APPENDIX D

INSTALLATION AND CALIBRATION OF INSTRUMENTS GUIDANCE (PROGRAMMATIC AND FACILITY)

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RECORD OF REVISIONS

Rev	Date	Description	POC	OIC
0	11/17/03	Initial issue.	Mel Burnett, *FWO-DECS*	Gurinder Grewal, *FWO-DO*
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CONTACT THE I&C STANDARDS POC

for upkeep, interpretation, and variance issues

Section D3060/F1050 App D	**Instrumentation & Controls POC/Committee**

1.0 PURPOSE

This appendix provides guidance for the mechanical installation and initial calibration of field installed instrumentation, equipment supports, and associated tubing systems.

2.0 SCOPE

This appendix applies to all I&C systems and devices and may be supplemented with specific installation and initial calibration requirements provided on design drawings or by other project specific documents.

2.1 Included

- Installation of instrument sensing lines and fittings
- Installation of instrument valves and manifolds
- Fabrication and installation of sensing lines and supports
- Location and installation of local, panel mounted, and rack mounted instruments
- Installation of instrument racks, panels, and enclosures
- Installation testing and inspection
- Location of instrumentation mounted in and on process equipment, vessels, or process piping
- Instrument calibration at component level

2.2 Not Included

- Installation and/or furnishing electrical raceway, conduit, cable and electrical terminations
- Periodic calibration
- Installation inspection and documentation of vendor installed instruments
- Installation of in-line mounted instruments
- Installation of control valves

3.0 ACRONYMS AND DEFINITIONS

3.1 ACRONYMS

ANSI - American National Standards Institute

ASME - American Society of Mechanical Engineers

HVAC - Heating, Ventilation and Air Conditioning

HP - High Pressure

ISA – The Instrumentation, Systems, and Automation Society

LP - Low Pressure

P&ID - Process and Instrumentation Diagram

RTD - Resistance Temperature Detector

3.2 DEFINITIONS

Calibration – The systematic process performed to determine outputs of a device corresponding to a series of values of the variable which the device is to measure, receive or transmit for the purpose of determining the error of the device compared against a standard and /or adjusting the device to bring it to the desired value, within a specified tolerance.

Cold Bend – Shaping tubing or piping by bending, drawing, stretching, or other stamping operations without the application of heat.

Design Agency – The organization performing the detailed design and analysis of a project or modification.

Design Authority – The person or group responsible for the final acceptability of and changes to the design of a system or component and its technical baseline (typically the manager of engineering).

Flaring – Increasing the diameter at the end of pipe or tube to form a conical section.

Gauge Glass – A glass or plastic tube for measuring liquid level in a tank or pressure vessel, usually by direct sight.

Impulse Line – The line, tubing or pipe, that connects the process to the primary measuring element of the instrument loop and is part of the process pressure boundary and containment. Sensing lines and impulse lines are the same.

In-Line Instrument/Device – Instrument/device installed in the process piping system (e.g, control valves, orifice plates, thermowell).

Installation Detail – Installation documentation in the form of standards, specifications, procedures, drawings, and quality inspection plans.

Instrumentation – A mechanical, electrical, pneumatic or hydraulic item (device/component/equipment) which is used for process monitoring or control. This also includes items such as sample probes and thermowells, which support instrumentation functions.

Line Mounted Instrument – Instrument installed in a connection attached to the process piping system (e.g., temperature indicators, temperature elements, temperature switches).

Local Mounted Instrument – Instrument installed locally on a wall, column, floor stand, etc. (e.g., transmitters, switches, indicators).

Pigtail – A 270° or 360° loop in pipe or tubing to form a trap for vapor condensate. Used to prevent high temperature vapors form reaching the instrument.

Root Valve – The first valve located in a sample line after it taps off the process. It is typically located in close proximity to the sample tap.

Seal Pot – Enlarged pipe sections in measurement impulse lines to provide a) a high area to volume displacement ratio to minimize error from hydrostatic head difference when using large volume displacement measuring elements, and b) to prevent loss of seal fluid by displacement into the process. A section of pipe (4 in. diameter) installed horizontally at the orifice flange union to provide a large area surge surface for movement of the impulse line fluid with instrument element position change to reduce measurement error from hydrostatic head difference in the impulse lines.

