NE C 8-6T

Supersedes RDT C 8-6T

May 1977

nuclear STANDARD

**HYDROGEN METER
FOR SERVICE IN
LIQUID SODIUM**

NOVEMBER 1983

*U. S. DEPARTMENT OF ENERGY
NUCLEAR ENERGY PROGRAMS*

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Operated by
Westinghouse
Hanford Company
for the USDOE

A subsidiary of
Westinghouse Electric
Corporation

NE Standards Transmittal

A subsidiary of
Westinghouse Electric
Corporation

P. O. Box 1970
Richland, WA 99352

Hanford Engineering Development Laboratory

HISup

DISTRIBUTION	DATE November 14, 1983	NO. 276	
Lists 1 and 3	RETURN COMMENTS TO	TYPE SUBMISSION	TYPE ACTION
	J. J. McCown Westinghouse Hanford Co. PO Box 1970 Richland, WA 99352	☐ 1. PRELIMINARY ☐ 2. DRAFT ☒ 3. TENTATIVE ☐ 4. FINAL ☒ 5. Revision	☐ A. APPROVAL ☐ B. INFORMATION ☐ C. COMMENTS ☒ D. TRIAL USE ☐ E.
	NOT LATER THAN		
	NUMBER	DESCRIPTION	ACTION
	NE C 8-6T	Hydrogen Meter for Service in Liquid Sodium, dated November 1983. Supersedes issue dated May 1977.	D

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

MASTER

Release for Announcement in
Energy Research Abstracts

SIGNATURE

R. A. Meade

FOREWORD

This standard supersedes the May 1977 issue of RDT C 8-6T and incorporates changes to that issue including:

1. Replacement of TID-26666 with a publicly-available reference document for sodium properties.
2. Editorial correction of RDT Standards to NE Standards.
3. Deletion of additional material requirements which have been deleted by the August 1983 issue of NE E 15-2NB.
4. Correction of some metric equivalents for consistency.

These changes are identified by the following marginal notations:

C	Change
D	Deletion
E	Editorial

No technical changes were made in this revision.

HYDROGEN METER FOR SERVICE IN LIQUID SODIUM

TABLE OF CONTENTS

	<u>Page</u>	
1. SCOPE	1	
1.1 Classification	1	
1.2 Definitions	1	
2. APPLICABLE DOCUMENTS	2	
2.1 NE Standards	2	E
2.2 American National Standards (ANSI)	3	
2.3 American Society of Mechanical Engineers (ASME) Publications	3	
2.4 American Society for Testing and Materials (ASTM) Publications	3	
2.5 Additional Documents	3	
3. TECHNICAL REQUIREMENTS	4	
3.1 General	4	
3.2 Design Requirements (Sodium System)	4	
3.3 Design Requirements (Vacuum System)	7	
3.4 Design Requirements (Instrument System)	10	
3.5 Environmental Conditions	11	
3.6 Interface Requirements	11	
3.7 Materials	11	
3.8 Fabrication Requirements (Sodium System)	12	
3.9 Fabrication Requirements (Vacuum System)	14	
3.10 Drawings	15	
3.11 Reports and Documentation	16	
4. QUALITY ASSURANCE REQUIREMENTS	17	
4.1 Quality Assurance Program	17	
4.2 Quality Assurance Documents	17	
4.3 Examination Requirements	18	
4.4 Acceptance Tests	21	
4.5 Test Instruments	22	
5. PREPARATION FOR DELIVERY	22	
5.1 Preparation	22	
5.2 Packaging and Packing	22	
5.3 Shipping	23	

TABLE OF CONTENTS (Cont'd)

	<u>Page</u>
6. NOTES AND ORDERING DATA	23
6.1 Compliance	23
6.2 Ordering Data Checklist	23

HYDROGEN METER FOR SERVICE IN LIQUID SODIUM

1. SCOPE

This standard establishes the requirements for the design, materials, fabrication, quality assurance, examination, and acceptance testing of a hydrogen meter and auxiliary equipment for use in radioactive or nonradioactive liquid sodium service. The meter shall provide a continuous and accurate indication of the hydrogen impurity concentration over the range 0.03 to 10 ppm hydrogen in sodium at temperatures between 800 and 1000°F (427 and 538°C). The meter may also be used to rapidly monitor changes in hydrogen concentration, over the same concentration range, and, therefore can be used as a sensor for sodium-water reactions in LMFBR steam generators.

1.1 Classification. Hydrogen meters shall be one of the following types:

Type I. This type of meter is used for accurate monitoring of the hydrogen concentration in sodium.

Type II. This type of meter is used for rapid monitoring of changes in the hydrogen concentration in sodium. Type II meters normally find application in water-to-sodium leak detection systems.

1.2 Definitions.

1.2.1 Diffusion Membrane. A thin metal membrane which is permeable to hydrogen, but not to sodium or to gases other than hydrogen. The diffusion membrane is an integral part of the vacuum system, but not part of the sodium housing.

1.2.2 Hydrogen Meter (Meter). The meter consists of the hydrogen meter, sodium system, vacuum system, and instrument system.

1.2.3 Hydrogen Meter Instrument System. That part of the meter that, for Type I meters, consists of the readout instruments, vacuum gauge and ion pump controllers, and other instruments or devices used in the operation of the meter. For Type II meters, the vacuum gauge instruments are not required.

1.2.4 Hydrogen Meter Sodium System. That part of the meter that consists of the sodium housing and fittings for connecting this component to the vacuum system and interfacing sodium system, plus auxiliary equipment.

