| | | | |
|---|---|---|---|
| PETROBRAS | **TECHNICAL SPECIFICATION** | Nº: I-ET-3010.00-1200-800-P4X-013 | |
| | CLIENT: | | SHEET 1 of 86 |
| | JOB: | | -- |
| | AREA: | | |
| SRGE | TITLE: **GENERAL CRITERIA FOR INSTRUMENTATION PROJECTS** | | INTERNAL |
| | | | ESUP |

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| | REV. 0 | REV. F | REV. G | REV. H | REV. J | REV. K | REV. L | REV. M | REV. N |
|---|---|---|---|---|---|---|---|---|---|
| DATE | DEC/18/18 | OCT/21/20 | NOV/12/20 | APR/19/21 | AGO/09/21 | SEP/13/21 | OCT/18/21 | SEP/30/22 | DEC/02/22 |
| DESIGN | ESUP | ESUP | ESUP | ESUP | ESUP | ESUP | ESUP | ESUP | ESUP |
| EXECUTION | CAMILA | CAMILA | CAMILA | CTTD | U5D6 | U44D | U44D | EHTF | U44D |
| CHECK | ANDRÉ LUIS | ANDRÉ LUIS | ANDRÉ LUIS | U49R | U4KE | U49R | U49R | U5D6 | U5D6 |
| APPROVAL | PEDRO | ANDREAZC | ANDREAZC | U4JB | U49R | U4JB | U4JB | CDC1 | CDC1 |

# SUMMARY

# 1 INTRODUCTION

## 1.1 Object

1.1.1 This specification comprises the minimum general requirements for instruments' specifications, applicable in Instrumentation projects in E&P Production Units.

1.1.2 The materials here specified are understood as the minimum required and materials with inferior characteristics shall not be accepted. If operational conditions are more severe, materials with mechanical or chemical characteristics that comply with these conditions shall be selected.

1.1.3 This specification includes only the most common instruments used. Other instruments not covered within this document shall be submitted to PETROBRAS for analysis.

## 1.2 About Interdisciplinary Interfaces, Materials Terminology and Numbering of listed items

1.2.1 The application of this document demands interactions among several disciplines and creating interfaces which are inherent to a production plant. Interfaces can exist in any item of this technical specification. However, where interfaces have been identified, the term **[INTERDISCIPLINARY INTERFACE]** is used, followed by the abbreviations of the disciplines that interact with I&A and can also interact between them. Since all indicated interfaces have interactions with I&A discipline its abbreviation is not indicated. Below is a list of all possible discipline abbreviations:

.#1) ARC: Architecture;

.#2) ARR: Arrangement;

.#3) COM: Commissioning;

.#4) ELE: Electrical;

.#5) HSE: Health, Safety and Environment;

.#6) HVAC: Heating, Ventilation and Air-conditioning

.#7) I&A: Instrumentation & Automation;

.#8) MEC: Mechanical;

.#9) NAV: Naval Architecture;

.#10) PIP: Piping;

.#11) PRO: Process;

.#12) SNAV: Marine Systems;

.#13) STR: Structure;

.#14) TBM: Turbo Machinery;

.#15) 3D: Project Automation and 3D Modeling.

1.2.2 For use within this document, the following terminology is applied:

.#1) Stainless steel AISI 304 refers to UNS S30400;

.#2) Stainless steel AISI 316 refers to UNS S31600;

.#3) Stainless steel AISI 316L refers to UNS S31603;

.#4) Stainless steel 316/316L dual certified (IOGP JIP33 S 563) means a material that has the same composition of stainless steel AISI 316L (UNS S31603) and mechanical resistance of Stainless steel AISI 316 (UNS S31600);

.#5) Stainless steel AISI 410 refers to UNS S41000;

.#6) Stainless steel AISI 416 refers to UNS S41600;

.#7) Stainless steel AISI 420 refers to UNS S42000;

.#8) Stainless steel 6Mo refers to UNS S3125.

1.2.3 When a requirement itemizes several items as a list, each subheading will be identified with the symbol ".#" followed by an integer starting with 1. When a reference is made to a specific subheading, it is done through a composition of the item number with the subheading. Below is given a fictitious example, that is, unrelated to the numbering of this document:

13.2.1 Lorem ipsum dolor sit amet:
.#1) Ut enim ad minim veniam;
.#2) Duis aute irure dolor in reprehenderit;
.#3) Excepteur sint occaecat cupidatat non provident.

Reference to the second subheading: 13.2.1.#2)

Therefore, a reference to second subheading of item 13.2.1 would be 13.2.1.#2), which differs from a reference to a possible item 13.2.1.2.

# 2 GENERAL

## 2.1 Definitions

VENDOR System or equipment supplier.

2.1.1 Refer to I-ET-3010.00-1200-940-P4X-002 – GENERAL TECHNICAL TERMS for the definition of words emphasized in upper case along this document.

## 2.2 Abbreviations, Acronyms and Initialisms

| | |
|---|---|
| ADV | Automatic Deluge Valve |
| AISI | American Iron and Steel Institute |
| ANP | *Agência Nacional do Petróleo, Gás Natural e Biocombustíveis* (The Brazilian National Agency of Petroleum, Natural Gas and Biofuels) |
| API | American Petroleum Institute |
| ASTM | American Society for Testing and Materials |

| | |
|---|---|
| BDV | Blowdown Valves |
| CJC | Cold Junction Compensation |
| CSS | Control and Safety System |
| DIN | German Institute for Standardization *(German: Deutsches Institut für Normung)* |
| ED | External Diameter |
| EMC | Electromagnetic Compatibility |
| EMI | Electromagnetic Interference |
| EN | European Norms |
| ESD | Emergency Shutdown |
| FS | Full Scale |
| HART | Highway Addressable Remote Transducer Protocol |
| ID | Internal Diameter |
| IEC | International Electrotechnical Commission |
| ILC | Interlock Control |
| INMETRO | *Instituto Nacional de Metrologia, Qualidade e Tecnologia* (The Brazilian National Institute of Metrology, Quality and Technology) |
| MCP | Manual Call Point |
| ND | Nominal Diameter |
| OD | Outside Diameter |
| PC | Personal Computer |
| RFI | Radio Frequency Interference |
| RP | Recommended Practice |
| RTD | Resistance Temperature Detector |
| SDV | Shutdown Valves |
| SI | International System of Units |
| SPDT | Single Pole - Double Throw |
| TP | Type |
| TW | Thermowell |
| VSL | Valve Specification Level |

# 3 REFERENCE DOCUMENTS, CODES AND STANDARDS

## 3.1 External references

3.1.1 International Codes, Recommended Practices and Standards

**IEC - INTERNATIONAL ELECTROTECHNICAL COMMISSION**

| | | |
|---|---|---|
| IEC | 60529 | DEGREES OF PROTECTION PROVIDED BY ENCLOSURES (IP CODE) |
| IEC | 60533 | ELECTRICAL AND ELECTRONIC INSTALLATIONS IN SHIPS - ELECTROMAGNETIC COMPATIBILITY (EMC) – SHIPS WITH A METALLIC HULL |
| IEC | 61000 | ELECTROMAGNETIC COMPATIBILITY (EMC) SERIES - ALL PARTS |

| | | |
|---|---|---|
| IEC | 60079 | EXPLOSIVE ATMOSPHERES |
| IEC | 60092 | ELECTRICAL INSTALLATIONS IN SHIPS |
| IEC | 60534 | INDUSTRIAL PROCESS CONTROL VALVES |
| IEC | 60584 | THERMOCOUPLES |
| IEC | 60331-11 | TESTS FOR ELECTRIC CABLES UNDER FIRE CONDITIONS - CIRCUIT INTEGRITY - PART 11: APPARATUS - FIRE ALONE AT A FLAME TEMPERATURE OF AT LEAST 750ºC |
| IEC | 60331-21 | TESTS FOR ELECTRIC CABLES UNDER FIRE CONDITIONS - CIRCUIT INTEGRITY - PART 21: PROCEDURES AND REQUIREMENTS - CABLES OF RATED VOLTAGE UP TO AND INCLUDING 0,6/1,0 KV |
| IEC | 60332 | FLAME-RETARDANT CHARACTERISTICS OF ELECTRIC CABLES |
| IEC | 60751 | INDUSTRIAL PLATINUM RESISTANCE THERMOMETERS AND PLATINUM TEMPERATURE SENSORS |
| IEC | 61892 | MOBILE AND FIXED OFFSHORE UNITS – ELECTRICAL INSTALLATIONS |

**ISO - INTERNATIONAL ORGANIZATION FOR STANDARDIZATION**

| | | |
|---|---|---|
| ISO | 2715 | LIQUID HYDROCARBONS - VOLUMETRIC MEASUREMENT BY TURBINE FLOWMETER |
| ISO | 5167-1 | MEASUREMENT OF FLUID FLOW BY MEANS OF PRESSURE DIFFERENTIAL DEVICES INSERTED IN CIRCULAR CROSS-SECTION CONDUITS RUNNING FULL - PART 1: GENERAL PRINCIPLES AND REQUIREMENTS - SECOND EDITION |
| ISO | 8573-1 | COMPRESSED AIR - PART 1: CONTAMINANTS AND PURITY CLASSES |

**API – AMERICAN PETROLEUM INSTITUTE**

| | | |
|---|---|---|
| API | STD 520 PT I | SIZING, SELECTION, AND INSTALLATION OF PRESSURE-RELIEVING DEVICES PART I-SIZING AND SELECTION - NINTH EDITION |
| API | STD 527 | SEAT TIGHTNESS OF PRESSURE RELIEF VALVES |
| API | RP 551 | PROCESS MEASUREMENT |
| API | RP 578 | GUIDELINES FOR A MATERIAL VERIFICATION PROGRAM (MVP) FOR NEW AND EXISTING ASSETS |
| API | STD 2000 | VENTING ATMOSPHERIC AND LOW-PRESSURE STORAGE TANKS |
| API | MPMS 4.2. | MANUAL OF PETROLEUM MEASUREMENT STANDARDS |

**DIN – DEUTSCHES INSTITUT FÜR NORMUNG**

| | | |
|---|---|---|
| DIN | 43760 | MEASUREMENT AND CONTROL; ELECTRICAL TEMPERATURE SENSORS; REFERENCES-TABLES FOR NICKEL RESISTORS FOR RESISTANCE THERMOMETERS |
| DIN | EN 13190 | DIAL THERMOMETERS |

**AGA – AMERICAN GAS ASSOCIATION**

| | | |
|---|---|---|
| AGA | REPORT NUMBER 7 | MEASUREMENT OF NATURAL GAS BY TURBINE METERS (2006) |

**ASME – AMERICAN SOCIETY OF MECHANICAL ENGINEERS**

| | | |
|---|---|---|
| ASME | PTC 19.3 TW | THERMOWELLS PERFORMANCE TEST CODES |
| ASME | B16.10 | FACE-TO-FACE AND END-TO-END DIMENSIONS OF VALVES |
| ASME | B40.100 | PRESSURE GAUGES AND GAUGE ATTACHMENTS |
| ASME | Section VIII, Division 1 | RULES FOR CONSTRUCTION OF PRESSURE VESSELS |

**VDI – VEREIN DEUTSCHER INGENIEURE**

| | |
|---|---|
| VDI / VDE 3513 BLATT 1 | VARIABLE-AREA FLOWMETERS - CALCULATION METHODS |

**ISA – INTERNATIONAL SOCIETY OF AUTOMATION**

| | |
|---|---|
| 75.01.01 | INDUSTRIAL-PROCESS CONTROL VALVES |

3.1.2 Brazilian Codes and Standards

**INMETRO – INSTITUTO NACIONAL DE METROLOGIA, QUALIDADE E TECNOLOGIA** (The Brazilian National Institute of Metrology, Quality and Technology)

| | |
|---|---|
| PORTARIA Nº 115 (21/MAR/2022) | REGULAMENTO DE AVALIAÇÃO DA CONFORMIDADE PARA EQUIPAMENTOS ELÉTRICOS PARA ATMOSFERAS EXPLOSIVAS, NAS CONDIÇÕES DE GASES E VAPORES INFLAMÁVEIS E POEIRAS COMBUSTÍVEIS. |

3.1.2.1 All SIT – *Secretaria de Inspeção do Trabalho* Regulatory Standards (NRs) shall be followed.

### 3.1.3 Classification Society

3.1.3.1 Detail design phase documentation of the project shall be submitted to approval by Classification Society. The design and installation shall take into account their requirements and comments.

3.1.3.2 The design, installation and operation shall strictly follow the classification society requirements, along with the specific requirements identified in this document, including also all referenced documents' requirements.

## 3.2 Internal References

### 3.2.1 Typical Documents

3.2.1.1 Typical Documents are those that contain functional and technical description of a system or equipment. They shall be used as the main specification to be used in the context of Project itself.

3.2.1.2 Typical Document List

| | |
|---|---|
| I-ET-3010.00-1200-940-P4X-002 | GENERAL TECHNICAL TERMS |
| I-ET-3010.00-1200-813-P4X-001 | GENERAL CRITERIA FOR FLOW METERING SYSTEMS |
| I-ET-3010.00-1200-956-P4X-002 | GENERAL PAINTING |
| I-ET-3000.00-5139-800-PEK-004 | HYDRAULIC POWER UNIT FOR SUBSEA EQUIPMENT WITH MULTIPLEXED ELECTROHYDRAULIC AND DIRECT HYDRAULIC CONTROL SYSTEM (OWN FLOATING PRODUCTION UNIT) |
| I-ET-3010.00-5139-390-P4X-001 | HYDRAULIC POWER UNIT (HPU) FOR TOPSIDES VALVES |

### 3.2.2 Specific Project Documents

3.2.2.1 This section specifies documents that are referenced along the test and are part of a specific project. For that reason, the documents identification number is not yet defined and may vary according to project. The documents title may also vary slightly from one project to another. Projects DOCUMENT LIST shall be consulted in order to verify the correct document number and title.

3.2.2.2 Specific Project Document List

PIPING SPECIFICATION

METOCEAN DATA ACQUISITION SYSTEM

GENERAL NOTES

SAFETY DATASHEET

3.2.3 PETROBRAS Reference Documents

| | |
|---|---|
| DR-ENGP-M-I-1.3 | SAFETY ENGINEERING GUIDELINE |
| DR-ENGP-I-1.15 | COLOR CODING |

### 3.3 Order of precedence

3.3.1 Brazilian regulatory standards (SIT section) and INMETRO regulations shall be followed, since they are enforced by Brazilian law. In cases where regulations listed in item 3.2 are more restrictive and comply with Brazilian regulatory standards, the internal references listed in item 3.2 shall be adopted.

### 3.4 Units

3.4.1 In accordance with the International System of Units, the following units shall be used for the main variables.

*Table 3.4-I – Units to be adopted*

| Quantity | | Unit | Notes |
|---|---|---|---|
| Temperature | | °C | |
| Flow | Liquid | $m^3/h$ | |
| | Water Vapor | t/h | |
| | Gas | $m^3/h$ (20 °C and 101.325 kPa) | |
| Pressure | | bar or kPa | Pressure measurements refer to manometric pressure, except where clearly specified. |
| Vacuum | | bar abs or kPa abs | |
| Level | | % of range, m or mm | |

## 4 TRANSMISSION AND CONTROL SIGNALS

### 4.1 Pneumatic Instrumentation

4.1.1 Pneumatic instrumentation range shall be 20 to 100 kPag (0.2 to 1.0 barg). For control valves, if necessary, 40 to 200 kPag (0.4 to 2.0 barg) range shall also be accepted.

### 4.2 Electronic Instrumentation

4.2.1 4 to 20 mA, with addition of digital communication using HART protocol, certified by HART FOUNDATION.

4.2.2 Exceptions: specific signals, such as: RTD (thermoresistance), thermocouple, opticals, etc. are exceptions which may be used, but shall be submitted to PETROBRAS approval.

### 4.3 Communication Network Signals

4.3.1 Networking cables shall have exclusive routing with proper protection against mechanical damage. They shall be placed in enclosed trays or in another way that allows the cable to be inspected without its removal. The minimum separation distance for power cables shall be observed, as recommended in communication protocol used.

## 5 POWER SUPPLY SYSTEMS

### 5.1 Pneumatic system

5.1.1 Quality of Compressed Air for Instrumentation

5.1.1.1 Instrument air shall be in accordance with requirements of standard ISO 8573-1 (Quality Standard for Instrument Air) for particle purity class 3. **[INTERDISCIPLINARY INTERFACE][MEC]**

5.1.1.2 The dew point temperature shall be the most restrictive among class 4 of ISO 8573-1 or be 10 °C (10 K) below the lowest ambient temperature defined in project's Metocean data document. This temperature is described as Absolute Minimum in the Metocean document. The tests shall be carried out in compliance with ISO 8573-3. **[INTERDISCIPLINARY INTERFACE][MEC]**

5.1.1.2.1 For the Commissioning phase, the documents of this discipline shall be consulted, because the temperatures of the place where the tests will be performed can be much lower than the ambient temperature of the final location mentioned in item 5.1.1.2. **[INTERDISCIPLINARY INTERFACE][COM]**

5.1.1.3 The purity class for total oil shall be class 3 according to ISO 8573-1. **[INTERDISCIPLINARY INTERFACE][MEC]**

5.1.1.4 For consumers that requires more stringent specifications stablished in items 5.1.1.1, 5.1.1.2 and 5.1.1.3, local filtering shall be provided upstream respective consumer with saturation signaling and that filters refills can be replaced without interrupting operation.

5.1.1.5 For more information on Metocean Data Acquisition System, see technical specification document of the project entitled METOCEAN DATA ACQUISITION SYSTEM.

5.1.2 Operating Conditions

5.1.2.1 Operating conditions shall be defined by Basic Project. Components directly submitted to air distribution pressure shall be dimensioned to work throughout all operational range. Example: air reservoirs defined in item 14.1.3.1 shall be dimensioned for minimum pressure and support the maximum pressure. On Table 5.1 I are presented typical operation reference values and values to be adopted shall be obtained from Project documentation of the unit.

*Table 5.1-I – Operating Conditions.*

| VARIABLE | CONDITION | VALUE |
|---|---|---|
| **Pressure** | Maximum | Higher value between 1,027 kPa (10.27 bar) and accumulated pressure of accumulator vessel of instrument air compressor system. |
| | Minimum | 485 kPa (4.85 bar) |
| **Temperature** | Maximum | 50 °C |
| | Normal | 40 °C |

5.1.3 Instrument Air Consumption

5.1.3.1 The correct sizing of instrument air compression system capacity shall be based on air consumption calculation according to data given by MANUFACTURERS and is elaborated by Process discipline. Equipment from other disciplines also consume instrument air from the same system. For example, pressurization of electrical motors, from Electrical discipline, and bearing seals of compressors, from Turbomachinery discipline. The relative consumption of equipment from other disciplines shall be obtained from each discipline. **[INTERDISCIPLINARY INTERFACE][PRO, SNAV, HVAC, ELE, TBM]**

5.1.3.2 In case of lack of data from the MANUFACTURER, the estimation of instrument air consumption shall be done considering the consumption of all instruments (of continuous operation) operating simultaneously, plus the consumption of instruments/devices of intermittent operation, according to the criteria stablish below:

.#1) Continuous Consumers

The average consumption of continuous operation instruments can be observed on Table 5.1-II.

*Table 5.1-II – Continuous Consumers of Instrument Air.*

| INSTRUMENT | AVERAGE CONSUMPTION ($Nm^3/h$) |
|---|---|
| Control Valve with Position Indicator | 2 |
| Modulated *Damper* with Position Indicator | 2 |
| *Booster* Relays | 2 |
| Analyzers | According to MANUFACTURER |
| Pressurized Panels | According to MANUFACTURER |

For other instruments, when precise data is not available, a consumption of 1.6 $Nm^3/h$ shall be adopted.

.#2) Intermittent Consumers

The consumption of Shutdown Valves (SDV), Blowdown Valves (BDV) and fire dampers shall not be considered in calculation, since in normal operating conditions the frequency of events that require their actuation (ESDs) is very low.

For air consumption of pneumatic pumps located in safety panels or in well control racks (production and/or injection) and hydraulic units, needed to pressurize hydraulic lines for actuating valves of Christmas Trees, the average consumption shall be adopted, and it cannot be less than 10 $Nm^3/h$. However, the instantaneous consumption shall be used for sizing the pneumatic power lines of pumps.

5.1.3.3 To the consumption provided by the sum of continuous and intermittent consumers it shall be added an extra capacity of 43% of the calculated consumption, which contemplates future expansions of the plant (30%) and a reserve to compensate purge from various instruments and possible leakage in air distribution system (10%).

5.1.4 Distribution of Air Supply

5.1.4.1 For each area, skid or PACKAGE UNIT, one air distribution manifold shall be provided, equipped with a condensate vessel with drain and block valves (AISI 316 stainless steel, ball type) at the inlet, near the manifold, and a block valve (AISI 316 stainless steel, ball type) on each outlet. A local pressure indicator (with drain and block valves) between the manifold and its inlet block valve shall also be supplied and installed.

5.1.4.2 The main distribution line of instrument air supply shall be divided into branches, per area/floor, equipped with locked open block valves (AISI 316 stainless steel, ball type). The piping branches shall be made on the top of the main distribution lines, to reduce risk of water arrest to branches.

5.1.4.3 In addition to the block valve installed at the air manifold outlet as per item 5.1.4.1, one another ball or needle valve should be installed near each consumer instrument, AISI 316 stainless steel made.

The additional block valve from item 5.1.4.3 can be dispensed in the situations below:

# HVAC System.
# Tubing length less than 6 meter and in the same deck or level of air manifold.

5.1.5 Use of natural gas as pneumatic fluid

5.1.5.1 This alternative may only be adopted in uninhabited and open areas, and it is subject to prior approval by the involved ASSET/Business Unit. In such cases, natural gas shall be conditioned, and solid residues shall be removed.

5.1.5.2 Alternation of fluid power between gas and instrument air is not acceptable.

5.1.5.3 Gas-supplied control lines shall not be accepted inside the control rooms.

### 5.2 Electrical System

5.2.1 Instruments shall be specified to operate in rated voltage of 24Vdc from (provided by) automation system panels and shall be in accordance with the established limits for powering systems in continuous current determined by IEC-61892-1.

5.2.1.1 PACKAGE UNITS and skids shall provide a calculation report to establish the minimum voltage necessary on the interface (minimum voltage to be supplied by UNIT to PACKAGE UNIT/skid) so that the minimum voltage required by its instruments is guaranteed.

## 6 GENERAL REQUIREMENTS FOR INSTRUMENTATION SPECIFICATION

This chapter describes requirements that shall be applied to all instruments. Instruments shall be in accordance with API RP 551. Instruments to which the metrological standards of INMETRO and the official regulation apply (Brazilian legislation and National Agency of Petroleum, Natural Gas and Biofuels - ANP) shall also be in accordance with the requirements described in I-ET-3010.00-1200-813-P4X-001 – GENERAL CRITERIA FOR FLOW METERING SYSTEMS**.**

### 6.1 Identification

6.1.1 An AISI 316 stainless steel identification plate with at least, the following information shall be permanently attached to the instrument:

.#1) Ex Certificate, gas group and temperature class, according to IEC 60079;

.#2) IP Certificate, according to IEC 60529. If IP68 is defined, the maximum depth shall be explicitly stated on the certificate;

.#3) Laboratory (who issued the certificate) and certificate numbers;

.#4) Serial number, model, and MANUFACTURER.

6.1.2 Besides the identification plate described in item 6.1.1, a stainless steel plate with a minimum size of 50 mm x 20 mm x 0.5 mm (Width x Height x Thickness) shall be provided with instrument respective TAG engraved in low relief with letters at least 3 mm high. This plate shall have rounded corners and the perimeter shall be smoothly finished so that it does not present a risk of laceration when handled. This plate shall be attached to the instrument by means of a flexible AISI 316 stainless steel wire with minimum wire gauge of 1 $mm^2$ (18 AWG).

### 6.2 Degree of Protection against Dust and Water ingress

6.2.1 The enclosure of instruments shall be resistant to weather conditions produced by the process and maritime environment. All instruments and their respective accessories installed in areas that are not sheltered or that are exposed to weather shall have, as a minimum, degree of protection IP56 in accordance with IEC 60529.

**Note:** An enclosure with only one degree of protection certification with the second characteristic numeral being 7 or 8 shall not be accepted in replacement of IP56 or IP66, unless it has a double certification (examples: IPX6 /IPX7 and IPX6 / IPX8, where X represents the first digit of the IP rating).

6.2.2 All equipment and instruments to be installed below the damage waterline, at places such as ballast pump rooms, tunnels, and trunks, shall have degree of protection specified on the following sub-items:

6.2.2.1 Double classified as at least IP66 / IP67, i.e. they shall be tested for IP66 and IP67.

**Note:** An enclosure that has only one (1) degree of protection with the second characteristic numeral 7 or 8 cannot be considered suitable for exposure to water jets, as recommended by IEC 60529. In order for the instrument to be suitable for both water jets and submersion, it shall be subjected to both water jets and submersion tests, thus being double-certified (e.g.: IPX6 / IPX7 and IPX6 / IPX8, where X stands for the first digit of the IP rating).

