ACKNOWLEDGEMENT

I would like to thank all those who have been instrumental in giving me such a wonderful opportunity to work closely with the Instrumentation section of the maintenance department at BPCL Kochi Refinery. I am very grateful to Mr.Mukilan.K, Chief Manager and my guide Mr. Keshav Kumar N, Engineer for making my training BPCL-KR meaningful. My special thanks to Mr. Pradeesh K Babu, Mr. Aneesh, Mr.Prabhul, Mr. Ravindra pillai, Mr.Haneefa, Mr. Sreejith , Mr.Sanal and all others in the department who have helped me during my training period. I am very grateful to BPCL-KR for offering such a training program, which has helped me a lot in understanding my area of study in a better way.

I am thankful to Dr.Jeevama Jacob, Professor and HOD Electrical Engineering Department, and Dr.Ashok.S, professor and course coordinator for providing such an opportunity. I thank all teaching and non teaching staff for their support and prayers.

INDUSTRIAL TRAINING REPORT

Done at

BPCL-Kochi Refinery

Submitted by

DILSHAD
(M140467EE)

In partial fulfilment for the award of the Degree of

MASTER OF TECHNOLOGY
IN
ELECTRICAL AND ELECTRONICS ENGINEERING
(Industrial Power And Automation)

DEPARTMENT OF
ELECTRICAL AND ELECTRONICS ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
NIT CAMPUS PO, CALICUT
KERALA, INDIA 673601.

JUNE 2015

ABSTRACT

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1

COMPANY PROFILE

1.1 INTRODUCTION

The Kochi refinery, formerly known as Cochin Refineries Limited is a public sector crude oil refinery situated in Ambalamugal, in Ernakulam district in Kerala state. The company is spread over an area of 1100 acres. Cochin Refineries Limited was incorporated as a public Limited Company in September 1963 with technical collaboration and financial participation from Philips Petroleum Company of USA. CRL was commissioned in 1966 with an initial capacity of 2.5 million metric tonnes per annum (MMTPA). The company was inaugurated by the then Prime Minister of India Ms.Indira Gandhi on 23 September 1966. Crude filtering was commenced on 23rd September 1966.

KRL became a subsidiary of Bharat Petroleum Corporation Limited (BPCL), when BPCL acquired Government of Indias equity holding in KRL in March 2001. Subsequently KRL has been merged with BPCL in 21st August 2006 and now has become a part of the corporation.

The capacity was increase to 3.3 MMTPA during the expansion project in September 1973. Aviation turbine fuel and Liquefied petroleum gas production was also started after the revamp.

In 1984, the refining capacity was further increased to 4.5 MTPA. The atmospheric residue obtained as furnace oil or Low Sulphur Heavy Stock (LSHS) after distillation in atmospheric column was about 30 to 45%. To get more middle distillate, a Fluid Catalytic Cracking Unit (FCCU) was set up in 1985. The heavier Vacuum Gas Oil (VGO) obtained from vacuum distillation column was broken up in to lighter components in the FCCU. Thus the FCCU was the most profitable plant in the refinery. The FCCU had an initial capacity of 1 MMTPA.

In 1989, Kochi refinery entered in to petro chemical business with the production on benzene and toluene. An aromatic recovery unit with capacity of 87200 TPA of benzene and 12000 TPA of tolune was set up.

A Light Ends Feed Preparation Unit to supply polybutenes feedstock to Cochin Refineries Balmer Lawrie Ltd. , a joint venture that later merged with KRL in April 2001, was commissioned in March 1993.

In 1994, the third stage of expansion took place increasing the refining capacity to 7.5 MMTPA. A new crude distillation unit CDU-2 was set up to achieve this. The FCCU capacity was increased to 1.4 MMTPA.

In the year 2000, a 2 MMTPA Diesel Hydro Desulphurisation (DHDS) plant was added to reduce the sulphur content in the fuel to meet the environment standards.

With the prestigious Crude Oil receipt facilities consisting of the Single Point Mooring (SPM) and the associated shore tank farm in place since December 2007, the refinery is equipped to receive crude oil in Very Large Crude Carriers (VLCCs). This facility helps Kochi refinery in reducing the freight charges to a great extent, over and above increasing flexibility in crude oil selection. This, thereby, is a major infrastructure facility accelerating the growth of Kochi Refinery.

To meet environment regulation of fuels, Kochi refinery implemented the project KEMP in 2009-10. The project included the expansion of CDU-2 capacity from 3 MMTPA to 5MMTPA, new CCR unit and new VGO HDS unit. At present the capacity of the refinery stands at 9.5 MMTPA. Kochi refinery has undertaken an ambitious expansion plan to enhance refining capacity to 15.5MMTPA. The project named Integrated Refinery Expansion Project is currently being carried out.

1.2 AWARDS AND CERTIFICATIONS

Awards received by BPCL-KR

Runner up for outstanding Safety performance awards in the category of Large Size Chemical Industries by National Safety Council, Kerala Chapter.

Winner for the best performance award for safety committee by National Safety Council, Kerala Chapter.

Received the 7th annual GREENTECH Environment Excellence Award in Petroleum Refinery sector for outstanding achievement in Environment Management for the year 2006.

Award of excellence from the Kerala state pollution control board for substantial performance and sustained efforts in pollution control activities.

International Systems and Standards

ISO 14001-2004: BPCL-KR is a n ISO 14001 Environmental Management Systems (EMS) certified Company since 1999. It got the re-certification from M/s Det Norske Veritas (DNV) later.

ISRS: BPCL-KR was certified LEVEL-7 in the initial audit itself as per the International Safety Rating System by Det Norske Veritas (DNV), which ensures that an established and well-documented Safety Management System is always in lace. BPCL-KR has achieved LEVEL-8 during the subsequent audit.

ISO 9001:2000: BPCL-KR has achieved another landmark in its history by way of aligning its quality management system with the ISO 9001:2000 standard. BPCL-KR achieved this milestone in August 2004 and the same was certified by M/s Det Norske Veritas (DNV).This forms part of BPCL-KRs efforts to make it a world class refinery and add to its capability to achieve global competitiveness and excellence to face the challenges of the future.

ISO 17025: BPCL-KR has achieved the ISO 17025 (Testing methods in quality control) certification from National Accreditation Board for testing and Calibration of Laboratories (NABL) in September 2005.

1.3 ORGANISATION SET UP AND OPERATIONS

The refinery operates 24hrs a day for 7 days in a week. For smooth functioning of the various plants, the operations is divided in to three shifts. The morning shift starts at 7:00am and ends by 3:00pm. The evening shift is from 3:00pm to 11:00pm. The night shift starts at 11:00pm and continues till 7:00am on the next day. The normal working hours of the industry is from 8:15am to 5:00pm. The maintenance staff and office staff work during the regular hours. However the officers of different sections are liable to attend plant emergencies during any hour of the day.

The organisation hierarchy of Kochi refinery is shown in the figure below.

1.4 PRODUCTS

1.4.1 Fuel products

Kochi Refinery is a fuel based refinery producing all petroleum fuel products such as

- Liquefied Petroleum Gas (LPG) and Superior Kerosene Oil (SKO) for households and industrial uses
- Motor Spirit (MS/ Petrol) and Hi-speed Diesel (HSD) for auto mobiles
- Naphtha, the major raw material for fertilizer and petrochemical industries
- Furnace Oil (FO), Light Diesel Oil (LDO) and Low Sulphur Heavy Stock (LSHS) as fuel for industries
- Aviation Turbine Fuel (ATF) for aircrafts

1.4.2 Speciality Products

The speciality products that are produced in the industry are

- Benzene for manufacture of caprolactum, phenol, insecticides and other chemicals
- Special Boiling Point Spirit (SBPS) used as solvent in tyre industry
- Toluene for manufacture of solvents and insecticides, pharmaceuticals and paint
- Mineral Turpentine Oil (MTO) for use in textile and paint industry
- Sulphur for use in fertilizer, sugar, chemicals and tyre industry
- Poly Isobutene (PIB) for manufacture of lubricants and cable jelly
- Propylene as a feedstock for various petrochemicals

1.4.3 Exclusive products

- Natural Rubber Modified Bitumen(NRMB) is one of Kochi Refinerys premium products that revolutionized road development. Kochi refinery with the help of some leading research institutes made an in-depth study on feasibility of using natural rubber available in abundance in Kerala, to develop the premium product NRMB. NRMB has been on a fast track since its introduction in 1999. NRMB is a superior mix of bitumen and natural rubber latex. It is superior in quality to ordinary bitumen in terms of penetration, softening point and elastic recovery.

- Bitumen emulsion, an eco friendly product used for road construction was introduced in June 2005. There is no need for the preliminary heating for this special bitumen. Reduced road maintenance cost, energy savings, longer service life for roads and reduced atmospheric pollution during road laying/ maintenance are some of the advantages of Bitumen Emulsion.

- Diesel additives of Kochi refinery is an indigenous product successfully tested in laboratories both locally and globally. When used along with diesel in a specified proportion, it improves the combustion inside engine cylinder, thereby reducing harmful exhaust emissions and assuring better fuel efficiency.

1.5 RAW MATERIALS AND RESOURCES

The crude oil that is processed in Kochi refinery comes from gulf countries as well as from Bombay high. The total crude requirement for BPCL and its group company is approximately 22 MMTPA. Part of the requirement, about 40%, is met out of indigenous crude production by ONGC and OIL. Balance requirement is met through Imports on Term and Spot basis.

An offshore crude oil receipt facility consisting of an offshore Single Point Mooring (SPM) facility and an associated shore tank farm has been set up by the company in Puthuvype in the island of Vypin. This was commissioned on December 2007. With this, the company is now equipped to receive crude oil in Very Large Crude Carriers (VLCCs). Pipeline is laid from the shore tanks to the refinery to transfer the crude. Water resource

The water needed for plant operation is taken from Periyar river under stand alone water supply scheme. A 40 inch pipeline is laid from Aluva pump house to refinery quarry at Chullichira. The capacity of this quarry is 150,000 m^3. Other quarries at refinery compound are DHDS quarry with capacity to hold 130,000 m^3 of water, old quarry 7000m^3 and new quarry 18,000m^3 of water. The pump house is provided with an electric motor operated pump as well as a diesel engine operated pump. Thus the supply of water is not interrupted during power failures.

The electric power needed for the company is generated from the in house generation plants and a minor percentage of power demand is met from Kerala state electricity board. KSEB power normally act as a backup supply in case of a fault or maintenance scheduled for the in house generators. The details of electrical system is discussed in section 2.2.

CHAPTER 2

PROCESS

2.1 OVERALL PLANT CONFIGURATION

Kochi Refinery presently has a crude oil processing capacity of 9.5 MMTPA in its two Crude Distillation units (CDU-1 and CDU-2). The refinery currently processes about 40% of Indigenous and 60% Imported crude oils. Crude oil is transported in ships from the point of origin to Kochi and is received through a Single Point Mooring (SPM) facility. Kochi SPM, located approximately 20km off the shore of Puthuvypin is capable of handling Very large Crude Carriers (VLCC) with crude oil carrying capacities up to 3.0 Lakh Tons.

Figure 2.1: SPM Facility

Crude oil from SPM is received in offshore tanks in Puthuvypeen and is then pumped to the refinery. Apart from the Crude Distillation Units, major processing facilities in the refinery include a Fluidized Catalytic Cracking (FCC) unit, Diesel Hydro Desulphurization (DHDS) unit, Kerosene Hydro Desulphurization (KHDS) unit, Sulphur Recovery Unit (SRU) and an Aromatics Block consisting of a Naphtha Splitter Unit (NSU), Naphtha Hydro Desulphurization (NDHS), Catalytic Reformer Unit (CRU) and Aromatics Recovery Unit (ARU).

Crude oil is first processed in the Crude Distillation Unit where it is heated up to around 360 to 380oC depending on the type of crude oil after removing impurities such as sodium and magnesium salts, water and other sediments. Crude oil is then fractionated in a distillation column where lighter fractions such as LPG, Naphtha, Kerosene and Diesel are separated. The products are routed to respective storage locations after cooling to atmospheric temperature.

