters (U. S. A. Chemical Corps Canister Aerosol No. E4R5) at floor level by a Eberbach blower (Eberbach Cat. No. T9713). The exhaust from the blower is discharged into the contaminated air system for the plant.

Helium detector elements are located in both the introductory and exhaust gas lines. Evaluation of the atmosphere in the welding box is determined by comparing the two readings.

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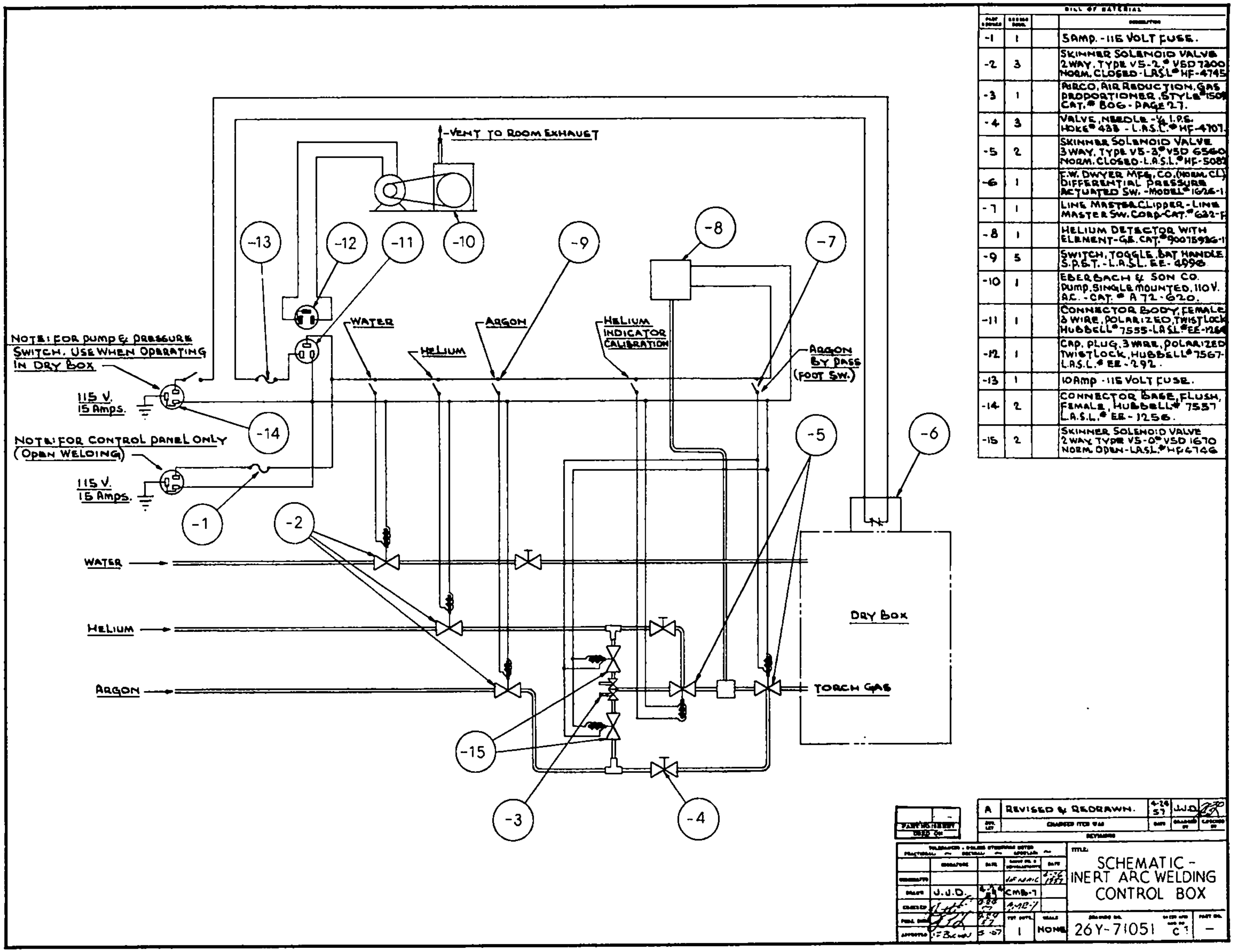