6.2.2.1.1 When installed inside the tanks they shall be IP68 certified and be resistant to at least 4 meters of water column during at least 30 minutes.

6.2.2.1.2 Display instruments such as ballast/sewage valve position indicators, position indicators for waterproof doors and hatches, position indicators for seawater tank valves, overboard valves, vent dampers and solenoid valves, installed inside or outside of tanks, shall meet degree of protection IP66 /IP68 requirements and be specified to withstand a minimum pressure equivalent to 4 meters of water column during at least 30 minutes.

6.2.3 Cable glands, junction boxes, passage boxes and accessories used for the aforementioned applications shall meet the same degree of protection requirements.

6.2.3.1 All cable glands used in classified areas and in non-sheltered areas shall be specified in order to reduce the effects of the cold-flow characteristic of the cables in accordance with IEC 60079-14, regardless of cable and multicable characteristics.

## 6.3 Materials

6.3.1 The material of cable glands shall be AISI 316 stainless steel.

6.3.1.1 For indoor areas, electroless nickel plated brass cable gland at least 10 microns of plating thickness is acceptable

6.3.1.2 For outdoor areas, electroless nickel plated brass gland at least 10 microns of plating thickness is acceptable unless there is no dissimilar material to avoid dissimilar metal corrosion (cable gland with cable armored or cable gland with equipment). For outdoor areas, the nickel-plated brass gland shall be covered by cable grand shoulder.

6.3.1.3 Aluminium cable gland is not allowed.

6.3.2 Boxes or enclosures of electronic field instruments shall be made of ASTM A351 Gr. CF8M stainless steel.

6.3.3 Protective measures shall be provided to avoid direct contact between metals where galvanic corrosion is expected. Painting alone is not considered a sufficient protective measure to avoid direct contact between the metals.

6.3.4 Paint specifications shall follow the color coding requirements of I-ET-3010.00-1200-956-P4X-002 - GENERAL PAINTING and DR-ENGP-I-1.15 - COLOR CODING.

## 6.4 Requirements for classified areas and unsheltered areas

6.4.1 All electrical / electronic instruments and equipment located in classified areas or unsheltered area shall comply and be installed in accordance with IEC 60079 and IEC 61892-7.

6.4.2 All instruments that operate with electric power (transmitters, analyzers, switches, valve positioners and solenoids, fire detectors, gas detectors, sight gas detector beam emitters, manual call points - MCPs etc.) shall be certified to operate in zone 2.

6.4.2.1 The type of protection to be used is Ex dc IIA T3 in open area and zone 2 and Ex db IIA T3 when installed in zone 1. The cases where another type of protection is acceptable are:

.#1) Manual call points, MCP;

.#2) Instruments installed in zone 0 (zero) shall have Ex ia IIA T3 certification. Other types of protection with EPL Ga are not accepted.

.#3) For analyzers, where the only available technology is pressurized type, an air reservoir, adjacent and exclusive to the analyzer, shall be provided. It shall allow a minimum autonomy equal to the operating time of the CSS equipment defined in DR-ENGP-M-I-1.3 – SAFETY ENGINEERING If the protection type used is for zone 1, Ex pX, all circuits (DC power, AC power, discrete signal, analog signal etc.) shall pass through the disconnecting device. **[INTERDISCIPLINARY INTERFACE][PRO, MEC, HSE]**

.#4) Protection type increased safety, Ex e, for junction boxes.

**NOTE:** Any other type of protection shall be submitted to PETROBRAS for evaluation.

6.4.2.2 The respective junction boxes shall be certified according to the zone in which they are installed and in open area the minimum certification must be for zone 2, even if the area is not classified. The minimum degree of protection shall be IP56.

6.4.2.3 For intrinsically safe circuits shall be used galvanic isolation barrier, where its functionality is ratified in item 18.2.3.

6.4.3 INMETRO "Certificates of Compliance" to prove compliance with the area classification shall be provided during the technical assessment phase, in accordance with INMETRO PORTARIA Nº 115 and its amendments, or that which is in force. Technical proposals without this documentation shall not be considered.

6.4.4 As required in IEC 60079-25, a descriptive memorandum shall be issued to demonstrate that the required safety level for intrinsically safe circuits was achieved. This description shall be a chapter in the Grounding and EMC descriptive memorandum required in the item 18.1.2.

## 6.5 Electrical and electronic characteristics, connections and general installation requirements

6.5.1 All process connections shall have an isolation valve (root valve), according to the technical specification document of the project entitled PIPING SPECIFICATION. Requirement not applicable for temperature measurement when using thermowell. **[INTERDISCIPLINARY INTERFACE][PRO, HSE, MEC, PIP, TBM, SNAV]**

6.5.1.1 Means shall be provided to depressurize and drain the section between the block valve (root valve) and the instrument. In measurements using impulse lines, this shall be done through:

.#1) 5-way manifold block (2 blockings, 2 drains and 1 equalization valves) when the measurement uses 2 impulse taps;

.#2) 2-way manifold block (1 blocking and 1 drain) where the measurement uses 1 impulse tap;

.#3) flushing ring in measurements using diaphragm seal, as defined in item 6.5.9.

6.5.2 For instruments, the use of single or double block valves with drain and vent and bypass valves shall be defined by a study conducted by the Safety disciplines and those involved with the Process in question, to define their need and type when starting, stopping and maintenance of the instrument. **[INTERDISCIPLINARY INTERFACE][PRO, HSE, MEC, PIP, TBM, SNAV]**

6.5.3 Ball valves, even with diameters of less than 2 inches, shall have body construction held by body fasteners, never threaded.

6.5.4 Instruments shall not be mounted on handrails and shall not be subjected to vibration beyond the limits specified for the instrument.

6.5.5 Instruments, other than manometers, thermometers, level gauges and in-line instruments, shall be installed on dedicated support and for temperature transmitters the item 7.5.1 and subitems shall be followed. **[INTERDISCIPLINARY INTERFACE][MEC, PIP]**

6.5.6 Instruments, its accessories and electrical, utility or process connections shall not be installed where would be under influence of heated surfaces or where would be under influence of vibration of equipment/piping/process connection. Where the location of installation is aggressive to the point that temperature and/or vibration degrades instrument performance after implemented items 6.5.5 and 7.5.1.1, it shall be demonstrated through a memory calculation that the installation does not propagate heat and vibration in levels that exceed instrument specifications. It shall be followed Chapter 19 which have additional requirements regarding aforementioned subject. **[INTERDISCIPLINARY INTERFACE][MEC, PIP]**

6.5.7 The capillary routing of remote seals shall be designed prior to definition of its length. The effective length of the capillary shall be determined applying a factor over the capillary routing of at least 1.1 to account for the irregular path of capillary, effect like cable snaking. Over this, it shall be added the length of 2 loops with a radius twice the minimum allowable bend for the capillary, one to be done at the instrument and one at the remote diaphragm seal, totalizing the capillary designed length. The effective capillary length shall be an off-the-shelf size, being the exact size of capillary designed length or the first length greater than the designed capillary length. **[INTERDISCIPLINARY INTERFACE][MEC, ARR, ARC, 3D]**

6.5.7.1 For differential pressure transmitters with remote seal, used for differential pressure, level measurements or other, the capillaries for high and low pressures shall have the same length and the diaphragm seals shall have the same diameter.

6.5.7.2 The capillary shall be protected in its entire routing by covered tray, tied every 2.5 m by metal tape coated with polymeric material. The capillary support shall be designed in such a way as to minimize mechanical stresses in the welding of the capillary with its flange.

6.5.8 Instrument flanges and respective accessories, such as diaphragm seal flanges and flanges of thermowells, shall be compatible with respective spec of pipe/equipment where instrument will be installed. As an example, an instrument flange in stainless steel AISI 316L connected to pipe/equipment with a carbon steel flange it shall be verified if the flange material of instrumentation scope is suitable to the conditions of both design pressure and design temperature of pipe/equipment flange. If instrumentation flange is still not suitable, another material shall be determined that is suitable to piping/equipment conditions. **[INTERDISCIPLINARY INTERFACE][MEC, PRO, SNAV, TBM, TUB]**

6.5.9 For any flanged process connection in which the instrument is connected through a diaphragm seal, a flushing ring shall be provided to allow cleaning and reduce maintenance time. Flushing ring shall be supplied with vent and drain valves as defined in chapter 19. The material of the flushing ring and aforementioned valves shall be AISI 316 stainless steel, stainless steel 316/316L dual certified (IOGP-JIP33 S-563) or a more exotic material suitable to process conditions.

6.5.9.1 When measuring differential pressure, an arrangement with tubing and 2-valve manifolds shall be provided to allow pressure equalization between the taps and drain/vent for each tap. A 2-valve manifold connected to each flushing ring shall be connected to each tap. In the flushing ring the connections shall be in the 12 o'clock and 6 o' clock positions.

6.5.9.2 When using differential pressure level measurements, an arrangement with tubing and block valves shall be provided to allow pressure equalization between the high pressure (lower) and the low pressure (upper) process taps. On each flushing ring a valve shall be installed in the 12 o'clock and 6 o' clock positions. The 6 o'clock valve of low pressure flushing ring shall be connected with tubing to the 12 o'clock valve of high pressure flushing ring. The 6 o'clock valve of low pressure flushing ring will work as vent and the 6 o'clock valve of high pressure flushing ring will work as drain valve.

6.5.10 For any flanged process connection in which an impulse line is used, a flange adapter shall be provided to make the transition between the flange of the process tap and the flange of the impulse tap. This flange adapter shall be made of AISI 316 stainless steel or stainless steel 316/316L dual certified (IOGP-JIP33 S-563). Other exotic materials shall be used if required by process conditions. **[INTERDISCIPLINARY INTERFACE][PRO, SNAV]**

6.5.11 All circuit boards with electrical / electronic components shall be marinized and tropicalized for proper protection from the application of the atmosphere to and from the fungal attack. VENDOR shall explain in its proposal the methods of marinization and tropicalization used and provide the applicable standards and procedures.

6.5.12 All electronic instruments and equipment shall be immune to electromagnetic and radio frequency interference (EMI / RFI). VENDOR shall state the level of immunity, test procedure and standards used.

6.5.13 Figure 6.5-I through Figure 6.5-III illustrate the definitions used in this document regarding process connections.

6.5.13.1 Using impulse lines

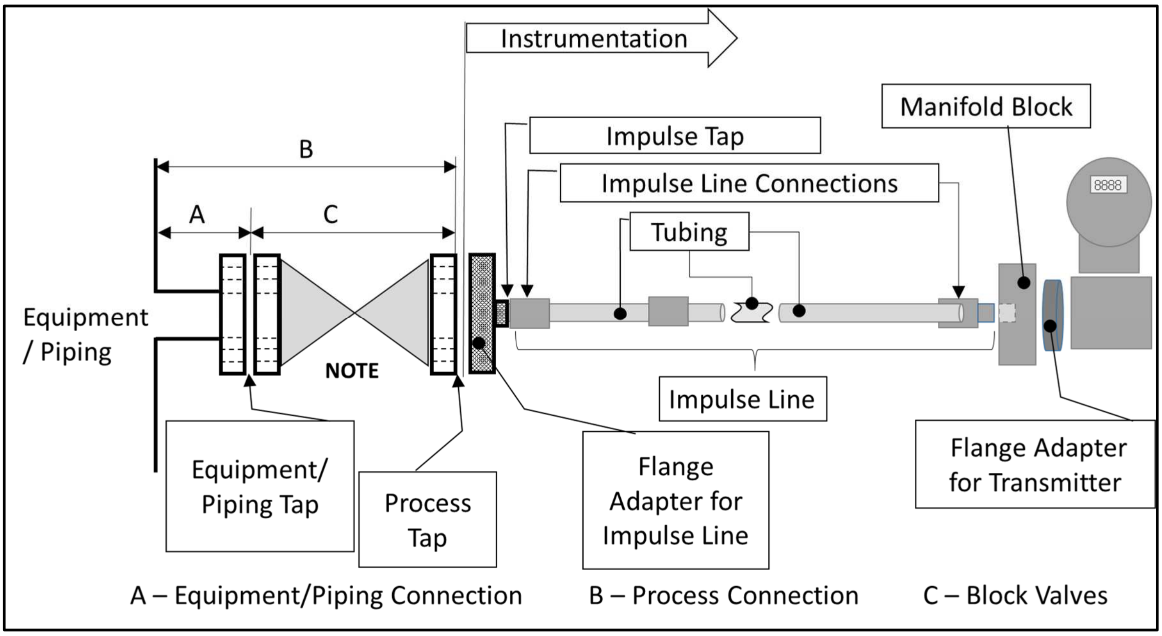

*Figure 6.5-I - Nomenclature for instrument mounting with impulse lines.*

**Note:** The use of single or double blockage shall be done according to item 6.5.2.

6.5.13.2 Using Remote Diaphragm Seal

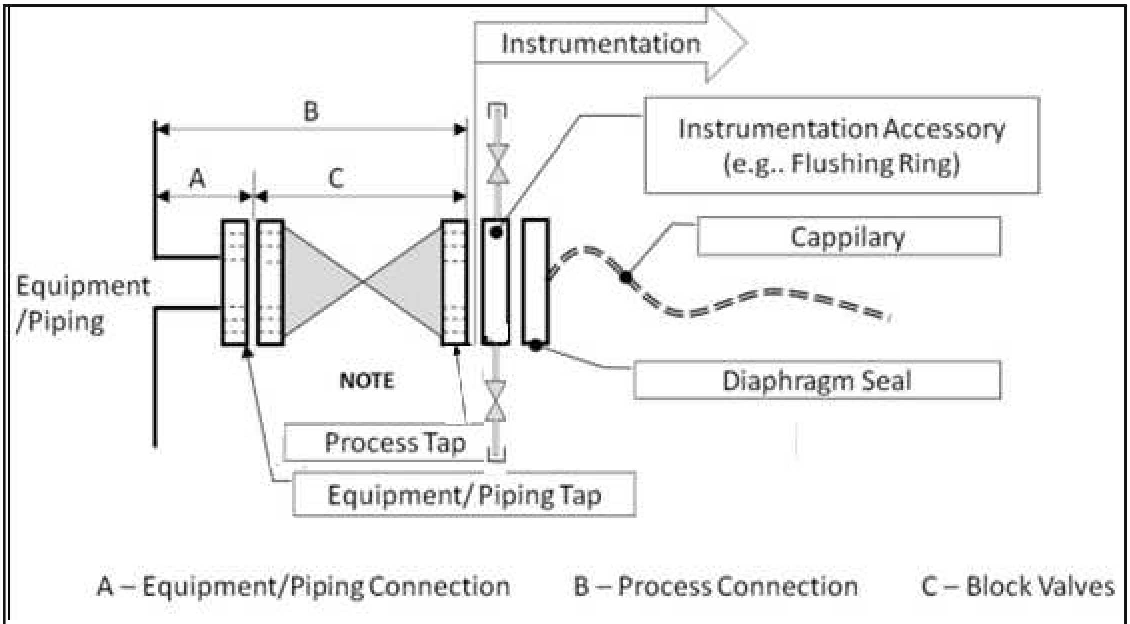


*Figure 6.5-II - Nomenclature for instrument mounting with remote diaphragm seal.*

**Note:** The use of single or double blockage shall be done according to item 6.5.2.

6.5.13.3 Using Direct Assembly

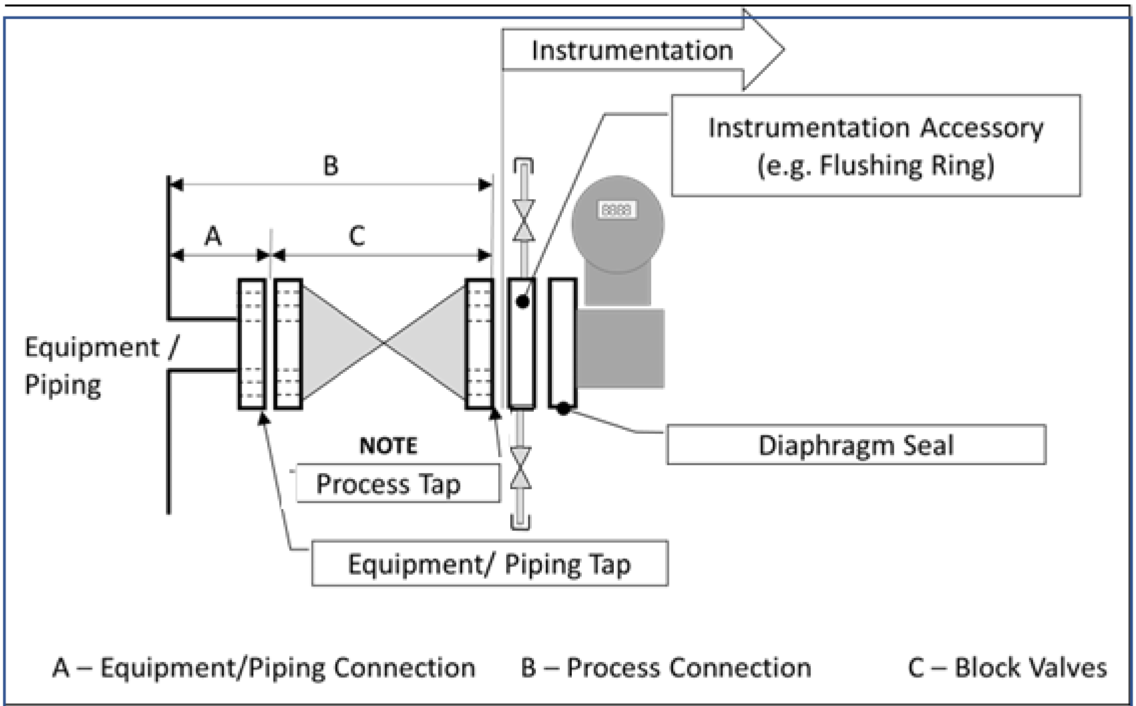


*Figure 6.5-III - Nomenclature for instrument mounting with single body diaphragm seal.*

**Note:** The use of single or double blockage shall be done according to item 6.5.2.

6.5.14 Pneumatic instrument connections shall be at least ¼" NPT (F). Tubing shall be specified according to Chapter 19.

6.5.14.1 When process dynamics require a faster response, larger diameter connections shall be provided (e.g. compressor anti-surge valves), respecting VENDOR requirements.

6.5.14.2 Tubing between instrument air manifold distribution and consumer shall have minimum diameter of 1/2” and shall be defined following requirements of Chapter 19.

6.5.15 Electrical connections shall be ½" NPT (F).

6.5.15.1 Instruments exposed to weather shall not have electrical connections facing upwards from the horizontal plane in order to reduce the risk of water ingress into the enclosure.

6.5.16 Instrument air intakes shall have a ball-type blocking valve associated with a regulating filter, with a double scaled local indicator (kPa and bar) of the outlet gauge pressure, close to the instrument.

## 6.6 Functionality and Performance

6.6.1 Transmitters, registers, indicators, controllers and converters shall meet, if not individually specified, the following specifications:

.#1) The total uncertainty of the instrument shall not exceed 0.5%, including process influences (temperature and static pressure) and combined effects of hysteresis and repeatability;

.#2) The dead band shall not exceed 0.25% of the measuring range;

.#3) A change in ambient temperature of up to 50ºC shall not affect the output signal by more than 1% of the measuring range.

6.6.2 Electronic transmitters shall have local indication of the output signal, with alphanumeric display, configurable in engineering units, except for fire and gas detectors.

6.6.3 Intelligent transmitters / positioners / converters (4 to 20 mA, associated with the HART protocol, properly approved by HART FOUNDATION) shall be used. These instruments shall have configuration and calibration tools (one portable device per instrument type), as well as software to perform these functions on PC, via multiplexer).

6.6.4 It shall be possible to configure the instrument in such a way that when the process variable exceeds the limits of the calibrated range, the output signal is limited to 4 mA for subrange, and 20 mA for over range.

6.6.5 Instruments based on the principle of differential pressure, with or without sealing diaphragm, such as PDITs, LITs, PDIs, FITs and others, shall withstand all differential pressure applied in only one of either inputs, with no pressure applied in the other input, and shall happen no damage to the instrument, no damage to its measuring sensor and calibration losses.

## 6.7 Ergonomics Requirements for Operation and Maintenance

6.7.1 Instruments with display that are installed in supports shall be positioned at 1.50 meters from the floor, if there is no documented restriction, and reading direction shall be horizontal.

6.7.2 There shall be sufficient workspace around the operator and around instruments to allow their operation, calibration, and maintenance **[INTERDISCIPLINARY INTERFACE][MEC, ARR, ARC, 3D]**.

6.7.3 Access shall be provided for all blocking valves of process connections. **[INTERDISCIPLINARY INTERFACE][MEC, ARR, ARC, 3D]**

6.7.4 Operation and maintenance access conditions shall be provided for all instruments, valves, analyzers, fire and gas detectors. The determination of instrument locations, their supports and ergonomic access to them shall be determined after ergonomic studies. **[INTERDISCIPLINARY INTERFACE][MEC, ARR, ARC, PIP, TBM, 3D]**

6.7.5 High temperatures and / or influence of heated surfaces shall be avoided as required in item 6.5.5.

### 6.8 Process Switches

All pre-alarm signals shall be generated internally in the controllers from field transmitter signals (4 to 20 mA). The use of process switches (thermostats, pressure switches, flow and level switches) shall be avoided and, when necessary, shall be previously approved by PETROBRAS.

6.8.1 Micro-switches driving process switches shall have a single SPDT contact and their movable parts shall be hermetically sealed.

6.8.2 The micro-switch contacts for pre-alarm, alarm and interlock circuits (shutdown or trip) shall be kept closed under normal process conditions.

## 7 TEMPERATURE INSTRUMENTS SPECIFICATION REQUIREMENTS

### 7.1 Sensor elements

7.1.1 The rod that holds the sensor element for insertion into thermowells shall be made of AISI 316 stainless steel with a 6 mm (1/4 ") outer diameter and shall be spring loaded type, sized to have full contact with the bottom of thermowell bore.

7.1.2 Thermocouples

7.1.2.1 The thermocouple shall be type K, according to IEC 60584 with tolerance class 2.

7.1.3 RTD (Thermo-resistance)

7.1.3.1 RTDs shall be PT100 type of 3 (or 4) wires, in accordance with IEC 60751 with tolerance class A, if not defined in the design. Attention shall be given to the type of RTD, 3 or 4 wires, when specifying the instrument that reads the signal.

7.1.3.2 RTDs shall be specified in accordance with IEC 60751 (equivalent to DIN 43760) with a temperature coefficient of $3.851 \times 10^{-3}$ ºC$^{-1}$. Callendar-Van-Dusen parameters shall be provided for parameterization of respective transmitter.

### 7.2 Thermometers

7.2.1 Mercury or glass bulb thermometers shall not be used.

7.2.2 Thermometers shall be of the bimetallic type.

7.2.2.1 Bimetallic angular type thermometers (“every angle”) shall not be used.

7.2.2.2 Bimetallic thermometers shall have the following general characteristics:

.#1) Display with minimum nominal diameter of 100 mm;

.#2) A ½" NPT (M) connection to the well;

.#3) AISI 304 stainless steel rod with external diameter (ED) of 6 mm.

.#4) Accuracy class 1 according to DIN EN 13190;

.#5) The indication range shall be such that the normal operating temperature is between 30 and 70% of this range, and the minimum and maximum temperatures can still be read within the indication range.

.#6) In applications subject to vibration or low temperature measurement, use with liquid filler. The vibration limit to which the thermometer may be subjected shall be checked.

7.2.2.3 The scales shall have a white background with black inscriptions. The ranges shall be chosen among the following, in degrees Celsius: 50/50; 0/100; 0/150; 0/200; 0/300; 0/500. Other ranges shall be presented to PETROBRAS for evaluation.

7.2.2.4 Enclosure shall be hermetically sealed and made of AISI 304 stainless steel or AISI 316 stainless steel.

7.2.2.5 The thermometers shall have a zero adjustment through micrometer pointer.

## 7.3 Selection Criteria

7.3.1 Bimetallic thermometers or electronic transmitters shall be used for local indication. Bimetallic thermometers shall not be used where there are vibrations or cryogenic applications.

7.3.2 RTD (thermoresistors) or thermocouples shall be used for telemetry and electronic temperature loops, usually connected via transmitters to PLC input cards.

7.3.3 In case of temperatures sensor with range within -50 to 450°C, RTD shall be used. If the temperature exceeds 500°C, thermocouple shall be used.

## 7.4 Installation and Equipment/Piping Connections

7.4.1 Protection and Test Thermowell

7.4.1.1 All temperature sensing elements for fluid measurement shall be installed with protection thermowells, equipped with integrally mounted sensors and transmitters (see item 7.5.1), or along with the associated thermometer, whichever is the case.

