Amersham Corporation
40 North Avenue
Burlington, Massachusetts 01803
Telephone (617) 272-2000

71-9033

23 August 1990

Mr. Charles MacDonald, Chief
Transportation Branch
Division of Safeguards
and Transportation, NMSS
United States Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. MacDonald:

I have submitted the additional information you requested concerning docket number 71-9033.

Drawing number 66025 has been revised to show the following corrections:

a) A copy of Mil-Spec W-6858 has been enclosed as Appendix A, the details of the spot welding procedure are includ ed within this specification. The welds are inspected to assure they meet the minimum requirements as specified in drawing 66025 sheet 3. This procedure is stated in Section 8.1.1.

b) The size, type and location of the spot welds on the bottom plate.

c) The reference to sheet 4 has been changed to sheet 3.

d) The shell material is specified as stainless steel for the new models, beginning with serial number 4488.

The Model 660 that was subjected to the drop and puncture test was manufactured in accordance with drawing number 66025, revision C, and consisted of the stainless steel shell. The gross weight of the package was 53 pounds. The test report has been revised to reflect these details.

The operating instructions have been revised to include a procedure that physically verifies that this package s empty prior to shipment.

These changes have been submitted as revised pages, and revision instructions are enclosed.

Amersham

NTOI 1/

I trust these changes answer all your questions, and allow you to complete your review. If I can provide any additional information, please contact me.

Sincerely,

Cathleen M. Roughan

Cathleen M. Roughan
Radiation Safety Officer

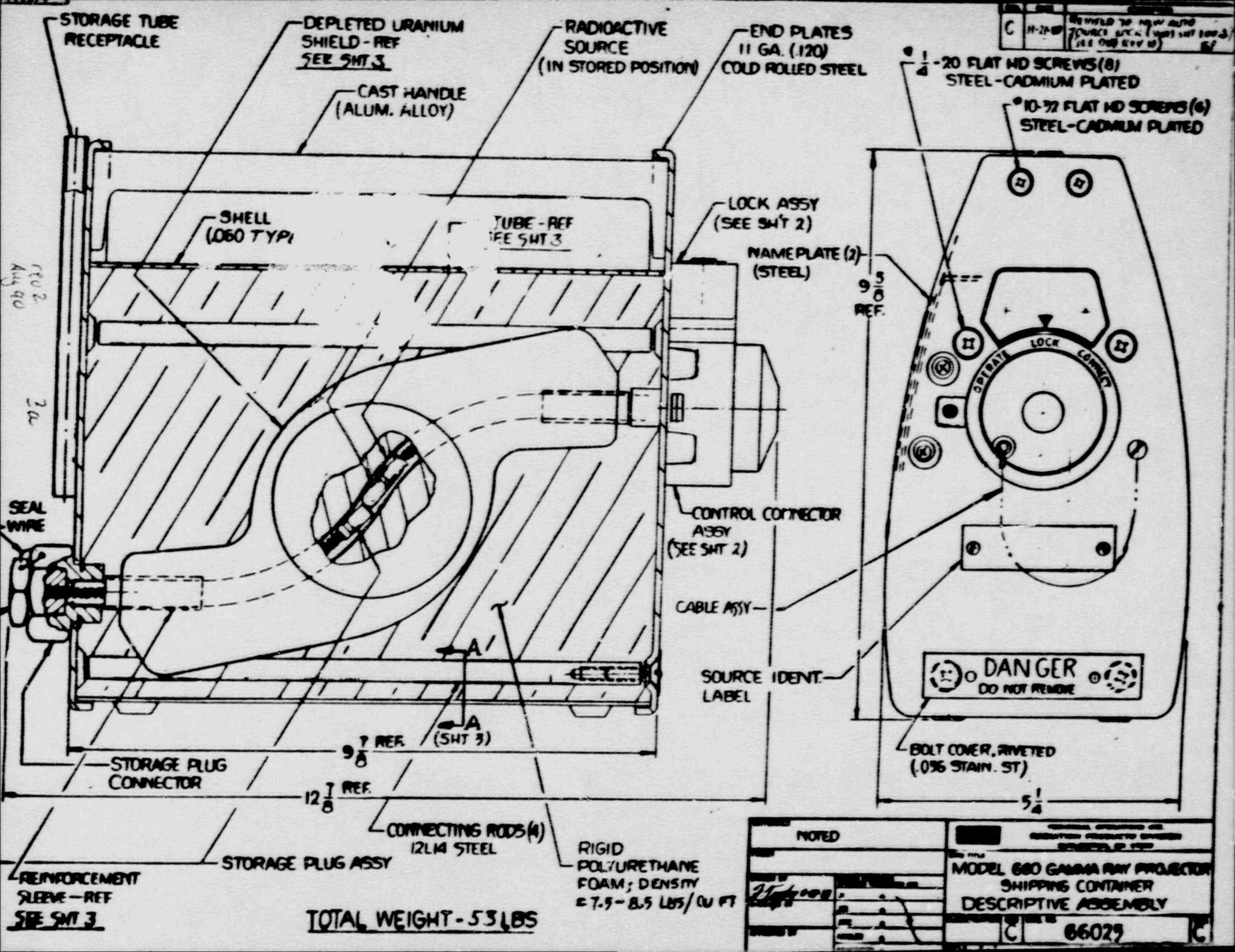
CMR/bt

Enclosures

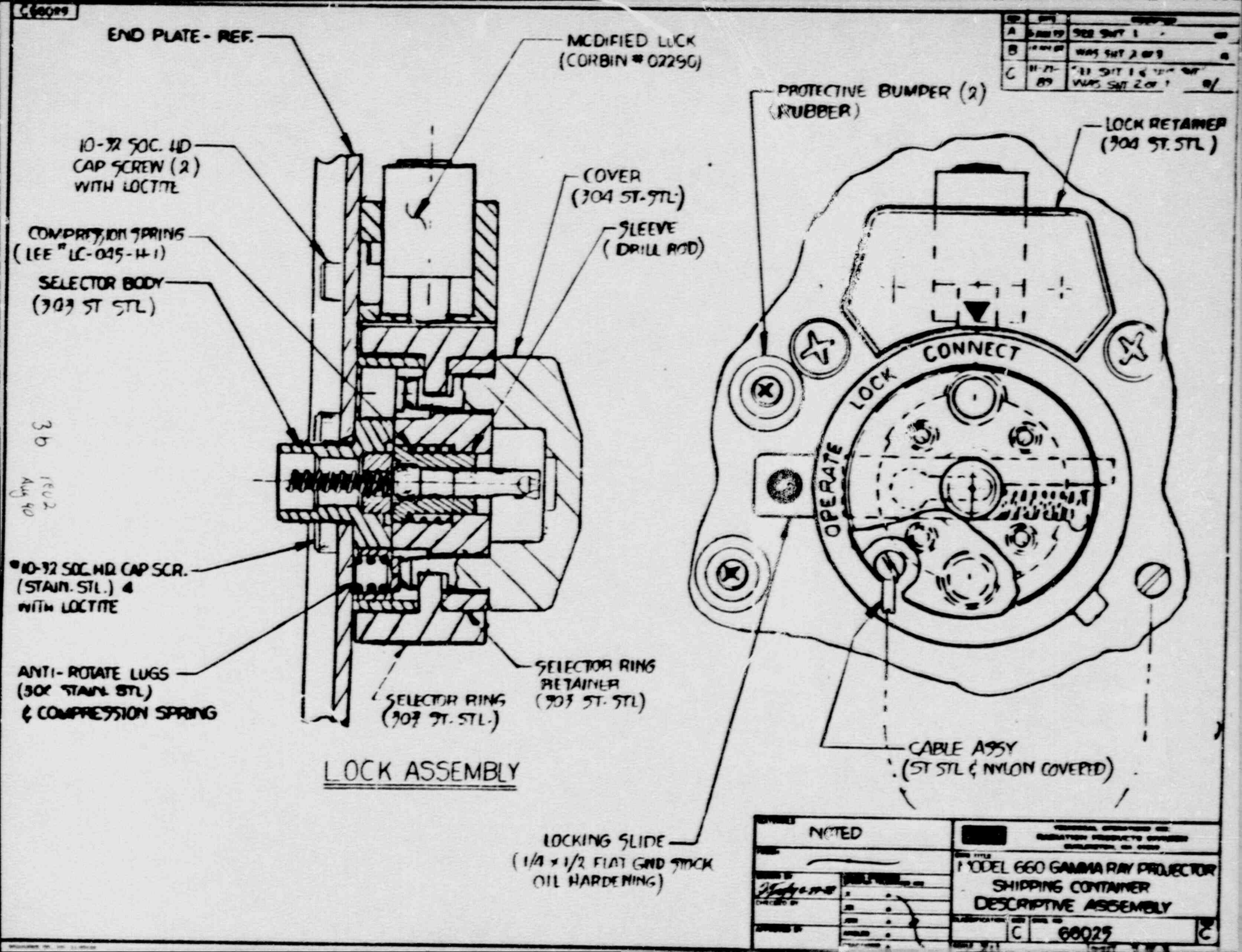
REVISION INSTRUCTIONS

REMOVE	INSERT
12b, Revision 2	12b, Revision 3
12e - f, Revision 2	12e - f, Revision 3
35 - 37, Revision 1	35 - 37b, Revision 2

APPENDIX A


STORAGE TUBE RECEPTACLE
DEPLETED URANIUM SHIELD - REF SEE SHT 3
CAST HANDLE (ALUM. ALLOY)
RADIOACTIVE SOURCE (IN STORED POSITION)
END PLATES 11 GA. (.120) COLD ROLLED STEEL
1/4-20 FLAT HD SCREWS (8) STEEL-CADMIUM PLATED
10-32 FLAT HD SCREWS (6) STEEL-CADMIUM PLATED
SHELL (.060 TYP)
TUBE - REF SEE SHT 3
LOCK ASSY (SEE SHT 2)
NAMEPLATE (2) (STEEL)
9 5/8 REF.
OPERATE
LOCK
CONNECT
SEAL WIRE
CONTROL CONNECTOR ASSY (SEE SHT 2)
CABLE ASSY
SOURCE IDENT. LABEL
DANGER
DO NOT REMOVE
A
A (SHT 3)
9 7/8 REF.
STORAGE PLUG CONNECTOR
12 7/8 REF.
BOLT COVER, RIVETED (.036 STAIN. ST)
5 1/4
CONNECTING RODS (4) 12L14 STEEL
RIGID POLYURETHANE FOAM; DENSITY = 7.5 - 8.5 LBS/CU FT
STORAGE PLUG ASSY
REINFORCEMENT SLEEVE - REF SEE SHT 3
TOTAL WEIGHT - 53 LBS
NOTED
MODEL 680 GAMMA RAY PROJECTOR SHIPPING CONTAINER DESCRIPTIVE ASSEMBLY
66029
C
C

A		SEE SHT 1
B		WAS SHT 2 OF 3
C	11-21-89	SEE SHT 1 & 3 WAS SHT 2 OF 3



LOCK ASSEMBLY

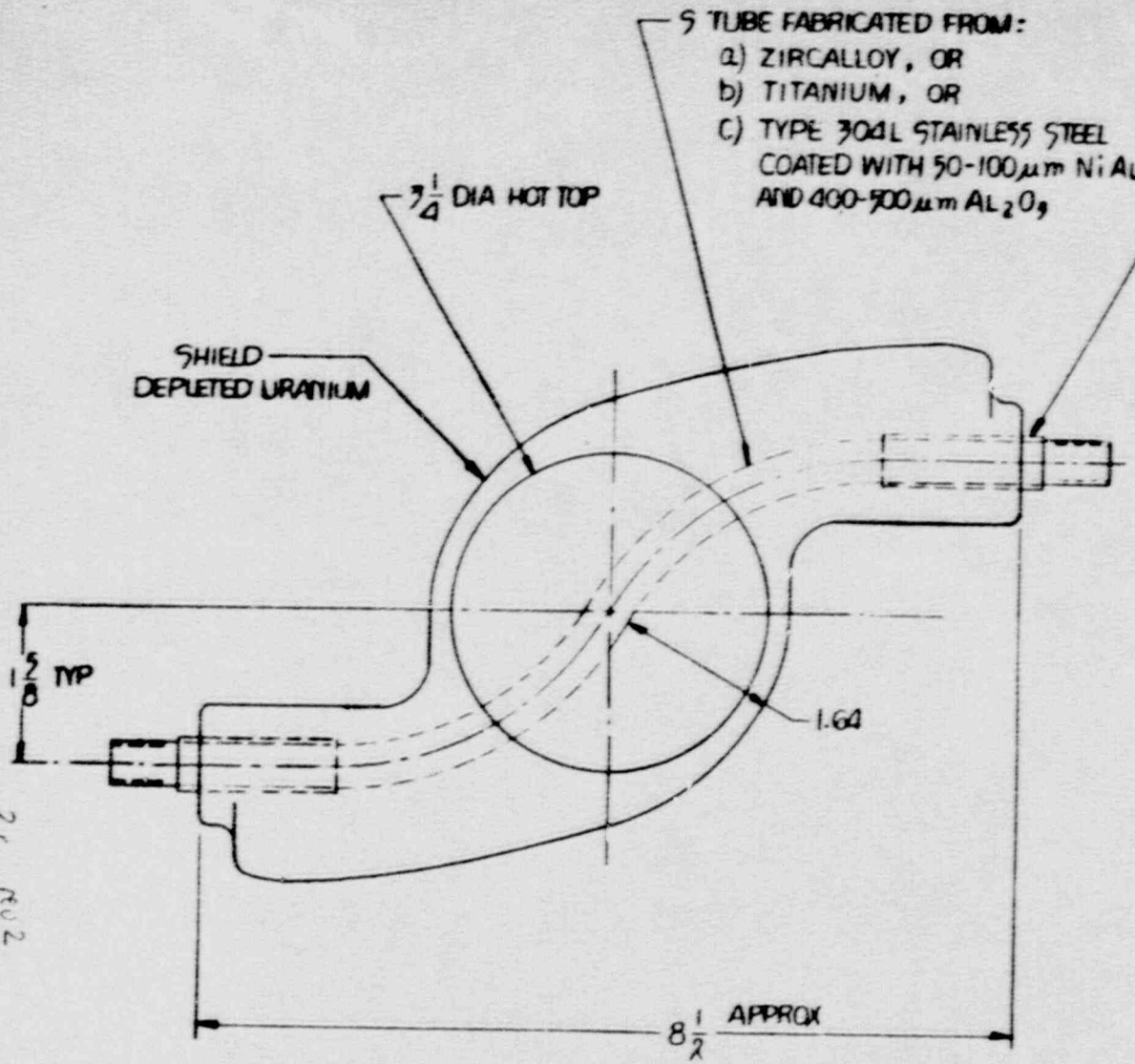
30 REV 2 Aug 90

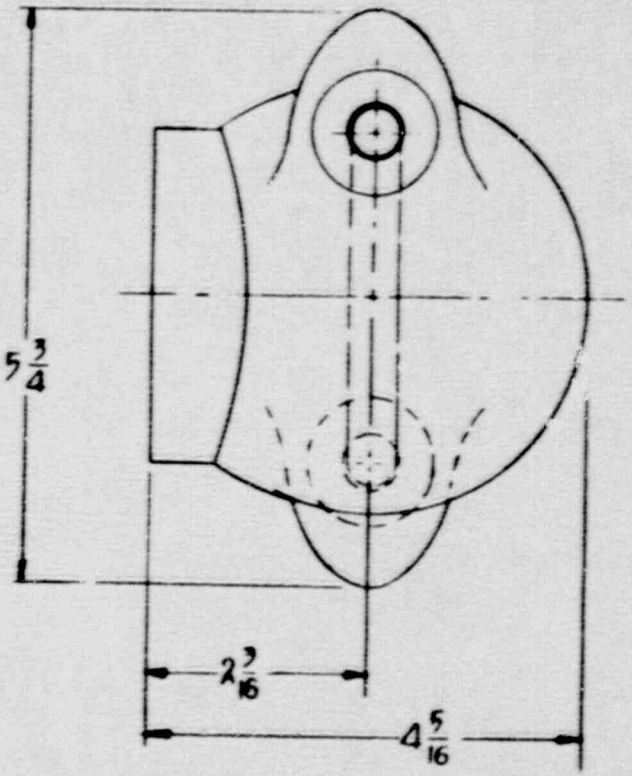
NOTED

MODEL 660 GAMMA RAY PROJECTOR SHIPPING CONTAINER DESCRIPTIVE ASSEMBLY

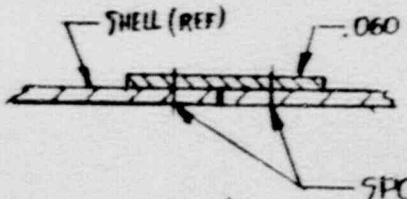
C 68029 C

C	11-22	WAS SHT 4 OF 4 & REV OF THIS SHT WAS — REV C ADDED SECT. A-A





3c REV 2 Aug 80



SECTION A-A
SCALE: 1/1

SHIELD DATA
37 LBS

AS NOTED

[redacted] RADIATION PRODUCTS DIVISION

MODEL 660 GAMMA RAY PROJECTOR
SHIPPING CONTAINER
DESCRIPTIVE ASSEMBLY

C 66025 C

TEST REPORT

BY: Cathleen Roughan
Dave Duncanson

DATE: 13 October 1989

SUBJECT: Model 660 Free Drop Test

On 29 September 1989, a prototype Model 660 package manufactured in accordance with drawing number 66025, revision C, was subjected to a free drop test in accordance with the requirements of 10 CFR 71.73(c) (1) and IAEA Safety Series No. 6, paragraph 719(a) The test package was constructed out of stainless steel, had an automatic securing mechanism and weighed 53 pounds. . This test was performed at Valley Tree Service, Groveland, Ma. The ambient temperature was approximately 50 degrees Fahrenheit with normal humidity.