1.2.5 Hydrogen Meter Vacuum System. That part of the meter that, for Type I meters, consists of the diffusion membrane, vacuum manifold, valves, flanges, pressure gauge and housing, roughing pump port, and ion vacuum pump, plus auxiliary equipment. For Type II meters, it consists of the diffusion membrane, vacuum manifold, roughing pump port, and ion vacuum pump, plus any auxiliary equipment.

1.2.6 Ion Vacuum Pump. A vacuum pump (ion pump) which provides "clean" vacuums in the range 10^{-4} to 10^{-9} torr (13 mPa to 0.13 μ Pa).

1.2.7 Sodium Housing. That part of the sodium system that mates with the interfacing sodium piping system and the vacuum system. It includes thermocouple wells for monitoring the operating temperature of the diffusion membrane.

1.2.8 Vacuum Gauge. A gauge which measures the hydrogen pressure in the vacuum chamber. The gauge includes its electronic control and readout unit.

1.2.9 Vacuum Manifold. Part of the vacuum system including piping, valves, flanges, vacuum gauge housing, and roughing pump port to provide interconnection of the major components of the vacuum system. Valves and the vacuum gauge housing are not required for Type II meters.

1.2.10 Ultrahigh Vacuum Valves. Ultrahigh vacuum (UHV) valves are all metal valves which are capable of operation down to 10^{-9} torr (0.13 μ Pa).

2. APPLICABLE DOCUMENTS

The following documents are a part of this standard to the extent specified in Sections 3 through 5. The issue of a document in effect on the date of the invitation to bid, including any amendments or other published changes also in effect, shall apply unless otherwise specified. Where this standard appears to conflict with the requirements of a reference document, such conflict shall be brought to the attention of the purchaser for resolution.

2.1 NE Standards.

| E

NE C 7-6T	Thermocouple Material and Thermocouple Assembly, Chromel-P versus Alumel, Stainless Steel Sheathed, Magnesium Oxide Insulated
NE E 15-2NB-T	Class 1 Nuclear Components (Supplement to ASME Boiler and Pressure Vessel Code, Section III, Subsections NA and NB)
NE F 2-2	Quality Assurance Program Requirements

NE F 3-6T	Nondestructive Examination (Supplement to ASME Boiler and Pressure Vessel Code, Section V)
NE F 5-1T	Cleaning and Cleanliness Requirements for Nuclear Components
NE F 7-2T	Packaging, Packing, and Marking of Components for Shipment and Storage
NE F 7-3T	Marking of Components and Parts
NE F 9-4T	Requirements for Construction of Nuclear System Components at Elevated Temperatures (Supplement to ASME Code Cases 1592, 1593, 1594, 1595 and 1596)

2.2 American National Standards (ANSI).

ANSI B46.1 Surface Texture

ANSI Y14 Series Drafting Manual

2.3 American Society of Mechanical Engineers (ASME) Publications.

ASME Boiler and Pressure Vessel Code

Section III, Nuclear Power Plant Components

2.4 American Society for Testing and Materials (ASTM) Publications.

ASTM B 152	Specification for Copper, Sheet, Strip, Plate, and Rolled Bar
ASTM B 161	Specification for Nickel Seamless Pipe and Tube
ASTM B 162	Specification for Nickel Plate, Sheet, and Strip
ASTM F 239	Specification for Nickel Alloy Cathode Sleeves for Electron Devices

2.5 Additional Documents.

AVS 3.2*	Flanges Bakeable to 500°C
MIL-S-862	Steel Bars, Corrosion Resisting, and Steel Billet, Corrosion Resisting, Reforging Applications
QQ-S-763	Steel Bars, Wire Shapes and Forgings, Corrosion-Resisting

*American Vacuum Society

ANL-CEN-RSD-1 Thermophysical Properties of Sodium, Joanne K. Fink and Leonard Leibowitz, Argonne National Laboratory, May 1979. | c

3. TECHNICAL REQUIREMENTS

3.1 General. The hydrogen meter consists of the sodium system, vacuum system, and instrument system. A schematic of the Type I meter is shown in Fig. 1. The Type II meter is similar except the valve and vacuum gauge and its controller are not required. The Type I hydrogen meter shall be operable in either of two modes:

1. The equilibrium mode in which the valve to the ion vacuum pump is closed and the hydrogen pressure in the vacuum manifold is in equilibrium with the hydrogen in the sodium.
2. The dynamic mode in which the valve to the ion vacuum pump is open and the continuous hydrogen flux across the membrane, a measure of the hydrogen activity in the sodium, is indicated by the current to the ion pump.

The operation of the hydrogen meter in the equilibrium mode permits the determination of the hydrogen concentration of the sodium directly without a calibration procedure. The Type I meter may be operated continuously in the dynamic mode with occasional operation in the equilibrium mode to provide calibration for the dynamic mode operation. The Type II meter shall be operated in the dynamic mode only.

The type of meter required and the supplier's responsibility to supply all or only part of the meter and the exact configuration of the vacuum manifold shall be as specified in the Ordering Data.

3.2 Design Requirements (Sodium System).

3.2.1 Design Criteria. The design of the hydrogen meter sodium system shall conform to the following requirements and those specified in the Ordering Data:

Temperature (sodium)	1200°F (649°C) max.
Thermal transients (sodium)	<ol style="list-style-type: none"> a. 1000 cycles between ambient and operating temperature over the service life for the sodium housing and diffusion membrane b. 100°F/min (1°C/s) rate of temperature change
Pressure	150 psi (1.0 MPa) at 1200°F (650°C)

Fig. 1. Hydrogen Meter.

