Industrial Electrical/Electronic Control Technology Level-III

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ACRONOMY

ANSI…… American National Standards Institute

ASME…….. American Society of Mechanical Engineers

BPCS…… Basic Process Control Systems

Cx……. Commissioning

Cx A……. Commissioning Authority

EBCS…… Ethiopian building code standard

EELPA……. Ethiopian Electric Light and Power Authority

EEPCO……. Ethiopian Electric Power Corporation

ISA…… Instrumentation, Systems and Automation

ITS…… International Temperature Scale

LAC…….. Low Ambient Control

NEC…….. National Electrical Code

OPR…….. Owner's Project Requirements

ORI…….. On Rise Inlet

ORO…… On Rise Outlet

PRV…….. Pressure Reducing Valves

SIS…… Safety Instrumented Systems

SP……. Sterile Processing

SPD…….. Sterile Processing Department

Introduction to the Module

In Electrical field; the commissioning of instrumentation and control system helps to know the quantity of work; to estimate the quantity of material required; to determine the cost of the work; to estimate the expect project completion time for electrical filed.

This module is designed to meet the industry requirement under the industrial electrical machine control occupational standard, particularly for the unit of competency: Commission Instrumentation and Control System.

This module covers the units:

- **Introduction About Commissioning**
- **Commissioning Operation**
- **Commissioned Systems and Equipment**

Module Instruction

For effective use this modules trainees are expected to follow the following module instruction:

1. Read the information written in each unit
2. Accomplish the Self-checks at the end of each unit
3. Perform Operation Sheets which were provided at the end of units
4. Do the “LAP test” given at the end of each unit and
5. Read the identified reference book for Examples and exercise

UNIT ONE: INTRODUCTION ABOUT COMMISSIONING

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- OHS policies and procedures on Instrumentation and control device
- Instrumentation and control standards
- Instrumentation and control system
- Benefits and goals of commissioning
- Commissioning procedures and Process

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Follow OHS policies and procedures on Instrumentation and control device
- Identify Instrumentation and Control standards
- Inspect and Test Instrumentation and control system
- Describe benefits and goals of commissioning
- Follow Commissioning procedures and process

1.1. OHS policies and procedures on Instrumentation and control device

- **Electrical Safety Policy**

Electric shock can be received by either direct or indirect contact with an energized item, tracking through or across a medium (such as water), or by arching. Electrical burning and arching from equipment can also release toxic gases and air contaminants.

Organizations under the WHS Regulations are obligated to protect workers and others from the risk of injury from the use of electricity, and from working in the vicinity of electricity. The Electrical Safety Module is a document that provides guidance on the management strategies and mechanisms organization can implement to eliminate, or reduce and control risks arising from electricity. The policy includes:

- Electrical Safety Policy
- Electrical Safety Procedure
- Electrical Equipment Register
- Electrical Safety Checklist

Electrical, Control & Instrumentation (EC & I) in the onshore Chemicals, Explosives and Microbiological Sectors. In many processes and activities, EC & I equipment and systems provide important prevention and mitigation measures against accidents.

Functional safety

Functional safety is the part of the overall safety of plant and equipment that depends on the correct functioning of safety-related systems and other risk reduction measures such as safety instrumented systems (SIS), alarm systems and basic process control systems (BPCS).

SIS

SIS is instrumented systems that provide a significant level of risk reduction against accident hazards. They typically consist of sensors and logic functions that detect a dangerous condition and final elements, such as valves, that are manipulated to achieve a safe state.

The general benchmark of good practice is BS EN 61508, Functional safety of electrical/electronic/programmable electronic safety related systems. BS EN 61508 has been used as the basis for application-specific standards such as:

- BS EN 61511: process industry
- BS EN 62061: machinery
- BS EN 61513: nuclear power plants

1.2. Instrumentation and Control standards

- Ethiopian building code standard EBCS: Ethiopian building code standard EBCS -10 and EBCS-11, various Ethiopian ES on electrical materials and standards
- Regulations for consumers' electrical installations: Regulations for consumers' electrical installations, 1969, issued by Ethiopian Electric Light and Power Authority (EELPA), (now EEPCO)
- ISA (Instrumentation, Systems and Automation): Society (formerly Instrument Society of America)
- ANSI(American National Standards Institute)
- ASME (American Society of Mechanical Engineers)
- NEC (National Electrical Code)

SPECIFICATIONS AND STANDARDS

- ANSI/ASME B 16.5: Pipe Flanges and Flanged Fittings
- API RP-550 : Manual on Installation of Refinery Instruments and Control Systems, Part 1 - Process Instrumentation and Control Sections 1 Through 13
- ASTM A 312 Stainless Steel Piping
- ISA-RP60.6 Nameplates, Labels, and Tags for Control Centers
- ISA-RP7.1 Pneumatic Control Circuit Pressure Test
- ISA-RP12.6 Installation of Intrinsically Safe Systems for Hazardous (Classified) Locations
- ISA-S5.1 Instrument Symbols and Identification
- ISA-S5.4 Instrument Loop Diagrams

- ISA-S12.4 Instrument Purging for Reduction of Hazardous Area Classification
- ISA-S20 Specification Forms for Process Measurement and Control Instrumentation; Primary Elements and Control Valves
- ANSI/AWWA C701 Cold-Water Meters - Turbine Type for Customer Service
- ANSI/AWWA C702 Cold-Water Meters - Compound Type
- ASTM A 126 Specification for Gray Iron Castings for Valves, Flanges and Pipe Fittings
- ASTM B 61 Specification for Steam or Valve Bronze Castings

ENVIRONMENTAL CONDITIONS

A. **General:** All instrumentation and control system components and associated wiring shall be suitable for use in a treatment facility environment where there may be high energy AC fields, DC control pulses, and varying ground potentials between transducers and system components. The system design shall be adequate to provide proper protection against interferences from all such possible situations.

B. **Field Situated Equipment:** The instrumentation and control system shall be installed on a wastewater treatment plant site. All devices shall be designed to exist in environments rated (G2)(G3)(GX) per ISA S71.04. The system design shall be adequate to provide proper protection the environment typically associated with these facilities. As a minimum, the instrumentation and control systems shall be designed and constructed for satisfactory operation and low maintenance requirements under the following environmental conditions:

1. Temperature Range: 0 through 50 degrees C (32 through 122 degrees F)

2. Thermal Shock: 0.55 degrees C per minute (1.0 degrees F per minute)

3. Relative Humidity: 20 through 95 percent (non-condensing)

C. **Control Room Situated Equipment:** Control rooms shall be air conditioned to achieve the environmental noted in item B herein. (No positive control of relative humidity is provided.) In the event of a failure of the air conditioning system, all

components of the instrumentation and control system shall be rated to operate in an environment where the ambient temperature is 15 through 35 degrees C (59 through 95 degrees F) and the relative humidity is 20 to 95 percent (non-condensing).

D. **Noise Tolerance:** The instrumentation and control system components shall not exceed a db level of 55 when monitored 3-feet away from the devices. If upon testing it is found that this limit is exceeded at the option of the CONSTRUCTION MANAGER and at no additional cost to the OWNER, devices shall be replaced in order to achieve a maximum level of 55 db or sound absorption materials shall be added.

1.3. Instrumentation and control system

- Pressure measurement and control loop
  - ✓ Head Pressure Control Valves Operation

LAC-4 – The valve designation LAC stands for Low Ambient Control. The LAC-4 is a three way modulating valve that responds to discharge pressure. As shown in Figures 1 and 2, the discharge pressure bleeds around the pushrod to the underside of the diaphragm. The discharge pressure opposes the dome pressure. When the outdoor ambient falls, the condensing pressure falls. This causes the discharge pressure to fall as well. When the discharge pressure falls below the dome pressure, the valve modulates open to the discharge port which allows discharge gas to bypass the condenser. Mixing the discharge gas with the liquid creates a high pressure at the condenser outlet, reducing the flow and causing liquid to back up in the condenser. Flooding the condenser reduces the area available for condensing. This reduction in effective condenser surface area results in a rise in condensing pressure. During summer conditions, the discharge pressure is high thus closing the discharge port. Hence, there is full liquid flow from the condenser to the receiver.

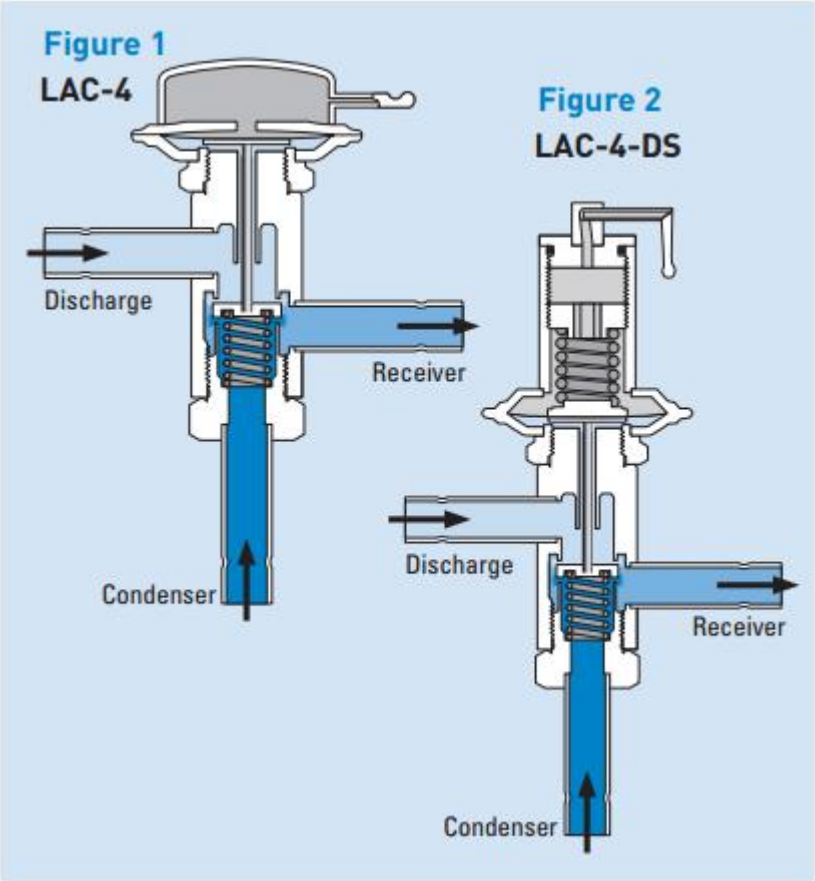


Figure 1: Low Ambient Control (LAC-4)

LAC-5, LAC-10 – The LAC-5 and LAC-10 are also three way modulating valves but they respond to receiver pressure. As shown in Figure 3, the receiver pressure acts under the diaphragm. As the receiver pressure drops below the valve setting, the seat moves away from the discharge port allowing discharge gas to bypass the condenser. This discharge gas warms the liquid in the receiver and raises the pressure to the valve setting. At the same time discharge gas is bypassing the condenser, liquid flow from the condenser is restricted, which allows liquid to back up in the condenser. Flooding the condenser reduces the area available for condensing thus raising the condensing pressure. During summer conditions, the seat closes the discharge port due to high pressure in the receiver. Therefore, there is full liquid flow from the condenser to the receiver.

