

John F. Kennedy Space Center, NASA

Specification for Pipe, 36% Nickel,  
Iron-Base (Invar 36)

This amendment forms a part of KSC-SPEC-Z-0001A.

Delete Table I of paragraph 3.1.1 Chemical Composition and substitute in its place, the following tabulation:

TABLE I. CHEMICAL COMPOSITION

ELEMENTS	COMPOSITION (% by Weight)
Carbon	0.10 Max.
Manganese	0.30 to 0.60
Phosphorus	0.025 Max.
Sulfur	0.025 Max.
Silicon	0.35 Max.
Nickel	35 to 37
Cobalt	0.50 Max.
Chromium	0.50 Max.
Molybdenum	0.50 Max.
Iron	Remainder

Design Engineering Directorate  
APPROVED:


  
Raymond L. Clark  
Director of Design Engineering

KSC-SPEC-Z-0001 A  
September 22, 1975  
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KSC-SPEC-Z-0001  
Dated 20 February 1968

JOHN F. KENNEDY SPACE CENTER, NASA

SPECIFICATION FOR

PIPE, 36% NICKEL, IRON-BASE (INVAR 36)

APPROVED BY   
Raymond L. Clark  
Director of  
Design Engineering

JOHN F. KENNEDY SPACE CENTER  
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
PIPE, 36% NICKEL, IRON-BASE (INVAR 36), SPECIFICATION FOR

1. SCOPE

1.1 Scope - This specification covers weldable seamless or welded, 36 percent nickel, iron-base pipe, commercially known as Invar 36 or equal and suitable for service between plus 125°F and minus 454°F. The material covered by this specification is characterized by having a very low coefficient of thermal expansion.

1.2 Classification - The pipe shall be of the following types, as specified in the ordering document: (If not specified, either seamless or welded may be furnished).

Type I - Seamless

Type II - Welded

2. APPLICABLE DOCUMENTS

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

SPECIFICATIONS

Kennedy Space Center

KSC-SPEC-Z-0003

Welding of Stainless Steel and Invar Pipe,  
Tubing and Associated Fittings

Military

MIL-I-6866

Penetrant Method of Inspection

MIL-I-6868

Magnetic Particle Inspection Process

MIL-C-16173

Corrosion Preventive Compound, Solvent  
Cutback, Cold-Application

MIL-I-25135

Inspection Materials, Penetrant

NHB 5300.4(1C)

Inspection System Provisions for Aeronautical  
and Space System Materials, Parts;  
Components and Services - Reliability and  
Quality Assurance

STANDARDS

Federal

FED-STD-151                      Metals, Test Methods  
FED-STD-183                      Continuous Identification Marking of Iron  
   and Steel Products

Military

MIL-STD-129                      Marking for Shipment and Storage  
MIL-STD-163                      Steel Mill Products Preparation for Shipment  
   and Storage

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

2.2 Other Publications

The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply:

AMERICAN SOCIETY FOR TESTING AND MATERIALS  
ASTM A658 Pressure Vessel Plates, Alloy Steel, 36 Percent Nickel

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia 3, Pennsylvania 19103.)

AMERICAN SOCIETY OF MECHANICAL ENGINEERS  
ASME Boiler and Pressure Vessel Code, Section IX

(Application for copies should be addressed to the ASME Order Department, United Engineering Center, 345 East 47th Street, New York, N.Y. 10017.)

AMERICAN NATIONAL STANDARDS INSTITUTE  
ANSI B36.10 Wrought Steel and Wrought Iron Pipe  
ANSI B36.19 Stainless Steel Pipe

(Application for copies should be addressed to the American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.)

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## AERONAUTICAL MATERIAL SPECIFICATIONS

AMS 2248 Chemical Check Analysis Limits-Wrought Heat and Corrosion  
Resistant Steels

(Application for copies should be addressed to Society of Automotive Engineers, Inc., 2 Pennsylvania Plaza, New York, N.Y. 10001.)

OFFICIAL CLASSIFICATION COMMITTEE  
Uniform Freight Classification Rules

(Application for copies should be addressed to the Official Classification Committee, 1 Park Avenue, at 33rd Street, New York, N.Y. 10016.)

