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Purification of Butene in Production of Polyethylene

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Abstract

Butene is an organic material derived from the modifying of natural gas or from the cracking of crude oil into other components like naphtha. Under the changes in conditions of temperature, pressure and catalysis in the polyethylene process, the presence of this material may play an importance role in polyethylene final product. In this work the purification of butene material and its application via the chemical reaction with other additives has been discussed in producing polyethylene. Clear information has been given related to the purification of butene to use in the polyethylene process. In addition, some calculations on the material and energy balances were evaluated in this work. The process control on the polymerization unit has been presented to understand the instruments to monitor the key process variables during plant operation

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1. Introduction

Butene is an organic material has been used in range of applications depending on the particular type. It is used to produce the polyethylene plastic materials. it was observed that the distillation of hydrocarbon fuels ethane in this case into lighter groups called “fractions” some of which are combined with other catalysts to produce plastics typically via polymerization or poly-condensation processes. It is a homo-polymer. It is composed of a single monomer constituent in this case ethylene: $\text{CH}_2=\text{CH}_2$ and butane structure C_4H_8 .

1-1 Butene

Butene is one of the simplest hydrocarbons which gives the chemical symbol C_4H_8 . This hydrocarbon has eight hydrogen atoms bound to a four of carbon atoms. It is a colorless flammable gas with a faint "sweet and musky" when pure [1]. butene has been discovered by Johann Joachim Becher, who obtained it by heating ethanol with sulfuric acid [1]. butene commercially can be considered as a precursor for larger organic (containing carbon and hydrogen) materials. Single butene molecules can be bonded together to help for making polyethylene. This type of material “Polyethylene” is used to make plastics, such as trash bags and films. Additionally, it can be used to make detergents and synthetic lubricants, which are chemicals used to reduce friction [2].

butene can be used to form styrene's, which are used in the making of rubber and protective packaging. Additionally, it is used in footwear, particularly in sports shoes, and in tires. These products are commercially important for many industries [2]. Also, butene is the raw material used in the manufacture of some polymers such as polyethylene (PE), polyethylene terephthalate (PET), polyvinyl chloride (PVC) and polystyrene (PS) as well as fibres and other organic chemicals. These products are used in a wide

variety of industrial and consumer markets such as the packaging, transportation, electrical/electronic, textile and construction industries as well as consumer chemicals, coatings and adhesives [3].

1.2 Polyethylene

Polyethylene is derived from modifying natural gas (a methane, ethane, propane mix) or from the catalytic cracking of crude oil into gasoline. In a highly purified form, it is piped directly from the refinery to a separate polymerization plant. Under the conditions of temperature, pressure and catalysis, the double bond of the ethylene monomer opens up and many monomers link up to form long chains. In commercial polyethylene, the number of monomer repeat units ranges from 1000 to 10000 (molecular weight ranges from 28000 to 280000). Polyethylene production has increased rapidly the major tonnage plastics material worldwide (45×10⁶ ton capacity in 1995). Due to the side reactions occurring at the high temperatures employed in polyethylene process, the polymer chains branched, and densities of 915-925 kg/m³ were typically obtained. The densities of completely amorphous and completely crystalline polyethylene would be 880 and 1000 kg/m³, respectively [1].

During the 1950s three research groups working independently discovered three different catalysts which allowed the production of essentially linear polyethylene at low pressure and temperature. These polymers had densities in the region of 960kg/m³, and became as high density polyethylene (HDPE), in contrast to the polymers produced by the extensively commercialized high-pressure process, which were named low-density polyethylene (LDPE).

1.2.1 Characteristics of Polyethylene

PE is classified as a “thermoplastic” (as opposed to “thermoset”), and the name has to do with the way the plastic responds to heat. Thermoplastic materials become liquid at their melting point (110-130 degrees Celsius in the case of LDPE and HDPE respectively). A major useful attribute about thermoplastics is that they can be heated to their melting point, cooled, and reheated again without significant degradation. Instead of burning, thermoplastics like Polyethylene liquefy, which allows them to be easily “injection molded” and then subsequently recycled. By contrast, thermoset plastics can only be heated once “typically during the injection molding process“. The first heating causes thermoset materials to set (similar to a 2-part epoxy) resulting in a chemical change that cannot be reversed. If a thermoset plastic heat to a high temperature a second time it would simply burn. This characteristic makes thermoset materials poor candidates for recycling.

1.3 Aim and objectives

The aim of this work is to clarify the used of butene in producing the polyethylene structure. To achieve this aim, a continuous supply of other materials such as ethylene, butene, nitrogen and hydrogen into chemical reactor with catalyst were applied. A major objective is to identify the purification process of butene structure to produce a polyethylene.

1.4 Organization of the work

The thesis is organized as follows. Chapter 2, presents a literature review discussing various issues concerned. Chapter 3, gives the material balance

of the process. Chapter 4, presents the energy balance throughout the heat exchanger unit. Chapter 5, provides a special design related to the heat exchanger unit. Chapter 6, presents some information related to the piping and the instrumentation. Chapter 7, deals with safety issues.

2. Literature Review

2.1 Natural gas

Natural gas is a vital component of the world's supply of energy. It is one of the cleanest, safest, and most useful of all energy sources. Despite its importance, however, there are many misconceptions about natural gas. For instance, the word 'gas' itself has a variety of different uses, and meanings. When we fuel our car, we put 'gas' in it. However, the gasoline that goes into your vehicle, while a fossil fuel itself, is very different from natural gas. The 'gas' in the common barbecue is actually propane, which, while closely associated and commonly found in natural gas, is not really natural gas itself. While commonly grouped in with other fossil fuels and sources of energy, there are many characteristics of natural gas that make it unique. Below is a bit of background information about natural gas, what it is exactly, how it is formed, and where it is found in nature .

Natural gas, in itself, might be considered an uninteresting gas it is colorless, shapeless, and odorless in its pure form. Quite uninteresting – except that natural gas is combustible, abundant in the United States, and when burned it gives off a great deal of energy with fewer emissions than many other sources. Compared to other fossil fuels, natural gas is cleaner burning and emits lower levels of potentially harmful byproducts into the air. We require an ever-increasing supply of energy to heat our homes, cook our food, and generate our electricity. It is this need for energy that has elevated natural gas to such a level of importance in our society, and in our lives. Natural gas is a combustible mixture of hydrocarbon gases. While natural gas is formed primarily of methane, it can also include ethane, propane, butane and pentane. The composition of natural gas can vary widely, but below is a chart outlining the typical makeup of natural gas before it is refined.

Typical Composition of Natural Gas

Methane	CH ₄	70-90%
Ethane	C ₂ H ₆	
Propane	C ₃ H ₈	0-20%
Butane	C ₄ H ₁₀	
Carbon Dioxide	CO ₂	0-8%
Oxygen	O ₂	0-0.2%
Nitrogen	N ₂	0-5%
Hydrogen sulphide	H ₂ S	0-5%
Rare gases	A, He, Ne, Xe	trace

In its purest form, such as the natural gas that is delivered to your home, it is almost pure methane. Methane is a molecule made up of one carbon atom and four hydrogen atoms, and is referred to as CH₄. The distinctive “rotten egg” smell that we often associate with natural gas is actually an odorant called mercaptan that is added to the gas before it is delivered to the end-user. Mercaptan aids in detecting any leaks. Ethane, propane, and the other hydrocarbons commonly associated with natural gas have slightly different chemical formulas. Click on the link for a closer look into the combustion of methane.



Figure 2.1 Methane molecule, CH₄

Natural gas is considered 'dry' when it is almost pure methane, having had most of the other commonly associated hydrocarbons removed. When other hydrocarbons are present, the natural gas is 'wet'. Natural gas has many uses in residential, commercial, and industrial applications; see more on the multiple uses of natural gas [here](#).

Found in reservoirs underneath the earth, natural gas is often associated with oil deposits. Production companies search for evidence of these reservoirs by using sophisticated technology that helps to find the location of the natural gas, and drill wells in the earth where it is likely to be found. Click on the link to learn more about the new technologies and their environmental impact. Once brought from underground, the natural gas is refined to remove impurities such as water, other gases, sand, and other compounds. Some hydrocarbons are removed and sold separately, including propane and butane. Other impurities are also removed, such as hydrogen sulfide (the refining of which can produce sulfur, which is then sold separately). After refining, the clean natural gas is transmitted through a network of pipelines, thousands of miles of which exist in the United States alone. From these pipelines, natural gas is delivered to its point of use. For more information on how natural gas gets from underneath the ground to its final destination,.

