Liquid Metal Engineering Center

Operated for
the U.S. Atomic Energy Commission by Atomics International Division
Rockwell International Corporation

P.O. Box 1449
Canoga Park, California 91304

RDT STANDARDS TRANSMITTAL

DISTRIBUTION

RETURN COMMENTS TO

NO. SC455, May 19, 1975

COGNIZANT ENGINEER

B. E. Fischer

PHONE

(213) 341-1000

EXTENSION

6464

NOT LATER THAN

TYPE SUBMISSION

- ☐ 1. DRAFT
☐ 2. TENTATIVE
☐ 3. AMENDMENT
☒ 4. REVISION
☐ 5.

TYPE ACTION

- ☐ A. INFORMATION
☐ B. COMMENTS
☒ C. TRIAL USE
☐ D.
☐ E.

Distribution List No. 1

NUMBER

DESCRIPTION

ACTION

RDT C 5-1T

Inductive Level Measurement Sensor
for Use in Liquid Metal, March 1975

C

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or 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.

MASTER

Release for Announcement in
Nuclear Science Abstracts

SIGNATURE

J. O. Bates

Manager, Test Engineering
Liquid Metal Engineering Center

RDT C 5-1 T

Supersedes
RDT C 5-1T, April 1970

RDT Standard

INDUCTIVE LEVEL MEASUREMENT SENSOR FOR USE IN LIQUID METAL

MARCH 1975

Any further distribution by any holder of this document or of the data therein to third parties representing foreign interests, foreign governments, foreign companies, and foreign subsidiaries or foreign divisions of U. S. companies should be coordinated with the Director, Division of Reactor Research and Development, U. S. Energy Research and Development Administration.

**U.S. Energy Research and Development Administration
Division of Reactor Research and Development**

MASTER

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.

Send copy and distribution inquiries to:

RDT Standards Office
Holifield National Laboratory
Building 1000, Room 118-C
P. O. Box X
Oak Ridge, Tennessee 37830

Printed in the United States of America
USERDA Technical Information Center, Oak Ridge, Tennessee

FOREWORD

This standard supersedes the April 1970 issue of RDT C 5-1T and incorporates those changes to that issue of the standard that were approved and published as Amendments 1 and 2. These changes are identified by the following marginal notations:

- A1 Amendment 1, October 1971
- A2 Amendment 2, September 1974

Editorial changes that were made during preparation of this revision are not identified.

RDT STANDARD

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
DIVISION OF REACTOR RESEARCH AND DEVELOPMENT

RDT C 5-1T
DATE March 1975
PAGE i OF ii

INDUCTIVE LEVEL MEASUREMENT SENSOR FOR USE IN LIQUID METAL

TABLE OF CONTENTS

	<u>Page</u>
1. SCOPE	1
1.1 Classification	1
1.2 Definitions	2
2. APPLICABLE DOCUMENTS	3
2.1 Exceptions	3
2.2 RDT Standards	3
2.3 American National Standards (ANSI)	4
2.4 American Society of Mechanical Engineers (ASME) Publications	4
2.5 American Society for Testing and Materials (ASTM) Publications	4
2.6 American Welding Society (AWS) Specifications	5
3. TECHNICAL REQUIREMENTS	5
3.1 Performance Requirements	5
3.2 Environmental Requirements	5
3.3 General Design Requirements	6
3.4 Detail Design Requirements	6
3.5 Materials	17
3.6 Manufacturing Processes	17
3.7 Reports	18
3.8 Drawings	20
3.9 Nameplates	22
3.10 Manuals	22
4. QUALITY ASSURANCE REQUIREMENTS	23
4.1 Quality Assurance Program	23
4.2 Inspection	23
4.3 Nondestructive Examination	23
4.4 Examination of Materials	24
4.5 Tests	24

	<u>Page</u>
5. PREPARATION FOR DELIVERY	25
5.1 Sealing, Packaging, Packing, and Marking	25
5.2 Shipping Requirements	26
5.3 General Requirements	26
6. NOTES AND ORDERING DATA CHECKLIST	26
6.1 Notes	26
6.2 Proposal Information	27
6.3 Ordering Data Checklist	27

RDT STANDARD

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
DIVISION OF REACTOR RESEARCH AND DEVELOPMENT

RDT C 5-1T
DATE March 1975
PAGE 1 OF 30

INDUCTIVE LEVEL MEASUREMENT SENSOR FOR USE IN LIQUID METAL

1. SCOPE

This standard is to be used as the basic document for the procurement of inductive liquid metal level measurement sensors. It is intended that this standard will be supplemented by additional requirements dictated by the specific application.

The standard presents the requirements for the design, material selection, fabrication and examination of the sensor portion only of an inductive liquid metal level measurement system. With one exception, that of the portable differential transformer, "Tri-coil" sensor, it does not include the related readout or control equipment.

1.1 Classification. The sodium level sensors shall be classified into basic types as follows:

A1

Type I	Single Coil (Figure 1)
Type II	Multi Coil Temperature Compensated (Figure 2)
Type III	Mutual Inductance (Figure 3)
Type IV	Differential Transformer (Figure 4)
Type V	Balanced Bridge (Figure 5)

In addition, the sodium level sensor shall be subclassified as follows:

1. The letters A, B, or C shall be placed after the type number as applicable and will have the following meaning:

A = Continuous measuring sensor

B = Discrete point sensor

C = Variable position sensor

2. Dash numbers X and Y shall be placed after the type number and letter to designate the following:

X = The distance in feet and tenths of feet from the sensor cap mounting reference plane to the upper active coil or upper limit of the measuring range.

Y = The distance in feet and tenths of feet between the upper and lower active coils or for the measuring range of a continuous measuring or variable position sensor.