The Model 660 package was dropped from a height of 9.1 meters (30 feet) onto a target. The target consisted of a concrete cube, each side measuring 1.2m (48 inches) upon which had been wet floated a steel plate 0.9m (36 inches) wide, 0.9m (36 inches) long, and 25mm (one inch) thick. This target conforms to the guidance for an essentially unyielding surface as prescribed in paragraph 701 of IAEA Safety series No. 37.

The package struck the target with the center of gravity over the locking assembly as shown in the drawing. This caused the package to strike at a 45 degree angle, impacting the bottom edge of the locking assembly.

As a result of this test, there was no impairment of any design or safety features of the package. There was no structural damage to the locking assembly or package closure. There was no release of the package contents. Photographs showing the damage are attached to this test report.

A shielding efficiency test performed subsequent to the completion of the Model 660 test program demonstrated that the free drop tests did not reduce the shielding efficiency of the package.

Revision 3
August 1990

CMR230

TEST REPORT

BY: Cathleen M. Roughan
Dave Duncanson

DATE: 2 March 1990

SUBJECT: Model 660 Puncture Test

On 29 September 1990, a prototype Model 660 manufactured in accordance with drawing number 66025, revision C, was subjected to a puncture test in accordance with the requirements of 10 CFR 71.73(c) (2) and IAEA Safety Series No. 6, paragraph 719(b). The test package was constructed out of stainless steel, had anautomatic securing mechanism and weighed 53 pounds. This test was performed at Valley Tree Service, Groveland, MA.

Immediately following the free drop test, the prototype Model 660 package was dropped from a height of one meter onto a target. The target consisted of a right circular cylindrical steel billet 152mm (6 inches) in diameter and 203mm (8 inches) high, mounted onto the target used in the free drop tests.

During the drop, the package impacted the target squarely on the shipping cap of the locking assembly. There was no observable additional deformation as a result of this drop.

As a result of these tests, there was no impairment of any design or safety features of the package. There was no structural damage to the locking assembly or package closure. There was no release of the package contents.

A shielding efficiency test performed subsequent to completion of the Model 660 test program demonstrated that these puncture tests did not reduce the shielding efficiency of the package.

A second puncture test on the same package that was subjected to the previous tests was conducted on 2 March 1990, in order to assess the impact of a 45 degree drop on the puncture bar.

The steel billet described above was set on an essentially yielding surface (a 4-foot by 4-foot by 1/2 inch thick steel plate, on a concrete slab 20 feet by 20 feet by 3 feet thick).

The 660 was dropped from a height of one meter onto the target. The 660 lock assembly hit the puncture bar on 45 degrees at the edge of the puncture bar. Since this was not a solid impact with the entire weight of the container over the lock assembly, we conducted another puncture test.

Revision 3
August 1990

In the second puncture test, the lock assembly impacted a 45 degree angle in the middle of the puncture bar. In this test the weight of the 660 was over the lock assembly. As a result of this test there was only minor damage to the package as indicated in the photographs. The lock assembly was still secured to the package with no movement of the lock assembly.

The cumulative damage due to both the 30-foot drop test and the 3 puncture tests was minimal and did not impair the structural integrity of the package. A shielding evaluation indicated there was no increase in radiation levels.

12. Secure the source(s) in the source changer in accordance with the appropriate source changer instruction manual.

13. Disconnect the control unit and source guide tube from the exposure device as in Step 23 of the Operating Procedure and disconnect the source guide tube from the source changer.

14. Remove the source identification plate from the exposure device and attach it with seal wire to the source holddown cap.

15. If the exposure device contains a source, affix the identification plate of the new source to the exposure device. If not, attach an EMPTY tag to the handle of the exposure device.

16. If the source changer is to be transported, survey it to determine the correct shipping label required as in Shipping Radioactive Material. (Radiation levels must not exceed 200 mR/hr at the surface nor 10 mR/hr at one meter from the surface.) Bolt the source changer cover in place and secure it with seal wire.

17. Return the source changer promptly to Amersham. Demurrage rental charges will be assessed for containers held beyond normal operating time.

Shipment of Radioactive Source

1. Ensure that the source is locked into place in its storage position. To check this, the lock should be in the down position, the key removed, and the selector ring should be immobile. Attach a tamper proof security seal with an identification mark to the storage plug.

2. If the shipping container is to be packaged in a crate or other outer packaging, the outer packaging must be strong enough to withstand the normal conditions of transport. These requirements are outlined in 10 CFR 71. The shipping container should be put in the outer package with sufficient blocking to prevent shifting during transportation.

3. Perform a radioactive contamination wipe test of the outer shipping package. This consists of rubbing filter paper or other absorbent material, using heavy finger pressure, over an area of 100 cm2 (16 in2) of the package surface. The activity on the filter paper should not exceed 0.001 uCi of removable contamination.

4. Survey the package with a survey meter at the surface and at a distance of one meter from the surface to determine the proper radioactive shipping labels to be applied to the package as required by 49 CFR 172.403. The radiation exposure limits for each shipping label are given in Figure 4.1. If radiation levels above 200 mR/hr at the surface or 10 mR/hr one meter from the surface are measured, the container must not be shipped.

5. Properly complete two shipping labels indicating the radioactive isotope, activity and the Transport Index. The Transport Index is used only on Yellow II and Yellow III labels and is defined as the maximum radiation level in milliroentgens per hour measured at a distance of one meter from the surface of the package. Put these two labels on opposite sides of the container after making sure any previous labels have been removed. The package should be marked with the proper shipping name (Radioactive Material, Special Form, n.o.s., UN 2974). If the exposure device is packaged inside an outer container, mark the outside package "INSIDE PACKAGE COMPLIES WITH PRESCRIBED SPECIFICATIONS - TYPE B USA/9033/B(U)."

6. Complete the appropriate shipping papers - These shipping papers must include:

   a. Proper shipping Name (Radioactive Material, Special Form, n.o.s.) and Identification Number (UN 2974).

   b. Name of Radionuclide (Iridium-192).

   c. Activity of the Source (in Curies).

   d. Category of Label Applied (i.e. Radioactive Yellow II).

   e. Transport Index.

   f. Package Identification Number (i.e. USA/9033/B(U) Type B(U)

   g. Shipper's Certification.

   "This is to certify that the above named materials are properly classified, described, packaged, marked and labeled and are in proper condition for transport according to the applicable regulations of the Department of Transpor tation."

Notes:

1. For air shipments, the following shipper's certification may be used:

   "I hereby certify that the contents of this consignment are fully and accurately described above by proper shipping name and are classified, packed, marked and labeled, and are in proper condition for carriage by air according to applicable national govermental regulations."

2. For air shipments to, from or through the United States, a "CARGO AIRCRAFT ONLY" label and the shipping papers must state:

   "THIS SHIPMENT IS WITHIN THE LIMITATIONS PRESCRIBED FOR CARGO ONLY AIRCRAFT."

6. Due to the depleted uranium used as shielding in the exposure device, a notice must also be enclosed in or on the package included with the packing list, or otherwise forwarded with the package. This notice must include the name of the consignor or consignee and the following statement:

   "This package conforms to the conditions and limitations specified in 49 CFR 173.424 for expected radioactive material, articles manufactured from depleted uranium, UN 2909.

7. Return the container to Amersham Corporation according to proper procedures for transporting radioactive material as established in 49 CFR 171-178.

   NOTE: The U.S. Department of Transportation, in 49 CFR 173.22 (c) requires each shipper of Type B quantities of radioactive material to provide prior notification to the consignee of the dates of shipment and expected arrival.

Shipment of an Empty Package

1. For shipment of an empty model 660, you must first assure there are no unauthorized source assemblies or cropped sources within the container, by performing the following procedure.

   a) Remove the authorized source assembly from the model 660 in accordance with the applicable operations manual for the storage device.

   b) After removing the source and disconnecting the source assembly, attach the jumper (dummy connector without a serial number) to the male connector of the drive cable.

   c) Return the drive cable and connector to the model 660 and disconnect the controls.

   d) Insert dust cover cap, place selector ring in lock position, depress lock and remove the key. Insert the shipping plug and seal wire. Place an EMPTY tag on the device.

2. Assure that the levels of removable radioactive contamination on the outside surface of the outer package do not exceed 0.001 microcurie per 100 square centimeters.

3. When you have assured the model 660 is empty, survey the device and prepare the package for transport depending upon the radiation levels obtained, as given below.

   a) If the radiation level is below 0.5 mR/hr at the surface, and there is no measurable radiation level at one meter from the container, no label is required. Mark the outside of the package with the proper shipping name (Radioactive material, articles manufactured from depleted uranium UN 2909). Mark the outside of the package:

   "Exempt from specification packaging, shipping paper and certification, marking and labeling and exempt from the requirements of Parts 171-178 per 49 CFR 173.421-1 and 49 CFR 173.424."

   NOTE: This does not exempt the shipment from the reporting requirements listed in Parts 171-178 pertaining to the reporting of contamination incidents or other radiation incidents.

   Additionally, a notice must be enclosed in or on the package included with the packing list or otherwise forwarded with the package. This notice must include the name of the consignor or consignee and the statement:

   "This package conforms to the conditions and limitations specified in 49 CFR 173.424 for excepted radioactive materials, articles manufactured from depleted uranium, UN 2909."

b) If the surface radiation level exceeds 0.5 mR/hr, or if there is a measurable radiation level at one meter from the surface, use the criteria of Table 1 to determine the proper shipping labels to be applied to the package. Mark the outside of the oute shippng package with the proper shipping name and identification number (Radioactive Material, LSA, n.o.s., UN 2912).

If the container is packaged inside a crate or other outer packaging, mark the outer package with the statement " INSIDE PACKAGE COMPLIES WITH PRESCRIBED SPECIFICATIONS", USA/9006/B(U), Type B.

Properly complete the shipping papers as listed in section 7.1, according to the instructions in Shipment of Radioactive Sources. The isotope will be Uranium-238 and the activity is 5 millicuries.

APPENDIX A

MIL-W-6858C
1 OCTOBER 1984
SUPERSEDING
MIL-W-6858B
3 NOVEMBER 1980

MILITARY SPECIFICATION

WELDING, RESISTANCE: ALUMINUM, MAGNESIUM, NON-HARDENING STEELS OR ALLOYS, NICKEL ALLOYS, HEAT-RESISTING ALLOYS, AND TITANIUM ALLOYS; SPOT AND SEAM

This specification is mandatory for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers requirements for resistance spot and seam welding of the following nonhardening materials (as defined herein—see 4.1.5.):

Group (a)—Aluminum, aluminum alloys, and magnesium alloys.

Group (b) Steels, austenitic and ferritic and precipitation hardening steels, nickel and cobalt base alloys.

Group (c)—Titanium and titanium alloys.

NOTE: Hereafter, the above metals shall be referenced when the word "alloys" is used.

1.2 Classification. Classification shall be based on function of the spot and seam welded joint. Welds shall be classified as follows:

Class A—Used in joints, the single failure of which during any operating condition would cause loss of the weapons system or one of its major components, loss of control, unintentional release of, or inability to release any armament store, failure of gun installation components, or which may cause significant injury to occupants of the manned weapons system.

Class B—Used in joints, the failure of which would reduce the overall strength of the weapons system or preclude the intended functioning or use of equipment.

Class C—A weld which is considered noncritical and for which no stress analysis is requested.

1.2.1 The classification of welds in foil thicknesses (0.008 inch or less) shall be limited to class A (structural applications) and class C (nonstructural applications). Unless requirements for foil thickness materials are specifically noted on the drawing or specifications for the component, the requirements of this specification shall apply.

1.2.2 The class of welding shall be designated on the item specification or drawing. Class A spot welding shall require the specific approval of the procuring activity, except that the Inspector may approve application for which satisfactory spot welded prototypes exist. Approval will be based upon available evidence of the adequacy of the design and pattern of spot welding, and where considered necessary by the procuring activity, upon the satisfactory performance of suitable static and repeated loading tests.

1.2.3 Unless special shear strength requirements are established (see 1.2.3.1, 1.2.3.2, and 1.2.3.3), the shear strength for classes A, B, and C shall be in accordance with tables I, II, III, and IV, as applicable.

1.2.3.1 The requirements specified herein are considered applicable in most of the conditions encountered in resistance welding. When special conditions are encountered which render the requirements of this specification inapplicable, the contractor shall submit alternate

FSC THJM

procedures and requirements for approval by the procuring activity. The request for approval shall include a description of the conditions which render the requirements inapplicable, such as reduced flange widths and space limitations, and shall include data to indicate that the alternate procedures and requirements are adequate for the application. Previous approvals of alternate procedures shall remain in effect under this specification until the contractor is notified otherwise by the procuring activity.

1.2.3.2 Increased minimum shear strength values may be maintained in classes A and B welds, provided all other requirements specified herein are met. The design shear strength shall conform to the requirements of 1.2.3.3.

1.2.3.3 When reduced or increased minimum shear strength values are used, the engineering drawing or applicable process document must specify the minimum test shear strength values established. Unless otherwise approved by the procuring activity, the design shear strength values calculated for the strength of spot welded joints shall not exceed 80 percent of the specified minimum shear strength values established as permitted by 1.2.3.1 and 1.2.3.2.

1.2.4 Tack welds are applicable in this specification only to the extent specified in 7.5 and 7.5.1.

TABLE I. *Minimum required shear strength per weld for spot weld shear specimens and minimum average strength*[1]

Nominal thickness of thinner sheet (inch)[1]	Group (a) materials							
	Ultimate strength 85,000 psi and above		Ultimate strength 55,000 to 84,999 psi		Ultimate strength 19,500 to 54,999 psi		Ultimate strength below 19,500 psi	
	Pounds per weld							
Thickness, see Standard MS33537[1]	Minimum	Minimum average	Minimum	Minimum average	Minimum	Minimum average	Minimum	Minimum average
0.010	60	75	50	65	----	----	----	----
0.012	75	95	65	85	30	40	20	25
0.016	110	140	100	125	70	90	50	65
0.018	125	160	115	145	85	110	65	85
0.020	140	175	135	170	100	125	80	100
0.022	160	200	155	195	120	150	95	120
0.025	185	235	175	200	145	185	110	140
0.028	215	270	205	260	175	220	135	170
0.032	260	325	235	295	210	265	165	210
0.036	305	385	275	345	255	320	195	245
0.040	345	435	310	390	300	375	225	285
0.045	405	510	370	465	350	440	260	325
0.050	465	585	430	540	400	500	295	370
0.056	555	670	515	645	475	595	340	425
0.063	670	840	610	765	570	715	395	495
0.071	825	1,035	720	900	645	810	450	565
0.080	1,025	1,285	855	1,070	765	960	525	660
0.090	1,255	1,570	1,000	1,250	870	1,090	595	745
0.100	1,490	1,865	1,170	1,465	940	1,175	675	845
0.112	1,780	2,225	1,340	1,675	1,000	1,255	735	920
0.125	2,120	2,650	1,625	2,035	1,050	1,315	785	985
0.140	2,525	3,160	1,920	2,400	----	----	----	----
0.160	3,120	3,900	2,440	3,050	----	----	----	----
0.180	3,725	4,660	3,000	3,750	----	----	----	----
0.190	4,035	5,045	3,240	4,050	----	----	----	----
0.250	7,350	9,200	6,400	8,000	----	----	----	----

[1] Strength of material shall be based on its guaranteed minimum ultimate tensile strength. In the case of "O" temper materials the maximum tensile shall apply.