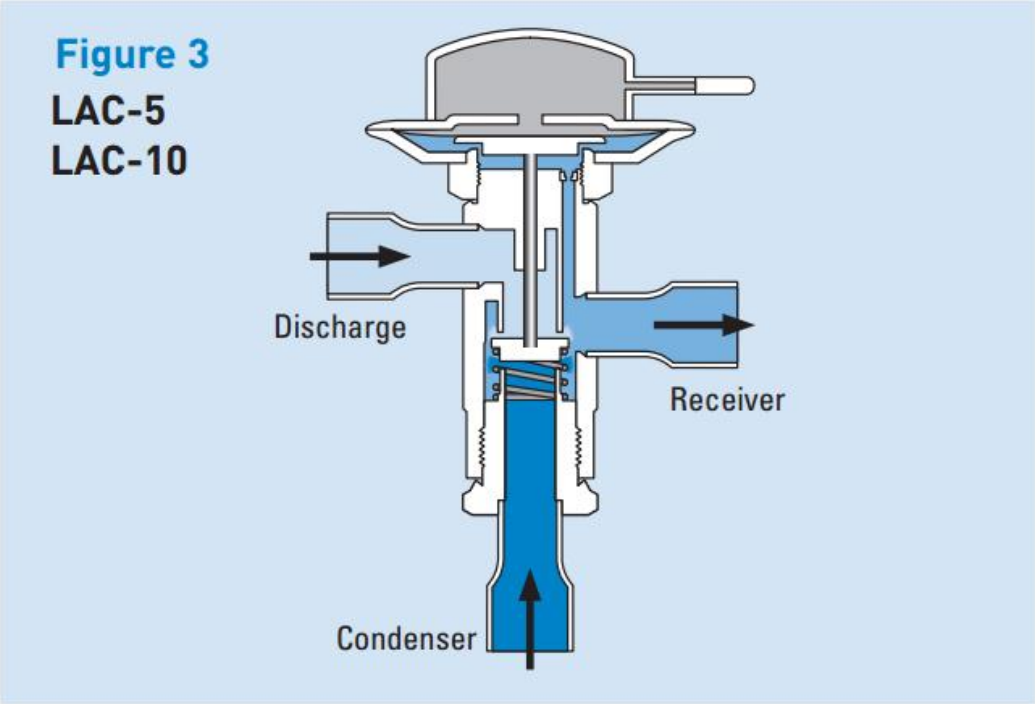


Figure 2: Low Ambient Control (LAC-5 and 10)

OROA – The OROA is a nonadjustable head pressure control valve which performs the function of limiting the flow of liquid refrigerant from the condenser and at the same time regulates the flow of hot gas around the condenser to the receiver. The main orifice of the OROA valve is controlled by the valve diaphragm which causes the orifice to Open on Rise of Outlet pressure. As shown in Figure 4, the inlet and outlet pressures are exerted on the underside of the seat disc in an opening direction. Since the area of the port is small in relationship to the diaphragm area, the inlet pressure has little direct effect on the operation of the valve. Therefore, the outlet or receiver pressure is the control pressure which actuates the valve. The force on top of the diaphragm, which opposes the control pressure, is due to the air charge in the element. These two forces are the operating forces of the OROA valve that control the main port.

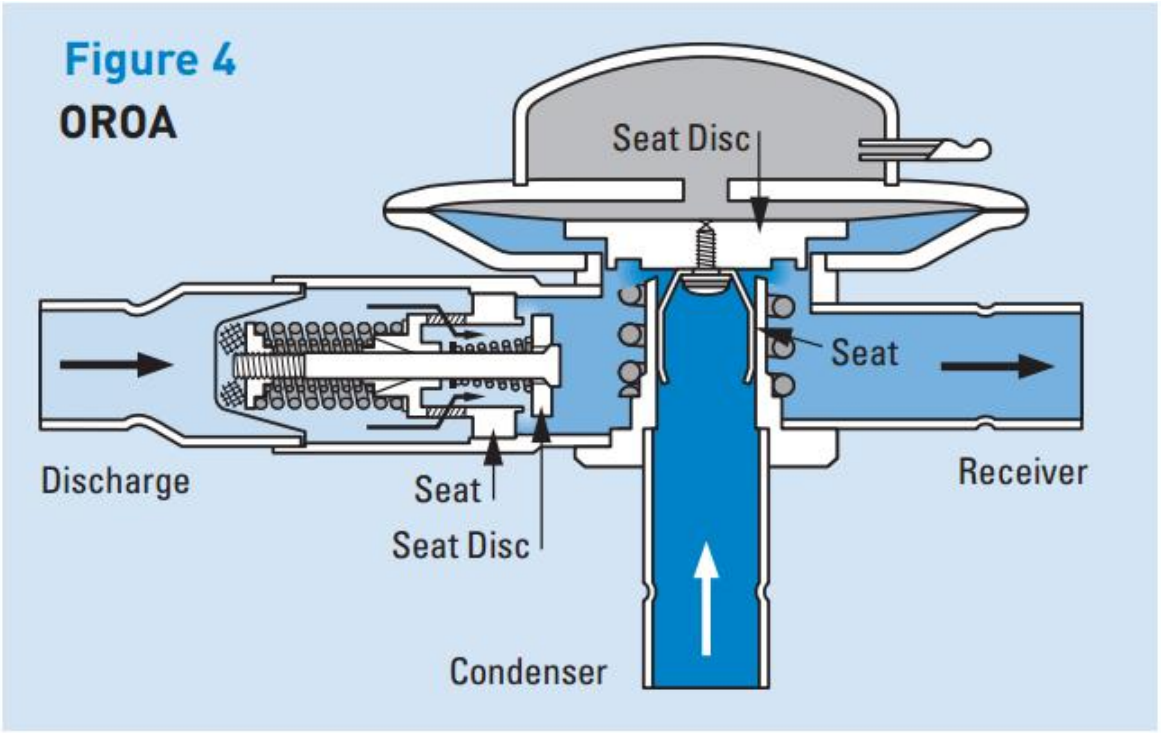


Figure 3: On Rise Outlet (ORO)

As shown in figure, the ORI is located in the liquid drain line between the condenser and the receiver. And the ORD is located in a hot gas line bypassing the condenser. During periods of low ambient temperature, the condensing pressure falls until it approaches the setting of the ORI valve. The ORI then throttles, restricting the flow of liquid from the condenser. This causes refrigerant to back up in the condenser thus reducing the active condenser surface and raising the condensing pressure. Since it is really receiver pressure that needs to be maintained, the bypass line with the ORD is required.

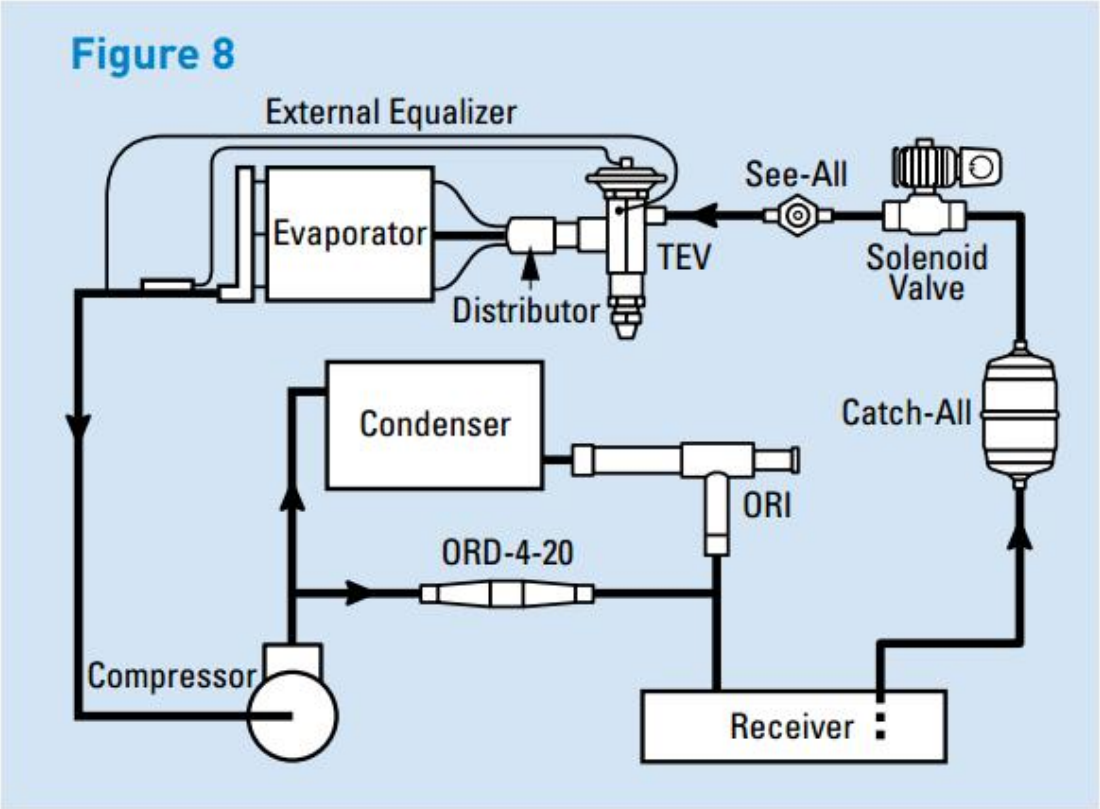


Figure 4: On Rise Inlet (ORI)

- Level measurement and control loop

  This topic discusses the basic principles of level measurement and control in industrial process applications. Sensing and controlling product levels in containers involves a wide range of materials, including liquids, powders, slurries, and granular bulk. In all level measurement a sensing device, element, or system interacts with material inside a container. A wide variety of physical principles are used to measure level. Common types include sight, pressure, electric, sonic, and radiation-each of which we discuss here. We will also explore level switches and a level control application.

  Sight-type Instruments

  There are three common sight-type level sensors: glass gauges, displacers, and tape floats. Glass gauges are the most widely used instruments for measuring the level in a process tank.