7.4.1.1.1 The internal bore to accommodate the sensor rod (item 7.1.1) shall have a diameter of 6.6 mm.

7.4.1.1.2 The connection to the thermowell shall be done using union and 1/2” NPT nipples, in the following sequence: NPT(F) thermowell, NPT (MxM) nipple, NPT (FxF) union, (MxM) nipple and NPT(F) temperature Instrument (sensor / thermometer / transmitter).

7.4.1.2 The stem of the thermowell shall have a tapered profile, and, if it does not meet the vibration and tension requirements (see item 7.4.1.10), a step shank profile shall be used. Straight profiles may only be used if the tapered and stepped types prove to be incompatible with process conditions.

7.4.1.3 The thermowell center piece where sensor is inserted shall be machined from bar stock with no welds. The material shall be in stainless steel 316/316L dual certified (IOGP-JIP33 S-563), except where this material is not suitable to process conditions.

7.4.1.4 For flanged thermowells the welded joint that attaches the flange to thermowell center piece must be full penetration weld following API RP 551 and ASME PTC 19.3 TW, or a flanged thermowell machined from single piece, i.e. with no weld to attach the flange, in stainless steel 316/316L certified (IOGP-JIP33 S-563). In the case the rating of stainless steel 316/316L certified (IOGP-JIP33 S-563) is not suitable for the conditions of pipe pressure and temperature, another material shall be specified that is suitable for both mechanical efforts and corrosion resistance, such as Duplex and Superduplex.

7.4.1.4.1 For flanged thermowells with welded thermowells it is mandatory the supply of:

.#1) The welding procedures;

.#2) Non-destructive weld test procedures (penetrating liquid or magnetic particle according to the material);

.#3) Reports of non-destructive tests performed.

7.4.1.4.2 Item 6.5.8 shall be followed regarding thermowell flange material **[INTERDISCIPLINARY INTERFACE][MEC, PRO, SNAV, TBM, PIP].**

7.4.1.5 Only where process conditions requires a material different from stainless steel 316/316L dual certified (IOGP-JIP33 S-563), forged or not, Duplex or Superduplex stainless steel, it is allowed thermowells of lap-joint type (Van Stone). Insulation gaskets shall be used wherever there is potential for galvanic corrosion. **[INTERDISCIPLINARY INTERFACE][MEC, PRO, SNAV, TBM, PIP]**.

7.4.1.6 Thermowell material shall be clearly printed on its flange, if any. In threaded wells, the thermowell material shall be printed on the body.

7.4.1.7 In straight piping lengths with nominal diameters smaller than 3” an expansion to 3” shall be provided and when nominal diameter is 3” or 3 1/2" the expansion shall be to 4”. The expansion shall be provided as stablished by PIPING SPECIFICATION. **[INTERDISCIPLINARY INTERFACE][PRO, PIP, SNAV]**

7.4.1.8 Thermal isolation shall be provided in the temperature measuring points on lines with nominal diameter up to 4”, whether being and expansion or the original line diameter. **[INTERDISCIPLINARY INTERFACE][PRO, PIP, TBM, SNAV]**

7.4.1.9 The region of the thermowell where its sensor is located shall be within the optimum region for temperature measurement. This region is within 1/4 and 3/4 of internal diameter. The Figure 7.4-I demonstrates the described concept.

7.4.1.9.1 In lines with small diameters, up to 4”, the sensor shall be positioned so that most of it is accommodated within the internal diameter.

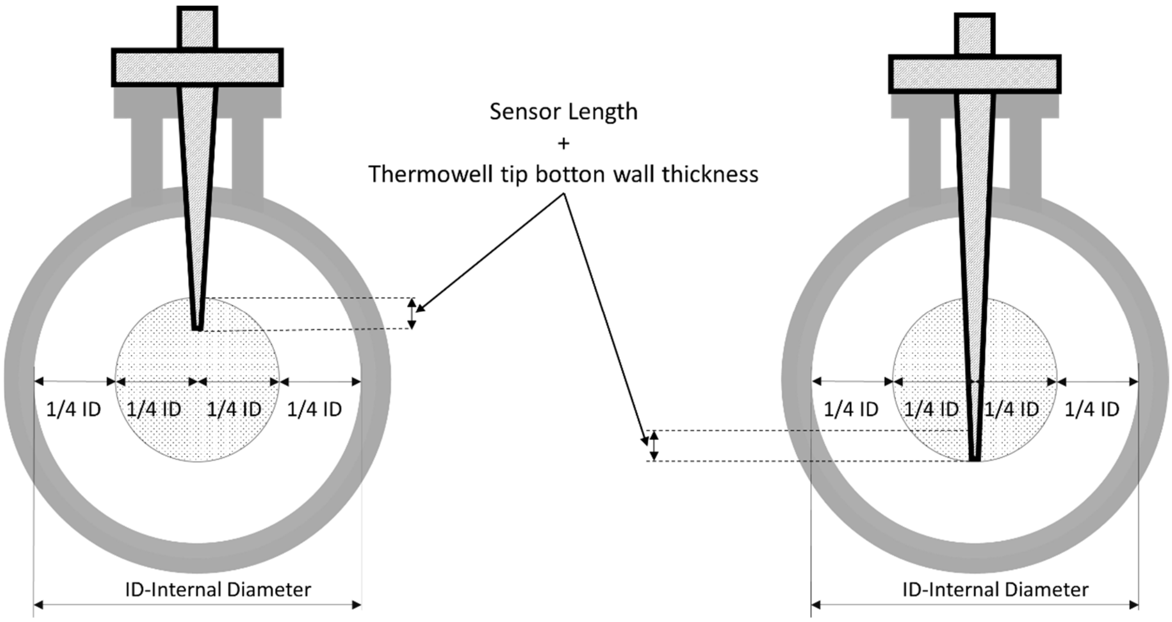


Figure 7.4-I – Necessary immersion for thermowells to position the temperature sensor within optimum temperature measurement region.

7.4.1.10 The thermowells shall comply with the requirements established in ASME PTC 19.3 TW, latest revision and possible errata, and shall ensure suitability throughout the operational range.

7.4.1.11 When the fluid velocity profile is not fully developed where thermowell is installed, a computational analysis of fluid dynamics shall be carried out to determine the velocity profile at the point of installation.

7.4.1.12 When the thermowell is not covered by ASME PTC 19.3 TW, a finite element analysis shall be performed for the proposed thermowell as mentioned in API RP 551.

7.4.1.13 The use of a support collar is not acceptable.

**Note:** A perfect contact between the collar and the support point on the neck where the thermowell is inserted cannot be guaranteed. This way, the collar does not immobilize the thermowell, which changes the unsupported length, invalidating the vibration calculations, besides constituting a point of fatigue for the thermowell.

7.4.1.14 For temperature measurement after mixing of fluids the wells shall be installed 10 nominal diameters downstream of the liquid mixing point and 25 nominal diameters downstream of the gas mixing point. Smaller distances may be used provided that temperature stabilization is verified through computational simulations.

7.4.1.15 Equipment connection for thermowell in vessels, towers and tanks shall be flanged, in the same pressure class as the equipment in which the thermowell will be installed and shall have the following diameters: **[INTERDISCIPLINARY INTERFACE][PRO, MEC]**

.#1) 1 1/2", for equipment connection with schedule up to 160 and flange pressure class up to 600#; **[INTERDISCIPLINARY INTERFACE][PRO, SNAV, TBM, MEC]**

.#2) 2", for equipment connection with schedule greater than 160 or flange pressure class greater than 600#; **[INTERDISCIPLINARY INTERFACE][PRO, SNAV, TBM, MEC]**

.#3) 2", when no 1 1/2" piping diameter is provided for the respective line specification in the technical specification document of the project entitled PIPING SPECIFICATION;

.#4) 3", for vessels with inner coating.

7.4.1.16 Standpipe installation is not permitted. **[INTERDISCIPLINARY INTERFACE][PRO, MEC]**

7.4.1.17 In vessels, towers and tanks the immersion length shall be as per Table 7.4-I. **[INTERDISCIPLINARY INTERFACE][MEC]**

*Table 7.4-I - Immersion Length for Flanged Wells Installed in Vessels, Tanks and Towers.*

| Diameter of Vessel or Tower | Immersion Length | Service |
|---|---|---|
| Any diameter | 300 mm | Liquids |
| < 800 mm | 200 mm | Gases |
| ≥ 800 mm and < 1200 mm | 300 mm | Gases |
| ≥1200 mm | 400 mm | Gases |
| **NOTE:** In the case of vessels with small diameters, the immersion length shown shall be reduced so as not to exceed half value of the inner diameter of the vessel. | | |

7.4.1.18 Minimum sizes for thermowell connection to piping are presented in the technical specification document of the project entitled PIPING SPECIFICATION. These sizes can be increased after thermowell design, especially in extreme cases, such as high flow rates and XXS schedules. In order to avoid contact of thermowell and connection to process to inner wall (pipe branch inner wall), due to its vibrations and also the uncertainties inherent in the piping connection, the following formula shall be used: **[INTERDISCIPLINARY INTERFACE][PRO, PIP]**

$$\emptyset Root_{well} + U\_\emptyset Root_{well} \leq 2 \times \left\{ \frac{(DI_{CT} - U\_DI_{CT})}{2} - G - \tan 0.5^{o} \times \left[ D_{F_{T}CT} + \left( E_T + U_{E_T} \right) \right] - 1/16'' \right\}$$

Where:

$\emptyset Root_{well}$ : Nominal diameter of thermowell's root, on flange side;

$U\_\emptyset Root_{well}$ : Further uncertainty in the nominal diameter of the well root, on flange side;

$DI_{CT}$ : Internal diameter of the connection to piping;

$U\_DI_{CT}$ : Less uncertainty of the internal diameter of the connection to piping;

$G$ : Safety margin. Distance between well and piping wall at the beginning of the internal diameter of the piping. Use 6mm;

$D\_F\_T_{CT}$ : Standard distance from the top of the flange of the piping connection to the outer wall of the piping. For the values to be used, see projects technical specification DR-ENGP-I-1.1 - Piping Material Standard for Oil Production and Process Facilities;

$E_T$ : Process piping wall thickness;

$U\_E_T$ : Further uncertainty in the thickness of Process piping wall.

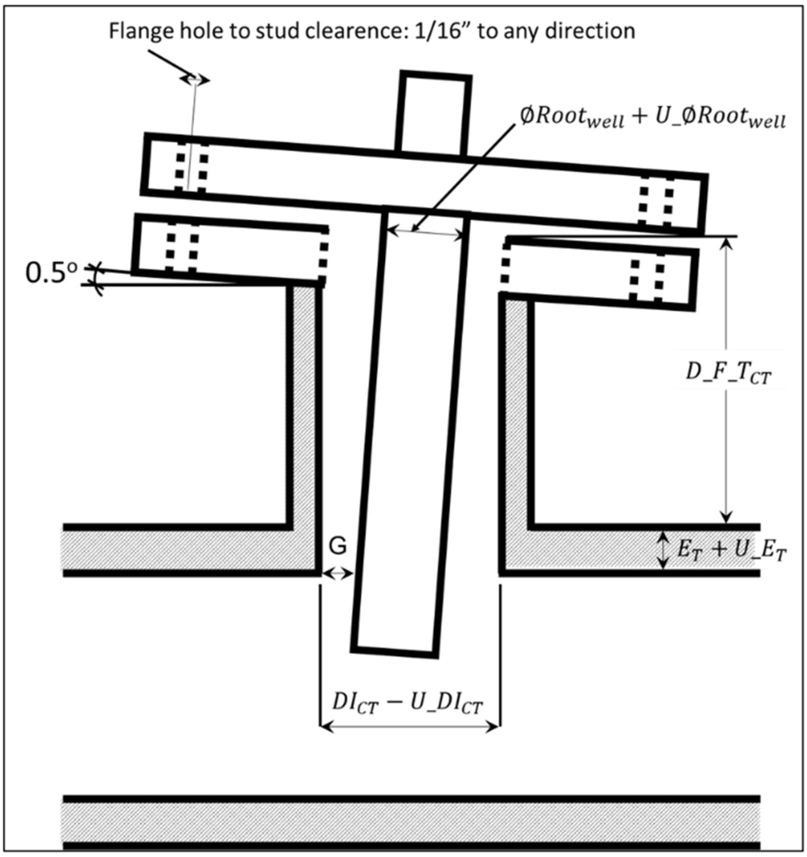


*Figure 7.4-II - Out-of-scale representation of the effects of piping connection uncertainties in the installation and dimensioning of thermowells.*

7.4.1.19 For lines and vessels with thermal insulation, the equipment /piping connection shall be flanged and shall be of a length necessary for the flange to be external to insulation and so that the union required in item 7.4.1.1.2 is external to the thermal insulation. **[INTERDISCIPLINARY INTERFACE][MEC, PIP]**

7.4.1.20 On lines and vessels with thermal insulation an appropriate extension shall be provided to reduce the temperature up to the reading instrument (transmitter) or sensor head to values that meet the instrument and legislation requirements.

## 7.5 Transmitters

7.5.1 Transmitters and sensing elements shall be integrally mounted, forming a single body, with 4-20 mA signal transmission + HART with 2 (two) wires with the loop powered by the reading device.

7.5.1.1 When it is confirmed that the local of installation will expose the transmitter to excessive vibration or temperatures outside the operational range or the ergonomics study indicates that the measuring point is not easy of access, the sensor part shall be decoupled from the transmitter, installed in the well with the use of a sensor head with passive terminal blocks and interconnected to the transmitter. Support shall be provided for the transmitter and routing shall be provided for the cables. The final assembly shall conform to Ex and IP classification as defined in this technical specification.

7.5.2 Temperature transmitters shall have:

.#1) Configurable reading range;

.#2) The ability to read RTDs, thermocouples etc., through configuration;

.#3) Cold junction compensation (CJC);

.#4) Galvanic isolation between input and output;

.#5) Automatic detection of thermocouple input fault (burnout) with configurable fault indication for subrange or over range;

.#6) Linearization calculation of the output signal through a table and also by the Callendar-van-Dusen coefficients;

.#7) Enclosure with dual compartment housing and electrical connections forming a 90° angle between them (one to the side and one to the bottom) or with both connections at the botton or with both connections at the sides, as required in item 6.5.15.1.

# 8 PRESSURE INSTRUMENTS SPECIFICATION REQUIREMENTS

## 8.1 Selection Criteria

8.1.1 Bellows or diaphragm pressure sensors shall be used for very low pressure or vacuum.

8.1.2 To measure very high pressures, strain-gauge sensors can be used.

8.1.3 Electronic pressure transmitters and differential pressure transmitters shall be of the capacitive type, resonant silicon or piezo resistive. They shall be equipped with drain in each chamber.

8.1.4 The selection of the pressure instrument range shall take into account an occasional overpressure of the system and shall be capable of standing, instantly, at least 1.3 times the maximum pressure of the selected work range.

8.1.5 The working range of the pressure instruments shall be chosen so that the maximum value is 75% of the range and the minimum is 15% of the range.

8.1.6 Pressure instruments and differential pressure instruments in the service of crude oil, produced water, fouling fluids, corrosive fluids or toxic fluids shall be installed with a diaphragm seal.

8.1.6.1 For services that require a quick response from transmitter or that the delay caused by the set capilaries/diaphgram seal compromises the measurement, it shall not be used diaphragm seal but impulse line with no seal fluid. Impulse line and transmitter internal materials shall be defined taking into account process conditions. This requirement shall be evaluated for all services but following services are defined to not be installed with any type of sealing for anti-surge system of compressors. **[INTERDISCIPLINARY INTERFACE][PRO, SNAV, TBM]**

8.1.6.1.1 Pressure and differential pressure for flow measurements which are part of the Flow Metering System shall follow the requirements of I-ET-3010.00-1200-813-P4X-001 - GENERAL CRITERIA FOR FLOW METERING SYSTEMS and should not use sealing of any type unless stated otherwise.

## 8.2 Manometers

8.2.1 Shall comply with ASME B40.100.

8.2.2 Manometers with bourdon type sensors shall be used.

8.2.3 The manometer shall have a nominal diameter of 114 mm or 100 mm. Other diameters will need prior approval from PETROBRAS.

8.2.4 The color of the manometer display shall be white and the numbers and characters shall be black.

8.2.5 Casing material shall be thermoset phenolic polymer. This material can be modified if required by environmental or process conditions.

8.2.6 Casing display of the manometer shall be of laminated safety glass with at least 75% transparency.

8.2.7 The manometer housing assembly shall be glycerin filled, with a solid front and with a rupture disc at the rear part.

8.2.7.1 Item 8.2.7 does not apply to pressure gauges receivers used for reading pneumatic signals, such as 3 to 15 psi. Currently, this type of instrument has few applications. Example of use: pressure indicator on control valve positioners.

8.2.8 The material of the components of the moving mechanism of the manometer pointer shall be AISI 304 or AISI 316 stainless steel.

8.2.9 The material of the manometer connection socket shall be the same as the AISI 316 stainless steel sensor element, unless the process fluid requires a more suitable and resistant material.

8.2.10 Manometers with electrical contacts shall not be used, neither pointers indicating maximum pressure.

8.2.11 The manometer shall have double scale indication (kPa and bar).

8.2.12 The scales of the differential pressure gauges shall be of the direct reading type.

8.2.13 The operating range shall be between 1/4 and 3/4 of the nominal range and the accuracy class shall be ± 1,0% (full scale), or better, along the whole nominal range.

8.2.14 Pressure gauges shall be adequate for operating with working pressure equal to the upper limit of the nominal range.

8.2.15 Manometers shall not be specified for the types of assembly not accepted in item 8.5.8.

## 8.3 Transmitters

8.3.1 All differential pressure transmitters shall have both high and low pressure taps ("H" and "L" respectively) clearly and visibly indicated on their bodies. These transmitters shall be connected to the impulse lines through 5-way manifold blocks.

8.3.1.1 The blocking, equalizing and drainage valves of the manifold blocks shall be of the needle type and the obturator shall be non-rotating stem tip, i.e. the obturator is not integral with the rod.

8.3.1.2 Plugs shall be provided in the pressure class of the manifold in the drain and vent.

8.3.2 The accuracy class shall be ± 0.5% of full scale (FS), or better.

## 8.4 Pressure Switches

The use of pressure switches is restricted. See item 6.8.

8.4.1 Pressure switches cannot be used in pulsed flow services. For these cases, a pressure transmitter shall be used. **[INTERDISCIPLINARY INTERFACE][PRO]**

8.4.2 The point of actuation of the pressure switch shall be within the second third of the operational range covered by the instrument.

8.4.3 The pressure switches shall be equipped with adjustment of the actuation point. This adjustment shall be weather protected, having no contact with the external atmosphere, except when the adjustment is performed.

## 8.5 Installation and Process Connection of Pressure Instruments

8.5.1 For differential pressure measurements, also refer to item 6.5.9.1.

8.5.2 Table 8.5-I shows the connections and taps of pressure Instruments to vessels and towers and equipment. **[INTERDISCIPLINARY INTERFACE][PRO, MEC, 3D].**

| INSTRUMENT TYPE | EQUIPMENT CONNECTION/ PROCESS CONNECTION/ PROCESS TAP Note (2) | IMPULSE TAP |
|---|---|---|
| **INSTRUMENT WITHOUT DIAPHRAGM SEAL (FLANGED)** | | |
| Manometer Indicator/Differential Pressure Gauge/Pressure Switch/ Pressure Transmitter | 2"/2"/2" | 1/2" NPT (F) |
| **INSTRUMENT WITH DIAPHRAGM SEAL (FLANGED) (Note 1)** | | |
| Manometer Indicator for minimum pressure up to 300 Kpag | 3"/3"/3" or 4"/4"/4" if 3" schedule is XXS | Capillary factory sealing. |
| Manometer Indicator for minimum pressure above to 300 Kpag/ Pressure Transmitters above to 300 Kpag with direct or remote mounting | 2"/2"/2" or 3"/3"/3" if 2" schedule is XXS | Capillary factory sealing. |
| Differential Pressure Gauge , Pressure Transmitter or Differential Pressure Transmitters up to 300 Kpag, both direct or remote mounting | 3"/3"/3" or 4"/4"/4" if 3" schedule is XXS | Capillary factory sealing. |

*Table 8.5-I - Connection Table of Pressure Instruments to Vessels and Towers and Equipment*

Notes:

(1) For vessels, tower and equipment with internal coating or when schedule of connection is XXS, the connections to equipment and process as well process tap shall all be increased to 3" if table indicates a smaller connection.

(2) All process connections to pressure vessels shall be flanged and minimally specified for at least pressure class of 150 #.

8.5.3 Piping connections shall be as follows. [INTERDISCIPLINARY INTERFACE][PRO, SNAV, TBM, PIP, SNAV,3D]:

8.5.3.1 All piping connections shall be flanged. No threaded connections are to be used, even at low pressures.

8.5.3.2 Table 8.5-II shows the connections and taps for piping. **[INTERDISCIPLINARY INTERFACE] [PRO, MEC, SNAV, TBM, 3D]**.

| INSTRUMENT FLANGE SIZE | PIPE NOMINAL DIAMETER Note (3) | IMPULSE TAP |
|---|---|---|
| **PRESSURE INSTRUMENTS WITHOUT DIAPHRAGM SEAL** | | |
| ¾” Flange | ¾” | Flange adaptor |
| 1” Flange | 1” | Flange adaptor |
| 1 ½ Flange | 1 ½” all pressure class | Flange adaptor |
| 1 ½ Flange | >= 2” and Pressure class up to 900# | Flange adaptor |
| 2” Flange | >= 2” and Pressure class above 1500 # | Flange adaptor |
| **PRESSURE INSTRUMENTS WITH DIAPHRAGM SEAL Note (4)** | | |
| 3" or 4” when schedule of 3” is XXS | All diameter with working pressure/differential pressure up to 300 Kpag | Capillary factory sealing. |
| 2" or 3” when schedule of 2” is XXS | All diameter with working pressure above to 300 Kpag | Capillary factory sealing. |

*Table 8.5-II Connection Table of Pressure Instruments to Piping connection*

Note:

(3) The size of a piping connection when instrument is installed using impulse line, either for pressure or differential pressure measurements

(4) The use of 3” flange for diaphragm seal on pipe nominal diameter less the 2” shall be avoided and, when necessary, details of installation shall be submitted for Petrobras analysis

8.5.4 When measuring liquids, impulse lines shall have a downward slope requested in Chapter 19.

8.5.5 When measuring gas, the impulse lines shall have a rising slope requested in Chapter 19.

8.5.6 When measuring water vapor, the design of the impulse lines depends on the relative position of the instrument for the impulse tap:

.#1) It shall have a downward slope requested in Chapter 19 from the impulse tap to the manifold block of the instrument when the transmitter is installed below the impulse tap.

.#2) It shall have an upward slope requested in Chapter 19 from the impulse tap to the manifold block of the instrument when the transmitter is installed above the impulse tap with a horizontal syphon assembly (coil syphon).

8.5.7 The material of the parts in contact with the fluid shall be AISI 316 stainless steel, unless the process fluid requires a more suitable and resistant material.

8.5.8 The following pressure gauge assemblies shall not be accepted: bottom connection for panel mounting with hole fixing and surface mounting with concentric or eccentric rear connection.

# 9 LEVEL INSTRUMENTS SPECIFICATION REQUIREMENTS

## 9.1 Level Gauges

9.1.1 Magnetic level gauges shall be applied taking into account pressure and type of fluid. Regarding pressure magnetic level gauge shall be used for class 600# and above, for any type of fluid. Regarding the type of fluid, independently of pressure, magnetic level gauges shall be used for the following services:

.#1) hydrocarbon fluids;

.#2) services with oil and water;

.#3) produced water;

.#4) chemical products;

.#5) oil-water interface;

.#6) gas condensate;

.#7) cooling water;

.#8) make-up water;

.#9) hot water;

.#10) any fluid with impurities that adheres to the glass.

9.1.1.1 The application of reflex type level gauges is restricted to clean and transparent fluids with pour point below the Absolute Minimum Temperature defined in the Metocean Data Document and that are not defined by item 9.1.1.

9.1.2 Level gauges shall be of the top-bottom connections type, allowing adjustment of the visual field by turning the display. **[INTERDISCIPLINARY INTERFACE][MEC, 3D]**

9.1.3 The lines between the process connection on the vessel up to the level display cannot form pockets. **[INTERDISCIPLINARY INTERFACE][MEC, PIP, 3D]**

9.1.4 Reflective or transparent glass level gauges shall only use glass sections of dimensions 7, 8 or 9 with a maximum height limited to 5 (five) units of size 9 (nine).

9.1.5 The level gauge of any type in each of its process connections shall be fitted with an angular-type ball valve (off-set) to stop a leak if the display is broken.

9.1.6 Level gauges shall have drain / vent valves with 3/4" NPT connections to the gauge to allow cleaning of the display during operation.

9.1.7 Installation of level gauges shall have isolation valves (root valve) as defined in items 6.5.1 and 6.5.2. **[INTERDISCIPLINARY INTERFACE][PRO, HSE, MEC, PIP, TBM, SNAV]**

9.1.8 The magnetic type gauges shall have flag-type indicators and a hermetically sealed measuring tube in AISI 316 stainless steel. Where this material is not suitable for process conditions, other more suitable material shall be used.