A1

Example:	Type	IV	C	-	2.0	-	5.0
Differential Transformer		—					
Variable Position Sensor			—				
Two feet from mounting flange to top of measuring range				—			
Five foot measuring range					—		

1.2 Definitions.

1.2.1 Sodium Level Sensor. That part of the liquid level measurement system that is inserted into a sensor thimble that has been provided for it in the sodium containment vessel or system component. The sensor probe shall consist of the sensor sheath, internal circuitry and insulation, and mounting provisions. The standard does not include input power supply, signal transmission lines, nor output signal read-out or control equipment or both.

A1

1.2.2 Sensor Probe Assembly. That part of the level sensor that is inserted into the sodium containment vessel or system component, and actually senses the sodium level. The sensor probe shall consist of the sensor sheath, if required, internal circuitry and insulation, and mounting provisions.

1.2.3 Sensor Head Assembly. The sensor head assembly receives the input power and conditions it for input to the sensor probe. The sensor head assembly also receives the signal from the sensor probe and conditions it for transmission to the readout or control equipment. The sensor head assembly may be mounted directly to or near the probe assembly mounting flange, and shall contain electrical or electronic signal conditioning equipment and required electrical connectors or terminal strips.

1.2.4 Availability Factor. The percentage of time that plant and equipment are available for service, whether in operation or not.

1.2.5 Reliability. The probability that a component will perform its intended function for a specified interval under stated conditions.

1.2.6 Maintainability. The probability of being able to perform the necessary maintenance during a scheduled downtime. The scheduled downtime shall be as specified by the purchaser.

1.2.7 Sensor Cap. Upper termination and integral part of the sensor probe containing probe mounting and electrical connections. | A1

1.2.8 Power Supply. An integral part of the sensor head assembly which receives input power from an external source and conditions it for input to the sensor probe. | A1

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 invitation to bid, including any amendments or other published changes also in effect, shall be as specified in the Ordering Data. 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 Exceptions. Where materials or standards employed in the manufacture of any part are not identified in this standard or in specifications referenced herein, the material or standard proposed for use shall be submitted to the purchaser for approval.

2.2 RDT Standards.

RDT C 17-5T	Metal-Sheathed, Mineral Insulated Cable Bulk Material	A2
RDT C 18-1T	Ceramic Electrical Insulators	
RDT E 15-2T	Requirements for Nuclear Components (Supplement to ASME Boiler and Pressure Vessel Code, Section III)	
RDT F 2-2	Quality Assurance Program Requirements	
RDT F 3-6T	Nondestructive Examination (Supplement to ASME Boiler and Pressure Vessel Code, Section V)	
RDT F 4-20T	Operation and Maintenance Manuals	A2
RDT F 5-1T	Cleaning and Cleanliness Requirements for Nuclear Components	
RDT F 7-2T	Preparations for Sealing, Packaging, Packing, and Marking of Components for Shipment and Storage	
RDT F 7-3T	Marking of Components and Parts	

RDT M 1-1T	Stainless Steel Covered Welding Electrodes (ASME SFA-5.4 with Additional Requirements)	
RDT M 1-2T	Stainless Steel Welding Rods and Bare Electrodes (ASME SFA-5.9 with Additional Requirements)	
RDT M 5-1T	Stainless Steel Plate, Sheet, and Strip (ASME SA-240 with Additional Requirements)	
RDT M 7-3T	Stainless Steel Bars and Shapes (ASME SA-479 with Additional Requirements)	A1
RDT M 7-12T	Nickel Wire	
RDT M 7-13T	Ceramic Insulated Magnet Wire	

2.3 American National Standards (ANSI).

ANSI Y14	Drafting Manual
ANSI B46.1	Surface Texture

2.4 American Society of Mechanical Engineers (ASME) Publications.

ASME SFA-5.4	Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes	
ASME SFA-5.9	Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes	
ASME SA-240	Stainless and Heat-Resisting Chromium and Chromium-Nickel Steel Plate, Sheet, and Strip for Fusion-Welded Unfired Pressure Vessels	
ASME SA-479	Stainless and Heat Resisting Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels	
ASME Boiler and Pressure Vessel Code		
Section III	Nuclear Power Plant Components	
Section V	Nondestructive Examination	
Section IX	Welding and Brazing Qualifications	

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

ASTM A 240	Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Fusion-Welded Unfired Pressure Vessels	A2
------------	--	----

ASTM A 269	Seamless and Welded Austenitic Stainless Steel Tubing for General Service	
ASTM A 478	Chromium-Nickel Stainless and Heat Resisting Steel Weaving Wire	
ASTM A 479	Stainless and Heat-Resisting Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels	A2
ASTM A 511	Seamless Stainless Steel Mechanical Tubing	
ASTM A 555	General Requirements for Stainless and Heat Resisting Steel Wire	

2.6 American Welding Society (AWS) Specifications

A2

AWS A5.4	Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes	
AWS A5.9	Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes	

3. TECHNICAL REQUIREMENTS

3.1 Performance Requirements. The liquid level measurement sensor supplied in accordance with this standard shall meet the following performance requirements unless otherwise specified in the Ordering Data.

3.1.1 Measurement Range. The measurement range shall be determined by the specific application, and shall be as specified in the Ordering Data.

3.1.2 Accuracy. The accuracy of the level measurement, including thermal shifts, shall be within $\pm 5\%$ of the measurement range unless otherwise specified in the Ordering Data.

3.1.3 Linearity. The output signal shall be linear within $\pm 1\%$ over the total measurement range of the sensor unless otherwise specified in the Ordering Data.

3.1.4 Time Response. The time response of the level measurement shall be one second or less unless otherwise specified in the Ordering Data.

