INCH-POUND

MIL-W-6873C
13 May 1991
SUPERSEDING
MIL-W-6873B
6 September 1968

MILITARY SPECIFICATION

WELDING; FLASH, CARBON AND ALLOY STEEL

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

1. SCOPE

1.1 Scope. This specification covers procedures for flash welding alloy steels and steels of medium and low carbon content to be used in the as-welded or heat treated condition.

2. APPLICABLE DOCUMENTS

2.1 Government documents

2.1.1 Specifications and standards. The following specifications and standards form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: ASD/ENES, Wright-Patterson AFB OH 45433-6503 by using the self-addressed Standardization Document Improvement Proposal.

AMSC N/A FSC 3432

SPECIFICATION

MILITARY

MIL-H-6875 - Heat Treatment of Steel Process for

STANDARD

MILITARY

MIL-STD-1949A - Inspection, Magnetic Particle

(Unless otherwise indicated, copies of federal and military specifications, and standards are available from the Standardization Documents Order Desk Bldg 4D, 700 Robbins Avenue, Philadelphia PA 19111-5094.)

2.2 Other publications. The following document(s) form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation.

AMERICAN SOCIETY FOR TESTING AND MATERIALS

ASTM A370 - Mechanical Testing of Steel Products
ASTM E8 - Tension Testing of Metallic Materials

(Application for copies should be addressed to American Society for Testing and Materials, 1916 Race Street, Philadelphia PA 19103.)

AMERICAN WELDING SOCIETY

ANSI/AWS A3.0 - Standard Welding Terms and Definitions

(Application for copies should be addressed to American Welding Society, Inc., 550 N.W. LeJeune Road, P.O. Box 351040, Miami FL 33135.)

(Nongovernment standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. GENERAL REQUIREMENTS

3.1 Requirements. The flash welding equipment shall be capable of consistently producing welds which meet the requirements of this specification.

3.1.1 Equipment. The equipment shall be automatically controlled with respect to:

a. Feeding of the joint during flashing
b. The rates and distance of travel of the sections to be welded
c. Controlling the secondary voltage and current magnitudes and timing
d. The time of current cutoff

The equipment shall be capable of bringing the two sections to be welded in contact with a pressure/force capability and machine rigidity adequate to produce sound and properly aligned welded assemblies. The equipment shall be capable of bringing the two sections to be welded into contact, initiating the flow of current, and forming a "flashing" action between the two adjacent pieces of metal. As the metal on the surfaces is burned or flashed away, the movable platen shall advance and maintain the gap within the appropriate limits, such that the flashing is maintained until the mating surfaces and adjacent areas have attained a degree of plasticity suitable for welding. The surfaces shall be rapidly brought together with sufficient force to close all craters formed during flashing, expel molten metal and substantially all oxides and impurities from the weld proper, upset the adjacent metal, and produce welds of acceptable quality.

3.1.2 Operation. The equipment shall be automated so that manually controlled flashing shall not exceed 15 percent of the total flashing travel.

3.1.3 Calibration of controls. All controls, meters, timers, and recorders used to regulate the welding current and voltage, upset pressure and travel, duration of current flow, and weld sequence time shall have the sensitivity, resolution, response rate, and accuracy necessary to permit control of the essential process variables. Calibration of process controls and instrumentation shall be carried out at a frequency that will ensure consistent performance.

3.1.4 Electrodes. The electrodes shall be of adequate size, shall be so fitted to the surfaces of the parts to be welded that the necessary current will be uniformly distributed about the contact zone, and shall be conducted from the electrode to the work without damage owing to localized overheating.

3.1.5 Control of machine variables. The equipment shall be set up by experienced operators under the supervision of a welding engineer, or other authorized personnel.

3.1.6 Welding schedules. Complete flash welding procedure schedules shall be established as specified herein for the joints to be welded in production and approved by the authorized inspector before a machine may be used in the welding of items to be furnished on Government contract.

3.1.7 Flash removal. A sufficient amount of the extruded or upset metal shall be removed from all weld areas in order that no defective or unsound material remains. A weld shall be rejected if it is necessary to machine below the level of the surface of the parent metal to remove surface defects. Unless otherwise specified, the removal of the internal flash from joints in hollow shapes will not be required.

3.1.8 Maintenance of equipment. All equipment shall be inspected periodically as recommended by the manufacturer. Adequate maintenance shall be furnished, and defective parts affecting machine operation shall be replaced as production welding is initiated or resumed.

3.2 Materials. Plain carbon and alloy steels of not more than .50 percent nominal carbon content may be welded, provided all requirements of this specification are met.

3.2.1 Heating and shielding gases. When required by this specification, heating and shielding gases shall meet the requirements of 3.2.1.1 through 3.2.1.4.

3.2.1.1 Propane or propane mixture. Minimum 85 percent propane by volume. Balance to be propylene, ethylene, butane, or mixtures thereof.