Glass Gauges

Two types of level glass gauges are used to measure liquid level: tubular and flat. The tubular type works in the same way as a manometer, that is, as the liquid level in a vessel rises or falls the liquid in the glass tube will also rise or fall. The gauges are made of glass, plastic, or a combination of the two materials. The material from which the transparent tubes are made must be able to withstand the pressure in the vessel, and they are generally limited to 450 psi at 400°F. Figure 6-1 shows two common applications of tubular sight glasses: an open or vented process vessel and a pressurized vessel. For the pressurized tank, the upper end of the tube is connected to the tank. This creates an equilibrium pressure in both ends of the tube, and the liquid in the tube rises to the same level as the liquid in the vessel. A calibrated scale is normally mounted next to the sight gauge to indicate the level in the tank.

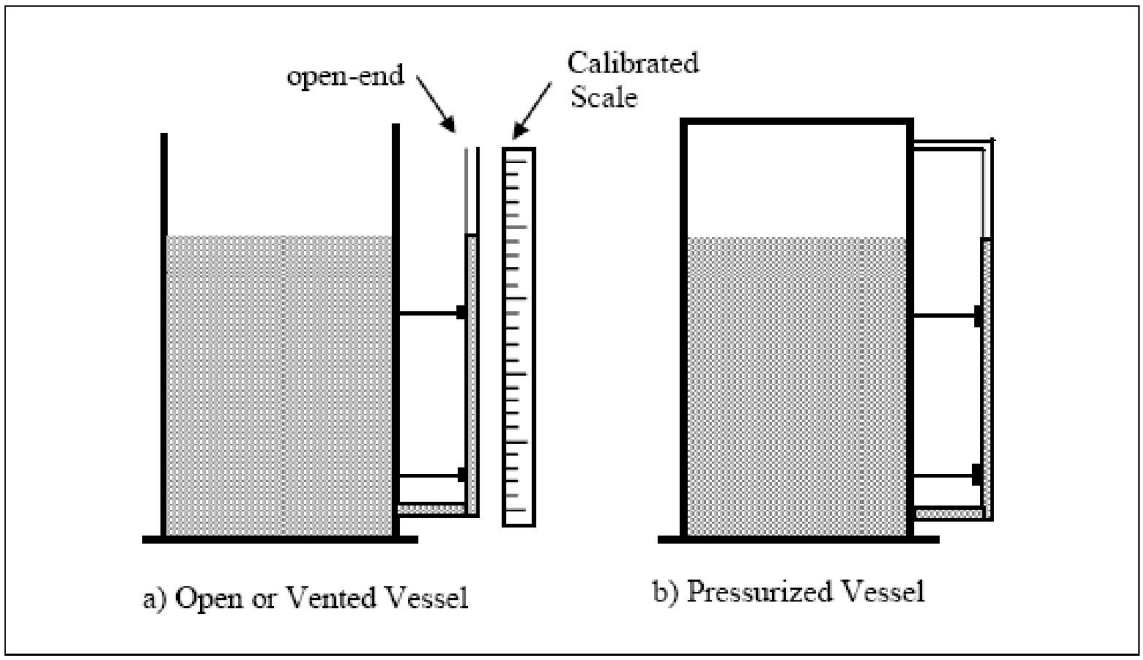


Figure 6-1. Tubular sight glass gauges

Figure: 5 glass gauge level measurement

- **Flow measurement and control loop**

Introduction

We begin this chapter by discussing the basic principles of flow, then move on to derive the basic equations for flow velocity and volumetric flow. The chapter concludes with a discussion of the common types of flow measuring devices and instruments, such as orifice plates, venturi
tubes, flow nozzles, wedge flow elements, pitot tubes, annubars, turbine flow meters, vortex shedding devices, magnetic flow meters, ultrasonic flow meters, positive-displacement flow meters, mass flow meters, and rotameters.

The study of fluids in motion, or flow, is one of the most complex branches of engineering. This complexity is reflected in such familiar examples as the flow of a river during a flood or a swirling cloud of smoke from a process plant smokestack. Each drop of water or each smoke particle is governed by Newton's laws, but the equations for the entire flow are very complicated. Fortunately, idealized models that are simple enough to permit detailed analysis can represent most situations in process control.

Flow Principles

Our discussion in this topic will consider only a so-called ideal fluid, that is, a liquid that is incompressible and has no internal friction or viscosity. The assumption of incompressibility is usually a good approximation for liquids. A gas can also be treated as incompressible if the differential pressure driving it is low. Internal friction in a fluid gives rise to shearing stresses when two adjacent layers of fluid move relative to each other, or when the fluid flows inside a tube or around an obstacle. In most cases in process control, these shearing forces can be ignored in contrast to gravitational forces or forces from differential pressures.

- Temperature measurement and control loop

Introduction

This topic explores the more common temperature-measuring techniques and transducers used in process control, including filled-system thermometers, bimetallic thermometers, thermocouples, resistance temperature detectors (RTDs), thermistors, and integrated-circuit (IC) temperature sensors. We will discuss each transducer type in detail, but we will first consider the history of temperature measurement, temperature scales, and reference temperatures.

The International Temperature Scale (ITS) is based on such phenomena. Revised in 1990, it establishes the seventeen reference temperatures shown in Table 7-1. The ITS-90, as this new version is called, is designed so that temperature values obtained on it do not deviate from the Kelvin thermodynamic temperature values by more than the uncertainties of the Kelvin values as they existed at the time the ITS-90 was adopted. Thermodynamic temperature is indicated by the symbol T and has the unit known as the Kelvin, symbol K. The size of the Kelvin is defined to be 1/273.16 of the triple point of water. A triple point is the equilibrium temperature at which the solid, liquid, and vapor phases coexist.

EXAMPLE 7-2

Problem: Express a temperature of 200°F in degrees Celsius and then degrees Kelvin.

Solution: First, we convert 200°F to degrees Celsius as follows:

$$T(^\circ\mathrm{C}) = \frac{5}{9}(T(^\circ\mathrm{F}) - 32^\circ)$$

$$T = \frac{5}{9}(200 - 32)^\circ\mathrm{C}$$

$$T = 93.33^\circ\mathrm{C}$$

Now, we convert the temperature in degrees Celsius to Kelvin as follows:

$$T\,(K) = T(°C) + 273.15$$

$$T\,(K) = 93.33°C + 273.15$$

$$T = 366.48\ K$$

Table 7-1. Defining Fixed Points of the ITS-90

Description	K	°C
Vapor pressure (VP) point of helium	3 to 5	-270.15 to -268.15
Equilibrium hydrogen at triple point (TP)	13.8033	259.3467
Equilibrium hydrogen at VP point	≈17	≈-256.15
Equilibrium hydrogen at VP point	≈ 20.3	≈-252.85
Neon at TP	24.5561	248.5939
Oxygen at TP	54.3584	218.7916
Argon at TP	83.8058	189.3442
Mercury at TP	234.3156	38.8344
Water at TP	273.16	0.01
Gallium at melting point (MP)	302.9146	29.7646
Indium at freezing point (FP)	429.7485	156.5985
Tin at FP	505.078	231.928
Zinc at FP	692.677	419.527
Aluminum at FP	933.473	660.323
Silver at FP	1234.93	961.78
Gold at FP	1337.33	1064.18
Copper at FP	1357.77	1084.62

1.4. Benefits and Goals of commissioning

The ultimate benefit of new facility and system commissioning is the documented performance of the facility and systems as it is transitioned into the long-term operations and maintenance function. Commissioning, used as a more forensic problem identification and solutions-based process, can be applied to an existing facility or system even if not initially commissioned, as described in Existing Building Commissioning. Commissioning assists in the delivery of a project and helps to provide an efficient, safe and healthy facility; optimizes energy and water use; reduce operating costs; facilitate O&M staff orientation and training; and improve installed building systems documentation and operations. These functions can result in increased profitability in both facility and staff operations.

Commissioning benefits Owners through improved facility performance including higher quality workplace environments, and prevention of potential business losses. The cost of not commissioning is equal to the increased costs of correcting design and construction deficiencies later, plus the costs of inefficient operations. For example, in mission critical facilities, the cost of not commissioning can be measured by the cost of downtime and lack of appropriate facility use.

The primary goal of commissioning any project or system is to ensure that success for the project is clearly defined in the Owner's Project Requirements (OPR) and that the building and systems perform as intended to fulfill that mission. The commissioning process can be applied to an entire facility or to any specific system or assembly if new, upgraded or modified.

In addition to energy efficiency and overall performance drivers, another factor increasing demand for commissioning is the Owner's desire to obtain certification through building performance rating systems. These rating systems have been developed to improve the project planning, design, construction, and performance of energy and water efficiency, environmental conditions in buildings, verification, documentation, and operations practices. A building certified to these rating systems can include highly efficient gas, water, power and lighting systems, solar photovoltaics, and other energy and resource technologies. From an Owner's perspective, investment in these and other

sophisticated building technologies must be accompanied by rigorous design and construction quality assurance and performance verification measurement, which are provided holistically through the commissioning process.

The principal goals of building commissioning are to:

1. Include the project requirements including the commissioning process in the OPR document.
2. Verify that the OPR requirements, including commissioning, are in the project design and construction documents for new projects.
3. Facilitate delivery of buildings and construction projects that meet the Owner's Project Requirements.
4. Prevent or eliminate problems in a cost-effective manner through proactive quality techniques.
5. Verify systems are installed and working as intended and benchmark that operation.
6. Provide and collect documentation and records on the design, construction, and testing to facilitate operations and maintenance of the facility.
7. Facilitate training functions and system operation documentation and Cx tools for O&M staff performance and implementation of ongoing Cx.
8. Lower overall first costs and life-cycle costs for the Owner.

1.5. Commissioning process and procedure

Commissioning process

- Pre-Design/Design Phase: Establishing the owner's needs and objectives, and developing the commissioning plan and specifications.
- Construction Phase: Installing, starting up and testing the equipment and systems, and resolving any issues or defects.
- Occupancy Phase: Fine-tuning and adjusting the performance of the equipment and systems, and providing training and documentation to the owner and operators.
- Process/System Startup Phase: Initiating the operation of the equipment and systems, and verifying the functionality and safety.
- Performance Verification Phase: Measuring and evaluating the performance of the equipment and systems, and ensuring they meet the design criteria and owner's requirements.

Pre-Design/Design Phase: Establishing Needs

Achieving commissioning objectives means clearly defining the owner's needs, and the earlier the better. Engaging a Commissioning Authority in the pre-design or design is best for determining and documenting the Owner's Project Requirements (OPR). The OPR then becomes the keystone of the project, and the Commissioning Authority ensures all activities align with meeting these requirements.