Natural gas can be measured in a number of different ways. As a gas, it can be measured by the volume it takes up at normal temperatures and pressures, commonly expressed in cubic feet. Production and distribution companies commonly measure natural gas in thousands of cubic feet Mcf, millions of cubic feet MMcf, or trillions of cubic feet Tcf. While measuring by volume is useful, natural gas can also be measured by potential energy output. Like other forms of energy, natural gas is commonly measured and expressed in British thermal units Btu. One Btu is the amount of natural gas

that will produce enough energy to heat one pound of water by one degree at normal pressure. To give an idea, one cubic foot of natural gas contains about 1,027 Btus. When natural gas is delivered to a residence, it is measured by the gas utility in 'therms' for billing purposes. A therm is equivalent to 100,000 Btu, or just over 97 cubic feet, of natural gas.

2.2 The Formation of Natural Gas

Natural gas is a fossil fuel. Like oil and coal, this means that it is, essentially, the remains of plants and animals and microorganisms that lived millions and millions of years ago. But how do these once living organisms become an inanimate mixture of gases. There are many different theories as to the origins of fossil fuels. The most widely accepted theory says that fossil fuels are formed when organic matter (such as the remains of a plant or animal) is compressed under the earth, at very high pressure for a very long time. This is referred to as thermogenic methane. Similar to the formation of oil, thermogenic methane is formed from organic particles that are covered in mud and other sediment. Over time, more and more sediment and mud and other debris are piled on top of the organic matter. This sediment and debris puts a great deal of pressure on the organic matter, which compresses it. This compression, combined with high temperatures found deep underneath the earth, breaks down the carbon bonds in the organic matter. As one gets deeper and deeper under the earth's crust, the temperature gets higher and higher. At low temperatures (shallower deposits), more oil is produced relative to natural gas. At higher temperatures, however, more natural gas is created, as opposed to oil. That is why natural gas is usually associated with oil in deposits that are 1 to 2 miles below the earth's crust. Deeper deposits, very far underground, usually contain primarily natural gas, and in many cases, pure methane.

Natural gas can also be formed through the transformation of organic matter by tiny microorganisms. This type of methane is referred to as

biogenic methane. Methanogens, tiny methane-producing microorganisms, chemically break down organic matter to produce methane. These microorganisms are commonly found in areas near the surface of the earth that are void of oxygen. These microorganisms also live in the intestines of most animals, including humans. Formation of methane in this manner usually takes place close to the surface of the earth, and the methane produced is usually lost into the atmosphere. In certain circumstances, however, this methane can be trapped underground, recoverable as natural gas. An example of biogenic methane is landfill gas. Waste-containing landfills produce a relatively large amount of natural gas from the decomposition of the waste materials that they contain. New technologies are allowing this gas to be harvested and used to add to the supply of natural gas.

A third way in which methane (and natural gas) may be formed is through abiogenic processes. Extremely deep under the earth's crust, there exist hydrogen-rich gases and carbon molecules. As these gases gradually rise towards the surface of the earth, they may interact with minerals that also exist underground, in the absence of oxygen. This interaction may result in a reaction, forming elements and compounds that are found in the atmosphere (including nitrogen, oxygen, carbon dioxide, argon, and water). If these gases are under very high pressure as they move toward the surface of the earth, they are likely to form methane deposits, similar to thermogenic methane.

2.3 Natural Gas Under the Earth

Although there are several ways that methane, and thus natural gas, may be formed, it is usually found underneath the surface of the earth. As natural gas has a low density, once formed it will rise toward the surface of

the earth through loose, shale type rock and other material. Some of this methane will simply rise to the surface and dissipate into the air. However, a great deal of this methane will rise up into geological formations that 'trap' the gas under the ground. These formations are made up of layers of porous, sedimentary rock (kind of like a sponge that soaks up and contains the gas), with a denser, impermeable layer of rock on top.

This impermeable rock traps the natural gas under the ground. If these formations are large enough, they can trap a great deal of natural gas underground, in what is known as a reservoir. There are a number of different types of these formations, but the most common is created when the impermeable sedimentary rock forms a 'dome' shape, like an umbrella that catches all of the natural gas that is floating to the surface.

There are a number of ways that this sort of 'dome' may be formed. For instance, faults are a common location for oil and natural gas deposits to exist. A fault occurs when the normal sedimentary layers 'split' vertically, so that impermeable rock shifts down to trap natural gas in the more permeable limestone or sandstone layers. Essentially, the geological formation, which layers impermeable rock over more porous, oil- and gas-rich sediment, has the potential to form a reservoir. The picture below shows how natural gas and oil can be trapped under impermeable sedimentary rock, in what is known as an anticlinal formation. To successfully bring these fossil fuels to the surface, a hole must be drilled through the impermeable rock to release the fossil fuels under pressure. Note that in reservoirs that contain oil and gas, the gas, being the least dense, is found closest to the surface, with the oil beneath it, typically followed by a certain amount of water. With natural gas trapped under the earth in this fashion, it can be recovered by drilling a hole through the impermeable rock. Gas in these reservoirs is typically under pressure, allowing it to escape from the reservoir on its own. In addition to being

found in a traditional reservoir, natural gas may also be found in other 'unconventional' formations.

2.4 Types of polymer

2.4.1 Thermosetting polymer

It's also called a thermoset. It is a plastic that is irreversibly cured from a soft solid or viscous liquid prepolymer or resin.^[1] The process of curing changes the resin into an infusible, insoluble polymer network, and is induced by the action of heat or suitable radiation often under high pressure, or by mixing with a catalyst.

Thermoset resins are usually malleable or liquid prior to curing, and are often designed to be molded into their final shape, or used as adhesives. Others are solids like that of the molding compound used in semiconductors and integrated circuits. Once hardened a thermoset resin cannot be reheated and melted to be shaped differently. Thermosetting polymers may be contrasted with thermoplastic polymers, which are commonly produced in pellets, and shaped into their final product form by melting and pressing or injection molding.

2.4.2 Curing process

Curing a thermosetting resin transforms it into a plastic, (rubber) by cross-linking or chain extension through the formation of covalent bonds between individual chains of the polymer. Crosslink density varies depending on the monomer or prepolymer mix, and the mechanism of crosslinking.

Acrylic resins, polyesters and vinyl esters with unsaturated sites at the ends or on the backbone are generally linked by co-polymerization with unsaturated monomer diluents, with cure initiated by free radicals generated from ionizing radiation or by the photolytic or thermal decomposition of a radical initiator the intensity of crosslinking is influenced by the degree of backbone unsaturation in the prepolymer; Epoxy functional resins can be homo-polymerized with anionic or cationic catalysts and heat, or copolymerised through nucleophilic addition reactions with multifunctional crosslinking agents which are also known as curing agents or hardeners. As reaction proceeds, larger and larger molecules are formed and highly branched crosslinked structures develop, the rate of cure being influenced by the physical form and functionality of epoxy resins and curing agents – elevated temperature postcuring induces secondary crosslinking of backbone hydroxyl functionality which condense to form ether bonds.

Polyurethanes form when isocyanate resins and prepolymers are combined with low- or high-molecular weight polyols, with strict stoichiometric ratios being essential to control nucleophilic addition polymerisation – the degree of crosslinking and resulting physical type (elastomer or plastic) is adjusted from the molecular weight and functionality of isocyanate resins, prepolymers, and the exact combinations of diols, triols and polyols selected, with the rate of reaction being strongly influenced by catalysts and inhibitors; polyureas form virtually instantaneously when isocyanate resins are combined with long-chain amine functional polyether or polyester resins and short-chain diamine extenders – the amine-isocyanate nucleophilic addition reaction does not require catalysts. Polyureas also form when isocyanate resins come into contact with moisture.

Phenolic, amino and furan resins all cure by polycondensation involving the release of water and heat, with cure initiation and polymerisation exotherm control influenced by curing temperature, catalyst selection/loading and processing method/pressure – the degree of pre-polymerisation and level of

residual hydroxymethyl content in the resins determine the crosslink density.

2.4.3 Thermoset polymers characterization

Thermoset plastic polymers characterised by rigid, three-dimensional structures and high molecular weight, stay out of shape when deformed and undergo permanent or plastic deformation under load, and normally decompose before melting. Thermoset elastomers, which are soft and springy or rubbery and can be deformed and revert to their original shape on loading release, also decompose before melting. Conventional thermoset plastics or elastomers therefore cannot be melted and re-shaped after they are cured which implies that thermosets cannot be recycled for the same purpose, except as filler material. There are developments however involving thermoset epoxy resins which on controlled and contained heating form crosslinked networks that can be repeatedly reshaped like silica glass by reversible covalent bond exchange reactions on reheating above the glass transition temperature. There are also thermoset polyurethanes shown to have transient properties and which can thus be reprocessed or recycled.