3.1.5 Service Life. The sensor shall perform within the limits specified in 3.2.1 through 3.2.4 for a service life of 5 years.

3.2 Environmental Requirements. The level sensor supplied in accordance with this standard shall be designed to perform within the limits specified in 3.2 while subjected to the following environmental conditions unless otherwise specified in the Ordering Data.

3.2.1 Sensor Probe. The sensor probe shall withstand the following conditions when installed in the liquid metal containment vessel or system component:

Temperature	250 to 1200°F
Radiation	10 ⁶ r/hr gamma 10 ¹¹ nv fast neutrons 10 ¹⁹ nvt fast neutrons
Pressure	0 to 250 psig
Mechanical Loads and Vibrations	As specified in the Ordering Data for the specific application

3.2.2 Sensor Head. Unless otherwise specified in the Ordering Data, the sensor head shall withstand the following environmental conditions for the life of the instrument:

Temperature	40 to 150°F
Pressure	0 to 15 psig
Mechanical Loads and Vibrations	As specified in the Ordering Data for the specific application

A2

3.3 General Design Requirements. The liquid metal level sensor designed in accordance with this standard shall be as specified herein, and in accordance with the Ordering Data.

3.3.1 Safety. The sensor shall conform to the safety analysis requirements for the specific installation. These requirements shall be as specified in the Ordering Data.

3.3.2 Availability, Reliability, and Maintainability. When the sensor is designed to meet specific availability, reliability, and maintainability requirements, these requirements shall be as specified in the Ordering Data.

3.4 Detail Design Requirements. The inductive liquid metal level measurement sensor designed in accordance with this standard may be one of many configurations. The configuration used shall be dictated by the specific application and shall be as specified by the purchaser.

3.4.1 Sensor Thimble. The sensor thimble must be in accordance with Section III of the ASME Boiler and Pressure Vessel Code (the Code) supplemented by RDT E 15-2. However, the thimble shall not be considered

A1

a part of the sensor nor shall its requirements be a part of this standard. Those thimble design parameters which are essential to the design, calibration, and performance of the sensor shall be as specified in the Ordering Data.

A1

3.4.2 Mounting Provisions. Detailed mounting provisions for mating the sensor with the sensor thimble shall be in accordance with the Ordering Data. When specified in the Ordering Data, the sensor shall be supplied with a sheath and mounting arrangement so as to function as a secondary sodium containment in the event of a leak in the thimble. The sheath and mounting parts shall be fabricated from materials compatible with both the sensor thimble and sodium. Sheath welds and sheath-to-mounting part welds shall be either by electron beam welding or by the inert gas process with or without filler rod, with welder qualification in accordance with Section IX of the Code. Weld examination shall be by liquid penetrant in accordance with RDT F 3-6, with no indications permitted. If filler rod is used, the filler rod shall meet the requirements of RDT M 1-2. The sensor probe-to-sensor thimble mounting arrangement shall be such that, with the space between sheath and thimble containing helium, the helium leak rate as determined in accordance with RDT F 3-6 shall not exceed 1×10^{-7} atm cc/sec. The sensor probe mounting parts shall provide a means for pressurizing the space between sheath and thimble for this test and also for subsequent check of the thimble integrity prior to removing the sensor probe. The sensor probe-to-sensor thimble sealing arrangement shall be designed to withstand the temperatures and sodium/sodium vapor environment which would occur in the event of a thimble failure.

A1

3.4.3 Coil Assembly - Single.

3.4.3.1 Core. The coil assembly or assemblies required for a particular type of inductive sensor shall be wound on coil cores. The core material shall be in accordance with the applicable RDT, ASME, or ASTM material standard listed in Table 1. The coil assembly shall be provided with any necessary spacers or alignment lugs required to properly position the coil within the sensor thimble. The length of the coil core shall be as specified in the Ordering Data.

3.4.3.2 Coil. The coils shall be wound with high temperature wire of a type suitable for use in the specified environment. The wire material shall be in accordance with the requirements of the applicable material standard listed in Table 1. If the coil core is metallic, the coil shall be wound on an insulated bobbin. If the coil core is nonmetallic, such as alumina, the coil may be wound from bare wire and need not be insulated from the coil core. However, when bare wire is used, provision shall be made to insulate one turn from another to preclude the possibility of turn-to-turn short circuit. The lead wires to and from each coil shall be from one length of wire. Splices below the mounting flange or plate shall be welded. The coil lead wires shall pass through and be insulated from the mounting plate, and shall be

Table 1. Material Selection Table

A2

Sensor Part	Material, Type, or Both	RDT or Other Material Designation
Sheath assembly:		
Sheath	Stainless steel tubing	ASTM A 511* ASTM A 269*
End cap	Stainless steel bar	RDT M 7-3, ASME SA-479, or ASTM A 479*
Coil core	Stainless steel bar	RDT M 7-3, ASME SA-479, or ASTM A 479*
	Ceramic tubing	RDT C 18-1
	Iron cobalt alloy - high magnetic permeability and curie point	Manufacturer's Specs.
Coils	Magnet wire - ceramic insulated	RDT M 7-13
	Constantan wire	Manufacturer's Specs.
	Nickel wire	RDT M 7-12
	Stainless steel weaving wire	ASTM A 478* or ASTM A 555*
	Metal sheath, mineral insulated cable	RDT C 17-5
Electrical insulators	Ceramic electrical insulators	RDT C 18-1
Electrical connectors	High-temperature - hermetically sealed	Supplier's choice, subject to purchaser approval
Mounting provisions	Stainless steel plate, sheet, and strip	RDT M 5-1, ASME SA-240, or ASTM A 240*
Welding materials	Stainless steel welding electrodes - covered	RDT M 1-1, ASME SFA-5.4, or AWS A5.4
	Stainless steel welding rods - bare	RDT M 1-2, ASME SFA-5.9, or AWS A5.9

*Any supplemental or modified requirements shall be as specified in the Ordering Data.

secured to the coil core in such a manner that short circuits between the lead wires and sensor thimble shall be prevented. Connections shall be as shown schematically in Figure 1.