Depending on the specific requirements, the CxA may also have the following duties:

- Develop the written Cx plan
- Identify systems to be commissioned
- Specify testing for the construction phase of the project
- Define the scope and schedule for Cx activities, including drafting a project's general Cx requirements to be inserted into the project specifications.
- Complete design reviews and map the design plans back to the OPR
- Begin establishing training guidelines for operations and maintenance (O&M) staff

Construction Phase: Installation, Startup and Testing

The construction phase of a system or assembly is the crux of a project and where much of the hands-on Cx activities occur. If the organization serving as your CxA completed your OPR and Cx plan prior to this point, it will be well prepared to implement activities and testing. The key objective during this phase is to ensure all components of the critical infrastructure, as well as the system as a whole, operate as intended and in accordance with the OPR.

The CxA and team will be busy during construction with many key activities such as the following:

- Review submittals of commissioned equipment and controls
- Participate in factory witness testing for major components of the system
- Ensure proper equipment installation prior to startup
- Witness vendor startup of critical equipment
- Develop and conduct all functional and systems tests and complete acceptance testing
- Document problems or weaknesses identified during testing and make sure issues are addressed
- Prepare systems operating documentation
- Oversee training for O&M staff based on pre-established training guidelines

Occupancy Phase: Fine-tuning and Adjusting

When the system or assembly is complete, there is still Cx work to be done. Many project owners keep their CxA on board up to a year post occupancy. During the occupancy phase, the CxA can do the following:

- Perform deferred or seasonal testing
- Adjust systems and equipment as needed to ensure optimal performance
- Conduct a warranty review
- Assist with requirements for Leadership in Energy & Environmental Design (LEED) certification, if applicable
- Participate in a lessons-learned workshop

Self check 1.1

PART I. Choose the correct answer for the following question

1. A document that provides guidance on the management strategies and mechanisms organization can implement to eliminate, or reduce and control risks arising from electricity.

A. Electrical Safety Module C. A Electronics Safety Module

B. Computer Safety Module D. Machine Safety Module

2. Is instrumented system that provide a significant level of risk reduction against accident hazards

A. **BPCS** B. Alarm systems C. **SIS** D. All

3. EBCS stands for

A. Electronic basic control system

B. Ethiopian building code standard

C. Ethiopian building control standard

D. Electronic basic code system

4. ISA-RP7.1 Specification and standards for

A. Instrument Symbols and Identification

B. Instrument Loop Diagrams

C. Cold-Water Meters - Turbine Type for Customer Service

D. Pneumatic Control Circuit -- Pressure Test

5. In the event of a failure of the air conditioning system, all components of the instrumentation and control system shall be rated to operate in an environment where the ambient temperature is

A. 15 through 35 degrees C C. 5 through 25 degrees C

B. 15 through 25 degrees C D. 5 through 35 degrees C

6. The instrumentation and control system components shall not exceed a db level of ….. when monitored 3-feet away from the devices

A. 65db B. 55db C. 45db D. 25db

7. Low Ambient Control valve which is a three way modulating valve that responds to discharge pressure is

A. LAC-4 B. LAC-5 C. LAC-10 D, LAC-6

8. Is a nonadjustable head pressure control valve which performs the function of limiting the flow of liquid refrigerant from the condenser and at the same time regulates the flow of hot gas around the condenser to the receiver

A. OROA B, LAC 4 C. LAC5 D. LAC10

9. Are the most widely used instruments for measuring the level in a process tank.

A. displacers sight-type B. Glass gauges sight-type C. tape sight-type D. All

10. A temperature of 200°F in degrees Celsius is?

A. 366.48 ^{0}C B. 66.48 ^{0}C C. 93.33 ^{0}C D. 393.48 ^{0}C

11. Commissioning assists in the delivery of a project and helps to provide

A. Efficient operations B. safe and healthy facility C. reduce operating costs D. All

12. The primary goal of commissioning any project or system is?

A. To ensure that success for the project is clearly defined in the Owner's Project Requirements

B. The building and systems perform as intended to fulfill that mission

C. To improve the project planning, design, construction, and performance of energy

D. All

13. In which commissioning phase the Cx.A prepare systems operating documentation?

A. Pre-Design/Design Phase B. Occupancy Phase C. Construction Phase D. All

PART II. Short answer questions (Total 30 Point)

1. List at least four the principal goals of building commissioning
2. Explain the five phases of commissioning process
3. List the common temperature-measuring techniques and transducers used in process control, including filled-system thermometers
4. Explain safety instrumented systems (SIS)

UNIT TWO: COMMISSIONING OPERATION

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Commissioning work
- Inspection of Instrumentation Process and System
- Inspection Of Control Device And System
- Testing of Instrumentation Process and System
- Testing of Control Device and System
- Documentation on Commissioning Operation

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Perform Commissioning work
- Perform Inspection of Instrumentation Process and System
- Perform Inspection Of Control Device And System
- Perform Testing of Instrumentation Process and System
- Perform Testing of Control Device and System
- Prepare Documentation on Commissioning Operation

2.1 Commissioning work

Commissioning work means to formally choose someone to do a special piece of work, or to formally ask for a special piece of work from someone.

Project commissioning is the process of ensuring that all systems and components of a building or industrial plant are designed, installed, tested, operated, and maintained according to the owner's or final client's operational requirements. A commissioning process may be applied not only to new projects but also to existing units and systems subject to expansion, renovation or revamping.

In practice, the commissioning process is the integrated application of a set of engineering techniques and procedures to check, inspect and test every operational component of the project: from individual functions (such as instruments and equipment) up to complex amalgamations (such as modules, subsystems and systems).

Commissioning activities in the broader sense applicable to all phases of the project from the basic and detailed design, procurement, construction and assembly until the final handover of the unit to the owner, sometimes including an assisted operation phase.

The main objective of commissioning is to effect the safe and orderly handover of the unit from the constructor to the owner, guaranteeing its operability in terms of performance, reliability, safety and information traceability. Additionally, when executed in a planned and effective way, commissioning normally represents an essential factor for the fulfillment of schedule, costs, safety and quality requirements of the project.

2.2 Inspection of Instrumentation Process and System

The stages in the inspections process are: Planning, Overview meeting, Preparation, Inspection meeting, Rework and Follow-up. The Preparation, Inspection meeting and Rework stages might be iterated.

The three most common types of quality inspections.

- Pre-Production Inspection.
- During Production Inspection.
- Final Random Inspection.

There are three main elements to the inspection framework;

- Strategy and Governance;
- Delivery; and
- Outcomes.

Constants in each of these areas and throughout each inspection are equality and fairness, together with standards and best practice.

Instrument Inspection for the Instrument Specialist

Instrument inspection is one of the critical tasks for which Sterile Processing (SP) technicians are responsible. For some SP departments (SPDs), instrument processing is their only focus; other facilities' SPDs, however, are responsible for additional tasks, such as management of case carts, supply inventory and durable medical equipment. Regardless of the assigned tasks, every SPD is busier today than in the past. This is partially due to the number of new medical devices being introduced and the complexity of those devices. This lesson reviews basic processes for instrument inspection, assembly and maintenance.

The importance of accurate instrument inspection and assembly

Many facilities have experienced labor freezes, cutbacks or a higher volume of procedures without adding staff. Regardless, it is important for all healthcare workers, including SP professionals, to remember that basic procedures do not change just because they are busier, or their resources are more thinly stretched. Instrument inspection is one such process that cannot be rushed or overlooked. Basic instrument inspection processes apply to all types of instruments, regardless of their complexity. Giving in to the pressure of a rapid turnover of instruments or sets jeopardizes both staff and patient safety. Further, failure to diligently check for soil and debris can cause an unsterile instrument or set to be used on a patient, if the debris is not noticed in the procedure area before the case begins. This can potentially cause a surgical site infection (SSI) or worse. When an instrument is not properly assembled or its function is not checked, a physician may attempt to use a non-functional instrument that can harm the patient, physician or both. Unsharpened scissors and improperly functioning forceps and graspers, for example, can cause tissue damage in the patient, which can increase recovery time and lead to an infection. Improperly inspected needle holders may allow a needle to slip into a surgical site and cause delays while the surgical team tries to locate the needle before it can cause harm. A soiled or clogged lumen may introduce debris into a patient and prevent the surgical team from clearing the surgical site, thereby impeding the surgeon's vision or causing the patient to bleed longer than necessary. Failure to take enough time to string instruments correctly, protect sharp instruments or keep small parts close to the instrument in which they belong, or include all instruments on a count sheet can lead to devastating consequences during a procedure. It is vital that instrument assemblers always remember and apply the basic principles of instrument inspection and assembly.

Basic instrument inspection processes

Instrument inspection should begin as soon as a technician receives a tray from the decontamination area. When an instrument or set is selected for assembly, technicians should observe the overall condition of the instrument or set while on the way to the preparation table. If the tray looks overcrowded or heavy items are placed on top of more delicate items, there is a greater risk of instruments becoming damaged or soiled. Poor decontamination practices should be documented and reported to the appropriate person; such practices can be harmful to patients, physicians and other staff and prove costly to the facility. When watching an experienced instrument technician inspect instruments, it may appear that the process is simple and easy, but it is not. Instrument inspection is a detailed, technical and multistep process. There are many steps to the inspection process, including:

Verifying cleanliness. Once the instrument or set is selected, cleanliness testing [using a commercially prepared adenosine triphosphate (ATP) or proteinbased product] should be performed according to facility policy. Some facilities require testing of a few instruments from each tray, while others follow random sampling. If soil is found, the entire tray of instruments should be sent back to the decontamination area for re-cleaning, because the entire tray is considered contaminated. Positive and negative test results should be carefully documented. Lumened instruments and items with small crevices should be inspected. The use of a properly sized borescope is helpful with this process. This includes not only suction devices but flexible, semi-flexible and rigid endoscopes and many orthopedic items, such as cannulated screwdrivers, arthroscopes, power equipment and phacoemulsification handpieces. Again, soiled lumened instruments—and other instruments in the tray with which they were processed—should be returned to the decontamination area for recleaning. Note: It is important to clean every borescope after each use following the manufacturer’s instructions for use (IFU).

Drying. Unless otherwise stated in its IFU, each instrument should be completely dried. Wet instruments will change the wet-dry ratio in the sterilizer causing an unusable load of instruments that will require reprocessing. Reusable tray liners (e.g., silicone mats) must also be dried completely. Additionally, wet instruments will rust and can also contribute to mineral damage and staining.

Instrument inspection. Lighted magnification should be used to carefully check each part of every instrument and verify functionality. Inspection guidelines for various components are as follows:

Serrations—Carefully check all serrations for cleanliness and alignment. Close the instrument and confirm that the serrations are aligned to allow the instrument to completely close from the tip of the jaw to the serrations' end toward the middle of the instrument or at the hinge (box lock).

Teeth—All teeth should be present, and the tips of the instrument should fit together smoothly. Carefully check that the tips of the teeth are intact and not damaged; damaged tips can cause unnecessary tissue damage during a procedure. If the teeth do not fit together or tooth damage is present, remove the instrument from service and send it out for repair. Do not try to realign the instrument as it may further damage the device.