3.2.1.2 Argon. In accordance with CGA-G11.1, type I or II, grades C, D, or E.

3.2.1.3 Helium. In accordance with CGA-G9.1, type I with dew point -75°F or lower.

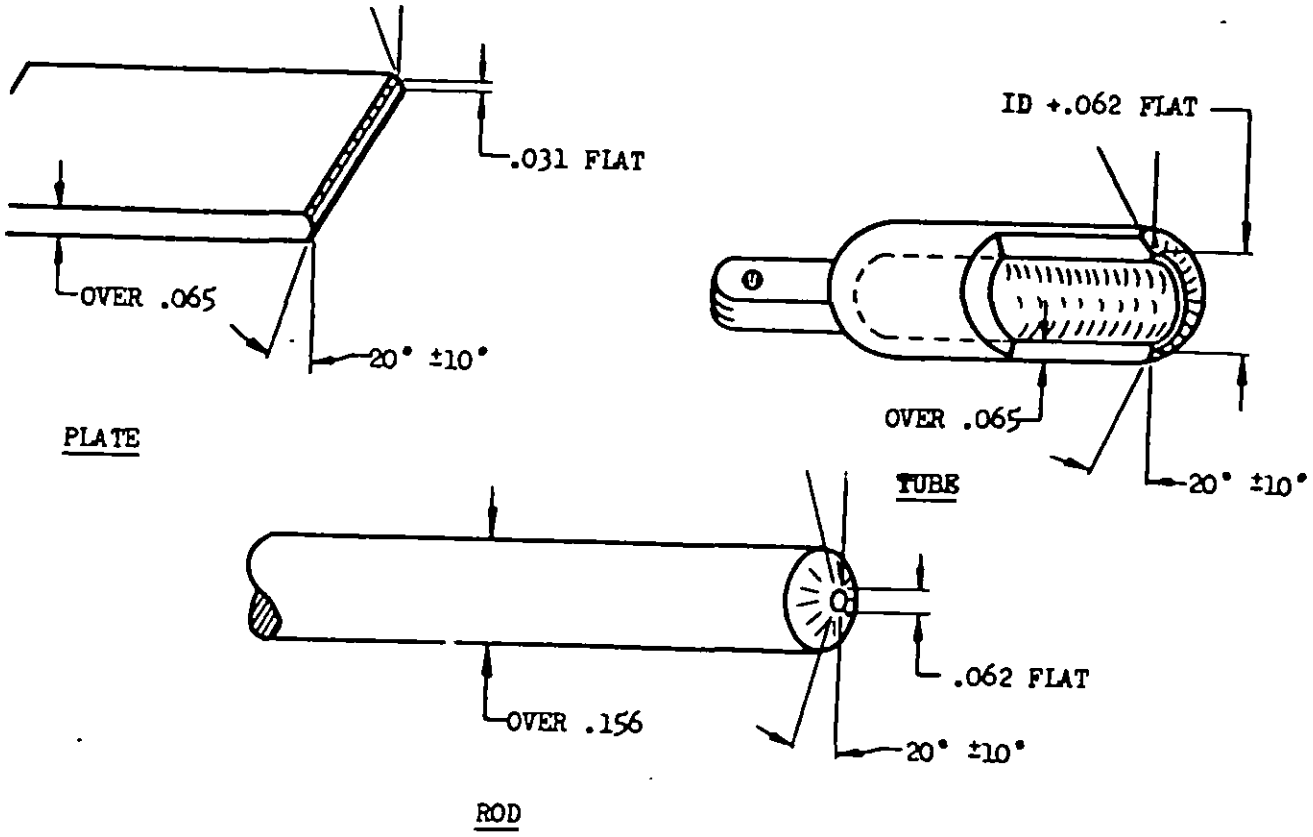
3.2.1.4 Nitrogen. In accordance with CGA-G10, type I or II, grades L, M, Q.

3.2.2 Cleaning. The surfaces of the parts contacting the electrodes and the surfaces at the fusion zones shall be clean and free from oxides, paint, grease, dirt, or foreign matter which would interfere with the flow of current or fusion of the metal. Chemical cleaning or grit blasting are preferred. Sandblasting may be employed provided the surfaces are treated to remove embedded sand particles prior to welding.

3.3 DETAILED REQUIREMENTS

3.3.1 Joint preparation. The mating parts shall be aligned in such a manner that heat generated by the flow of the current will be uniformly distributed over the section. The details of joint preparation shall be determined by the contractor and shall become a part of the welding schedule for the respective joint. Suggested configurations are shown on figure 1.

3.3.2 Limitation on tubing. Tubing possessing a ratio of outside diameter to wall thickness of greater than 30:1 shall not be flash-welded, unless the equipment is capable of meeting the more rigid alignment tolerances for 35:1 and 40:1 ratios specified in 3.3.4.1.



NOTE: a. THE ENDS OF PARTS TO BE WELDED SHALL BE OUT SQUARE WITHIN PLUS OR MINUS 1/2 A DEGREE.

b. WHEN THE NOMINAL STOCK THICKNESS EXCEEDS THE VALUES GIVEN IN THIS FIGURE, CHAMFER ONE OF THE PARTS AS SHOWN. IN THE EVENT IDENTICAL PARTS ARE TO BE WELDED TO EACH OTHER RESULTING IN EACH BEING CHAMFERED, CHANGE THE ANGLE TO 10 DEGREES.

UNLESS OTHERWISE SPECIFIED, DIMENSIONS IN INCHES.