2.4.4 Thermosetting polymer properties

Thermosetting are generally stronger than thermoplastic materials due to the three-dimensional network of bonds (crosslinking), and are also better suited to high-temperature applications up to the decomposition temperature since they keep their shape as strong covalent bonds between polymer chains cannot be easily broken. The higher the crosslink density and aromatic content of a thermoset polymer, the higher the resistance to heat degradation and chemical attack. Mechanical strength and hardness

also improve with crosslink density, although at the expense of brittleness.^[11]

2.4.5 Fiber reinforced composites

When compounded with fibers thermosetting resins form fiber-reinforced polymer composites, which are used in the fabrication of factory finished structural composite OEM or replacement parts, and as site-applied, cured and finished composite repair and protection materials. When used as the binder for aggregates and other solid fillers they form particulate-reinforced polymer composites, which are used for factory-applied protective coating or component manufacture, and for site-applied and cured construction, or maintenance, repair and overhaul (MRO) purposes.

2.5 What is Butene

Butene is a linear alpha olefin (alkene), produced either by separation from crude C4 refinery streams or from the reaction of ethylene. It is distilled to give a very high purity product.

2.5.1 How is Butene used

butene is used in the manufacture of a variety of other chemical products. It fills an important role in the production of materials such as linear low density polyethylene (LLDPE). The co-polymerisation of ethylene and 1-butene produces a form of polyethylene that is more flexible and more resilient.

butene can also help to create a more versatile range of polypropylene resins. It is also used in the production of polybutene, butylene oxide and in

the C4 solvents secondary butyl alcohol (SBA) and methyl ethyl ketone (MEK).

Butene is an extremely flammable, colourless gas that is generally stored and transported in pressurised liquid form. In use butene may form a flammable/explosive vapour-air mixture. Electrostatic charges may be generated during handling. Direct contact with liquefied butene can cause frostbite-like burns to the eyes and skin due to the rapid evaporative cooling of the liquid. Inhaling high concentrations of butene gas may cause dizziness, headache and nausea. The gas is of low toxicity if inhaled and is only slightly toxic if swallowed or if it comes into contact with the skin. The gas is slightly irritating to the skin, eyes and respiratory tract. It is not expected to cause an allergic reaction.

In the aquatic environment, butene will evaporate rapidly, followed by rapid atmospheric oxidation. If dissolved in water, it is expected to have low toxicity to aquatic life.

2.5.2 Storing and transporting Butene

Care should be taken during handling and transferring butene as electrostatic charges may be generated; discharge may cause fire. A nitrogen blanket is recommended for storage. Butene is transported in pressurised liquid form in gas tanks by road, rail and sea.

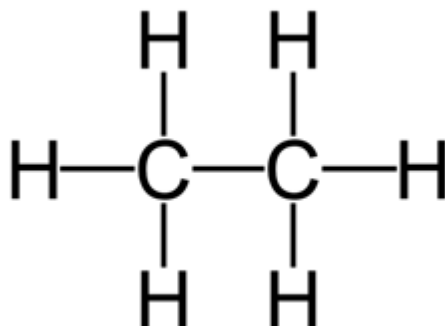
Risk Characterization Summary

Risks associated with exposure to this product have been evaluated for the "commerce" activities: manufacture, storage, product transfer, transportation, and customers/markets. Due to health, safety and environmental considerations, it is only manufactured, stored and transported to customers in closed systems. limited to those who only use the product in closed systems as an intermediate for the manufacture of

other chemicals. Proper equipment design and handling procedures maintain low risk from exposure to the product where the product

2.6 Alkenes

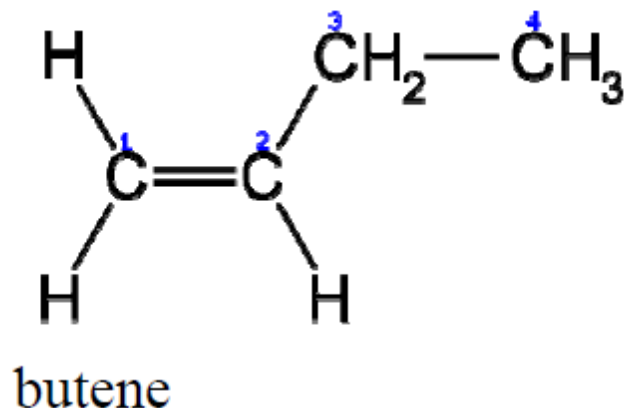
Alkenes are molecules containing a C=C double bond. They are also sometimes referred to as olefins or as unsaturated compounds. They called unsaturated because the C atoms in a C=C double bond don't have as many hydrogens bonded to them as an alkane does. Molecules with one double bond are called monounsaturated. Molecules with multiple double bonds are called polyunsaturated. In contrast, alkane molecules with no double bonds are saturated.



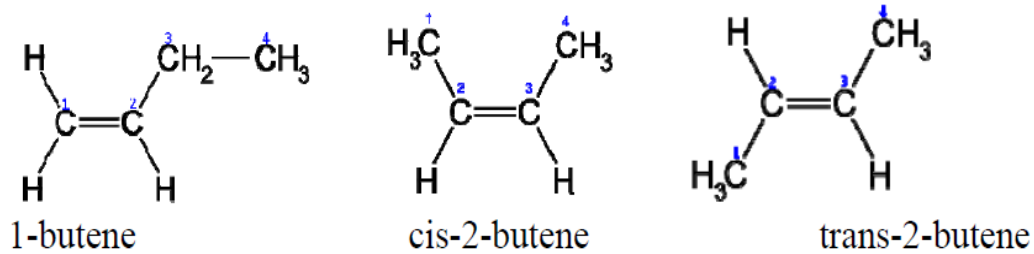
Ethane (saturated)

2.6.1 Naming Alkenes

To name alkenes, we count the number of C atoms in the longest unbranched chain, take the name of the corresponding alkane and change -ane to -ene.



When we put a double bond into butane, naming gets a little more complicated. There are two places where we can put a double bond: between the first and second carbons, or between the second and third C atoms. Furthermore we have the possibility for cis-trans isomers when the double bond is between the 2nd and 3rd C atoms. Can you see why there are no cis-trans isomers when the double bond is between 1st and 2nd C's? In order for cis-trans isomers to exist, there must be two different groups attached to both C atoms of the C-C double bond. To name molecules with double bonds, pick out the longest chain containing the double bond. Start numbering the chain from the end closest to the double bond even if it results in larger numbers for other groups branching off the main chain. To indicate where the double bond is, specify the number of the first C in the double bond. The three isomeric butenes are:

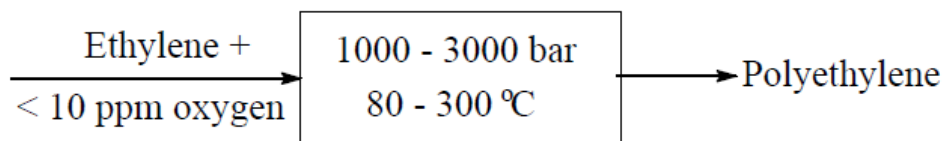


2.7 Polyethylene Manufacturing Process

Polyethylene manufacturing processes are usually categorized into "high pressure" and "low pressure" operations. The former is generally recognized as producing conventional low density polyethylene (LDPE) while the latter makes high density (HDPE) and linear low density (LLDPE) polyethylenes. The difference between these polyethylene processes and types is outlined below.

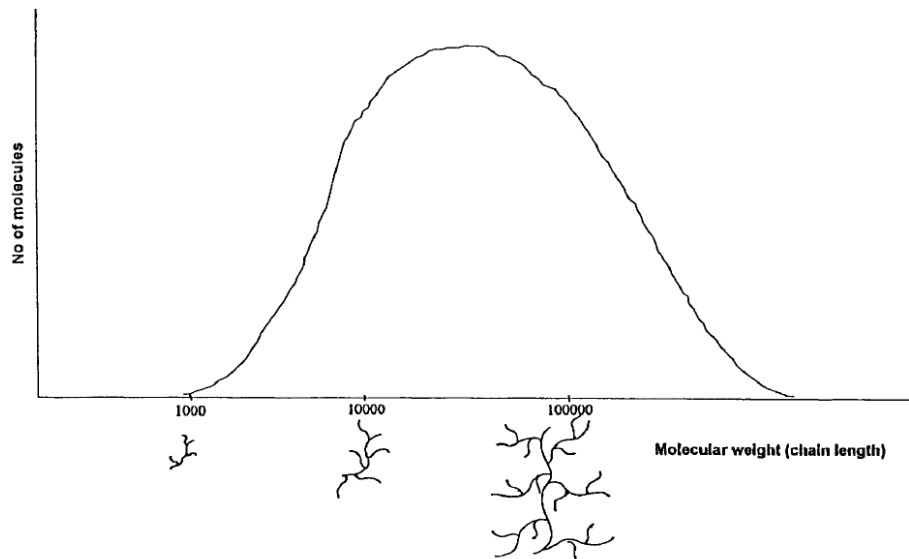
2.7.1 At High Pressure

Polyethylene was first produced by the high pressure process by ICI, Britain, in the 1930's. They discovered that ethylene gas could be converted into a white solid by heating it at very high pressures in the presence of minute quantities of oxygen:



The polymerisation reaction which occurs is a random one, producing a wide distribution of molecule sizes. By controlling the reaction conditions, it is possible to select the average molecule size (or molecule weight) and the

distribution of sizes around this average (molecular weight distribution). The chains are highly branched (at intervals of 20 – 50 carbons). Figure 1 shows the molecular weight distribution and long chain branching for LDPE.