9.1.8.1 The enclosure of the flags shall not have contact with the process.

9.1.9 The demagnetizing temperature (Curie temperature) of the magnetic type gauge buoy shall be greater than the upper design temperature of the process fluid by at least 20 °C.

9.1.10 Magnetic level gauges principle of operation is based on a fixed density, i.e., the density for what the buoy was designed. When process fluid of vessel/tank/tower varies its density, the following mitigating measures shall be taken:

.#1) The buoy shall be designed for the minimum fluid density; **[INTERDISCIPLINARY INTERFACE][PRO]**

.#2) The vessel/tank/tower drain equipment connection (nozzle) shall be below to the high pressure equipment connection for the instrument; **[INTERDISCIPLINARY INTERFACE][MEC]**

.#3) It shall be issued a design calculation showing that instrument is adequate to operate throughout fluid density range, showing the expected level indication for 5 values of density equally spaced from minimum to maximum value(e.g. being 0% the minimum density 0% and 100% the maximum density, it shall be calculated for 0%, 25%, 50%, 75% and 100%). **[INTERDISCIPLINARY INTERFACE][PRO]**

## 9.2 Level Transmitters

9.2.1 Selection by technology and respective assembly constraints

The effectiveness of each technology is intrinsically linked to assembly aspects for operation, maintenance and calibration assurance. Therefore, specifications listed on Table 9.2-I shall be followed.

*Table 9.2-I - Selection of Technologies for level transmitters linked to the use of Standpipes (SP) and Hot Tap and Extraction Tool (HT).*

| Service | | | Technology | | | | |
|---|---|---|---|---|---|---|---|
| | | | Differential Pressure 1 | Radar 2 | Ultrasonic 3 | Capacitive 6 | Energy Absorption 5 |
| Service | Vessels | Level of Liquid (a) | Mandatory: SP in case of disturbances that cause level variations within the vessel. | Only Free Wave Conical or Matrix Antenna Type. Parabolic aerial or guided wave are prohibited. | Forbidden | Mandatory: SP | Mandatory: HT |
| Service | Vessels | Water - Oil Interface (b) | See item 9.2.1.1.2 | | | | |
| Service | Non-structural Tanks | Level of Liquid (c) | Mandatory: SP in case of disturbances that cause level variations within the vessel. | Analyzed upon request | Forbidden | Acceptable (observe tank geometry) | Analyzed upon request |
| Service | Non-structural Tanks | Water - Oil Interface (d) | Mandatory: SP | Forbidden | Forbidden | Mandatory: SP and coated probe | Mandatory: HT |
| Service | Structural Tanks | Cargo Tank (e) | Forbidden | Acceptable | Forbidden | Forbidden | Forbidden |
| Service | Structural Tanks | Ballast Tank (water only) (f) | Submerged type only | Acceptable | Forbidden | Forbidden | Forbidden |
| Service | Structural Tanks | Void Space (g) | High sensitivity type only (Ceramic) | Acceptable | Acceptable | Forbidden | Forbidden |
| Service | Structural Tanks | Other Tanks Level of Liquid (h) | Analyzed upon request (submerged type is prohibited for hazardous or flammable fluids) | Acceptable | Forbidden | Analyzed upon request | Analyzed upon request |
| Service | Structural Tanks | Other Tanks and Water - Oil Interface (i) | Forbidden | Analyzed upon request | Forbidden | Analyzed upon request | Analyzed upon request |

9.2.1.1 For water/oil interface measurement in separating vessels and oil dehydrators, the meters shall be installed inside the vessel (without standpipe) and shall be selected from the following technologies: energy absorption, nuclear profiler and electrical conductivity profiler. **[INTERDISCIPLINARY INTERFACE][PRO, MEC, 3D]**.

9.2.1.1.1 For energy absorption technology, 3 meters shall be used, with devices for hot extraction and insertion: one bottom punctual meter for identification of the boundary of the aqueous phase; an intermediate installed in a vertically inclined position, control antenna type for interface control; and a punctual superior to monitor emulsion height and to avoid the presence of high water content in the oil dehydrator electrodes.

9.2.1.1.2 For water/oil interface measurement in other vessel types, the technologies provided in row (d) of Table 9.2-I are permitted.

9.2.1.2 Differential pressure transmitters principle of operation is based on a fixed density, i.e., the density value used in its calibration. When process fluid of vessel/tank/tower varies its density, the following mitigating measures shall be taken:

.#1) Transmitter shall be calibrated for the minimum density value; **[INTERDISCIPLINARY INTERFACE][PRO]**

.#2) The vessel/tank/tower drain nozzle shall be below to the high pressure equipment connection for the instrument; **[INTERDISCIPLINARY INTERFACE][MEC]**

.#3) It shall be issued a design calculation showing that instrument is adequate to operate throughout fluid density range, showing the expected level indication for 5 values of density equally spaced from minimum to maximum value (e.g. being 0% the minimum density 0% and 100% the maximum density, it shall be calculated for 0%, 25%, 50%, 75% and 100%). Additionally, on-off level control, alarm setpoint and interlocking setpoint values shall be defined for all density range and shall be demonstrated that transmitter perform correctly. **[INTERDISCIPLINARY INTERFACE][PRO]**

9.2.1.2.1 If after all measures from item 9.2.1.2.#1) to 9.2.1.2.#3) a single transmitter does not comply with process conditions, it shall be implemented the measurement of fluid density to automatically correct the density to the level transmitter or select another level measurement technology allowed by *Table 9.2-I*.

9.2.2 Parts of the level transmitters that may get in contact with process fluid should be AISI 316 stainless steel. In cases where this material is not suitable for process conditions, or the instrument specification requires nobler material, other more suitable material shall be used.

## 9.3 Standpipe

9.3.1 Standpipes should be made with 4” body and 4” equipment connection. The process connection in the vessel to the standpipe shall be made with a block valve according to the technical specification document of the project entitled PIPING SPECIFICATION and according to item 6.5.2. For connections and taps for instrument see Table 9.5-I. **[INTERDISCIPLINARY INTERFACE][PRO, SNAV, MEC, 3D]**.

9.3.2 Interface instrument standpipes and standpipes for instruments with principle of operation based on fluid density that varies must have at least 3 equipment connections**. [INTERDISCIPLINARY INTERFACE][PRO, MEC]**

9.3.2.1 For interface measurement the equipment connections must be one bottom, one top, and the third in the center of the range where the phases are supposed to form emulsion. Other inputs should be used in this emulsion range to ensure that the distance between them does not exceed 500 mm. **[INTERDISCIPLINARY INTERFACE][PRO, MEC]**

9.3.2.2 For the services which density varies either due to process variation throughout unit lifetime or to different services with different fluids, the equipment connections must be one bottom, one top, and one in the middle of the instrument. **[INTERDISCIPLINARY INTERFACE][PRO, MEC]**

9.3.3 Standpipes must have facilities for bottom drainage and top gas purge.

9.3.4 Follow item 9.4.2.7.

## 9.4 Installation

9.4.1 For level application, the installation design of the instruments listed below shall ensure the feasibility of instrument removal without the need to interrupt the operation of the vessel / tank / equipment:

.#1) Differential pressure;

.#2) Radar (for cargo tanks monitoring only);

.#3) Displacer;

.#4) Capacitive.

9.4.1.1 For differential pressure level measurements on crude oil, produced water, fluids with plugging or fouling tendencies, corrosive fluids or toxic fluids, a diaphragm seal shall be used and item 6.5.9.2 shall also be followed.

9.4.2 Standpipe usage and installation requirements:

9.4.2.1 For water/oil interface measurements in separating vessels and oil dehydrators, standpipes shall not be used.

9.4.2.2 Instruments used with the control function shall have a level gauge installed in the same standpipe to reduce the number of nozzles in the equipment. **[INTERDISCIPLINARY INTERFACE][PRO, MEC]**

9.4.2.3 When multiple level gauge sections are needed to cover the required range, there shall be a minimum overlap of 50 mm between sections in the measuring range.

9.4.2.4 Standpipe shall be used to ensure the feasibility of removing the instrument without the need to interrupt the operation of the vessel / tank / equipment. **[INTERDISCIPLINARY INTERFACE][PRO, MEC]**

9.4.2.5 Never nest series standpipes.

9.4.2.6 Instrumentation installed on standpipes shall be mounted on top, except for differential pressure device with independent cells. In this case, a blind flange shall be provided at the top of the standpipe, with diameter according to Table 9.5-I to allow future top installations. **[INTERDISCIPLINARY INTERFACE][MEC]**

9.4.2.7 Resources shall be used to maintain the process temperature inside standpipes. Electric heat tracing is a possible solution, but thermal demand shall be defined by respective discipline responsible for the system and the design of heat tracing is by Electrical discipline. These disciplines shall liaise in order to correctly design the heating demand versus heating capacity. **[INTERDISCIPLINARY INTERFACE] [PRO, SNAV,MEC, ELE]**

9.4.3 The installation of level instruments shall be made to mitigate the influence of inclinations of the UNIT. This caution shall be initiated in the arrangement of equipment/vessels/tanks/towers, minimizing the influence of UNIT balance. **[INTERDISCIPLINAR INTERFACE] [ARR].**

9.4.4 The centerline of the lower process connection (high pressure process tap) for transmitters shall be positioned 100 mm below the minimum value of transmitter calibrated range to ensure that the instrument adequately performs throughout its measuring range. **[INTERDISCIPLINARY INTERFACE] [MEC]**

9.4.5 The heights of the nozzles for installation of the process taps of instruments dedicated to the process level control loops and to interlocking loops shall always be at the same elevation. **[INTERDISCIPLINARY INTERFACE][MEC]**

9.4.5.1 Nozzles for level gauges shall be such that their range contains the range of their respective transmitters, that is the upper nozzle shall be at a level above the nozzle of the transmitters and the lower nozzle shall be at a position below the nozzles of the transmitters. The nozzles of level gauges shall be located to ensure that the level display covers the range from the lower elevation of the lower nozzle of the transmitters and the upper elevation of the upper nozzle of the transmitters. **[INTERDISCIPLINARY INTERFACE][MEC, PRO]**

9.4.6 Level instruments shall always be connected to standpipe or, when specified, to the equipment (vessel, tank, tower, etc.) and never connected to lines, such as flow lines, drain lines or vent lines. **[INTERDISCIPLINARY INTERFACE][MEC, PRO]**

9.4.7 Process connections on the lower cap of vases and towers or tank bottoms shall never start from the lowest point and shall penetrate the vessel/tower/tank by 100 mm to avoid ingress of debris into process tap and into the instrument. **[INTERDISCIPLINARY INTERFACE][MEC]**

9.4.8 Separator vessels shall have a 6” nozzle at the top, near the spillway, to allow future installation of internal instruments. **[INTERDISCIPLINARY INTERFACE][PRO, MEC]**

9.4.9 The design of separating vessels and oil dehydrators shall provide 4” flanged taps on the side of the vessel in the water, emulsion and oil phases, with respective block valves, near the water outlet location, so that possible future interface measurement technologies can be installed. **[INTERDISCIPLINARY INTERFACE][PRO, MEC**].

9.4.10 In separating vessels the water/oil interface measuring instrument shall be installed near the baffle, and in oil dehydrator it shall be installed in the measuring region of interest. **[INTERDISCIPLINAR INTERFACE][PRO, MEC]**

9.4.11 For interface measurement and for level measurements with principle of operation based on fluid density that varies, the equipment shall provide at least 3 equipment connections. **[INTERDISCIPLINARY INTERFACE][MEC]**

9.4.11.1 For interface measurement the equipment connections shall be one lower, one upper and the third in the center of the range where the phases are supposed to form emulsion. Other entries shall be used in this emulsion range to ensure the distance between them does not exceed 500 mm. **[INTERDISCIPLINARY INTERFACE][PRO, MEC]**

9.4.11.2 For the services which density varies either due to process variation throughout unit lifetime or to different services with different fluids, the equipment connections must be one bottom, one top, and one in the middle of the instrument. **[INTERDISCIPLINARY INTERFACE][PRO, MEC]**

## 9.5 Connections and Taps Table for Level Instruments Measurement

*Table 9.5-I - Connections and Taps for Level Instruments Table.*

| INSTRUMENT / ACESSORIES | EQUIPMENT CONNECTION/ PROCESS CONNECTION/ PROCESS TAP (Notes 1, 2) | IMPULSE TAP |
|---|---|---|
| Level Gauges | 2"/2"/2" | - |
| Differential Pressure Transmitters (DP) | 2"/2"/2" | According to Chapter 19 |
| Differential Pressure Transmitters (DP) with remote diaphragm seal | 3"/3"/3" | Capillary factory seal |
| Vessel Top Level Transmitter (future) | 6"/-/- | - |
| Interface transmitter mounted directly on side of vessel | 3"/3"/3" | |
| Standpipe of 4" ND | 4"/4"/4" | - |
| Level Transmitters mounted on top of *standpipe* | (Note 3)/-/- | - |

**Notes:**

(1) For vessels and tanks with internal coatings or when the specification to withstand working pressure results in equipment tap with an inside diameter of less than 50mm, the connections and process taps defined as 2" shall be increased to 3". **[INTERDISCIPLINARY INTERFACE][PRO, SNAV, MEC, 3D]**

(2) All pressure vessel connections, equipment and process, shall be flanged and minimally specified for the pressure class of 150#. **[INTERDISCIPLINARY INTERFACE][PRO, SNAV, MEC, 3D]**

(3) Connection to equipment (standpipe) shall be as required by the instrument where concentric reductions may be used.

# 10 REQUIREMENTS FOR GAS AND FLAME DETECTORS

## 10.1 Flame Detectors

### 10.1.1 Installation

10.1.1.1 In order to avoid spurious actions due to flare flame, the flame detectors shall be installed opposite to the flare with their line of sight pointed down, at an angle to the horizontal. The angle to the horizontal shall be determined following the recommendations of the MANUFACTURER in conjunction with the location studies made in 3D models where the position and size of the flame of the flare shall be modeled and the detector viewing cone cannot pick up the flame of the flare. **[INTERDISCIPLINARY INTERFACE][HSE, 3D]**

10.1.1.2 Weather protection shall be provided for all detectors installed in open area.

### 10.1.2 Calibration and testing

10.1.2.1 A calibration kit, one per detector type, shall be provided in order to stimulate the detector at the distances established by the MANUFACTURER.

## 10.2 Gas Detectors

### 10.2.1 Installation

10.2.1.1 A hydrophobic filter shall be provided for any sensor installed in an open area to protect against bad weather.

### 10.2.2 Gas Detector Cell Lifetime

10.2.2.1 In order to maximize the lifetime use of sensor cells, the date of delivery by the VENDOR shall be made at a later date than the respective transmitters, being three (3) months before leaving the unit for its final location.

10.2.2.2 In order to perform the loop tests, an additional number of sensors equal to 5% of the number of detectors shall also be delivered after the transmitters but before the period described in 10.2.2.1.

10.2.2.3 The delivery time of the sensors shall be described in the technical reports to enable programming by the Commissioning of the date to start supplying the sensors.

### 10.2.3 Calibration and testing

10.2.3.1 A calibration kit shall be provided, one per detector type.

10.2.3.2 A sufficient number of bottles with standard gas shall be provided per type of gas sensor, for calibration of each detector to test them at least two (2) times.

# 11 REQUIREMENTS FOR THE SPECIFICATION OF FLOW INSTRUMENTS AND RESTRICTION ORIFICES

Instruments that shall comply with the INMETRO metrological framework and official regulations (ANP) shall also meet the requirements described in I-ET-3010.00-1200-813-P4X-001 – GENERAL CRITERIA FOR FLOW METERING SYSTEMS.

## 11.1 General Criteria

11.1.1 For instruments that do not need to comply with I-ET-3010.00-1200-813-P4X-001 – GENERAL CRITERIA FOR FLOW METERING SYSTEMS when totalization is specified, the flow signal shall be transmitted in one of the following ways, where compatibility with the reading equipment shall be checked in advance:

.#1) pulses up to 10kHz;

.#2) totalized in the instrument transmitter itself and transmitted via non-proprietary field network.

11.1.2 Every meter shall have a block valve and drain/vent valve, upstream and downstream, for maintenance purposes. Follow I-ET-3010.00-1200-813-P4X-001 – GENERAL CRITERIA FOR FLOW METERING SYSTEMS with regard to the block valve on fiscal, appropriation and custody transfer measurements.

11.1.2.1 Each meter with an operational purpose shall have, in addition to the block valves mentioned in item 11.1.2, by-pass valves. This requirement does not apply to fiscal, appropriation and custody transfer measurements as defined by the ANP. **[INTERDISCIPLINARY INTERFACE][PRO, PIP, 3D]**

11.1.3 In the installation of turbines, positive displacement meters and Coriolis type mass meters, the piping arrangement and meter installation location shall be designed to prevent fluid vaporization through the meter. **[INTERDISCIPLINARY INTERFACE][PRO, PIP, 3D]**

11.1.4 For all components, shall be observed the maximum speed to which they can be subjected, and not only the meter itself, e.g. gas filters, which generally have a maximum input velocity of 20 m/s. The design of the lines shall maintain these limits and the necessary diameters shall be fed back to the design of the instruments and accessories. **[INTERDISCIPLINARY INTERFACE][PRO, PIP, 3D]**

11.1.5 The length of straight pipe runs shall be designed taking into account the maximum uncertainty of pipe internal diameter, that is, nominal pipe diameter (NPD) plus maximum uncertainty. This is to guarantee that pipe run length will always be greater than actual constructed pipe run. To the calculated pipe run it shall be added a length of 0.5D.

Example: For minimum straight pipe run of 17D it shall be used:

Length to be used for a necessary pipe run of 17D shall be 17x(NPD+maximum uncertainty)+0.5x(NPD+maximum uncertainty). This shall also be taken into account for installation of flow conditioners and sampling probe positioning downstream any disturbance.

## 11.2 Restriction Orifices

### 11.2.1 Application

Used whenever it is necessary to obtain a permanent pressure drop in a straight section of the piping or when a restriction is desired for a flow. Examples: Flow limitation in on-off control of condensate in vessels, limitation of gas flow when condensate level control loop is lost (gas blow-by) and flow limitation in BDVs.

### 11.2.2 Materials and Constructive Details

11.2.2.1 Restriction orifices shall be made of AISI 316 stainless steel. Where this material is not suitable for process conditions, other more suitable material shall be used.

11.2.2.2 For fluids with subcritical flow, the manufacturing dimensions and tolerances shall be in accordance with ISO 5167-1 standard. For critical flow a calculation report and a dimensional drawing shall be submitted for analysis by PETROBRAS, in accordance to annexes A and B.

### 11.2.3 Installation

11.2.3.1 Restriction orifices shall be installed between flanges, pressure class 150# minimum.

### 11.2.4 Calculation of Restriction Orifices

11.2.4.1 For subcritical flow the calculation of restriction orifices shall be in accordance with ISO 5167-1 standard, taking into account the permanent pressure drop for straight edge orifice with 2 ½ D and 8 D pipe taps.

11.2.4.2 For critical flow, a calculation report shall be presented for PETROBRAS analysis, according to annexes A and B. As an example of application, restriction orifices associated with BDVs can be considered.

11.2.4.3 For vessel on-off level control, the time of emptying of the liquid is determined by the restriction orifice. In the event of a failure in the control, opening XV, gas migration will occur through the restriction orifice (gas blow by) with a flow being a consequence of the same dimensioning. The Process discipline shall determine the time of emptying as well as the design of the protection devices downstream of the restriction orifice in the blowby gas condition. **[INTERDISCIPLINARY INTERFACE][PRO, PIP, 3D]**

11.2.4.4 For vessel level control, the calculation of the control valve and the restriction orifice shall be done in an iterative manner. First, the valve for liquid level control is calculated, without considering the orifice. Then the orifice is calculated to restrict the gas flow in a blowby gas condition, considering total opening of the control valve. Then, the valve is recalculated to the liquid level control condition, this time considering the orifice calculated in the previous step. Orifice and control valve calculations are performed until their respective parameters converge. **[INTERDISCIPLINARY INTERFACE][PRO, PIP, 3D]**

## 11.3 Coriolis Mass Flowmeters and Volumetric Flow Meters of Positive Displacement (PD) Type

11.3.1 Application Criteria

11.3.1.1 A set of meters (parallel installation) shall be specified whenever a single meter cannot cover the entire flow range. **[INTERDISCIPLINARY INTERFACE][PRO, PIP]**

11.3.1.2 Where there is vibration in the process line or pulsating flow, mass-type meters (Coriolis) shall be avoided. For the case of line vibration, item 11.3.3.4 can be used as an alternative. **[INTERDISCIPLINARY INTERFACE][PRO]**

11.3.2 Materials, Accessories and Construction Details

11.3.2.1 The parts of the meters that have contact with process fluid shall be made of AISI 316 stainless steel. Where this material is not suitable for process conditions, other more suitable material shall be used.

11.3.2.2 Positive displacement (PD) type meters shall be equipped with drain and vent valves or plugs, as well as upstream filters.

11.3.3 Installation

11.3.3.1 Where there is a significant presence of gases or vapors in the fluid, a gas elimination device shall be installed upstream of the meter to ensure continuous immersion of liquids in the meter in operation. **[INTERDISCIPLINARY INTERFACE][PRO, PIP, 3D]**

11.3.3.2 For positive displacement type meters, when the flow rate can reach values greater than the maximum flow rate of the meter, the flow measurement shall be made through a setpoint flow control loop at the maximum flow rate of the meter, in order to protect it. **[INTERDISCIPLINARY INTERFACE][PRO]**

11.3.3.3 Follow item 11.1.3.

11.3.3.4 As an alternative to the vibration problem in the line mentioned in item 11.3.1.2, upstream and downstream expansion joints of Coriolis meters shall be installed. **[INTERDISCIPLINARY INTERFACE][PIP, PRO]**

## 11.4 Turbine Type Meters

11.4.1 Application Criteria

11.4.1.1 Turbine-type flow meters shall have their measurement uncertainty of up to 0,6% and the loop uncertainty of up to 1%, taking into account the range of viscosity of the fluid and its temperature.

11.4.1.2 For pulsed flow services, turbine type meters shall be avoided. **[INTERDISCIPLINARY INTERFACE][PRO]**

11.4.1.3 Pulsed flow services are not suitable for turbines, where the measurement uncertainty increases considerably. Another technology shall be chosen, less susceptible to pulsations in the line or eliminate the pulses, installing pulse dampers.

11.4.2 Materials and Constructive Details

11.4.2.1 If used for the measurement of produced oil, turbines with helical type rotor shall be specified.

11.4.2.2 Turbine gas meters shall withstand 25% overspeed without damaging their mechanisms.

11.4.3 Installation

11.4.3.1 Preferably, turbine type meters shall be installed horizontally, in vibration-free lines and distant from electrical equipment radiating electromagnetic fields. **[INTERDISCIPLINARY INTERFACE][PIP, 3D]**

11.4.3.2 The installation of turbine-type meters for gas or liquid totalization shall be made in such a way that there is no accumulation of liquid points in the gas measurement or gas (or vapor) accumulation in the liquid measurement. **[INTERDISCIPLINARY INTERFACE][PIP, 3D]**

11.4.3.3 A filter sized in accordance with ANSI/ ISA-RP31.1 recommendations or a more stringent filtration when specified or recommended by the MANUFACTURER shall be installed upstream of each meter. **[INTERDISCIPLINARY INTERFACE][MEC, PRO, ARR, PIP, 3D]**

11.4.3.3.1 When there is no spare meter, two filters in parallel shall be installed upstream of the turbine meter. These filters shall be sized according to ANSI/ISA-RP31.1 recommendations or more stringent filtration when specified or recommended by the MANUFACTURER. This requirement applies to both liquid and gas flows. These filters shall be installed upstream of the by-pass described in item 11.1.2.1. **[INTERDISCIPLINARY INTERFACE][MEC, PRO, ARR, PIP, 3D]**

11.4.3.4 The minimum straight piping lengths upstream and downstream of the meter shall follow the recommendations of the MANUFACTURER and the API-MANUAL OF PETROLEUM MEASUREMENT STANDARDS chapter 5, section 3 and ISO 2715 for liquid operation, and AGA REPORT NUMBER 7 for gas operation. In the latter case, the position on the pipe of the temperature measuring point shall also be according to the same AGA report. **[INTERDISCIPLINARY INTERFACE][ARR, PIP, 3D]**

11.4.3.5 Follow item 11.1.3 to avoid vaporization of fluids.

## 11.5 Variable Area Meters

11.5.1 Application Criteria

11.5.1.1 Variable area meters (rotameters) shall only be used for local indication and shall not be used for signal transmission.

11.5.1.2 Rotameters are recommended for services with liquids and gases, both clean and with no significant variation of viscosity.

11.5.1.3 In applications with air, inert gases or water and in diameters up to 2”, the rotameter can be constructed with impact resistant glass tubes.