FIGURE 1. Recommended end preparation for flash butt welding of tubing, flat sheets, and bar

3.3.3 Joint alignment tolerances. Flash-welded joints shall be sound and free from injurious defects, such as cracks, inclusions, die burns, and porosity which affect the strength or serviceability of the part. Welds with suspected discontinuities will be acceptable only when tests indicate that all requirements in this specification are met.

3.3.4 Alignment tolerances

3.3.4.1 Sheet and tubular joints. For sheet thickness or wall thickness of tubing .080 inch or less, the misalignment of thickness shall not exceed .005 inch or 8 percent of the nominal thickness, whichever is greater. For sheet or wall thickness greater than .080 inch, the misalignment of thickness shall not exceed 10 percent of the nominal section thickness up to a maximum of .030 inch, except for the following two higher ratios where a smaller misalignment is required. Misalignment tolerance shall be in accordance with table I.

TABLE I. Misalignment tolerances

O.D wall ratio	Percent maximum
Over 30:1 to 35:1	6
Over 35:1 to 40:1	4

Misalignment shall be measured at, or near, the plane of the weld before the flash is removed.

3.3.4.2 Bars. The misalignment of the surfaces in joints between bars and rods shall not exceed 5 percent of the diameter or thickness when measured at, or near, the plane of the weld, before the flash is removed.

3.3.4.3 Angular misalignment. The angular misalignment of the welded joints shall not exceed .002 inch per inch of length.

3.3.5 Qualification of Welding Procedures

3.3.5.1 General. A welding procedure shall be established by the contractor for each joint differing in material, area, or contour from joints previously welded in accordance with approved procedures, or for each welding machine over an appropriate range of cross-sectional areas, or wall thickness, or both.

Part/drawing identification number_____
Manufacturer of machine_____
Type and serial number_____
Capacity of machine _____
Transformer tap setting _____
Transformer turns ratio_____
Secondary voltage _____
Preheat treatment_____
Flashing time _____
Beginning of upset to current cutoff (cycles)_____
Burnoff (inches)_____
Total metal loss (inches)_____
Upset travel (inches)_____
Platen travel control cam number _____
Electrode type and part number_____
Area of electrode contact _____
Work locaters employed _____
Material, heat treat condition and surface condition _____
Shielding gases_____
Welding machine post heat treatment settings _____
Details of joint preparation _____
(Show sketch and dimensions)

_____
1/ Signature (Welding Engr.)

_____
1/ Signature (Authorized Inspector)

1/ The supervisory welding engineer or authorized alternates, and the authorized inspector shall sign the welding schedule form.

FIGURE 2. Typical welding schedule.

3.3.5.2 Welding procedure schedule. A complete welding schedule shall include the preparation of the parts to be welded, choice of electrodes and fittings, and appropriate machine control devices and settings to provide the proper sequence of events. The record of a welding schedule shall include the appropriate items on figure 2.

3.3.5.3 Use of sensors for in-process control. Where sensors are used to monitor the welding process or used to control the process variables, these sensors must be in operation during the establishment of the welding procedure as described in 3.3.6. Charts and electronically stored process data must be retained for future examination of the authorized inspector.

3.3.6 Establishing welding procedures

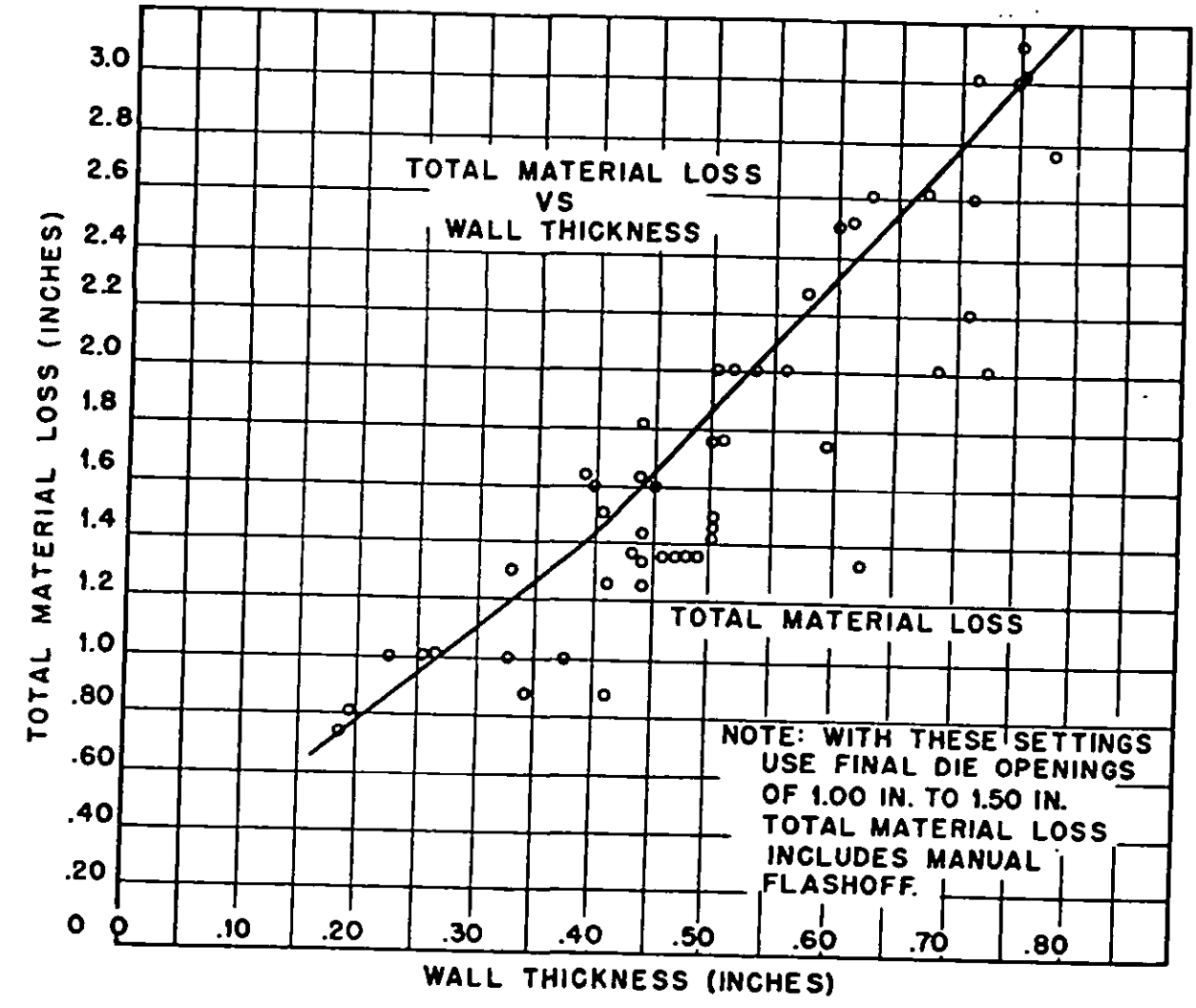
3.3.6.1 General. Welding procedures may be established by the contractor by one of four methods:

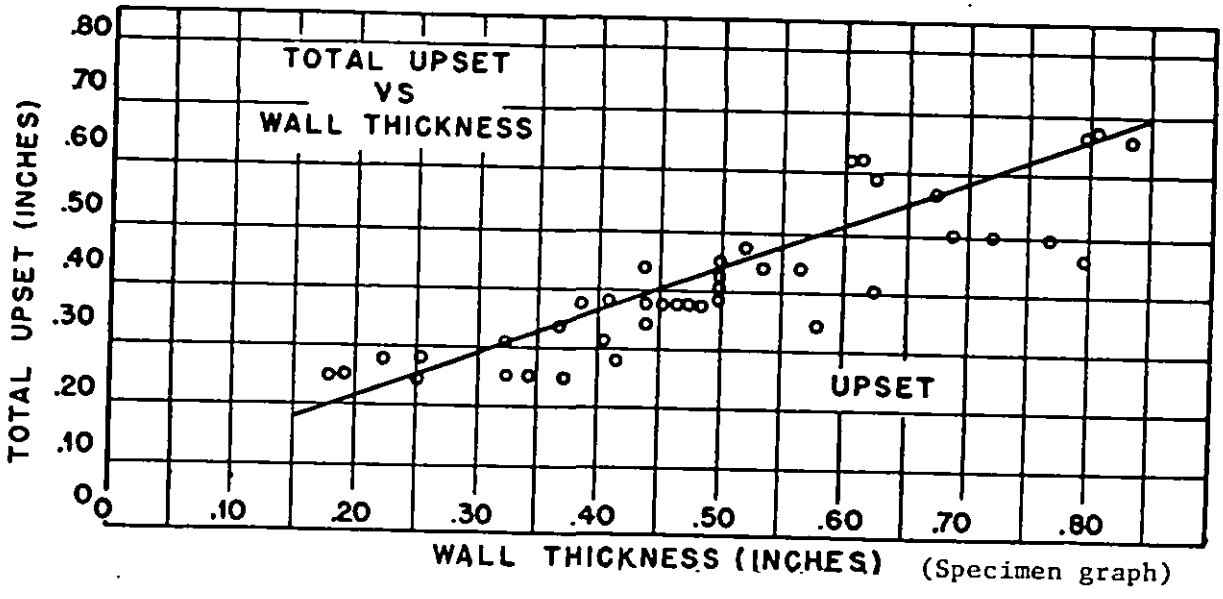
a. Machine qualification (see 3.3.6.2)
b. Alternate method (see 3.3.6.4)
c. Additional procedures (modification) (see 3.3.6.5)
d. Individual part qualification (see 3.3.6.6)

3.3.6.2 Machine qualification. The three initial welding procedures established by the contractor for a given machine shall represent joints of the greatest and the least cross-sectional areas to be welded in production, plus one joint of intermediate area. To determine the acceptability of the settings and the consistency of the resultant welds, at least 15 joints shall be welded at each of the three conditions. Each joint shall be inspected as specified in 4.4.1 and 4.4.2 and tested as specified in 3.3.7.3. The test data will be submitted to the authorized inspector with a request for approval of the welding procedure represented. Assemblies welded with the respective machine shall not be acceptable as items furnished on a Government contract until the suitability of the welding procedures has been demonstrated and approved as specified herein. Welding procedures shall not be changed during a production run, except as provided in 3.3.6.5.