Pressure drop	<1 psid (<7 kPa)
Sodium flow rate	1 gpm ($6 \times 10^{-5} \text{ m}^3/\text{s}$) max.

3.2.2 Structural Design Requirements. The design of the sodium containing parts of the meter shall be in accordance with Section III of the ASME Boiler and Pressure Vessel Code (the Code) for Class 1 as supplemented by NE E 15-2NB. For design temperatures exceeding 800°F (427°C), NE F 9-4 shall apply. The pressure containing parts shall be designed for operation under the Levels A, B, C, and D service conditions, and testing conditions as defined in the Code.

Temperatures, pressures, and thermal transients for all service conditions shall be as specified in the Ordering Data.

3.2.2.1 Service Life. The sodium housing shall be structurally capable of operating for the service life specified in the Ordering Data.

3.2.2.2 Seismic Loading. The design of the sodium system and auxiliary equipment shall ensure capability of withstanding the seismic loadings specified in the Ordering Data.

3.2.2.3 Vibration. The sodium system and all its parts shall be designed so that they will not be damaged or caused to malfunction either by internally generated vibrations, such as flow-induced vibrations, or by environmental vibrations. Provisions shall be made to minimize damaging vibrations in areas where localized fluid velocities are high.

3.2.2.4 Piping Reactions. The sodium system shall be designed to accommodate the forces and moments exerted on it by its associated piping as specified in the Ordering Data.

3.2.2.5 Corrosion Allowance. A corrosion allowance for all pressure boundaries of the sodium system shall be established by the supplier based upon criteria provided in the Ordering Data, or the pressure boundary shall be of a thickness in excess of that determined by the design formula as specified in the Ordering Data. The allowance shall include compensation for the loss of material due to erosion, corrosion, or other intergranular penetration effects.

3.2.3 Thermal and Hydraulic Design. Pockets, dead flow spaces, internal crevices, and erosion of surfaces due to high velocity hydraulic effects shall be avoided. Freezing and melting of the liquid metal shall not of itself cause damage. The purchaser will provide a means of liquid access to a free surface.

The physical properties of sodium to be used in thermal and hydraulic calculations shall be as specified in ANL-CEN-RSD-1.

The pressure drop through the sodium system shall be the minimum consistent with the requirements of this standard, and shall not exceed the maximum value specified in 3.2.1.

3.2.4 Size. The critical and limiting dimensions of the sodium housing for Type I meters shall conform to the requirements of Fig. 2; those for Type II meters shall be as specified in the Ordering Data. The vacuum system connection and orientation shall be specified in the Ordering Data.

3.2.5 Special Tools. Instruments, tools, and other maintenance equipment necessary for maintenance of the meter, removal and replacement of the electrode assembly shall be classified as special tools and shall be considered as part of the meter. Special tools shall be supplied as specified in the Ordering Data.

3.3 Design Requirements (Vacuum System).

3.3.1 Design Criteria. The design of the vacuum system shall meet the following requirements:

Volume of vacuum chamber (Shaded area)	150 mL maximum
Internal diameter of vacuum system piping except for the membrane	3/8 in. (9.5 mm) minimum
Surface roughness of vacuum system piping and components (internal) except for the membrane	Smoother than 63 μ in. (1.6 μ m) AA
Bakeability for degassing purposes	All components to 750°F (400°C)
Thickness of diffusion membrane	0.010 $\pm$ 0.001 in. (0.25 $\pm$ 0.02 mm)

3.3.2 Structural Design Requirements. That part of the vacuum system which is integral with the sodium housing (Fig. 2) shall be designed to the requirements of 3.2 and 3.3.

The rest of the vacuum system shall be designed to accepted UHV practices and the design shall be submitted for purchaser approval. The use of flanges shall be minimized.

The diffusion membrane shall be self-supporting or provided with stiffening devices to prevent collapse from operation at the design pressure and temperature.

Fig. 2. Critical Dimensions of the Sodium Housing (Type I).

3.3.2.1 Service Life. An expected service life of greater than 10 years for the vacuum manifold (not including the diffusion membrane, roughing pump, port, vacuum gauge, valve seats, and the ion pump) shall be provided. Provisions shall be made using AVS 3.2 UHV copper-gasketed flanges for replacement of the roughing pump port, vacuum gauge, and the ion pump. The vacuum valve seat shall be replaceable by removal of the stem and bellows assembly.

3.3.2.2 Vibration. The vacuum system and all its parts shall be designed so that they will not be damaged or caused to malfunction by environmental vibrations.

3.3.3 Thermal Design. Trace heaters shall be provided for baking the ion pump and valves to 257°F (125°C) and other components of the vacuum system to 750°F (400°C). Heaters shall operate at one-half their rated voltage. They shall be attached to permit heater removal and replacement without chipping, grinding, cutting, or rewelding of any parts or attachments. Heater selection and installation procedures shall be approved by the purchaser. | E

3.3.4 Size. The size of the vacuum system shall meet the requirements of 3.3.1 and the following requirements. The configuration and surface area of the diffusion membrane shall be approved by the purchaser. A membrane surface area of 6.2 in² (40 cm²) is recommended for general use. Corrugated or otherwise reinforced closed tubes have been found to be satisfactory configurations. | E

3.3.5 Components. Type I meters require the following components as part of the vacuum manifold:

1. Diffusion membrane.
2. Ion pump.
3. Port for a roughing pump.
4. One throttling type vacuum valve or two on-off vacuum valves (in parallel), one of which has an on-line orifice to permit opening the valve to the ion pump when the equilibrium hydrogen pressure is expected to exceed the ion pump starting pressure.
5. Vacuum gauge.