ICI named their new plastic "polythene" and found that they were able to produce it in a density range of about 0.915 to 0.930g cm⁻³. It is known today as LDPE and has its single biggest useage in blown film.

2.7.2 At Low pressure

The initial discovery of LDPE was an accident. So was the discovery of HDPE in 1952. Researchers in Germany and Italy had succeeded in making a new aluminium based catalyst which permitted the polymerization of ethylene at much lower pressures than the ICI process. The polyethylene product of this process was found to be much stiffer than any previous with a density range of about 0.940 - 0.970g cm⁻³. The increased stiffness and density were found to be due to a much lower level of chain branching. The new HDPE was found to be composed of very straight chains of ethylene with a much narrower distribution of molecular weights (or chain lengths)

and a potentially very high average chain length. LLDPE is made by copolymerising with a small amount of another monomer, typically butene, hexene or octene.

2.7.3 Raw material for polyethylene process

The operation of manufacturing the Polyethylene is starting by supply the raw materials in the raw materials refining metals to be purified and cleared of impurities in interacting process to reduce impurities which like O₂, C₂H₂, CO, CO₂ and Sulfur; to the minimum the total quantity of the ethylene which enter the reactor is reaching (10 Tons/hour) and the quantity of the union Biotin is reaching (1 ton/ Day) for the first production line, and (15 Tons/Day) for the second production line, Hydrogen quantity is reaching (1 Ton/Day) for each production line. All those quantities which enter to both reactors are producing (10 Tons/Hour) of Polyethylene from each reactorevel of 0.000001 these elements can kills the interacting process. Then the required raw materials will be charged to the manufacturing processes to the reactors unit which are ethylene, the prime biotin and Hydrogen in a specific commissioning circumstances of temperature and pressure in additional to accelerating factor.

The process of producing the polyethylene is happening inside the reactor, then transferring the powder to granulation unit to granulate the final product in additional to the necessary improvers as pear the produced types. The granulated product is ready to be transferred to the handling unit to be evaluated, bagging and stored

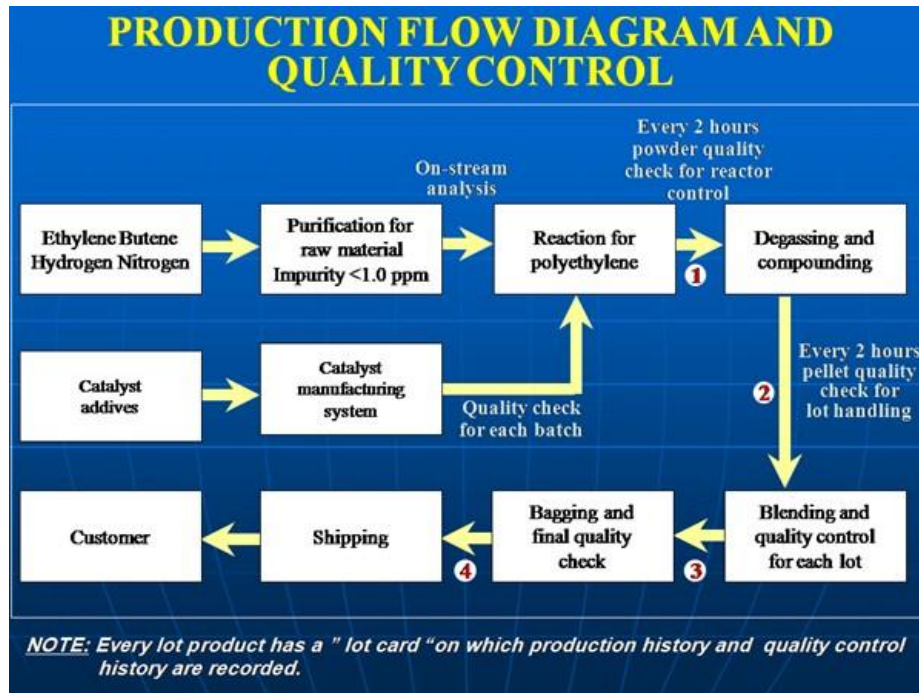


Figure 2.2 production flow diagram and quality control

3. Material Balance

The basic calculation required to produce 10 ton/hr from pure polyethylene P.E will discuss in the following

2.1 Butane Process Description

C4 mixture from naphtha crackers is introduced into the 1st extractive distillation section to remove 1,3-Butadiene and acetylenes. Butene-1 rich stream obtained as the distillate of the extractive distillation column is sent to the 1st Fractionator through isobutene Removal Unit (out of scope of zeon), where isobutene is removed.

- It well know that the Conversion of the fresh feed is 99.95%

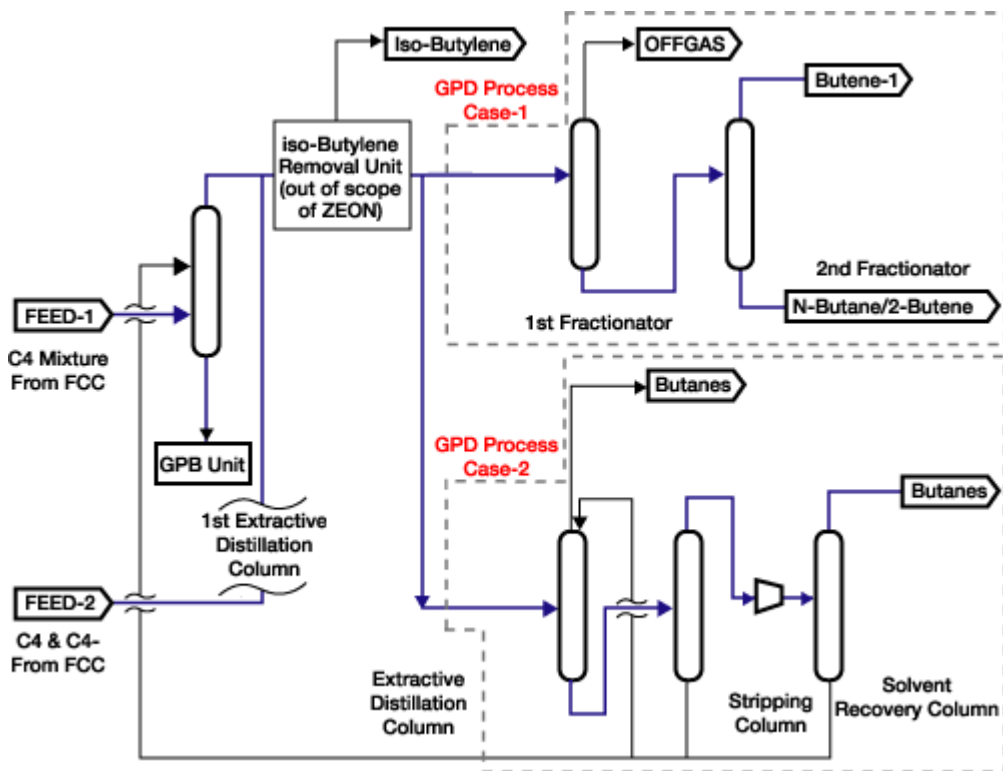


Figure 3.1 butene process description

Table 3.1The total mixture feed rate of (1) stream

Component		Flow rate Kg / hr	mole %	Mw	Kgmole/hr
Butene	C ₄ H ₈	991.38	95.89	52	19.06
Water	H ₂ O	31.8	4.021	18	1.766
Hydrogen	H ₂	19.998	0.089	2	9.99
Total	=====	1034.2	100	=====	30.82`