[2] For test data requirements on class A welds in material thicknesses of 0.008 inch or less see table IV.

[3] Standard MIL-STD-204 may be used as an alternate. Interpolation can be used to establish strength values.

TABLE II. *Minimum required shear strength per weld and minimum average strength for spot weld shear test specimens*

Nominal thickness of thinner sheet (inch) [1]	Group (b) materials [2]							
	Ultimate strength above 185,000 psi		Ultimate strength 160,000 to 185,000 psi		Ultimate strength 90,000 to 160,000 psi		Ultimate strength below 90,000 psi	
	Pounds per weld							
Thickness, see Standard MS33537	Minimum	Minimum average	Minimum	Minimum average	Minimum	Minimum average	Minimum	Minimum average
0.009	200	245	175	210	130	160	100	125
0.010	245	305	205	255	160	195	115	140
0.012	350	410	275	340	200	245	150	185
0.016	480	595	400	495	295	365	215	260
0.018	590	725	490	600	340	415	250	305
0.020	635	785	530	655	390	480	280	345
0.022	730	905	610	755	450	550	330	405
0.025	870	1,075	725	895	530	655	400	495
0.028	1,025	1,260	855	1,055	635	785	465	575
0.032	1,250	1,545	1,045	1,280	775	955	565	695
0.036	1,500	1,850	1,255	1,545	920	1,140	690	860
0.040	1,750	2,150	1,460	1,800	1,065	1,310	815	1,000
0.045	2,100	2,600	1,795	2,210	1,285	1,585	1,005	1,240
0.050	2,450	3,000	2,125	2,620	1,505	1,855	1,195	1,475
0.056	2,880	3,550	2,550	3,145	1,770	2,185	1,460	1,800
0.063	3,550	4,375	3,090	3,815	2,110	2,595	1,760	2,170
0.071	4,200	5,150	3,730	4,595	2,535	3,125	2,080	2,560
0.080	4,850	6,000	4,410	5,440	3,005	3,705	2,455	3,025
0.090	5,600	6,900	5,090	6,275	3,515	4,335	2,885	3,560
0.100	6,300	7,750	5,720	7,050	4,000	4,935	3,300	4,070
0.112	7,000	8,600	6,365	7,855	4,545	5,610	3,795	4,675
0.125	7,785	9,600	7,080	8,730	5,065	6,250	4,300	5,310

[1] For test data requirements on class A welds in material thicknesses of 0.008 inch or less, see table IV.

[2] Strength of material shall be based on its guaranteed minimum ultimate tensile strength.

[3] Standard MIL-STD-204 may be used as an alternate. Interpolation can be used to establish strength values.

TABLE III. *Minimum required shear strength per weld for spot weld shear specimens and minimum average strength* [1]

Nominal thickness of thinner sheet (inch)	Group (a) materials				Nominal thickness of thinner sheet (inch)	Group (a) materials			
	Ultimate strength above 100,000 psi		Ultimate strength 100,000 psi or below			Ultimate strength above 100,000 psi		Ultimate strength 100,000 psi or below	
	Pounds per weld					Pounds per weld			
Thickness, see Standard MS33522 [2]	Minimum	Minimum average	Minimum	Minimum average	Thickness, see Standard MS33522 [2]	Minimum	Minimum average	Minimum	Minimum average
0.010	205	265	160	210	0.045	1,795	2,340	1,285	1,670
0.012	275	360	200	260	0.050	2,125	2,760	1,505	1,910
0.016	400	520	295	385	0.056	2,550	3,320	1,770	2,300
0.018	490	635	340	445	0.063	3,000	3,900	2,110	2,730
0.020	530	690	390	510	0.071	3,380	4,400	2,395	3,115
0.022	610	795	450	585	0.080	3,810	4,960	2,700	3,510
0.025	725	945	530	690	0.090	4,290	5,570	3,040	3,955
0.028	855	1,110	635	825	0.100	4,760	6,170	3,380	4,395
0.032	1,045	1,360	775	1,000	0.112	5,320	6,800	3,785	4,925
0.036	1,255	1,630	920	1,200	0.125	5,950	7,700	4,220	5,490
0.040	1,460	1,900	1,065	1,385					

[1] Strength of material shall be based on its guaranteed minimum ultimate strength.

[2] Standard MIL-S-7742 may be used as an alternate. Interpolation can be used to establish strength values.

[3] For test data requirements on class A welds in material thicknesses of 0.008 inch or less, see table IV.

TABLE IV. *Minimum required shear strength per linear inch, and spacing for spot weld shear specimens*

Thickness of thinnest outer sheet (inch)	Spots/inch		Group (a) materials		Group (b) and (c) materials			
			Ult. str.		Ult. str.	Ult. str.	Ult. str.	Above 125 ksi
	Standard (N_s) [1]	Range [2,3]	Below 56 ksi	56 ksi and above	Below 90 ksi	90 to 150 ksi (exclusive)	150 to 125 ksi (inclusive)	
			Minimum shear strength--pounds per inch (Xm)					
0.001	40	1-50	20	30	45	65	80	90
0.002	20	1-30	40	60	90	130	160	180
0.003	12	1-17	65	100	150	205	260	300
0.004	10	1-14	90	135	190	285	350	405
0.005	9	1-13	115	165	235	340	425	490
0.006	7	1-10	125	185	275	380	475	540
0.007	6	1-8	140	210	320	440	550	630
0.008	5	1-7	160	235	355	490	610	690

[1] When number of spots per inch is within 15 percent of the standard spots per inch requirement, the tabulated minimum shear strengths noted above shall apply.

[2] When number of spots differs from the standard spots per inch by 15 percent or greater, but do not exceed the noted range of spots per inch, applicable minimum shear strength shall be determined as noted below

$$\frac{Xm}{N_s}(K)N_r = X_r$$

Where:

Xm = Min. shear str. in accordance with table IV

N_s = Standard spots per inch in accordance with table IV

N_r = Required spots per inch (production part)

X_r = New min. shear strength requirement

K = (See below)

K = 1.15 when number of spots per inch is reduced greater than 15 percent of the standard spacing of table IV. (See 4.)

K = 0.90 when number of spots per inch is increased greater than 15 percent of the standard spacing, but within the range of table IV

[3] When the number of spots per inch is above the range indicated in table IV, the minimum shear strength shall remain constant at the value obtained at the top of the range.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on date of invitation for bids or request for proposals, form a part of this specification to the extent specified herein:

STANDARDS

MILITARY

MIL-STD-204—Thickness of Sheet and Strip Metals

MS33528—Thickness, Sheet, and Strip Metal

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement function should be obtained from the procuring activity or as directed by the contracting officer.)

3. EQUIPMENT

3.1 Welding machine. The welding machine shall consist of a suitable source of electrical energy, suitable electrodes, means of adequately cooling the electrodes, and a means of reliably controlling and indicating the magnitude of the current, the welding force, and the time of current flow to fulfill the requirements specified herein. The force and current controls shall operate so that no current flows until the welding force is applied at the welding electrodes. The current shall be cut off before the force is removed.

3.2 Electrodes. Suitable electrode material shall be used to perform welding in conformance with this specification.

3.3 Shear testing machines. The contractor shall provide spot weld shear testing machines as required. All shear testing machines shall be accurate within ±2 percent of the indicated reading. Portable spot weld shear test machines shall be checked for accuracy at intervals not to exceed 2 months.

3.4 Surface resistance indicators. The contractor shall provide one or more surface resistance indicators for checking the effectiveness of cleaning solutions and procedures engaged in preparing aluminum or magnesium alloys for spot welding. Surface resistance indicators shall be checked for accuracy and recalibrated as necessary.

3.5 Jigs and fixtures. All tooling that is required to locate welds or assist in the assembly of welded parts that must pass through the magnetic field during the welding operation in a manner that would cause magnetic disturbances to the welding cycle, shall be made of nonmagnetic materials insofar as possible. When the presence of the magnetic material requires a change in the welding current setting of more than 10 percent from the established setting, a separate welding schedule shall be established as outlined in section 6. Jigs and fixtures must be so designed that no welding current shunts through the locating devices rather than the work pieces. This will require the insulation of pins and locating strips.

3.6 Maintenance equipment. Unless otherwise specified, each item of equipment shall be inspected periodically as recommended by the manufacturer. Adequate maintenance shall be furnished, and defective parts affecting machine operation shall be replaced before production welding is resumed.

3.7 Definitions. For definitions of terms used in this specification, see 10.2.

4. MATERIALS AND METHODS OF PREPARATION

4.1 Permissible combinations. The combinations of alloys which may be welded shall be subject to the approval of the procuring activity. Specific approval of each combination is not required except when specified herein or when requested by the procuring activity.

4.1.1 *Aluminum and aluminum alloys.* Aluminum and aluminum alloys may be welded in any combination except that the following combinations and conditions shall not be welded without specific approval of the procuring activity:

(a) Bare to bare high strength heat treatable alloys (2014, 2024, 7075).

(b) Clad 2014 to bare 2024, clad 2014 to bare 7075.

(c) Clad 2014 to bare 2014.

(d) When the parts are exposed to severe corrosion, similar to that on seaplanes and amphibians, the welding of bare high strength alloys in any combination.

(e) Clad 7075 material in thickness less than 0.020 inch.

4.1.2 Magnesium alloys may be welded in any combination except for the alloy combinations not meeting the requirements of 4.1.5. The welding of magnesium alloys which may be exposed to sea water shall be subject to the approval of the procuring activity.

4.1.3 *Ferrous, nickel base, cobalt base and heat-resisting alloys.*

4.1.3.1 *Permissible combinations.* Austenitic heat and corrosion-resistant steels, precipitation hardening steel, nickel, and cobalt base alloys may be welded in any combination, except for alloy combinations not meeting requirements of 4.1.5.

4.1.3.2 Plain carbon steel with 0.15 percent or less nominal carbon content may be welded in any combination.

4.1.4. *Titanium and titanium alloys.* Titanium may be welded in any combination, except for the alloy combination not meeting the requirements of 4.1.5.

4.1.5 *Other materials.* Materials other than those covered in 4.1.1, 4.1.2, 4.1.3, and 4.1.4, previously not welded in production, shall require establishment of nonhardening and weld ductility characteristics. This evaluation shall be conducted without special heating sequence applied purposely to temper weld, as the spot welds in these materials shall develop an average tension strength not less than 25 percent of the minimum average shear strength of tables I, II, III and minimum values in table IV, when tested "as welded" and also after any thermal treatment which the part receives after welding. The tension specimen (tensile pull-out) configuration may be of any type which will satisfactorily apply axial tension load to the spot weld. Evaluation may be conducted on one gage thickness only. Materials which satisfactorily meet this requirement may be welded in production without further tension strength evaluations. If tension strength levels established herein are not obtained, the welding of such materials shall be considered outside the scope of this specification and any welding of these materials shall be in accordance with other specifictaions established or approved by the procuring activity.

4.2 Surface conditions. The surface of the parts to be welded shall be free from objectionable films such as oxides, scale, ink, grease, dirt, or other substances detrimental to the welding process.

4.2.1 *Resistance measurements.* The ability of the cleaning solutions and procedure to effectively clean the surfaces of group (a) materials shall be checked by surface resistance measurements. The contractor shall establish the maximum surface resistance readings acceptable, based on the surface condition immediately after cleaning.

4.2.2 *Group (a) materials.* Oxide coatings may be removed by abrasive means, such as wire brush, or by a suitable chemical treatment. The maximum time between the cleaning of parts and spot welding shall be established by the contractor. The contractor shall demonstrate that no deterioration of surface condition has taken place by making surface resistance measurements or suitable spot welding tests on at least two gage combinations of material on multiple spot shear specimens containing 25 consecutive welds in accordance with section 6. Typical conditions for storing the parts or materials shall be used for the demonstration.

4.2.3 *Cleaning procedure.* Where the cleaning procedure is changed, the contractor shall demonstrate to the satisfaction of the Inspector (1) by surface resistance measurements that the maximum value and consistency of surface cleanliness produced is at least equal to that of the previous method. The procedure shall also be spot checked on one gage combination of material on multiple spot shear specimens containing 25 consecutive welds in accordance with section 6, or (2) by recertifying all welding schedules in accordance with section 6 that are not within ±5 percent from the established settings, or by ±10 percent when only one setting is adjusted.

4.2.4 *Surface coatings.* Coatings which will improve the corrosion resistance or sealing characteristics without adversely affecting the weldability of the material may be applied prior to welding. Pertinent details shall be forwarded to the procuring activity for its information.

4.2.5 *Mating parts.* Mating parts assembled for welding shall fit so that before the first and each successive weld is made, the surfaces to be joined by the weld are in contact with each other or can be made to contact each other with manual pressure at the area where the weld is to be placed.

4.2.6 *Joint thickness.* Joint thicknesses shall be limited to those thicknesses or combination of thicknesses on which weld schedules can be established and production parts made to meet the requirements of this specification. (See section 7.)

5. QUALIFICATION OF WELDING MACHINES

5.1 Welding machines. Qualification tests of welding machines shall be performed to determine the consistency of operation of the machines at or near the desired operating range. To have his equipment qualified and approved for use, the contractor shall prepare test specimens as specified herein. Machines to be used for class C foil welding shall be considered acceptable provided welding schedules can be established to meet requirements of this specification (see section 6). The machine qualification data shall furnish the information indicated by reports A, B, and C (see figures 1, 2, and 3), as applicable. These reports shall be maintained by the contractor and shall be available for review by procuring activity.

5.1.1 *Test materials.* Test materials for group (a) qualification tests shall be either 2024-T3 or 7075-T6 alclad aluminum alloy, and for groups (b) and (c) qualification test material shall be a 300 series corrosion-resisting steel. Selection is at the option of the contractor. Under conditions where such materials are not welded in production, material most commonly used in production shall be used.

5.2 Machine qualification. Machines shall be qualified to meet the weld requirements for the highest classification for which it is intended to be used in production. A machine qualified to weld requirements of a higher weld classification shall be automatically considered qualified for lower weld classification. Only one machine of a distinctive type shall be required to pass the qualification tests specified herein and all other machines of the same type shall be considered qualified, provided satisfactory production settings for each have been established. Except for material 0.008 inch in thickness, only machines to be used for class A welding shall require qualification.

5.2.1 *Types of equipment.* Distinctive types of equipment are those differing in any of the following respects:

(a) Manufacturer of machine or control panel, or type of machine or model number.
(b) Electrical rating or capacity.
(c) Type of electrical energy.
(d) Type of pressure application.

5.2.2 *Requalification.* When the equipment has once been qualified, it need not be requalified for future contracts or production provided no change in basic material or range of settings is involved. A change of location within a plant, not involving a change in power line, does not necessitate requalification. Requalification shall be required if the machine is rebuilt or if significant operational changes are made therein. Approval of machines qualified under superseded specifications shall be honored except as specifically provided herein. A machine requiring requalification shall be recertified, as specified in section 6, on the thinnest-to-thinnest and thickest-to-thickest material combination welded in production. When machines doing class A welding require requalification, the welds shall also meet the radiographic quality requirements of 5.5.1.

5.3 Test specimens. For each group of alloys, a minimum of two sets of test specimens shall be required, one at each limit of the range of machine settings for which qualification is desired. For materials other than foil thicknesses, each set shall contain not less than 105 consecutive welds. For group (a) materials multiple spot shear specimens as indicated in figure 4 shall be prepared. For groups (b) and (c) materials, single spot specimens in accordance with figure 6 or multiple spot specimens as shown in figure 4 may be used. For foil thicknesses, groups (a), (b) and (c) materials, multiple spot joint efficiency specimens as indicated in figure 5 and containing standard spots per inch as indicated in table IV shall be pre-

pared. No maintenance attention or control adjustments are permitted during the welding of a set of specimens. The process details used in preparing specimens for qualification, such as method of cleaning, machine settings, and tip radii shall be those which would be used in production. The external quality of all welds shall meet the requirements of section 7. Internal quality shall be in accordance with requirements specified in this section.

5.4 Test requirements.

5.4.1 *Spot and roll spot welding (intermittent spaced welds made with fixed or rotating type electrodes).* Spot and roll spot welding machines shall be qualified as follows:

(a) For other than foil thickness materials: Class A, B, or C by making of not less than 105 welds per set. One hundred welds shall be tested in shear with the joint unrestricted and 5 welds shall be sectioned for metallurgical examination.