3.3.6.3 Plotting of control settings. Graphs of the following items or their equivalents shall be plotted by the contractor and used (together and the sensor data, if obtained) as an appropriate guide in establishing welding schedules for other joints as needed:

a. Machine settings (such as upset, final die opening, material loss, and so forth) versus wall thickness or cross-sectional area. (see figure 3)
b. Flashing time versus wall thickness. (see figure 4)
c. Voltage versus cross-sectional area. (see figure 5)





(Specimen graph)

FIGURE 3. Machine settings versus wall thickness

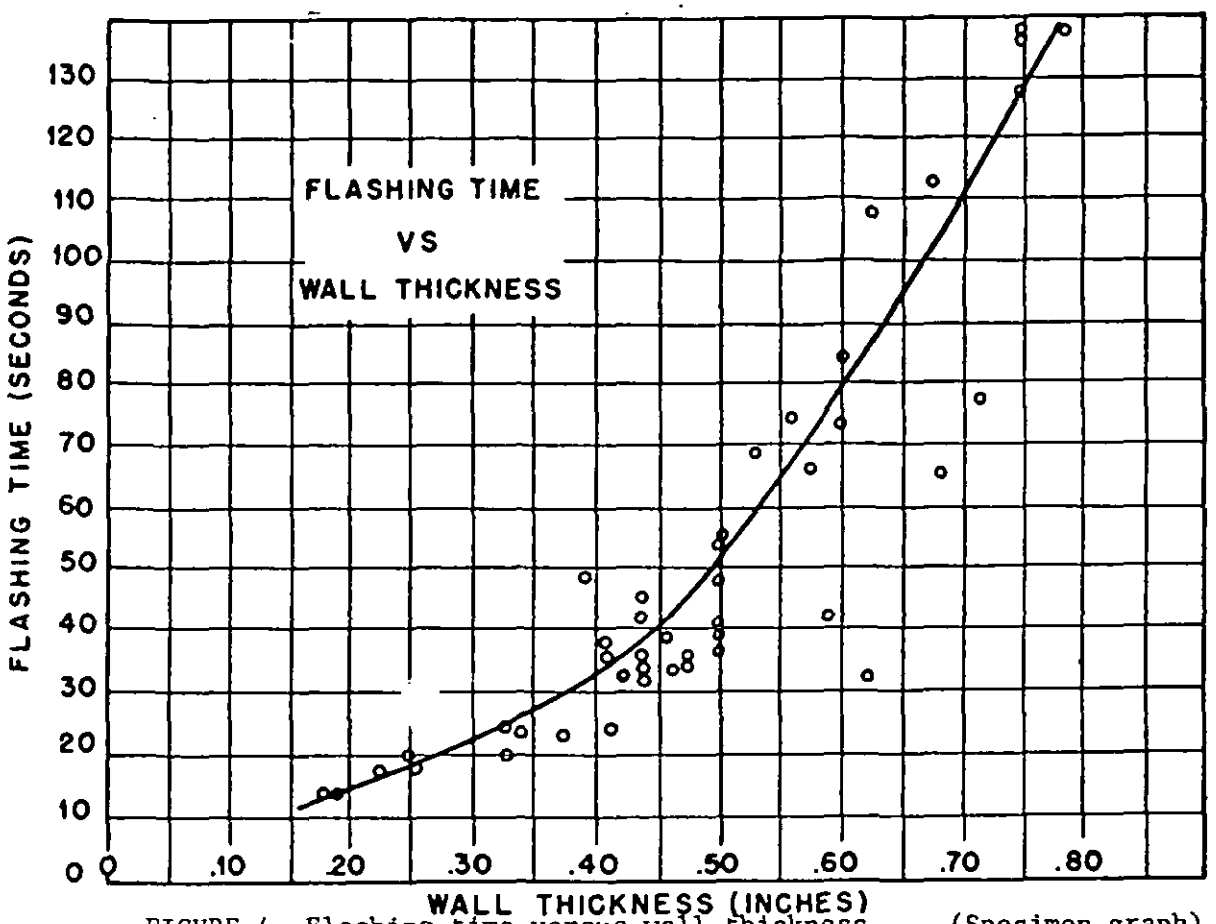


FIGURE 4. Flashing time versus wall thickness (Specimen graph)