11.5.1.4 For services with toxic fluids, flammable or in diameters above 2”, the body of rotameters shall be made of metal.

11.5.2 Materials and Constructive Details

11.5.2.1 Rotameters constructed with glass tubes shall be impact resistant, taking into account the pressure and temperature limits of the process.

11.5.2.2 Metal body rotameters shall have vertical inlet and side outlet and their floats shall be removable from the top. The indication shall be made by magnetic coupling between the float and the indicating element.

11.5.2.3 For applications where flow is subject to sudden or periodic (pulsed flow) variations, the rotameter shall have a guide rod to maintain float alignment.

11.5.2.4 Rotameters may have embedded electrical contacts as long as they are not part of any emergency action. They shall also comply with what was established in item 6 (GENERAL REQUIREMENTS FOR INSTRUMENTATION SPECIFICATION).

11.5.3 Installation

11.5.3.1 Rotameters shall be installed vertically with upward flow. **[INTERDISCIPLINARY INTERFACE][PRO, ARR, PIP, 3D]**

11.5.3.2 The installation shall avoid points of accumulation of liquid or gas.

11.5.3.3 By-pass valves and block valves shall be provided. **[INTERDISCIPLINARY INTERFACE][PRO, ARR, PIP, 3D]**

11.5.4 Performance criteria

11.5.4.1 When not specified in design, the measurement uncertainty shall be a maximum of 3% of the measured value. The minimum uncertainty class shall be chosen according to VDI/VDE 3513 BLATT 1.

**11.6 Flow Switches**

11.6.1 Application Criteria

11.6.1.1 Thermal dispersion type flow switches may be used for interlocking systems in process fluids and utility fluids that serve the process when the use of flow transmitter is not of interest for the nominal flow rate. **[INTERDISCIPLINARY INTERFACE][PRO]**.

# 12 REQUIREMENTS FOR THE SPECIFICATION OF CONTROL VALVES

## 12.1 Selection of the body type

12.1.1 Applicability limits respected, the type of valve used for usual services shall be defined according to the following order, being that the latter option may only be used when the previous option is not technically feasible and formal consultation shall be made to PETROBRAS analysis:

.#1) single seat cage globe valves;

.#2) butterfly valves.

**NOTE:** Other types of valves can be used in cases where the types mentioned are not the best solutions.

12.1.2 For cases where the flow coefficients (Cv) of a globe valve are not sufficient and small differential pressure is required, butterfly valves may be used.

12.1.3 The minimum leakage class for any type of control valve is Class IV, according to the standard FCI 70-2.

12.1.3.1 Where line isolation and/or absolute tight shut-off is required in normal operation, such as pressure control valves aligned to flare, the valve shall be inspected and tested according to API STD 598 and a certificate shall be issued. Following tests/documents are required to be implemented/issued:

.#1) High pressure backseat test (API STD 598);

.#2) High pressure closure test (API STD 598);

.#3) Test fluid for tests 12.1.3.1.#1 and 12.1.3.1.#2 shall be inert gas (API STD 598);

.#4) The temperature of fluid in tests 12.1.3.1.#1 and 12.1.3.1.#2 shall the maximum operational temperature stated in valve datasheet (API STD 598);

.#5) Certificate of Compliance stating all required tests (API STD 598);

.#6) Material test report for stem (API STD 598);

.#7) Control valve stroke test (see item 12.7.5 for additional information).

## 12.2 Inherent Characteristic of the Valve

12.2.1 The flow characteristic shall be chosen according to the following criteria:

X= ΔP_valve/ΔP_system

Where:

ΔP_valve is the differential pressure through the valve in the normal operating flow condition;

ΔP_system is the total dynamic differential pressure (pressure drop on pipelines and equipment) of the system in which the valve is inserted, including the differential pressure through the valve at the normal operating flow. This differencial pressure is divided into 3 parts: First is the differential pressure between the first controlled pressure point or pump discharge up to the valve inlet flange; The second is the differential pressure through the valve, the ΔP_valve; The third is the differential pressure between the valve outlet flange up to the next controlled pressure point. **[INTERDISCIPLINARY INTERFACE] [3D, MEC, PRO, PIP]**

**NOTE 1**: Values for static pressure differential shall not be considered.

Therefore:

.#1) for X greater than or equal to 0.6 use linear characteristic;

.#2) for X greater than 0.4 and smaller than 0.6, use modified parabolic characteristic or equal percentage;

.#3) for X greater than or equal to 0.2 and less than or equal to 0.4, use equal percentage characteristic;

.#4) avoid X less than 0.2, as the control capacity of the valve is compromised in this range.

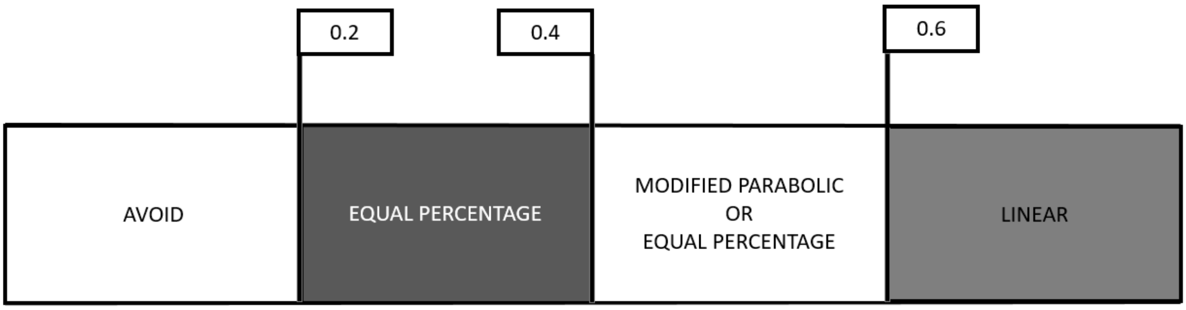


*Figure 12.2-I - Inherent characteristic of control valves as a function of ratio "X".*

12.2.2 For compressor recycling (anti-surge) and flare alignment services, control valves shall have an inherent linear characteristic. **[INTERDISCIPLINARY INTERFACE][TBM]**

### 12.3 Installation

12.3.1 Each control valve shall have block valves. In control loops where response time is compatible with local manual actuation positioned by operator intervention, one or more globe valves in parallel shall be provided for execution of this local manual control. The arrangement of manual globe valves in parallel shall be designed to encompass the entire operational range of the automatic control valves. **[INTERDISCIPLINARY INTERFACE][PRO, PIP, ARR, 3D]**

12.3.2 Closed failure type control valves shall have a 3/4" NPT drain/vent valve upstream and downstream of the valve. Open failure type control valves shall have a 3/4" NPT upstream.

## 12.4 Constructive Characteristics

### 12.4.1 Connections

12.4.1.1 The flanges shall be in conformity to ANSI B-16.5 and the face-to-face dimension in accordance with ASME B16.10.

### 12.4.2 Internals

12.4.2.1 In cases where pressure drop produces loud noise and/or cavitation, balanced or pilot shutter type internals shall be used. When necessary, anti-cavitation and noise reducing cage or special valves shall be used for severe applications, considering valves for severe applications where the total pressure drop is obtained through successive drops of pressure in order to limit the speed of the fluid along the valve, minimizing the noise generated and the Vena Contracta pressure and consequently the wear caused by excessive speed and cavitation.

### 12.4.3 Materials

12.4.3.1 The usual material for the control valve body shall be carbon steel, except when the process conditions or the specification of the piping require other material. Cast iron valves may be accepted when permitted by the piping specification.

12.4.3.2 The internals (shutters and seats) shall be at least AISI 304 stainless steel. In cases where this material is not suitable for process conditions or piping specification, other more suitable material shall be used.

12.4.3.3 Internals shall be made of hardened stainless steel when the pressure differential through the valve exceeds 10 bar in flashing services, with fluids containing solid particulates in suspension, or when cavitation occurs.

12.4.3.4 The packing material shall be PTFE, unless the process conditions require other material.

## 12.5 Sizing

12.5.1 The sizing shall conform to ISA 75.01.01 standard and shall take into account: rangeability, flow type - subcritical or critical with flashing or cavitation, influence of viscosity, biphasic flow, flow velocity (limited to 10m/s for services with liquid and 110m/s for services with gases or vapors) and noise level, which shall be limited to 82 dBA measured at 1.0 m downstream of the valve and 1.0 m of the piping surface in accordance with IEC 60534. Valves for severe application/service shall be used for cases where there is cavitation, flashing, biphasic flow, flow velocity or noise above the limits previously mentioned in this item.

12.5.2 The sizing of the actuator shall take into account the largest pressure differential to which the valve will be subjected.

12.5.3 The flow coefficient of the chosen control valve (CV valve) shall be such that:

.#1) CV_minimum shall be achieved with an opening greater than or equal to 10%;

.#2) CV_maximum shall be achieved with an opening less than or equal to 90%;

.#3) CV_normal shall be obtained in openings less than 70%.

12.5.4 The chosen CV shall be immediately higher than the calculated theoretical value, extracted from MANUFACTURERS' catalogs.

## 12.6 Actuators

12.6.1 The control valve actuators shall preferably be of the diaphragm type. If the ΔP does not allow its use, the piston type shall be used. Other special actuators may be used in specific applications, subject to prior approval by PETROBRAS.

12.6.2 All valves shall be equipped with a stem opening percentage indicator.

## 12.7 Valve Positioners

12.7.1 All control valves used in control loop (PID, etc.) shall be equipped with electro-pneumatic smart positioners.

12.7.2 Valve positioners shall be capable of implementing the various flow characteristic curves as a function of valve opening as defined by ANSI/ISA-75.11.01 standard as well as being capable of working with specific curves for the application or specific points, determined externally and transferred to the positioner or even from set of points fed into the positioner, being the curve generated by positioner itself. The positioner shall be able to work with sets of at least 12 pairs of coordinates.

12.7.3 Filter regulator and positioner shall be provided already installed on the valve. Pneumatic connections and tubing shall be as per Chapter 19.

12.7.4 The pressure gauges supplied together with filters and valve positioners shall be made of AISI 304 stainless steel or thermoset phenolic polymer. The mechanism and pointer shall also be AISI 304 stainless steel and AISI 316 stainless steel connection.

12.7.5 It shall be demonstrated that the positioner Cv is adequate to guarantee the valve opening or closing stroke time required by the system. In situations where is required from the valve a fast response, as in a PV aligned to flare that must open quickly to avoid a very high pressure (PSHH), it shall be foreseen, in this order, a positioner with a high flow capacity or a booster. Over again, it shall be demonstrated that the positioner Cv is adequate to guarantee the valve opening or closing stroke times. See item 6.5.14 and sub items for requirements regarding tubing and connections for pneumatic air supply to consumers. **[INTERDISCIPLINARY INTERFACE][PRO, TBM, SNAV, PIP]**

12.7.6 Maximum pressure drop from instrument air distribution header and consumer are defined in Chapter 19.

## 12.8 Accessories

12.8.1 The use of manual drive devices (hand wheels) for valves with a diameter equal to or greater than 8" shall be studied on a case-by-case basis. **[INTERDISCIPLINARY INTERFACE][ARC]**

## 12.9 Minimum Pump Flow

12.9.1 For minimum flow control of centrifugal pumps, an automatic control valve self-operated by flow shall be used, except in cases where the control is implemented via variable frequency or speed drive for the pump actuator. **[INTERDISCIPLINARY INTERFACE][PRO, PIP]**

12.9.2 When the above solutions are not recommended, a control valve associated with a flow controller shall be used.

12.9.3 If necessary, a restriction orifice in the recirculation line downstream of the minimum flow control valve may be used to reduce the differential pressure on the valve, the ΔP _valve.

## 12.10 Choke Type Valves with Actuators

12.10.1 These valves shall only be used for regulating the pressure of crude oil (before the production collector) and in gas/water injection services and shall comply, at least, with the following requirements:

.#1) The valve diameter should not be smaller than the nominal line diameter minus 2” (e.g. in a 10” diameter line the choke diameter should not be less than 8”);

.#2) Be of the cage type with outer sleeve or be of the plug and cage type;

.#3) Valves with a nominal diameter greater than 3” must be balanced (compensation system) to reduce the torque required by the valve for its operation;

.#4) The valve bonnet can be threaded to nominal diameters up to 2”. Above this diameter the valve bonnet shall be held to body by fasteners;

.#5) The actuator shall preferably be electrical type (4-20 mA + HART signal command), being acceptable the alternative of the steeping type actuator with pulse signal command for each step, in both ways (open and close);

.#6) The inherent characteristic of the valve shall be of equal percentage;

.#7) All valves shall have a manual operation device for opening and closing;

.#8) They shall have an electronic position transmitter (4 - 20mA, 2 wire, 24 Vdc) for remote monitoring; the linearity of these devices over the entire range shall be guaranteed. Other position transmission systems will be subject to prior approval by PETROBRAS;

.#9) A local position indicator shall also be provided, with a scale covering 0 - 100% aperture, and with an uncertainty less than 0.5% of its total range.

12.10.2 For each code YY (material family) of the coding rule of the piping specification, exposed on technical specification document of the project entitled PIPING SPECIFICATION, valve materials, test requirements and design temperature limits are described in

12.10.3 Table *12.10-I*.

*Table 12.10-I - Choke Valve Requirements.*

| YY CODE | BODY MATERIAL | SEAT / INTERNALS MATERIAL | TEST REQUIREMENTS | MIN./MAX. DESIGN TEMPERATURE (ºC) |
|---|---|---|---|---|
| 12 | ASTM 995 Gr. 6A | TUNGSTEN CARBIDE | API 6A PR2 PSL 3G | -50/+110 |
| 16 | ASTM 995 Gr. 4A | TUNGSTEN CARBIDE | API 6A PR2 PSL 3G | -50/+100 |
| 30 | INCONEL 625 (UNS N06625) | TUNGSTEN CARBIDE | API 6A PR2 PSL 3G | -100/+150 |
| 31 | ASTM A522 Type I | TUNGSTEN CARBIDE | API 6A PR2 PSL 3G | -100/+93 |

# 13 REQUIREMENTS FOR THE SPECIFICATION OF RELIEF DEVICES

## 13.1 Safety and Relief Valves of Pressure and Vacuum

13.1.1 Selection and Sizing Criteria

13.1.1.1 Selection and sizing shall be in accordance with standards API STD 526 and API STD 520 PT I. Valves intended for atmospheric tanks shall comply with API STD 2000.

13.1.1.2 Pilot-operated valves may only be used conditioned to PETROBRAS approval.

13.1.2 Installation

13.1.2.1 PSVs shall have upstream and downstream valves. Block valves shall be according to the technical specification document of the project entitled PIPING SPECIFICATION. **[INTERFACE INTERDISCIPLINAR][MEC, PIP, PRO]**

13.1.2.2 On installations with backup PSVs, a device for mechanical interlocking between the upstream and downstream block valves shall be provided in order to always ensure that a flow capacity of less than 100% of the design depressurization is never in line. This shall be ensured even during an operation to remove a PSV for maintenance, i.e. the spare PSV(s) is (are) aligned before locked the PSV(s) to be removed for maintenance. Mechanical interlocked valves shall be highlighted on P&IDs with Interlock Control (ILC) propriety. **[INTERFACE INTERDISCIPLINAR][MEC, PIP, PRO]**

13.1.2.2.1 The blocking valve downstream of each PSV shall always remain open when installed, even if it is not in operation. The blocking valve downstream of the PSV can only be closed to allow the PSV to be removed for maintenance. The mechanical interlock described in item 13.1.2.2 shall comply with this requirement, having a sequence for alignment and a sequence for blockage and withdrawal of PSV for maintenance.

13.1.2.3 The pressure and diameter classes of the inlet and outlet flanges of the PSVs shall be in accordance with the tables of item 11 of API STD 526 for the specified orifice. The pair of inlet and outlet flanges shall be chosen to provide the desired set pressure at the desired relief temperature. If the pressure class of the inlet or outlet flange is greater than the pressure class of the line that connects to it, it shall be revised to the same PSV flange pressure class. **[INTERDISCIPLINARY INTERFACE][PRO, MEC, PIP]**

13.1.3 Materials and Technical Requirements

The materials used in the components of the safety and relief valves shall be in accordance with annex K of PIPING SPECIFICATION.

13.1.3.1 In cases where these materials are not appropriate to the process conditions, other more suitable material shall be used.

13.1.3.2 All safety and relief valves shall have capacity certificates in accordance with ASME Section VIII Division I, provided by a qualified and competent certifying entity.

13.1.3.3 Safety and relief valve certificates shall include the pressure setting range of the spring provided. The spring shall allow adjustments of +/- 10% of the relief pressure for pressures up to 1800 kPa (18 bar) and +/- 5% for pressures above 1800 kPa (18 bar). The adjusting screw shall be protected by a cap or hood (threaded or screwed).

**13.2 Rupture Disks**

13.2.1 The use of rupture disks as safety and relief devices is defined by the Process discipline. When used, its rupture tolerance, deviation between the stamped burst pressure and the actual burst pressure, shall conform to ASME, Section VIII, Division I, UG-127 (a). The rupture disk shall be specified to make compatible the process and temperature ranges, rupture disk operating ratio, rupture disk setpoint value and rupture disk burst pressure range between manufacturing lots. **[INTERDISCIPLINARY INTERFACE][PRO]**

13.2.2 Rupture disks shall not be used when the difference between yield stress of the disk in operating and relief temperatures is higher than 3%. In any service, the relief and operating temperatures shall be specified.

13.2.3 The design of rupture disks shall be non-fragmenting type.

13.2.4 Rupture disk damage ratio shall be less or equal to 1. Damage ratio shall never be above 1.

13.2.5 Rupture disk reversal ratio shall be less or equal to 1. Reversal ratio shall never be above 1.

13.2.6 Rupture disk manufacturing range shall be 0%.

13.2.7 The minimum operating ratio shall be 90%. When designing a rupture disk, it shall be taken into account different manufacturing lots. Therefore, it shall be demonstrated that two rupture disks from different manufacturing lots are compatible with process conditions even when considered all process variations, process back pressure and all uncertainties and factors that would make rupture disk from first lot to burst at the lowest pressure and rupture disk from second lot to burst at the highest pressure. Higher operating ratios may be considered for more critical conditions when aforementioned demonstration reveals not possible with 90% operating ratio. **[INTERDISCIPLINARY INTERFACE][PRO, SNAV. MEC]**

### 13.3 Buckling Pin Valves

The use of buckling pin valves is acceptable, once the following requirements are followed:

13.3.1 The use of Buckling Pin Valves as safety and relief devices is defined by the Process discipline. When used, they shall be used in accordance with ASME section VIII, Division 1 and Case 2091.3 (Buckling Pin Pressure Relief Devices Section VIII, Division 1). **[INTERDISCIPLINARY INTERFACE][PRO]**

13.3.2 Leak tests shall follow API STD 527.

13.3.3 Installation and maintenance procedures shall comply with API STD 520 PT II.

## 14 VALVES FOR EMERGENCY SHUTDOWN (SDV), AUTOMATIC DEPRESSURIZATION (BDV), ALIGNMENT AND ON-OFF CONTROL (XV)

### 14.1 Emergency Shutdown Valves (SDV) and Automatic Depressurization Valves (BDV)

14.1.1 Concept

14.1.1.1 Shutdown valves or emergency shutdown valves are the final automatic control elements which are actuated by the Production Unit Safety System and/or equivalent unit of the PACKAGE UNIT, having the function of blocking certain process circuits and equipment, or opening other circuits to allow the flow of fluid and depressurizing equipment (in this case they are called Blowdown Valves or automatic depressurization valves).

14.1.1.2 These valves are continuously maintained in the operating position, open for SDVs and closed for BDVs, by signals received from the Safety System or the interlocking (protection) logic of the PACKAGE UNIT.

14.1.1.3 If a trip or emergency shutdown occurs, the signal mentioned in item 14.1.1.1 is interrupted, which brings the valve to its safe position. See item 14.1.2.2 to determine the required valve response time.

14.1.2 Characteristics

14.1.2.1 Valves SDVs and BDVs shall be designed following the valve specification level (VSL) and the requirements established on the technical specification document of the project entitled PIPING SPECIFICATION.

14.1.2.2 The necessary valve travel time from operational to its safe position, cited in item 14.1.1.3, shall be determined by the discipline responsible for the system. The actual valve travel time shall be, at least, 1 second for each inch of nominal valve diameter, where shorter times can be required when determined by the necessary valve travel time. Times greater than 1 second for each inch of nominal valve diameter can only be used in specific situation such as described in item 14.1.5.1.1. In any case, the actual valve travel time shall be a maximum of 45 seconds, as per API RP 14C. **[INTERDISCIPLINARY INTERFACE][HVAC, PRO, SNAV, TBM]**

14.1.3 BDV Valves - Installation

14.1.3.1 All BDV valves shall have an air reservoir sized to perform alone, 1 (one) BDV operation. This vessel shall be calculated from the minimum instrument air distribution pressure after opening the BDV, so that the remaining vessel pressure is 30% above the minimum pressure of the pneumatic specification of the valve actuator.

14.1.3.2 In order to limit the rate of depressurizing of the unit according to the calculation of aperture sequencing of the various BDVs, whenever there is a need for flow restriction, it shall be done through a calculated restriction orifice and constructed to produce a critical flow.

14.1.3.3 In blackout situations, when all electric energy to automation system fails, all solenoids of all BDVs will be deenergized simultaneously. To avoid a massive depressurization that would surpass the capacity of the Flare, some BDVs listed by Process and Safety disciplines must have a mechanical temporization skid to delay its opening by a specific amount of time defined for each BDV.

14.1.3.3.1 The temporization delay skid shall be based on pneumatic principle and respective time delay value shall be achieved through a stored volume of instrument air at the pressure less or equal to the minimum instrument air distribution that will be depressurized through a to needle valves in series, one being a precision needle valve and the other a metering valve (calibrated needle valve with defined flow capacity for each opening). The BDV shall open when the accumulated pressure reaches 2 barg. Item 14.1.6.5 shows the schematic of a pneumatic control of a BDV with mechanical temporization delay.

14.1.4 Actuators

14.1.4.1 The VENDOR of the respective valve shall specify and supply the actuator.

14.1.4.2 Passive protection in actuators shall be applied following the specifications of the Safety Discipline specifications. **[INTERDISCIPLINARY INTERFACE][HSE]**

14.1.4.3 These valves shall be driven by pneumatic circuits which shall have quick exhaust valves. The drive circuit passes through a three-way valve, or other type of valve, depending on the specific needs of the safety function.

14.1.4.4 These valves are continuously powered by signals received from the Safety System or the interlocking (protection) logic of the PACKAGE UNIT.

14.1.4.5 During normal operation, with the pilot valve energized, the actuation circuit keeps the valve actuator pressurized. If a trip or emergency shutdown occurs, the signal to the pilot valve is interrupted, deenergizing it, initiating the depressurization of the actuator through the pilot and consequently activating the quick escape valve, depressurizing the actuator completely with reversion of the valve to its safe position.

14.1.4.6 Actuators for the actuation of SDV or BDV shall be pneumatic piston type, with spring return. Only for SDV actuation, hydraulic circuits shall be used whenever at least one of the following conditions is satisfied, ND being the nominal diameter. BDVs actuators shall always be pneumatic type:

.#1) Simultaneously ND greater than or equal to 4" and Pressure class greater or equal to 1500#;

.#2) Simultaneously ND greater than or equal to 8" and Pressure class greater than or equal to 900#;

.#3) Simultaneously ND greater than or equal to 12" and Pressure class greater than or equal to 600#;

.#4) ND greater than or equal to 14";

.#5) All SDVs of Pressure Class 10000#.

14.1.4.7 Multi-spring actuators may be used using sets of 2 bagged springs or single springs in configurations of up to three sets/single springs at 120° or two sets/single springs in series.

14.1.4.7.1 Configurations of multi-spring actuators that extrapolate those mentioned in the item above can only be adopted by submitting test reports that prove its long-term functionality for analysis and release by PETROBRAS.

14.1.4.8 Actuation shall be designed so that during actuator depressurization the flow of vented instrument air path passes by actuator springs compartment and to non-pressurized piston compartment. The purpose is to allow clean air to be directed into these compartments instead of ambient air from a marine atmosphere which is potentially corrosive. Item 14.1.6 depicts this requirement.

14.1.4.9 For hydraulic actuators, a similar solution shall be implemented, with depressurized hydraulic fluid path passing by non-pressurized compartment. Item 14.1.6 depicts this requirement. Regarding actuators springs it shall be proposed a solution to avoid air from marine environment to enter springs compartment.

14.1.4.10 Sizing

14.1.4.10.1 In both opening and closing, the actuator shall be capable of providing a torque 2 times greater than the torque required by the valve, throughout its course of action. The largest torque supplied by the actuator shall not exceed the maximum torque allowed by the stem of the valve (MAST - Maximum Allowable Stem Torque).

14.1.4.10.2 The design of the automatic depressurizing valve actuator, BDVs, shall be done considering the maximum differential pressure, considering the overpressure of the PSV.