Type II meters require the following components as part of the vacuum manifold:

1. Diffusion membrane.
2. Ion pump.
3. Port for a roughing pump.

3.3.5.1 Ion Pump. The ion pump shall be sized to match the surface area and thickness of the diffusion membrane such that when operated in the dynamic mode, it will pump in the range of 10^{-6} to 10^{-8} torr (130 to 1.3 μ Pa) for the hydrogen content of the sodium specified in the Ordering Data. The size (pumping capacity) of the pump shall be submitted for purchaser approval. Other requirements for the ion pump shall be as specified in the Ordering Data.

3.3.5.2 Vacuum Valves (Type I Meter). The vacuum valves shall be capable of operating at 10^{-9} torr (0.13 μ Pa). When closed, their leak rate shall be less than 2×10^{-10} std cm^3/s across the seat for a minimum of 200 open-close cycles.

3.3.5.3 Vacuum Gauge (Type I Meter). The vacuum gauge shall be of the ionization or capacitance manometer type and shall be capable of continuously measuring hydrogen pressures in the range of 0.5 to 10^{-5} torr (67 μ Pa to 1.3 μ Pa). The gauge shall be calibrated over its operating range with hydrogen gas using a reference gauge (of the same type) traceable to master or reference gauges calibrated by the U. S. Bureau of Standards. The type of gauge shall be as specified in the Ordering Data. | C

3.3.5.4 Roughing Pump. A molecular sieve roughing vacuum pump and special accessories and tools for starting the ion pump are also part of the vacuum system. Specifications for the roughing pump shall be as required in the Ordering Data.

3.4 Design Requirements (Instrument System). Equipment for operation of the hydrogen meter sodium system, and instruments for monitoring its performance, shall be designed, rated, fabricated, and tested in accordance with applicable industry codes and standards recommended for approval prior to fabrication. The responsibility for supplying the components of the instrument system shall be as specified in the Ordering Data.

3.4.1 Controls and Instrumentation. The ion pump controller shall have a pump current readout which covers the pressure range of 10^{-8} to 10^{-4} torr (1.3 μ Pa to 13 mPa) and have a recorder output jack. The ion pump controller shall be operated with a power input having voltage regulation of +1%. The output signal noise shall be less than 1% of the signal for all ranges.

Temperature sensors shall be furnished to provide necessary temperature monitoring as required for operation of the meter. One sensor shall be in a well which provides a measurement of the sodium temperature at the reference electrode position (cell temperature). The distribution, location, attachment, and final specification of the sensors shall be determined by the meter design, and submitted for approval. Unless otherwise specified in the Ordering Data, the sensors shall be supplied as part of the instrument system. One or more redundant temperature sensors shall be installed in locations where a sensor cannot

be replaced or serviced without extensive disassembly of the hydrogen meter sodium system.

Temperature sensors shall be thermocouples, fabricated of Chromel-Alumel wire. The wire insulation and sheath, if any, shall be capable of withstanding the maximum operating temperature and environmental conditions of the component at the sensor location. Requirements for grounded or ungrounded thermocouples shall be as specified in the Ordering Data. Thermocouples for measurement of cell temperatures shall conform to NE C 7-6. Heat transfer cements shall not be used in contact with the meter housing.

Signal leads shall be terminated by plug-in connectors of the type as specified in the Ordering Data. The connector shall be located for ease of access by operating personnel. Each termination shall be identified as to its location on the component and designated on drawings showing sensor locations.

Detailed specification for temperature readout and recording devices shall be as specified in the Ordering Data.

3.4.2 Heaters. The recommended size and location of all heaters required for a programmed preheat of the hydrogen meter sodium system when full of solid sodium and from ambient to preheat temperature shall be furnished as specified in the Ordering Data. Heaters shall be designed to operate at one-half their rated voltage. The use of electrical heaters in contact with sodium shall not be permitted.

3.5 Environmental Conditions The environmental conditions to which the meter will be exposed shall be as specified in the Ordering Data. The data will include ranges of the following environmental parameters:

1. Atmosphere.
2. Temperature.
3. Pressure.
4. Radiation levels.

Environmental conditions during user storage will be specified in the Ordering Data and will include the environmental extremes and durations for preinstallation storage time and preoperational idle time.

3.6 Interface Requirements. Special interface requirements for mechanical, electrical, and structural interfaces, as applicable, shall be as required by the Ordering Data.

3.7 Materials.

3.7.1 Sodium System. Materials to be used for containment of sodium shall be Type 304 or Type 316 austenitic stainless steel with 0.04% minimum carbon content conforming to the requirements of the Code and other standards as given in the Ordering Data.

Metal surfaces in contact with sodium shall have a 250 μ in. (6.4 μ m) or smoother finish as measured by ANSI B46.1.

3.7.2 Vacuum System. Materials to be used for the vacuum system components shall be 300-series stainless steels which meet the requirements of MIL-S-862 or QQ-S-763.

Nickel for the diffusion membrane and transition pieces shall be Type 201 or 270 meeting the requirements of ASTM B 161, ASTM B 162, or ASTM F 239, Grade 2. Vacuum gasket material shall be oxygen-free soft copper meeting the requirements of ASTM B 152, No. 102 or 103.