3. REQUIREMENTS3.1 Materials

3.1.1 Chemical Composition - The 36 percent nickel alloy pipe material shall conform to the requirements of Table I.

TABLE I. CHEMICAL COMPOSITION

Elements	Composition (Percent)(by Weight)
Carbon	0.10 max.
Manganese	0.30 to 0.60
Phosphorus	0.025 max.
Sulfur	0.025 max.
Silicon	0.35 max.
Nickel	0.35 max.
Product Analysis	35 to 37
Heat Analysis	35.5 to 36.5
Cobalt	0.50 max.
Chromium	0.50 max.
Molybdenum	0.50 max.
Iron	Remainder

3.1.1.1 Chemical Check Analysis - Unless otherwise specified, chemical check analysis variations shall meet the requirements of AMS 2248.

3.2 Mechanical Properties

3.2.1 Tensile Properties - The tensile properties of the 36 percent nickel alloy pipe shall conform to Table II.

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TABLE II. TENSILE PROPERTIES AT ROOM TEMPERATURE

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Tensile Strength		
min., Ksi (MPa)	65	(448)
Yield Strength		
min., Ksi (MPa) (0.2% offset)	35	(241)
Elongation in 2 inches or 50 mm min.*percent		30

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\* Allow a 1.50 percent deduction for each 1/32 inch decrease in wall thickness below 3/16 inch from the basic minimum elongation.

3.2.2 Flattening - The material shall not develop cracks, craze cracking, or other linear defects when deformed at room temperature by flattening as specified in 4.4.2.3.

3.2.3 Hydrostatic Test - Each length of finished pipe shall be tested by the manufacturer and shall withstand the internal hydrostatic test pressure as specified in 4.4.2.5 without developing leaks, bulges, or other defects.

### 3.3 Manufacture

3.3.1 Material - The material shall be made by the electric-arc, induction, or vacuum-arc remelt processes.

3.3.1.2 No welding is permitted on plate, sheet or strip prior to forming into pipe.

3.3.2 Annealing - The pipe material shall be annealed by heating to 1450+/-50°F. (790+/-28°C), holding at a temperature ½ hour per inch of thickness but in no case less than 15 minutes, and cooling in still air. Before heating, all surfaces shall be cleaned of oily grease, or contaminants containing sulfur, lead, tin, zinc, mercury or other harmful substances.

3.3.3 Welded Pipe - Welded pipe shall be made from hot-or cold-finished plate, sheet or strip. Welded pipe shall be manufactured using the gas tungsten arc (GTAW) or the gas metal arc (GMAW) welding processes. Filler wire of composition as shown in Table III shall be used in sufficient volume to prevent crack sensitivity. The joints shall be reinforced at the center of the welds by 1/16" of weld bead made in accordance with procedures and by welders or welding operators qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX or KSC-SPEC-Z-0003, and shall be full penetration welds. The certified report required for each shipment of material shall include the results of the chemical analysis of the filler metal utilized as well as the results of the testing performed to qualify the welding procedure.

TABLE II. INVAR WELDING WIRE AND  
FILLER ROD COMPOSITION

Element	Percent by Weight
Nickel	35.0-37.0
Manganese	2.00 - 3.00
Titanium	0.70 - 1.20
Carbon	0.10 (max.)
Silicon	0.20 (max.)
Sulfur	0.01 (max.)*
Phosphorus	0.02 (max.)*
Iron	Remainder

\*Sulfur and Phosphorus content shall be kept as low as possible. Their sum shall not exceed 0.025 percent.

3.3.4 Non-Destructive Test - Non-destructive testing shall be accomplished as follows:

3.3.4.1 Magnetic Particle or Liquid Penetrant Tests - All pipe welds shall be magnetic particle or liquid penetrant tested for surface defects as specified in 4.4.3 or 4.4.4.

3.3.5 Defects - Defects shall be thoroughly removed by grinding or machining prior to repair welding. Defects may also be removed by grinding or machining providing such removal does not reduce the material below minimum specified dimensions. Areas shall be faired smoothly into the surrounding areas. All repairs shall be welded in accordance with the ASME Code, Section IX or KSC-SPEC-Z-0003.

3.3.6 Descaling - All material shall be free of scale and other foreign matter after final processing. After chemical descaling, the material shall be thoroughly neutralized and washed in water to remove the descaling solution. Nitric-hydrofluoric acid pickling solutions shall not be used. Cleaning solutions and procedures shall be compatible with the material.