Snug Tight – Snug tight is a solid connection obtained using standard tools where bolting hardware has been sufficiently tightened to bring contacting surfaces of the bolted assembly into solid contact without damaging or distorting the assembly or hardware

Standpipe – A vertical tube filled with a liquid.

Thermowell – A pressure tight receptacle adapted to receive a temperature sensing element and provided with external threads or other means for pressure tight attachment to a vessel.

Wet-Leg – A liquid filled sensing line in a differential pressure level measuring system.

4.0 MATERIALS

A. Before fabrication all materials should be visually examined for defects.

B. Material should be controlled during construction at all times to ensure that it is identifiable as acceptable material.

C. Tubing, fittings and valve ends should be sealed to prevent moisture, dirt and foreign matter from entering the tubing/valves during storage.

D. Material should be compatible with the environment in which it is located. If contact is made with the process, the material should also be compatible with the measured medium at the specified operating conditions. Consideration should be given to the affects of corrosion, abrasion, contamination, and degradation due to excessive pressure or temperature.

5.0 PROCESS TAPS

A. The general location of the process tap with respect to other taps/branches should be shown on a P&ID. The exact location of process connections may be shown on area piping composite drawings, piping isometric drawings, HVAC drawings, or the equipment vendor drawings.

B. The placement of the tap on the process pipe should take into consideration instrument operability concerns, such as required number of pipe diameters up or downstream of a fitting / sensing device. If the tap can perform its function in a number of locations, choose the one nearest the sensing device.

C. During the placement of the tap, strive for maintenance accessibility of root valves and a vertical stem installation.

D. The process tap should be located near a pipe support to minimize vibration.

6.0 INSTRUMENT LOCATION AND INSTALLATION GUIDANCE

A. The Design Agency should consider the following design aspects for location of instruments:

1. Routing of sensing line from the process tap to the instrument
2. Sensing line penetrations through walls and floors

3. Space requirements for installation, operation, maintenance, calibration, accessibility and electrical flex conduit installation
4. Operational Environmental Specifications
5. Vibration-free mounting on available structures
6. Radiation level of mounting area. Instruments are to be located in low radiation and non-hazardous areas where possible
7. Chemical Exposure

B. Instruments should be installed such that servicing, calibration, or replacement can be made with a minimum of sensing line disassembly and with easy access to all connections.

C. Local instruments, other than direct actuated indicators such as pressure gauges, should be mounted at an accessible location on columns, walls, or floor-mounted structures rather than mounted on process piping.

D. Instrument mounting heights from the floor should be approximately 1.4 meters (4 feet-6 inches) for wall-mounted instruments and floor stand mounted instruments when measured from the centerline of the instrument. Deviations from the indicated location should be a maximum of ±1.5 meters (±5 feet) in plan, and ±30.5 cm (±1 feet) in elevation.

E. Instruments should be located near operating spaces but should not obstruct aisles or walkways.

F. Avoid locating instruments in areas where there is likelihood of damage to the instrument or instrument sensing lines. If instruments must be located in a potentially hazardous area, protective barriers should be installed.

G. Gas and liquid pockets in liquid and gas sensing lines can be avoided with sufficient slope (See Item I, Section 7.0) and locating instruments relative to the process connection as follows:

Fluid	**Preferred Instrument Location Elevation**
Liquid	Below Line Connection
Steam over 138 Kilopascal Absolute (20 psia)	Below Line Connection
Steam not over 138 Kilopascal Absolute (20 psia)	Above Line Connection
Gas	Above Line Connection

H. Instruments should be located such that the sensing lines are as short as practical to minimize slope requirement problems. Instruments that cannot be connected with proper slope should be provided with vent or drain points.

7.0 INSTRUMENT SENSING LINE INSTALLATIONS

A. Instrument sensing lines should be installed in accordance with the guidance presented in this appendix, design drawings, and installation details. The safety classification of piping for instrument tubing systems should be, as a minimum, consistent with the requirements of the process system to which the instrument is connected.

B. Sensing lines should not be installed in a manner that would interfere with or prevent maintenance and/or operational activities. Minimum headroom clearance of known and identified passageways should be 2.1 meters (7 feet).