3.8 Fabrication Requirements (Sodium System).

3.8.1 Fabrication Criteria. Detailed fabrication procedures meeting the requirements of the Code as supplemented by NE E 15-2NB shall be submitted prior to the start of fabrication. The fabrication procedures shall include the proposed sequences and procedures for material procurement, fabrication, cleaning, maintenance of cleanliness, examination, inprocess inspection, and testing of all parts of the sodium system that are to be provided.

3.8.2 Welding. Welding, welding procedures, processes, materials, and examinations applicable to the meter shall conform to the requirements of NE E 15-2NB and the Code. In addition:

1. All welds on the meter housing shall be full penetration welds, unless express approval of a deviation is given by the purchaser.
2. Electron beam (EB) or tungsten arc-inert gas (TIG) welding may be used to attach the diffusion membrane to the sodium housing. The EB welding process shall be carried out in a vacuum of less than 10^{-4} torr (13 μ Pa). The detailed EB or TIG welding procedure shall be submitted for approval.

3.8.2.1 Dissimilar Metal Welds. Carbon or alloy steel parts shall not be welded directly to a stainless steel pressure containment part.

3.8.2.2 Weld Repair. Purchaser approval is required to make weld repairs to remove defects that recur:

1. After the first cycle of weld repair of defects at the fusion zone, adjacent base metal, or both.
2. After the second cycle of weld repair in welds that are heat treated after each repair cycle.

Repair of crater cracks restricted to the crater of the weld pass does not require purchaser approval.

3.8.3 Heat Treatment. Austenitic stainless steel which has become sensitized during heat treatment, welding, or forming shall be solution annealed or protected against corrosion and moisture during all subsequent manufacturing, testing, and storage operations. |D

Prior to welding to the sodium housing, the nickel diffusion membrane shall be annealed by hydrogen firing at $1472 \pm 45^\circ\text{F}$ ($800 \pm 25^\circ\text{C}$) for 24 to 30 h in hydrogen gas saturated [at 70 to 80°F (21 to 27°C)] with water vapor, followed by furnace cooling. |E

3.8.4 Bending and Forming. Bending and forming procedures for material shaping shall be prepared in accordance with the applicable standards or procedures and submitted for purchaser approval. The wall thickness after the bending and forming operations shall be not less than the minimum design thickness. The out-of-roundness in any circular cross section of pipes and tubes after bending shall not exceed 8% of the outside diameter. The need shall be evaluated for heat treatment for stress relief or material structure improvement following bending or forming operations. After bending or cold straightening which causes plastic deformation, austenitic stainless steel shall be solution annealed. Such solution annealing shall be conducted on the entire part.

3.8.5 Plating. Plating and the use of clad materials shall not be permitted unless purchaser approval has been obtained.

3.8.6 Machining. Surface roughness, as defined in ANSI B46.1, shall be a maximum of 90 $\mu\text{in.}$ ($2.3 \mu\text{m}$) AA.

3.8.7 Cleaning. The fabrication of the sodium system shall be conducted to facilitate cleaning and inspection for cleanliness, and to minimize contamination during fabrication.

All metal surfaces shall be clean and free of pits, corrosion products, and oxides. The cleaning of materials and the degree of cleanliness shall be in accordance with procedures and acceptance criteria of NE F 5-1, as specified in the Ordering Data. The following shall be submitted for purchaser approval before conducting cleaning operations:

1. General cleaning procedures to be employed.
2. Flushing procedures.
3. Acceptance standards for contamination.
4. Drying methods to be employed on cleaned equipment.
5. Description of inhibitors employed for minimizing corrosion, when applicable, and procedures for their removal.

3.8.8 Assembly. The assembly of component parts shall be done in accordance with detailed assembly procedures. The procedures shall contain as a minimum:

1. Assembly sequence.
2. Cleaning procedures, sequence, and precautionary rules.
3. Any special machining or fitting-at-assembly instructions.
4. Intermediate and final inspection criteria and hold points.
5. Handling and storage methods and procedures.
6. Tightening torques for threaded parts.
7. Procedures for the locking of locking devices or tack welding.
8. Drawings or photographs required to illustrate assembly problem areas or assembly techniques.

3.8.9 Interchangeability. All parts and components fabricated to the same drawings shall be interchangeable. Information shall be furnished (such as specifications and drawings of special gauges and fixtures, as-built dimensions, tolerances, fabrication procedures, and such dimensional reference points as may be required to achieve or maintain perpendicularities, concentricities, and accumulative tolerances) as may be required to achieve such interchangeability.

3.8.10 Identification and Marking. Components, parts, assemblies, and auxiliary components shall be identified in accordance with NE F 7-3 and the Code.

3.9 Fabrication Requirements (Vacuum System).

3.9.1 Fabrication Criteria. Detailed fabrication procedures meeting accepted requirements for UHV fabrication shall be submitted prior to the start of fabrication. The fabrication procedures shall include the proposed sequences and procedures for material procurement, fabrication, cleaning, maintaining cleanliness, examination, inprocess inspection, and testing of all parts of the meter that are to be provided.

3.9.2 Welding. The TIG or EB process shall be used for weld assembly of the vacuum system and components. Purchaser approval shall be obtained prior to use of other welding processes.

3.9.3 Machining. Surface roughness, as defined in ANSI B46.1, shall be a maximum of 63 μ in. (1.6 μ m) AA for all internal surfaces. The components of the vacuum system may be cleaned or treated by special

processes (approved by the purchaser) which provide smoother surface texture than normally available from machining and forming processes.