-1	1		5AMP. -115 VOLT FUSE.
-2	3		SKINNER SOLENOID VALVE 2 WAY. TYPE V5-2, # V5D 7200 NORM. CLOSED - L.A.S.L. # HF-4745
-3	1		AIRCO, AIR REDUCTION, GAS PROPORTIONER, STYLE # 150, CAT. # 806 - PAGE 27.
-4	3		VALVE, NEEDLE - ¼ I.P.S. HOKE # 433 - L.A.S.L. # HF-4707.
-5	2		SKINNER SOLENOID VALVE 3 WAY. TYPE V5-3, # V5D 6560 NORM. CLOSED - L.A.S.L. # HF-5082
-6	1		F.W. DWYER MFG. CO. (NORM. CL.) DIFFERENTIAL PRESSURE ACTUATED SW. - MODEL # 1626-1
-7	1		LINE MASTER CLIPPER - LINE MASTER SW. CORP. - CAT. # 632-F
-8	1		HELIUM DETECTOR WITH ELEMENT - G.E. CAT. # 9007593G-1
-9	5		SWITCH, TOGGLE, BAT HANDLE S.P.S.T. - L.A.S.L. EE-4996
-10	1		EBERBACH & SON CO. PUMP, SINGLE MOUNTED, 110 V. A.C. - CAT. # A 72-620.
-11	1		CONNECTOR BODY, FEMALE, 3 WIRE, POLARIZED, TWISTLOCK HUBBELL # 7555 - L.A.S.L. # EE-1264
-12	1		CAP, PLUG, 3 WIRE, POLARIZED TWISTLOCK, HUBBELL # 7567 - L.A.S.L. # EE-292.
-13	1		10 AMP - 115 VOLT FUSE.
-14	2		CONNECTOR BASE, FLUSH, FEMALE, HUBBELL # 7557 L.A.S.L. # EE-1256.
-15	2		SKINNER SOLENOID VALVE 2 WAY TYPE V5-0, # V5D 1670 NORM. OPEN - L.A.S.L. # HF-4746

Fig. 2. Welding box arrangement.