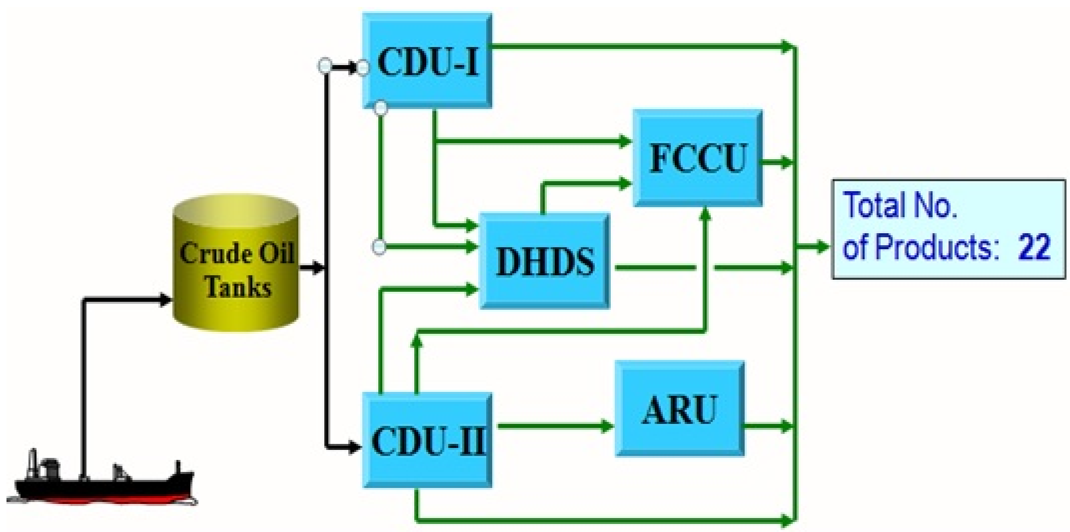


Figure 2.2: Refinery flow diagram

LPG is treated using Di-Ethanol Amine (DEA) to remove the impurities before being stored as product LPG. Part of the Naphtha is processed in the Aromatics Block to produce Benzene, Toluene and a solvent SBPS (Special Boiling Point Spirit). Part of the Kerosene is treated either in a MEROX unit or in KHDS to produce Aviation Turbine Fuel (ATF) and Mineral Turpentine Oil (MTO). Diesel from the CDU is processed in DHDS unit to produce BS-II/ Euro-III grade Diesel.

Remaining heavier portion of the crude oil is further distilled under vacuum in a Vacuum Distillation Unit (VDU) to separate Vacuum Gas Oil (VGO) and Vacuum Residue (VR) as major fractions. The VGO is processed in FCC unit where the heavier molecules are broken down to produce LPG, Gasoline (also called Motor Spirit or Petrol) and Diesel. Refinery is currently capable of producing both BS-II and Euro-III grade Petrol.

With the commissioning of Continuous Catalyst Regeneration (CCR) Reformer and VGO Hydro Desulphurization Unit (VGO HDS), the refinery will be capable of producing nearly 70% MS (Motor Spirit) and HSD (High Speed Diesel) meeting Euro-III specifications and 30% MS and HSD meeting Euro-IV specifications.

Vacuum Residue (VR) from VDU is routed to a Biturox Unit to produce Bitumen or to a Vis-Breaker Unit (VBU) to produce Furnace Oil (FO). VR can also be directly routed to LSHS (Low Sulphur Heavy Stock fuel used in Boilers, Power Plants, etc.) pool if the crude oil processed in CDU is of low sulphur content (less than 0.5 wt%). A state of the art Sulphur Recovery Unit (SRU) recovers sulphur from the gases produced within the refinery before it is consumed as fuel gas.

Effluent Treatment Plants (ETP) takes care of the liquid effluent from the process units and other off site areas. The treated effluent after meeting the MINAS (Minimum National Standards) is discharged to inland rivers. Other Utilities and Off-site facilities such as tankages, flare system and connected pipelines are installed in the refinery to match with the requirements of processing, storage and products dispatch.

2.2 ELECTRICAL SYSTEM

The electric power required for the daily operation of industry is generated in the captive power plant of the industry. In house generation is achieved by using three generators. They include a gas turbine generator , a steam turbine generator and a turbo generator. The gas turbine generator or GT-1 produces 22 MW and is the oldest generator in KRL. The steam turbine generator or STG produces 17.5 MW of power. The turbo generator or TG produces around 2.2 MW of power. An additional gas turbine generator or GT-2 with a capacity 34.5 MW was installed in 2010 considering the expansion of the refinery. Emergency backup power is provided by EDGs or emergency backup generators, they are present in all plants to provide power to critical lighting loads. They are also used for the black start for the in house generators.

The STG at Kochi refinery generates a power of 17.5 MW at 11kV. It is manufactured by Shin Nippon, Japan. The turbine is run using high pressure steam and medium pressure steam is let out as exhaust. The exhaust steam is used for other purposes in the plant.

The gas turbine generator GT-1 package in the CPP of Kochi refinery is of frame 5 gas turbine supplied by BHEL in collaboration with General Electric company USA. The gas turbine was commissioned in March 1991 and could achieve 21.98MW on base load test. The terminal voltage is 11kV.

High pressure steam produced in the boiler has to be lowered to medium pressure steam to be used in the refinery. This process leads to a loss in energy. The energy lost in depressurizing instead of being let to waste is converted into electrical energy. This is done by using the high pressure steam to run a turbo generator. The turbo generator or TG uses steam at 37 kg per square cm as the input to drive the turbine the exhaust steam comes out at 18 kg per square litre producing approximately 2.2 MW of electric power at 3.3kV. The TG is manufactured by BHEL.

The new gas turbine generator GT-2 manufactured by BHEL produces around 34 MW of power at 11kV. It works on the principle of brushless excitation. A 33kV Gas Insulated Substation(GIS) was also been set up to receive power from GT-2. A generator transformer is provided to step up the voltage to 33KV and is fed into GIS as shown in the figure below.

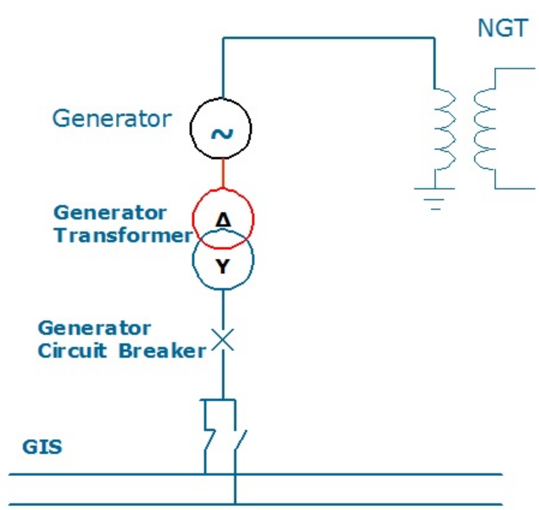


Figure 2.3: Generator transformer, GT2

External power supply

A supply from Kerala State Electricity Board is paralleled with the in house generators. Kochi refinery is an EHT consumer and the power is drawn at 220kV from 220kV substation, Ambalamughal. The contract demand is 40MVA. Two transformers rated 50MVA, 220/33kV are installed by refinery to import power from KSEB. A time of day meter is provided at the 220kV side and the billing is made in 3 part tariff. A 33kV Gas Insulated Substation (GIS) has been set up to receive the power from the transformers. Two 33kV feeders run from the GIS to the 33kV switchgear of Kochi refinery.

The Single Line Diagram of the electrical system is shown in figure below.

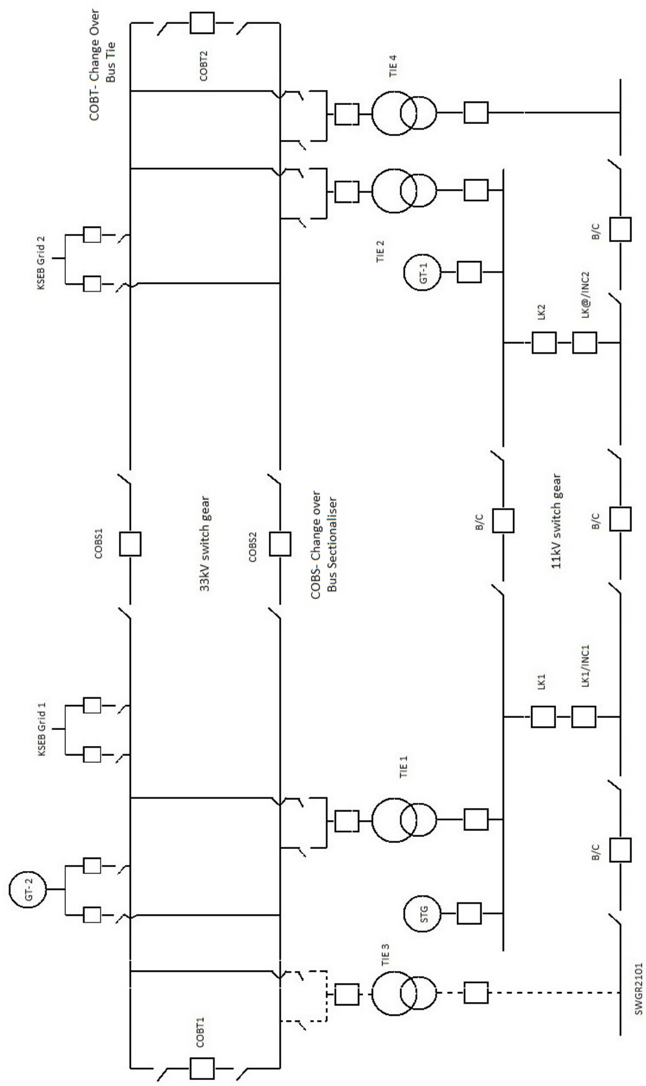


Figure 2.4: Single Line Diagram of Electrical system

The KSEB supply acts as a backup supply in case the generators fails or is out of service for maintenance. The generators at CPP operate in two different modes; pre select mode and part load mode. In pre select mode, a fixed value of power is set from the control room and the generators operate at this value with little deviation from the set point. In part load mode, the generator adjusts its output depending upon the power demand of the system. Under normal operation, the in house generators are operated in pre select mode and the KSEB supply accounts for the deviation in power demand of the system. The power demand of the industry is almost constant when all the plant are running smoothly. In case the supply from KSEB fails, one of the generators, automatically changes to part load mode of operation.

Islanding

Islanding is a method followed to isolate the KSEB supply from the refinery grid in case of any disturbances in the KSEB supply. This helps to protect the in house generators from the faults at KSEB side. If all the generators are online, the sensitivity of the controller is kept high, thus isolating KSEB supply even for minor disturbances. In cases were atleast 1 generator is out of service and relatively higher load is being taken from KSEB, the sensitivity is kept low.

2.3 TECHNOLOGIES USED

2.3.1 Process variable measurement and control

Various technologies have been utilized for measuring and controlling the different plant variables such as temperature, pressure, level, flow rate etc. [1]

Temperature measurement

Temperature measurement is usually achieved through thermocouples. A Thermocouple is a sensor used to measure temperature. Thermocouples consist of two wire legs made from different metals. The wires legs are welded together at one end, creating a junction. This junction is where the temperature is measured. When the junction experiences a change in temperature, a voltage is created. The voltage can then be interpreted using thermocouple reference tables to calculate the temperature.

Another method employed for temperature measurement is by the use of resistance temperature detector. These are sensors used to measure temperature by correlating the resistance of the RTD element with temperature. Most RTD elements consist of a length of fine coiled wire wrapped around a ceramic or glass core. The element is usually quite fragile, so it is often placed inside a sheathed probe to protect it. The RTD element is made from a pure material, typically platinum, nickel

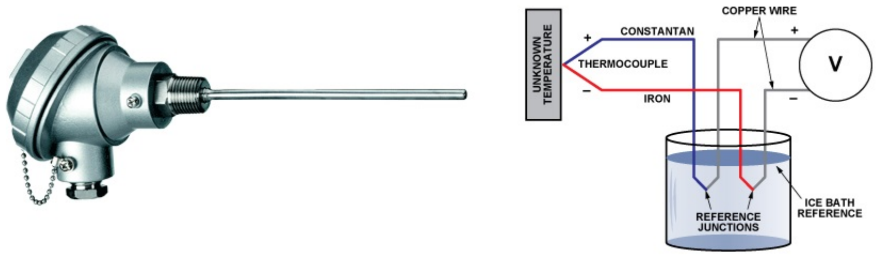


Figure 2.5: Thermocouple

or copper. The material has a predictable change in resistance as the temperature changes and it is this predictable change that is used to determine temperature.

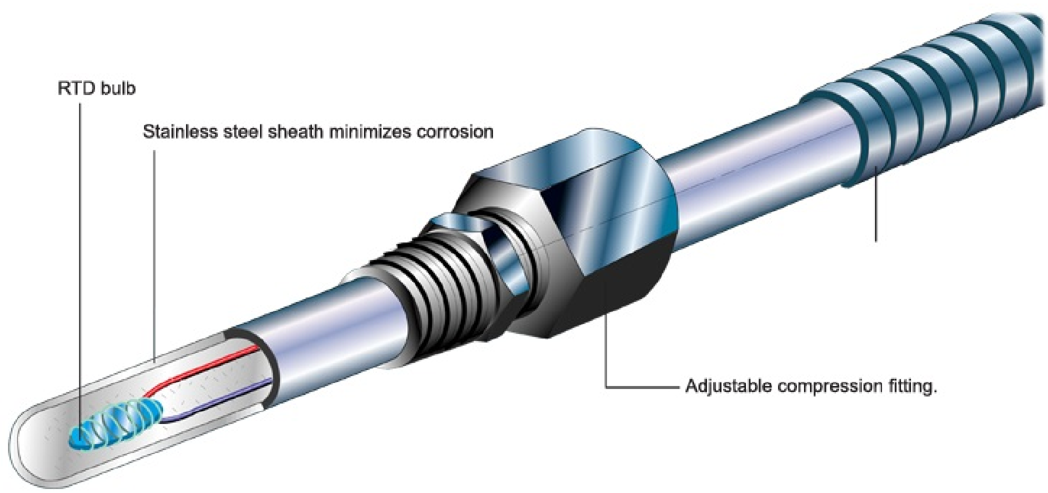


Figure 2.6: Resistance temperature detector

Pressure measurement

A pressure sensor measures pressure, typically of gases or liquids. Pressure is an expression of the force required to stop a fluid from expanding, and is usually stated in terms of force per unit area. A pressure sensor usually acts as a transducer. It generates a signal as a function of the pressure imposed.