3.9.4 Cleaning. The fabrication of the vacuum system shall be conducted to facilitate cleaning and inspection for cleanliness, and to minimize contamination during fabrication. Before conducting cleaning operations, the general cleaning procedure and materials and solvents to be employed shall be submitted for approval.

3.9.5 Assembly. The assembly of component parts shall be done in accordance with detailed assembly procedures. The procedures shall contain as a minimum:

1. Assembly sequence.
2. Cleaning procedures, sequence, and precautionary rules.
3. Any special machining or fitting-at-assembly instructions.
4. Intermediate and final inspection criteria and hold points.
5. Handling and storage methods and procedures.
6. Tightening torques for threaded parts.
7. Procedures for the locking of locking devices or tack welding.
8. Drawings or photographs required to illustrate assembly problem areas or assembly techniques.

3.9.6 Interchangeability. All parts and components fabricated to the same drawings shall be interchangeable as specified in 3.8.9.

3.9.7 Identification and Marking. Components, parts, assemblies, and auxiliary components shall be identified in accordance with NE F 7-3.

3.10 Drawings. Drawings shall be prepared in accordance with ANSI Y14. Additional drawing requirements and submittal requirements shall be as specified in the Ordering Data.

3.10.1 Sectional Assembly Drawings. The assembly drawings shall depict in cross section, components, subassemblies, or parts thereof and include the following and any additional information required to permit the preparation of the necessary drawings for fabrication and installation of the meter:

1. A parts list giving index or piece number, number of parts (or subassemblies) required, nomenclature of part (or subassembly), material, material specification, form specification or

standard (or manufacturer's identification and model number), and detail or subassembly shown on the assembly drawing.

2. The location of final closure welds and seal welds, with appropriate procedure designations.
3. Dimensions establishing fits and clearances between parts.
4. Pressure, flow, and temperature data, including design pressure, flow, and temperature, and test pressure.
5. Pertinent references to cleaning, marking, handling, and packaging instructions.
6. Assembly and installation requirements.

3.10.2 Detail Drawings. Detail drawings shall contain all information necessary for fabrication, including the following information, as applicable:

1. Tolerance block, including geometric tolerances.
2. Detailed dimensions, tolerances, and maximum roughness of each machined surface.
3. Identification of material specification and any special requirements including nondestructive examination, heat treatment, and hardness.
4. Fabrication instructions, including welding, cleaning, and inspection symbols.

3.10.3 Drawing and Specification Lists. A current listing of all drawings and specifications shall be maintained. Each drawing number shall include the current revision designation. Each specification number shall include the applicable revision date.

3.10.4 Parts List. A complete separate list of parts, organized by assemblies, shall be provided. Each drawing number shall include the current revision designation. A copy of the parts list which shall serve as a baseline against which further changes can be monitored shall be provided.

3.11 Reports and Documentation.

3.11.1 Design Report. A design report shall be submitted as specified in the Ordering Data. As a minimum, the design report shall include the following:

1. A design description of the meter including drawings showing that the critical dimensions (Fig. 1 and 2) will be met.

2. A list of the selected materials of construction (refer to 3.7 and 3.8).
3. A stress report satisfying the rules of the Code and any applicable high temperature design requirements.
4. A thermal transient stress analysis.
5. Vibration analysis.
6. Corrosion allowance used.

All information furnished in the design report shall be in sufficient detail to permit independent checking. Additions or corrections to the design report as are required to keep the information current shall be made. These revisions shall be numbered and dated, and shall be submitted for approval.

3.11.2 Operations and Maintenance Manual. Meter operation and maintenance information shall be provided to form part of the plant operations manual. This manual shall reflect the as-built configuration of the delivered item and shall include copies of special manuals for auxiliary equipment and instruments, or special components. Information shall include, but not be limited to, the following:

1. A description of the meter and its operation.
2. General operation conditions.
3. Installation and startup of a meter.
4. Special test procedures.
5. Malfunction description and corrective action.
6. A list of recommended spare parts.

4. QUALITY ASSURANCE REQUIREMENTS

4.1 Quality Assurance Program. A documented quality assurance program shall be planned, established, implemented, and established which meets the requirements of Sections 1 through 5 and 8 of NE F 2-2 and the following.

4.2 Quality Assurance Documents. The following documents based on the requirements of NE F 2-2 shall be prepared and submitted as specified in the Ordering Data:

1. Quality assurance program plan.
2. Inspection and test plan.
3. Special process control and nondestructive examination procedures.
4. Inspection and test procedures including sampling plans.

5. Nonconforming item documentation.
6. Handling, preservation, packaging, and storage procedures.
7. Proposed new codes, standards, and practices.
8. Design descriptions.

4.2.1 Quality Records. As a minimum, the following documents shall be submitted pertinent to each meter:

1. Parts list of items by part number, drawing number and revision, part name, serial number, and lot or heat number.
2. A reproducible set of assembly drawings.
3. Certifications of special processes and nondestructive examination procedures and equipment qualifications.
4. A copy of each nonconformance and corrective action record including rework, repair, and retest procedures.
5. Certification of conformance including:
 - a. Chemical and physical test results, heat treatment data, and test results of material test coupons traceable to their related finished components.
 - b. Results of final nondestructive examinations including radiographic films, recorder charts, and photographs.
 - c. Copy of test results and analyses of test results.
 - d. A copy of final inspection data and results.