C. Whenever practical, sensing lines should be routed along walls, columns, or ceilings, avoiding open or exposed areas. Structural channels or a track should be installed to protect sensing lines in exposed locations subject to accidental crushing or damage. This type of protection, however, should not render the tubing and fittings inaccessible.

D. Instrument sensing lines should be routed separately from process lines and equipment where vibration, abnormal heat, or stress could affect the lines. Tubing and piping that must be connected to vibrating equipment should be fabricated with adequate flexibility.

E. Instrument sensing lines should not come in contact with structural steel and concrete surfaces of building members. In no case should tubing be installed in direct contact with painted or unpainted concrete surfaces, except for penetrations requiring closure. Grout should only be used for tubing with temperatures below 93° C (200°F).

F. Instrument sensing lines routed through penetrations, shield walls or other barriers where visual contact is impaired or lost, should be labeled with a permanent tag attached securely on each side of that barrier displaying the corresponding instrument identifier.

G. The spacing around sensing lines should always be wide enough to allow each tube to expand independently at all turns without striking adjacent tubes or other equipment.

H. Heat tracing should be used for sensing lines containing liquid that may freeze or become viscous, or a wet gas from which moisture may condense. The heat tracing should provide enough heat to prevent freezing or condensation, but not great enough to boil the liquid in the sensing line.

I. Sensing lines should have continuous slope to promote their being kept either full or free of fluid (unless noted otherwise). The preferred slope is 8.3 cm/m (1 inch per foot), however, 2.1 cm/m (1/4 inch per foot) is acceptable. For instruments sensing steam at pressures up to 138 kilo pascals absolute (20 psia), the instrument lines should slope a minimum of 16.7 cm/m (2 inches per foot). Minimum slope will begin after the root valve and terminate at the instrument valve inlet. The sensing lines may be level through and on each side of a valve manifold or instrument connection shut off valve for a distance of up to 10 cm (4 inches). Instrument sensing lines may be level through and on each horizontal leg of a vertically oriented tee or cross connection for a distance of up to 10 cm (4 inches), and through a penetration for a total cumulative length of 30 cm (12 inches) outside the ends of each penetration.

J. Bends, rather than tube or pipe fittings, should be used to change the direction of sensing lines. The cold bending method is advised for all bends. A minimum bend radius of at least two and one quarter (2 1/4) times the tubing outside diameter should be employed for bends in stainless steel tubing and copper tubing. The minimum bend radius for capillary tubing, aluminum, and plastic tubing should be per manufacturer recommendations. Refer to the LANL Engineering Standards Manual, Mechanical Chapter, for tube bending requirements and the determination of wall thinning effects.

K. Where fittings must be used and an installation detail document specifies the size and type of fitting, a combination of fittings of other sizes may be substituted if the specified part is unavailable or it is more convenient to use the combination. The fittings must, however, be of the same equivalent type and produce the same or better overall effect. A weld fitting may replace a threaded or flareless joint; however, a threaded or flareless connection should not be used if welded fittings are required. Flareless fittings should be installed using the manufacturer's assembly instructions. For compression fittings, refer to LANL Master Specification 40 0511, Compression Fittings on Copper and Stainless Steel Tubing.

L. For threaded connections of stainless steel to stainless steel, lubrication should be applied to prevent seizing and galling. Low or no chloride content lubricants should be used with stainless steel. Although Teflon tape is allowed in many applications, it should not be used as a sealant or lubricant on threaded instrument connections. The use of compound or lubricant on threads should consider the potential reaction with either the service fluid or the piping material.

M. Sensing lines should be blown clear of any foreign material with clean, oil free, dry air or nitrogen before the system is placed in operation. Demineralized water may be used to flush tubing, provided the process system to which the tubing is connected will also be flushed or hydro-tested with water in accordance with applicable construction procedures. Open lines, fittings or valves should be sealed after being blown clear. Instrument tubing between the manifold valve and the instrument is not required to be blown down or flushed if visual inspection is performed prior to final connection and tightening of fittings.