3.3.7 Special Requirements - Substances containing certain elements, such as sulfur and lead, can cause embrittlement during heating operations. Once this embrittlement has occurred, the metal cannot be restored to usefulness. Precautions must therefore be taken.

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- a. The following must be removed before heating, hot forming, or welding:
  - (1) Lubricants used in forming, machining, or other processing.
  - (2) Marking materials used in processing.
  - (3) Possible grinding wheel contaminants such as sulfur, copper, or lead.
- b. Rolling lubricants or marking materials containing sulfur and low melting point elements such as lead and mercury, in other than trace amounts, shall not be used.
- c. Other materials used, such as marking materials, shall not contain any element which, under the conditions of production, could adversely affect the properties of the material.

### 3.4 Dimensions

3.4.1 Schedules - Unless otherwise specified, pipe dimensions shall be in accordance with ANSI B36.10 or B36.19.

3.4.2 Permissible Variations - The following outside diameter and wall thickness variations are permissible:

3.4.2.1 Outside Diameters - The diameter shall not exceed +/-0.5 percent of the specified outside diameter.

3.4.2.2 Minimum Wall Thickness - The wall thickness at any point shall not be more than 12.5 percent under the nominal wall thickness specified.

3.4.3 Length - Unless otherwise specified, pipe shall be supplied in random lengths, with not less than 75 percent by weight being furnished in 18 to 24 feet inclusive, and the balance not less than 12 feet. When ordered to exact lengths, the tolerance in length shall be minus 0 inch, plus 1/4 inch. Circumferential welds shall not be permitted.

### 3.5 Finish

3.5.1 Ends - Finished pipe shall, unless otherwise specified, be furnished with plain, square-cut ends. All burrs shall be removed.

3.5.2 Straightness - The maximum deviation from a 10-foot straight edge shall be 1/8 inch.

3.5.3 Out-of-Roundness - The difference between the major and minor outside diameters shall be maintained within 1.0 percent of the nominal diameter at any point on the pipe.



### 3.7 Marking

3.7.1 Pipe shall be legibly marked in accordance with FED-STD-183 and as follows:

- a. Each length of pipe, 1½ inch nominal pipe size and larger, shall be marked continuously.
- b. Pipe smaller than 1½ inch shall be bundled. A metal tag, containing the required identification, shall be securely affixed at each end of each bundle.
- c. Identification marking shall include the following information:
  - (1) Supplier's name, trademark, or symbol.
  - (2) Specification number and type number.
  - (3) Heat and lot number or code identifying heat and lot number.
  - (4) Pipe size and schedule number.
- d. Metal die stamping, chisels or electric arc marking shall not be used except for heat identification on the end faces. (The vendor must still provide for the marking required above.)
- e. When marked with fluid, the marking shall not rub off nor smear by normal handling.
- f. The marking fluid shall not contain any harmful metal, or metal salts, such as zinc, lead, or copper, which cause corrosive attacks when heated or in service.
- g. Vibratory tool (carbide point) may be used, providing the depth does not exceed 0.010 inch nor reduce the wall thickness below the minimum. Marking shall be clearly legible.

3.8 Workmanship - Workmanship shall be first class in every respect. The pipe shall be sound, of uniform quality and free from laps, laminations, piping, undue segregation, cracks, or other detrimental defects.

### 4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection Requirements - The supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own or any other inspection facilities and services acceptable to KSC. Inspection and test records shall be kept complete and, upon request, made available to the procuring activity or its designated representative. Non-destructive examinations and tests required by this specification shall be performed on the product as offered for acceptance. The procuring activity, or its designated representative, reserves the right to perform any or all of the inspections set forth

in the specification to assure that the end item conforms to the prescribed requirements. Performance of the examinations or tests set forth in this specification does not relieve the supplier of his responsibility to provide a product which meets all the requirements of this specification.

4.1.1 Quality Control Systems - The supplier shall provide and maintain an adequate quality assurance plan acceptable under the provisions of NHB 5300.4(1C).

4.1.2 Reports - Certification is required for each lot with each shipment of material furnished to this specification. Each certification shall contain results of chemical analyses, of mechanical tests, welding qualifications, and of other inspections and tests required by this specification, and shall be identified with the lot of material offered for acceptance. It shall be signed by an authorized representative of the supplier.