3.4.4 Coil Assembly - Multicoil, Temperature Compensated. The multicoil temperature compensated coil assembly shall be wound in accordance with the requirements of 3.4.3.2 except as noted.

1. A second coil, for use as a reference coil, shall be added to the active coil. Connections shall be as shown schematically in Figure 2.
2. The reference coil shall be located above the maximum level of the liquid metal.

A1

3.4.5 Coil Assembly-Mutual Inductance. Closely coupled coil assemblies shall be wound in accordance with 3.4.3.2 except as noted:

A2

1. Two coils shall be wound on the same coil core to form a winding as shown in Figure 3.
2. Connections shall be as shown schematically in Figure 3.

3.4.6 Differential Transformer - Permanently Installed - Fixed Position. The coil assemblies of the differential transformer, "Tri-coil," sensor shall be wound in accordance with the requirements of 3.4.3.2 and the following exceptions or additional requirements:

3.4.6.1 Primary Coil Assembly. The primary coil assembly shall be wound on a core of high magnetic permeability having curie point as specified in the Ordering Data. The coil assembly shall be wound from one continuous length of wire. The active length of the coil shall be as specified in the Ordering Data. The leads shall be connected to the input terminals as indicated in Figure 4.

3.4.6.2 Secondary Coil Assembly. Two secondary coils shall be wound on either side of the primary coil and on the same coil core. Each of the two secondary coils shall be wound from one continuous length of wire in the configuration shown in Figure 4. The secondary coils shall be equal in length. The length shall be as specified in the Ordering Data.

3.4.6.3 Probe Assembly. The primary and secondary coil assemblies shall be permanently fixed to a support rod which is connected to the mounting plate. The coil leads shall pass through, and be electrically insulated from, the mounting plate. The entire assembly shall be encased in a suitable metallic protective sheath. The protective sheath shall be terminated at, and welded to, the mounting plate. The opposite, lower end, shall be capped such that it is completely closed.

A1

Figure 1. Single Coil Inductance Sensor

A1

Figure 2. Multi-coil Temperature Compensated Sensor

A1

Figure 3. Mutual Inductance Sensor Winding

A2

Figure 4. Differential Transformer, Tri-coil, Sensor

3.4.6.4 Head Assembly. The head assembly shall contain all signal conditioning circuitry, both input and output, necessary to the proper operation of the sensor assembly. The electronic circuitry shall use solid state devices.

A1

3.4.7 Differential Transformer - Portable. The portable differential transformer sensor shall be a completely self-contained sensing system consisting of three major components: (1) sensor, (2) signal conditioning and readout box, and (3) interconnecting cable. The portable sensor assembly shall be in accordance with the requirements of 3.4.6 except as follows:

3.4.7.1 Head Assembly. The sensor head assembly shall be an integral part of the probe or "dipstick," and shall house the electrical connections between the sensor coils and the interconnecting cable. Unless otherwise specified in the Ordering Data, the type of connection shall be determined by the supplier and approved by the purchaser.

3.4.7.2 Interconnecting Cable. The interconnecting cable shall be a multiconductor flexible cord or cable with provisions for connection to the sensor assembly and signal conditioning and readout box. The length shall be as specified in the Ordering Data.

3.4.7.3 Signal Conditioning and Readout Box. The signal conditioning and readout box shall be connected to the sensor through the interconnecting cable, and shall contain all signal conditioning circuitry, indicating meter, balance adjustment, and batteries. The readout box shall be in accordance with the following additional requirements.

1. The overall readout box assembly size and weight shall be the minimum consistent with reliable operation and performance.
2. The indicating meter shall be of sufficient size and so positioned to be easily read. The meter size and location shall be approved by the purchaser.
3. The balance adjustment shall be readily accessible.
4. The batteries shall be readily accessible and easily replaced or recharged.

3.4.8 Differential Transformer - Permanently Installed - Variable Position. The variable position differential transformer sensor shall be wound in accordance with the requirements of 3.4.6 and the following exceptions or additional requirements.

3.4.8.1 Mounting Provisions. The sensor probe assembly shall be designed such that it may be mounted to a servo-mechanism allowing its position to vary automatically or be controlled from a remote location. Mounting provisions shall be as specified in the Ordering Data.

3.4.8.2 Sensor Head. The sensor head shall be the same as specified for a "Permanently Installed Fixed Position" instrument except that the input and output leads shall be flexible, coiled cord or equivalent. Minimum lead length and end terminations shall be as specified in the Ordering Data.

3.4.9 Balanced Bridge Sensor. The balanced bridge type sensor shall be in accordance with the requirements of 3.4.6 through 3.4.8 depending on the specific application as specified in the Ordering Data.

A1

The coil assembly shall be wound in accordance with 3.4.6 except that the primary coil shall be omitted and the two remaining coils shall not be designated as secondary coils. This configuration shall be as illustrated in Figure 5. The coils shall be equal in length and contain an equal number of turns. The coil length and distance between coils shall be as specified in the Ordering Data.