(b) For foil thickness materials. Class A by making one multiple spot joint efficiency panel of not less than 12 inches of consecutive welds. Ten 1-inch mupltiple spot test specimens shall be tested in shear with the joint unrestricted and a minimum of 1½ inches of welds shall be sectioned for metallurgical examination.

5.4.1.1 *Dimensions of shear test specimens.* After welding, the multiple spot specimens conforming to figure 4 or 5, as applicable, shall be cut into single or multiple spot shear specimens prior to testing. Dimensions of shear test specimens shall be as given in table V, unless otherwise specified.

5.4.2 *Seam welding (pressure) tight joints or overlapping spot welds made with roller-type electrodes.* Seam-welding machines shall be qualified:

(a) For other than foil thickness materials: Class A, B, or C by making a test specimen (s) consisting of at least 24 inches of seam weld. Details of test and metallurgical specimens required are noted in figure 7.

(b) For foil thickness materials: Class A by making a test specimen consisting of at least 12 inches of consecutive seam welds. Details of test and metallurgical specimens required are noted in figure 8.

5.4.2.1 Machines qualified for seam welding shall be considered qualified for equal weld classification roll spot welding, provided the machines meet the requirements of the certification tests of section 6.

5.4.3 *Intermittent spot welding (spot welds spaced two diameters or less apart).* Machines qualified for spot, roll, or seam welding shall be considered qualified for equal weld classification intermittent spot welding.

5.5 Radiographic examination (class A welds). All welds shall be subjected to radiographic examination for determination of internal defects and shall meet the quality requirements of this section. Radiographic examination is not required for classes B and C, but the specimens shall meet the quality requirements specified in section 7.

5.5.1 *Radiographic quality (for class A only).* For all metals, radiographs shall indicate that all welds are sound and free from cracks and spit-outs. Porosity, either singly or in combination, shall not have an aggregate area in group (a) materials greater than 5 percent and for group (b) and (c) materials greater than 10 percent of the area of the weld nugget in the plane in which the radiograph is taken, nor a linear dimension greater than

TABLE V. *Dimensions of shear test specimen in inches*

Nominal thickness of thinner sheets	Width or overlap (W) (minimum)		Length (A)
	Group (a) materials	Group (b) and (c) materials	
0.008 and under...	⅜ lap	⅜ lap	As required to perform shear test
0.009 to 0.030.....	⅜	⅜	
0.031 to 0.050.....	¾	1	
0.051 to 0.100.....	1	1	
0.101 to 0.130.....	1¼	1¼	
0.131 and over....	1½	1¼	

15 percent of the weld diameter and shall not extend to within 15 percent (of the welded diameter) of the boundaries of the cast weld structure. In addition, for those alloys whose radiographs have a high resolution of the internal structure, all the welds shall be free from lack of fusion, cladding inclusions, and the fused zone of the weld shall be generally consistent in size and regular in shape.

5.5.2 Internal quality standards other than specified in 5.5.1 may be established at the option of the contractor. The establishment of quality standards more restrictive than specified in 5.5.1 will not require special approval.

5.6 Metallurgical examination. Test section in accordance with 5.4 shall be cross sectioned, polished, and etched as closely as possible through the center of the weld for metallurgical examination. Class A welds shall be examined as a microsection at the minimum of 25X to a maximum of 40X. Classes B and C welds shall be examined as a macrosection at 7X to 10X maximum. Weld quality shall meet the quality requirements of section 7 unless otherwise specified in this section.

5.7 Shear strength requirements.

5.7.1 *Minimum requirements.* For spot welds and materials other than foils, the shear strength of each weld or of multiple welds shall be in accordance with the minimum requirements of table I, II or III, as applicable. The failure of one weld shall be the cause for rejection of the entire set, and the welding methods or equipment shall be modified and the test repeated for the particular combination involved.

5.7.2 *Average shear strength requirements.* For materials other than foils, the average shear strength of each set of spot welds shall be equal to or exceed the minimum average strength shown in tables I, II, and III, depending upon the metal involved.

5.7.3 *Strength consistency requirements.*

5.7.3.1 *Group (a) materials.* A variation in shear strength of ±12½ percent of the average value will be permitted in 90 percent of the specimens tested, and a maximum variation of 25 percent in the remaining specimens.

5.7.3.2 *Groups (b) and (c) materials.* A variation in the shear strength of spot welds of ±10 percent of the average value will be permitted in 86 percent of the specimens tested, and a maximum variation of 20 percent in the remaining specimens.

5.7.4 *Minimum requirements for spot and seam welding for foil materials.*

5.7.4.1 *Seam welds.* Seam welds in foil thickness materials shall not show any evidence of leakage across or through the joint while under pressure load. After leakage checks, specimen shall be loaded to destruction, failure shall not occur through the joint in shear, but by metal failure adjacent to or away from the seam weld. Failure to meet these requirements shall be cause for rejection, and the welding methods or equipment shall be modified and the test repeated for the particular combination involved.

5.7.4.2 *Spot welds.* The minimum shear strength of each set of spot welds shall be equal to or exceed the values shown in table IV, depending upon the metal involved.

5.8 Machine and process data. Reports A, B, or C, as applicable (see figures 1, 2 and 3) shall be filled out by the contractor and submitted with the application for approval. After receiving approval, the basic material(s) thickness combinations and data on which the machines were qualified shall be posted in the neighborhood of the machines.

5.9 Qualification approval. Qualification approval of the welding equipment and welds authorized by this specification shall be based on the consistent properties of the welds as shown by the contractor's tests. Except for "Other materials" (see 4.1.5) qualification by one procuring activity shall be qualification for all Department of Defense activities.

6. CERTIFICATION OF WELDING PROCESS OR SCHEDULE

6.1 Welding schedule. The contractor shall establish suitable welding schedules for each material or permissible combination of different materials and each thickness combination to be welded in production from the machine under consideration. Thickness combinations, of the metals listed, falling within the following limits shall not require separate welding schedules, provided acceptable weld

can be produced within the control adjustment limits of 8.5:

(a) *For group (a) materials (other than foil thicknesses)*:
  (1) 0.004 inch or 10 percent, whichever is greater, variation in thickness of any outer sheet.
  (2) 0.004 inch or 10 percent, whichever is greater, variation in the overall thickness of the combination to be welded.

(b) *For groups (b) and (c) materials (other than foil thicknesses)*:
  (1) 20 percent variation in thickness of any outer sheet.
  (2) 10 percent variation in the overall thickness of the combination to be welded.

(c) *For groups (a), (b), and (c) foil thickness materials*:
  (1) 0.001 inch variation in thickness of any outer sheet.
  (2) 0.001 inch variation in the overall thickness of the combination to be welded.

6.1.1. The welding schedule shall be established prior to the welding of production parts and shall include the procedure for preparation of the material (including cleaning practices which will produce consistent and uniform surface conditions on the work to be welded), all details of machine setup, and the control settings for each machine to be used in production welding. The suitability of the welding schedules shall be established by making and testing of not less than the number of welds listed in table VI for the particular class for which certification is desired. The welding schedules and test results shall be available at all times to the procuring activity for examination and evaluation.

6.2 Test requirements.

6.2.1 *Shear specimens.* Two thickness combinations shall be tested in accordance with figure 13. Three or more thickness combinations shall be tested in accordance with figure 14. When examining welds in multiple thickness combinations containing four or more thicknesses, each weld diameter at each plane not subjected to shear test loading shall be evaluated for nugget diameter size. Nugget diameter measurements shall be obtained from the metallurgical specimen. (See 6.2.3 and 7.4.2.)

6.2.1.1 *Minimum shear strength requirements.* The shear strength of each weld or multiple weld shall be in accordance with the minimum requirements of tables I, II, III and IV, as applicable. The failure of one weld shall be cause for rejection of the entire set, and the welding methods or equipment shall be modified and the test repeated for the particular combination involved.

6.2.1.2 *Average shear strength requirements.* The average strength of each set of spot welds shall be equal to or exceed the average strength shown in table I, II, III, or IV, depending upon the metal involved.

6.2.1.3 *Strength consistency requirements.*

6.2.1.3.1 *Group (a) materials.* A variation in shear strength of spot welds in aluminum, aluminum alloys, and magnesium alloys of ±12½ percent of the average value will be permitted in 90 percent of the specimens specified in table VI, and a variation of ±25 percent in the remaining specimens, except for class C welds which may be evaluated in accordance with 8.7.4.

6.2.1.3.2 *Groups (b) and (c) materials.* A variation in the shear strength of spot welds in nonhardening (by the welding process) steels, austenitic steels, nickel alloys, heat-resisting alloy and titanium and titanium base alloys of ±10 percent of the average value will be permitted in 86 percent of the specimens specified in table VI, and a variation of 20 percent in the remaining specimens, except for class C welds which may be evaluated in accordance with 8.7.4.

6.2.2 *Seam weld requirements.* Seam-welded test specimens shall conform to:

(a) Other than foil thickness materials: Metallurgical requirements as specified in this specification (see table VI).

(b) Foil thickness materials: Pressure and peel test requirements as specified in this section (see table VI).

(c) Overlapping of the weld nugget shall be in accordance with 7.2.3.

6.2.2.1 *Pressure test requirements.* Evalua-

tion of class A foil thickness seam welds shall be conducted in accordance with figure 8. Specimens shall withstand without leakage the maximum pressurization required of the production part and destructive test requirements of 5.7.4.

6.2.3 *Nugget diameter measurements (intermittent spot welding).* The number of welds, as specified in table VI for the particular class of welding involved, shall be sectioned through their centers (see table VI, note 2). Each weld and each separate interface if more than 2 thicknesses shall be measured and recorded. Each nugget diameter shall equal or exceed the minimum nugget diameters as established in table VII. Class A intermittent spot welding records shall also show the average and minimum diameters of nuggets.

6.2.3.1 *Nugget diameter method (class A spot welds).* When it is contemplated to use nugget diameter for routine check specimens (see 8.4.1.2), each weld in the metallurgical specimens shall be carefully measured and the diameters recorded. Records shall show the average and minimum diameter of nuggets. (This will establish the basis for controlling nugget diameters on class A welds when this method is selected over shear strength testing during production quality control.)

6.2.4 *Metallurgical requirements.*

6.2.4.1 *Class A welds.* Internal quality as indicated by radiographic examination shall meet the following: Porosity, either singly or in combination, shall not have an aggregate area in group (a) materials greater than 5 percent and for group (b) materials greater than 10 percent of the area of the weld nugget in the plane in which the radiograph is taken, nor a linear dimension greater than 15 percent of the weld diameter and shall not extend to within 15 percent (of the welded diameter) of the boundaries of the cast weld structure. Other internal requirements and the appearance and external defects shall conform to applicable portions of section 7.

6.2.4.2 *Classes B and C welds.* The internal and external quality of classes B and C welds shall conform with the applicable portion of section 7.

6.3 Peel test requirements—foil thicknesses.

6.3.1 Peel test shall be conducted as indicated in figure 12.

(a) Class A welds: Peel test shall exhibit 95 percent button type failures. Fusion at the interface shall indicate fusion zone diameters or widths which do not vary more than 20 percent. When more than three thicknesses are involved, a cross-sectional type specimen (see fig. 11) may be used in lieu of peel testing for nugget size measurements (see 7.4).

(b) Class C welds: Peel test shall exhibit 85 percent button type failures. The balance of the welds may fail through cleavage at interface, but fusion at interface shall be evident.

6.4 Certification outside of qualification limits.

6.4.1 Machines for classes A, B, and C welding may be certified to weld material thicknesses greater than or less than originally qualified as long as a welding schedule can be established and production parts made to meet requirements of this specification.

6.5 Certified records. There shall be made readily available to the machine operator and authorized inspection personnel for reference at any time, records showing the welding machine settings for all variable controls and minimum and average spot shear strengths or nugget diameters for all alloys and thickness combinations welded on that machine.

6.5.1 Recertification. Recertification of a welding schedule may be required at any time, if the procuring activity for any reason doubts the ability of a welding machine or machines to make satisfactory welds.

6.6 When the amount of magnetic material in the throat of the machine, the curvature of the part, and other conditions in production welding require control adjustments outside of the limits specified in 8.5, specific welding schedules shall be established for each joint requiring such adjustments. The schedule shall also specify the tests and examinations which will be used to determine the conformance of the welds to the requirements specified herein. The test welds shall be made so that they represent welds in the production part.

TABLE VI. *Test specimens required for certification tests*

Class of weld	Weld method	Material			
		Group (a) materials		Group (b) and (c) materials	
		Ultimate shear strength or pressure test specimen	Metallurgical or peel specimen [3]	Ultimate shear strength or pressure test specimen	Metallurgical or peel specimen [3]
A	Spot weld—other than foil thicknesses.[1] [4]	20 Shear.	5 Welds microsection.	10 Shear.	3 Microsection.
B		10 Shear.	6 Welds macrosection.	5 Shear.	3 Macrosection.
C		3 Shear.	2 Welds macrosection.	3 Shear.	2 Weld macrosection.
A B	Seam weld—other than foil thicknesses.[4]	None required.	12 Inches of weld (see fig. 9).	None required.	12 Inches of weld (see fig. 9).
C			3 Inches of weld (see fig. 10).		3 Inches of weld (see fig. 10).
A	Intermittent spot weld—other than foil thicknesses.[1]	10 Nugget diameter measurements.	20 Welds (10 microsectioned) (see fig. 11).	10 Nugget diameter measurements.	20 Welds (10 microsectioned) (see fig. 11).
B		5 Nugget diameter measurements.	10 Welds (5 Macrosectioned) (see fig. 11).	5 Nugget diameter measurements.	10 Welds (5 Macrosectioned) (see fig. 11).
C		3 Nugget diameter measurements.	3 Welds macrosection (see fig. 11).	3 Nugget diameter measurements.	3 Welds macrosection (see fig. 11).
A	Spot or intermittent spot welds—foil thicknesses.[1] [4]	Five 1 inch shear (see fig. 5).	3 inches of weld (see fig. 12).	Five 1 inch shear (see fig. 5).	3 inches of weld (see fig. 12).
C		None required	3 inches of weld (see fig. 12).	None required.	3 inches of weld (see fig. 12).
A	Seam weld—foil thicknesses.[1] [4]	One pressure test specimen (see fig. 8).	1 inch of weld (see fig. 8).	One pressure test specimen (see fig. 8).	1 inch of weld (see fig. 8).
C		None required.	3 inches of weld (see fig. 12).	None required.	3 inches of weld (see fig. 12).

TABLE VII. *Nugget diameter (all metals)*

Nominal thickness of thinner sheet (inch)	Spot diameter minimum (inch)	Nominal thickness of thinner sheet (inch)	Spot diameter minimum (inch)
0.001	0.010	0.036	0.150
.002	.015	.040	.160
.003	.020	.045	.170
.004	.030	.050	.180
.005	.035	.056	.190
.006	.040	.063	.200
.007	.045	.071	.210
.008	.050	.080	.225
.010	.060	.090	.240
.012	.070	.100	.250
.016	.085	.112	.260
.018	.090	.125	.280
.020	.100	.140	.300
.022	.105	.160	.320
.025	.120	.180	.340
.028	.130	.190	.350
.032	.140		

NOTE: Nugget diameter is based on minimum shear strength specified in this specification. Nugget diameter shown above is not applicable if shear strength values other than established herein are used or established.

7. QUALITY STANDARDS

7.1 Appearance. The outer surface of all test specimen welds shall be smooth, and free of cracks, tip pickup, pits, and other defects which indicate that the spot welds were made with dirty electrodes, improperly prepared surfaces, or that undue penetration of the weld nugget has taken place. The maximum acceptable number of defects for production parts shall be not greater than that shown in table VIII.

7.1.1 *External defects.* Test specimen welds shall be free of external defects. For production parts, except as noted in 9.8, the following defects are not acceptable: Pits, surface flashes, tip pickup, expulsion of metal between the sheets, external cracks, edge bulge crack, and blown spots.

7.1.2 *Sheet separation.* Sheet separation, as measured at a distance from the edge of the weld approximately equal to half the diameter of the electrode indentation, is not acceptable if:

(a) In excess of 10 percent of the average thickness of the two outer sheets joined or 0.005 inch, whichever is greater, for class A welds (for group (a) materials).

(b) In excess of 10 percent of the average thickness of the two outer sheets joined or 0.006 inch, whichever is greater, for class A welds (for groups (b) and (c) materials).

(c) In excess of 0.003 inch for class A welds in foil thickness materials (for all metals).

(d) In excess of 15 percent of the average thickness of two outer sheets joined or 0.006 inch, whichever is greater, for classes B and C welds (for all metals).