Fine-tipped instruments—Some instruments, including fine Adson forceps, towel clips and jewelers forceps, are easily damaged or misaligned. The teeth of forceps and the distal prongs of towel clips frequently have damage at their tips. All fine-tipped instruments should be carefully closed to ensure they align correctly. All tips and hinges should be intact, and the ratchets checked for proper functionality.

Hinges/box locks—Soil left in the hinge/ box lock area can create a patient safety issue and cause rust to form. Debris can also cause a device's open and close function to become rough and may prevent the instrument from closing properly. Carefully check this area with the instrument in different positions of opening and closing. Also, diligently inspect the area around the hinge for stress cracks. When stress cracks are

noted, remove the instrument from service, as it may break when pressure is applied during a procedure.

Small crevices—All crevices must be carefully checked for cleanliness. If a crevice is not originally a part of the device, it is an indicator of damage. Pull the device from service and send it for repair.

Ratchets and locks—Test each ratchet and lock per the manufacturer's IFU. Malfunctioning ratchets and locks can loosen during a procedure, obstructing the physician's view of the wound or releasing a vessel and blocking the field with blood.

Instrument sharpness—Scissors and other sharp instruments, including curettes, chisels, rongeurs and biopsy punches, should be checked to ensure they are sharp every time they are processed. Dull instruments will tear tissue rather than cut it, causing a longer recovery time for the patient and potentially leading to an infection from the tissue damage. Follow the manufacturer's IFU for the proper way to test each device's sharpness, ensuring the correct testing material is used for each instrument type and size. Remove all dull devices from service and send them out for repair.

Needle holders—Carefully check the insert area of each needle holder to confirm that the insert is intact, with no smooth areas. Cracked inserts can dislodge during a procedure and potentially be introduced into the patient's surgical site. Further, smooth areas will not properly grip a needle and can cause the needle to fall into a patient. Always follow the specific needle holder's IFU for the proper way to inspect the jaw area. Remove defective needle holders from service and send out for repair.

Marking systems—Every type of marking system—tape, nylon coating or etching—should be carefully inspected. Note: Instruments with damaged tape or coating give microorganisms a place to hide from cleaning, disinfecting and sterilizing agents.

- Tape—Carefully inspect for any indication of dryness, flaking, peeling, puckering or discoloring. If any of these issues are seen, the tape should be completely removed and reapplied following the manufacturer's IFU.

- Nylon-coated or nylon-dipped instruments—Check the entire coated surface for scratches and nicks. If any damage or wear is noted, remove the instrument from service and send for recoating.
- Etching systems (laser, electrochemical etching, etc.)—Verify that the information is still legible. Information may become illegible from use or refurbishment. When this occurs, the instrument should be removed from service and relabeled. Items labeled with an impact etcher and subsequently showing wear should be removed from service; this labeling method scratches through the protective surface of the instrument and causes it to rust and pit.

Insulation—All insulated instruments, including insulated forceps and scissors and insulated laparoscopic, robotic and neurologic instruments, should be carefully inspected each time the instrument is processed. Be sure to check each device's IFU for the proper testing equipment to use and process to follow. Faulty insulation can burn or shock the physician or patient.

Cords—All cords must be carefully checked for cleanliness and function. Many cords are dark in color, which makes it more difficult to see blood and body fluids. Using a dampened, low-lint cloth, carefully wipe the surface of the entire cord. If debris (color) transfers to the cloth, send the cord back to the decontamination area for recleaning. Check the proximal and distal ends of the cord for cleanliness and damage and inspect the entire length for nicks and cuts. As with all instrumentation, use lighted magnification to help identify any damage. Confirm the cord's functionality prior to packaging.

Demagnetization—Some devices, especially cardiovascular instruments, become magnetized during procedures. This is caused by the type of equipment used during those surgeries. It is important to check these instruments for magnetization before packaging the set. It is often easy to tell which instruments have become magnetized, as they will attract other metal devices. Demagnetizers are inexpensive devices that can be used to correct the magnetization. If a demagnetization device is not available, most repair companies will perform the process for a small fee. Never place a magnetized instrument in a set, as it may magnetize the other instruments. Needle holders that are magnetized, for example, may not release a needle when the physician is closing a wound.

Multipart instruments—Each piece of a multipart instrument must be inspected for cleanliness. The device should then be assembled to ensure all parts are available and fit together properly. Test the device's functionality, then disassemble it for disinfection or sterilization. Keep all parts of the device close together, ensuring that small pieces are contained and do not become lost.

Note: When inspecting instruments, it is essential to diligently follow each specific instrument's IFU. If a technician or department is unsure about any step, they should contact the manufacturer for clarification

2.3 Inspection of Control Device and System

Control panels: Control panels shall be provided with redundant power supplies which are configured in a fault-tolerant manner to prevent interruption of service upon failure and interruption of service necessitated by the replacement of a power supply. All power supplies shall have an excess rated capacity of 40 percent. The failure of a power supply shall be annunciated locally and shall generate an alarm to the DCS.

A. General: Control panels, including those furnished by equipment manufacturers, and shall be provided according to the following requirements.

1. Where indicated, control panels shall be provided with all required taps, fittings, rotameters, regulation and alarm interlocks to enable the implementation of a purge system which is in conformance with ISA-S12.4 Type Z requirements. Dimensions shall be in accordance with manufacturer's requirements. Elevations and horizontal spacing shall be subject to CONSTRUCTION MANAGER'S approval.

2. All control panels which require NEMA 3 or 4 ratings will be provided with window kits to preserve the panel's integrity and enable operations ready access to information.

3. Panels shall be fabricated, piped and wired by fully qualified workmen who are properly trained, experienced and supervised.

4. See Appendix C for control panels to be provided under this Contract.

B. **Materials:** 1. Panel section faces shall be #10 gage minimum thickness steel for free standing panels and #14 gage minimum thickness steel for smaller panels. All materials shall be selected for levelness and smoothness. 2. Relay rack high density type panels shall utilize standard relay racks with 14 gage steel frame and supports. 3. Structural Shapes and Strap Steel: ASTM A 283. 4. Bolting Material: Commercial quality carbon steel bolts, nuts and washers, all ½- inch diameter with UNC threads. Carriage bolts shall be used for attaching end plates. All other bolts shall be hex head machine bolts. All nuts shall be hot pressed hex, American Standard, heavy. Standard wrought washers shall be used for foundation bolts and attachments to building structures. All other bolted joints shall have S.A.E. standard lock washers.

C. Fabrication:

1. End plates, top plates and top closure panels shall be furnished when required. End plates, top plates and top closure panels shall be removable with countersunk bolts to match panels. Top closure panels shall be furnished in lengths which match the widths of standard panels, except that one top closure panel may extend across two 4-feet 6-inches wide or five 2-feet 0-inches wide standard panels. The vertical joints of these panels shall align with the vertical joints of the standard panels.

2. End closure or rear closure doors shall be provided. Such doors shall be flush fitting and gasketed and be of the hinged lift-off type with lockable door handles. A common key shall be provided for all doors on one panel assembly. Where removable access panels are indicated, they shall be furnished with dished handle fasteners. Screw driver 1/4 turn type fasteners are not acceptable.

D. Framework and Supports:

E. Finish:

F. Mounting of Instruments:

G. Piping Requirements for Control Panels:

1. General: a. The CONTRACTOR shall provide terminal connections near the top, rear of the panel for all tubing and piping which connect to instruments, valves, air supply and other pressure leads external to the panel. Terminal connections for tubing shall be bulkhead tube unions. Those for pipe shall be threaded couplings, plugged for shipping purposes. b. Each terminal connection shall have an engraved metal or plastic plate with a terminal and instrument tag number affixed nearby. c. The CONTRACTOR shall provide the air supply pressure reducing station, all instrument and supply piping and all pneumatic tubing or piping to terminal connections and between instruments located within the confines of the panel and supporting framework.

2. Air Supply Piping:

a. The contractor shall provide air supply piping from a point near the top of the panel framework to the inlet side of the pressure reducing station, or alternately to the inlet side of individual filter regulators.

b. Piping, fittings and valves downstream of the filters at the air supply reducing station shall be brass or copper. Headers may be extruded aluminum if the tube wall section is thick enough to accept threaded connections.

c. The low pressure instrument air supply header shall extend from the down stream side of the main pressure reducing valves across the length of panel which includes air users. Where the header must be broken for shipping purposes, brass unions shall be provided at the panel section junctions.

d. A separate air supply take-off consisting of a 1/4-inch brass connection braced into the air header (if brass or copper) shall be furnished for each instrument requiring an air supply. An additional 10 percent of the take-offs shall also be provided. Take-offs for 3/4-inch size headers may be made by using 3/4-inch by 3/4-inch by 1/4-inch reducing tees.

e. Each take-off shall be fitted with a 1/4-inch brass diaphragm of needle type shut-off valve. Provide circular type handle with tag number shown thereon.

f. The dead end of the air header opposite the supply end shall be fitted with a plugged ½-inch brass gate valve.

g. The connection from the shut-off valves air head to the instruments shall be by means of 1/4-inch or 3/8-inch O.D. tubing as required

H. Electrical Requirements for Control Panels:

1. The contractor shall provide all wiring, conduit, wire ways, and switches required to make instruments and other panel electrical devices operational.

2. Conduit, wire ways, junction boxes and fittings shall be installed for all signal wire, all thermocouple and resistance thermometer lead wire including those between temperature sensors and temperature indicators.

3. Each terminal connection shall have a plastic plate with a terminal and instrument tag number. All wiring shall be identified with stamped tubular wire markers.

4. Freestanding panels shall be provided with switched 100-watt incandescent back of-panel lights which are powered from a source independent from that which powers the panel devices. One light shall be provided for every 4 feet of panel width and shall be mounted inside in the top of the back-of-panel area.

5. Freestanding panels shall be provided with a 15-amp, 120 volt service outlet circuit within the back-of-panel area which are powered from a source independent from that which powers the panel devices. The circuit shall be provided with one 3-wire, 120-volt, 15-ampere, duplex receptacle for every 4 feet of panel width spaced evenly along the back-of-panel area. As a minimum, 2 duplex outlets shall be provided for each panel.

6. Smaller panels shall be sized to adequately dissipate heat generated by equipment mounted in or on the panel.

7. Where smaller panels are mounted outside or in unshaded areas, they shall be provided with thermostatically controlled heaters capable of maintaining inside temperatures above 40 degrees F.

8. Smaller panels shall be provided with a hand-switch controlled 100-watt incandescent light and a breaker protected 120-volt, 15-amp duplex receptacle.

9. Wiring Methods: Wiring methods and materials for all panels shall be in accordance with the NEC requirements for General Purpose unless otherwise indicated. Opening wiring in close cabinet type panels is allowed when indicated.