3.4.10 Insulation Resistance. The minimum insulation resistance of the completed sensor coil assembly, on a per foot of probe length basis up to 10-ft lengths (see 6.1), shall be as follows, unless otherwise specified in the Ordering Data:

A2

<u>Temperature</u> (°F)	<u>Applied</u> <u>Voltage</u> (Vdc)	<u>Insulation</u> <u>Resistance</u> (megohm-ft)
77	50	100,000
1200	50	0.2

EXAMPLE: >100 kmegohm for 1 ft,
>50 kmegohm for 2 ft, >33.3 kmegohm
for 3 ft, etc.

3.4.11 Input Power. The input power from an external source supplied to the sensor head assembly shall be as specified in the Ordering Data. The frequency and current required by the mutual inductance bifilar sensor for any specific application shall be determined by the supplier and approved by the purchaser.

A1

3.4.12 Output Signal. The output signal as measured at the sensor output terminals or connector interface with the signal transmission lines shall be determined by the supplier and approved by the purchaser.

A1

Figure 5. Balanced Bridge Sensor

3.5 Materials. Unless otherwise specified in the Ordering Data, the materials to be used shall be recommended by the supplier and shall be purchased in accordance with the standards and specifications listed in Table 1. However, RDT M 1-1, RDT M 1-2, RDT M 5-1, and RDT M 7-3 material shall be used when the probe is in contact with the coolant or a part of the primary pressure boundary. All materials used in the sensor shall be subject to purchaser approval. Certification shall be provided that all materials used in the construction of the level sensor are compatible with the sensor thimble and sensor sheath materials and do not contain impurities which are known to react with the thimble and sheath materials.

A2

3.5.1 Contaminants. Contaminants from production material or fabrication processing which could adversely affect performance of the sensor, or which are not compatible with the thimble or sheath materials, shall be avoided.

A1

3.5.2 Alternate Materials. Alternate materials shall be recommended whenever a substitute material is considered to offer a means of achieving an improved product. Approval of the purchaser shall be required for all material substitutions.

3.5.3 Material Identification. Materials shall be identified in accordance with the requirements of the referenced material standard.

3.6 Manufacturing Processes. Manufacturing processes shall be in accordance with the RDT standards listed in Section 2, unless otherwise specified in the Ordering Data.

3.6.1 Fabrication Procedures. Detailed shop fabrication procedures shall be submitted to the purchaser for approval. Approval shall be obtained prior to the initiation of fabrication. The procedures shall define the fabrication sequence and shall include all operations such as cleaning, in-process inspection, nondestructive testing, material handling and storage, welding, heat treatment, assembly, and preparation for shipment.

3.6.2 Inspection Point Program. The inspection program shall be in accordance with RDT F 2-2. It shall be adequately cross referenced to the fabrication procedure. The program shall be submitted to the purchaser for approval prior to the initiation of fabrication. "Hold Points" for inspection shall be identified at the time of approval of the fabrication procedure. Any changes in the fabrication procedure will identify any proposed changes in the "Hold Points."

3.6.3 Manufacture Release. Components or parts may be released for manufacture upon approval by the purchaser of outline, assembly or detail drawings, or both, of the part or the assembly, the design report, fabrication, and inspection point program. The design report may be in preliminary form. However, it shall be complete with respect to design adequacy verification.

3.6.4 Tooling and Fixtures. Special tools or fixtures or both used in the fabrication process shall be identified in the fabrication procedure of 3.6.1.

3.6.5 Surface Finish. All surfaces shall have a finish that complies with the following, unless otherwise specified in the Ordering Data:

1. Locating surfaces shall have a surface finish of 63 microinches or better in accordance with ANSI B46.1.
2. Machined surfaces shall have a surface finish of 125 microinches or better in accordance with ANSI B46.1.

3.6.6 Cleaning. Surfaces of the liquid level sensor shall meet the cleanliness requirements of RDT F 5-1.

3.6.7 Specialized Fabrication Processes. Technical documentation to prove the adequacy and feasibility of unique or unusual manufacturing processes or the novel adaptation of generally accepted processes shall be submitted. This documentation shall be in addition to any normal qualification processes and shall be submitted as part of the design report (3.7.1).

3.6.8 Identification of Parts. Component parts, assemblies, and auxiliary components shall be identified in accordance with RDT F 7-3. Component parts, assemblies, and equipment that must be assembled by the purchaser shall be permanently marked with part and serial number.

A1

3.6.9 Assembly. A detailed procedure for assembly of component parts shall be prepared and submitted for purchaser approval. The procedure shall contain the following, as a minimum:

1. Assembly sequence.
2. Cleaning methods and precautionary measures.
3. Special machining or fitting at assembly.
4. Intermediate and final inspection criteria.
5. Handling methods and precautions.
6. Drawings or photographs or both.

3.7 Reports.

3.7.1 Design Report. A design report shall be prepared and submitted to the purchaser at least 30 days prior to the planned initiation of fabrication. Fabrication shall not begin prior to approval of the design report.

3.7.1.1 Design Analysis. A design analysis of the proposed sensor shall be conducted. The analysis shall include selection of materials such as metals, insulators, electrical wire, wire terminals,

connectors, and feedthroughs. When applicable, thermal and mechanical stress analysis shall be conducted to demonstrate the sensors ability to withstand its environment.

3.7.1.2 Performance Analysis. A performance analysis of the proposed sensor shall be conducted. The items that shall be included are:

1. Electrical inputs(s).
2. Output signal.
3. Type of readout.
4. Linearity.
5. Range.
6. Accuracy.
7. Insulation resistance.

3.7.1.3 Interim Design Report. An interim design report shall be submitted to the purchaser for approval prior to completion of the final design report. The purpose of the interim report is to obtain initial agreement on the basic design at an early state. This preliminary review will reduce or eliminate the need for extensive redesign when, in the opinion of the purchaser, the design contains features that require additional justification.