#### 4.2 Lot Definition

4.2.1 Chemical Analysis - A lot shall consist of all pipe produced from the same heat.

4.2.2 Visual and Dimensional Examination, Defect Inspection and Mechanical Properties Tests - A lot shall consist of all material from the same heat, of the same nominal size, from the same heat treatment batch or from a continuous process under the same conditions of temperature, time at heat, and atmosphere.

#### 4.3 Sampling

4.3.1 Chemical Analysis Samples - One sample shall be taken from each heat. The sample may be taken from a broken tensile test specimen or other approved method per FED-STD-151.

4.3.2 Visual and Dimensional Inspection Samples - Each piece of each lot shall be examined for compliance with the requirements of 3.0.

4.3.3 Non-Destructive Test Samples - Each piece of each lot shall be examined by magnetic/particle or liquid penetrant testing.

4.3.4 Mechanical Properties Test Samples - Samples shall consist of the following percentages:

4.3.4.1 Tensile Tests - Five percent of the pipes shall be tested from each lot, but in no case less than two. When a lot consists of one pipe, only one sample is required.

4.3.4.2 Flattening Tests - Flattening tests shall be made on five percent of the pipes in each lot, but no less than two. When a lot consists of one pipe, only one sample is required.

4.3.4.3 Hydrostatic Test - One hundred percent of the pipe shall be tested.

#### 4.4 Test Procedures and Acceptance Criteria

4.4.1 Chemical Analysis - The chemical analysis shall be performed in accordance with FED-STD-151, and shall conform to Table I within allowable variations, or the lot shall be rejected. At the option of the supplier, each piece may be analyzed at the suppliers expense. Each piece not conforming to the allowable variations shall be rejected.

4.4.2 Mechanical Properties Test - Testing shall be accomplished as follows:

4.4.2.1 Tensile Test Procedure - One specimen shall be cut from each tensile test sample. The largest possible R-type or T-type specimen, as governed by the wall thickness of the pipe, shall be cut from the sample in accordance with FED-STD-151. Each tensile specimen shall be tested in accordance with FED-STD-151. The yield strength shall be determined at a limiting offset of 0.2 percent. The cross-head speed for the yield strength determination shall not exceed 1/16 inch per-minute-per-inch of gage length, and for the tensile strength determination shall not exceed 1/2 inch per-inch of gage length.

4.4.2.2 Tensile Test Acceptance Criteria - If any test specimen fails to conform to the requirements of Table II, the lot represented by that specimen shall be rejected. At the option of the supplier, each piece in the rejected lot may be tested at the supplier's expense; and each piece that fails to conform to the requirements of Table II shall be rejected.

4.4.2.3 Flattening Test Procedures - Testing shall be accomplished as follows:

4.4.2.3.1 Seamless Pipe - A section of pipe not less than 2½ inches in length shall be flattened cold between parallel plates in two steps as follows:

- a. During the first step, which is a test for ductility, no cracks or breaks on the inside, outside, or end surfaces shall occur until the distance between the plates is less than the value of "H" calculated by the following formula:

$$H = \frac{(1+e)t}{e+t/D}$$

- Where H = distance between flattening plates in inches.  
t = specified wall thickness in inches.  
D = specified or calculated (from the specified inside diameter and wall thickness) outside diameter in inches.  
e = deformation per unit length (.09).

- b. During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet.

4.4.2.3.2 Welded Pipe - A section of welded pipe not less than 4 inches in length shall be flattened cold between parallel plates. The weld shall be placed 90° from the direction of the applied force. The flattening test shall be accomplished in two steps as follows:

- a. During the first step, which is a test for ductility, no cracks or breaks on the inside or outside surfaces shall occur until the distance between the plates is less than the value of "H" calculated by the equation in 4.4.2.3.1.a.
- b. During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet.

4.4.2.4 Flattening Test Acceptance Criteria - Evidence of cracks or laminated or defective material or weld revealed during the entire flattening test shall be cause for rejection.

4.4.2.5 Hydrostatic Test Procedure - Each length of finished pipe shall be tested by the supplier to a hydrostatic pressure which will produce in the pipe wall a stress no less than 60 percent of the minimum specified yield strength. The test pressure shall be determined by the following formula:

$$P = \frac{2St}{D}$$

Where: P = hydrostatic test pressure in psi.  
S = allowable fiber stress (60 percent of the specified minimum yield strength in psi).  
t = specified wall thickness in inches.  
D = Inside diameter.