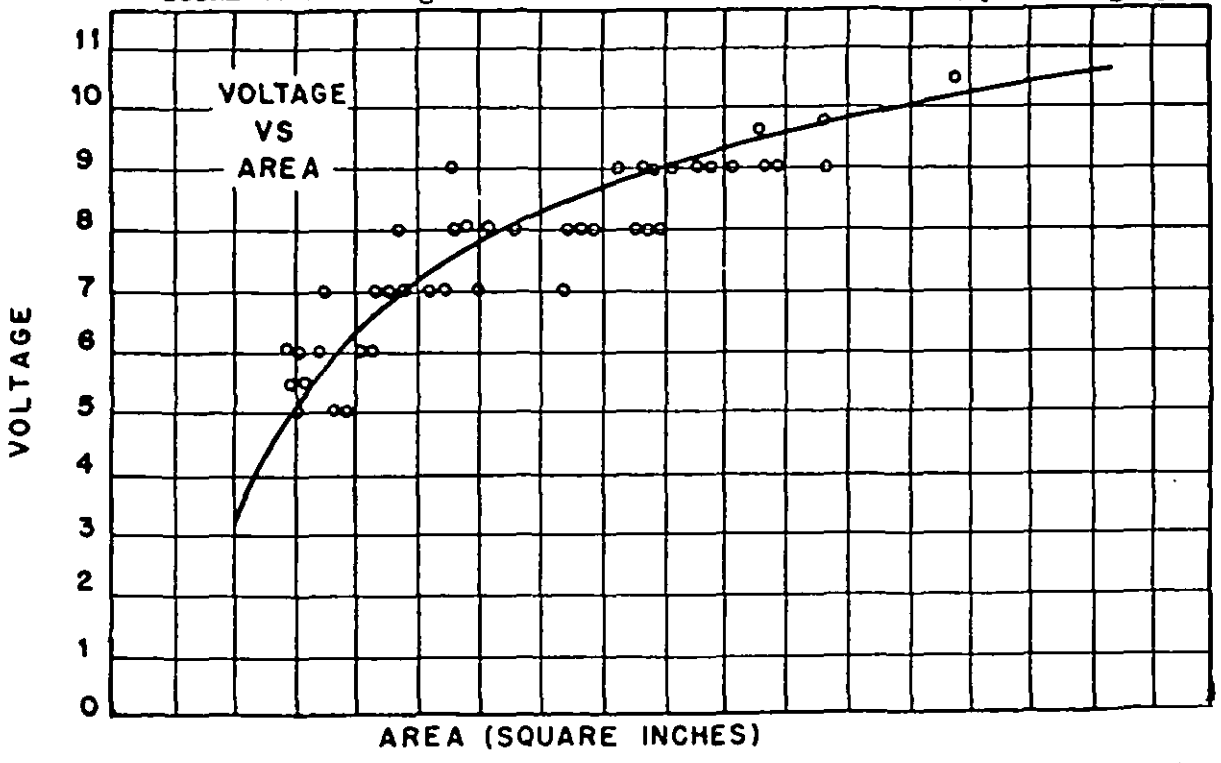


FIGURE 5. Voltage versus cross-sectional area (Specimen graph)

3.3.6.4 Alternate method. When welding data for a machine have been accumulated by the contractor prior to certification for use under Government contract, and the settings are appropriate and records complete, the data may be used as an alternate basis for establishing the required graphs. In such cases, the suitability of all welding schedules shall be demonstrated in accordance with the procedure specified in 3.3.6.5.

3.3.6.5 Additional schedules or modification of existing schedules. To weld parts with cross-sectional areas other than those specifically checked above, or to accomplish minor modification of existing schedules as may be necessary, the contractor shall demonstrate that the settings for these secondary points are acceptable on five sample parts or control specimens. If unsatisfactory results are obtained for a secondary point, a sample of 15 shall be run to check the point, after suitable adjustments in settings have been made. Specific approval of each additional schedule will not be required, but complete records shall be made readily available to operating personnel and authorized inspection personnel for reference at any time.

3.3.6.5.1 Development of graphs and storage of data. Additional settings shall be plotted as available and the graphs adjusted as experience indicates. When sufficient data have been accumulated, a band will be developed for each machine within which acceptable welds may be obtained. The corresponding sensor data may be used for process control.

3.3.6.6 Individual part certification. When one, or a limited number of joint types are to be welded in production and complete qualification of the machine is not considered necessary or desirable, the contractor may establish individual schedules on the basis of 15 test specimens.

3.3.6.7 Production run. Unless otherwise specified, one setting of the machine shall satisfactorily weld the maximum and minimum cross-sectional areas scheduled during a production run. No change in setting shall be made during a run without approval of the authorized inspector.

3.3.6.8 Certification test specimens. Either production parts or simulated parts may be for welding procedure qualification test specimens. The mating surfaces to be joined and the electrode contact areas shall be identical with the production part in cross-sectional area contour and finish. The part shall be made from the same alloy and heat treat condition as the production part and the joint shall be welded in accordance with the proposed welding procedure and with the requirements specified herein.

3.3.7 Heat treatment of specimens

3.3.7.1 Joints for service as welded. Welded specimens representing parts made of steel in the normalized or the "as received" condition to be used as welded and without further heat treatment may be stress relieved prior to testing.

3.3.7.2 Joints to be heat treated prior to service. Welded specimens representing parts to be heat treated to higher strength levels shall be heat treated to not less than the design strength level in accordance with MIL-H-6875.

3.3.7.3 Type of specimens. Specimens shall be tested in full section, whenever practical. Where test specimens are too large to be tested in full section, tensile coupons conforming to an appropriate type as defined in ASTM E8 may be cut from locations, such that the weld zone is included in the test section. Tensile specimens from tubular specimens may be prepared as indicated on figure 6. The aggregate weld area of the coupons shall not be less than 50 percent of the area of the weld joint represented.

4. QUALITY ASSURANCE PROVISIONS

4.1. Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements (examinations and tests) as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

4.1.1 Responsibility for compliance. All items shall meet all requirements of section 3. The inspection set forth in this specification shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept defective material.

4.2 Production Control. All specimens required herein for checking production flash welding shall be welded in accordance with the established schedule.