14.1.4.10.3 For emergency shutdown valves (SDV) the spring shall be dimensioned to guarantee the closing time according to item 14.1.1.3. For emergency shut-off valves (SDV) with resources (system with valves and associated lines) to reduce the difference between the upstream and downstream pressures (differential pressure in closed condition) for opening the SDV, the actuator sizing may consider this differential pressure for valve opening. For emergency shut-off valves without the resources for differential pressure reduction in closed condition, the actuator shall be dimensioned by the maximum differential pressure developed after closing the actuator.

14.1.4.10.3.1 The valve used for differential pressure reduction in closed condition shall also be an SDV and be specified with the same requirements applicable to the main SDV.

14.1.4.10.4 The alternative of installing differential pressure reduction features in closed condition shall be evaluated from the point of view of cost/benefit and safety.

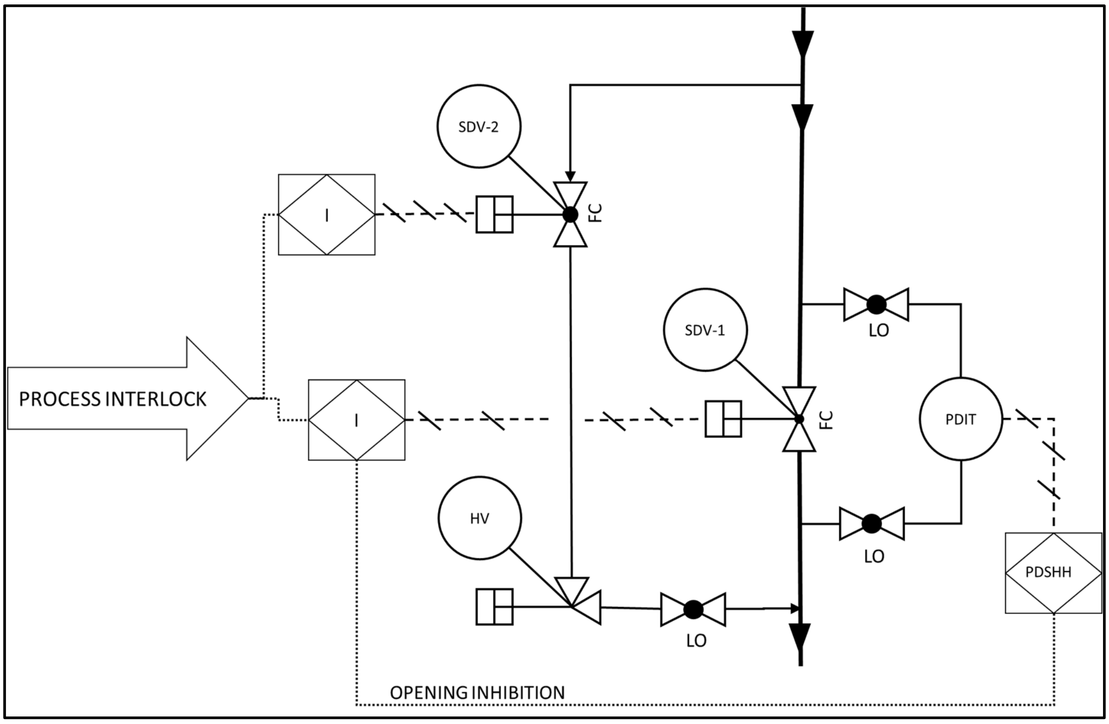


*Figure 14.1-I – Feature example of differential pressure reduction.*

## 14.1.5 Accessories

14.1.5.1 Actuators shall be equipped with accessories such as position switches, pilot valves, quick exhaust valves, flow regulators and their associated installation materials. The quick exhaust valves shall always be external type to easy inspection and maintenance. Therefore, it is not acceptable, for example, quick exhaust valves embedded in flanges.

14.1.5.1.1 It shall be possible to control opening and closing time of BDVs and SDVs. This is necessary to avoid unnecessary energy, either pneumatic or hydraulic, during opening and avoid, during closing, the possibility for hydraulic shock. Nevertheless, the valve actuation time shall be in conformity with item 14.1.2.2. See in items below simplified schematics for SDV and BDV actuations (PSVs for valve actuators are not represented).

14.1.5.2 Position switches shall have their contacts actuated by magnetic coupling and shall have a rotating mechanical position visual indication with transparent protection mechanism of the movable part, with open/closed indication by means of different colors and black inscriptions. The current position of the valve shall be easily viewed from the side and top of the indicating device. They shall also allow adjustment of the actuation points without disassembling the valves. The contact of the position indication switches shall be Normally Open (NO) and close when the valve reaches the limit switch.

14.1.6 Schematics for SDV and BDV actuations

14.1.6.1 Legend for *Figure 14.1-III* to *Figure 14.1-VI*.

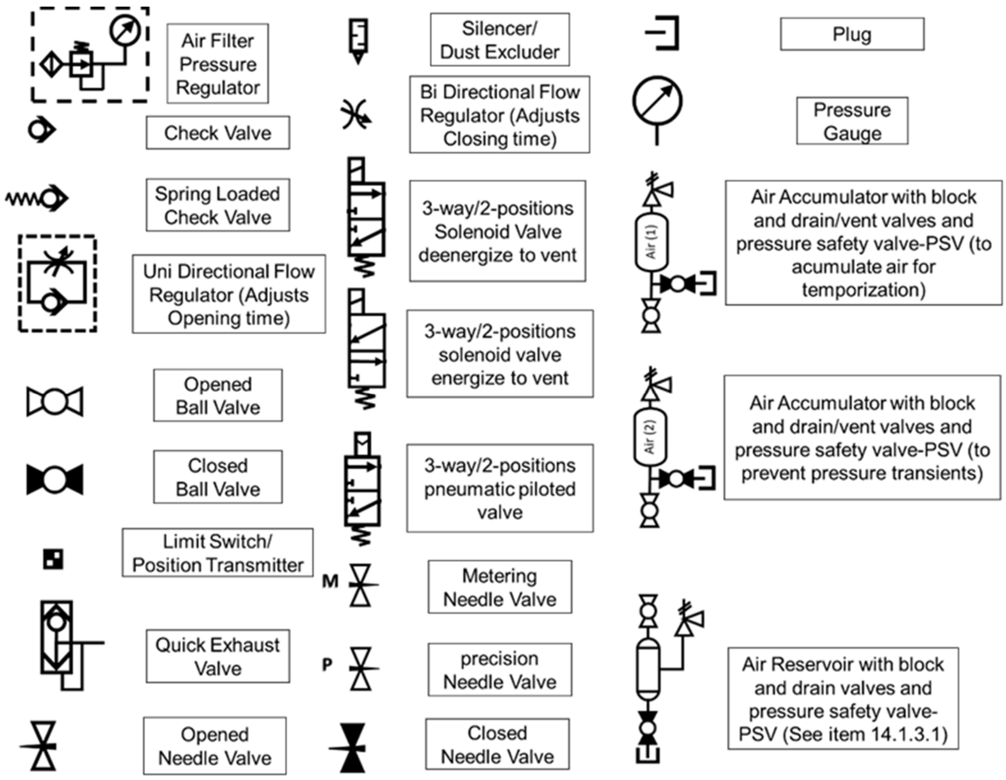


*Figure 14.1-II – List of components used in Figure 14.1-III to Figure 14.1-VI.*

14.1.6.2 Schematics for SDV pneumatic actuation

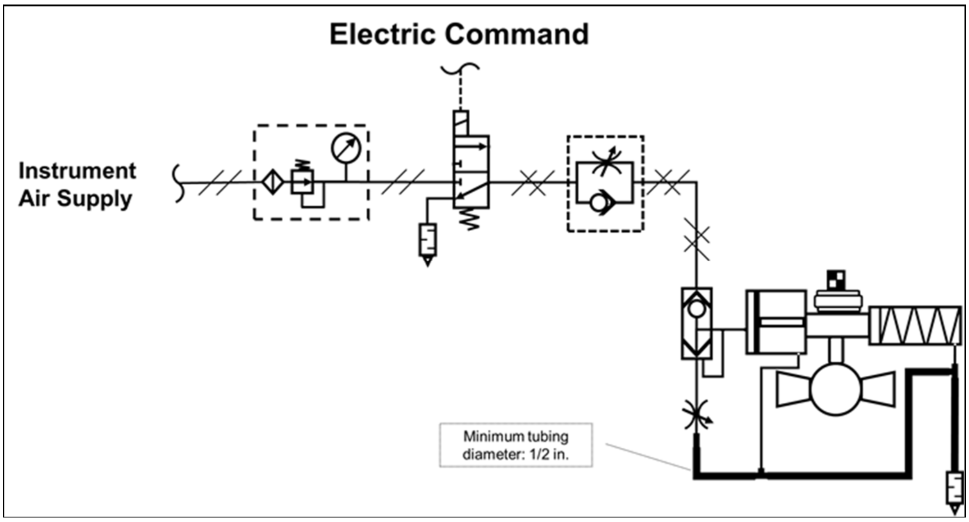


*Figure 14.1-III – Simplified schematic for pneumatic SDV actuation*

14.1.6.3 Schematics of SDV hydraulic actuation

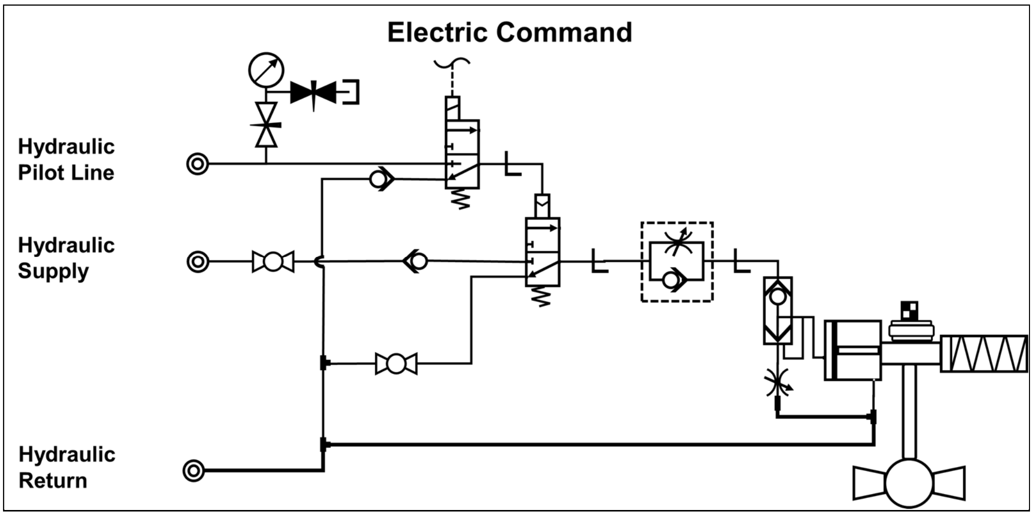


*Figure 14.1-IV – Simplified schematic for hydraulic SDV actuation*

14.1.6.4 Schematics of BDV pneumatic actuation without pneumatic mechanical opening delay.

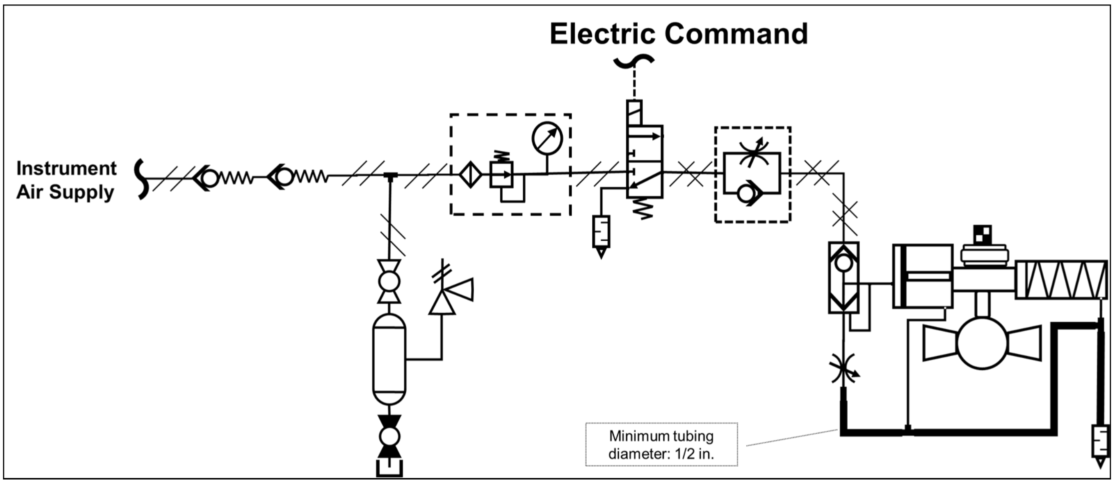


*Figure 14.1-V – Simplified schematic for pneumatic BDV actuation without pneumatic delay opening*

14.1.6.5 Schematics of BDV pneumatic actuation with temporized with pneumatic mechanical opening delay described in items 14.1.3.3 and 14.1.3.3.1.

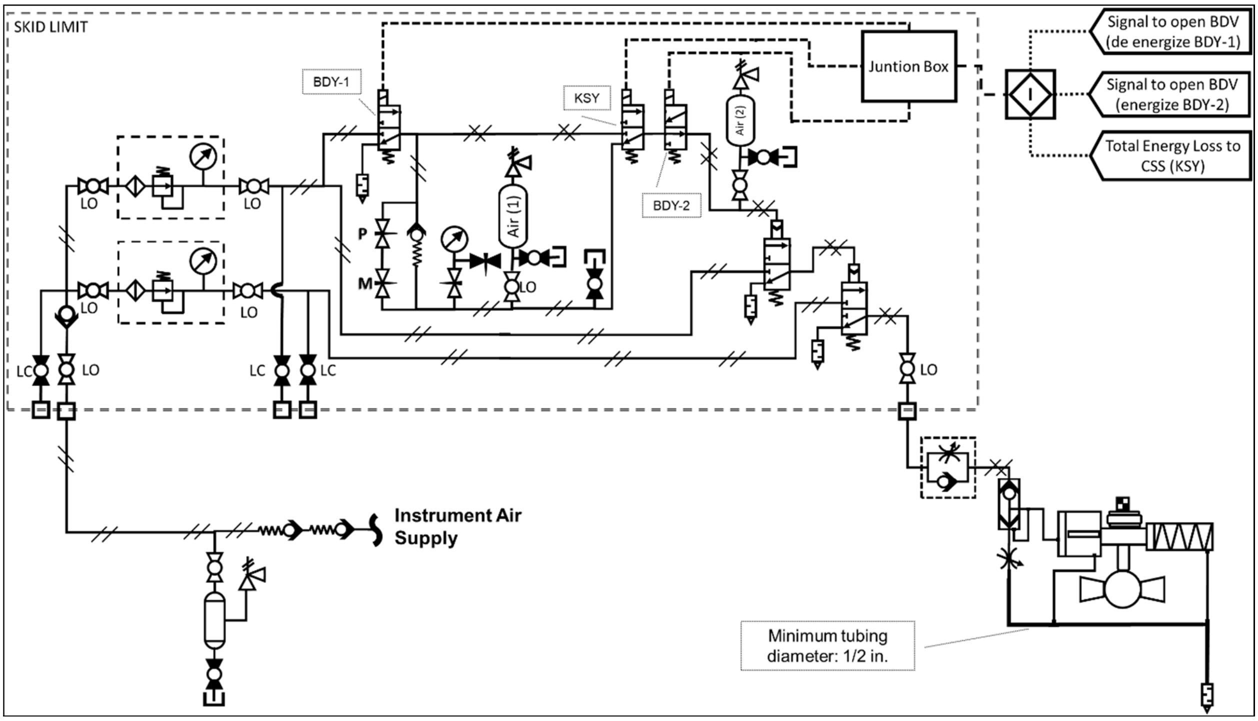


*Figure 14.1-VI – Schematic for pneumatic BDV actuation with temporized pneumatic mechanical opening delay (See items 14.1.3.3 and 14.1.3.3.1).*

## 14.2 Valves for Process Alignment and ON-OFF Control (XVs)

For Valves of Naval Systems, the specifications of the respective discipline shall be followed. **[INTERDISCIPLINARY INTERFACE][SNAV]**

14.2.1 Concept

14.2.1.1 Valves XVs shall be designed following the valve specification level (VSL) and the requirements presented on the technical specification document of the project entitled PIPING SPECIFICATION.

14.2.1.2 XVs valves are the final elements for e.g. automatic level control and for directing process fluids. They are actuated by the Control Unit of the Production Unit and/or equivalent system of the PACKAGE UNIT.

14.2.1.3 These valves may assume any position depending on the current process demand: open, closed or an intermediate position. **[INTERDISCIPLINARY INTERFACE][HVAC, PRO, SNAV, TBM]**

14.2.1.4 These valves have a failure condition determined by the process, such as fail open, fail closed or fail as is. **[INTERDISCIPLINARY INTERFACE][HVAC, PRO, SNAV, TBM]**

14.2.1.5 When the upper and lower values are not determined by the Process discipline, the opening time as well as the closing time shall be no more than 2 seconds for each inch of nominal valve diameter.). **[INTERDISCIPLINARY INTERFACE][HVAC, PRO, SNAV, TBM]**

14.2.2 Actuators

14.2.2.1 The VENDOR of the respective valve shall specify and supply the actuator.

14.2.2.2 XV valves shall be actuated by pneumatic actuators. The driving circuit shall meet the specific function needs for the time required for closing and opening. Hydraulic circuits can be used when power available for actuation is hydraulic (see item 14.1.4.6). **[INTERDISCIPLINARY INTERFACE][HVAC, PRO, SNAV, TBM]**

14.2.2.2.1 For fail as is type XVs, the actuator shall be supplied with an accessory that allows manual mechanical actuation. Electric actuators can be used on fail as is type XVs in position, provided they are commanded via the communication network. **[INTERDISCIPLINARY INTERFACE][SNAV, TBM, ARR, 3D]**

14.2.2.3 Passive protection in actuators shall be applied following the specifications of the Safety Discipline specifications. **[INTERDISCIPLINARY INTERFACE][HSE]**

14.2.2.4 These valves are continuously supplied by signals received from the Control System or control logic of the PACKAGE UNIT.

14.2.2.5 Pneumatic actuators shall be of the piston type. If there is a defined failure condition, the actuator shall be spring return.

14.2.2.5.1 Multi-spring pneumatic actuators may be used using sets of 2 bagged springs or single springs in configurations of up to three sets/single springs at 120º or two sets/single springs in series.

14.2.2.5.2 Configurations that extrapolate those mentioned in the item above can only be adopted by submitting test reports that prove its long-term functionality for analysis and release by PETROBRAS.

14.2.2.6 Actuation shall be designed so that during actuator depressurization the flow of vented instrument air path passes by actuator springs compartment and to non-pressurized piston compartment. The purpose is to allow clean air to directed into these compartments instead of ambient air from a marine atmosphere which is potentially corrosive. Item 14.2.4 depicts this requirement.

14.2.2.7 For hydraulic actuators with spring return, a similar solution shall be implemented, with depressurized hydraulic fluid path passing by non-pressurized compartment. Item 14.2.4 depicts this requirement. Regarding actuators springs it shall be proposed a solution to avoid air from marine environment to enter springs compartment.

14.2.2.8 Sizing

14.2.2.8.1 In both opening and closing, the actuator shall be capable of providing a torque 2 times greater than the torque required by the valve, throughout its course of action. The largest torque supplied by the actuator shall not exceed the maximum torque allowed by the stem of the valve (MAST - Maximum Allowable Stem Torque).

14.2.3 Accessories

14.2.3.1 Actuators shall be equipped with accessories such as position switches, pilot valves, quick exhaust valves, flow regulators and their associated installation materials. The quick exhaust valves shall always be external type to easy inspection and maintenance. Therefore, it is not acceptable, for example, quick exhaust valves embedded in flanges.

14.2.3.2 It shall be possible to control opening and closing time of XVs. This is necessary to avoid unnecessary energy, either pneumatic or hydraulic, during opening and avoid, during closing, the possibility for hydraulic shock. Nevertheless, the valve actuation time shall be in conformity with item 14.2.1.5. See in items below simplified schematics for XV actuations (PSVs for valve actuators are not represented).

14.2.3.3 Position switches shall have their contacts actuated by magnetic coupling and shall have a rotating mechanical position visual indication with transparent protection mechanism of the moving part, with open/closed indication by means of different colors and black inscriptions. The current position of the valve shall be easily viewed from the side and top of the indicating device. They shall also allow adjustment of the actuation points without disassembling the valves. The contact of the position indication switches shall be Normally Open (NO) and close when the valve reaches the limit switch.

14.2.4 Schematics for XV actuations

14.2.4.1 Legend for *Figure 14.2-I* and *Figure 14.2-III*.

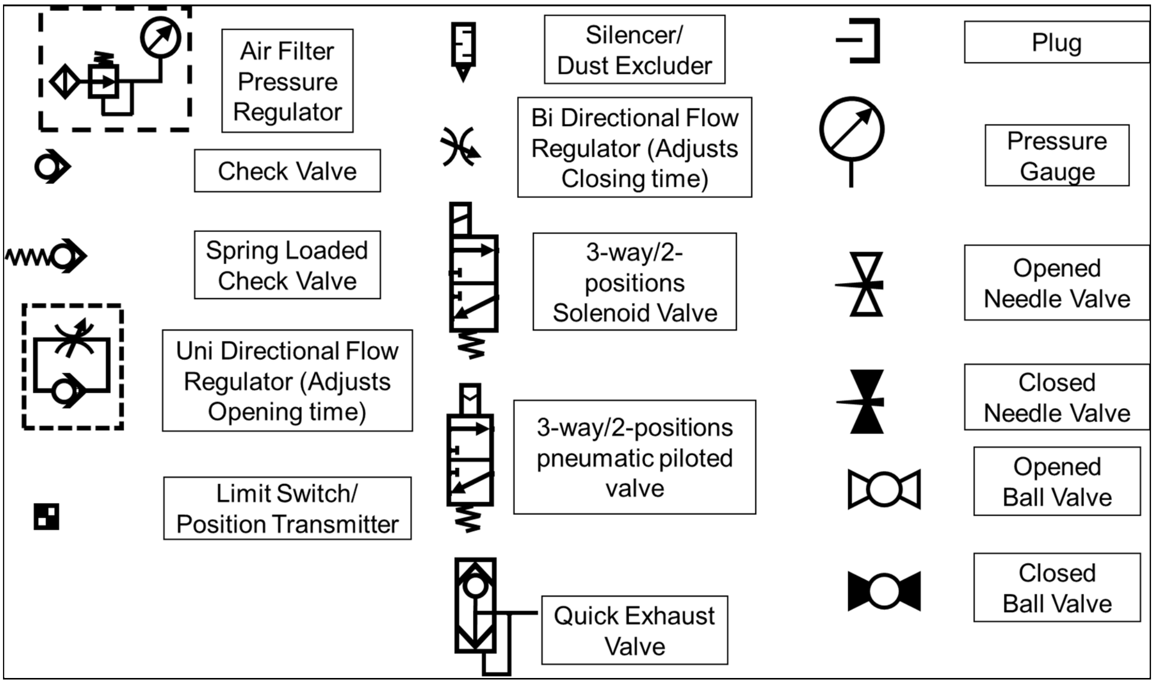


*Figure 14.2-I – List of components used in Figure 14.2-I* and *Figure 14.2-III*

14.2.4.2 Schematics for XV pneumatic actuation with spring return.

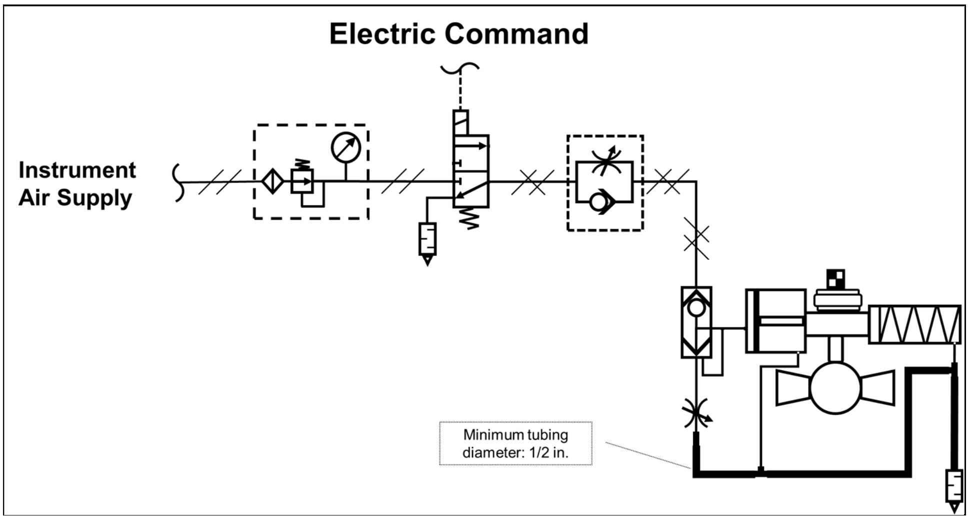


*Figure 14.2-II – Sschematic for pneumatic spring return XV actuation*

14.2.4.3 Schematics of XV hydraulic actuation with spring return

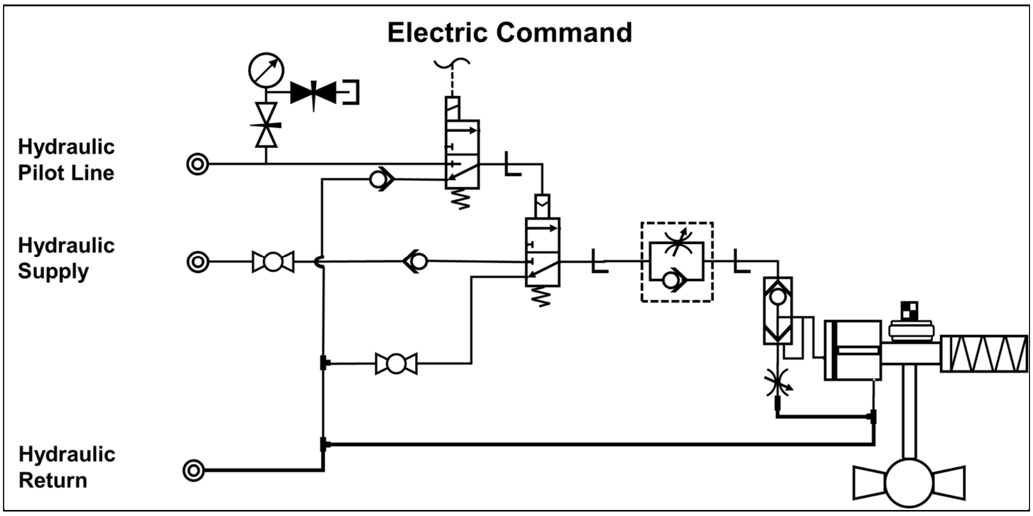


*Figure 14.2-III – Schematic for hydraulic spring return XV actuation.*

### 14.3 Multi-directional Valves

14.3.1 When using a multi-directional valve for the production direction service for test and production separation trains, it shall comply with the following minimum requirements:

.#1) Be actuated remotely by means of a rotary actuator;

.#2) Have position indicators for each of the possible positions of the valve;

.#3) Be capable to transmit its position signals via non-proprietary protocol field communication network.