10. Construction:

a. Wire for 115-volt circuits shall be No. 14 AWG stranded with Type THWN or THHN insulation. All terminals for external wiring connections shall be suitable for No. 12 AWG wire.

b. Flexible conduit is not acceptable.

c. Conduit fittings shall be cast fittings.

d. Terminal boxes for incoming and outgoing signal leads shall be located at the top or bottom of the panel as indicated or as otherwise required.

11. Power Supply Wiring:

a. Unless otherwise indicated, all instruments, all alarm systems, and all motor controls shall operate on 24 VDC circuits.

b. The CONTRACTOR shall furnish terminal box connections for the main power supply entry as indicated.

c. Power supply switches for alarm units shall be three pole type, arranged to open both the power and alarm circuits. Each annunciator shall be equipped with a separate switch.
d. Instruments located on a single panel section which serve one process unit may be connected to a common branch power circuit. The number of branch circuits shall be such that no circuit load exceeds 10 amps. Different panel sections and instruments serving different process units shall not use common branch circuits. A 15-amp, two-pole circuit breaker shall be provided in each branch circuit. When instruments do not come

equipped with integral fuses, the panel fabricator shall furnish and install fuses as required for the protection of individual instrument against fault currents. Fuses shall be mounted on the back of the panel, in a fuse holder, with each fuse identified by a service name tag.

e. Each potentiometer type instrument, electronic transducer, controller or analyzer shall have an individual disconnect switch. Disconnect switches shall have metal or plastic tags listing the associated instrument tag numbers. Individual plug and cord set power supply connections may be used without switches when indicated.

f. Where alarm units are single unit types, one switch may be used to disconnect not more than six alarm units located on the same or adjacent panels.

12. Alarm Wiring: The contractor shall provide all alarms including light cabinets, audible signal units, test and acknowledge switches and remote logic units as indicated. Interconnecting wiring to panel mounted initiating devices shall also be provided. Wiring from external initiating devices shall be provided by the contractor. Where plug and cord sets are provided for component interconnection, the contractor shall harness and support the cables in a neat and orderly fashion. Where separate wire is required, the contractor shall install 16 AWG with thwn or thhn insulation between all components.

13. Signal Wiring:

a. Computer and Non-Computer Use: Signal wire shall be twisted shielded pair or triads in conduit or troughs. Cable shall be constructed of No. 16 AWG copper signal wires with THWN or THHN insulation. Color code for instrument signal wiring shall be:

(1) Positive - Black (+)

(2) Signal Ground Negative - White (-)

(3) Equipment Ground - Green

(4) Ungrounded - Red

(5) Energized by voltage sound external to panel - Yellow

(6) DC circuit - Blue

b. Multi conductor cables where indicated shall consist of No. 16 AWG copper signal wires twisted in pairs, with 600 volt fault insulation. A copper drain wire shall be provided for the bundle with a wrap of aluminum polyester shield. The overall bundle jacket shall be PVC.

c. Multi-conductor cables, wire ways and conduit shall provide for 10 percent allocation of spare, unused signal wires in addition to the indicated requirements.

14. Thermocouple Wiring:

a. The CONTRACTOR shall provide metal wire troughs, pull boxes, and thin walled conduit for duplex thermocouple lead wire in a manner which will facilitate field installation of lead wire without splices or terminal connections. The contractor shall also provide the lead wire connections between multipoint temperature sensors and temperature indicators when indicated. When a thermocouple junction box is indicated, it shall be located with the approval of the construction manager. The panel manufacturer shall install conduit and troughs and lead wires between the junction box and the instruments. Terminal material shall be compatible with extension wire used.

b. Thermocouple lead wire shall be No. 16 AWG with high temperature PVC insulation on each wire and PVC jacket overall, and shall conform to the latest ISA Specification for standard grade.

c. Conduit for thermocouple lead wire shall be in accordance with the following:

CONDUIT SIZE	½"	3/4"	1"	1½"	2"
NO. OF DUPLEX LEADS	1	4	6	16	26

d. Where the number of duplex lead wires exceeds 26, the wires shall be installed in rectangular ducts filled to not more than 40 percent capacity.

e. All thermocouple wireways and main conduits shall be sized to allow for 10% spare thermocouple leads.

f. Each signal, control, alarm, and indicating circuit conductor shall be designated by a single unique number which shall be shown on shop drawings. These numbers shall be marked on all conductors at every terminal using white numbered wire markers which shall be plastic-coated cloth, or shall be permanently marked heat-shrink plastic.

15. Terminal Blocks: Terminal blocks shall be molded plastic with barriers and box lug terminals, and shall be rated 15 amperes at 600-volts. White marking strips, fastened securely to the molded sections, shall be provided and wire numbers or circuit identifications shall be marked thereon with permanent marking fluid.

I. Color Conventions: Lens covers for indicating lights on all panels will be colored as follows:

1. Red-ON when;

- Motor not running (STOPPED)
- Valve CLOSED (not fully opened)
- Device not energized.
- Circuit breaker OPENED

2. Green-ON when;

- Motor running in forward direction (fast speed for multi-speed motors).
- Valve OPEN (not fully closed)
- Device energized.
- Circuit breaker CLOSED

3. White-ON when;

- Power available

- System in AUTOMATIC mode.
- Monitoring taking place.

Sizing and selection of control valves

Normative references

- ✓ IEC 60534-2-1, Industrial process control valves –Flow capacity –Sizing under installed conditions

  This part of IEC 60534 includes equations for predicting the flow of compressible and incompressible fluids through control valves.
- ✓ IEC 60534-2-3, Industrial process control valves –Flow capacity –Test procedures

  This part of IEC 60534 is applicable to industrial-process control valves and provides the flow capacity test procedures for determining the following variables used in the equations given in IEC 60534-2-1:

  a) Flow coefficient C;

  b) Liquid pressure recovery factor without attached fittings FL;

  c) Combined liquid pressure recovery factor and piping geometry factor of a control valve with attached fittings FLP;

  d) Piping geometry factor FP;

  e) Pressure differential ratio factors xT and xTP;

  f) Valve style modifier Fd;
- ✓ IEC 60534-7, Industrial process control valves –Control valve data sheet
  - ❖ Preliminary valve specification
  - ❖ Inquiry valve specification
  - ❖ Order valve specification
- ✓ IEC 60534-8-2, Industrial process control valves –Noise considerations – Laboratory measurement of noise generated by hydrodynamic flow through control valves

Process data

The following data should at least be known:

a) Type of fluid and its chemical, physical and thermodynamic characteristics, such as: pressure p; temperature T; vapour pressure pv; thermodynamic critical pressure pc; specific mass ; kinematic viscosity or dynamic viscosity ; specific heat at constant pressure Cp, specific heat at constant volume Cv orspecific heat ratio ; molecular mass M; compressibility factor Z; ratio of vapour to its liquid (quality); presence of solid particles; flammability; toxicity; other.

b) Maximum operating range of flow rate related to pressure and temperature of fluid at valve inlet and to differential pressure p across the valve.

c) Operating conditions (normal, maximum, minimum, start-up, emergency, other).

d) Ratio of pressure differential available across the valve to total head loss along the process line at various operating conditions.

e) Operational data, such as: maximum differential pressure with closed valve; stroking time; plug position in case of supply failure; maximum allowable leakage of valve in closed position; fire resistance; maximum outwards leakage; noise limitations.

f) Interface information, such as: sizing of downstream safety valves; accessibility of the valve; materials and type of piping connections; overall dimensions, including the necessary space for disassembling and maintenance, design pressure and temperature; available supplies and their characteristics.

- Valve specification

On the basis of the above data it is possible to finalise the detailed specification of the valve (data sheet), i.e. to select: valve rating; body and valve type; body size, after having calculated the maximum flow coefficient Cv with the appropriate sizing equations; type of trim; materials trim of different trim parts; leakage class; inherent flow characteristic; packing type; type and size of actuator; accessories.

2.4 Testing of Instrumentation Control Device and System

Testing of Pressure Reducing Valves

General Pressure Reducing Valve: Device that restricts downstream static and residual pressures. May be either direct-acting or pilot-operated.

Master Pressure Reducing Valve: Generally a pilot-operated PRV, Master PRVs control the pressures to a zones of systems containing more than one sprinkler system and/or standpipe valve. Master PRVs typically allow for numerous other downstream valves to not be pressure reducing.

Sprinkler Pressure Reducing Valve: PRV that regulates downstream static and residual pressures for a single sprinkler system. These are generally a direct -acting PRV.

Standpipe Pressure Reducing Valve: PRV that regulates downstream static and residual pressures for a single standpipe hose valve. These are generally a direct -acting PRV.

Specifications and requirements:

Testing of Master, Sprinkler, and Standpipe Pressure Reducing Valves (PRVs) is necessary to ensure that the PRVs provide sufficiently high pressure in order to ensure system operation, while also limiting pressures low enough to meet the listings of downstream components.

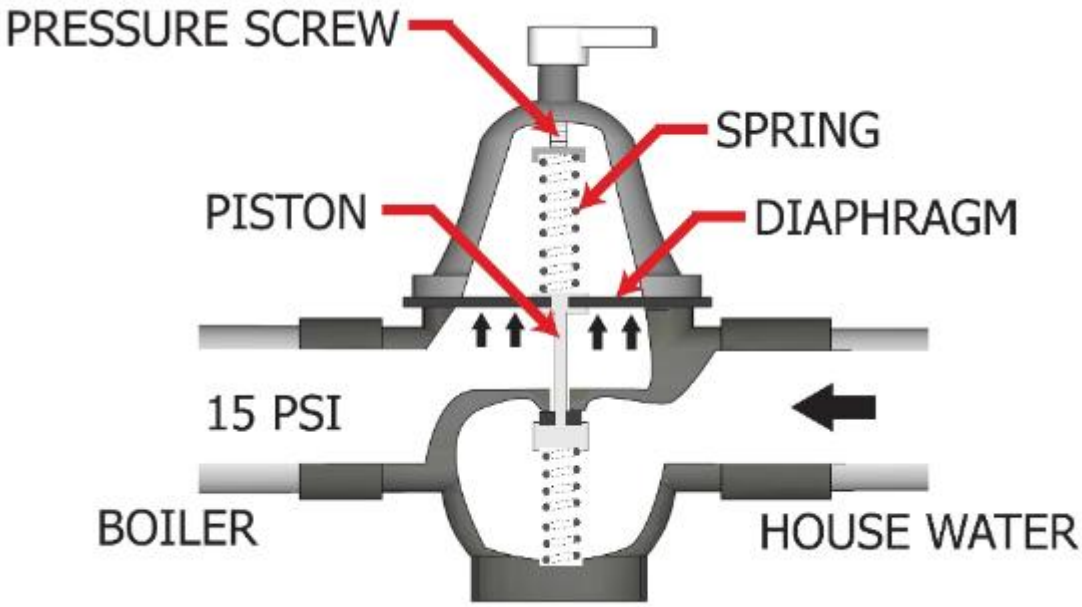


Figure 6: Pressure reducing valve

Acceptance testing

Pre-flow

- ✓ Determine the flow and pressure criteria for the PRV. Flow and pressure criteria must be determined by review of the approved plans. Flow and pressure shall be in accordance with manufacturer data.
- ✓ Determine how flow will be captured. Flow must be directed to a drain, captured in a tank, or flowed outdoors in a manner approved by the AHJ. When flowing to a drain, the drain size shall be equal to or greater than the PRV size.
- ✓ Determine how pressure downstream of the PRV will be measured. Typically, the pressure is measured with a pressure gauge immediately downstream of the PRV device.