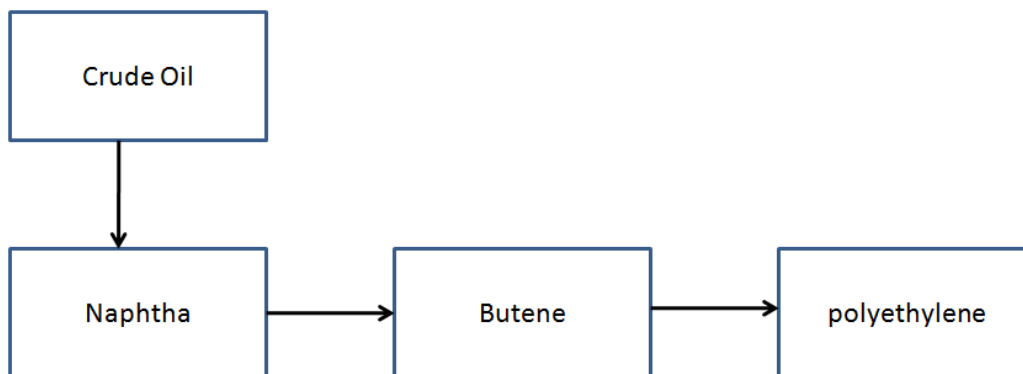


Figure 3.2 cracking diagram

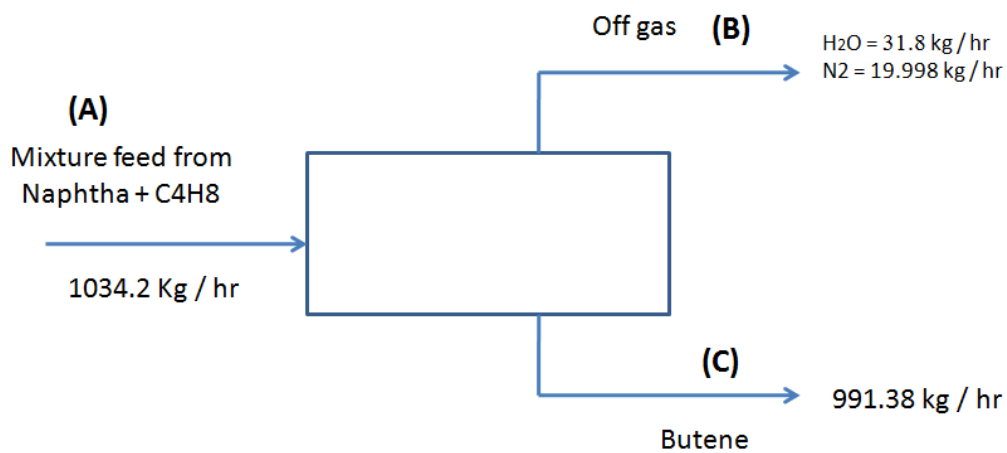


Figure 3.3 Material balance about degassing column

- The basic calculation is 100 kgmole of feed

$$A = B + C$$

- Partial balance around the butene stream C₄H₈ can be found from the equation

$$100 * 0.9589 = B * 0 + C * 0.9995$$

$$95.89 = 0.9995 C$$

$$C = 95.93 \text{ kgmole} / 100 \text{ kgmole of feed}$$

- Partial balance around the H₂O can be found from the equation

$$100 * 0.04021 = B * 0.9822 + C * 0$$

$$4.021 = 0.9822 B$$

$$B = 4.09 \text{ kgmole} / 100 \text{ kgmole of feed}$$

$$A = 4.09 + 95.93 = 100$$

❖ Molecular weight calculation

Molecular weight of (A) stream

$$\begin{aligned} M &= 0.9589 * 56 + 0.04021 * 18 + 0.089 * 2 \\ &= 53.69 + 0.723 + 0.178 \\ &= 54.59 \text{ kg} / \text{kgmole} \end{aligned}$$

Molecular weight of (B) stream

$$\begin{aligned} M &= 0.04021 * 18 + 0.089 * 2 \\ &= 0.723 + 0.178 \\ &= 0.901 \text{ kg} / \text{kgmole} \end{aligned}$$

Molecular weight of (C) stream

$$M = 0.9995 * 56$$

$$= 55.97 \text{ kg / kgmole}$$

❖ The flow rate of mixture feed is 1034.2 kg/hr

$$\begin{aligned}\text{For the stream A} &= 1034.2 * 54.59 / 100 \\ &= 564.5 \text{ kgmole /hr}\end{aligned}$$

$$\begin{aligned}\text{For the stream B} &= 0.901 * 1034.2 / 100 \\ &= 9.318 \text{ kgmole /hr}\end{aligned}$$

$$\begin{aligned}\text{For the stream C} &= 55.79 * 1034.2 / 100 \\ &= 576.9 \text{ kgmole /hr}\end{aligned}$$

❖ To change the stream flow rate to kg/hr

$$\text{Flow A} = 564.5 * 54.59 = 30821 \text{ kg/hr}$$

$$\text{Flow B} = 9.318 * 0.901 = 8.395 \text{ kg/hr}$$

$$\text{Flow C} = 576.9 * 55.97 = 32289 \text{ kg/hr}$$

$$A = B + C$$

$$30821 = 8.395 \text{ kg/hr} + 32289 \text{ kg/hr}$$

$$30821 = 32297$$

$$\text{Error \%} = 0.95 \%$$

4- Energy Balance

- In this chapter, due to the limiting time, we only calculated the energy balance around the condenser.

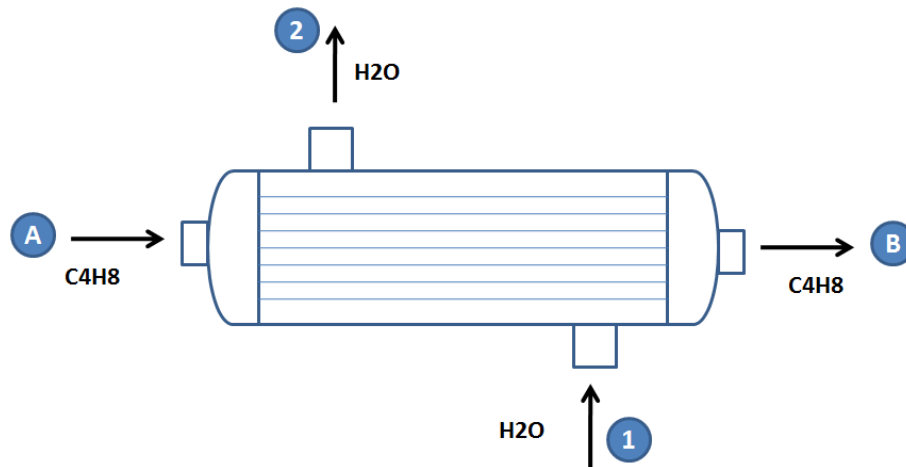
Heat capacity or thermal capacity is a measurable physical quantity equal to the ratio of the heat added to (or removed from) an object to the resulting temperature change. The specific heat of buten = J/gmol .°C

$$Cp = a + bT + cT^2 \text{ (J/gmol .}^\circ\text{C)}$$

Table 4.1 the constant value of a, b and c

Component	a	$b \times 10^{-5}$	$C \times 10^{-5}$
H ₂ O	33.46	0.6880	0.6704

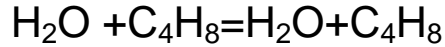
Component	a	$b \times 10^{-2}$	$C \times 10^{-5}$
C ₄ H ₈	82.88	- 17.27	25.64



The equation balance can be calculated as the following:

$$\text{Input} = \text{output}$$

$$1 + A = 2 + B$$



The following equation is used to calculate the heat capacity

$$\Delta H = M C_p \Delta T$$

Input : $\Delta H = (M C_p \Delta T)_{\text{H}_2\text{O}} + (M C_p \Delta T)_{\text{C}_4\text{H}_8}$

Output: $\Delta H = (M C_p \Delta T)_{\text{H}_2\text{O}} + (M C_p \Delta T)_{\text{C}_4\text{H}_8}$

H₂O	Temp., °C (IN)	Temp., °K (IN)	Temp., °C (OUT)	Temp., °K (OUT)
	T1		T2	
	25	298	30	303
C₄H₈	Temp., °C (IN)	Temp., °K (IN)	Temp., °C (OUT)	Temp., °K (OUT)
	t1		t2	
	40	313	32	305

- To calculate the heat quantity (enthalpy) for the input system

Input :- (H₂O)

$$\Delta H = (M c_p \Delta T)_{\text{H}_2\text{O}} + (M c_p \Delta T)_{\text{C}_4\text{H}_8}$$