4.3 Examination Requirements. The following examination requirements shall comprise the minimum acceptable for the liquid metal containment structures. The requirements to be used for nonliquid metal containment structures shall be recommended in the quality assurance plan.

4.3.1 Code Required Inspections. All examinations shall be in accordance with the Code and are a supplier responsibility.

4.3.2 Calibration and Control of Instruments. All instruments and measurement and test devices used for nondestructive examinations, inspections, and acceptance tests shall be calibrated and controlled in accordance with the Code and NE F 2-2.

4.3.3 Visual Examination. All raw materials shall be examined visually to detect obvious defects and state of cleanliness. Visual examination shall be in conformance with the requirements of NE E 15-2NB.

4.3.4 Requirements for Nondestructive Examination.

4.3.4.1 Personnel Qualification. Personnel performing nondestructive examinations or interpreting the results of such examinations shall be qualified in accordance with NE E 15-2NB. The certification level (Level I, II, or III) shall be specified for personnel who perform the tests, and interpret the results relative to acceptance criteria.

4.3.4.2 Procedures and Acceptance Standards. Detailed procedures for all required nondestructive examinations shall be prepared and submitted for approval prior to use. Calibration levels and acceptance standards shall be as specified in the applicable NE material and process standards.

4.3.5 Markings and Identification.

4.3.5.1 Materials. All materials shall be examined to ensure compliance with requirements of the Code. When raw material is cut or sectioned, all markings shall be transferred to the unmarked portion of the material.

4.3.5.2 Permanent Marking. All finished components, spare parts, and special handling fixtures to be delivered as part of the contractual requirements shall be examined to ensure that they are permanently marked for purposes of identification in accordance with 3.8.10 and 3.9.7. Sample material shall be examined for identification, location, and orientation.

4.3.6 Material Repairs.

4.3.6.1 Repair Welding. Where the applicable material standard and the Ordering Data allow the use of welding processes for repair of defects in the material, the quality assurance provisions of the repair weld shall be accomplished in accordance with the requirements of 3.8.2.2.

4.3.6.2 Examination of Materials Repairs. Weld repaired areas shall be re-examined by the inspection methods which revealed the original defect in accordance with the requirements of the Code. In addition, where necessary, other nondestructive examination methods which will ensure that the quality of the material has been maintained shall be used. The examination methods shall be in accordance with 4.3.4.2.

4.3.7 Nondestructive Examination During Fabrication.

4.3.7.1 Fabrication Examination. All items shall be subjected to visual and dimensional examination to verify conformance with drawing requirements.

4.3.7.2 Liquid Penetrant Examination. Nonmagnetic materials shall be examined by liquid penetrant methods. Following examination, the surface shall be cleaned in accordance with procedures prepared in accordance with NE F 5-1.

4.3.7.3 Welds. Examinations of welds, both visual and dimensional, and nondestructive examination shall be in accordance with the requirements of NE E 15-2NB. Welds specified in the Ordering Data as "critical" shall be volumetrically examined by two independent non-destructive examination methods.

4.3.7.3.1 Visual Examination. All welds shall be visually examined for the following characteristics:

1. Weld identification.
2. Weld thickness shall be equal to or greater than the parent (base) metal thickness at its thinnest section (no concave welds), unless deviation is specifically allowed by NE E 15-2NB.
3. Weld surface and adjacent base metal shall blend smoothly without reduction of thickness in excess of 10% of the base metal thickness or 1/64 in. (0.4 mm) whichever is less. This depression may extend the entire length of the weld. The remaining thickness shall not be reduced below the minimum allowable design thickness.

4.3.7.3.2 Radiographic Examination. All welds shall be radiographed in accordance with the requirements of the Code as supplemented by NE E 15-2NB, unless satisfactory radiographic examination cannot be accomplished due to the weld configuration. Purchaser approval is required for any weld design that cannot be radiographed satisfactorily.

4.3.7.3.3 Ultrasonic Examination. All welds which cannot be satisfactorily examined by radiography shall be inspected by ultrasonic methods in accordance with the requirements of the Code as supplemented by NE E 15-2NB.

4.3.7.3.4 Liquid Penetrant. Welds shall be examined by a liquid penetrant method in accordance with the requirements of NE E 15-2NB. As a minimum, the root and final layers of all welds shall be examined by a liquid penetrant method.

For welds made from both sides, a liquid penetrant examination shall be performed after backgrooving to sound metal and on both finished welds surfaces. In addition, all accessible welds shall be liquid penetrant examined at the completion of the pressure test (4.3.8.1) and the helium leak test (4.3.8.2).

If radiographic or ultrasonic examination of the weld is not possible, all weld layers shall be examined by liquid penetrant. Following liquid penetrant examination, weld areas shall be thoroughly cleaned in accordance with procedures prepared in accordance with NE F 5-1 before proceeding to the next weld pass.

4.3.7.3.5 Examination of Weld Repairs. Weld repairs shall be examined in accordance with 4.3.7.3.1, 4.3.7.3.2, 4.3.7.3.3, and 4.3.7.3.4.

4.4 Acceptance Tests. The following tests shall be performed. Additional requirements for tests, test provisions, and test equipment shall be as specified in the Ordering Data.

4.4.1 Pressure Test. The pressure test shall be pneumatic using a test gas of the purity as specified in the Ordering Data. Pneumatic tests shall be as specified in the Code. The procedure shall include all requirements of the Code plus those of this standard.