Pressure measurement by piezoresistive strain gauge uses the piezoresistive effect of bonded or formed strain gauges to detect strain due to applied pressure, resistance increasing as pressure deforms the material. Common technology types are Silicon (Monocrystalline), Polysilicon Thin Film, Bonded Metal Foil, Thick Film, and Sputtered Thin Film. Generally, the strain gauges are connected to form a Wheatstone bridge circuit to maximize the output of the sensor and to reduce sensitivity to errors.

Pressure measurement by capacitive principle uses a diaphragm and pressure cavity to create a variable capacitor to detect strain due to applied pressure, capacitance decreasing as pressure deforms the diaphragm. Common technologies use metal, ceramic, and silicon diaphragms.

Figure 2.7: Pressure Transmitter with Flush Diaphragm

Level measurement

Level measurement for liquids, granulars, slurries and interfaces can be accomplished with several different level technologies.

The most frequently used device for the measurement of level is a differential pressure transmitter. This device does not really measure level. It measures the head pressure that the diaphragm senses due to the height of the material in the vessel multiplied by a second variable, the density of the product. This gives you the resultant force being exerted on the diaphragm, which is then translated into a measurement of level.

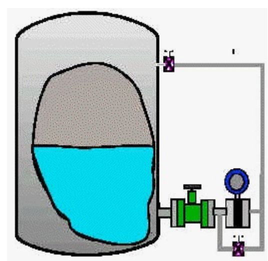


Figure 2.8: Level measurement by differential pressure

This simple level measurement has a dip tube installed with the open end close to the bottom of the process vessel. A flow of gas (usually air) passes through the tube and when air bubbles escape from the open end, the air pressure in the tube corresponds to the hydraulic head of the liquid in the vessel. The air pressure in the bubble pipe varies proportionally with the change in head pressure.

Another technique is by the use of Archimedes Principle. When a body is immersed in a fluid, it loses weight equal to the liquid weight displaced. By detection of the apparent weight of the immersed displacer, a level instrument can be devised. If the cross sectional area of the displacer and the density of the liquid is constant, then a unit change in level will result in a reproducible unit change in displacer weight.

Ultrasonic transmitters work on the principle of sending a sound wave from a peizo electric transducer to the contents of the vessel. The device measures the length of time it takes for the reflected sound wave to return to the transducer. Two

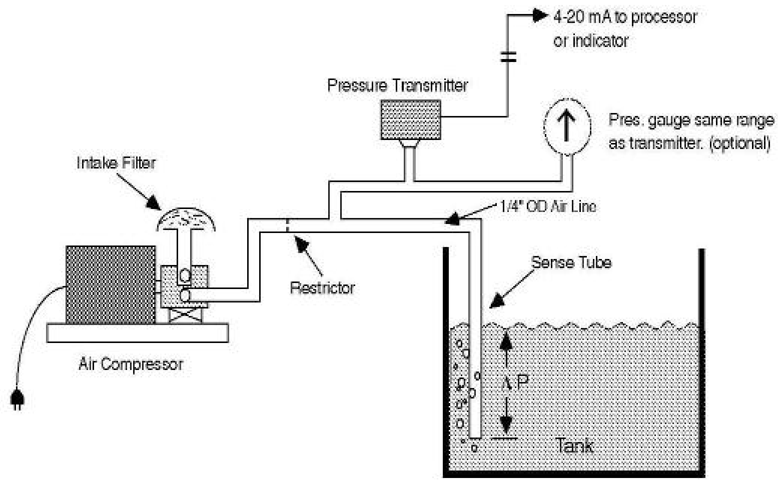


Figure 2.9: Level measurement by purging

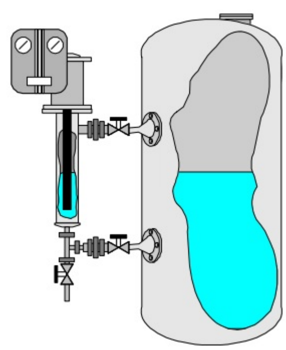


Figure 2.10: Level measurement by displacer

technologies on the market are frequency modulated continuous wave (FMCW) or pulsed wave time of flight. FMCW is fast enough for tank gauging, but normally too slow to measure the turbulent surfaces encountered in agitated process applications. The sensor emits a microwave pulse towards the process material. This pulse is reflected by the surface of the material and detected by the same sensor which now acts as a receiver. Level is inferred from the time of flight (transmission to reception) of the microwave signal. Microwave echoes are evaluated by sampling echoes and building up a retarded profile of the echoes. [2]

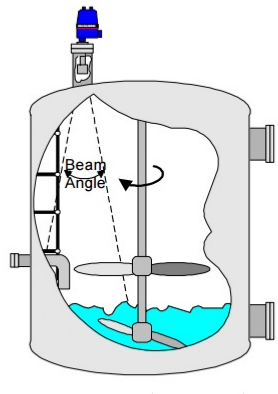


Figure 2.11: Level measurement by radar

Flow measurement

Flow measurement is the quantification of bulk fluid movement. Flow can be measured in a variety of ways. Positive-displacement flow meters accumulate a fixed volume of fluid and then count the number of times the volume is filled to measure flow. Other flow measurement methods rely on forces produced by the flowing stream as it overcomes a known constriction, to indirectly calculate flow. Flow may be measured by measuring the velocity of fluid over a known area.

There are several types of flow meter that rely on Bernoulli's principle. One method is by the use of orifice plate. With an orifice plate, the fluid flow is measured through the difference in pressure from the upstream side to the downstream side of a partially obstructed pipe. The plate obstructing the flow offers a precisely measured obstruction that narrows the pipe and forces the flowing fluid to constrict. The orifice plates are simple, cheap and can be delivered for almost any application in any material. The Turn Down Rate for orifice plates are less than 5:1. Their accuracy are poor at low flow rates. A high accuracy depend on an orifice plate in good shape, with a sharp edge to the upstream side. Wear reduces the accuracy

Rotameter can be used to measure small levels of flow. The rotameter consists of a vertically oriented glass (or plastic) tube with a larger end at the top, and a metering float which is free to move within the tube. Fluid flow causes the float to rise in the tube as the upward pressure differential and buoyancy of the fluid overcome the effect

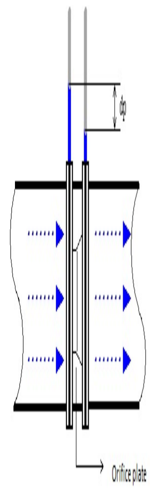


Figure 2.12: Flow measurement by orifice plate

of gravity.

The rotameter consists of a vertically oriented glass (or plastic) tube with a larger end at the top, and a metering float which is free to move within the tube. Fluid flow causes the float to rise in the tube as the upward pressure differential and buoyancy of the fluid overcome the effect of gravity.

Direct mass measurement sets Coriolis flowmeters apart from other technologies. Mass measurement is not sensitive to changes in pressure, temperature, viscosity and density. With the ability to measure liquids, slurries and gases, Coriolis flowmeters are universal meters.

Another type of meter,the Coriolis Mass Flow meter uses the Coriolis effect to measure the amount of mass moving through the element. The fluid to be measured runs through a U-shaped tube that is caused to vibrate in an angular harmonic oscillation. Due to the Coriolis forces, the tubes will deform and an additional vibration component will be added to the oscillation. This additional component causes a phase shift on some places of the tubes which can be measured with sensors.

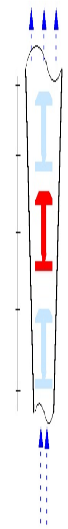


Figure 2.13: Flow measurement by rotameter

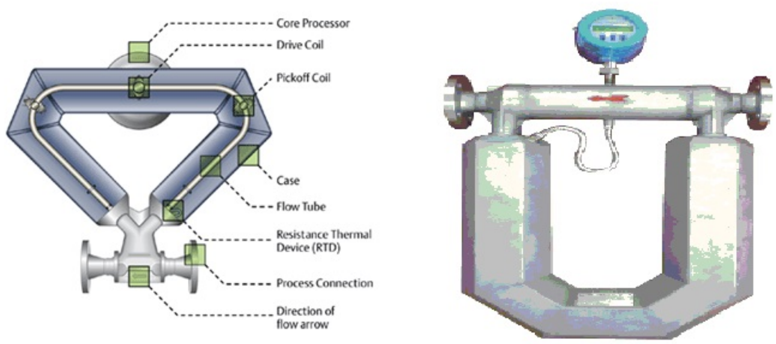


Figure 2.14: Flow measurement by Coriolis Flow Meter

The Coriolis flow meters are in general very accurate, better than +/-0,1% with an turndown rate more than 100:1. The Coriolis meter can also be used to measure the fluids density.

Control valve Control valves are used to control conditions such as flow, pressure, temperature, and liquid level by fully or partially opening or closing the valve in response to signals received from controllers that compare a SetPoint to a Process-Variable whose value is provided by sensors that monitor changes in such conditions. The opening or closing of control valves is usually done automatically by electrical, hydraulic or pneumatic actuators. Positioners are used to control the opening or closing of the actuator based on electric, or pneumatic signals. These control signals, traditionally based on 3-15psi, more common now are 4-20mA signals for industry, 0-10V for HVAC systems and the introduction of HART, Fieldbus Foundation, and Profibus being the more common protocols.

Figure 2.15: Control valve

There are two types of control action in valve; Direct acting and Reverse acting. A direct acting controller is one whose output tends to increase as the measurement signal increases. For example an air to close valve tend to close when the measurement signal increases. The spring will bring it back to open position. A reverse acting controller is one whose output tends to decrease as the measurement signal increases. For example an air to close valve tend to open when the measurement signal increases.
Shut Down Valve

A shut down valve is an actuated valve designed to stop the flow of a hazardous fluid or external hydrocarbons (gases) upon the detection of a dangerous event. The valve can also be used to open in cases where the flow should not be stopped to avoid dangerous situation. This provides protection against possible harm to people, equipment or the environment. The shut down valves has only discrete control. That is it can be either fully close or fully opened. Intermediate valve position is not possible. Shutdown valves form part of a Safety instrumented system. The process of providing automated safety protection upon the detection of a hazardous event is called Functional Safety. The shut down valves are normally controlled by separate PLC rather than the DCS system use to control the process.

Figure 2.16: Shut Down valve

Shutdown valves are primarily associated with the petroleum industry although other industries may also require this type of protection system. Emergency Shutdown Valves are required by law on any equipment placed on an offshore drilling rig to prevent catastrophic events.

2.3.2 Distributed control system

A distributed control system (DCS) is a control system for a process or plant, wherein control elements are distributed throughout the system. This is in contrast to non-distributed systems, which use a single controller at a central location. In a DCS, a hierarchy of controllers is connected by communications networks for command and monitoring. A DCS typically uses custom designed processors as controllers and uses both proprietary interconnections and standard communications protocol for communication. Input and output modules form component parts of the DCS. The processor receives information from input modules and sends information to output modules. The input modules receive information from input instruments in the process (or field) and the output modules transmit instructions to the output instruments in the field. The inputs and outputs can be either analog signal which are continuously changing or discrete signals which are 2 state either on or off . Computer buses or electrical buses connect the processor and modules through multiplexer or demultiplexers. Buses also connect the distributed controllers with the central controller and finally to the Humanmachine interface (HMI) or control consoles.

Distributed control systems (DCSs) are dedicated systems used to control manufacturing processes that are continuous or batch-oriented, such as oil refining, petrochemicals, central station power generation, fertilizers, pharmaceuticals, food and beverage manufacturing, cement production, steelmaking, and papermaking. DCSs are connected to sensors and actuators and use setpoint control to control the flow of material through the plant. The most common example is a setpoint control loop consisting of a pressure sensor, controller, and control valve. Pressure or flow measurements are transmitted to the controller, usually through the aid of a signal conditioning input/output (I/O) device. When the measured variable reaches a certain point, the controller instructs a valve or actuation device to open or close until the fluidic flow process reaches the desired setpoint. Large oil refineries have many thousands of I/O points and employ very large DCSs. A typical DCS consists of functionally and/or geographically distributed digital controllers capable of executing from 1 to 256 or more regulatory control loops in one control box. The input/output devices (I/O) can be integral with the controller or located remotely via a field network. Todays controllers have extensive computational capabilities and, in addition to proportional, integral, and derivative (PID) control, can generally perform logic and sequential control.