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[1] Total number of ultimate strength shear specimens for each class shall be multiple spot shear or single spot shear specimens conforming to figure 4 or 6. The multiple spot shear specimens shall be cut into single spot shear specimens conforming to figure 4 for testing.

[2] Metallurgical specimens shall conform to the requirements of figure 11. Specimen shall be cross sectioned, polished, and etched closely as possible through the center of the weld for metallurgical examinations. Microsections for class A shall be examined at a minimum of 25X to a maximum of 40X. Macrosections for class B or C, if required, shall be visually examined with the naked eye or under low magnifications (7X to 10X maximum). Peel specimen shall conform to the requirements of figure 12, and shall be considered as an option to a metallurgical specimen for class C welding of foil thicknesses.

[3] Nugget diameter measurements shall be obtained from the metallurgical specimens.

[4] Seam welds may be accomplished by the overlapping of spot welds with fixed-type electrodes when so permitted on the engineering drawing or other applicable documents. Parts, seam welded in this manner, shall be certified and controlled in accordance with seam-welding requirements.

[5] Spot welds spaced less than 2 diameters apart utilizing fixed-type electrodes shall be certified and controlled in accordance with intermittent spot welding requirements.

[6] Number of spots per inch shall be in accordance with production part requirements and minimum shear strength requirements shall be determined in accordance with requirements of table IV.

[7] Pressure test specimens shall withstand without leakage the maximum pressurization requirements of the production part. At the option of the contractor, certification may be accomplished in accordance with requirements for "other than foil thicknesses." When class A seam welds are applied for other than pressurization purposes, shear testing may be accomplished in accordance with requirements for spot or intermittent spot welds.

[8] Special application machines. See figure 5. When the mechanical and electrical machine settings used for qualification tests are identical to the machine settings to be used in production, certification tests as required herein may be waived. However, the test data and mechanical and electrical machine settings shall be recorded on the proper forms and made available as required in this section (see 6.5)

TABLE VIII. *Maximum acceptable number of defects*

Nature of weld defect	All metals					
	Acceptable without repair (percent) [1]			Additional repairable (percent) [1]		
	Class of weld					
	A	B	C	A	B	C
	External defects					
Cracks open to surface [2]	0	0	5	0	0	5
Edge bulge cracks	0	0	10	0	0	0
Sheet separation exceeding established limits	3	5	10	0	0	0
Blown spots and pits more than 1/16 inch diameter	0	0	10	0	0	5
Pits less than 1/16 inch diameter	3	5	10	2	5	10
Metal expulsion between sheets (spits) and surface flashes	3	5	10	0	5	10
Tip pickup	2	3	5	0	0	0
Excessive indentation	5	10	10	0	0	0
	Internal defects [3]					
Cracks, porosity	0	6	NA	5	10	NA
Duds (no fusion)	0	0	0	1	2	5
Cladding inclusions	0	5	NA	0	0	NA
Insufficient penetration	0	3	NA	0	0	NA
Excessive penetration	0	3	NA	0	0	NA

[1] Total of all defects shall not exceed 10 percent for class A, 15 percent for class B, and 20 percent for class C.

[2] Except for seam welds—cracks open to surface on seam welds shall be rejected and subjected to a salvage or review committee.

[3] In excess of limitations established in section 7. NA = Not applicable

NOTE. Percentage fractions shall be interpreted as the next highest number of welds for the purpose of determining the additional repair permissible.

7.1.3 *Surface indentation.* Where aerodynamic considerations are a requisite, the electrode indentation shall not exceed 0.004 inch for other than foil thicknesses and 20 percent of sheet thickness for foil thicknesses. In all other cases, electrode indentions are not acceptable if the depth exceeds the following limitations:

(a) Class A and B, for other than foil thicknesses, 10 percent or 0.005 inch (whichever is greater) and for foil thicknesses 30 percent of the thickness of the sheet in which the indentation occurs.

(b) Class C, for other than foil thicknesses 20 percent or 0.005 inch (whichever is greater) and for foil thicknesses 40 percent of the thickness of the sheet in which the indentation occurs.

7.2 Penetration and internal defects. Weld penetration and soundness shall be determined by examination of a metallurgical section through the center of welds in test specimens welded according to production welding schedule. The outline of the fusion zone shall be generally consistent in size and generally regular in shape.

7.2.1 *Internal defects.* Weld defects such as porosity, cracks, lack of fusion, or voids within the weld nugget for all alloys, or macrosegregation within the weld nugget for nickel or cobalt base alloys, are acceptable if the maximum extent of the defect does not exceed one of the following limits:

(a) As indicated by metallographic examination of section (see figure 15):

(1) For class A welds, 10 percent; for class B welds, 15 percent; and

for class C welds, 25 percent of the weld diameter.

(2) Twenty-five percent of the respective sheet thickness extension into an outer sheet for class A and B and 50 percent for class C.

(3) Extension within 15 percent (of the weld diameter) of the boundaries of the nugget structure for all classes.

(4) Incipient melting, within the weld-affected area shall be considered acceptable provided it does not extend to within 10 percent of an outer sheet surface or result in excessive sheet separation (see 7.1.2).

NOTE: Macrosegregation is characterized by localized alloy segregation in the fused zone at the line of demarcation (original interface line).

Incipient melting is generally characterized by thickened grain boundaries..

7.2.1 *Internal defects (certification and routine check specimens)*. The contractor shall establish the extent of internal defects to be permitted in controlling test specimens. In no case shall the internal defects exceed the limits of 7.2.1 for routine check specimens and 6.2.4.1 for class A certification test specimens and 7.2.1 for class B and C certification test specimens.

7.2.2 *Fusion between sections (clad aluminum)*. The outline of the nugget area at the interface shall be generally smooth and regular. There shall be no unfused cladding material within the weld nugget. The extent of the cladding into the columnar zone of the weld shall not exceed 10 percent of the weld diameter.

7.2.3 *Nugget zone (seam welding)*. The outline of the nugget zone on a plane perpendicular to the sheets joined and through the centerline of the seam weld shall show uniform overlapping of welds and consistency of penetration.

7.2.3.1 The width of the fused zone in seam welds shall be not less than the minimum spot weld diameters listed in table VII. The width shall be determined by transverse sections as indicated in figure 9 for classes A and B welds and in figure 10 for class C seam welds.

7.2.4 *Minimum penetration spot and intermittent spot welds*. Minimum penetration of the nugget zone into each outer sheet shall be in accordance with (a) or (b) below, as applicable, at any point over an area whose major axis is 80 percent of the weld diameter at the interface.

(a) Equal thickness combinations—Penetration shall be a minimum 20 per cent of the original outer sheet thickness.

(b) Unequal thickness combinations—Penetration into the thinner outer sheet shall be a minimum of 20 percent of the original sheet thickness.

Penetration into the thicker or other outer sheet shall be:

(1) For two thickness combinations: A minimum of 20 percent of the thinner sheet thickness. (See figure 18a.)

(2) Multiple thickness combinations: A minimum of 20 percent of the thicker or other outer sheet thickness (see figure 18b); or equal to the sum of the inter-sheet thickness(es), plus a minimum of 20 percent of the thinner outer sheet thickness, whichever is less (see figure 18c).

7.2.5 *Minimum penetration (seam welding)*. Minimum penetration of the nugget zone into each outer sheet shall be in accordance with (a) or (b) requirements of 7.2.4.

7.2.6 *Maximum penetration*. Penetration into either or both of the outer sheets shall not exceed the percent value (see table IX) of the reduced sheet thickness (thickness at weld centerline).

7.3 The ultimate shear strength of every spot weld specimen shall be equal to or exceed the respective minimum values shown in tables I, II, III, and IV for the corresponding nominal thickness of the material.

TABLE IX. *Penetration requirements*

Class of weld	Weld method	Group (a) materials		Group (b) and (c) materials	
		Minimum percent penetration	Maximum percent penetration	Minimum percent penetration	Maximum percent penetration
A	Spot and intermittent spot welding.	See 7.2.4.	80	See 7.2.4.	90
B			80		90
C			90		90
A	Seam welding.	See 7.2.5.	80	See 7.2.5.	90
B			80		90
C			90		90

7.4 The nugget diameters of every intermittent spot or spot weld (when nugget diameter measurements are used to control spot welds) shall equal or exceed the minimum nugget diameter as established in table VII.

7.4.1 *Unequal thickness combination.* In a joint between sections of unequal thickness, or of alloys of different strengths, the minimum shear strength requirements shall be based on the thickness of the thinner sheet or the strength of the weaker material, whichever requirement is lower. Minimum nugget diameter requirements shall be determined by the thickness of the thinner sheet.

7.4.2 *Multiple thickness combinations.* When more than two sheets of material are welded together, the weld shear strength requirements shall apply separately to each weld between each pair of adjacent outer sheets, and nugget requirements shall apply between each pair of intermediate sheets, if these planes are not shear tested.

7.5 **Tack welds.** Tack welds shall not be used on class A parts unless finally removed or completely covered by subsequent production welding or allowed by engineering drawings or applicable documents.

7.5.1 Tack welds require no test specimens and shall be of sufficient strength to fulfill their temporary fastening function, and are not subject to the requirements of this specification with exception to defects that may be detrimental to the production part. The defects, internal and external, shall not exceed limits established for production parts.

8. QUALITY ASSURANCE PROVISIONS (PRODUCTION QUALITY CONTROL)

8.1 **Production welding and inspection.** Production welding shall be so accomplished as to obtain welds of uniform strength above the accepted minimum and of acceptable metallographic structure, rather than welds of maximum strength irrespective of metallographic structures. All test specimens selected for checking production welding shall be representative of manufacturing practice. Specimens shall be tested by the contractor under the general supervision of the authorized inspector. Prior to welding, all production parts shall be checked for conformance to the applicable requirements of section 4.

8.2 **Schedules.** Qualified personnel in each plant shall be responsible for the control of machine settings and all welding schedules. Records of all current schedules shall be available for examination by an authorized inspector at any time.

8.3 **Weld location.** Welds shall be located as specified on the engineering drawing or applicable document. The edge distance of each weld shall be such that no deformation or bulging will occur at the edge of the sheet. Jigs shall be used whenever necessary to locate welds as specified above.

8.4 **Routine check specimens.**

8.4.1 *Test specimens.* A three-spot welded lap joint, or three single-spot shear specimens, or specimens containing a minimum of 8 inches of seam weld, or three intermittent spot welds,

as applicable, for other than foil thicknesses, or 8-inch peel specimen or three 1-inch multiple spot shear specimens for class A welds and a 1-inch peel specimen for class C welds for foil thicknesses, or a simulated section of the production joint containing mentioned weld quantity requirements, shall be welded and tested or examined, as applicable, for routine check purposes for each of the following conditions:

(a) Class A welding. At intervals not to exceed 1 hour of production welding and at the end of a run, if more than 30 minutes of welding has elapsed since the last check.

(b) Classes B and C. At intervals not to exceed 2 hours of production welding and at the end of a run, if more than 1 hour of welding has elapsed since the last check.

(c) Upon replacement of the welding electrodes.

(d) At the start of each welding schedule.

4.4.1.1 Single spot shear specimens shall be tested for ultimate strength (see 4.7). Seam welds shall be metallurgically examined for weld quality (see 4.4.4). Intermittent spot welds shall be examined for nugget diameter size (see 4.4.1.2). Peel specimens shall be examined for button failures. For class A, welds shall also be examined for nugget diameter size consistency (see 6.3.1).

4.4.1.2 When nugget diameter measurements are used in lieu of the shear test specified above, or when examining intermittent spot welds, the following method shall be used:

(a) Test specimens or simulated section of the production joint containing the same quantity of welds (see 4.4.1) shall be examined. Specimens shall be cross sectioned, polished, and etched in accordance with figure 11, as closely as possible through centers of welds and each nugget diameter measured and recorded. If the specimen contains more than two thicknesses, nugget diameter at each interface shall be measured and recorded.

(b) For class A welds, the average nugget diameter shall be not more than 10 percent or 0.02 inch (whichever value is greater) below the average nugget diameter obtained during certification of the welding schedule. On multiple thickness combinations of four or more thicknesses, this requirement shall apply to welds in between outer planes only. The minimum nugget diameter, at all planes, shall be not less than the minimum shown in table VII.

(c) For classes B and C welds, each nugget diameter shall be not less than the minimum listed in table VII.

4.4.2 The test specimens shall conform to the production parts they represent with respect to material, thickness combination, surface condition, machine settings, and electrode tip contours. When the amount of magnetic material in the throat of the machine, the curvature of the part, and other conditions require control adjustments outside the limits of 4.5, the test specimens and testing procedures shall conform to the requirements established under 4.6.

4.4.3 *Shear specimens.* Two thickness combinations shall be tested in accordance with figure 13. Three or more thickness combinations shall be tested in accordance with figure 14. At the option of the contractor three or more thickness combinations may be tested in accordance with figure 16. When testing under figure 16 conditions, the shear strength shall be equal to or greater than the highest required for either pair of adjacent outer sheets. Shear strength shall also meet applicable requirements specified herein (see 4.7.1). Under conditions where the shear strengths of three or more thicknesses do not meet the required strengths, when tested in accordance with figure 16, the specimens shall be tested by loading each outer plane separately as noted in figure 14.

4.4.4 *Metallurgical specimens.*

4.4.4.1 *Class A welds.* Three or more welds or 3 inches of seam welds, as applicable, from a production joint or a simulated section of a production joint (see figure 11) shall be macrosectioned to reveal the structure of the welds at the lesser of the following intervals:

(a) At the beginning of a shift or job and approximately every 4 hours thereafter or

(b) After approximately 5,000 production welds.

8.4.4.1 Under conditions where nugget diameter measurements are used for routine check purposes, specimens may be prepared as a microsection at the intervals required in 8.4.4.1 and substituted therefor.

8.4.4.2 *Class B welds.* Three or more welds or 3 inches of seam welds, as applicable, from a production joint or a simulated section of production joint (see fig. 11) shall be macrosectioned to reveal the structure of the welds at the start of each welding schedule.

8.4.4.3 *Class C welds.* Metallurgical examination for weld quality in this class is not required, provided this examination is made in the certification of the welding schedule.

8.4.4.4 All metallurgical specimens shall meet the applicable quality requirements of section 7. When examining welds in multiple thickness combinations containing four or more thicknesses, each weld at each interface not subjected to shear test loading shall be evaluated for nugget diameter. Nugget diameter size shall equal or exceed the minimum nugget diameters as established in table VII.

8.5 **Control adjustment.** When routine check tests indicate that adjustment of the control settings is desirable, the settings may be varied by ±5 percent from the established values, or by ±10 percent when only one setting is adjusted. If satisfactory welding cannot be maintained within these limits of adjustment, welding shall be stopped and the machine shall be checked for faulty operation. If it can be shown that conditions other than certified welding schedule requirements were the cause of faulty welding and with the correction of these conditions the original certified welding schedule is capable of producing acceptable welds, the establishment of a new welding schedule in accordance with section 6, will not be required. For class A welds, also see 8.7.4.1.

8.6 **Surface resistance—aluminum, aluminum alloys, and magnesium alloys.** A daily check of the surface resistance in microhms shall be made for class A welds. A minimum of five readings shall be made on samples typical of the material being welded and its surface condition. The details of the method of obtaining the surface resistance measurement shall be the same as those used for the certification of welding schedules or cleaning procedure, and the values of the surface resistance shall not exceed the limits of consistency and maximum values established at that time.

8.7 **Routine shear check tests requirements.**

8.7.1 For class A welds, the average shear strength of the three specimens shall be not lower than 10 percent below the average shear strength value obtained during certification of the welding schedule (see sec. 6), and the minimums shown in tables I, II, III and IV. For aluminum alloys and other alloys in which the strength of the welds increase after welding because of aging, this requirement may be based on the strength of the unaged specimens in both the certification tests and the routine check tests. After testing in shear, each of the fractured welds shall be visually (macroscopic) examined for fusion and evidence of obvious defects, such as cracks, porosity, lack of fusion, spits, and cladding inclusions.

8.7.2 For classes B and C welds, the minimum shear strength of the three specimens shall be not lower than the minimum shown in tables I, II, III, and IV. After testing in shear, each of the fractured welds shall be visually examined for fusion and evidence of obvious defects, such as cracks, porosity, lack of fusion, spits, and cladding inclusions.

8.7.3 When using nugget diameter measurements, the welds shall be visually examined for fusion and evidence of obvious internal defects, such as cracks, porosity, lack of fusion, spits, and cladding inclusions.