N. Capillary tubes sealed to the instrument by the manufacturer should not be opened or cut during or after installation unless specifically required by the installation drawing or manufacturer's instruction. Slope requirements do not apply to capillary tubing. Manufacturer's installation requirements, including those relating to minimum bend radius, should be followed. Excess lengths of capillary tubing should be neatly coiled in protected enclosures. The maximum amount of unprotected capillary should be no more than 15 cm (6 inches) at any one location, except at capillary enclosures, process connections, instrument connections, and penetrations. At the entrance and exit of capillary enclosures, process connections and instrument connections, the maximum unprotected capillary should be 45 cm (18 inches). Capillaries in trays should be tied down or clamped every three feet. At the entrance and exit of penetrations, the maximum unprotected capillary should be 30 cm (12 inches).

O. Primary sensing lines at local panels and racks should be neatly arranged with easy access to test, drain, and vent connections, instruments valves, and manifold. Primary tubing between the instrument valve or manifold and the instrument should be arranged in accordance with the vendor's instruction and with adequate flexibility to avoid undue strain to the instruments.

8.0 Instrument Sensing Line Penetrations

A. Penetration closure materials should be considered for the effects on the free movement or restraint of instrument sensing lines. A support should be located within 91 cm (3 feet) of each end of the wall or floor. No supports are required through filled penetrations. All filled penetrations should be considered a 3-directional anchor.

B. Where several instruments have sensing lines that share a common penetration, careful attention should be given to temperature effects. If adverse effects are possible, proper insulation or separate penetrations should be provided.

C. Instrument sensing lines should not be routed with electrical conduit/tray through the same penetration.

9.0 Supports / Anchors / Guides

A. Support intervals for sensing lines should not exceed those shown in the following table.

Outside Diameter	Material	Wall Thickness	Max Unsupported Span Metric
¼″	Stainless & Carbon Steel & Copper	All	91 cm (3 ft.)
3/8″	Stainless & Carbon Steel & Copper	All	1.5 m (5 ft.)
1/2″	Stainless & Carbon Steel & Copper	All	1.5 m (5 ft)
3/4″	Stainless & Carbon Steel & Copper	All	1.8 m (6 ft.)
1″	Stainless & Carbon Steel	All	2.1 m (7 ft.)
Capillary Tubing	Carbon Steel & Copper	All	See Item N, Section 7.0

B. Multi-tube bundles should be supported in accordance with the manufacturer's recommendations.

C. Support structures for sensing lines should not be attached to instruments and should not be supported from or connected to root valves or root nipples.

D. An instrument tray, angle iron, and/or channel should be used to minimize the number of supports required to support sensing lines. These options also provide protection for the sensing lines.

E. Sensing lines should be supported by a combination of 3-directional anchors and 2-directional guides. A dummy tube should be installed in the unused hole of the 3-directional clamps. Clamps and fittings should not be installed within the arc of tubing bends.

F. Anchors, consisting of connections to root valves, instrument valves, or any type of clamp that when fastened to tubing prevents axial movement of the tube, should be placed in each straight run of tubing that requires a support. The connection to the instrument is not considered an anchor point for this purpose.

G. Sensing lines should be supported with guides wherever a longitudinal movement along the line axis is involved due to temperature, vibration, and related ambient conditions. When two or more tubes are attached to a single support, each line should be guided so that it can move axially independent of the others, unless the support is designed specifically as an anchor. It will always be assumed that each tube expands and contracts individually and independent of all others.

H. For portions of a sensing line run which may be subjected to temperatures greater than 60°C, the following limitations apply:

1. Anchors should be used only where the axial movement cannot be controlled easily by other means.
2. Every effort should be made to support vertical runs and to control end movement of horizontal runs by thoughtful placement of guides near turns and offsets

I. All fasteners should be at least snug tight. Bolted Fasteners, as a minimum, should have the end of a bolt to be at least flush with the outer surface of the nut. In the event that vendor instruction, design drawings or specification specify torque requirements, the vendor instruction shall take precedence. The torque values below should be used in the absence of specified values.