The Distributed Control System used in FCCU unit of Kochi refinery is CENTUM CS from Yokogawa. CENTUM CS is a best-seller model of Large scale production control system. It was first introduced in the year 1993.With Windows Remote Desktop capability, plant operation, monitoring, and engineering can be performed from a personal computer in the office or at a remote field location without any additional software. The same human interface displays in the control room can be shown on the PC in the office. For production facilities in remote locations around the world, remote operation and monitoring can be simply structured. The engineering work for modification can be performed remotely via a network, eliminating the need for dispatching engineers and reducing both maintenance and engineering cost.

The DCS can employ advanced process/supervisory control applications, operator-centric, enterprise-integrated information, configuring disparate systems into a holistic process overview and coordinated control strategy. A DCS utilizes a more distributed node topology. A system overview is shown in the figure below.

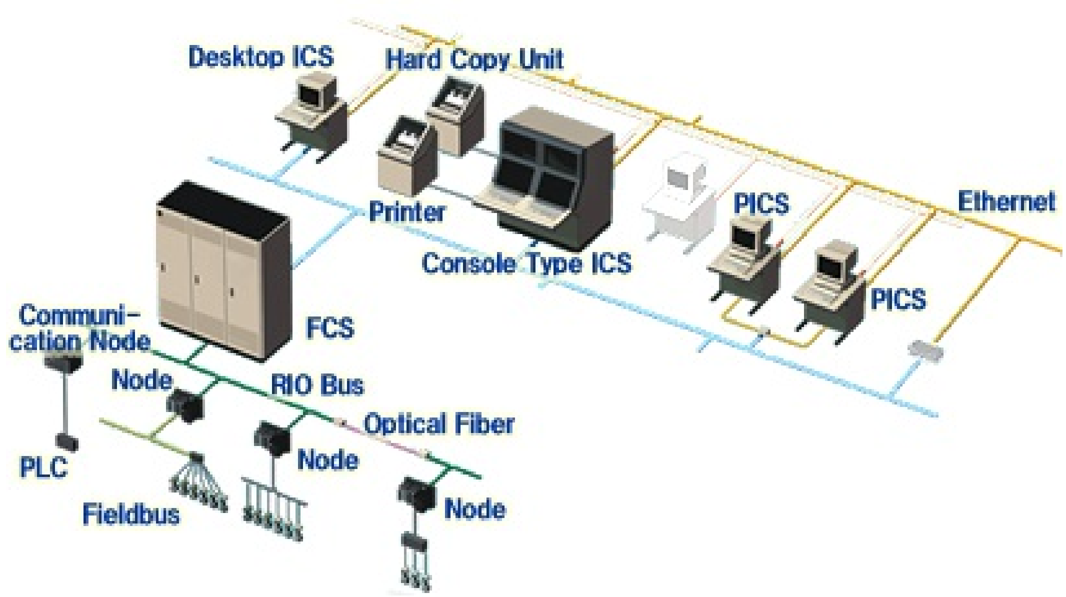


Figure 2.17: DCS overview

Information Command Station (ICS): A station for operating and monitoring the plant process control. Yokogawa provides three types of ICS according to the needs, Console Type ICS: The Console type ICS is an operator console designed based on the human engineering with extensive capability and high reliability. It has one CRT or two stacked CRTs which support touch-panel function and eight-loop simultaneous manipulation. Desktop ICS: The ICS on the desktop, the main body, CRT and keyboard are separated. This is a space-saving type of ICS with extensive capability and high reliability. PICS: The ICS is a general-purpose personal computer with UNIX operating system. It also has space-saving advantage. Field Control Station (FCS): The control unit for plant process control. The FCS inherits the renowned reliability of the entire CENTUM series. Truly the most reliable FCS in the industry. Since the processor cards perform control calculations, duplexes dual-redundant configuration of these cards is essential to prevent loss of control upon a hardware failure.In addition, two CPUs are paired in each processor card, thus the transient calculation errors can be detected. (This type of duplexes dual-redundant configuration is referred to as 'Pair & Spare' configuration.) In order to meet various requirements, in the FCS lineup, standard type, compact type and migration type FCSs are available for space saving installation, and high-distributed type FCS is also available for decentralized control structure.

Node: A remote input and output unit that passes the field signals to FCS control unit via remote buses.

Engineering Work Station (EWS): A workstation with engineering capabilities used for system configuration and system maintenance.

Bus Converter (ABC):Bus converters are required if a system contains multiple domains or contains the legacy CENTUM project.

Communication Gateway (ACG): A communication gateway unit is for linking a supervisory computer to control bus.

V Net: Real time control bus for linking FCS, ICS and ABC.

E Net: The information LAN of the system for linking ICSs and EWS.

2.3.3 Programmable logic controller

programmable logic controller (PLC) is a digital computer used for automation of typically industrial electromechanical processes such as control of machinery on factory assembly lines, amusement rides, or light fixtures. In process industries PLCs are often used to operate shut down valves or to trip a circuit according to the logic downloaded to the controller. A PLC is designed to withstand more harsh factory conditions and provide real time deterministic control and monitoring.

Before the advent of solid-state logic circuits, logical control systems were designed and built exclusively around electromechanical relays. Since these could number in the hundreds or even thousands, the process for updating such facilities for the yearly model change-over was very time consuming and expensive, as electricians needed to individually rewire the relays to change their operational characteristics.

Digital computers, being general-purpose programmable devices, were soon applied to control of industrial processes. Early computers required specialist programmers and stringent operating environmental control for temperature and power quality. Using a general-purpose computer for process control required protecting the computer from the plant floor conditions. An industrial control computer would have several attributes; it would tolerate the shop-floor environment, it would support discrete (bit-form) input and output in an easily extensible manner, it would not require years of training to use and it would permit its operation to be monitored. The response time of any computer system must be fast enough to be useful for control. The required speed varying according to the nature of the process. Since many industrial processes have timescales easily addressed by millisecond response times, modern (fast, small, reliable) electronics greatly facilitate building reliable controllers, especially because performance can be traded off for reliability. *Yokogawa PLC STARDOM FCN* STARDOM FCN provide high reliability for systems that control critical processes. The dual redundant capability of the field control node (FCN) autonomous controller ensures that these processes continue without interruption even when a damaged module is replaced. The following are the features of the PLC

- CPU unit, power supply unit, FOUNDATION fieldbus module, and control network can all be dual redundant.
- Automatic switchover to stand-by CPU
- Automatic data transfer from control side to replaced stand-by CPU
- Hot-swappable modules including CPU
- Fault-tolerant design (including ECC memory)

If the control-side CPU fails, the stand-by CPU automatically detects this and takes over control. To maintain consistency, all process data is synchronized on the stand-by and control-side CPUs. When a hot-swappable CPU module is replaced, the module automatically functions as the stand-by CPU by synchronizing both application and database without interrupting the process. No PC tools are required to perform this synchronization.

No special engineering work or dedicated CPU modules are required for redundant applications. The stand-by and control CPUs also use the same spare parts, allowing users to keep fewer parts in stock.

Power failure during disc access is a major cause of file corruption in the CPU module. Without having to replace the entire CPU module, it is possible to recover a damaged file system by replacing just the FCN system card.

2.3.4 Compressor control

A gas compressor is a mechanical device that increases the pressure of a gas by reducing its volume. Compressors are similar to pumps. Both increase the pressure on a fluid and both can transport the fluid through a pipe. As gases are compressible, the compressor also reduces the volume of a gas.

There are mainly two types of compressors. Reciprocating and rotating. Reciprocating compressors are similar to an IC engine, but here the linear motion is used to compress the gas. Rotating compressors can be further divided in to axial and centrifugal types. Axial type is used for high flow rate applications and centrifugal type is used to get high compression ratio. A combination of axial and centrifugal type is also available.

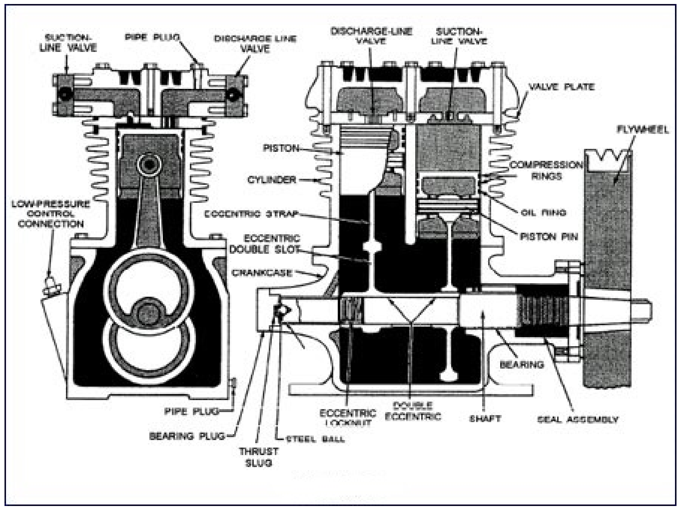


Figure 2.18: Reciprocating compressor

Operating map

Compressor map or performance map is used to describe the operating range of a compressor. Quantities like gas flow and pressure are measured to get the process/operating information and thus the operating point of the compressor is set. Any change in the process variables will change the operating point of the compressor too.

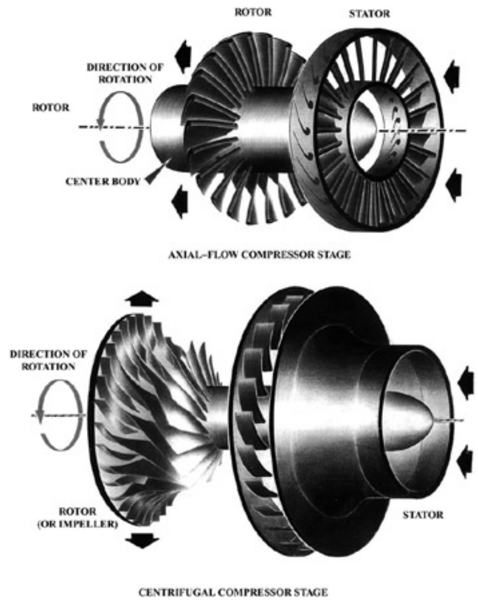


Figure 2.19: Axial and centrifugal compressor

Surge

The surge region, located on the left-hand side of the compressor map (known as the surge line), is an area of flow instability typically caused by compressor inducer stall. The turbo should be sized so that the engine does not operate in the surge range. When turbochargers operate in surge for long periods of time, bearing failures may occur. When referencing a compressor map, the surge line is the line bordering the islands on their far left side. Compressor surge is when the air pressure after the compressor is actually higher than what the compressor itself can physically maintain. This condition causes the airflow in the compressor wheel to flow in the opposite direction. In cases of extreme surge, the thrust bearings of the turbo can be destroyed, and will sometimes even lead to mechanical failure of the compressor wheel itself. Surge cycles happen in about 0.33 to 3 seconds interval. A typical surge cycle is shown in figure 2.21.

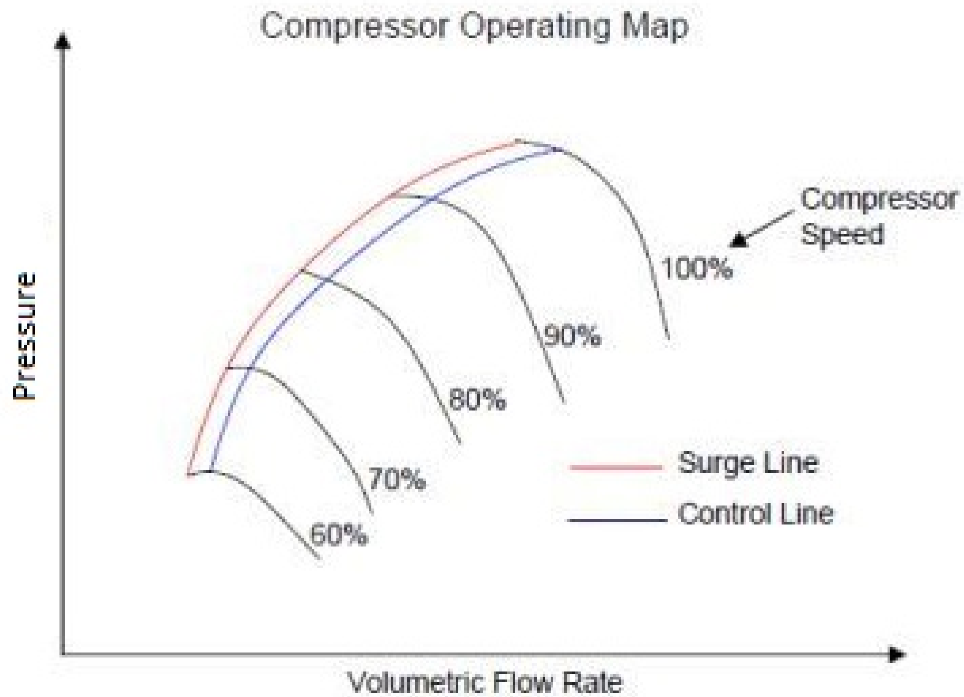


Figure 2.20: Compressor operating map

There are certain other factors also that has to be considered. The desired area of operation of a compressor is as shown in the graph below. The shaded region shows the safe region of operation.