- The flow rate of water and butene into the condenser are

$$M_{\text{H}_2\text{O}} = 1234 \text{ Kg/hr}, M_{\text{C}_4\text{H}_8} = 991.38 \text{ Kg/hr}$$

$$C_{p\text{H}_2\text{O}} = a + \frac{b}{2} (T_1 + T_2) + \frac{c}{3} (T_1^2 + T_1 T_2 + T_2^2)$$

$$C_{p_{H_2O}} = 33.46 + \frac{0.6880 \cdot 10^{-5}}{2} (298 + 303) + \frac{0.6704 \cdot 10^{-5}}{3} (298^2 + 298 \cdot 303 + 303^2)$$

$$C_{p_{H_2O}} = 35.5 + 0.605$$

$$C_{p_{H_2O}} = 36.105 \text{ kJ/Kg K}$$

Input :- (C₄H₈)

$$C_{p_{C_4H_8}} = a + \frac{b}{2} (T_1 + T_2) + \frac{c}{3} (T_1^2 + T_1 T_2 + T_2^2)$$

$$C_{p_{C_4H_8}} = 82.88 + \frac{25.64 \cdot 10^{-2}}{2} (313 + 305) + \frac{-17.27 \cdot 10^{-5}}{3} (313^2 + 313 \cdot 305 + 305^2)$$

$$C_{p_{C_4H_8}} = 162.1 - 16.49$$

$$C_{p_{C_4H_8}} = 145.61 \text{ KJ/Kg K}$$

Energy balance :-

$$\text{Input : } \Delta H = (M C_P \Delta T)_{H_2O} + (M C_P \Delta T)_{C_4H_8}$$

$$\Delta H = 1234 \times 36.105 (303 - 298) + 991.38 \times 145.61 (305 - 313)$$

$$\Delta H = 222767.85 - 1154396 = -931628 \text{ KJ}$$

- To calculate the heat quantity (enthalpy) for the output system

Output:- (H₂O)

$$A + 1 = B + 2$$

Mass flow rate for all the streams

$$1234+991.38 = m_{H_2O} + 983.96$$

$$m'_{H_2O} = 1241.42 \text{ kg/hr}$$

$$c_{p_{H_2O}} = 18.2964 + \frac{47.212 \cdot 10^{-2}}{2} (303+298) + \frac{-133.88}{3} (303^2 + 303 \cdot 298 + 298^2)$$

$$c_{p_{H_2O}} = 160.16 + 120.89$$

$$c_{p_{H_2O}} = 39.26 \text{ kJ/Kg K}$$

$$C_{p_{C_4H_8}} = a + \frac{b}{2} (T_1 + T_2) + \frac{c}{3} (T_1^2 + T_1 T_2 + T_2^2)$$

$$C_{p_{C_4H_8}} = 82.88 + \frac{25.64 \cdot 10^{-2}}{2} (305+313) + \frac{-17.27 \cdot 10^{-5}}{3} (305^2 + 305 \cdot 313 + 313^2)$$

$$C_{p_{C_4H_8}} = 162.1 - 16.49$$

$$C_{p_{C_4H_8}} = 145.61 \text{ kJ/kg k}$$

Energy balance :-

$$\text{Output : } \Delta H = (M C_P \Delta T)_{H_2O} + (M C_P \Delta T)_{C_4H_8}$$

$$\Delta H = 1241.42 \times 39.26 (298-303) + 983.96 \times 145.61(313-305)$$

$$\Delta H = -244868+330779.3 = 85911$$

5. Special Design

5.1 Design for Heat Exchanger

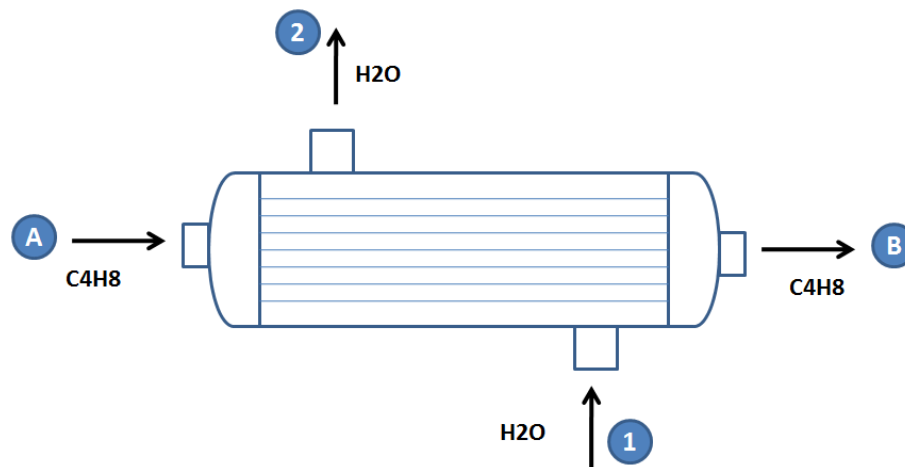
The heat exchanger in this work was selected as the following type which is contained on the tube and shell sides (type 2 passes). Also, the cooling water was in shell side while the butene was in tube side.

Shell side

Water

tube side

butene



Two passes

The outer diameter OD=0.25m

inner diameter ID=0.02m

Length of tubes L=4.88m

$Q_h \text{ (butene)} = Q_c \text{ (water)}$

$m_h C_{p_h} (T_{h1} - T_{h2}) = m C_{p_c} (T_{c1} - T_{c2})$

$$Q_c = m_c C_{p_c} (T_{c1} - T_{c2}) \quad \text{Water}$$

$$= 1234 * 36.105 (30 - 25)$$

$$Q_c = 222.77 \text{ Kw/hr}$$

$$Q_h = m_h C_{p_h} (T_{h1} - T_{h2}) \quad \text{butene}$$

$$= 991.38 \text{ kg/h} * 145.61 (40 - 32)$$

$$Q_h = 1154.84 \text{ kw/hr}$$

❖ Calculate the log mean temperature difference ΔT_m

:- for counter current :-

$$LMTD = \frac{T_{h1} - T_{c2} - T_{h2} - T_{c1}}{\ln\left(\frac{T_{h1} - T_{c2}}{T_{h2} - T_{c1}}\right)}$$

$$= \frac{(40 - 25) - (32 - 30)}{\ln\left(\frac{40 - 25}{32 - 30}\right)}$$

$$LMTD = 6.452$$

$$R = \frac{T_1 - T_2}{t_2 - t_1} = \frac{40 - 32}{30 - 25} = \frac{8}{5}$$

$$R = 1.6$$

$$S = \frac{T_1 - T_2}{T_2 - T_1}$$

$$S = \frac{30 - 25}{40 - 32}$$

$$S = \frac{5}{8} = 0.63$$

- ❖ The correction factor $F_1=0.98$

$$\Delta T_m = F_1 * LMTD$$

$$\Delta T_m = 0.98 * 6.452 = 6.32$$

- ❖ Assume overall heat transfer coefficient

$$U = 250 - 750 \text{ w/m}^2\text{c} \quad \text{“organic solvent”}$$

$$U = \frac{250+750}{2} = 500\text{w/m}^2\text{c}$$

- ❖ For provisional area

$$A = Z/(u.\Delta T_m)$$

$$A = 991.38 * 10^3 / 500 * 7.32$$

$$A = 0.314 \text{ m}^2$$

- ❖ Number of tubes:

$$N_t = \frac{A}{PI * d * l}$$

$$N_t = 314 / (3.14 * 0.25 * 4.88)$$

$$= 81.96$$

- ❖ Number of tubes per pass:

$$N_{tP} = \frac{N_t}{\text{number of passes}}$$

$$= 81.96 / 2 = 40.98$$

- ❖ The mass velocity :-
- ❖ The cross sectional area

$$\begin{aligned} \text{Pi} \frac{(d)^2}{4} &= \\ \text{Pi} \left(\frac{0.02}{4} \right)^2 &= 3.14 \cdot 10^{-4} \text{ m}^2 \end{aligned}$$

So area per pass = $N_{tp} \cdot P$ * cross sectional area

$$= 40.98 \cdot 3.14 \cdot 10^{-4} = 0.0128 \text{ m}^2$$

$$\text{Volumetric flow} = \frac{\text{massflowrate}}{\text{density}}$$

$$= \frac{0.93}{0.62} = 1.5 \text{ m/s}$$

$$\text{Tube sidevelocity} = \frac{\text{volumetricflowrate}}{\text{areaperpass}}$$