- a. The test pressure shall be held for a minimum of 10 minutes. For welded pipe, the test pressure shall be held for a time sufficient to permit the inspector to examine the entire length of the welded seam.
- b. Pipe sizes 14 inches in outside diameter and smaller shall be tested to one and one-half times the specified working pressure, provided the fiber stress corresponding to those test pressures does not exceed 60 percent of the specified minimum yield strength of the material as determined by the above formula.
- c. When one and one-half times the specified working pressure exceeds the minimum yield strength, the test pressure shall be a matter of agreement between the purchaser and supplier.

4.4.2.6 Hydrostatic Test Acceptance Criteria - If any length of pipe shows leaks, cracks, or a visible permanent deformation during the hydrostatic test, it shall be rejected.

4.4.3 Liquid Penetrant Inspection - Inspection shall be accomplished as follows:

4.4.3.1 Liquid Penetrant Inspection Procedure - Penetrant inspection shall be performed in accordance with Military Specification MIL-I-6866. Non-water washable dye penetrant conforming to MIL-I-25135 (Group I penetrant) shall be used. The liquid penetrant inspection shall include a record of the following:

- a. Brand name and specific type of penetrant, penetrant remover and developer.
- b. Details of the pre-test cleaning method, cleaning materials and drying time.
- c. Method of penetrant application including time it remains on the surface.
- d. Method of removing penetrant and drying the surface before applying developer.
- e. Method of applying the developer and length of developing time before inspection.
- g. Defects and their locations.

4.4.3.2 Liquid Penetrant Inspection Acceptance Criteria - All surfaces shall be free of crack-like indications and linearly-disposed rounded indications, if such rounded indications number four or more and separation between adjacent rounded indications is less than 1/16 inch. Indications such as above shall be removed and actual nature of defect determined by visual inspection: magnification up to ten times may be used to aid in evaluation. Indications evaluated as cracks, lack of fusion, or lack of penetration shall be cause for rejection. Indications identified as fine porosity less than 1/64 inch in largest dimension shall not be cause for rejection.

4.4.4 Magnetic Particle Inspection - Inspection shall be performed as follows:

4.4.4.1 Magnetic Particle Inspection Procedure - Magnetic particle inspection shall be performed in accordance with MIL-I-6868.

4.4.4.2 Magnetic Particle Inspection Acceptance Criteria - Acceptance criteria for magnetic particle inspection shall be as stated in 4.4.3.2.

## 5. PREPARATION FOR DELIVERY

5.1 Preparation for Packaging and Packing - Preparation shall be as follows:

- a. Pipe shall be clean and free of dirt, chips or foreign matter. After final pickling and washing, the material must be dried sufficiently

to retard corrosion, and the ends plastic capped to maintain cleanliness. Individual lengths of pipe may be sealed in polyethylene bags or coated with Grade 2, Soft Film, conforming to MIL-C-16173. All pipes shall be free of damage resulting from handling, such as cuts, dents, scratches, or abrasions.

- b. Pipe shall be segregated as to heat number, type, size, and wall thickness.

5.2 Packaging and Packing - The level of packaging and packing shall be as specified in the ordering document.

5.2.1 Levels A and B - Pipe shall be prepared for shipment in accordance with MIL-STD-163. When specified, pipe shall be packed in sheathed lifts.

5.2.2 Level C - Pipe shall be packed to insure carrier acceptance and safe delivery to destination at the lowest applicable rate. Containers or method of shipment shall comply with the Uniform Freight Classification Rules or other carrier regulations applicable to the mode of transportation.

5.3 Marking for Shipment - Marking for shipment shall be in accordance with MIL-STD-129. Nomenclature shall be the exact nomenclature approved in the contract or order.

## 6. NOTES

6.1 Intended Use - This specification covers 36 percent nickel, iron alloy pipe (Invar 36) intended for use with jacketed piping assemblies in welded liquid-transfer systems, for applications ranging from 125°F to -454°F temperatures.

6.2 Ordering Data - Procurement documents should specify the following:

- a. Title, number, and date of this specification.
- b. Type required. (See 1.2.)
- c. Nominal pipe size and schedule.
- d. Working pressure in PSIG.
- e. Length of pipe and whether random or exact lengths.
- f. Level of packaging and packing and sheathed lifts, if required.
- g. Special requirements.

Notice - When KSC drawings, specifications, or other data are used for any purpose other than in connection with a definitely related KSC procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that KSC may have formulated, furnished, or in any way supplied to said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

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