4.3 Sampling

4.3.1 Destructive sample. Each time a machine is set up for a production run according to a qualified welding procedure, the set up shall be checked by welding and testing three parts, or simulated production parts, as specified in 4.4.4. Alternate nondestructive inspection procedures may be used provided that the suitability of the procedures has been established by destructive tests and approved by the procuring agency of the Government.

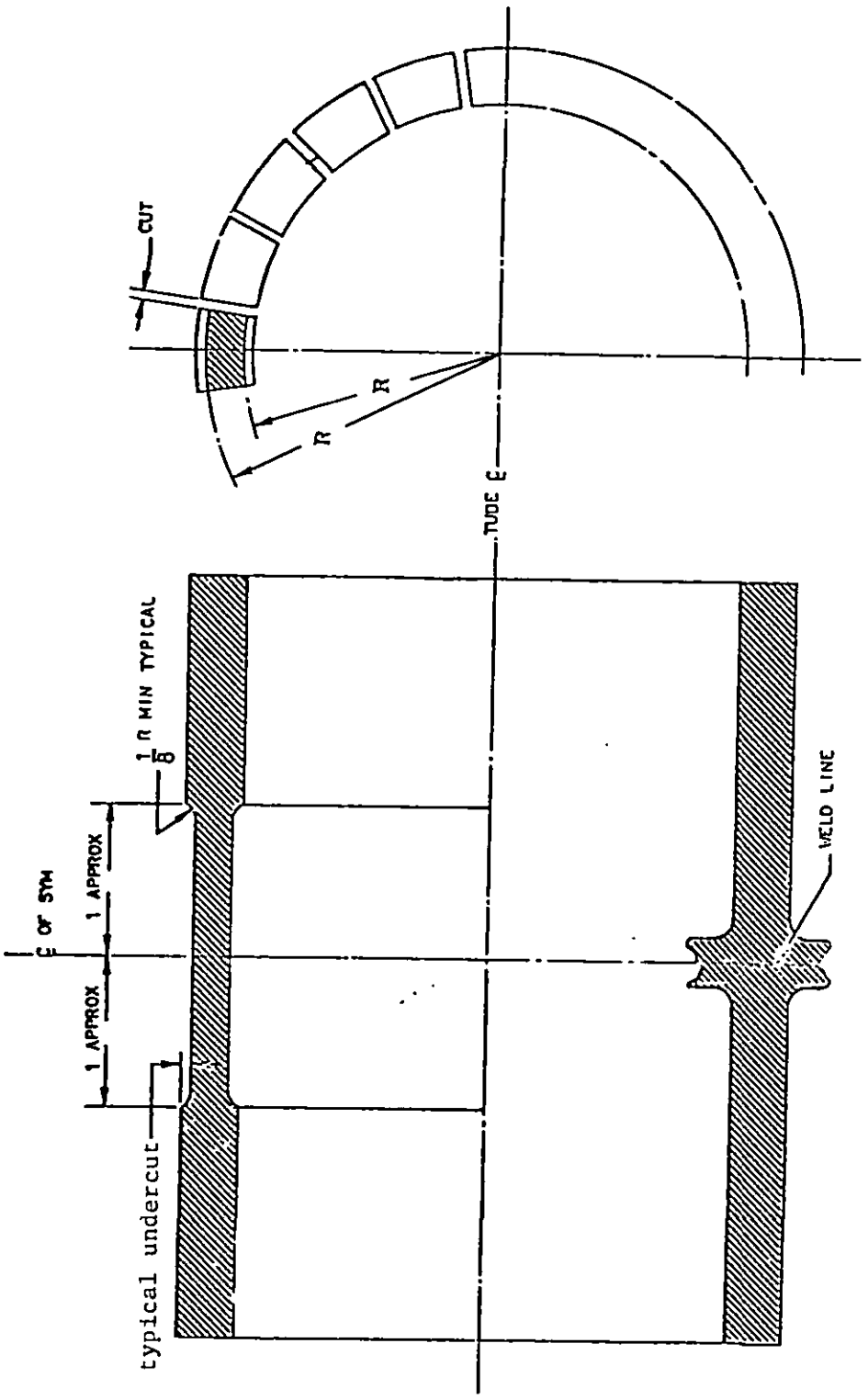


FIGURE 6. Alternate configuration for friction gripped tensile coupon

4.3.2 Proof-testing sample. Unless greater frequency of sampling is specified, production lots of critical and structural parts shall be sampled for proof testing as specified in table II.

TABLE II. Proof-testing sample.

Lot Size	Sample Size
Less than 31	All
31 - 50	30
51 - 100	42
101 - 200	55
201 - 400	60
401 - 800	65
801 - 4000	70
4000 - 10000	75

When the sample size is less than the lot size, the samples used for proof testing shall be distributed uniformly within the production lot.

4.4 Inspection methods

4.4.1 Visual examination. Each flash-welded joint shall be examined for cracks, die burns, telescoping, and other indications of unsound welding before and after the flash is removed.

4.4.2 Magnetic inspection. All production welds in magnetic materials shall be inspected by magnetic particle inspection in accordance with MIL-STD-1949A.

4.4.3 Destructive tensile test. Destructive tensile tests shall be performed in accordance with the requirements specified in 4.4.4. Other destructive weld tests may be required by the procuring activity but these will be specified, in advance, in the contract or purchase order.