- ✓ Determine how flow rate will be measured. The flow rate must be verified to ensure that the required system flow is being flowed through the PRV device. Typically, this is accomplished with an in-line flow meter located immediately after the PRV discharge and discharge gauge.
- ✓ Pre-connect hose or temporary piping from the PRV discharge to the drain/tank/outdoors, while adding in-line pressure gauge and flow meter.
- ✓ Determine how flow through the PRV is controlled with a valve for the purpose of this test. The test control valve must be situated downstream of the PRV, pressure gauge, and flow meter.

Flow

- ✓ Start the fire pump.
- ✓ Record the static pressure downstream of the PRV.
- ✓ Open the PRV test control valve.
- ✓ After flow stabilizes, record the residual pressure downstream of the PRV and the flow through the flowmeter.
- ✓ Close the PRV test control valve.
- ✓ Tag the valve with the date of the test and the flow and pressure.
- ✓ Record the valve location, flow and pressure.
- ✓ After testing is complete, turn off the fire pump and return pump to automatic mode.

Post-Test

- ✓ Compare test data to the plans to ensure that the PRV does not allow a higher static pressure, does not deliver a lower residual pressure.

Periodic testing

Pre-flow

a) Determine the flow and pressure criteria for the PRV. Flow and pressure criteria must be determined by review of the originally approved plans or by review of original acceptance records. When such records do not exist, the required flow

and pressure criteria must be calculated in a manner approved by the AHJ. Flow and pressure shall be in accordance with manufacturer data.

b) Determine how flow will be captured. Flow must be directed to a drain, captured in a tank, or flowed outdoors in a manner approved by the AHJ. When flowing t o a drain, the drain size shall be equal to or greater than the PRV size. Where existing installations do not provide test outlets, such as the case may be for sprinkler system PRVs and master PRVs, temporary outlets must be provided, or other means acceptable to the AHJ shall be established to provide full system flow through the PRV.

c) Determine how pressure downstream of the PRV will be measured. Typically, the pressure is measured with a pressure gauge immediately downstream of the PRV device. Where a pressure gauge is not already installed downstream of the PRV, a temporary gauge installation must be provided, or other means acceptable to the AHJ shall be established to accurately measure pressures downstream of the PRV.

d) Determine how flow rate will be measured. The flow rate must be verified to ensure that the required system flow is being flowed through the PRV device. Typically, this is accomplished with an in-line flow meter located immediately after the PRV discharge and discharge gauge. Where a flow meter is not installed, temporary means to measure flow must be provided, or other means acceptable to the AHJ shall be established to accurately measure flows through the PRV.

e) Pre-connect hose or temporary piping from the PRV discharge to the drain/tank/outdoors, while adding in-line pressure gauge and flow meter.

f) Determine how flow through the PRV is controlled with a valve for the purpose of this test. The test control valve must be situated downstream of the PRV, pressure gauge, and flow meter.

Flow

a) Start the fire pump.

b) Record the static pressure downstream of the PRV.

c) Open the PRV test control valve.

d) After flow stabilizes, record the residual pressure downstream of the PRV and the flow through the flow meter.
e) Close the PRV test control valve.
f) Tag the valve with the date of the test and the flow and pressure.
g) Record the valve location, flow and pressure.
h) After testing is complete, turn off the fire pump and return pump to automatic mode.

Post-Test

a) Compare test data to previous data to ensure that the PRV does not allow a higher static pressure, does not deliver a lower residual pressure, and provides for as much flow as the static pressure, residual pressure and flow determined on the plans. Where previous data is not available, compare the recorded data to the calculated pressure and flow requirements approved by the AHJ.

2.5 Documentation on Commissioning Operation

Record keeping

For each PRV, the following information shall be recorded:

i. PRV location.
ii. System served by each PRV.
iii. PRV make and model number.
iv. Provide a copy of the manufacturer's specifications for the PRV.
v. PRV setting (if applicable).
vi. Static pressure downstream of the PRV, calculated/required.
vii. Static pressure downstream of the PRV, tested.
viii. Residual pressure downstream of the PRV, calculated/required.
ix. Residual pressure downstream of the PRV, tested.
x. Flow GPM through the PRV, minimum calculated/required.
xi. Flow GPM through the PRV, tested.

Sample Test form for switch board and circuit breakers

Switchboard and Circuit Breakers	Items tested /checked by Contractor	Items witnessed By project engr.
a) No visible damage to impair safety.	*Yes/No/N.A.	*Yes/No/N.A.
b) Appropriate devices provided for isolation and switching.	*Yes/No/N.A.	*Yes/No/N.A.
c) Every circuit breaker provided with a legible and durable identification label	*Yes/No/N.A.	*Yes/No/N.A.
d) An up-to-date schematic diagram displayed.	*Yes/No/N.A.	*Yes/No/N.A.
e) All accessible live parts screened with insulating plate or earthed metal	*Yes/No/N.A.	*Yes/No/N.A.
f) All exposed conductive parts effectively earthed.	*Yes/No/N.A.	*Yes/No/N.A.
g) Earthing system effectively connected.	*Yes/No/N.A.	*Yes/No/N.A.
h) Warning notice displayed at main bonding connections.	*Yes/No/N.A.	*Yes/No/N.A.
i) All protective devices are functioned properly and correctly set	*Yes/No/N.A.	*Yes/No/N.A.
j) Initial /maintenance test carried out according to relevant recognized standards and manufacturers' recommendation, where appropriate, with test reports. (Insulation resistance test, pressure test etc.)	*Yes/No/N.A.	*Yes/No/N.A.
k) Other inspection items as required by the manufacturers of related equipment are satisfactory	*Yes/No/N.A.	*Yes/No/N.A.

Self check 2.1

PART I. Choose the correct answer for the following question

1. In practice, the commissioning process is the integrated application of

1. A set of engineering techniques C. A and B are answer
2. A set of engineering procedures D. None

2. The main objective of commissioning is to effect the safe and orderly handover of the unit from the constructor to the owner, guaranteeing its operability in terms of

   A. Performance B. Reliability C. Safety and information traceability D. All

3. Instrument inspection should begin
   A. As soon as a technician receives a tray from the decontamination area.
   B. Before a technician receives a tray from the decontamination area.
   C. After a technician receives a tray from the decontamination area.
   D. All
4. Which one of the following is not true about Instrument inspection
   A. A detailed process B. Non technical process C. A detailed process D. All
5. All power supplies shall have an excess rated capacity of
   A. 30 percent B. 20 percent C. 40 percent D. 10 percent
6. Control Panels shall be fabricated, piped and wired by fully qualified workmen who are
   A. Properly trained B. Properly experienced C. Properly supervised D. All

Part II: Matching
Direction: match column A with column B. writes your answer on the space provided before the number.

	Column A	**Column B**
1	Red ON	A. Motor running
2	White ON	B. Flow capacity –Sizing under installed condition
3	Green ON	C. Valve open
4	IEC 60534-2-1	D. Motor stopped
5	IEC 60534-2-3	E. Power available
		F. Valve closed
		G. Flow capacity –Test procedures

PART II. Short answer question

1. Explain about Project commissioning
2. List the three most common types of quality inspections
3. List the three main elements to the inspection framework
4. Describe the objective of the Validation and Verification Manual

Operation sheet 2.1: Transformer Polarity test

- **Operation title: Polarity test**
- **Purpose:** To identify and measure the polarities of Transformer
- **Instruction:** Using the figure below and given equipment's identify and measure the polarities of Transformer. You have given 45 minutes for the task.

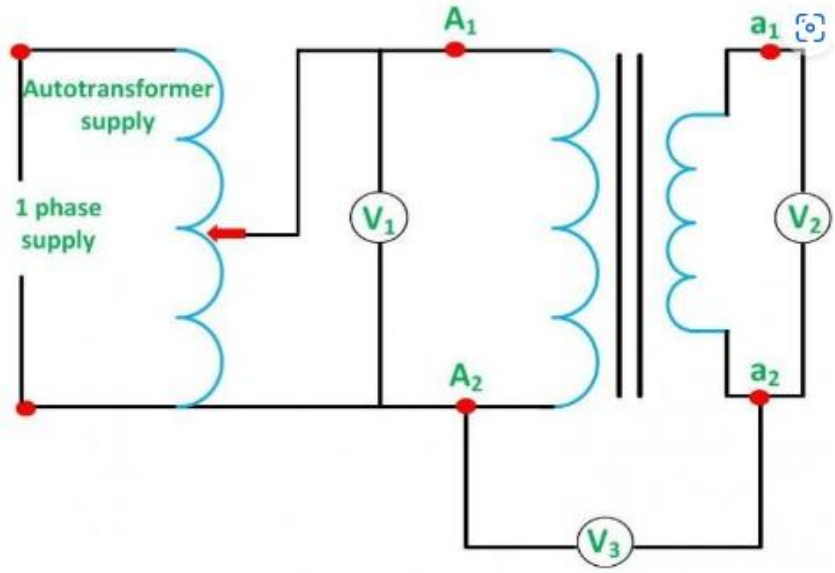


Figure 2. 1: figure given for operation sheet 2.1

- **Tools and equipment:**
  - Digital multimeter
  - Screw driver
  - 2.5 mm^2 flexible wire
  - Autotransformer
  - Stepdown transformer
- **Steps in doing the task**
  1. Steps to Perform Polarity Test
  2. Connect the circuit as shown in the above circuit diagram figure and set the autotransformer to zero position.
  3. Switch on the single-phase supply
  4. Record the values of the voltages as shown by the voltmeter V1, V2 and V3.

5. If the reading of the V3 shows the addition of the value of V1 and V2 that is V3 = V1+V2 the transformer is said to be connected in additive polarity.
6. If the reading of the V3 is the subtraction of the readings of V1 and V2, then the transformer is said to be connected in subtractive or negative polarity.
7. Complete Your work by confirming the recorded measurement

- **Quality Criteria:** use VOM with ±0.5 accuracy
- **Precautions:** use PPE.