$$= \frac{1.5}{0.121} = 12.39 \text{ m/s}$$

❖ Calculate the bundle and shell diameter

$$D_b = d_o \left(\frac{N_t}{K_t} \right)^{1/n_i}$$

$$= 0.25 \left(\frac{81.96}{0.156} \right)^{1/2.291}$$

$$= (0.25) \cdot (525.4)^{0.436}$$

$$D_b = 3.84 \text{ m}$$

❖ Assume heat exchanger is fixed , so the bundle diameter clearance ,
BDC

$$\text{BDC} = 22\text{mm} = 0.022\text{m}$$

- ❖ The shell diameter

$$D_s = D_b + \text{BDC}$$

$$= 3.84 + 0.022$$

$$D_s = 3.862\text{m}$$

- ❖ The baffle spacing:-

$$l_b = 0.4 D_s$$

$$= 0.4 * 3.862$$

$$l_b = 1.5448\text{m}$$

- ❖ The Reynolds number:-

$$\text{Re} = \frac{\rho U d}{\mu}$$

$$\mu = \text{viscosity of 1-butene} = 7.76 * 10^{-3} \text{ MPa}$$

$$= 7.76 \text{ KPa}$$

$$\text{Re} = \frac{\rho U d}{\mu} = \frac{0.62 * 500 * 0.020}{7.76}$$

$$= \frac{6.2}{7.76} = 0.80$$

- ❖ The pitch

$$P_t = 1.25 d_o$$

$$= 1.25 * 0.25$$

$$P_t = 0.687$$

- ❖ The area for cross flow:-

$$A_s = \frac{(P_t - d_o) D_s * l_b}{P_t}$$

$$= \frac{(0.687 - 0.25) 3.862 * 1.54}{0.687}$$

$$A_s = 3.8\text{m}^2$$

- ❖ The shell diameter:-

$$de = \frac{1.27}{do} (Pt^2 - 0.785do^2)$$

$$= \frac{1.27}{0.25} (0.6872 - 0.785 \cdot 0.252)$$

$$de = 2.15$$

- ❖ volumetric flow rate on shell side:-

$$Gs = \frac{mh}{As} = \frac{991.38}{3.8} = 261 \text{ kg/m}^2 \cdot \text{s}$$

- ❖ The shell side velocity:-

$$Us = \frac{Gs}{\rho_{H2O}}$$

$$Us = \frac{261}{1038} = 0.251 \text{ m/s}$$

- ❖ The Reynolds number:-

$$Re = \frac{GsDs}{\mu} = \left(\frac{261 \cdot 3.862}{5.03 \cdot 10^{-3}} \right)$$

$$= 200394.03$$

- ❖ The prandtl number

$$Pr = \frac{\mu c_p}{K} = (5.03 \cdot 10^{-3} \cdot 36.105) / 0.62$$

$$Pr = 0.293$$

$$Nu = \frac{hsde}{K_f} = J_h Re Pr^{0.33} (\mu/\mu_w)$$

- ❖ Assume the Paffle cut percent is 2s

$$J_f = 0.0017$$

$$J_h = 0.033$$

From figure(2,3)

- ❖ $Nu = 0.033 \cdot 200394.04 \cdot 0.293^{0.33} \left(\frac{7.76}{5.03} \right)^{0.14}$
- $= 21309.63$

$$H_s = \frac{NuK}{de} = \frac{21309 \cdot 0.62}{2.15}$$

$$H_s = 6444.76 \text{ w/m}^2 \cdot \text{C}^\circ$$

❖ The pressure drop:-

$$\Delta P_t = N_p \left[8 f \left(\frac{L}{d_i} \right) \left(\frac{M}{\mu_w} \right) + 2.5 \right] \frac{P_{us}}{2}$$

Where ΔP_t = tube side pressure drop N/m^2 (Pa)

N_p = number of tube side passes

U_t = tube side of velocity m/s

L = length of one tube

$$= 2 \left[8 \cdot 0.054 \left(\frac{4.88}{0.02} \right) + 2.5 \right] \frac{0.62 \cdot 0.439^2}{2}$$

$$= 18705.96 \text{ Pa}$$

$$= 18.705 \text{ KPa}$$

$$\Delta P_s = 8 J_h \left(\frac{D_s}{de} \right) \frac{L}{t_b} \left(\frac{P_{ut}^2}{2} \right) \left(\frac{\mu}{\mu_w} \right)^{0.14}$$

Where L = tube length

t_b = baffle spacing

$$= 8 \cdot 0.033 \left(\frac{3.862}{2.15} \right) \left(\frac{4.88}{1.5448} \right) \frac{1038 \cdot 0.436^2}{2} = 147.71$$

6. Piping and Instrumentation

6.1 Introduction

The process flow-sheet shows the arrangement of the major pieces of equipment and their interconnection. It is a description of the nature of the process. The Piping and Instrument diagram (P and I diagram or PID) shows the engineering details of the equipment, instruments, piping, valves and fittings; and their arrangement. It is often called the Engineering Flow-sheet or Engineering Line Diagram.

The design of piping systems, and the specification of the process instrumentation and systems, is usually done by specialist design groups, and a detailed discussion of piping design and control systems is beyond the scope of this book. Only general guide rules are given. The piping handbook edited by Nayyar *et al.* 2000 is particularly recommended for the guidance on the detailed design of piping systems and process instrumentation and control. The references cited in the text and listed at the end of the chapter should also be consulted.

6.2 The P and I diagram

The P and I diagram shows the arrangement of the process equipment, piping, pumps, instruments, valves and other fittings. It should include:

1. All process equipment identified by an equipment number. The equipment should be drawn roughly in proportion, and the location of nozzles shown.
2. All pipes, identified by a line number. The pipe size and material of construction should be shown. The material may be included as part of the line identification number.

3. All valves, control and block valves, with an identification number. The type and size should be shown. The type may be shown by the symbol used for the valve or included in the code used for the valve number.
4. Ancillary fittings that are part of the piping system, such as inline sight-glasses, strainers and steam traps; with an identification number.
5. Pumps, identified by a suitable code number.
6. All control loops and instruments, with an identification number. For simple processes, the utility service lines can be shown on the P and I diagram.

For complex processes, separate diagrams should be used to show the service lines, so the information can be shown clearly, without cluttering up the diagram. The service connections to each unit should, however, be shown on the P and I diagram. The P and I diagram will resemble the process flow-sheet, but the process information is not shown. The same equipment identification numbers should be used on both diagrams.

6.3 Symbols and layout

The symbols used to show the equipment, valves, instruments and control loops will depend on the practice of the particular design office. The equipment symbols are usually more detailed than those used for the process flow-sheet^[3].

6.4 Basic symbols

The symbols illustrated below^[3]:

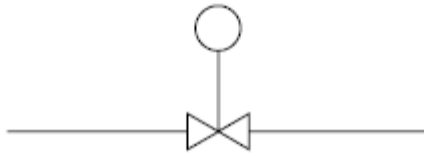


Figure (6.1)Control valve .

This symbol is used to represent all types of control valve, and both pneumatic and electric actuators.

The direction of the arrow shows the position of the valve on failure of the power supply.

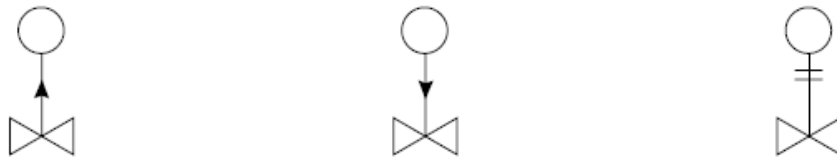
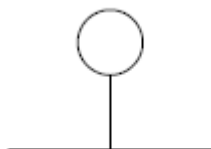
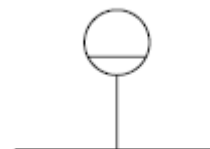


Figure (6.2): Failure mode : Fails open , Fails shut , Maintains position .



Locally mounted



Main panel mounted

Figure (6.3) : Instruments and controllers: Locally mounted ,Main panel mounted .

Locally mounted means that the controller and display is located out on the plant near to the sensing instrument location. Main panel means that they are located on a panel in the control room. Except on small plants, most controllers would be mounted in the control room ^[3].

6.5 Type of instrument

This is indicated on the circle representing the instrument-controller by a letter code see Table (6.1).

Table (6.1): Letter Code for Instrument Symbols.

Property measured	First letter	Indicating only	Recording only	Controlling only	Indicating and controlling	Recording and controlling
Flow-rate	F	FI	FR	FC	FIC	FRC
Level	L	LI	LR	LC	LIC	LRC
Pressure	P	PI	PR	PC	PIC	PRC
Quality, analysis	Q	QI	QR	QC	QIC	QRC
Radiation	R	RI	RR	RC	RIC	RRC
Temperature	T	TI	TR	TC	TIC	TRC
Weight	W	WI	WR	WC	WIC	WRC
Any other property (specified in a note)	X	XI	XR	XC	XIC	XRC

❖ Consult the standard for the full letter code.

The first letter indicates the property measured; for example, F =flow. Subsequent letters indicate the function; for example, I =indicating, RC=recorder controller.

The suffixes E and A can be added to indicate emergency action and/or alarm functions. The instrument connecting lines should be drawn in a manner to distinguish them from the main process lines. Dotted or cross-hatched lines are normally used.

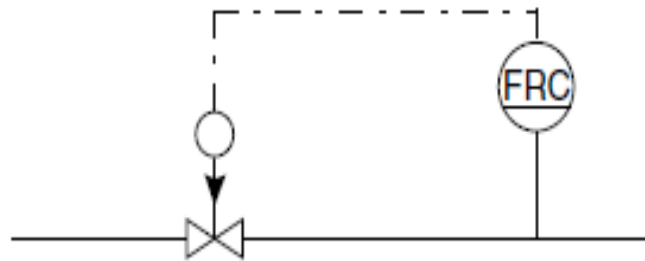


Figure (6.4) : A typical control loop .