4.4.4 Tensile tests. The whole weld test specimen shall be subjected to tensile tests in accordance with ASTM A370. Where specimens are too large to be tested in whole, they may be cut into tensile coupons prior to testing in whole, they may be cut into tensile coupons prior to testing in accordance with ASTM E8, except that reduction in size of the test section of the specimens will not required. If the test section is reduced in size, the thickness of the material shall not be less than the wall thickness of the part as it will exist in the proof test. Specimens may be stress relieved or normalized to facilitate machining, but shall be heat treated as specified herein prior to testing. The entire test specimen, except that removed by machining, shall be tested when cut into coupons. The ultimate strength of the parent metal will be determined from the average of not less than three tensile tests. Specimens of welded joints having failures completely outside of the weld may be substituted for tensile specimens of the parent metal.

4.4.4.1 Tensile tests results. The tensile tests results shall furnish evidence that the parent material has been heat treated as specified in 4.4.4.

4.4.5 Proof tests. All specimens of the production sample selected as specified in 4.3.2 shall be proof tested in a manner and with loading conditions specified by the procuring activity. Parts that require heat treatment after welding shall be proof tested after heat treatment.

4.4.5.1 Proof test inspection. After proof testing, the weldment shall be magnetic particle inspected in accordance with MIL-STD-1949A.

4.5 Test requirements

4.5.1 Whole specimens. The results of the tests on whole specimens shall conform to the following:

a. No specimen tested in the "as-welded" condition shall fail in the weld.

b. For other specimens and conditions, failure in the weld shall be acceptable, provided the stress at failure is not less than 95 percent of the ultimate strength of the base metal determined in accordance with 4.4.4.

4.5.2 Strip test coupons. Provided that no defects associated with faulty welding conditions are present, the results of tests on coupons shall be acceptable when:

a. The average strength of all the coupons from each specimen is not less than 95 percent of the average strength of the parent material.

b. The minimum test value shall not be less than 80 percent of the average strength of all coupons.

4.5.3 Proof tests. All specimens shall pass the specified proof test, except when other methods of production testing have been approved by the procuring activity. Any noticeable yielding at the joint (determined visually) during proof testing shall be cause for rejection. If any specimen or part fails to pass the proof test, the entire production run of parts which the sample represents shall be subjected to proof testing and the schedule shall be rechecked or recertified.

4.5.4 Records. The contractor shall keep a record of tests and a list of all parts corresponding to each setup and test. The record shall include all procedure details as shown on figure 2 and other data stored permanently on charts and in electronic media. The records shall be subject to examination by the inspector.

5. Not Applicable PACKAGING

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. The procedures covered by this specification are intended for aircraft and missile application, and other applications where control procedures are desired.

6.2 Definitions

6.2.1 Definition of terms. The definitions of the terms herein are, in general, in accordance with ANSI/AWS A3.0, Standard Welding Terms and Definitions.

6.2.2 Weld failure. "Weld failure," as used herein is a failure, either partially or wholly in the weld plane, except for partial weld-plane failures in heat treated whole specimens. Partial weld-plane failure in heat treated whole specimens is not considered a weld failure where fracture in the weld plane does not exceed 25 percent of the weld area and is accompanied by visual necking down of the parent metal.

6.2.3 Production run. A "production run," as referred to herein, is the production of flash welding of identical parts without a change in machine setup for four hours of continuous operation or as established by the contractor from results of tests or prior production experience.

6.3 Protective atmosphere welding. For greater assurance of weld quality, tubing with wall thickness over .149 inch should be welded in a protective atmosphere. (see 3.2.1)

6.4 Figures 3, 4, and 5 are examples of initial curves established for a machine.

6.5 Subject (key word) listing.

Flash welding, alloy steels
Low and medium carbon
Welding

6.6 Publications. When requesting publications, refer to both title and number.

6.7 Change from previous issue. Marginal notations not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Custodians:
Army - MR
Navy - AS
Air Force - 11

Reviewer activity:
Army - MI

User activities:
Army - AT, ME
Navy - OS

Preparing activity:
Air Force - 11

(Project 3432-1057)

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
2. The submitter of this form must complete blocks 4, 5, 6, and 7.
3. The preparing activity must provide a reply within 30 days from receipt of the form.

NOTE: This form may not be used to request copies of documents, nor to request waivers, or clarification of requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or to amend contractual requirements.

I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER	2. DOCUMENT DATE (YYMMDD)
	MIL-W-6873C	91 May 13

3. DOCUMENT TITLE

Welding; Flash, Carbon and Alloy Steel

4. NATURE OF CHANGE (Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME (Last, First, Middle Initial)	b. ORGANIZATION	
c. ADDRESS (Include Zip Code)	d. TELEPHONE (Include Area Code) (1) Commercial (2) AUTOVON (If applicable)	7. DATE SUBMITTED (YYMMDD)

8. PREPARING ACTIVITY

a. NAME	b. TELEPHONE (Include Area Code) (1) Commercial	(2) AUTOVON
ASD/ENES	(513) 255-6295	785-6295
c. ADDRESS (Include Zip Code) Wright-Patterson AFB OH 45433-6503	IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT: Defense Quality and Standardization Office 5203 Leesburg Pike, Suite 1403, Falls Church, VA 22041-3466 Telephone (703) 756-2340 AUTOVON 289-2340	