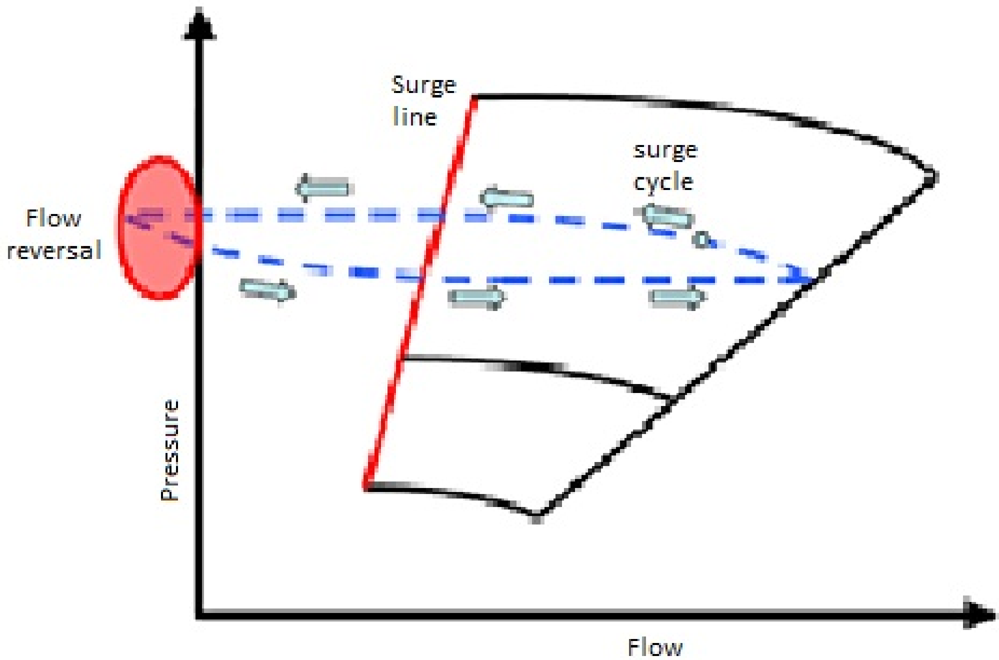


Figure 2.21: Compressor surge cycle

For efficient operation of the compressor, the operating point should lie as close as possible to the surge line. At this point, the compressor is loaded to its rated value and the energy used to compress a unit of gas would be less. Thus the efficiency of the compressor is greatly improved. To achieve this, a turbomachinery control solutions from Compressor Controls Corporation(CCC) is implemented in the Gas Concentration Unit of Kochi refinery.

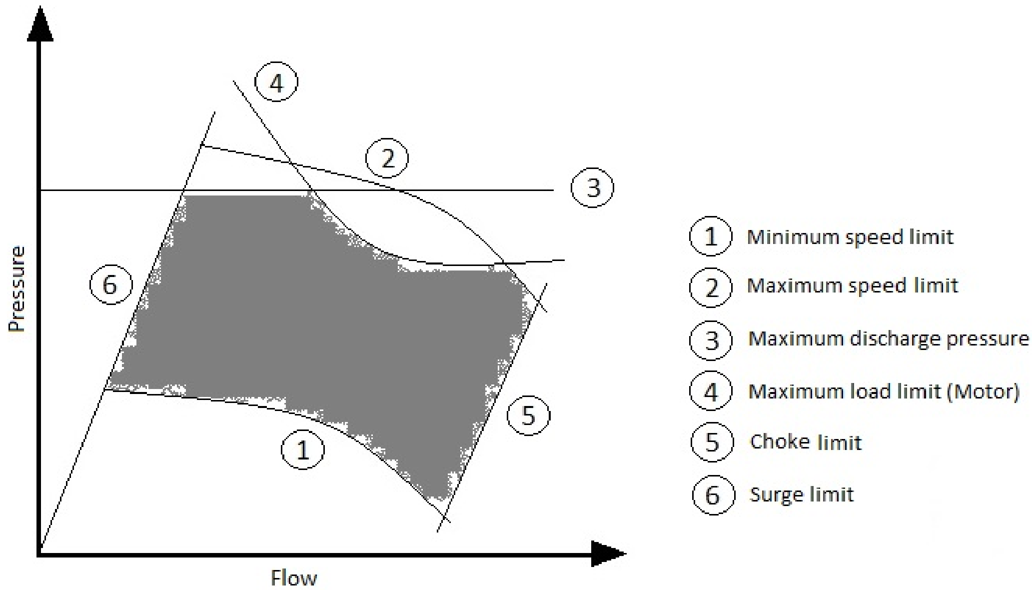


Figure 2.22: Compressor operating curve

From the outlet of the compressor, a separate pipe is laid back to the suction of the compressor. A spill back valve is employed on this line to control the circulation of gas flow from outlet to suction. By opening the valve, the pressure at the outlet can be reduced and surging may be avoided. The controller creates an imaginary line very close and on right side of the surge line as shown in the graph below. The controller now tries to maintain the operating point of the compressor on this line. Whenever the operating point tends to shift to the left of surge control line[3], the spill valve is opened proportional to the shift. Thus the pressure is brought down and the operating point comes back to the right of surge control line.

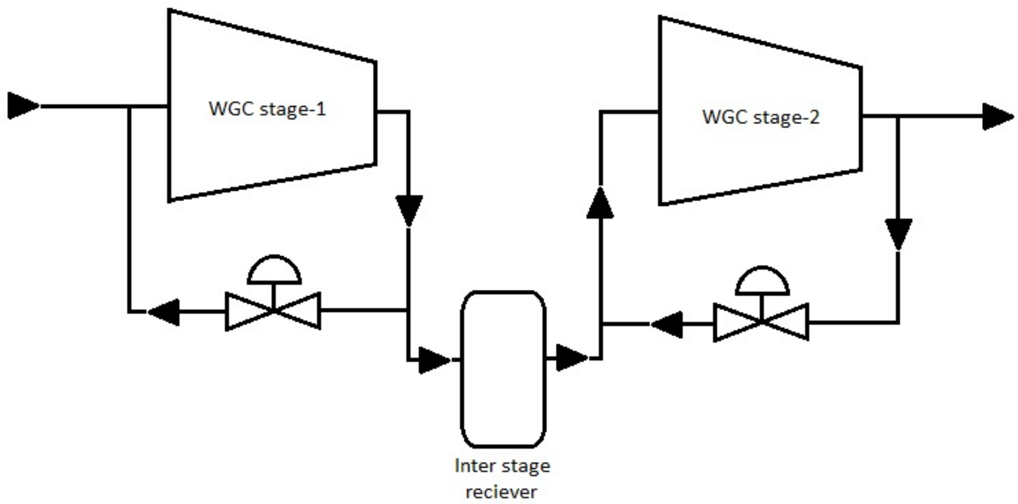


Figure 2.23: Wet gas compressor spill valves

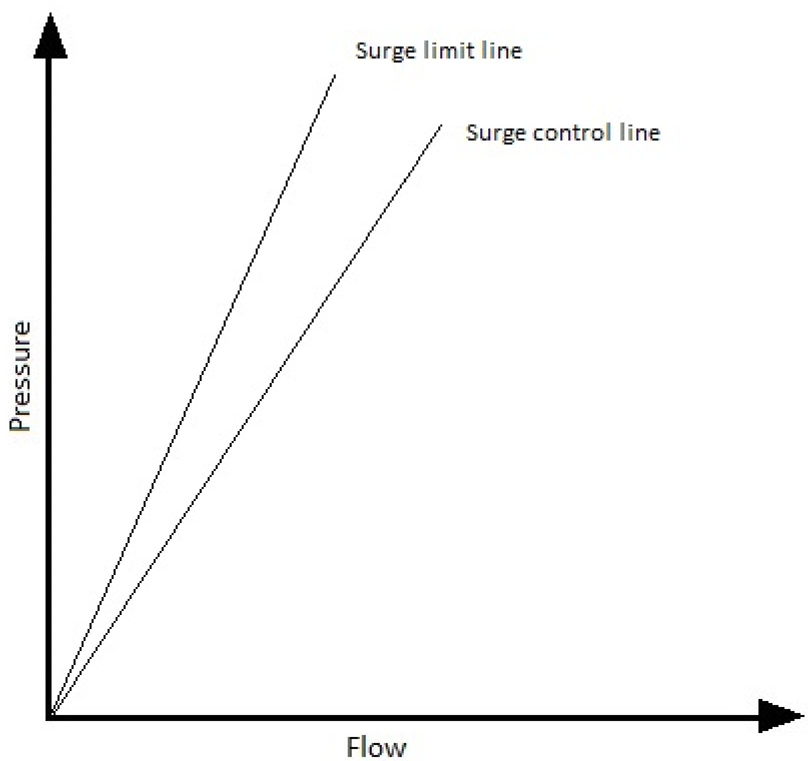


Figure 2.24: Surge control line

CHAPTER 3

FLUID CATALYST CRACKING UNIT

In oil refineries, heavy oil after first stage of crude distillation is cracked in to lighter and more valuable hydrocarbons. There are several methods to crack the heavy oil. The most economic and efficient way of cracking is by the use of a catalyst. This process is known as catalytic cracking. It is widely used to convert the high-boiling, high-molecular weight hydrocarbon fractions of the petroleum crude oil to more valuable gasoline, LPG, and other products. Cracking of petroleum hydrocarbons was originally done by thermal cracking, which has been almost completely replaced by catalytic cracking because it produces more gasoline with a higher octane rating. It also produces by-product gases that have more olefin, and hence more valuable than those produced by thermal cracking.

3.1 PROCESS FLOW

The catalyst cracking plant area is divided in to 3 major sections namely [4]

- Feed Preparation Unit (FPU)
- Fluid Catalyst Cracking Unit (FCCU)
- Gas Concentration Unit (GCO)

3.1.1 Feed Preparation Unit

The function of FPU is to prepare the feed,that is Vacuum Gas Oil (VGO)for the FCC Unit. The feed preparation unit consists of 2 sections; Vacuum furnace and Vacuum distillation column. The vacuum furnace is used to heat the feed up to the required temperature before feeding to the distillation column. In the vacuum furnace, the reduced crude is vaporized and collected at different chimney trays of the column. The components are vaporized at a lower temperature due to the reduced pressure inside the column. The outputs obtained from the vacuum column are, vacuum diesel oil, light vacuum gas oil, heavy vacuum gas oil, slop distillate and vacuum residue. The block diagram of the feed preparation unit is illustrated in the figure below.

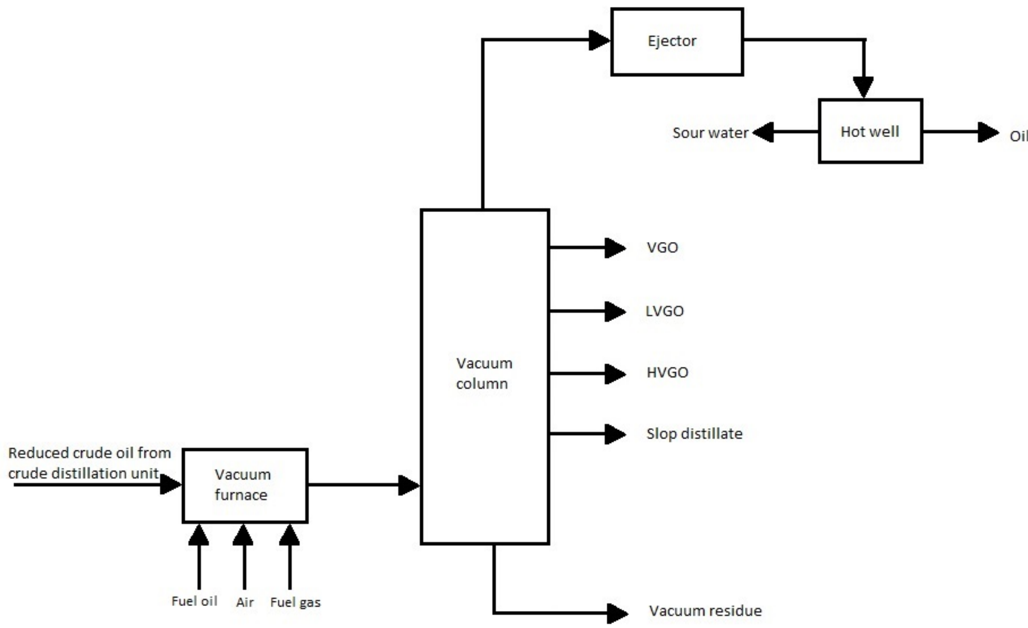


Figure 3.1: Block diagram of Feed Preparation Unit

Vacuum furnace: The reduced crude oil (RCO) from the crude distillation unit (CDU) at 320^0c is directly pumped to the vacuum furnace of the feed preparation unit (FPU) for pre heating. The main incomer pipe which is carrying the RCO is split in to 4 pipes which have individual flow control valves. Medium pressure steam lines join these pipes in order to maintain the flow rate and to avoid coking. The steam injection rate can be adjusted by controlling the valves on the steam lines. The steam lines can be closed completely in cases where steam is not necessary to run the process. The steam RCO mixture then enters the vacuum furnace where it is heated using flame.