LAP Test 2.1

Practical Demonstration

Name: _____ Date: _____

Time started: _____ Time finished: _____

Instruction I: Given necessary templates, tools and materials you are required to perform the following tasks within 1 hours.

- Task-1: Perform visual inspection of single phase UPS.
- Task-2: Perform Voltage test on the output terminal.
- Task-3: Record measurements using standard procedure
- Task-4: Complete commission report

UNIT THREE: CHECKING COMMISSIONED OPERATION

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Verification of Commissioned Work
- Reporting Commissioned activity

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Verify Commissioned Work/System
- Check Commissioned Work.
- Prepare Commissioned activity Report

3.1 Validation and Verification of Commissioned Work

The objective of the Validation and Verification Manual is to provide guidance to increase the consistency, quality and transparency of validation and verification of projects under the VCS Program and to provide guidance on assessing methodologies under the VCS methodology approval process.

Validation Objectives

Validation involves the assessment of a project description wherein VVBs must assess the following:

- Project conformance to VCS rules;
- Project conformance to the applied methodology, including the procedure for the demonstration of additionality specified in the methodology; and
- Likelihood that methods and procedures set out in the project description will generate verifiable GHG data and information when implemented.

Verification Objectives

Verification is conducted once project implementation has commenced. It is the ex-post assessment of the monitored GHG data and information. During verification, VVBs must evaluate the monitoring report and assess the following:

- The extent to which methods and procedures, including monitoring procedures, have been implemented in accordance with the validated project description . This includes ensuring conformance with the monitoring plan.

- The extent to which GHG emission reductions and removals reported in the monitoring report are materially accurate.

Complete verification testing of control systems is a key aspect of a fully commissioned building, but one that is not always done in a comprehensive way. This informative

session will explain the importance of 100% verification of these crucial systems, as well as how test and balance and commissioning firms can join forces and use their combined expertise to carry out the needed testing, verification and documentation.

Standard requirements

The Associated Air Balance Council, National Standards For Total System Balance, requires the following:

- Work with the temperature control contractor to ensure the system is operating within the design limitations, and to obtain mutual understanding of intended control system.
- Verify all hard-wired safety-limiting controllers such as freezestats and high/low static pressure shutdown controllers are calibrated, set at the required set-point, and functional.
- Verify that all flow monitoring stations for air and water are properly calibrated and reading correctly.
- Verify all temperature, humidity, and pressure sensors are properly calibrated and reading correctly.
- Verify that controller set-points meet the specification.
- Confirm that the sequences of operation for all control modes are in compliance with the final approved control submittal.
- Verify the settings and operation of end switches, pressure-electric switches, solenoid valves, contactors, etc.
- Check the operation of lockout or interlock systems.
- Check the operation of all control valve and damper actuators. Verify the valve or damper opens and closes 100%.
- Determine that all controlled devices are properly connected.
- For a pneumatic control system, verify the operation of pilot positioners.
- Confirm that all controlled devices are operated by the intended controller.
- Confirm that all controlled devices are in the position indicated by the

- controller: open, closed, or modulating. Note any controlled devices that do not have free travel.
- Verify that all controlled devices are properly installed in the distribution system in relation to direction of flow and location.
- Test the fail-safe modes of all controlled devices.
- Verify simultaneous heating and cooling does not occur.
- Verify all sensors are installed as shown on the contract documents.
- Check the location and installation of all sensors to determine if they will sense only the intended temperature, humidity, or pressure. Also check for potential erratic operation due to outside influences such as sunlight, drafts, outside walls, etc.

Sensor Calibration and Control Point Verification Form

Unit Number	DDC Point	POINT TO POINT	DDC Value	Actual Value	Date	Remark
VAV-1-1	ABC-1-1:Room Temperature	OK	72.0°F	71.8°F	2-2-15	
VAV-1-1	ABC-1-1:Room Temperature Set-point	OK	72.0°F		2-2-15	
VAV-1-1	ABC-1-1:Airflow Setpoint	OK	500/250 CFM		2-2-15	
VAV-1-1	ABC-1-1:Airflow	OK	500/250 CFM		2-2-15	See Air Distribution Data
VAV-1-1	ABC-1-1:Airflow Damper Position	OK	0-100%		2-2-15	
VAV-1-1	ABC-1-1:Hot Water Reheat Coil Control Valve Position	OK	0-100%		2-2-15	
VAV-1-1	ABC-1-1: Terminal Unit Discharge Air Temperature	OK	54.0°F	54.2°F	2-2-15	
VAV-1-1	ABC-1-1: Terminal Unit Discharge Air Temperature	OK	94.0°F	94.2°F	2-2-15	

- Acceptance Phase –Functional Performance Testing

  Functional Performance Testing should achieve the following:

  - ✓ Verify all elements of the sequence of operations indicated in the project documents is functional as installed
  - ✓ Verify appropriate interlocks and tuning have been performed to ensure stable operation and control of temperatures and pressures within the facility
  - ✓ Verify proper alarming setup within the Control System
  - ✓ Document the operation of the SYSTEM across the entire operating range (maximum to minimum)
  - ✓ Any issues or non-standard conditions should be noted in the Commissioning Issues Log (CxIL) for record.
  - ✓ The CxA should write test procedures, facilitate and document testing with assistance from the TAB Firm, Contractor, Controls Vendor and Owner's O&M personnel.

Variable Volume Control Verification:

- ✓ Systematically operate terminal units / valves within a variable volume system individually or in groups across the entire operating range from maximum to minimum
- ✓ Verify static pressure and differential pressure reset ranges (TAB data should be reviewed and verified by the CxA during this step.)
- ✓ Report operating data for the system at minimum control conditions (this indicates energy savings to the Owner)
- ✓ Verify Lead / Lag staging of equipment

Fire Alarm / Smoke Control Sequences

- ✓ Initiate sequences in coordination with fire alarm testing
- ✓ Verify equipment failure scenarios
- ✓ Verify critical equipment transfer to backup power systems
- ✓ Verify Fireman's Override and local controls in addition to automatic control sequences for HVAC equipment
- ✓ Duct Mounted Smoke Detector differential pressures at minimum airflows should be verified by either the TAB personnel or the Fire Alarm contractor in accordance with the manufacturer's recommendations.

Commissioning Materials: means all artwork, copy, models, designs, photographs, software, films, sound records and all other material the creation of which is commissioned by the Agency from third parties being part of the Service under the contract.

Proper commissioning ensures your equipment system continually operate according to factory requirements.

Commissioning Form

A commissioning plan is a document that outlines the process of ensuring that a building or system is functioning properly and efficiently before it is put into operation.

3.2 Reporting Commissioned activity

As the Commissioning Authority (CxA), ERS provides planning and oversight to help ensure your project is completed on time and on budget according to the project requirements. Our commissioning activities include:

- Help owner define and verify project requirements
- Commission per LEED requirements (if applicable)
- Develop commissioning specifications and plan
- Perform design review and verify Basis of Design (BoD)
- Ensure that all systems and assemblies are properly installed
- Test and verify the critical mechanical and electrical infrastructure
- Conduct integrated systems testing
- Ensure operating manuals are developed
- Verify training is conducted
- Verify complete and accurate documentation including Commissioning Report
- Conduct seasonal testing and warranty review

At the end of the commissioning process, we will document the entire project in the form of a comprehensive Commissioning Report. This report includes the following:

- A statement that systems have been completed in accordance with the contract documents and that the systems are performing in accordance with the final OPR document
- Identification and discussion of any substitutions, compromises, or variances between the final design intent, contract documents and as-built conditions
- Final completed testing procedures and all supporting data (i.e. screenshots, trending results, PQM results, etc.)
- Summary of all issues resolved and unresolved and any recommendations for resolution

- Lessons learned for use in future commissioning project efforts

In conjunction with the general commissioning activities, the following specific commissioning activities are addressed during the

Occupancy/Post-Occupancy Phase.

Systems Manual

ERS commissioning engineers work with your general contractor to prepare a thorough Systems Manual for all commissioned building systems. These documents ensure that your O&M staff has the right resources for troubleshooting and future training and that your staff is equipped to efficiently and effectively operate your systems for years to come.

Seasonal Testing

Some critical tests can only be performed once systems are fully operational. Other tests cannot be performed until the occupancy phase of a project because they require specific environmental conditions that cannot be simulated during construction. During the project's occupancy phase, we will perform any deferred or seasonal testing and provide documentation of all test results.

Warranty Review and Supplemental Report

Our commissioning services team will conduct a thorough onsite warranty review to identify any operational or system performance issues that may be covered under the terms of your warranty. They will work with your general contractor to make sure these issues are resolved before the warranty expires. In addition, a warranty review supplemental report will be developed and delivered to the owner for final project closeout

Final Completion

Finalize Commissioning Report: Make final inspection (when notified by the Contractors that the substantial completion punchlist is complete) with Consultant to determine if all of the punchlist items are fully complete. Deliver comments to PDC. Assist the Consultant with all close out procedures. Prepare final Project Closeout Report.

SELF CHECK 3.1

PART I. Short answer question

1. When verification is conducted on commissioning process?
2. List at least four the Functional Performance Testing should achieve
3. What mean by Commissioning Materials?
4. What is commissioning plan?
5. List what commissioning activities include?

Operation sheet 3.1: UPS commissioning check list

- **Operation title: Commissioning work**
- **Purpose:** To perform acceptance of 3 phase UPS
- **Instruction:** Using the 3phase UPS and given equipment's perform acceptance of 3 phase UPS. You have given 45 minutes for the task.

Switchboard and Circuit Breakers	Items tested /checked by Contractor	Items witnessed By project engr
Section A - Visual and Electrical/Mechanical Inspection	*Yes/No/N.A	*Yes/No/N.A
a) Exterior of equipment		
b) Completeness of assembly		
c) Indicating lights		
d) Switch for freedom of movement		
e) Timing settings		
f) Proper grounding		
g) Proper voltage connections		
h) Tightness of bolted connections		
Section B - Electrical tests		
i) A-GRD		
j) B-GRD		
k) C-GRD		
l) A-B		
m)B-C		
n) C-A		

- **Tools and equipment:**
  - Digital multimeter
  - Screw driver
  - 3 Phase UPS
- **Steps in doing the task**
  1. Steps to Perform visual inspection of UPS
  2. Steps to Perform Electrical voltage test of all phase of UPS.
  3. Record the values of the voltages of all the three phases(A-B, B-C and A-C).
  4. Complete Your work by confirming the recorded measurement

Reference

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- Testing and Commissioning Procedure for Electrical Installation, 2007 edition. Architectural Services Department the Government of The Hong Kong Special Administrative Region.
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The trainers who developed the curriculum

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