The temperatures of the material and gas shall be continuously monitored during the test. Instruments used to monitor and record pressure and temperatures shall be calibrated in accordance with NE F 2-2 for the overall system accuracy of +2% in the range of the test unless otherwise specified in the Ordering Data.

Upon completion of the pneumatic tests, the assembly shall be protected from contamination by maintaining the sealed conditions and by keeping the internal environment of test gas at 5 to 7 psig (34 to 48 kPa) pressure, until the helium leak test is performed.

4.4.2 Helium Leak Test. The pressure boundary of all components shall be leak tested by the method of helium leak test specified in the Ordering Data. Helium leak testing shall be performed in accordance with NE F 3-6. The helium leak test shall be performed after the pressure test is completed. For the sodium system, any helium leak of 1×10^{-7} standard cm^3/s or larger shall be cause for rejection. For the vacuum system, any helium leak of 1×10^{-9} standard cm^3/s or larger shall be cause for rejection.

4.4.3 Vacuum Tightness (Type I Meter). After final assembly and appropriate bakeout for degassing purposes, each Type I meter shall be tested for vacuum tightness. The procedure shall involve pumping the system to less than 1×10^{-8} torr (1.3 μPa) with the ion pump, closing the valve(s), and noting the pressure on the vacuum gauge. This entire test shall be performed at an ambient temperature of $125 \pm 5^\circ\text{F}$

($52 \pm 3^{\circ}\text{C}$) with pure argon on the sodium side of the diffusion membrane. The argon shall be 99.9995% pure, with a dew point less than -105°F (-76°C). Failure shall be determined by inability to achieve less than 1×10^{-8} torr ($1.3 \mu\text{Pa}$) with the ion pump or by an increase in the pressure measured by the vacuum gauge to greater than 5×10^{-6} torr ($0.66 \mu\text{Pa}$) in less than 1 h after the valve(s) have been closed.

4.4.4 Diffusion Membrane Acceptance Test. Each diffusion membrane shall be checked for dimensional tolerances. Measurements shall be made as required to assure that in all areas the thickness is within tolerance [± 0.001 in. (± 0.02 mm)]. After heat treatment (3.9.3) and welding to the sodium housing, the membrane shall be helium leak tested at 930°F (500°C) with helium. Leak rates $> 1 \times 10^{-9}$ std cm^3/s are cause for rejection. The procedure for this test shall be submitted for purchaser approval prior to use. |E

4.4.5 Electrical System Tests. Tests of the electrical components and control system of the meter shall be conducted in accordance with procedures and to standards for acceptance, which the supplier shall recommend for approval.

4.5 Test Instruments. Instruments commonly used in test and research laboratories shall be used in testing the component with the following limitations:

1. Mercury or mercury-containing instruments shall not be used.
2. Soft metals, such as lead, copper, and aluminum shall not be brought in direct contact with the internal parts used for sodium containment.
3. Halogens and halogen containing materials shall not be used.
4. Sulfur and sulfur compounds shall not be used.

5. PREPARATION FOR DELIVERY

5.1 Preparation. Upon completion of all shop testing and inspection, all items shall be prepared for delivery. This shall include, but is not limited to, all disassembly (as required), recleaning (if necessary), surface preparation, and examination. Prior to final packaging, all open ends shall be capped with closed-end mating fittings (caps or plugs) to preserve cleanliness of the internal parts.

5.2 Packaging and Packing. Items subject to deterioration, corrosion, or damage shall be all sealed, packaged, packed, and marked in accordance with NE F 7-2. The sodium system shall be attached to the vacuum system and shall be packaged separately from the instrument system. Packaging shall protect the item while at the supplier's facilities and during transportation.

5.3 Shipping. All technical documents, instructions, drawings, reports, and materials that are to accompany the meters during shipment shall be identified.

6. NOTES AND ORDERING DATA

6.1 Compliance. This standard, together with the Ordering Data, is intended to meet the requirements for the design specification. When this standard is used as a basis for procurement, the purchase specification will be certified by a registered professional engineer representing the purchaser to be correct, complete, and in compliance with the design specification requirements of Section III of the Code.

6.2 Ordering Data Checklist. The following technical and procurement data will be furnished by the purchaser. Any necessary data not furnished with the purchase document shall be requested from the purchaser before submitting a bid.

<u>Item</u>	<u>Refer to Paragraph</u>	
1. Classification	1.1	
2. General	3.1	
3. Design criteria	3.2.1	
4. Structural design requirements	3.2.2	
5. Service life	3.2.2.1	
6. Seismic loading	3.2.2.2	
7. Piping reactions	3.2.2.4	
8. Corrosion allowance	3.2.2.5	
9. Size	3.2.4	
10. Special tools	3.2.5	
11. Ion pump	3.3.5.1	
12. Vacuum gauge (Type I meter)	3.3.5.3	
13. Roughing pump	3.3.5.4	
14. Design requirements (Instrument System)	3.4	
15. Controls and instrumentation	3.4.1	
16. Heaters	3.4.2	
17. Environmental conditions	3.5	
18. Interface requirements	3.6	
19. Materials of construction (Sodium System)	3.7.1	E
20. Materials of construction (Vacuum System)	3.7.2	
21. Cleaning	3.8.7	
22. Drawings	3.10	
23. Quality assurance documents	4.2	
24. Repair welding	4.3.6.1	
25. Welds	4.3.7.3	
26. Acceptance testing	4.4	E
27. Pressure tests	4.4.1	
28. Helium leak test	4.4.2	