The flame required for heating is obtained by burning fuel oil and fuel gas in the presence of air. The fuel oil is mixed with medium pressure steam in order to split the oil in to fine particles before injecting in to the furnace. This steam is sometimes called as atomising steam. Thus there are 3 lines carrying fuel oil, fuel gas and MP steam to the furnace and a return line for the fuel oil. Air necessary for the combustion is taken from the atmosphere using draft fans. A provision is also provided to take air through natural suction in case the draft fan fails. All the

4 streams of RCO exit the furnace at 386^0c and combines to form a single stream. This is then pumped to the vacuum distillation column for distillation.

Vacuum Distillation Column: Vacuum distillation is a method of distillation whereby the pressure above the liquid mixture to be distilled is reduced to less than its vapour pressure, usually less than atmospheric pressure. This causes evaporation of the most volatile liquids with the lowest boiling points. This distillation method works on the principle that boiling occurs when the vapour pressure of a liquid exceeds the ambient pressure. Vacuum distillation is used with or without heating the mixture.

The vapour liquid mixture from the vacuum furnace is transferred to the vacuum distillation column through transfer lines. The pressure of the mixture at entry is at 25mmHg. The pressure at the top of the column is maintained by keeping the pressure of 7mmHg at the ejector suction. The vacuum column has 4 chimneys trays and 5 packed beds.

Overhead system

Vacuum in the column is maintained by a 3 stage ejector system with surface condensers. Steam jet ejectors offer a simple, reliable, low-cost way to produce vacuum. They are based on the ejector-venturi principal and operate by passing motive steam through an expanding nozzle. The nozzle provides controlled expansion of the motive steam to convert pressure in to velocity which creates a vacuum with in the body chamber to draw in and entrain gases or vapours. The motive steam and suction gas are then completely mixed and then passed through the diffuser or tail, where the gases velocity is converted in to sufficient pressure to meet the predetermined discharge pressure. They are especially effective in the chemical industry where an on-site supply of the high-pressure steam is available. An Ejector Does not need any source of power other than steam. Since they have no moving parts, they are reliable vacuum producers. They are easy to install, operate and maintain.

The overhead gases from vacuum distillation column pass through the first stage of ejectors. The non-condensate from the first stage is taken to the second stage and then to the third. Condensate from all the three sets of ejectors flow down to a hot

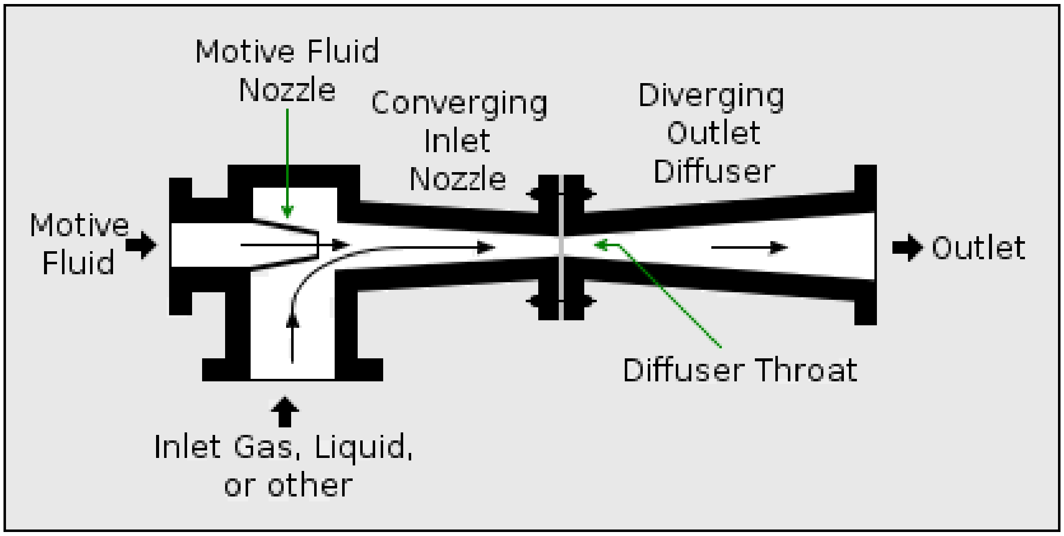


Figure 3.2: Ejector

water well through separate barometric legs. The non-condensible bubble through water seal in hot well and escape to atmosphere through a high point vent. Hot well gases are sent to atmosphere through high point vents. Sour water which is collected at the middle section of hot well is pumped to sour water stripper. The middle section is separated from another section at the end by a baffle. The oil that float on the water overflows to the next section. This is then pumped to storage tanks.

Vacuum Diesel Oil(VDO) system

Vacuum diesel oil is drawn from top most tray of the vacuum distillation column at 162^0c for arab mix crude and at 150^0c for Bombay high crude. From the pump discharge, one portion of the VDO joins the Heavy Vacuum Gas Oil(HVGO) cold reflux. Vacuum diesel is cooled in air fin cooler. A part of this cooled stream returns to the column tray as pump around to control the temperature of the tray.

Light Vacuum Gas Oil (LVGO) system

The LVGO is drawn from the second chimney tray of the vacuum distillation column. For arab mix crude the LVGO condenses at 240^0c and for Bombay high crude it condenses at 246^0c.

Heavy Vacuum Gas Oil (HVGO) system

The HVGO is drawn from the middle chimney tray of the vacuum distillation column. For arab mix crude the HVGO condenses at 272^0c and for Bombay high crude it condenses at 284^0c.

Slop Distillate system

Slop distillate is a very heavy product from the crude and has a lot of impurities. The value for this product is very less. The slop distillate is withdrawn from the bottom most chimney tray at 385^0c. The slop distillate is separated from VGO in order to remove elements like Nickel (Ni) and Vanadium (V) so that the catalyst life is improved in the FCC unit.

All the chimney tray compartments of the vacuum distillation column are equipped with level indicators, low level and high level alarms. Control valves are provided on the rundown line to control the level of the chimney trays automatically. Manual opening and closing of the valves are also possible from the control room.

An appropriate mixture of LVGO and HVGO is transferred to the Fluid Catalyst Cracking Unit to break down the heaver hydrocarbons in to lighter products which are more valuable.

3.1.2 Fluid Catalytic Cracking Unit

The products obtained after cracking are Fuel gas, Liquefied Petroleum Gas (LPG), Gasoline (C5, 160^0c), Heavy Naphtha (160-220), Light Cycle Oil (LCO), Heavy Cycle Oil (HCO) and Coke. The different sections of FCCU are listed below

- Feed pre-heat section
- Catalyst section
- Fractionation section

The block diagram of the catalytic cracking unit is illustrated in the figure below.

Feed pre heat section

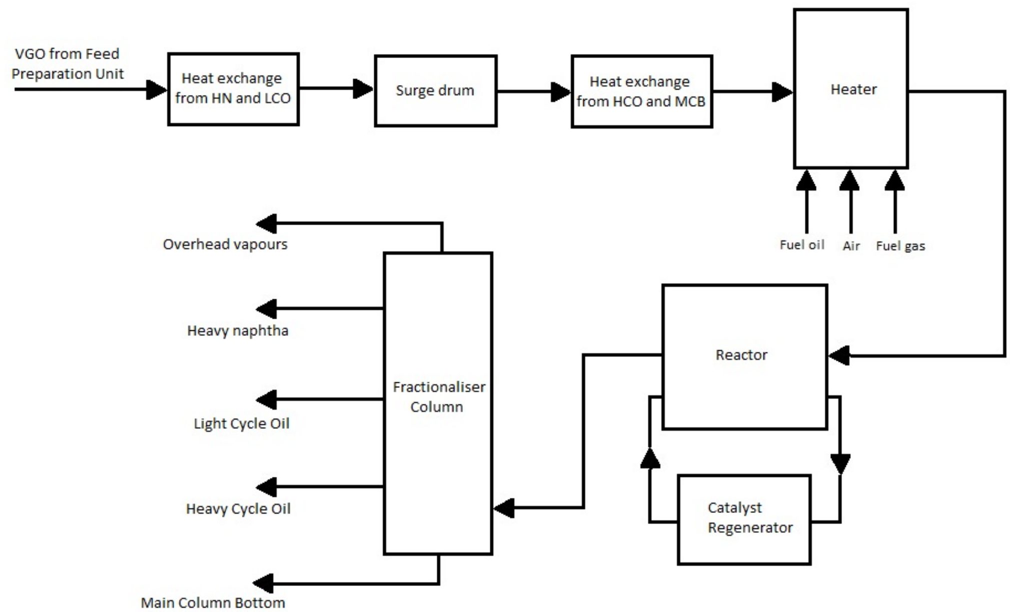


Figure 3.3: Block diagram of FCCU

The Vacuum Gas Oil from the vacuum distillation column is passed through a number of heat exchangers and a heater before letting it in to the catalytic reactor column. The heat exchange is done between the various products of the main fractionation column itself. The feed initially exchanges heat with Heavy naphtha and light cycle oil and reaches a surge drum. The VGO in the surge tank is at a temperature of 138^0c. It is then pumped to another heat exchanger where heat is transferred from heavy cycle oil to VGO. The feed VGO comes out at a temperature of 180^0c from this exchanger. Next the heat is transferred from main column bottom residue and VGO. The temperature of the VGO is again raised up to 295^0c at this point.

For further raising the temperature, a heater is provided after the final heat exchanger. Fuel oil and fuel gas is burned in the presence of air to generate heat. Steam at medium pressure is injected along with fuel oil to disperse it to fine particles for better combustion. The feed VGO exiting the heater is maintained at 330^0c.

Catalytic section

The catalytic section consists of two components; the reactor and the regenerator. The reaction between the catalyst and vacuum gas oil takes place in the reactor. The function of the regenerator is to regain the used catalyst after the reaction has taken place in the reactor.

The fresh feed mixed with medium pressure steam (dispersion steam) rises along with the catalyst in the riser of the reactor. Medium pressure stabilizing steam is injected in to the wye section via a ring distributor to smoothen the flow of the catalyst. Another medium pressure steam line is provided at the bottom to supplement the feed is case of any unexpected shut-off of feed flow. This stream is named as the emergency steam and has a velocity of 12.5 feet per second and 3133 Kg/hr of flow rate if activated. The emergency steam prevents the slumping of the riser with stagnant catalyst. The reaction between catalyst and VGO takes place in the reactor breaking the heavy hydrocarbon in to lighter components. The catalyst used is silica-alumina.

The bottom wye section of the reactor may cause turbulence and uneven catalyst flow pattern. Therefore a high density zone is provided to absorb the shocks and stabilize the catalyst flow.

The catalysts, after reaction is covered with coke. It is then separated from the gases with help of stripper steam fed in to the reactor from above. The spend catalysts comes down along the sides of the reactor and cracked petroleum gases moves up.

When the level of the spent catalyst goes above a certain limit, it is transferred in to the regenerator through a slide valve, generally called as the Spent Catalyst Slide Valve (SCSV). The activity of the spent catalyst flowing down the spent catalyst stand pipe is restored by burning off the coke deposited on the catalyst. Spent catalyst is distributed to the top of the bed by a ski-jump distributor installed at the spend catalyst standpipe exit. The air required for combustion is taken in to the regenerator with the help of an air blower referred to as Main Air Blower (MAB). In addition to the air, some amount of oxygen is supplied from the VPSA oxygen gas unit for complete combustion. The combustion of the coke happens instantly without any ignition due to the high temperature inside the regenerator under normal operation. The temperature inside the regenerator varies from 705^0c at the dense area at the bottom to about 765^0c at the dilute area at the top. The flue gases are routed to the CO burner via heat exchangers for heat recovery.