14.3.2 Its electrical components shall be suitable for the classification of the application area and shall meet degree of protection required in items 6.2 and 6.4, where minimum Ex certification shall be for zone 2 and minimum IP level shall be IP56. **[INTERDISCIPLINARY INTERFACE][HSE]**

## 15 REQUIREMENTS FOR THE SPECIFICATION OF SOLENOID VALVES

### 15.1 Solenoid Valves for Pneumatic Command

15.1.1 Solenoid valves shall be of integral assembly, whether they are of direct actuation or indirect actuation pilot operated.

15.1.2 Solenoid valves used for compressed air shall be of the compact type, without gaskets, with stainless steel body and internal parts, seat with shoulder and seats made of resilient material.

15.1.3 The insulation class of the solenoid valve coil shall be at least class F.

15.1.4 Solenoid valves used in interlock systems (shutdown or trip) shall be energized during normal operation and power consumption limited to 5 W per valve. For the particular case of $CO_2$ release solenoid valves greater consumption is acceptable. For any solenoid the power consumed by the solenoid added to the power dissipated in the interconnection cables shall be limited to the maximum power that the discrete pair card/channel output can provide. In this evaluation it shall be demonstrated that the minimum voltage of the solenoid actuation is complied.

15.1.5 Solenoids valves shall be equipped with suppression diodes (freewheeling diodes), installed inside the solenoid enclosure. It is not acceptable suppression diodes installed in junction boxes. This is applicable to all solenoids since the suppression diodes avoids a voltage surge at every solenoid de-energization that otherwise would propagate in the cable from solenoid to junction box terminals. It is of most concern for solenoids of $CO_2$ Flooding Firefighting System since its power consumption is generally higher and, therefore, the voltage surge will be higher.

### 15.2 Hydraulic solenoids

15.2.1 The requirements of I-ET-3000.00-5139-800-PEK-004 - HYDRAULIC POWER UNIT FOR SUBSEA EQUIPMENT WITH MULTIPLEXED ELECTROHYDRAULIC AND DIRECT HYDRAULIC CONTROL SYSTEM (OWN FLOATING PRODUCTION UNIT) and I-ET-3010.00-5139-390-P4X-001 - HYDRAULIC POWER UNIT (HPU) FOR TOPSIDES VALVES shall be followed.

15.2.1.1 Solenoid valves shall be equipped with suppression diodes (freewheeling diodes), installed within the solenoid casing.

## 16 ELECTRICAL INSTRUMENTATION CABLES

### 16.1 General

16.1.1 The minimum requirements for the design, fabrication and testing of instrumentation cables shall be in accordance with what is established in this documentation and with applicable standards, codes and recommendations, such as IEC 60092-350, IEC 60092-360 and IEC 60092-376.

## 16.2 Service Conditions

16.2.1 Cables shall be suitable for installation in trays or cable trays in areas exposed to the maritime atmosphere, subject to rain, liquid hydrocarbon spells and exposure to sunlight.

16.2.2 Cables and multi-cables that meet at least one (1) of the conditions listed below must be armed:

.#1) Cables and multicables that cross or are contained in classified areas classified as zone 0 or zone 1;

.#2) Cables and multicables of intrinsically safe circuits (Ex i circuits);

.#3) Cables and multicables that energizes the devices that involved in the opening and closing of BDV valves, as well as the cables and multicables of other circuits foreseen in the project that are involved in the staggering of BDV opening.

16.2.2.1 The armor cited in item 16.2.2 shall be of Steel Wire Braid (SWB and metal braid armor as per IEC 60092-350) and shall be compliant to IEC 60092-350, as material and coverage density.

16.2.3 Cables and multicables fully contained in sheltered and unclassified areas (control rooms, accommodation areas etc.) shall not be armored. **[INTERDISCIPLINARY INTERFACE][HSE]**

## 16.3 Constructive Characteristics

16.3.1 All cables shall be of naval type with a minimum insulation voltage of 150/250 V (300 V), in accordance with IEC 60092-376. Cables for intrinsically safe circuits shall follow the IEC-60079-14.

16.3.2 All materials shall be halogen free and low smoke emission. They shall be flame retardant and, where specified, fire-resistant.

16.3.3 As required by DR-ENGP-M-I-1.3 – SAFETY ENGINEERING, the following circuits need to operate in a fire condition and therefore shall be interconnected by fire-resistant cables in accordance with IEC 60331 and IEC 60332. Other circuits shall be analyzed during the project:

.#1) ADV, BDV: solenoid and limit switch cables;

.#2) SDV: cables for limit switches;

.#3) Dampers: cables for limit switches;

.#4) SDV contour for reducing SDV differential pressure in closed state: cable for solenoids and limit switches;

.#5) ESV (quick opening valve for flare gas recovery systems): cables for limit switches;

.#6) ESV (quick opening valve for flare staging): cables for solenoids and limit switches;

.#7) Back-up system for ESV (quick opening valves of flare gas recovery systems) - Example: Rupture disk and buckling pin valve: Cables that indicate actuation status/position;

.#8) Cables for gas and flame detectors, as well as cables for the emitters of line-of-sight gas detectors;

.#9) Cables for systems that start or are functional during ESD-3P, ESD-3T and ESD-4;

.#10) Cables related to fire-fighting systems (e.g. fusible plug network pressure transmitter, solenoids for CO2 release in HOODS, AFDS system cables).

16.3.4 MANUFACTURERS shall provide cable aging curves, where it shall be clear that after the lifetime adopted for the UNIT design, the insulation resistance of the cables shall not be less than 1 MΩ (MOhm).

16.3.5 All cables shall allow curvatures with a minimum radius of eight times their outer diameter.

16.3.6 The conductor shall be made of seven strands of soft copper, tinned throughout its length and stranded class 2.

16.3.7 The multicables shall be composed exclusively of pairs or terns or quads and may not shelter different types of units.

16.3.7.1 The number of pairs, terns and quads in a multicable shall be limited to 24 pairs, 16 terns and 12 quads.

16.3.8 At the end of the Acceptance and Performance Tests, there shall be an installed reserve, connected from the junction box terminal strip up to the panel, of 10% per signal type on the multicables that interconnect panels and junction boxes. This reserve shall be for each junction box/signal type composition. The type of signal shall be determined by: Analog or Discrete, Input or Output, Intrinsic Safety Circuit or not and subsystem to which it belongs to and whether it is an Intrinsically Safe Circuit or not.

16.3.8.1 The number of pairs/terns/quads reserved shall be rounded to higher integer number. Examples:

.#1) In an 8 pair multicable, 1 pair shall be reserve;

.#2) In a 12 pair multicable, 2 pairs shall be reserve;

.#3) In an 8 tern multicable, 1 tern shall be reserve;

.#4) In a 24 pair multicable, 3 pairs shall be reserve;

.#5) In an 8 quad multicable, 1 quad shall be reserve.

16.3.9 Cables and multicables shall have electrostatic shields covering each unit (pair, tern or quad) and made of an aluminum/polyester tape that shall be 0.065 mm to 0.1 mm thick, helically applied with 25% overlapping and with a drain wire in tinned and stranded copper.

16.3.9.1 Cables for discrete signals, cable for analog signals and multicables for discrete signals shall have general shielding and the latter shall have a drain wire.

16.3.9.2 Multicables (multiterns or multiquads) for analog signals shall have individual shielding per pair (per tern and per quad) and also a general shielding covering the whole set. Each shield shall have a dedicated drain wire.

16.3.9.3 Cables and multicables in accordance with item 16.2.2 shall receive on the assembly a metal frame composed of a braid of galvanized steel wire, sufficiently flexible and free of imperfections in galvanization and without discontinuities.

16.3.9.4 Cables shall be provided with a filler between the pairs/terns/quads and the overall shield to ensure circularity of the straight section of the cable along its entire length. The filler shall be of flame retardant halogen free material.

16.3.10 There shall be an outer sheath on the metal frame made of halogen free thermoset material (SHF 2).

16.3.10.1 It shall be ensured that there is no adhesion between the metal frame and the material of the outer sheath.

16.3.10.2 The outer sheath of the instrumentation cables shall be gray. Intrinsically safe cables shall have a blue outer sheath and shall be routed in accordance with IEC 60079. Fire-resistant cables shall have two diametrically opposite red stripes along its entire length.

16.3.11 All pairs, terns and quads shall be twisted with a maximum pitch of 60mm.

16.3.12 When used, see item 7.5.1.1, cables between the thermocouple heads and their transmitters may be of the Extension grade type, provided the cable is specified for the temperature to which it is subjected.

## 16.4 Sizing

16.4.1 The voltage drop in the interconnection cables shall be calculated for all consumers in such a way that the required minimum voltage is guaranteed in the instrument or equipment and higher section cables shall be used when necessary to guarantee this minimum voltage (e.g. signals interlocking logic outputs such as solenoid valves, 4-wire instruments, $CO_2$ flood fire-fighting solenoids, targeted type gas detector emitters, etc.). The minimum nominal sections to be used, even though the aforementioned sizing includes lower sections, are described below:

16.4.2 The nominal cross-section of the conductors used in connection with the field shall be 1.0 $mm^2$ for the following signals:

.#1) analog signals;

.#2) limit switches;

.#3) Discrete signals between panels without power feeding (e.g. Fault Summary, On-Off Status, Panel Status Information);

.#4) command signals to turn on or off electric drawers;

16.4.3 Minimum section of 1.5 mm² shall be adopted for the following signals:

.#1) Solenoid activation inside the same module (except main deck, riser balcony and pipe rack);

.#2) Activation of piezoelectric or electronic and visual audible alarms based on LED inside the same module (except main deck, riser balcony and pipe rack).

16.4.4 Minimum cross-section of 2.5 mm² shall be used for the following signs:

.#1) Activation of CO2 firing solenoids inside the same module (except main deck, riser balcony and pipe rack);

.#2) Activation of motorized and motorized visual alarms and/or based on incandescent lamps.

## 16.5 Identification and Polarization

16.5.1 The conductors shall have identifications and be used with the polarity as described in

16.5.2 *Table 16.5-I* , following IEC 60092-376.

*Table 16.5-I - Polarity and colors of conductors of cable and multicables.*

| Cable Type | Signal Type | Conductor 1 (Polarity) | Conductor 2 (Polarity) | Conductor 3 (Polarity) | Conductor 4 (Polarity) |
|---|---|---|---|---|---|
| Pairs | 4-20mA | Black (+) | White (-) | N.A. | N.A. |
| Terns | Power + 4-20mA | Black (+) | White (-) | Red (+, signal) | N.A. |
| | RTD | Black (+) | White (-) | Red (+, signal) | N.A. |
| Quads | Power + 4-20mA | Black (+) | White (-) | Red (+, signal) | Blue (-, signal) |
| | RTD | Black (+) | White (-) | Red (+, signal) | Blue (-, signal) |

16.5.3 In multicables, conductors of the same group (pair, tern or quad) shall all be identified by the same number printed at intervals as described in IEC 60092-376. The identification inside the group is made by the color of the insulation coating as described in item 16.5.1.

16.5.4 All cables and multicables shall be identified externally, indelibly and over their entire length, with data about the type, formation and nominal section of the conductors.

16.5.5 Fire-resistant cables shall have identification as required in item 16.3.10.2.

16.5.6 Color of the cover and conductors of the thermocouple extension cables shall conform to ASTM E230.

### 16.6 Tests

16.6.1 The cable VENDOR shall submit a complete report and homologation certificate from the Certifying Entity certifying that the cables have been approved in the tests prescribed in IEC 60092-376.

## 17 INTERCONNECTION

The applicable standards, codes and recommendations that shall be followed are listed in this documentation presented in item 2.

Regarding the interconnection of cables for the $CO_2$ Flooding Firefighting System, item 17.6 summarizes the rules to be followed regarding cables, multicables and junction boxes for this system.

Regarding the interconnection of cables for the BDVs, item 17.7 summarizes the rules to be followed regarding cables, multicables and junction boxes.

### 17.1 General Requirements

17.1.1 Cables and multicables shall have their routing so that they are below their respective connection in order to avoid a preferred path for rainwater (e.g. U-shaped routing or using pigtail).

### 17.2 Cable Glands and Clips

17.2.1 Cables and multicables shall be fastened along their routing trays by metallic tape-type clips coated with polymeric material.

### 17.3 Junction Boxes and Passage Boxes

17.3.1 Cables from field instruments shall converge to junction boxes, segregated into 3 (three) types:

.#1) for signals using fire-resistant cables;

.#2) for signals related to safety interlocks;

.#3) for signals related to process control.

17.3.1.1 Junction boxes interconnecting fire-resistant cables and multicables shall have passive protection to provide the same fire-resistance as the cables. The terminal strips shall also be of a fire-resistant material, such as ceramic.

17.3.1.2 The junction box shall be internally divided into two regions, one for discrete signals and one for analog signals.

17.3.1.3 Intrinsically safe signals shall be conditioned in a separate region inside the junction box, segregated from the other regions by a separating septum and identified as intrinsically safe signals. The terminal strips shall be blue.

17.3.2 Junction boxes for instrumentation cables in classified or open areas shall have a minimum degree of protection IP56 and shall have "Ex e" or "Ex d" certification and certified to work according to the area classification where it is installed. In open areas, the minimum certification shall be for zone 2 (EPL Gc).

17.3.3 Cables or multicables connecting instruments to the junction boxes may only enter through the side of the junction box.

17.3.3.1 Cables and multicables shall be routed so that they lie below their respective junction box connection before entering the junction box, in order to avoid a preferred route for rainwater (e.g. U-shaped routing).

17.3.4 Multicables that connect the junction box to a panel or to another junction box shall be connected to the bottom of the junction box.

17.3.5 Reinforcing items 17.3.3 and 17.3.4, cables and multicables entering through the top of the junction box are not allowed.

17.3.6 In the lower part of the junction boxes, the passage of cables and multicables shall be done using a removable blind plate.

17.3.7 The terminal strips used inside the junction boxes shall be firmly attached and suitable for use in vibrating conditions to avoid poor contact and consequent spark.

17.3.8 Junction boxes and passage boxes shall be made of AISI 316 stainless steel.

## 17.4 Cable trays

17.4.1 Cable trays shall be made of AISI 316 stainless steel. Cable trays made of galvanized steel may be used in sheltered areas (rooms, etc.). When tray/ladder covers (lids) are required (see items 17.4.4 and 17.4.5), their material and also the material of bolts, nuts and washers shall be of the same material as tray/ladder. See item 17.4.6 regarding cover/lid fastening.

17.4.2 The occupation of cable trays/ladders, calculated by considering that the cable occupies an area equivalent to the square of its respective diameter, shall be such that the free area at the top of the cable tray/ladder is, at least, 20% of the useful area of the cross section of the cable tray/ladder in fully open or sheltered areas and, at least, 40% of the useful area of the cross section of the cable tray/ladder in transition spaces between sheltered and unsheltered areas (see Figure 17.4-I and Figure 17.4-II).

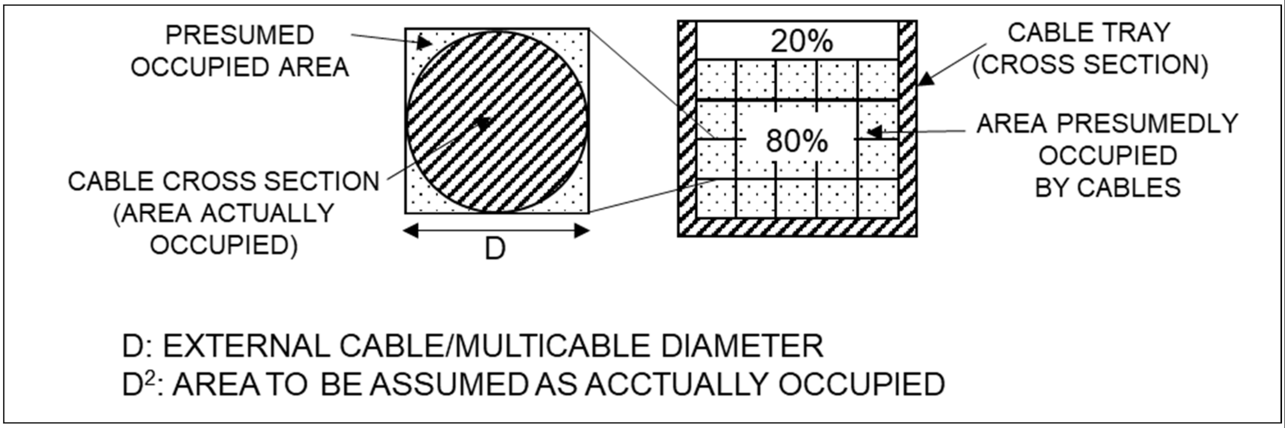


Figure 17.4-I - Occupation of cable trays for trays/ladders at the interface between open and closed areas.

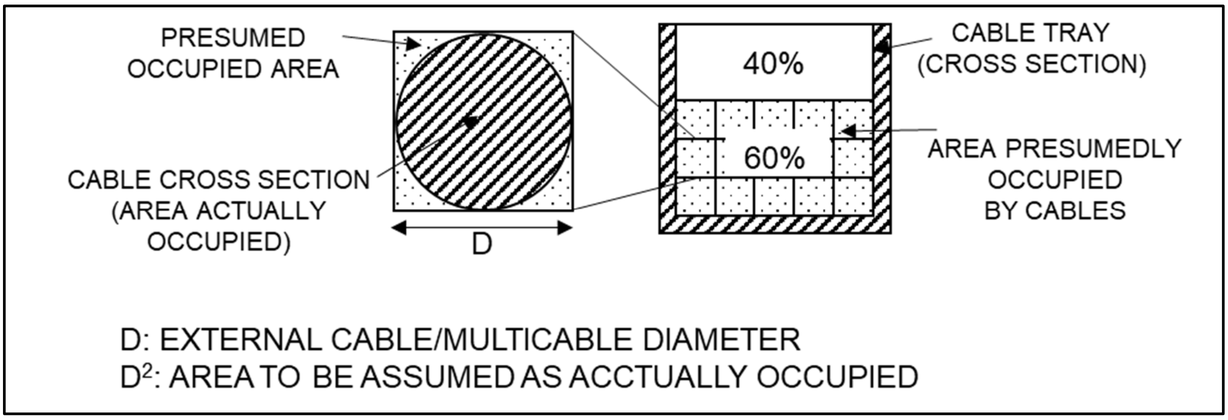


*Figure 17.4-II - Occupation of cable trays for trays/ladders at the interface between open and closed areas.*

17.4.3 Carbon steel shall be used in the manufacture of all supports for such trays, and they shall be painted in accordance with the painting procedure adopted in the design for such material. To avoid galvanic potential formation on the contact surface between the trays and the supports, an insulation material shall be used between them. Electrical continuity between tray sections and proper grounding, as specified, shall be ensured.

17.4.4 Covered cable trays shall be used in the following cases:

.#1) If the cables (one or more) are part of low voltage circuits (in the order of mV), such as the ones used for thermocouple and RTD signal transmission.

.#2) If the cables (one or more) are part of intrinsically safe circuits which, for reasons intrinsic to the instrument or equipment, are not armored as specified in item 16.2.2. This usage of unarmored cable shall previously be submitted to PETROBRAS for approval.

.#3) If there is risk of atmospheric discharge.

.#4) If the cables (one or more) are used for communication signal (communication protocols) transmission, such as described in item 4.3.

17.4.5 Covered cable trays/ladders shall be used in the following cases:

.#1) Where there is a risk of damage to cable/multicable due to fallen objects (tools, screws, bolts, weld splatter etc.) during maintenance of equipment;

.#2) When the exposure to UV (ultraviolet) rays may damage the cable/multicable during the expected lifetime of the UNIT;

.#3) Where there is a risk of hydrocarbon or other chemical products being spilled. The risk shall also be evaluated for cases such as flange leakage and loss of fluid containment between flanges, considering the area that the fluid may reach.

17.4.6 In cases where cable trays/ladders in open areas have covers/lids such as determined by items 17.4.4 or 17.4.5, covers/lids shall be fastened in such a way as to withstand stresses on the cover/lid due to the aerodynamic effect that creates a pressure difference in the cover/lid plate, with higher pressure inside the cable tray/ladder and a lower pressure outside caused by winds (Bernoulli effect). Fastening devices shall have proven robustness and shall not wear out over time, for example due to corrosion or weakening due to UV ray exposure.

## 17.5 Panels in open areas

17.5.1 To provide maintenance access for cables entering through bottom of panels, an elevation of 300 mm from the floor shall be provided. The elevation shall be opened on all sides to provide access. **[INTERDISCIPLINARY INTERFACE][ARR, STR, 3D]**

17.5.1.1 A platform leveled with the base of the panel shall be installed in front of the panel doors to provide ergonomic access. The platform shall have the width of the panel doors. This platform shall be removable with screw fixing to provide access to the cables and multicables. **[INTERDISCIPLINARY INTERFACE][ARR, STR, 3D]**

## 17.6 Interconnection for $CO_2$ Flooding Firefighting System

17.6.1 The cable of each pushbutton of every point of actuation must be interconnected to different junction boxes. This prevents that 2 loops from the same point of actuation are accidentally actuated during a maintenance, por example.

17.6.2 Cables for directional solenoid valve and for cylinder pilot solenoid valves that serves the same compartment/room must be connected to different junction boxes. This prevents that both directional and pilot valves are accidentally energized during a maintenance, for example.

17.6.3 Cables for directional solenoid valve and the cable of its respective limit switch for open position indication shall be directed to different junction boxes. Since both signals are used for an interlocking for $CO_2$ discharge, complying with IACS UI SC 252, separating the signals in different junction boxes and, therefore, different multicables eliminates the possibility of energizing the open limit switch loop due to multicable malfunction and also eliminates the chance for accidentally energizing both loops during a maintenance on a junction box.

17.6.4 Junction Boxes shall not mix signals for directional valves with signals for pilot solenoid valves, even for different compartment/rooms. By extension, multicables also shall not mix signals for directional valves with signals for pilot solenoid valves, even for different compartment/rooms. Since the flooding of an enclosure/room needs actuation of both directional solenoid valve and pilot solenoid valve, it prevents the flooding due to, for example, a damage on the multicable or during a maintenance on a junction box.

### 17.7 Interconnection for BDV actuation and Mechanical Temporization

By signals do BDVs it shall be understood the signals to open the BDV and the signal that informs that there is a total failure in electrical supply to CSS.

17.7.1 Multicables shall not mix signals to BDVs that have mechanical opening delay with signals to BDVs that do not have mechanical opening delay.

17.7.2 A junction box shall not mix signals to BDVs that have mechanical opening delay with signals to BDVs that do not have mechanical opening delay.