8.7.4 The variation in shear strength for each sample of three welds shall not exceed 0.35 and shall be established by using the sample range as outlined in 10.3. If and when the variation in shear strength is exceeded or when the shear strengths are below the permitted value, the previous production representative of that sample for that machine and any subsequent production on that machine under those conditions shall be rejected and subject to sal-

vage as indicated in 9.4. If investigation reveals that spot welding quality has deteriorated due to obvious causes, other than certified welding schedule requirements, such as improper cleaning or swaging of electrode tips or faulty machine operation, and with the correction of these conditions the original certified welding schedule is capable of producing acceptable welds, the establishment of a new welding schedule, in accordance with section 6, will not be required. For class A welds, also see 8.7.4.1.

8.7.4.1 Class A welds, under conditions where satisfactory conformance with previous machine qualification or certified welding schedules cannot be obtained (see 8.5 and 8.7.4) the machine shall be requalified and recertified. The new machine qualification tests shall be conducted in accordance with requirements of section 5. All previous certified class A welding schedules for the machine shall be discarded and new settings established in accordance with the requirements of section 6.

9. INSPECTION OF PRODUCTION PARTS

9.1 External defects. Production parts shall be visually examined for the presence of external defects specified in section 7. The acceptable number of external defects on welds in production parts shall not exceed the limits of table VIII.

9.2 Internal defects. Inspection of production parts for internal defects will not normally be required. When deemed necessary, the contractor shall test samples of actual production work. At the option of the contractor, examination for internal defects may be accomplished by radiographic examination. When metallographic examination is used, the number of welds having defects exceeding the limits of section 7 shall not exceed the number indicated in table VIII. When radiographic examination is used, the internal defects shall have the following limits:

(a) Class A welds, 25 percent; class B welds, 50 percent of the weld diameter or

(b) Extension to within 15 percent (of weld diameter) of the boundaries of the cast weld structure.

The number of welds exceeding these limits shall not exceed the number indicated in table VIII.

9.3 Distribution of defects. The maximum percentage and nature of defects which are acceptable without repair and which are acceptable with repair without recourse to a salvage or review committee are indicated in table VIII. Restriction on defects other than those described in table VIII shall be as stated herein. Defective spot welds indicated in table VIII as being acceptable with or without repair shall be randomly distributed unless it is demonstrated by the contractor that a particular clustering of defects, within the limits of table VIII is unavoidable in high quality production and not detrimental to the service intended.

9.4 Rejection. Any part containing welds with defects over and above the limits on permissible defects as defined herein shall be rejected. Special attention shall be given to a close grouping of defective welds.

10. NOTES

10.1 Intended use. This specification covers the requirements for equipment, materials, methods of preparing the materials and methods of weld process control in resistance spot, seam, and intermittent spot welding processes.

10.2 Definitions.

10.2.1 *Spot welding.* Spot welding is a resistance-welding process wherein coalescence is produced by the heat obtained from resistance to the flow of electric current through the work parts held together under pressure by electrodes. The size and shape of the individually formed welds are limited primarily by the size and contour of the electrode. Spot welding made with fixed type electrodes and roll spot welding are considered interchangeable.

10.2.2 *Seam welding.* Seam welding is a resistance-welding process wherein coalescence is produced by the heat obtained from resistance to the flow of electric current through the work parts held together under pressure by suitable electrodes. The resulting weld is a series of overlapping spot welds made progressively along a joint. Seam welding shall be considered a pressure tight joint.

MACHINE QUALIFICATION DATA
(SUGGESTED REPORT)
(Submit for approval with physical test report on spot weld specimens)

Company _____ Address _____ Date _____
Mfr. of Machine _____ Serial No. _____ Rated Capacity _____
Mfr. of Control Panel _____ Type of Machine _____
Control Mfr.'s Type No. _____
Surface Preparation _____

SHEET COMBINATION	Upper	Material
		Thickness (inch)
		Condition
	Lower	Material
		Thickness (inch)
		Condition
Electrode Tip Contour, Sketch, and Dimensions		Material
		UPPER / LOWER
Electrode Cooling		
Distance Between Arms		
Throat Depth		
Power Supply Frequency		
Primary Voltage		

Other control settings as required for particular type machine.

NOTE: All machine settings adjustable or adjusted to accomplish welding shall be recorded.

PRESSURE SEQUENCE	Squeeze	Gage Pressure (PSI)
		Electrode Pressure (lb.)
		Time (Cycles)
	Weld	Gage Pressure (PSI)
		Electrode Pressure (lb.)
		Time (Cycles)
	Forge	Gage Pressure (PSI)
		Electrode Pressure (lb.)
		Time (Cycles)
Welding Current (RMS Amperes)		
Weld Time (Cycles)		

(Welding Supervisor's Signature) (Authorized Inspector)

FIGURE 1. *Suggested report A.*

MACHINE QUALIFICATION DATA
(SUGGESTED REPORT)

(To Be Accompanied by Welding Schedule)

Company_____ Address_____ Date_____

Mfr. of Machine_____ Serial No._____ Mfr. of Control Panel_____

Qualification Group: (Note material covered by group (a) or (b) or both see section_____

Control Mfr.'s Type Number_____

Thickness Range: (Note minimum and maximum thickness actually qualified)

Surface Preparation

SHEET COMBINATION	Upper	Material			
		Thickness (inches)			
		Condition			
	Lower	Material			
		Thickness (inches)			
		Condition			
	Defects, Sections or Radiographic				
WELDED SPECIMENS	SHEAR STRENGTH, POUNDS PER WELD	1	26	51	76
		2	27	52	77
		3	28	53	78
		4	29	54	79
		5	30	55	80
		6	31	56	81
		7	32	57	82
		8	33	58	83
		9	34	59	84
		10	35	60	85
		11	36	61	86
		12	37	62	87
		13	38	63	88
		14	39	64	89
		15	40	65	90
		16	41	66	91
		17	42	67	92
		18	43	68	93
		19	44	69	94
		20	45	70	95
		21	46	71	96
		22	47	72	97
		23	48	73	98
		24	49	74	99
		25	50	75	100

Total of Shear Strengths

Average of Shear Strengths

Min. Value obtained on Test

Variation in Shear Strength

Average Weld Diameter Minimum Weld Diameter

Minimum Shear Strength on Table

(Laboratory Director's Signature) (Authorized Inspector)

FIGURE 2. *Suggested Report B.*

SEAM WELDING DATA

(Submit for Approval with Physical Test Report on Seam-Weld Specimens)

(SUGGESTED REPORT)

Date _____

Company _____ Address _____

Machine Make _____ Serial No. _____ KVA _____

Mfr. of Control Panel _____ Control Mfr.'s Type Number _____

WELDING DATA

SURFACE PREPARATION

Sheet Combinations	Upper	Material
		Thickness
		Condition
	Lower	Material
		Thickness
		Condition
Electrode Contour Sketch and Dimensions Electrodes		Diameter, Upper-Lower
		Contour
		Material
		Speed (in./min.)
		Weld Force, lb.

Electrode Cooling

Distance Between Arms

Throat Depth

Power Supply Frequency

Primary Voltage

Spot Spacing

Other control settings as required for particular type machine

NOTE: All machine settings adjustable or adjusted to accomplish welding shall be recorded.

_____ _____

(Machine Operator's Signature) (Authorized Inspector's Signature)

_____

(Welding Supervisor's Signature)

METALLURGICAL TEST REPORT OF SEAM WELD SPECIMENS

Etching Test

			Is Appearance of Weld Satisfactory?	Do Fusion Areas Overlap?	Depth of Penetration		Defects
					Max	Min	
TEST RESULTS	Longitudinal Sections	1					
		2					
		3					
		4					
	Transverse Sections	1					
		2					
		3					
		4					

_____ _____

(Laboratory Director's Signature) (Authorized Inspector's Signature)

FIGURE 3. *Suggested report C.*

MACHINE QUALIFICATION DATA
(SUGGESTED REPORT)

(To Be Accompanied by Welding Schedule)

Company_____ Address_____ Date_____

Mfr. of Machine_____ Serial No._____ Mfr. of Control Panel_____

Qualification Group: (Note material covered by group (a) or (b) or both see section_____

Control Mfr.'s Type Number_____

Thickness Range: (Note minimum and maximum thickness actually qualified)

Surface Preparation

SHEET COMBINATION	Upper	Material			
		Thickness (inches)			
		Condition			
	Lower	Material			
		Thickness (inches)			
		Condition			
	Defects, Sections or Radiographic				
WELDED SPECIMENS	SHEAR STRENGTH, POUNDS PER WELD	1	26	51	76
		2	27	52	77
		3	28	53	78
		4	29	54	79
		5	30	55	80
		6	31	56	81
		7	32	57	82
		8	33	58	83
		9	34	59	84
		10	35	60	85
		11	36	61	86
		12	37	62	87
		13	38	63	88
		14	39	64	89
		15	40	65	90
		16	41	66	91
		17	42	67	92
		18	43	68	93
		19	44	69	94
		20	45	70	95
		21	46	71	96
		22	47	72	97
		23	48	73	98
		24	49	74	99
		25	50	75	100

Total of Shear Strengths

Average of Shear Strengths

Min. Value obtained on Test

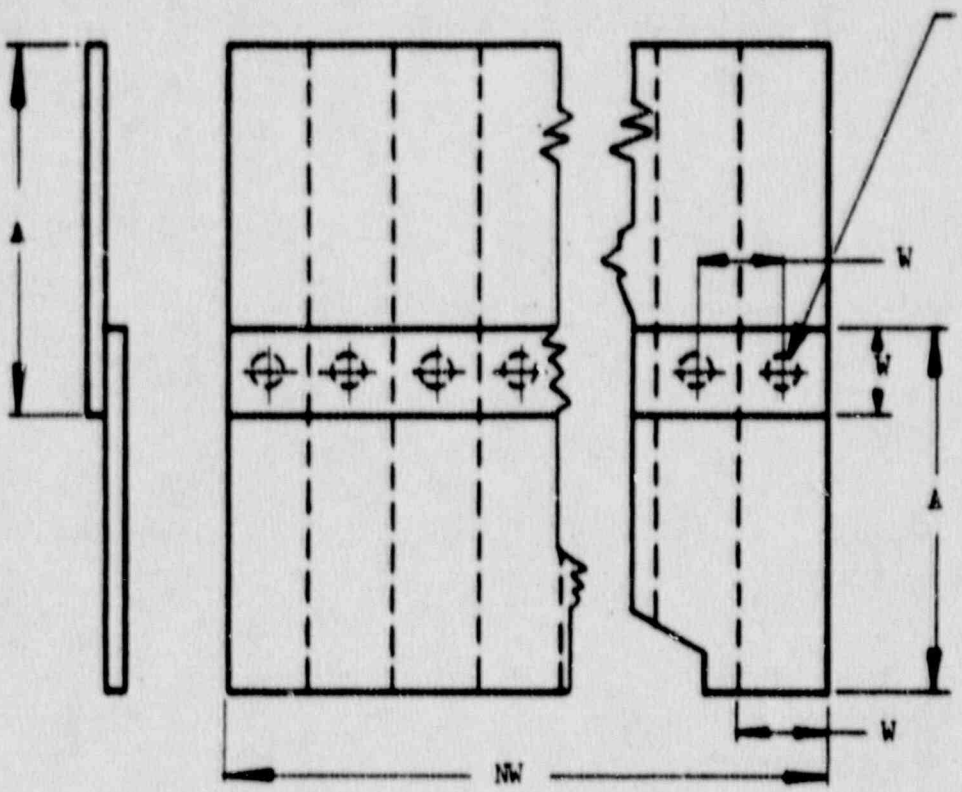
Variation in Shear Strength

Average Weld Diameter Minimum Weld Diameter

Minimum Shear Strength on Table

(Laboratory Director's Signature) (Authorized Inspector)

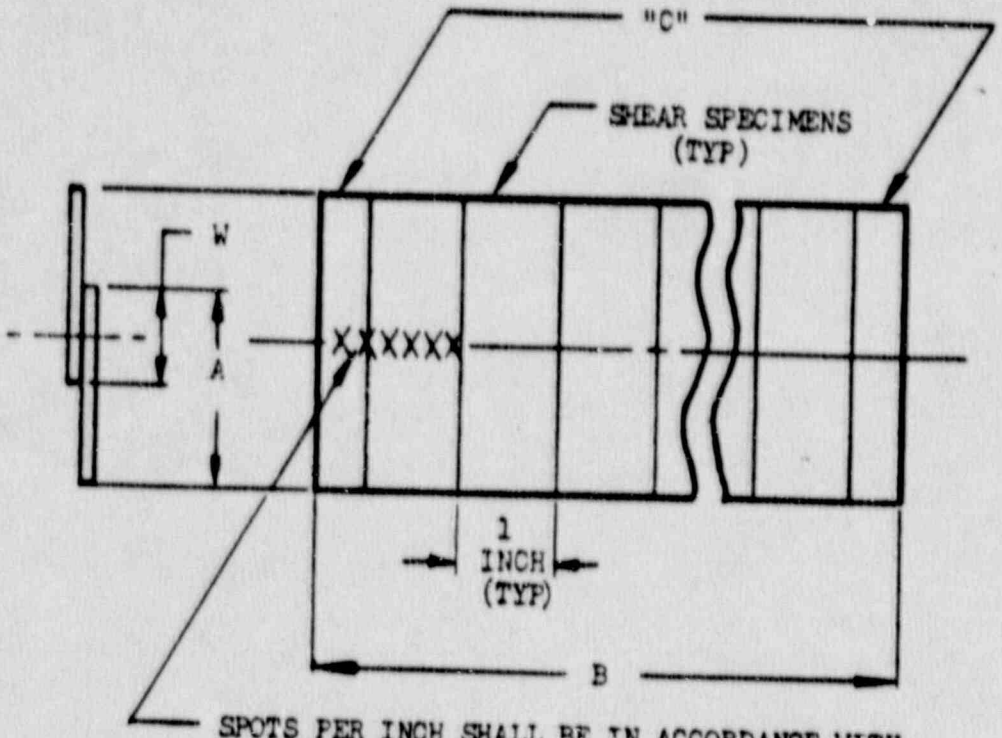
FIGURE 2. *Suggested Report B.*



(VALUES FOR W AND A ARE SHOWN IN TABLE V)

N = NUMBER OF SPOT WELDS AS SPECIFIED IN THE APPLICABLE PARAGRAPHS OF THE SPECIFICATION. THE NUMBER OF SPOT WELDS PER SET SHALL BE NOT LESS THAN 30.

FIGURE 4. *Multiple-spot shear specimen for other than foil thicknesses (to be cut after welding).*

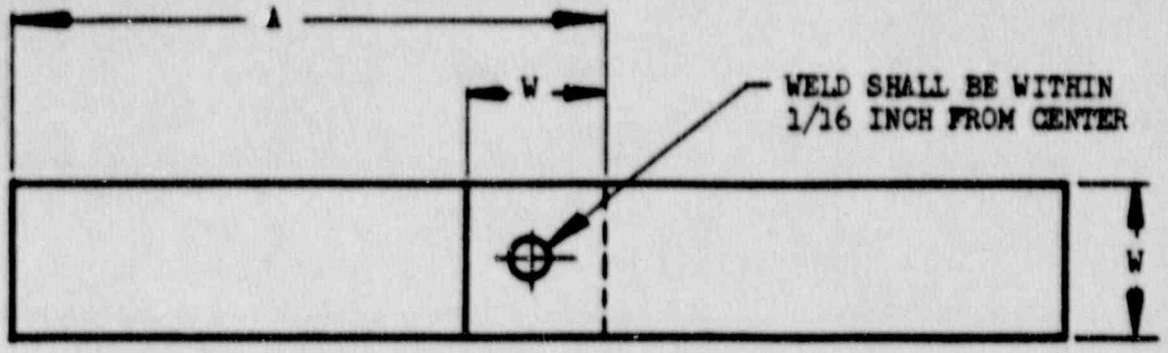


SPOTS PER INCH SHALL BE IN ACCORDANCE WITH STANDARD SPOTS PER INCH REQUIREMENTS OF TABLE IV FOR MACHINE QUALIFICATION TESTS AND IN ACCORDANCE WITH PRODUCTION PART REQUIREMENTS FOR CERTIFICATION TESTS.

VALUES FOR W AND A ARE SHOWN IN TABLE V.