3.7.1.4 Design Considerations. This section of the design report shall include, but not be limited to:

1. All known parameters, assumptions, approximations, and calculations in detail to permit independent checking.
2. A discussion of the validity of the data employed and conclusions which support the recommended designs.
3. Completely identified references from which data and formulae are taken.

When recognition of a design or fabrication practice is not widely accepted by industry, the reasons for using this design or fabrication practice and justification shall be given as noted in 3.6.7.

After approval of the final design report by the purchaser, additions or corrections to the report shall be made as necessary to keep the data correct. These revisions shall be numbered and dated, and shall be submitted to the purchaser for approval in the same quantities as the original report.

The number of copies of the design report supplied shall be as specified in the Ordering Data.

3.7.2 Fabrication Report. A fabrication report shall be prepared upon completion of fabrication of the sensor. This report shall be certified by the supplier with respect to the accuracy of the contained information after an audit is performed by the purchaser's representative(s). The report shall include, but not be limited to, the following:

1. Material log.
2. Written nondestructive examination procedures including any acceptance criteria.
3. Manufacturing deviations, which occurred during any phase of fabrication, and the corrective actions or dispositions taken.
4. A detailed record of findings, including radiographic film, recorder charts, and photographic records from all final non-destructive examinations performed on the sensor. For parts not accessible during the final examination, the record of the last examination performed at an earlier stage shall be included. The records shall be in detail to serve as a reference examination for comparison with future examinations as may be required during the service life of the sensor.

| A1

A material log showing the use of all materials in the fabrication of each sensor shall be maintained such that it will be possible to relate every finished part to the original certification of the material and the fabrication history of the part. The material log shall include the material certification, identification, use of materials, mill practice, shop operations, chemical and physical test results, material identification procedures, and nondestructive test results.

3.8 Drawings. Final engineering drawings and associated lists in accordance with ANSI Y14 shall be prepared and furnished. The title block of each drawing shall include:

1. Purchase order number.
2. Alphanumeric designation of this standard and revision.
3. Manufacturer's name.

Dimensions on fabrication or shop drawings shall be for room ambient (75°F) conditions.

3.8.1 Preliminary Drawings. Preliminary drawings, sketches, or data necessary to amplify descriptions and assertions shall be submitted with the initial bid. These drawings shall include, but not be limited to:

1. Design and salient features.
2. Outline dimensions, for both cold (70°F) and design conditions, in sufficient detail to establish limits of space in all directions plus clearance required for service or replacement.

3.8.2 Engineering Drawings.

Installation Control Drawings. The installation and control drawings shall include:

1. Sketches and dimensions in detail to establish limits of space in all directions required for installation, operation, and servicing of the sensor.
2. All information required for the preparation of installation plans.
3. Type, size, and location of connections and fittings.
4. Special instructions necessary for alignment, installation, or storage.
5. A complete list of reference drawings.

Drawing Lists. A listing of detail and assembly drawings shall be supplied to the purchaser. Drawings associated with the components of this standard shall be listed in numeric order with drawing title. Each number shall include a revision letter and the list shall be regularly revised to keep it current.

Approval of Drawings. All drawings shall be submitted to the purchaser for approval. The drawings shall be submitted in an orderly sequence with related parts drawings submitted together. All drawings shall be fully identified. The analysis for each part shall be completed and submitted prior to or with the part drawing.

Revisions to Approved Drawings. After drawings have been approved by the purchaser, no changes in design or fabrication shall be permitted without prior purchaser approval.

Microfilm. Drawings shall be suitable for microfilming. Microfilm copies of those drawings specified by the purchaser shall be supplied.

Drawing Quality. Width, spacing, and density of lines and characters shall be such that the drawings can be reduced to 11-in. height for use in manuals.

3.8.3 Photographs. Photographs shall be supplied of any steps the purchaser determines as significant in the fabrication process of the sensors. Photographs shall also be supplied of unique or unusual features or operations which will not be clearly shown in the assembly drawing. The date and subject of each photograph shall be identified. Each photograph shall include a familiar object or scale to indicate size.

3.9 Nameplates. Nameplates or metal tags shall be provided for the instrument in accordance with the following:

Nameplates or metal tags shall be of a corrosion-resistant steel or nickel-chromium-iron alloy.

3.9.1 Information Required.

1. Name of the component.
2. Name of the manufacturer.
3. Component serial number (assigned by manufacturer).
4. Date of manufacture.
5. Owner's name and contract number.
6. Type number.

3.9.2 Nameplate Mounting. The following requirements shall apply to the mounting of nameplates:

1. Nameplates shall be visible after the component is installed.
2. Nameplates shall not be painted or otherwise covered.

3.10 Manuals. Manuals for instrument operation, calibration, and maintenance shall be prepared in accordance with RDT F 4-20.

A2

3.10.1 Approval Procedure. Preliminary copies of the manuals shall be submitted to the purchaser for review and approval. Approval by the purchaser of the final corrected copies of printer's proofs shall be obtained prior to release to print final manuals. The number of preliminary manuals, printer's proofs, and final manuals shall be as specified in the Ordering Data.

3.10.2 Content. The manuals shall include, but not be limited to:

1. A detailed description of the instrument and instructions for installation, operation, care and maintenance.
2. Calibration procedures.
3. Instructions for use of special tools or equipment or both.

4. Drawings of special tools or equipment or both.
5. Reduced size drawings necessary for operation, maintenance, and instruction purposes.

3.10.3 Delivery. Final manuals shall be available at the time of sensor delivery.

3.11 Document Submittal and Approval. The requirements regarding time of submittal, approval, and number of copies of all procedures, drawings, reports, and manuals shall be as specified in the Ordering Data.