Slide valve control

The slide valves are the important components of the FCC unit. The slide valves control the flow of spent catalyst from reactor to the regenerator and the regenerated catalyst from the regenerator to the reactor. The regenerator contains air and temperature necessary for combustion and the reactor contains the fuel. Therefore any sort of mixing between the two columns will result in an explosion. Thus reversal of flow through the slide valves has to be avoided. To achieve this, a difference in pressure is always maintained across the either sides of the valve. This differential pressure ensure that the flow through the valves happen only in one direction. The control strategy for the valve operation is explained in the figure below.

SCSV control: The spend catalyst slide valve is operated according to the level of the catalyst in the reactor. Another important consideration is the differential pressure that is to be maintained across the valve so that reverse flow does not happen. Under normal operation the level of the catalyst is measured and compared with the set value. The valve is opened and used catalyst is transferred to the regenerator by taking feedback from the level transmitter. The differential pressure control acts as override control. In case the pressure difference drops across the valve, the least value among the differential pressure controller or level controller is taken by the low signal selector and the valve is operated. That is the valve tends to close when the differential pressure goes below the set value.

RCSV control: The regenerated catalyst slide valve is operated to maintain the required temperature of 536^0c at the reactor column. The regenerated catalyst after the coke has been burned out will be at a temperature of 705^0c and the feed VGO coming in to the reactor is at a temperature of 330^0c. By controlling the mixing of hot catalyst with the feed, the reactor temperature is maintained at 536^0c. The differential pressure is to be maintained across the RCSV too so that reverse flow does

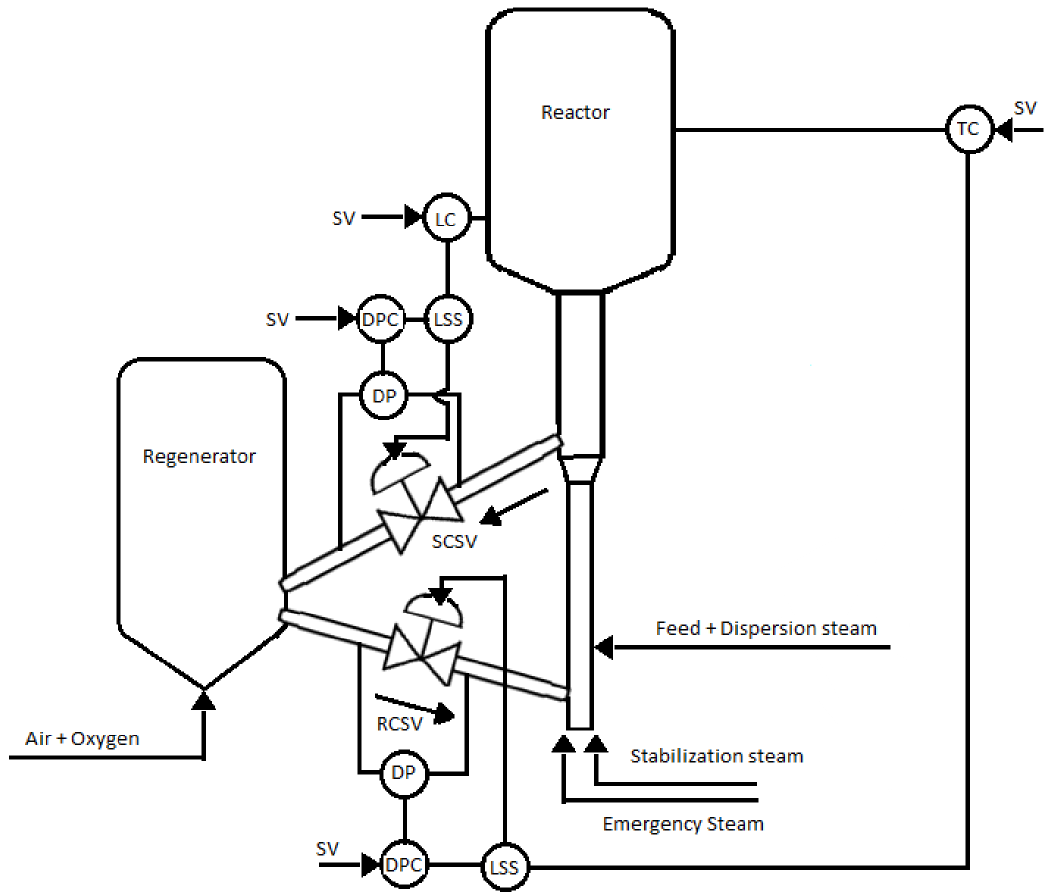


Figure 3.4: FCCU slide valve control strategy

not happen. Under normal operation the temperature of the regenerator is measured and compared with the set value. The valve is opened and regenerated catalyst is transferred to the reactor by taking feedback from the temperature controller. The differential pressure control acts as override control. In case the pressure difference drops across the valve, the least value among the differential pressure controller or temperature controller is taken by the low signal selector and the valve is operated. That is the valve tends to close when the differential pressure goes below the set value.

Fractionation section

The vapours from the reactor column comes to the fractionation section.The vapours are directed towards the bottom of the fractionation column. The temperature of the vapour is higher than the boiling temperature of its components. Low pressure steam is mixed with the vapour at the bottom of the main column.

Overhead system

The components with low boiling point moves to the overhead fin fan coolers condenses. The temperature of this tray is maintained at 111.5^0c with the help of reflux. Wash water is added at the inlet of air fin coolers to prevent fouling of heat exchanger. These gases are then cooled to 40^0c and goes to gas concentration unit. A part of this stream is pumped back to the main column as reflux flow.

Heavy naphtha system (HN)

Heavy naphtha is drawn off below bed no.1 at a temperature of 147^0c. The stream is distributed in to two. One goes to heavy naphtha stripper. Heavy naphtha is stripped out by passing medium pressure steam from the bottom of the stripper. Rest is cooled in air fin coolers and further to 40^0c and stored in tank.

Light cycle oil system (LCO)

Light cycle oil is drawn off below bed 3 at a temperature of 208^0c. An LCO stripper is used to strip LCO. The stream enters at the top of the stripper.A control valve is provided to control the bottom level in the tray. A stream from HCO at 313^0c joins LCO to the LCO stripper. The LCO stripper has 6 number of valvue trays. Vapour from top return to main column below bed no.3. Stripped LCO is pumped through heat exchangers to exchange heat with the feed VGO and then then to storage tanks.

The oil after heat exchange is at a temperature of 158^0c. Flow to stripper re-boiler controls the stripper overhead vapour flow. A portion of LCO from outlet at 156^0c branches off and goes to sponge absorber in GCU section. Cooled LCO at 40^0c acts as an absorbing medium for LPG and gasoline components in the sponge gas entering absorber vessel 2 from vessel 1. Rich oil from vessel 2 bottom, after getting heated up to 102^0c rejoins the remaining LCO stream from heat exchanger GE7 of GCU section. The combined stream of LCO at 106^0c and LCO from heat exchanger FE14 of FFCU section joins together and returns to the main column above bed no.3 as LCO circulating reflux at 161^0c. Provision exist to route hot LCO to raw oil charge drum as a recycle stream.

Heavy cycle oil system (HCO)

Heavy cycle oil is withdrawn from the partial draw off collector tray below the forth packed bed at 313^0C. The flow of HCO is listed below.

- HCO is routed to LCO stripper
- HCO is routed to Gas Concentration Unit for heat transfer to debutaniser bottom reboiler
- HCO is routed to tube side of raw oil/HCO heat exchanger
- HCO is routed to steam generator boiler.

Main column bottom system (MCB)

The main column bottom is drawn from the bottom of the main column with the help of suction pipes at a temperature of 345^0C. A redundant suction pipe is provided in case on pipe gets clogged. The pipeline to raw oil/MCB heat exchanger is taken from the top of the pump discharge manifold. The MCB flow is divided in to 3 streams.

- Stream 1 return to main column as MCB pump around above bed no.6 at 273^0C.
- Stream 1 return to main column bottom quench below bed no.6 at 273^0C.
- Stream 3 is filtered and is cooled in raw oil/CLO heat exchanger and then in to shell side of trim cooler. Afterwards it is pumped to storage tanks.

A line from discharge to inlet is provided for maintaining a minimum flow.

3.1.3 Gas Concentration Unit

The function of GCU is to separate Fuel gas, LPG and stabilised gasoline from overhead wet gases and unstabilized gasoline from main column overhead receiver. Fuel gas refers mainly to methane and ethane which are not suitable for sale outside, but are used for heating purpose within the refinery. Stabilized gasoline refers to normal petrol from which the low-boiling (high vapour pressure, volatile) hydrocarbons have been removed.

Wet Gas Compressor

The wet gas compressor is used to compress the overhead wet petroleum gases from the main column overhead system. There are two sets of gas compressors; WGC-1 and WGC-2. Each of these two gas compressors have compressing stage 1 and stage 2. In between the two stages, there is an interstage cooler and an interstage receiver.

WGC - First stage: The wet gases at 40^0C splits in to two and WGC-1 and WGC-2 via knock out drums (used to separate vapour and liquid). At the first stage, gas is compressed up to 5.48 kg/cm^2 and 92^0C. The gas then goes to inter stage cooler and interstage receiver. Wash water at 40^0C is added upstream using pump and flow controllers to remove sulphur content. Inter stage receiver pressure is controlled by the second stage spill back control valves. Recycle stream from the spill back control valve of the first stage join the main column overhead. Anti surge controllers maintain a minimum gas flow to avoid surging of compressor according to overhead receiver pressure.

WGC - second stage: The gases from the first stage at 5.48 kg/cm^2 is gaingcompressed at the second stage up to 15.55 kg/cm^2 and 99^0C. It then goes to air fin coolers where it meets the following streams.

- Overhead vapours from stripper at 65.4^0C
- Unstabilized gasoline from primary absorber bottom at 51^0C
- Wash water and condensate from interstage receiver at 40^0C
- LV1 liquid from primary unit

Primary absorber

Combined stream is cooled to 40^0C and taken to HP receiver. Recycle steam from the spill back control valve of the second stage joins he compressed gases from the first stage discharges. The gas rich liquid from HP receiver is pumped to primary absorber vessel to absorb light products such as LPG. Absorption media are unstabilized gasoline from main column overhead receiver and stabilized gasoline from debutanizer. The rich gases at 40^0C from the HP receiver enter the primary absorber below 36^{th} tray. Net overhead liquid from main column receiver at 40^0C enter 9^{th} tray. Stabilized gasoline after getting cooled is pumped to the top most tray of the primary absorber as a final wash.

Sponge absorber

Sponge absorber is a guard tower to absorb the remaining valuable components from primary absorber overhead gases using Light Cycle Oil. Primary absorber overhead gases at 51^0C enter sponge absorber below bottom bed of packing. LCO at 40^0C is pumped to upper bed of packing of sponge absorber. Lean gases from sponge absorber overhead at 48^0C goes to sponge absorber knock out drum after cooling at trim coolers. Rich oil fro bottom of sponge absorber at 64^0C return to LCO reflux after getting heated to 113^0C. Condensate collected in the sponge absorber knock out drum is also routed to the main column along with LCO reflux.

Debutaniser

The function of debutaniser is to separate LPG as an overhead product and stabilized gasoline as the bottom product. Stripped product from stripper bottom enters the debutaniser above 26th tray at 115^0C. Heat for reboiling of debutaniser bottom is supplied by a reboiler using circulating HCO as a heating medium. Overhead vapours from debutaniser overhead at 68^0C is condensed in air fin coolers and further cooled to 40^0C in trim coolers and stored in debutaniser overhead receiver. Overhead condensate is partially refluxed to first tray to control temperature for better separation. Stabilized gasoline from debutaniser bottom flows under system pressure to the tube of stripper bottom reboiler preheater,then to the tube side of stripper charge preheater. It is cooled and divided in to 2 streams.