Bolt Diameter	**Required Torque**
Less than ¼″	Snug Tight
1/4″	8.8 Nm (78 in lb) ± 0.7 Nm (6 in lbs)
5/16″	20 Nm (15 ft lb) ± 3 Nm (2 ft lb)
3/8″	29 Nm (22 ft lb) ± 4 Nm (5 ft lb)
1/2″	75 Nm (55 ft lb) ± 7 Nm (5 ft lb)
5/8″	81 Nm (60 ft lb) ± 8 Nm (6 ft lb)
3/4″	183 Nm (135 ft lb) ± 14 Nm (10 ft lb)
7/8″	183 Nm (135 ft lb) ± 14 Nm (10 ft lb)

* Nm = Newton Meter

10.0 INSTRUMENTATION VALVES

A. Vent, Drain and Calibration Valves

1. All normally closed valves should be installed with the flow arrow pointing in the direction of flow. For valves in static instrument lines the direction of flow should be considered away from the process tap so that when the valve is closed the pressure will be on the process side.

2. As a minimum, high point vents in liquid service sensing lines should be accessible by means of a portable ladder. Vent and drain valves in systems with normal operating temperatures greater than 49°C (120°F) should be labeled with an appropriate warning tag. Hazardous fluid systems, including cryogenics, should also be labeled with an appropriate warning.
3. All high points in liquid service sensing lines should have a valve vent connection located outside high radiation zones at an accessible elevation (if necessary at elevations accessible by means of a ladder). Vent valves should be located such that they are at the high point of the instrument line.
4. The use of hot blowdown for instrument lines should be avoided. Vents should be used for releasing trapped air, back flushing, or pre-filling of tubing systems. Vents should not be used for blowdowns. Lines subjected to temperatures above 93°C (200°F) should be designed for thermal expansion.
5. All vent and drain valves should be capped, plugged or have short pieces of tubing installed on the downstream side, unless specifically routed to a drain point. All drip legs should be a minimum of 61 cm (24 inches).
6. An accessible calibration connection should be provided between the instrument and its nearest isolation valve. The connection should be easily accessed for in-situ instrument calibration and servicing. This connection may be a vent or drain point provided that isolation from the process is acceptable. All such connections should be capped or plugged when not in use.

B. Root Valves

1. I&C design responsibility should begin at the outlet of the root valve.
2. When a root valve is located in a high radioactive or hazardous area, an accessible isolation valve should be provided.
3. The root valve should be installed clear of main line insulation in a horizontal or vertical orientation as required by specific conditions. Process connections and root valves should be located so that they are accessible.
4. For adapting stainless steel to main line class piping, socket welding should not be performed when the service temperature at a dissimilar weld is greater than 100°C (212°F). The methods of welding dissimilar materials in services above 100°C (212°F) should be provided by the Design Authority.

C. Isolation Valves

1. The instrument isolation valve is defined as the valve nearest the instrument.
2. A higher rated valve may be substituted for a lower rated valve of the same type (i.e., gate, globe, ball, etc).

3. An instrument line with a remote mounted instrument should have at least two valves between the process tap and the instrument. The root valve and instrument isolation valve will suffice, with the instrument isolation valve within reach of the instrument. For rack or panel-mounted instruments, the panel valve located at the panel process tap and the isolation valve located at the bulkhead will suffice. For locally mounted instruments, with the root valve within reach of the instrument, an additional isolation valve is not required.
4. Isolation valves should be located just beyond a penetration on the non-radioactive side of a shield wall. This will allow instrument maintenance during plant operation when the root valve is inaccessible.

D. All instrument valves (manifolds, vents, drains, isolations, etc.) in instrument process and sample tubing installations should be supported and considered a 3-directional anchor.

11.0 INSTRUMENT PANELS, RACKS, ENCLOSURES AND LOCAL MOUNTS

A. Mounting instruments to the supporting structure should be in accordance with design engineering drawings, manufacturer's instruction, and/or details shown on vendor drawings. Deviation from the indicated location should be ±1.5 m (5 ft.) maximum plan and ±30.5 cm (1 ft.) maximum elevation, unless otherwise noted on the drawings.

B. Indoor field fabricated racks should be of open construction with welded steel plates, angles, channels, pipe, and unistrut or equal as illustrated within the appropriate installation detail.

C. Outdoor field fabricated racks should be similar to the indoor racks but with a sheet metal enclosure if required by the instrument installation detail. Type NEMA 3S enclosure may be used for protection of instruments. The instruments should be weatherproof. Instruments requiring heat tracing and/or heated enclosures should be so indicated on P&ID and by the installation detail.

D. Each rack which has more than one electrical instrument may be provided with a terminal box. Interconnection between the terminal box and instrument should be made with rigid steel conduit or seal-tight flexible conduit.