A1

4. QUALITY ASSURANCE REQUIREMENTS

4.1 Quality Assurance Program. A quality assurance program shall be established and implemented in accordance with Sections 1 through 5 and 8 of RDT F 2-2. The requirements regarding time of submittal, approval, and number of copies of all quality assurance documents shall be as specified in the Ordering Data. Access for surveillance by the purchaser's authorized representative(s) shall be permitted to any place where material manufacture and storage, fabrication, assembly, inspection, and testing are performed, including subcontractor's facilities.

A2

A1

4.2 Inspection. The performance of all inspection requirements specified herein shall be the responsibility of the supplier. The supplier may utilize his own facilities or a commercial laboratory acceptable to the purchaser. The purchaser reserves the right to perform or witness inspections set forth in this standard. However, these requirements in no way relieve the supplier of his responsibility to furnish equipment and services as specified herein.

4.3 Nondestructive Examination. Nondestructive examination shall comply with Section V of the Code and RDT F 3-6. All nondestructive examination shall be in accordance with the applicable material and process standards and as supplemented below. When acceptance or rejection criteria are not specified, such criteria shall be recommended to the purchaser for approval. Detailed nondestructive examination procedures shall be submitted for approval; however, the minimum requirements specified in the documents and listed below shall be included in the procedures.

Where the specified examination cannot be accomplished, a written request for deviation outlining an equivalent inspection technique shall be submitted. Approval by the purchaser shall be required for deviations.

4.3.1 Calibration Requirements. Equipment and instruments used for nondestructive examination or testing shall be calibrated in accordance with the requirements of RDT F 2-2.

A1

4.4 Examination of Materials. In addition to the requirements of the appropriate material standards, materials used in the manufacture of the sensor shall be examined in the following manner.

4.4.1 Visual. Materials shall be examined visually to detect obvious defects, state of cleanliness, and distortions.

4.4.2 Dimensional. Raw materials shall be dimensionally spot checked for dimensions defining size and shape.

4.4.3 Marking. Raw material shall be examined for conformance to the requirements of the referenced material standard. Material shall be identified by manufacturer's name, type of material, appropriate material standard designation, heat and lot number. Components and equipment shall be examined for proper marking in accordance with RDT F 7-3. Required identification shall include manufacturer's name, item serial number, order or contract number, and any other special information necessary to identify the part.

4.5 Tests. Tests required by this standard or proposed to justify design features, prove adequacy, or satisfy requirements shall be described in detail in a test procedure. The test procedure shall be prepared and submitted for approval by the purchaser prior to initiation of any testing. Each procedure shall include, but not be limited to, the following:

1. Purpose of test.
2. List of equipment and assembly drawings.
3. Test procedure.
4. Data required.
5. Criteria for acceptance or rejection.

4.5.1 Inert Gas Leak. When specified in the Ordering Data, a helium leak test shall be performed to verify component leak tightness. Helium leak testing shall be performed in accordance with RDT F 3-6. The procedures shall be submitted for approval. (Halide type leak testing shall not be acceptable.) The maximum acceptable leak rate for this test shall be 1×10^{-7} scc/sec. Calibration of the leak testing equipment shall be in accordance with RDT F 3-6.

A1

4.5.2 Load Tests. When specified in the Ordering Data, such tests as necessary shall be performed to demonstrate the ability of the instrument to withstand the specified external loads and deflections without failure.

4.5.3 Vibration Test. When specified in the Ordering Data, such tests as necessary shall be performed to demonstrate the ability of the sensor to endure environmental vibration without failure, or to be free of harmful vibration induced by the environment.

Modifications to the sensor which are necessary to correct vibrational difficulties shall be the responsibility of the supplier.

4.5.4 Functional Tests. The functional and performance tests listed in this standard shall be performed by the supplier. These tests need not be performed in liquid metal test facilities. Test procedures shall be prepared and submitted for approval. Functional or performance tests, or both, shall be witnessed by the purchaser or his designated representative(s).

4.5.4.1 Sensor Calibration. Each sensor fabricated and delivered shall be calibrated in increments equal to 10% of full scale over the total measurement range of the sensor. The calibration shall be performed with the sensor positioned in a calibration fixture which contains a thimble of the same size, shape, and material as specified in the Ordering Data. A calibration curve shall be prepared and delivered along with each sensor.

4.5.4.2 Thermal Cycle Tests. The minimum number of sensors specified in the Ordering Data or as recommended by the supplier and approved by the purchaser shall be subjected to thermal cycle tests. The number of cycles, high and low temperatures, temperature ramp or rate, and frequency of calibration shall be as specified in the Ordering Data. Each calibration shall be performed in accordance with 4.5.4.1 and shall repeat the initial or record calibration within $\pm 1.0\%$.

4.5.4.3 High Temperature Soak Tests. The minimum number of sensors specified in the Ordering Data, or as recommended by the supplier and approved by the purchaser, shall be subjected to high temperature soak tests. The temperature, time, and calibration intervals shall be as specified in the Ordering Data. Each sensor calibration shall repeat the initial or record calibration within $\pm 1.0\%$.

4.5.5 Test Reports. Copies of test reports shall be maintained by the supplier. These test reports shall be identified to the specific liquid level sensor and transmitted to the purchaser simultaneously with delivery of the instrument.

5. PREPARATION FOR DELIVERY

5.1 Sealing, Packaging, Packing, and Marking. Sealing, packaging, packing, and marking shall be in accordance with RDT F 7-2 unless otherwise specified. The specific method of packaging and packing of the individual component shall be submitted for approval. Recommendations shall include the following shipping information as a minimum:

1. Protection of all surfaces during shipment and subsequent storing at the installation site.
2. Protection of components with particular reference to machined surfaces.
3. Special tools or handling equipment required during shipment.
4. Provisions for maintaining cleanliness during shipment.