17.7.3 A multicable shall only have signals to BDVs that have the same mechanical delay time (no delay is considered 0 s delay) and, additionally, the sum of peak flow of each BDV in a multicable shall be limited to 90% of Flare depressurization capacity. If a single BDV has a peak flow above 90% of Flare capacity the signals to this BDV shall be the only signal to BDV in a multicable.

17.7.4 Similarly to item 17.7.3, a multicable shall only have signals to BDVs that have the same mechanical delay time (no delay is considered 0 s delay) and, additionally, the sum of peak flow of each BDV in a junction box shall be limited to 90% of Flare depressurization capacity. If a single BDV has a peak flow above 90% of Flare capacity the signals to this BDV shall be the only signal to BDV in a junction box.

17.7.5 All signals to a specific BDV shall be in the same multicable. This shall also be followed between junction box to BDV by using a multicable between junction box and BDV temporization skid.

## 18 GROUNDING AND ELECTROMAGNETIC COMPATIBILITY (EMC)

### 18.1 Definitions

18.1.1 Grounding design and applications shall comply with IEC 61892 that describes grounding in offshore production units and IEC 60079 that has requirements for classified areas. According to item 6.4.2, instruments installed in open areas shall be certified for zone 2, so the requirements here presented shall be applied even if the area is not classified zone.

18.1.2 Grounding and electromagnetic compatibility (EMC) shall be considered as a system, and for this, a descriptive memorandum shall be issued during detailed design describing the requirements adopted justifying the design decisions, as well the test and maintenance procedures. The descriptive memorandum shall describe have a chapter for intrinsically safe circuits, according to IEC 60079-25 and required in the item 6.4.4.

18.1.3 The term PE means grounding for personal protection and to avoid the formation of static electricity (bonding).

18.1.4 The term IE means instrumentation grounding for circuits other than intrinsically safe protection type (Ex i), with the function of providing a path for the flow of electromagnetic noise. The (negative) reference of the control panels shall not be connected to this grounding.

18.1.5 The term IS means instrumentation grounding for intrinsically safe circuits (Ex i), in order to provide a path for the flow of electromagnetic noise. The (negative) reference of the control panels shall not be connected to this grounding.

## 18.2 General requirements for grounding

18.2.1 Equipment as control, panels of CSS and SOS systems and instruments mounted inside panels, such as analyzers, shall internally have distinct PE and IE grounding bars and, when intrinsically safe circuits are interconnected, IS bar. IE and IS bars shall be isolated from the equipment enclosure. For panel with many sections and that have more than one IE or IS bar, the bars with the same function (grounding type) shall be interconnected internally and grounded in only one point in a dedicated earth boss.

18.2.1.1 The panels grounding bars, PE, IE and IS, shall be connected to the structure, through earth bosses, with the shortest cable length possible. Shall be followed the minimum distance of 1 meter between earth bosses of PE and IE, as well as the minimum distance of 1 meter between PE and IS.

18.2.1.1.1 Inside panels, PE, IE and IS grounding bars shall be accessible to allow access for inspection and maintenance. Shall be located near the external cables entrance, to minimize the distances for parts of cables/multicables that shall be grounded, such as cable armor and shields.

18.2.2 To perform the grounding described in 18.2.1.1 shall be used tinned copper braid tape, with 1:5 width/height and 25 mm2 equivalent minimum cross section. The length shall be the shortest possible and not be longer than 500 mm.

18.2.3 As described in item 6.4.2.3, intrinsically safe circuits shall use galvanic isolation barriers to simplify the grounding requirements for this circuit type and, to reduce the creation of ignition sources risk.

18.2.4 The connection with the structure shall be done through earth boss welded in the structure, connections using direct fastening (e.g. Hilti pin) shall not be accepted.

18.2.4.1 The contact area shall be cleaned before the grounding cable connection and shall be protected with a protective coating to avoid corrosion. This protective coating shall be removable for inspection and maintenance. See Figure 18.2-I.

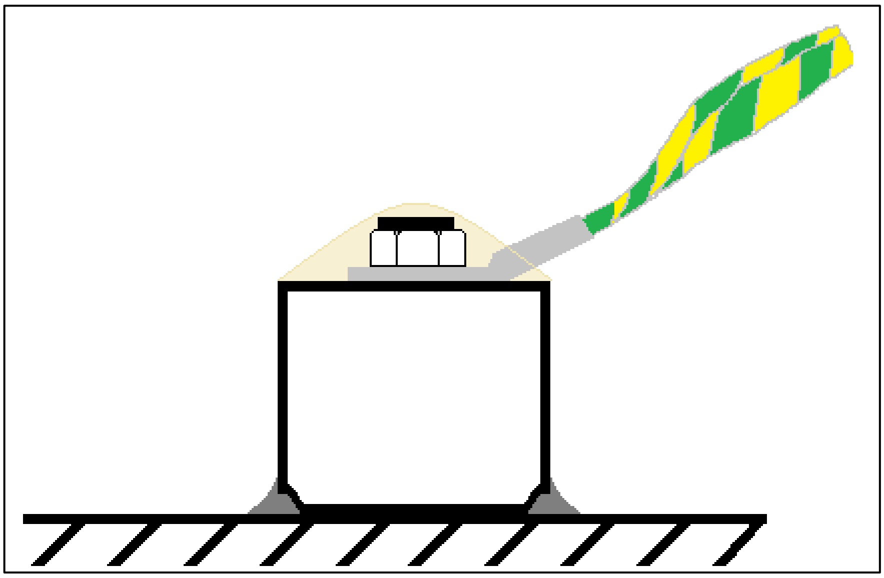

*Figure 18.2-l – Grounding connection to structure through a welded earth boss. On earth boss top is represented the protective coating against corrosion.*

## 18.3 General requirements for electromagnetic compatibility (EMC)

18.3.1 The guidance in IEC 61000-5-2 chapter 5, 6 and 8 shall be followed to optimize the parameters for electromagnetic compatibility (EMC).

18.3.2 As stated in item 18.2.1.1.1, the PE, IE and IS bar position is to minimize the length between parts of cable/multicable and respective grounding bar defined in items 18.4.5.1 and 18.4.5.2. This is necessary to minimize the disturbances in high frequencies.

## 18.4 Grounding related to Cables and Multicables

18.4.1 The enclosure of all instruments and panels, junction boxes, cable glands, cables and multicable armors shall be connected to the PE.

18.4.2 The drain wires of the cable and multicable electrostatic shields shall be grounded to the IE or IS according to the type of circuit on the side of the panel and insulated on the side of the instrument when the sensor is not grounded. When the sensor is grounded, the drain wire of the electrostatic overall shield shall be grounded on the side of the instrument and insulated on the side of the panel.

18.4.2.1 In the case of remote mounting for temperature measurement with the sensor installed on the connection head separate from the respective transmitter, the cable shield drain wire between the head and transmitter shall be grounded to the head and insulated on the side of the transmitter. The electrostatic shielding of the circuit between transmitter and panel shall be grounded only on the side of the panel in the IE or IS bar, depending on the type of Ex protection used.

18.4.3 Unused cores of non-intrinsically safe circuits, in open areas connection, classified zone or not, shall be connected in spare terminals and grounded to PE. It shall not be isolated.

18.4.4 Spare cables of intrinsically safe circuits, in open areas connection, classified zone or not, shall be connected in spare terminals at both ends and not be grounded. It shall be isolated among them and the earth.

18.4.5 Grounding for discrete and analog signals shall be carried out according to following figures:

18.4.5.1 *Figure 18.4-I- Interconnection of non-Intrinsically Safe (non Exi) discrete signals.* and Figure 18.4-II for interconnection of discrete signals:

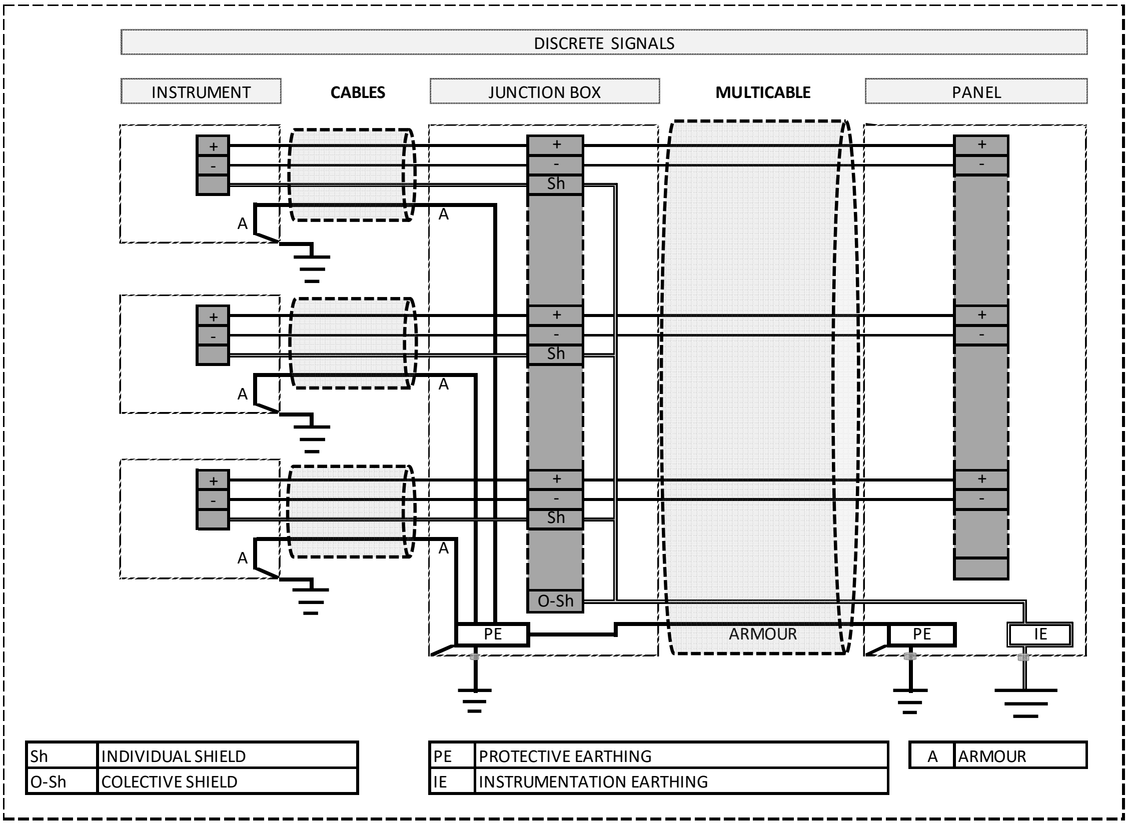


*Figure 18.4-I- Interconnection of non-Intrinsically Safe (non Exi) discrete signals.*

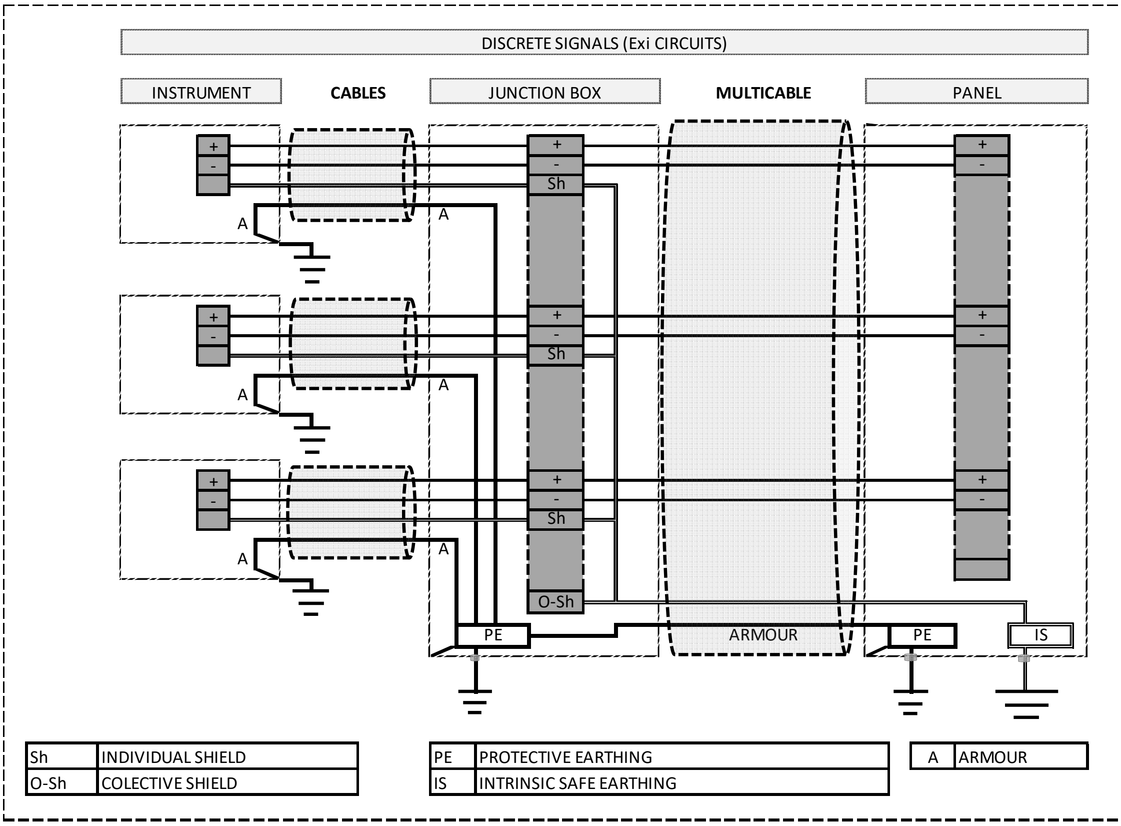


*Figure 18.4-II - Interconnection of Intrinsically Safe (Exi) discrete signals.*

18.4.5.2 *Figure* 18.4-III and Figure 18.4-IV for interconnection of analog signals:

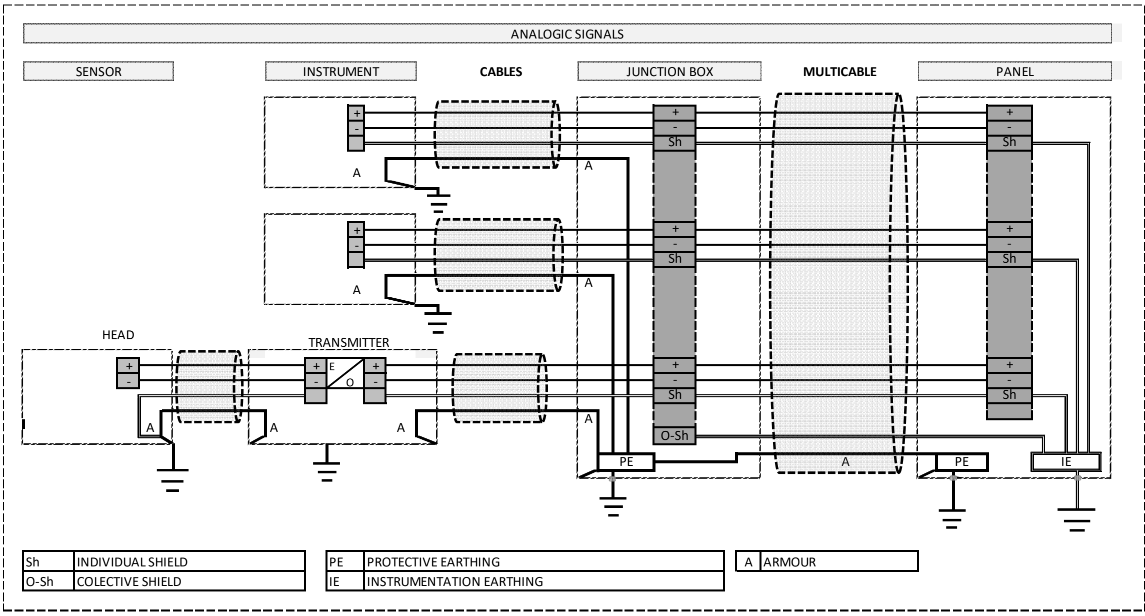


*Figure 18.4-III - Interconnection of non-Intrinsically Safe (non Exi) analog signals.*

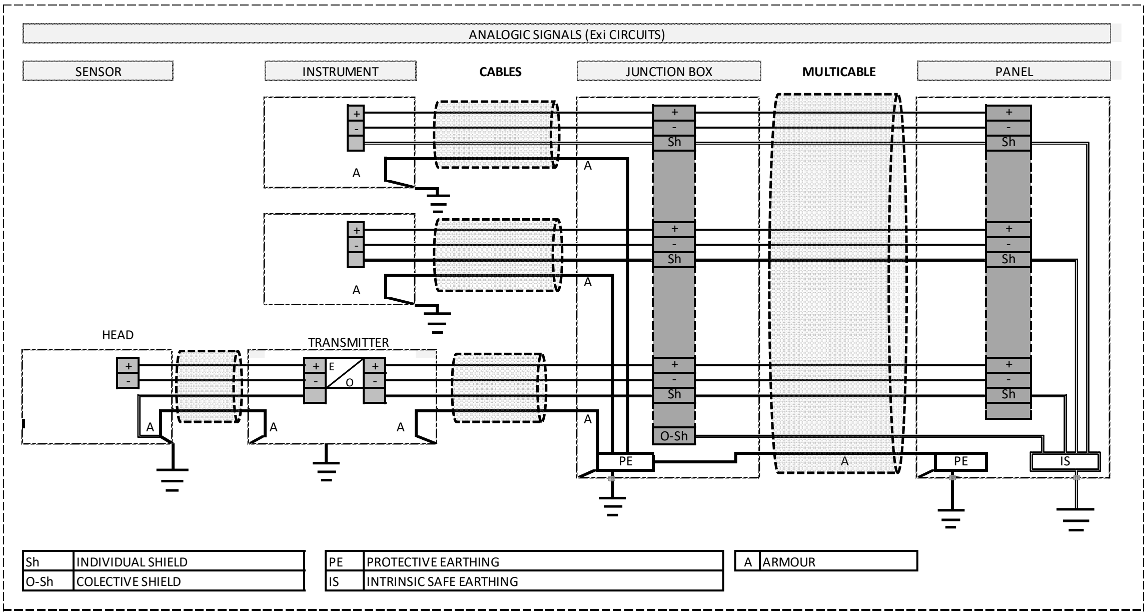


*Figure 18.4-IV- Interconnection of Intrinsically Safe (Exi) analog signals.*

# 19 IMPULSE LINES, PNEUMATIC TRANSMISSIONS AND HYDRAULIC TRANSMISSIONS

It shall be used the I-ET-3010.00-1200-800-P4X-015 - REQUIREMENTS FOR TUBING AND FITTING (ALIGNED TO IOGP-JIP33 S-716).

# 20 NETWORK OF FUSIBLE PLUGS FOR ADV DRIVING

## 20.1 Constructive Characteristics

20.1.1 Fusible plugs shall be built and tested, according to the following characteristics:

.#1) Body material: AISI 316 stainless steel;

.#2) Diameter of Connections: 3/8" OD or 1/4" NPT;

.#3) Melting (actuation) temperature range: 70ºC to 77ºC.

20.1.2 The following information shall be engraved on the body of the Fusible Plug:

.#1) Name of the MANUFACTURER;

.#2) Operating Temperature;

.#3) Manufacturing lot number.

20.1.3 All lots of fusible plugs shall be accompanied by a test certificate covering at least the following aspects:

.#1) Tightness and resistance to extrusion;

.#2) Under pressure softening temperature.

## 20.2 Features and Performance of Fusible Plugs Network

20.2.1 The Fusible Plug shall work under the same pneumatic air supply and operating pressure of ADV.

20.2.2 Fusible plugs shall be monitored by pressure transmitters. The quantity of pressure transmitters for each fusible plug network shall follow the requirements of DR-ENGP-M-I-1.3 – SAFETY ENGINEERING, and of each project's GENERAL NOTES and SAFETY DATASHEET.

20.2.3 Each ADV actuation system shall have a pilot valve directly actuated by a Fusible Plug network. ADVs shall be remotely actuated by an interlock system. The ADV actuation system shall also provide a local manual reset and shall allow manual opening, as shown in each project's GENERAL NOTES.

20.2.4 Each network of Fusible Plugs shall be dimensioned so that the ADV is open within the time determined by the DR-ENGP-M-I-1.3 – SAFETY ENGINEERING. This time shall be counted from the operation of 1 Fusible Plug to the full opening of the ADV. For this sizing, the opening of only 1 Fusible Plug located at the most unfavorable point for depressurization of the network shall be used.

20.2.4.1 For the purpose of commissioning tests, the low pressure detection of the network shall not be used by the pressure transmitters of the respective fusible plug network.

20.2.5 The length of the Fusible Plug network in a given scenario of the Fusible Plug depressurizing shall not exceed 300 meters. If more than one scenario is served by the same ADV, check valves can be used to segregate portions that are not part of the demand. However, the number of check valves in series for a given scenario shall not exceed 3.

20.2.5.1 If longer than 300m is required for a given scenario, a dynamic flow simulation shall be performed to verify compliance with item 20.2.4.

20.2.6 The small bore tubes (tubing) that make up the Fusible Plug network shall be of material according to Chapter 19.

20.2.7 Connections to be used to create the Fusible Plugs network shall be according to Chapter 19.

20.2.8 Opened and closed ADV position monitoring shall be provided to be displayed on the supervisory system screen.

20.2.9 All components of the actuation system of the ADVs shall be installed in a local stainless steel panel.

20.2.10 The Fusible Plug system shall conform to DR-ENGP-M-I-1.3 – SAFETY ENGINEERING.

# ANNEX A - CALCULATION OF THE DIMENSIONS OF THE RESTRICTION ORIFICE IN ISENTROPIC CRITICAL FLOW REGIME FOR REAL GAS

*Table 20.2-I - Calculation of The Dimensions of The Restriction Orifice in Isentropic Critical Flow Regime for Real Gas.*

$$W = C \cdot \beta^2 \cdot \frac{\pi \cdot D^2}{4} \cdot Y \cdot (P_1)_t \sqrt{\frac{PM}{8314.3 \cdot Z \cdot T_1}}$$

| PARAMETERS | DESCRIPTION |
|---|---|
| W | Mass flow [kg/s] |
| C | Coefficient of discharge in the conditions of critical flow: C = 0.839 (ref. Martins, Nelson, *"Manual de Medição de vazão"*) |
| β | Beta of the orifice at operating temperature |
| D | Internal pipe diameter [m] |
| PM | Molecular weight of the gas [kg/kmol] |
| Z | Compressibility factor of the gas |
| $T_1$ | Gas temperature upstream of the orifice [K] |
| Y | Isentropic critical flow coefficient for real gas: $Y = \sqrt{k.\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$ |
| k | Isentropic coefficient of gas |
| $(P_1)_t$ | Total pressure (of stagnation) upstream of orifice [Pa] (absolute) $(P_1)_t = P_1.\left[1+\left(\frac{k-1}{2}\right).M^2\right]^{\frac{k}{k-1}}$ |
| $P_1$ | Pressure upstream of orifice [Pa] (absolute) |
| M | Mach number $M = \frac{V_1}{V_S}$ |
| $V_1$ | Gas speed in the line upstream of the orifice [m/s] $V_1 = \frac{W}{A_1 \cdot \rho_1} = \frac{33257.2 \cdot W \cdot Z \cdot T_1}{\pi \cdot D^2 \cdot P_1 \cdot PM}$ |
| $V_S$ | Sound speed in the gas upstream of the orifice [m/s] $V_S = \sqrt{k \cdot \frac{R}{PM} \cdot T_1} = \sqrt{8314.3 \cdot \frac{k \cdot T_1}{PM}}$ |

## ANNEX B - CALCULATION OF THICKNESS OF RESTRICTION ORIFICES

Orifices subjected to tensions higher than the admissible by the material that they are made, suffer permanent deformation. In other to withstand the flow stresses and also to stablish a choked flow, the following shall be implemented:

.#1) the minimum plate thickness shall be:

| | |
|---|---|
| $t \geq \left[\frac{(0.681 - 0.651 \times \beta) \times \Delta P}{\sigma_y}\right]^{1/2} \times DI$ | Inequation B-I: Minimum plate thickness. |

Where:

- DI is the pipe internal diameter (mm);
- $\Delta P$ is the differential pressure at the orifice (Pascal);
- $\sigma_y$ is the Yield stress of the orifice material (Pascal);
- t is the minimum thickness of the restriction orifice (mm);

.#2) When choked flow is necessary, as in restriction orifices downstream BDVs, the plate thickness shall be between 1 plate internal diameter up 6 plate internal diameter.

| | |
|---|---|
| $1 \times DI \times \beta \leq t \leq 6 \times DI \times \beta$ | Inequation B-II: Plate thickness range to develop choked flow. |

**NOTE:** When t from inequation B-1 is thicker than 6xDIx$\beta$, Petrobras shall be consulted.

.#3) Plate minimum thickness:

- pipes up to 14 in of nominal diameter: t ≥ 1/8”;
- pipes from 16 in to 22 in nominal diameter: t ≥ 1/4”.