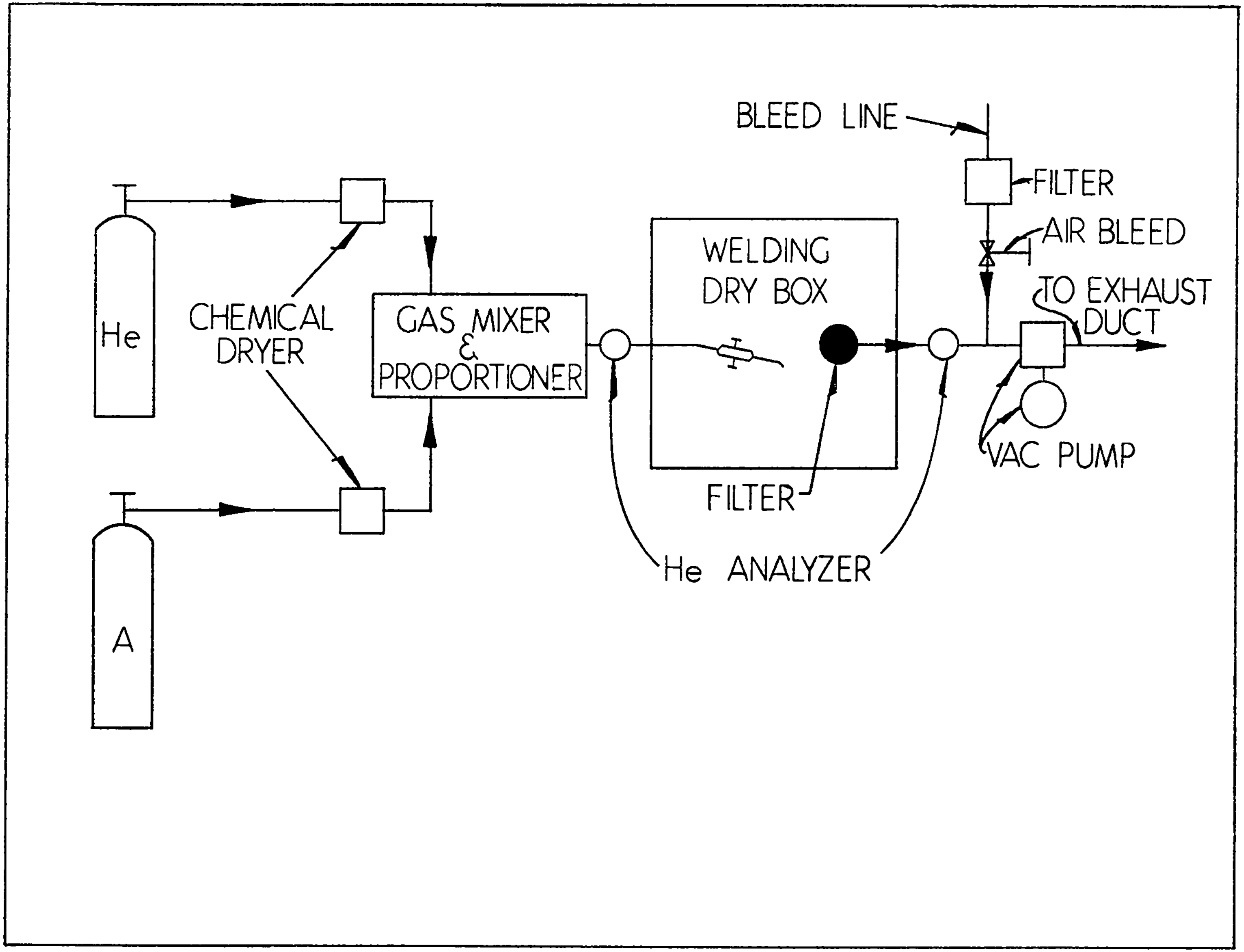

Fig. 3. Gas system for welding dry box.

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WELDING PREPARATION

Preparation of Materials

Just prior to welding, the plutonium surfaces are cleaned in the inert atmosphere of the welding box to remove oxide and foreign material. If the oxide film is light, it can be removed by wire brushing. If this is not satisfactory, sanding or an abrasive wheel can be used.

When plutonium is welded to a dissimilar metal, the other metal is cleaned using standard commercial techniques. For instance, uranium is electropolished or wire brushed, while stainless steel and nickel require no special preparation other than to be degreased.

Set-up Procedure

Plutonium is prepared in the same way as other metals for a butt, lap, corner, or other standard type of welding joint. For instance, in a butt weld, care is taken to have square and flat edges. On light gauge material, a metal back-up is used, if possible, to prevent the weld puddle from burning through; the back-up draws some of the heat generated by the arc away from the weld area. Copper or brass is satisfactory for this purpose. At 450°C, plutonium will react with many metals and alloys, particularly any alloy containing large amounts of iron or nickel.

WELDING TECHNIQUES

Materials

Plutonium stabilized in the delta phase can be welded to itself or a variety of other metals. Welding of alpha-phase plutonium is not recommended. This material undergoes a 15 percent volume change when it transforms from the beta to alpha phase at 125°C, which invariably cracks the weld or produces such severe strains and stresses in the weld area that it will fail when subjected to slight shock or pressure.

The delta-stabilized material has been successfully welded to the following metals and alloys: uranium, aluminum, iron, steels, nickel, copper, brass, molybdenum, platinum, niobium and Hastelloy. With the

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exception of aluminum, the melting points of the other materials are considerably higher than plutonium; therefore, the arc is normally directed on these rather than on the plutonium.

Tantalum and tungsten are welded to plutonium only with difficulty. These metals are very non-reactive with plutonium and the large difference in melting points makes it difficult to melt both materials in a normal welding joint.

Plutonium is welded using direct polarity DC or AC; DC is more satisfactory for heavy work where relatively deep penetration is desired, while AC is more satisfactory for thin work or spot welds.

It is usually difficult to duplicate settings on two welding machines of the same make and model and produce identical welds. This becomes more difficult with different makes and models because each make has inherent characteristics which become more evident when working with thin material. Table 1 gives the ranges of currents and other specifications found to be satisfactory for various types of welds using the Motor-Generator Set and P and H Machine described previously. Filler rod was not used.

Aluminum is welded to plutonium the same as if it were plutonium. Filler rod of the same composition as either the plutonium or aluminum metal can be used if desired.