5.2 Shipping Requirements. The following specific requirements shall be complied with when shipping the finished sensors procured in accordance with this standard.

5.2.1 Sensor and Associated Parts. The shipping closure design shall provide adequate protection to critical areas such as seating and sealing surfaces to prevent damage caused by walking on, dropping of tools, and similar conditions during shipment, storage, and installation.

5.3 General Requirements.

5.3.1 Marking. Components in shipping containers shall be clearly marked, in as many locations as necessary for legibility, with temporary signs of contrasting colors and of suitable composition as approved by the purchaser with the following statement: "Fragile-Delicate Instrument."

5.3.2 Loading. Supervision shall be provided for loading the sensors for shipment. Handling equipment and shipping containers shall prevent damage due to handling and shipping shock and vibration.

5.3.3 Supports. Required shipping position, supports, and crating shall be determined by the supplier and approved by the purchaser.

5.3.4 Storage. When specified in the Ordering Data, the sensors will be stored for significant periods of time prior to installation and use. The sealing, packing, packaging, and marking shall be designed accordingly. As a minimum the package shall:

1. Maintain cleanliness requirements of this standard.
2. Provide easy access for periodic inspection.
3. Provide instructions necessary to maintain storage conditions.

6. NOTES AND ORDERING DATA CHECKLIST

6.1 Notes. Minimum insulation resistance requirement for lengths greater than 10 ft is not defined at this time due to insufficient information with regard to effects on performance. The insulation resistance value for probes longer than 10 ft will be specified in the Ordering Data.

6.2 Proposal Information. The supplier's proposal shall include, but not be limited to, the following information:

1. Preliminary drawings noted in 3.8.1 depicting the relationship of component parts, appropriate dimensions, and electrical and mechanical interfaces of the sensor.
2. Materials of construction.
3. Quality assurance program.
4. Proposed tests, as required, to prove adequacy and proposed test instrumentation.
5. Sketches of shipping arrangements.
6. A detailed list of all items to be provided.
7. Detailed schedule.

6.3 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>	<u>Purchase Specifications</u>
<u>Classification</u>	1.1	_____
<u>Applicable Documents</u> (issue dates and amendments)	2.	_____
<u>Sensor Thimble</u>		
Material	3.4.1	_____
Length	3.4.1	_____
Inside diameter	3.4.1	_____
Outside diameter	3.4.1	_____
<u>Mounting Provisions</u> (Marman clamp, weld flange, etc.)	3.4.2	_____
<u>Performance Requirements</u>		
Range	3.1.1	_____
Accuracy	3.1.2	_____
Linearity	3.1.3	_____
Time response	3.1.4	_____
Service life	3.1.5	_____

<u>Item</u>	<u>Refer to Paragraph</u>	<u>Purchase Specification</u>
<u>Sensor Probe Requirements</u>		
External Loads		
Deflection	3.2.1	
Vibration (freq. and ampl.)	3.2.1	
Safety	3.3.1	
Availability	3.3.2	
Reliability	3.3.2	
Maintainability	3.3.2	
Length	3.4.1, 3.4.3	
Coil diameter	3.4.1, 3.4.3	
Distance between coils	3.4.6	
Insulation resistance	3.4.10	
Input power - current	3.4.11	
frequency	3.4.11	
Output signal	3.4.12	
<u>Sensor Winding</u>	3.4.3	
(Bifilar, Parallel, etc.)	through 3.4.9	
Coil assembly - single		
Core length	3.4.3.1	
Coil assembly - multicoil		
Location	3.4.4	
Differential transformer - fixed position		
Primary coil		
Material curie point	3.4.6.1	
Length	3.4.6.1	
Secondary coil		
Length	3.4.6.2	
Differential transformer - portable		
Head assembly connection	3.4.7.1	
Interconnecting cable length	3.4.7.2	

<u>Item</u>	<u>Refer to Paragraph</u>	<u>Purchase Specification</u>
Balanced bridge sensor		
Coil length	3.4.9	_____
Distance between coils	3.4.9	_____
<u>Sensor Head Requirements</u>		
Operating environment		
Temperature	3.2.2	_____
Pressure	3.2.2	_____
Atmosphere	3.2.2	_____
Radiation	3.2.2	_____
Size		
Length	3.4	_____
Width	3.4	_____
Height	3.4	_____
Minimum lead length	3.4.8.2	_____
End terminations	3.4.8.2	_____
Electrical connections		
Input signal	3.4.11	_____
Output signal	3.4.12	_____
Document submittal		
Engineering (No. of copies, time of submittal, and approval requirements)	3.11	_____
Quality assurance (No. of copies, time of submittal and approval requirements)	4.1	_____
<u>Test Requirements</u>		
Inert gas leak test	4.5.1	_____
Load test	4.5.2	_____
Vibration test	4.5.3	_____

<u>Item</u>	<u>Refer to Paragraph</u>	<u>Purchase Specification</u>
Functional tests		
Calibration	4.5.4.1	_____
Temperature	4.5.4.1	_____
Increments	4.5.4.1	_____
Thermal cycle		
Minimum number of sensors	4.5.4.2	_____
Upper temperature	4.5.4.2	_____
Lower temperature	4.5.4.2	_____
Cycle rate	4.5.4.2	_____
Frequency of calibration	4.5.4.2	_____
High temperature soak tests		
Minimum number of sensors	4.5.4.3	_____
Temperature	4.5.4.3	_____
Time	4.5.4.3	_____
Calibration interval	4.5.4.3	_____
Storage	5.3.4	_____