E. Floor mounted racks (not supported by a wall at the top) should be mounted a minimum of 76 cm (2.5 feet) out from a wall, to provide working space during both construction and operation.

F. When conditions require heated enclosures, instruments that must be heated should be in heated housings whose type and design allow for the following factors:

1. Frequency of access
2. Ease of access
3. Availability of space
4. Visibility of instrument
5. Availability of heating medium
6. Explosion hazard

7. Location of heat tracing connections
8. Insulation
9. Weather tightness
10. Weather resistance
11. The desired controlled temperature should be a minimum of 45°F (7°C).

12.0 PRESSURE / FLOW CONSIDERATIONS

A. In pressure measurement, the measuring device should come into direct physical contact with the process. However, special precautions should be taken if the process could potentially damage the device or be detrimental to instrument reliability. Consideration should be given to process temperature and pressure, corrosion, mechanical vibration, and process pressure pulsation. Pulsation dampers, insulation and bleed valves, seals and purges, as well as temperature insulation and heat tracing are options that may be necessary to maintain instrument reliability.

B. For gas service, the sensing lines connecting the pressure instrument to the process should be free of liquid. For liquid and vapor service, the lines should be filled with liquid and void of any pockets of gas.

C. The following is general guidance for differential-pressure instruments.

   1. Differential pressure sensing lines should be checked to make sure that they are connected to the proper sides of the instrument, High Pressure (HP) and Low Pressure (LP).

   1. Differential pressure sensing lines should be run together to the maximum extent practical so as to keep both lines at the same temperature. If they are insulated, they should be insulated together.

   2. The sensing lines for air or gas service should be self-draining so that condensate or impurities cannot accumulate on one side of the differential-pressure instrument.

   3. Differential pressure transmitters that are vented to atmosphere should have the vent connection constructed of solid material without a valve. The openings of vent connections should be in a downward direction to protect against falling particles. An insect screen should be installed at the end of the connection.

D. The following is specific guidance for pressure and differential-pressure instruments in liquid, steam, or vapor service.

   1. The effects of hydrostatic head pressure caused by condensed liquid in the sensing lines should be considered when installing the pressure instrument. Since accessibility may not allow the instrument to be installed directly at the process, most instruments provide a zero adjustment to offset the effect of hydrostatic head pressures.

2. Condensate chambers, also known as seal pots, should be installed to ensure the instrument sensing lines are filled with liquid. Water or other coolants can be applied to the seal pots to speed the condensing process. The pipe from a process connection to a seal pot should be insulated for process fluids hotter than 121°C (250°F).
3. The sensing lines to differential-pressure instruments should be installed to maintain the condensate legs at an equal height. A pair of seal pots should be at the same elevation ±0.6 cm (±1/4 inches) and as high or higher than the highest process connection.
4. A pigtail or wet-leg should be considered to protect an instrument that may be subject to high process temperatures. The pigtail should be located close to the instrument. A wet-leg should have a filling connection, usually at the top.
5. If there is a concern of moisture freezing in the sensing line, a diaphragm seal and low-temperature compatible fill fluid should be considered.

E. Pressure calibration/test points should be accessible. If the root valve is not accessible (accessible defined as not over 1.8 m (6 feet) from floor, grating, or platforms), tubing and an instrument valve should be installed at a convenient remote location.

13.0 LEVEL CONSIDERATIONS

A. For hydrostatic head level measurements, the High Pressure (HP) sensing line should be connected toward the bottom of the vessel but from the side. Connections from the bottom of the vessel are not recommended because of the possibility of trapping of solids in the sensing lines.

B. Differential pressure level instruments should be located at the zero reference point on the vessel, unless a bubble system is used, in which case the instruments may be located at any convenient elevation. Refer to Item C in Section 12.0 for level differential-pressure instruments in steam or vapor service.

C. A stilling well should be used where displacement or float-type elements are located inside a vessel subject to turbulence. A stilling well may be required to protect a bubble tube against excessive turbulence.

D. Level devices should be placed away from areas of turbulence and should not interfere with other vessel parts or instruments, such as thermowells or sample nozzles.