- To primary absorber as an absorbing medium using recycle gasoline pump

- To gasoline merox unit depending on debutaniser bottom level

3.2 HEAT AND MASS BALANCE

Heat balance of regenerator and riser The following are the data of product temperature in the reactor column. Reactor temperature : 970^0F Combined feed : 375^0F Lift gas : 100^0F Lift steam : 380^0F Feed steam : 380^0F Stripping steam : 380^0F

Regenerator avg. temperature : 1375^0F Regenerated catalyst : 1371^0F Flue gas : 1368^0F Air blower discharge : 399^0F HP boiler feed water : 220^0F Catalyst cooler steam : 463^0F

Catalyst cooler steam pressure : 452 psi

Flow rates Fresh feed : 412923 lb/hr Lift gas : 3250 lb/hr Lift steam : 12900 lb/hr Feed steam : 1800 lb/hr Stripping steam : 5000 lb/hr Total air to regenerator : 380200 lb/hr Catalyst cooler steam : 56033 lb/hr Catalyst cooler blowdown : 6952 lb/hr

Heat of combustion of coke

$$2CO_2 -> 2CO \tag{3.1}$$

For 2200*2 kCal/kg of C, 46216+1.47(1375^0F)= 48237 BTU/lb-mole

$$C + O_2 -> CO_2 \tag{3.2}$$

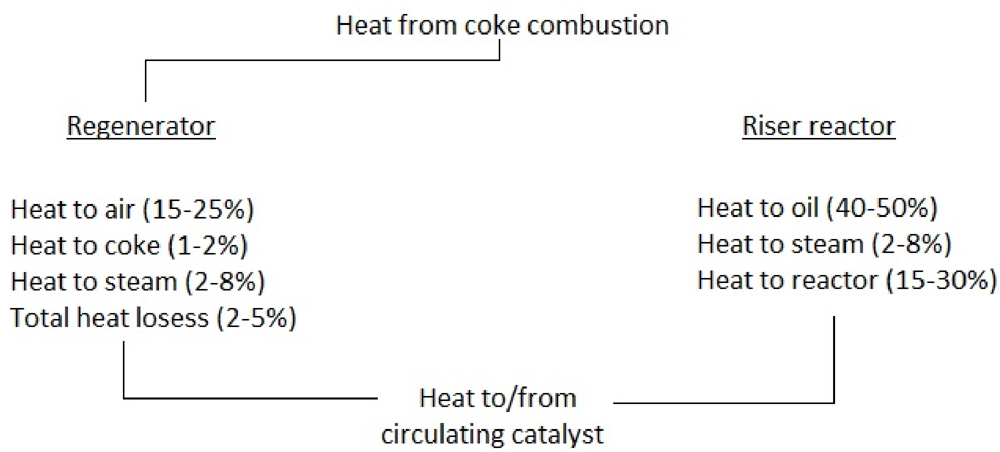
For 7800 kCal/kg of C, 169135+0.5(1375^0F)= 169822 BTU/lb-mole

$$H_2 + 1/2O_2 -> H_2O \tag{3.3}$$

For 28900 kCal/kg of H_2, 17090+110 BTU/lb coke= 17200 BTU/lb coke

The coke yield as a weight percentage of feed is dependent only on the heat requirement of the system and not on the feed or anything else.

Energy In + Energy produced = Energy Out + Energy consumed



$$-\Delta H_{air} - \Delta H_{spent\ Catalyst} - \Delta H_{coke} + \Delta H_{combustion\ Of\ Coke} = \Delta H_{removed} + \Delta H_{Reaction\ Losess} \tag{3.4}$$

That implies,

$$\Delta H_{spent\ Catalyst} = -\Delta H_{air} - \Delta H_{coke} + \Delta H_{combustion\ Of\ Coke} - \Delta H_{removed} - \Delta H_{Reaction\ losess} \tag{3.5}$$

If the reactor temperature is the reference base temperature,

$$\Delta H_{Regenerated\ Catalyst} = \Delta H_{Feed} + \Delta H_{Dilutents} + \Delta H_{Radiation\ Losses} + Heat\ of\ reaction \tag{3.6}$$

$$\Delta H_{Spent\ Catalyst} = Mass\ Flow\ C_p(Regenerator\ Temperature - Reactor\ Temperature) \tag{3.7}$$

$$\Delta H_{Regenerated\ Catalyst} = Mass\ Flow\ C_p(Reactor\ Temperature - Regenerator\ Temperature) \tag{3.8}$$

$$\Delta H_{Regenerated\ Catalyst} + \Delta H_{Spent\ Catalyst} = 0 \tag{3.9}$$

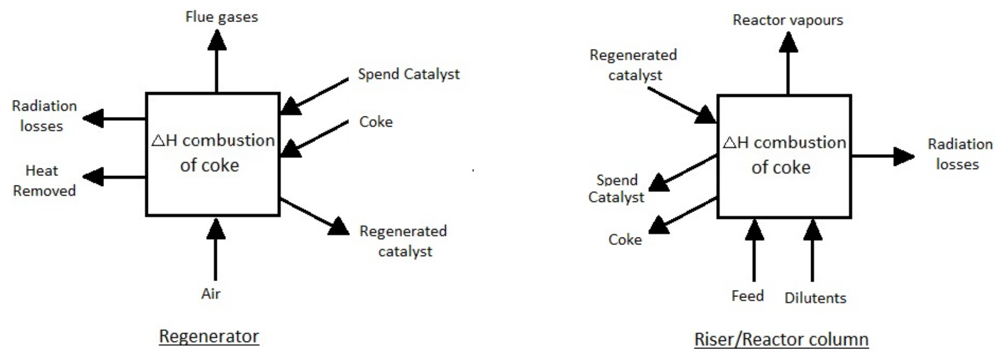


Figure 3.5: Heat balance in Regenerator/Reactor

Stream	Flow	Temperature	Pressure	API	Distillation	GC	Meter Factor
Feed(VGO)	Yes	Yes	-	Yes	D-1160	-	Yes
Air	Yes	Yes	Yes	-	-	-	Yes
MCB	Yes	Yes	-	Yes	D-1160	-	Yes
LCO	Yes	Yes	-	Yes	D-86	-	Yes
Gasoline	Yes	Yes	-	Yes	D-86	Yes	Yes
LPG	Yes	Yes	-	-	-	Yes	Yes
Sponge gas	Yes	Yes	Yes	-	-	Yes	Yes
Flue gas	-	-	-	-	-	Yes	-

Input data for Heat and mass balance

Liquid stream flow correction

$$Q = KR\sqrt{G_f}/G_b \tag{3.10}$$

Where K- Flow meter constant

R- Chart reading

G_f-Gravity at flowing temperature

G_b-Base gravity at 60^0F

Gas stream flow correction

$$Q = KR\sqrt{P_f/(T_f * SG)} \tag{3.11}$$

Fresh feed	Temp. (^{0}F)	Vol%	Wt%	Gravity At 60^{0}F	Vol. correction factor	Flowing gravity	Meter constant	BPSD	lb/hr
Fresh feed	173			0.9260	0.9545	0.8839	3380	30538	412601
MCB	462	6.04	6.79	1.0412	0.8806	0.9169	418	1843	28005
LCO	101	21.33	21.19	0.92	0.9838	0.9051	700	6515	87450
Gasoline	148	58.9	48.34	0.7599	0.9489	0.7211	2118	17987	199434
LPG	87	19.53	11.84	0.5612	0.9683	0.5418	632	5964	48833
Coke			6.1						25187
Sponge gas (Inert)	113		4.56					6589	18821
Sponge gas (Non-Inert)				0.6519	173		1518	6996	20887
Air to regenerator	415			1	44.5		46000	81721	374251
Air to catalyst cooler	230			1	56		325	520	2382
Air to distributor	230			1	56		635	1260	5771
Total air to regenerator								83502	382405

Where R- Flow meter reading

P_f-Pressure at flowing condition

T_f- Flow meter constant

SG-Specific gravity

Product yield

Product yield is given by product rate/Raw oil rate. Weight recovery must be 100+2% or 100-2%

$$Weight\%\, recovery = (Product\, in\, lb/hr*100)/(Fresh\, feed+Extraneous\, feed)lb/hr \tag{3.12}$$

$$Liquid\, volume\%\, recovery = (Product\, in\, bpsd*100)/(Fresh\, feed+Extraneous\, feed)lb/hr \tag{3.13}$$

$$Conversion\ volume\% = (Feed - LCO - HCO - MCB) * 100/Feed \tag{3.14}$$

Weight recovery = [(MCB+LCO+DeBt+LPG+Sponge gas+coke)*100]/[FF+ELPG+Egas] lb/hr Which works out to 98.82wtLiquid volume recovery = [MCB+LCO+DeBt+LPG]/[FF+ELPG] bpsd Which works out to 105.8 Volume

Steam flow The different pressure steams used and their consumption for the FCCU is listed in the table.

CHAPTER 4

PROPOSALS

4.1 INTERMITTENT STORAGE TANKS

Mostly between major processing plants, intermittent storage tanks are provided that acts as a buffer. In cases where the plant preceding the tank has stopped production, the plant succeeding the tank can still function without any interruption until the contents of the tank is fully utilizes. This gives some time for the first plant to normalize its operation.

Similarly in cases where the plant succeeding the tank has stopped unexpectedly and stopped taking in the feed, the plant preceding the tank can still operate and fill the tank until it is full. The succeeding plant only need to be normalizes within this time.

The operation of plants that are not connected through a storage tank are limited by sequential constrain. Both the plants should be simultaneously functional for the process to run smoothly. Any abnormality in either of the plant will affect both plants.

In refinery, the Fluid Catalytic Cracking Unit(FCCU) takes Reduced Crude Oil(RCO) as the feed from Crude Distillation Unit-1 (CDU-1). The RCO is one of the products taken from the bottom part of crude distillation unit. The RCO is directly pumped to the feed preparation unit of FCCU without any intermittent storage. Thus an occurrence of a trip in either of the two plants will need both the process to be stopped. To start up the plants from idle condition requires to follow a lot of procedures and utilizes additional energy and time. Unnecessary start/stop of plant could be avoided by providing a storage tank for RCO in between CDU-1 and Feed Preparation Unit of FCCU. The capacity of the tank should be decided according to the inflow rate to the tank and outflow rate from the tank. The average time required to start up the plants after a trip, should also be considered.

4.2 COMBINED CONTROL AND SHUT DOWN VALVE

On critical pipelines, two valves are provided. One for controlling the process variable such as flow rate, pressure etc.. The other valve is for shut down in case of any emergency situation for the sake of safety. The valve which control the process variable is called the control valve and takes input signals from Distributed control systems for operation. The valve is capable of opening/closing from 0 to 100%. A shut down valve on the other hand has only discrete control, either ON of OFF. The control signals to the shut down valve is given by a dedicated PLC.

By introducing a method to operate the same control valve on the signals of both DCS and PLC would save a lot of amount in terms of hardware as well as its maintenance cost. An illustration of such a system is shown below.

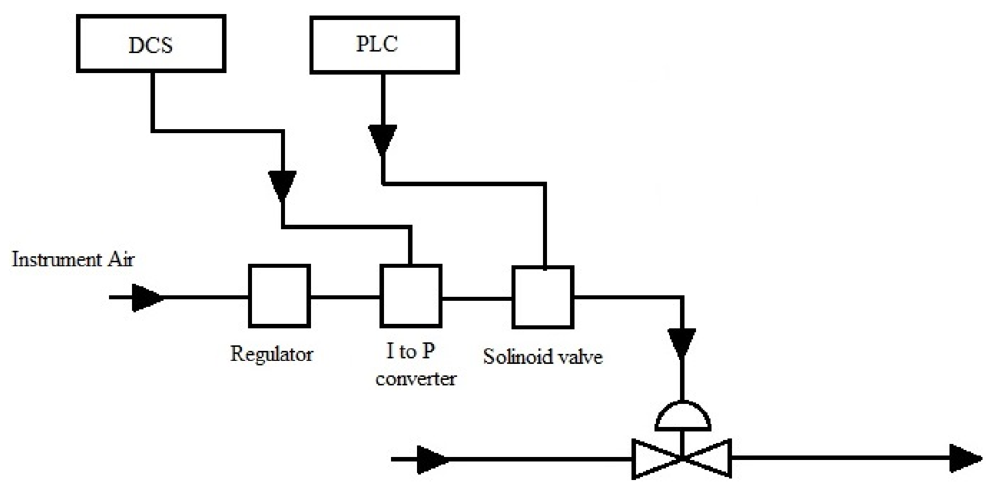


Figure 4.1: Control valve and Shut down valve combined control

Under normal conditions, the DCS control the valve by giving its signals to the current to pressure converter module. The output from the I to P in turn controls the valve position. When an emergency situation is detected and the PLC output is activated, the solenoid valve that is providing the instrument air gets closed and the air supply to the control valve is blocked. This will bring the valve to its normal position (Fail close/Fail open) as per plant design, thus avoiding a possible accident.

CHAPTER 5

CONCLUSION

The four week industrial training at BPCL-Kochi refinery was really helpful to me. The training has helped me to understand industrial instrumentation and process controls is a better way. Various equipments used to measure process variables such as temperature, pressure, level and flow were seen and its operating principle was studied. Process control using DCS and PLC was seen and its control and communication architecture was understood. I gained a lot in terms of how an large scale industry operates. Priority given for safety in the refinery was seen all over. The refinery has a unique bond with its environment which is evident in the green blanket so carefully nourished right around it. The refinery has been blessed with a fine topography and the entire complex, spreading across over thousand two hundred acres has been so constructed as to blend naturally with it. Finally, I am grateful to God for giving the chance to attend this training program.

REFERENCES

[1] D. R. Gillum, "Industrial level measurement," *ISA*, 1984.

[2] S. Parker, "Feature report - on the level," *Rosemount Measurement Division*, 1995.

[3] CompressorControlsCorporation, "Report of seminar presentation to BPCL-KR."

[4] B. P. C. L. KochiRefinery, "Fluid catalyst cracking unit operation manual."