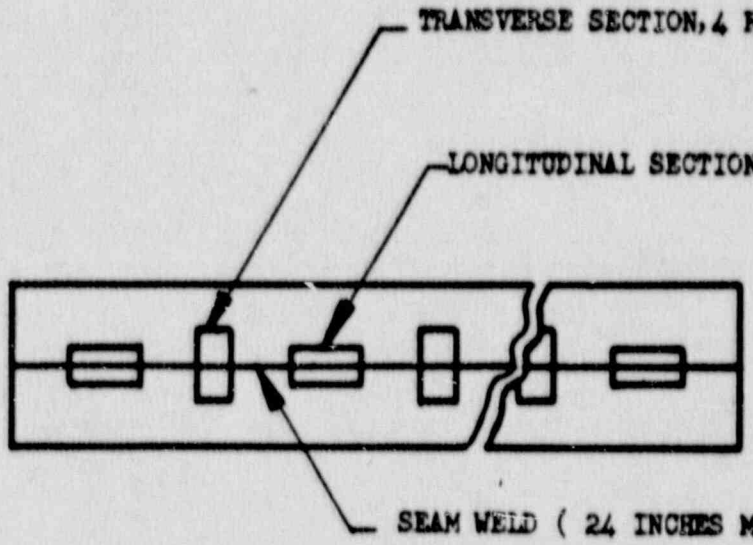
TYPE TEST	DIMENSION	
	B	C
QUALIFICATION TESTS (SEE 5.4.1(b))	12 IN.	METALLURGICAL SPEC.
CERTIFICATION TEST (SEE TABLE VI)	6 IN.	DISCARD

FIGURE 5. *Multiple-spot joint efficiency panel for foil thicknesses class A welds (to be cut after welding).*



(VALUES FOR W AND A ARE SHOWN IN TABLE V)

FIGURE 6. *Single-spot shear specimen.*



WHEN USING MULTIPLE STRIPS CONTAINING A SUM OF AT LEAST 24 INCHES OF WELD IN PLACE OF A SINGLE STRIP AS SHOWN ABOVE, THE MAXIMUM NUMBER OF MULTIPLE STRIPS SHALL BE FOUR. LONGITUDINAL AND TRANSVERSE SECTIONS SHALL BE EQUAL IN NUMBERS PER TEST STRIP AND SHALL BE NOT LESS THAN FOUR CROSS SECTIONS.

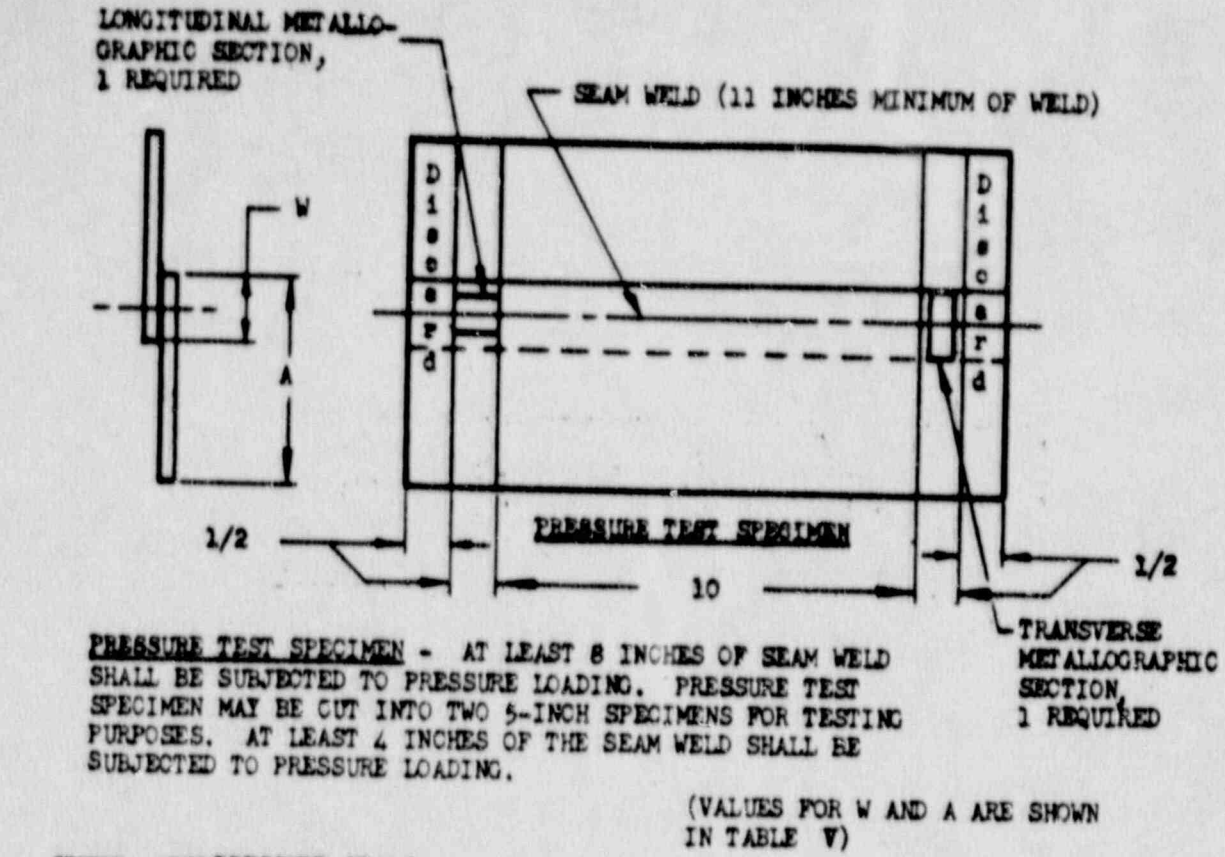
LONGITUDINAL SECTIONS SHALL BE PREPARED IN SUCH A MANNER THAT A LEAST A TOTAL LENGTH OF 1 INCH OF SEAM WELD IS EXAMINED.

TRANSVERSE SECTIONS SHALL BE OF SUFFICIENT LENGTH TO INCLUDE THE WELD NUGGET, THE HEAT AFFECTED ZONE, AND PORTIONS OF THE UNAFFECTED BASE METAL AT EACH END.

WIDTH OF TEST STRIP(S) SHALL BE AS SHOWN ON TABLE V FOR THE APPLICABLE THICKNESS REQUIRED.

LONGITUDINAL AND TRANSVERSE SECTIONS SHALL BE EXAMINED AS MICROSECTIONS FOR CLASS A AND AS MACROSECTIONS FOR CLASS B OR C.

FIGURE 7. *Qualification test specimen, class A, B, or C seam welding of other than foil thicknesses.*



PRESSURE TEST SPECIMEN - AT LEAST 8 INCHES OF SEAM WELD SHALL BE SUBJECTED TO PRESSURE LOADING. PRESSURE TEST SPECIMEN MAY BE CUT INTO TWO 5-INCH SPECIMENS FOR TESTING PURPOSES. AT LEAST 4 INCHES OF THE SEAM WELD SHALL BE SUBJECTED TO PRESSURE LOADING.

(VALUES FOR W AND A ARE SHOWN IN TABLE V)

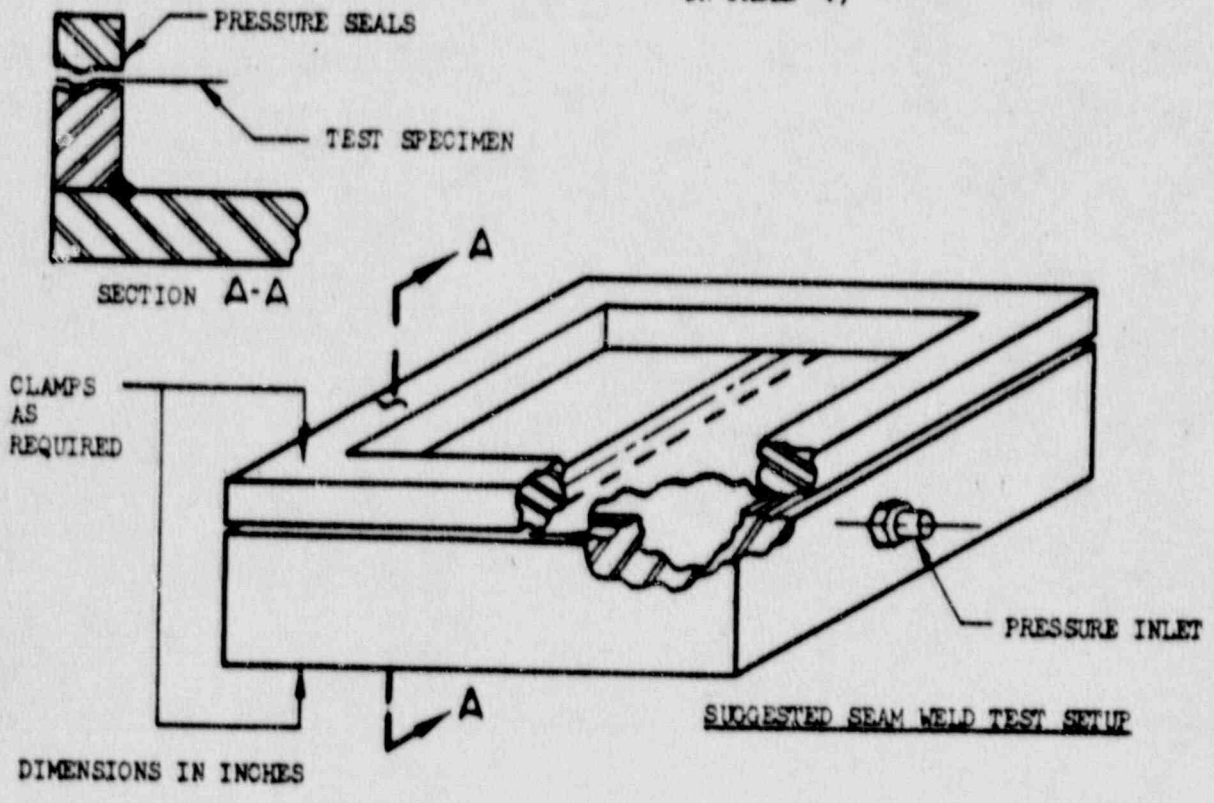
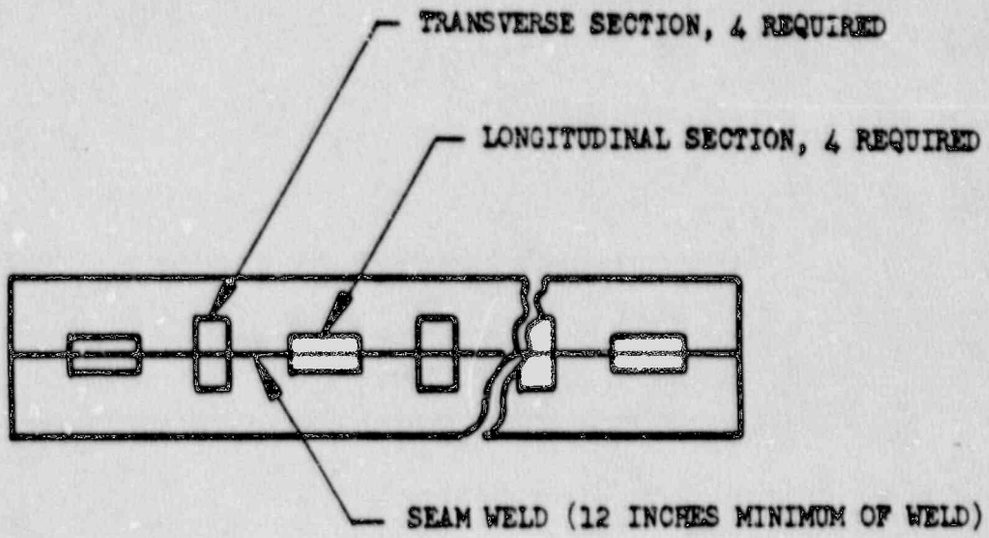


FIGURE 8. *Qualification test specimen, class A seam welding foil thicknesses.*



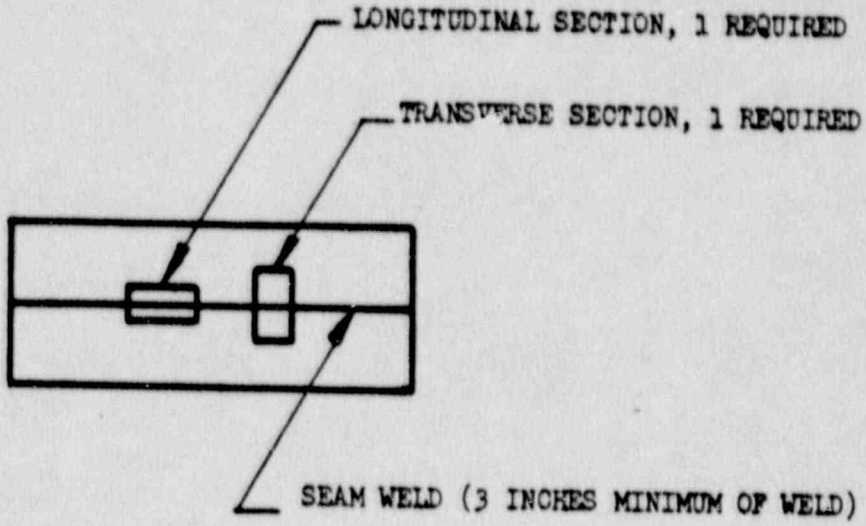
LONGITUDINAL SECTIONS SHALL BE PREPARED IN SUCH A MANNER THAT AT LEAST A TOTAL LENGTH OF 1 INCH OF SEAM WELD IS EXAMINED.

TRANSVERSE SECTIONS SHALL BE OF SUFFICIENT LENGTH TO INCLUDE THE WELD NUGGET, THE HEAT AFFECTED ZONE, AND PORTIONS OF THE UNAFFECTED BASE METAL AT EACH END.

WIDTH OF TEST STRIP SHALL BE AS SHOWN IN TABLE V FOR APPLICABLE THICKNESS REQUIRED.

LONGITUDINAL AND TRANSVERSE SECTIONS SHALL BE EXAMINED AS MICROSECTIONS FOR CLASS A AND AS MACROSECTIONS FOR CLASS B.

FIGURE 9. *Certification test specimen, class A or B seam welding.*



LONGITUDINAL SECTIONS SHALL BE PREPARED IN SUCH A MANNER THAT AT LEAST A TOTAL LENGTH OF 1 INCH OF SEAM WELDING IS EXAMINED.

TRANSVERSE SECTIONS SHALL BE OF SUFFICIENT LENGTH TO INCLUDE THE WELD NUGGET, THE HEAT AFFECTED ZONE, AND PORTIONS OF THE UNAFFECTED BASE METAL AT EACH END.

WIDTH OF TEST STRIP SHALL BE AS SHOWN ON TABLE V FOR APPLICABLE THICKNESS REQUIRED.

LONGITUDINAL AND TRANSVERSE SECTIONS SHALL BE EXAMINED AS MACROSECTIONS.