E. Stilling wells and bubble tubes should be firmly supported in accordance with the installation details. If they are to be removable, adequate room should be provided to allow them to be withdrawn.

F. Gauge glasses should be installed adjacent to the vessel and whenever possible, should be visible from a walkway.

G. Process connected level transmitters and indicators should be mounted within ±2.5 cm (±1 inch) of the design elevation. Liquid actuated level switches should be mounted within ±0.6 cm (±1/4 inch) of the design elevation.

14.0 TEMPERATURE CONSIDERATIONS

A. Temperature elements for hazardous fluid applications should be installed in a thermowell unless otherwise shown by the design specification. Temperature elements installed without a thermowell should be identified with a "CAUTION - NO THERMOWELL" tag.

B. The following design aspects should be considered for the location of thermowells:

1. Temperature elements installed in process piping should be located where accessible for servicing, calibration, or replacement, and should not be located where vibration or shock is expected.
2. Adequate space should be provided for the removal of thermocouples, RTDs, thermal bulbs or indicators from their protecting wells.
3. Elements for steam service should be located so that they are not submerged in condensate.
4. Elements for liquid service should be located so that they are submerged.
5. Elements for air and gas service should be located so that they sense the true or average temperature and are not submerged in liquid.
6. Installation of temperature elements into thermowells should be performed per vendor specifications to prevent element damage and ensure proper operation.

15.0 SHIELD WALL PENETRATIONS

A. The following should be considered to avoid radiation streaming from instrument sensing line penetrations in shield walls:

1. All instrument sensing line penetrations should be at a minimum height of 2.5 m (8 feet) above floor level.
2. The tubing penetrations should be skewed toward an inner corner of the operating compartment where possible, avoiding a direct streaming path to the surrounding areas.
3. If neither of the above is practical, the sensing lines penetrating the shield wall should be surrounded by a pipe sleeve with open space between the sensing line and sleeve filled with a suitable radiation absorbing material.

16.0 TESTS AND INSPECTIONS

A. Pressure tests should include the instrument process tubing, instrument valves and fittings up to but excluding the instrument. The instrument connecting tubing should be capped or plugged prior to testing.

B. Instrument tubing may be pressure tested along with the main process piping to which it is connected. Testing of individual instrument tubing systems may also be performed separately if found desirable.

C. Tubing leaks in low-pressure systems may not be detectable through pressure tests. Additional leak tests should be considered for such systems.

D. The instrument impulse tubing should always be tested to the same pressure as the process pipe system unless otherwise noted in the design specification. Test pressures can only be revised/waived by the Design Authority. Instrument air supply tubing should be tested at the same test pressure as the headers test pressure.

E. The following attributes should be either inspected or functionally tested, and documented as appropriate for fabrication and installation. The responsible technical and quality personnel must determine the required detail and oversight that is necessary based on the safety classification of the I&C equipment / system.

1. Verification of documentation from Construction Engineering
2. Sensing Line Protection
3. Sensing Line Slope
4. Drain Connections
5. Connection Lubricant
6. Condensate Pot Elevation
7. Stilling Well Location
8. Mounted Panel & Racks
9. Thermowell Installation
10. Bends in Sample Lines
11. Instrument Location
12. Instrument Orientation
13. Sample Tubing Supports
14. Material Identification
15. Instrument Tubing Supports
16. Panels & Racks Location
17. Blowdown / Flushing
18. Pressure Testing

17.0 CALIBRATION

A. Initial calibrations should be performed in accordance with the Laboratory Calibration Program.

B. As part of the initial calibration, the instrument details (i.e. manufacturer, model number, size, material of construction, range, etc.) should be verified to be in agreement with the design specification.

C. The component under calibration should be subject to input variations at a number of test points ascending and descending to sufficiently verify its response over the full span. The following test points should be used when no other specific direction is given in the applicable procedure or work document.

1. Switches – Trip and reset. Switches for which no reset value is specified or which have fixed dead band, the reset value should be documented on the calibration record for reference.

2. Valves – Full open/Full closed; modulating valves should also be verified at mid-travel (50%)

3. Mechanical and Electrical Indicator and/or Transmitter – at or near (within 10%) 0, 20, 40, 60, 80, and at or near 100% of span or reading increasing and 80, 60, 40, 20 and at or near 0% of span or reading decreasing.