Smaller welding machines can be used for light work, or the more versatile larger machines, coupled with the external resistor, operate satisfactorily where very low currents are required. Helium can be used in place of argon; however, it is impossible to strike an arc using helium at very low currents unless a strong high frequency source is available. The arc is struck in argon using the foot-switch operated bypass valve, and then the gas is switched to helium or a helium-argon mixture from the gas mixer and proportioner after the arc has been established. The gas or gas mixture for any weld containing plutonium will vary with the plutonium alloy and other metal used. Using the gas mixer and proportioner, various mixtures can be readily tried.

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TABLE 1

DELTA-STABILIZED PLUTONIUM WELDING DATA

Material and Thickness	Type of Weld	Welding Current, amp.	Welding Electrode[a]	Welding Torch[b]	Gas Flow,[c] liters/min.	Ceramic Cup[b]	Remarks
Pu to Pu 0.020 in. sheet	Lap with back-up	AC, 1-3	0.040	HW-9	Argon, 5	HW-4	Use external resistor in series with leads to torch to reduce current[d]
Pu to Pu 0.040 in. sheet	Lap or butt with back-up	AC, 2-6	1/16	HW-9	Argon, 5	HW-5	Use external resistor in series with leads to torch to reduce current[d]
Pu to Pu 0.040 in. sheet	Butt spot No back-up	AC, 5-7	0.040	HW-8 Series 4 spot gun	Argon, 5	HW-5	P and H machine using 30 - 50 cycles on spot gun timer and continuous high frequency
Pu to Pu 0.125 in. sheet	Lap or butt with back-up	AC or DC, 15-20	3/32	HW-9	Argon, 5 or 50% A-50% He	HW-6	DC preferred on lap for maximum penetration. AC preferred on butt to minimize burn-through
Pu to X[e] 0.040 in. sheet	Lap with back-up	AC or DC, 5-7	1/16 or 3/32	HW-9	Argon, 5 or 50% A-50% He	HW-5	Play arc on X metal only

[a] Two percent thoriated-tungsten electrodes.

[b] Linde Air Products Co.

[c] Flow through torch in a glove box containing less than 1 percent oxygen.

[d] Set welding machine at a suitable current where it will operate satisfactorily and use external resistor to control current. (Most welding machines are not stable at minimum power settings.)

[e] X = Uranium, aluminum, iron, steel, nickel, copper, brass, molybdenum, platinum, niobium , or Hastelloy.

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Weld Strength

It is very difficult to establish the exact strength of a plutonium-welded joint because the tensile strength of the parent metal can vary 50 percent or more, depending on the amount and specific delta-stabilizing material, the prior annealing and cold cycling treatment, and previous work hardening.

In general, plutonium-to-plutonium welded joints will be at least 80 percent as strong as the parent metal. Weaker joints can usually be traced to a poor inert atmosphere.

Frequently, plutonium welds to other metals will be stronger than the original plutonium. This depends on the alloy formed in the weld area.

Special Butt Welds

A technique was developed for making 3 in. continuous butt welds on 0.040 in. thick plutonium where no back-up or filler rod could be used. The two pieces were held against each other using a spring-loaded fixture which ensured pressure at the joint at all times. A 0.040 in. diameter platinum wire was held at the joint in the position of a feed filler rod. A 3 amp. DC arc was struck and maintained near the tip of the wire. As the plutonium becomes soft, it flows together at the wire tip. By moving the wire slowly along the joint, a seam with a slight cavity in the center was obtained. Extreme care is required in moving the wire so as not to push it through the plutonium. A fresh tip is required on the end of the wire for each weld.

This technique can also be used for obtaining spot welds on thin material.

SUMMARY AND CONCLUSIONS

Delta-stabilized plutonium can be welded to itself or a variety of other metals using standard inert-gas metal-arc techniques and equipment. An inert atmosphere is used in the welding enclosure to protect all surfaces from oxidation. The plutonium is prepared for welding by wire brushing or sanding the weld areas in an inert atmosphere just prior to welding.

External resistors can be used in the output leads of commercial welding machines to reduce and stabilize the current at the low current requirements for thin section welding.

Because of the large volume change of plutonium as it transforms from the beta to alpha phase at 125°C, pure plutonium invariably cracks when welded.

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