FIGURE 10. *Certification test specimen, class C seam welding.*

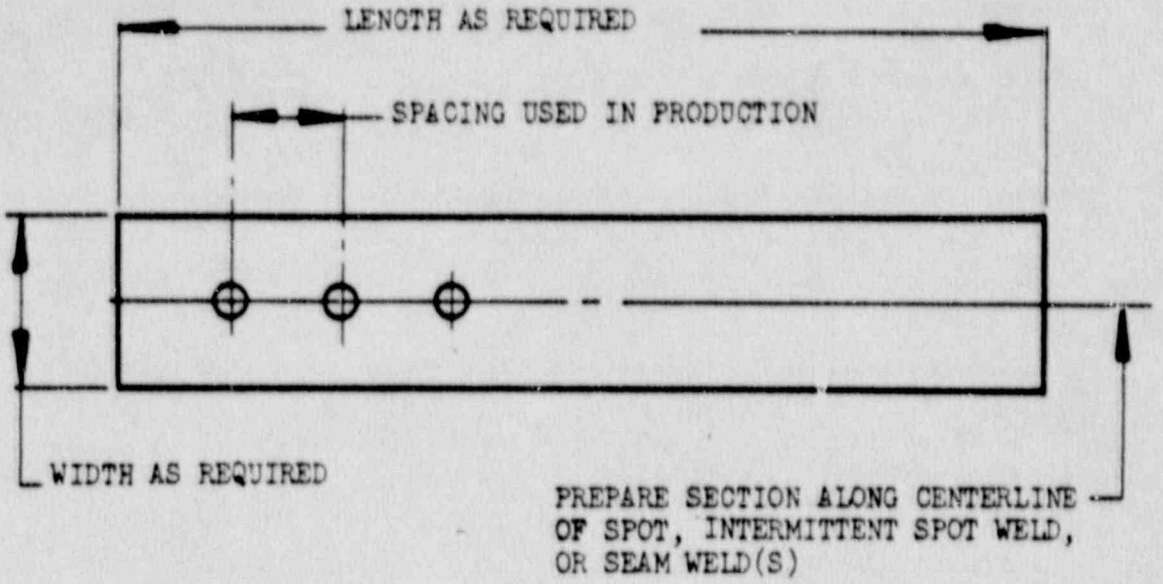
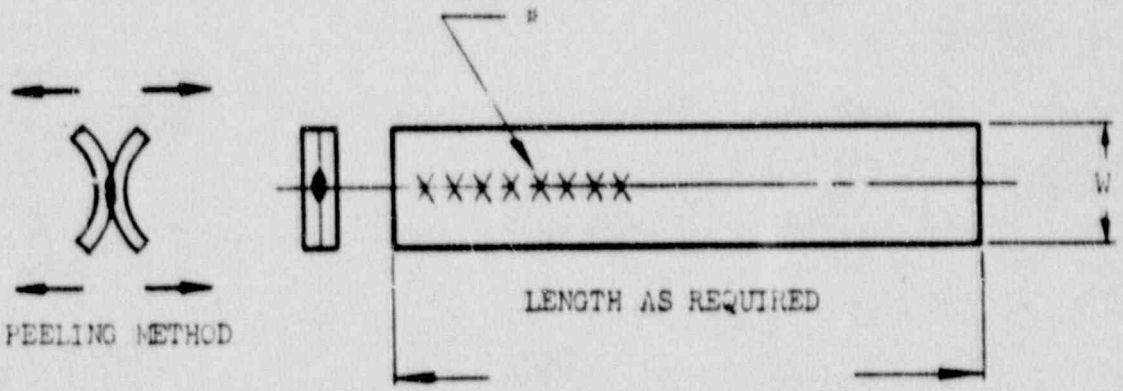
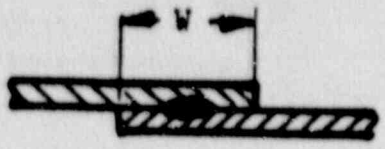


FIGURE 11. *Metallurgical specimen (macrosection or microsection).*



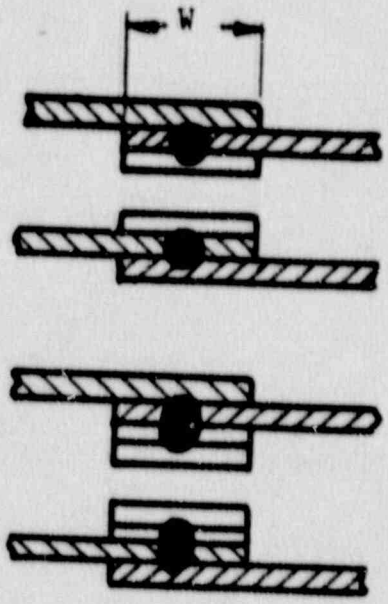
* SPOT SPACING AS USED IN PRODUCTION.
(VALUES FOR W ARE SHOWN IN TABLE V).

FIGURE 12. *Peel test specimen--foil thicknesses—spot and seam welding.*



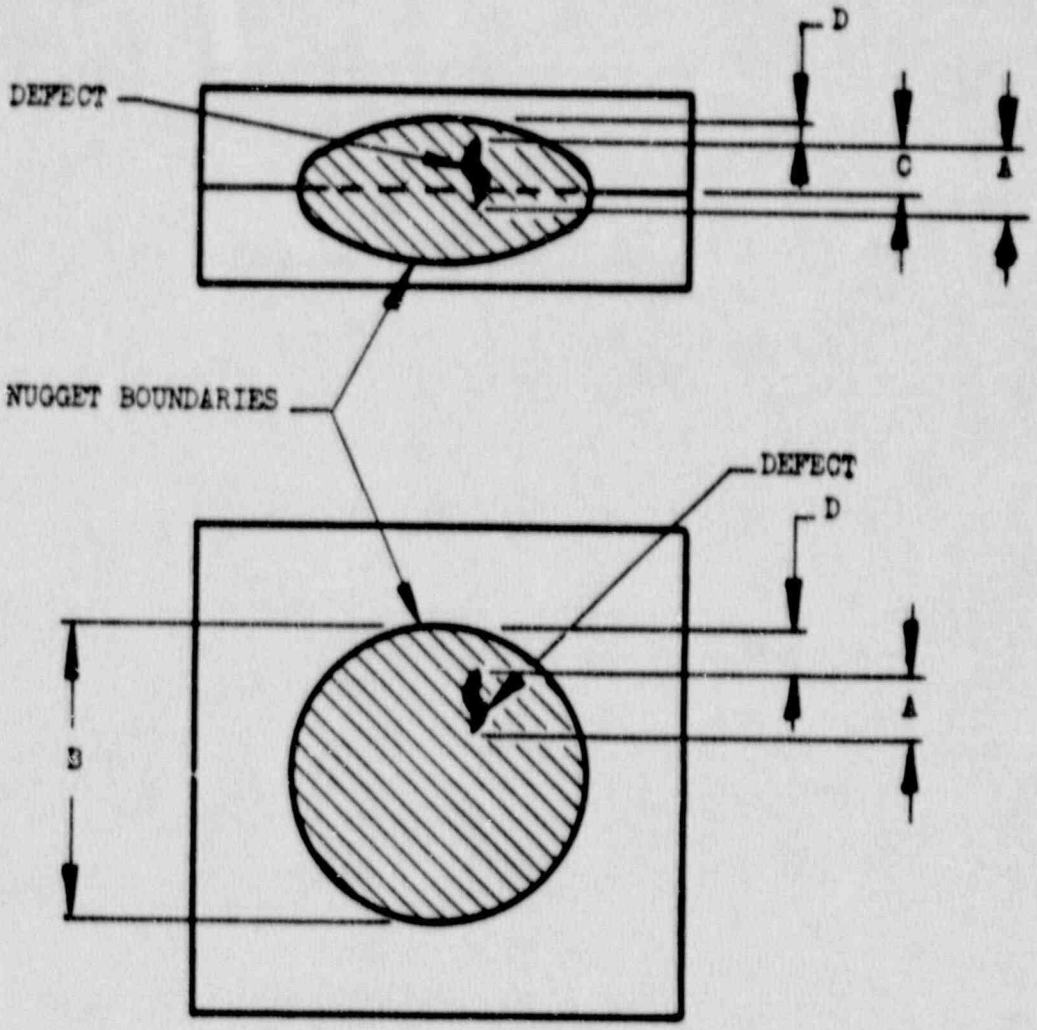
THE REQUIRED OVERLAP (W) SHALL BE MAINTAINED AS SPECIFIED IN TABLE V. (SEE 8.4.3.)

FIGURE 13. *Production quality control shear test specimen (2 thicknesses).*



TEST STRIPS NOT LOADED (UNSHADED) MAY BE LAID CROSSWISE OR PARALLEL WITH LOADED SPECIMEN OR MAY BE SHORT OR MAY BE BENT OUT OF THE WAY; HOWEVER, THE REQUIRED OVERLAP (W) SHALL BE MAINTAINED AS SPECIFIED IN TABLE V.

FIGURE 14. *Production quality control shear test specimens (3 or more thicknesses).*



A IS MAXIMUM EXTENT OF DEFECT. (SEE 7.2.1.)
B IS WELD DIAMETER. (SEE 7.2.1(a)(1).)
C IS EXTENSION INTO OUTER SHEET. (SEE 7.2.1(a)(2).)
D IS EXTENSION WITHIN NUGGET BOUNDARIES. (SEE 7.2.1(a)(3).)

FIGURE 15. *Internal defects.*

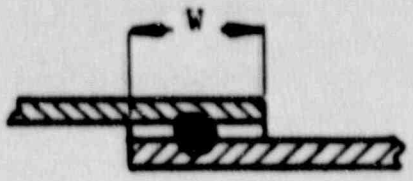
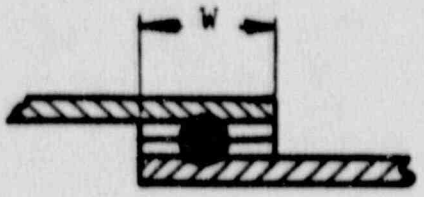


FIGURE 17 TEST METHOD PERMITTED FOR PRODUCTION QUALITY CONTROL TESTS ONLY - SEE 8.4.3.



TEST STRIPS NOT LOADED (UNSHADED) MAY BE LAID CROSSWISE OR PARALLEL WITH LOADED SPECIMEN OR MAY BE SHORT OR MAY BE BENT OUT OF THE WAY; HOWEVER, THE REQUIRED OVERLAP (W) SHALL BE MAINTAINED AS GIVEN IN TABLE V, SEE 8.4.3.

FIGURE 16. *Optional production quality control shear test specimens.*

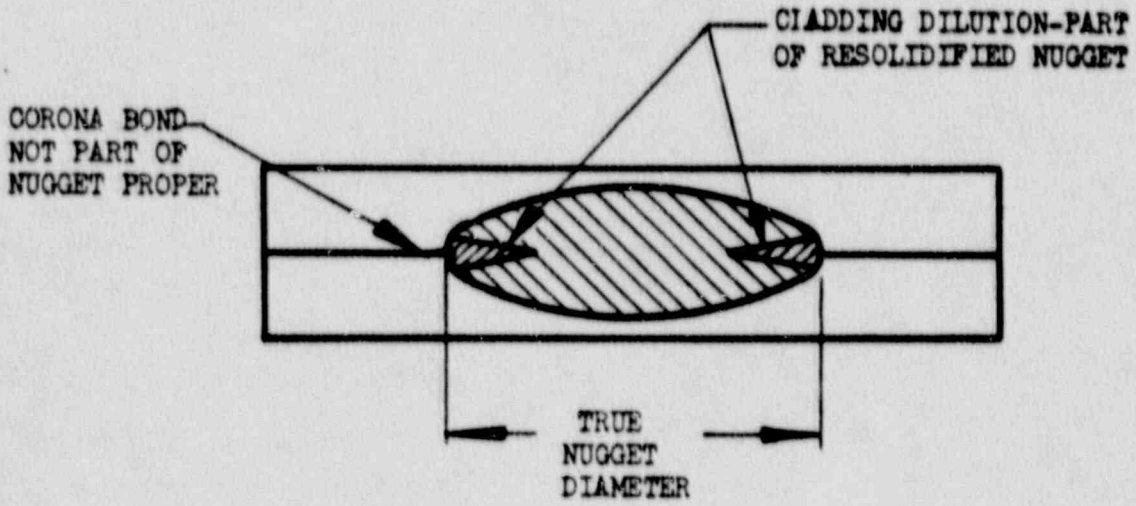


FIGURE 17. *Weld nugget diameter (see 10.2.4).*

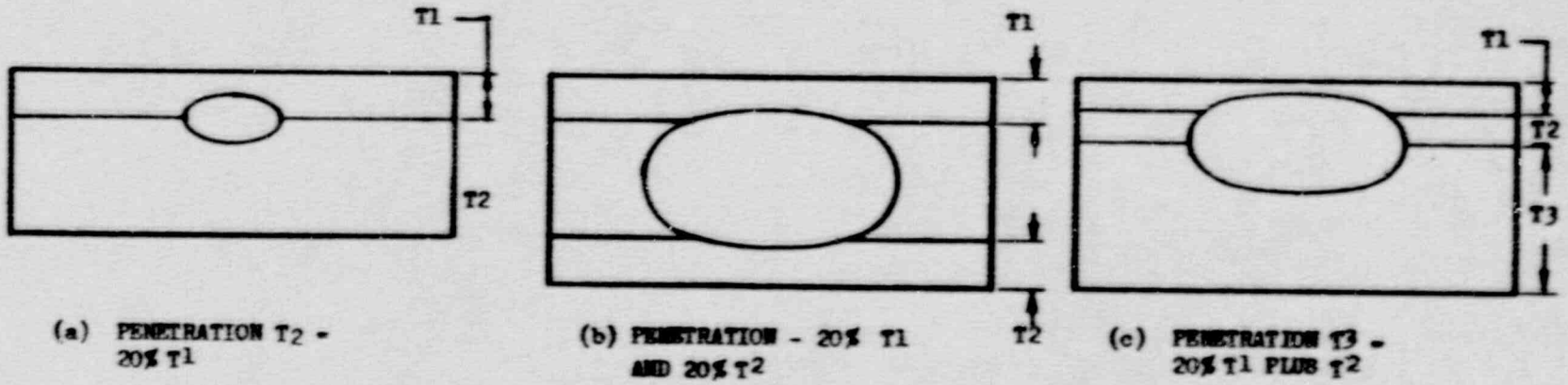


FIGURE 18. *Minimum penetration, spot and intermittent spot welds.*

10.2.3 *Intermittent spot welding.* Intermittent spot welding is a resistance-welding process wherein coalescence is produced by the heat obtained from resistance to the flow of electric current through the work parts held together under pressure by rotating or fixed electrodes. The resulting weld is a series of nonlapping fused zones, two nugget diameters or less apart, made progressively along a joint.

10.2.4 *Weld nugget or diameter.* The weld nugget or diameter is the fused zone of a spot, seam, or intermittent spot-weld. For nugget diameter measurements, this zone shall be considered to be the maximum width at the faying surfaces of the resolidified nugget, disregarding any penetration of cladding or other materials into the columnar zone. (See fig. 17.)

10.2.5 *Porosity (gas pocket).* Porosity is a welding cavity caused by entrapped gas, overheating or expulsion of the molten weld nugget.

10.2.6 *Macrosection.* A macrosection is a metallurigcal specimen prepared for examination with the naked eye or under low magnification of 7X to 10X maximum.

10.2.7 *Microsection.* A microsection is a metallurgical specimen prepared for examination under a microscope at a minimum of 25X to a maximum of 40X.

10.2.8 *Tack welds.* Tack welds are welds which are for convenience only and are not intended to carry a load.

10.3 **Estimating variation.**

$$\text{Variation} = \frac{\text{Range}}{\text{Average}}$$

$$= \frac{\text{Difference between largest and smallest shear strength value}}{\text{Average of individual shear strengths}}$$

10.3.1 *Sample calculation.*

Shear strength in pounds = 840, 810, and 870. Total = 1020.

$$\text{Average, pounds} = \frac{1020}{3} = 340$$

$$\text{Range, pounds} = 870 - 810 = 60$$

$$\text{Variation} = \frac{\text{Range}}{\text{Average}} = \frac{60}{340} = 0.176 \text{ or } 0.18$$

10.4 **Marginal indicia.** The margins of this specification have been marked to indicate where changes, deletions, or additions to the previous issue have been made. This has been done as a convenience only and the Government assumes no liability whatsoever for any inaccuracies in these notations. Figures are not so marked. Bidders and contractors are cautioned to evaluate the requirements of this document based on the entire content as written, irrespective of the marginal notations and relationship to the last previous issue.

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SPECIFICATION ANALYSIS SHEET

FORM APPROVED BUDGET BUREAU NO. 119-R004

INSTRUCTIONS

This sheet is to be filled out by personnel either Government or contractor, involved in the use of the specification in procurement of products for ultimate use by the Department of Defense. This sheet is provided for obtaining information on the use of this specification which will insure that suitable products can be procured with a minimum amount of delay and at the least cost. Comments and the return of this form will be appreciated. Fold on lines on reverse side, staple in corner, and send to preparing activity.

SPECIFICATION

MIL-W-6858C Welding, Resistance: Aluminum, Magnesium, etc., Spot and Seam

ORGANIZATION | CITY AND STATE

CONTRACT NO. | QUANTITY OF ITEMS PROCURED | DOLLAR AMOUNT $

MATERIAL PROCURED UNDER A

☐ DIRECT GOVERNMENT CONTRACT ☐ SUBCONTRACT

1. HAS ANY PART OF THE SPECIFICATION CREATED PROBLEMS OR REQUIRED INTERPRETATION IN PROCUREMENT USE?

A. GIVE PARAGRAPH NUMBER AND WORDING

B. RECOMMENDATIONS FOR CORRECTING THE DEFICIENCIES

2. COMMENTS ON ANY SPECIFICATION REQUIREMENT CONSIDERED TOO RIGID

3. IS THE SPECIFICATION RESTRICTIVE?

☐ YES ☐ NO *"IF YES" IN WHAT WAY?*

4. REMARKS (*Attach any pertinent data which may be of use in improving this specification. If there are additional papers, attach to form and place both in an envelope addressed to preparing activity*)

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