6.6 Control and instrumentation

Instruments are provided to monitor the key process variables during plant operation. They may be incorporated in automatic control loops, or used for the manual monitoring of the process operation. They may also be part of an automatic computer data logging system. Instruments monitoring critical process variables will be fitted with automatic alarms to alert the operators to critical and hazardous situations. It is desirable that the process variable to be monitored be measured directly; often, however, this is impractical and some dependent variable, that is easier to measure, is monitored in its place. For example, in the control of distillation columns the continuous, on-line, analysis of the overhead product is desirable but difficult and expensive to achieve reliably, so temperature is often monitored as an

indication of composition. The temperature instrument may form part of a control loop controlling, say, reflux flow; with the composition of the overheads checked frequently by sampling and laboratory analysis.

6.7 Instrumentation and control objectives

The primary objectives of the designer when specifying instrumentation and control schemes are:

1. Safe plant operation :

- (a) To keep the process variables within known safe operating limits.
- (b) To detect dangerous situations as they develop and to provide alarms and automatic shut-down systems.
- (c) To provide interlocks and alarms to prevent dangerous operating procedures.

2. Production rate :

To achieve the design product output.

3. Product quality :

To maintain the product composition within the specified quality standards.

4. Cost :

To operate at the lowest production cost, commensurate with the other objectives.

These are not separate objectives and must be considered together. The order in which they are listed is not meant to imply the precedence of any objective over another, other than that of putting safety first. Product quality, production rate and the cost of production will be dependent on sales

requirements. For example, it may be a better strategy to produce a better-quality product at a higher cost. In a typical chemical processing plant these objectives are achieved by a combination of automatic control, manual monitoring and laboratory analysis. The following procedure can be used when drawing up preliminary P and I diagrams^[3]:

1. Identify and draw in those control loops that are obviously needed for steady plant operation, such as :
 - (a) level controls.
 - (b) flow controls.
 - (c) pressure controls.
 - (d) temperature controls.
2. Identify the key process variables that need to be controlled to achieve the specified product quality. Include control loops using direct measurement of the controlled variable, where possible; if not practicable, select a suitable dependent variable.
3. Identify and include those additional control loops required for safe operation, not already covered in steps 1 and 2.
4. Decide and show those ancillary instruments needed for the monitoring of the plant operation by the operators; and for trouble-shooting and plant development. It is well worthwhile including additional connections for instruments which may be needed for future trouble-shooting and development, even if the instruments are not installed permanently. This would include: extra thermo wells, pressure tappings, orifice flanges, and extra sample points.
5. Decide on the location of sample points.
6. Decide on the need for recorders and the location of the readout points, local or control room. This step would be done in conjunction with steps 1 to 4
7. Decide on the alarms and interlocks needed; this would be done in conjunction with step 3.

6.8 Typical control system

6.8.1 Level control

In any equipment where an interface exists between two phases e.g. liquid vapour, some means of maintaining the interface at the required level must be provided. This may be incorporated in the design of the equipment, as is usually done for decanters, or by automatic control of the flow from the equipment. Figure (6.5) shows a typical arrangement for the level control at the base of a column. The control valve should be placed on the discharge line from the pump.

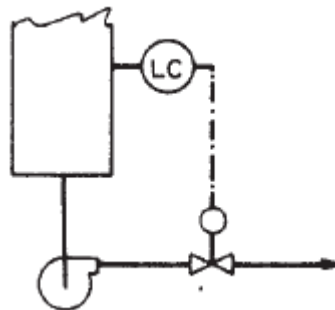


Figure (6.5) : Level control .

6.8.2 Pressure control

Pressure control will be necessary for most systems handling vapour or gas. The method of control will depend on the nature of the process. Typical schemes are shown in Figures (6.6) a,b,c,d. The scheme shown in Figure (6.6 a) would not be used where the vented gas was toxic, or valuable. In these circumstances the vent should be taken to a vent recovery system, such as a scrubber.

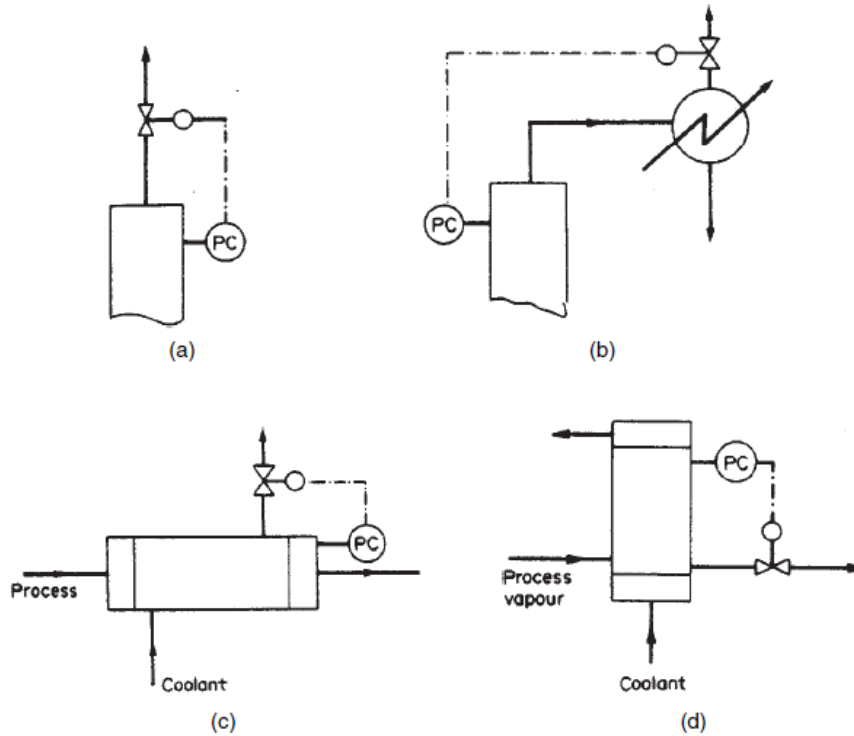


Figure (6.6) : (a) Pressure control by direct venting ,(b) Venting of non-condensables after a condenser ,(c) Condenser pressure control by controlling coolant flow ,(d) Pressure control of a condenser by varying the heat-transfer area, area dependent on liquid level .

6.8.3 Flow control

Flow control is usually associated with inventory control in a storage tank or other equipment. There must be a reservoir to take up the changes in flow-rate ^[3].To provide flow control on a compressor or pump running at a fixed speed and supplying a near constant volume output, a by-pass control would be used, as shown in Figures (5.7).

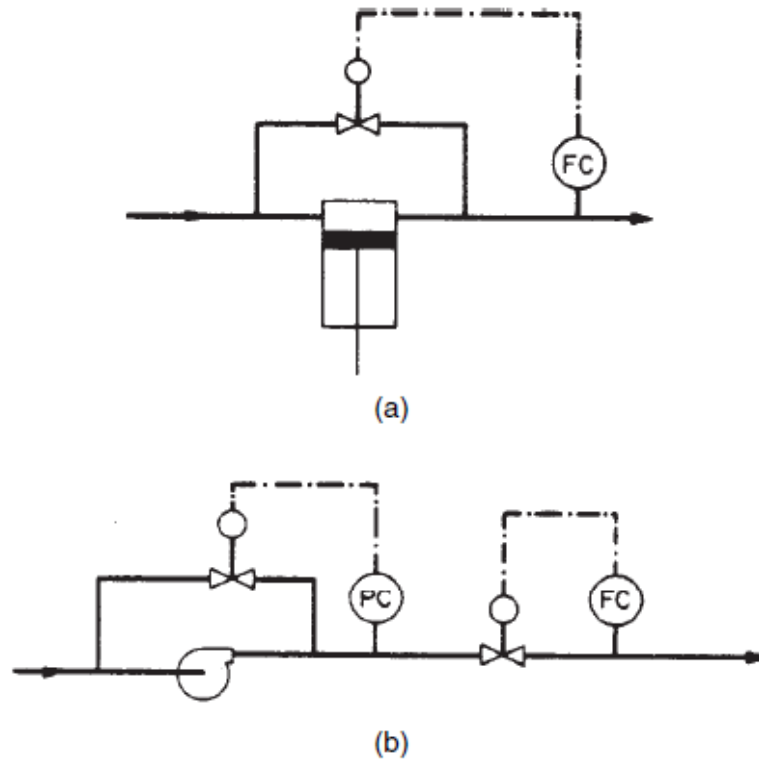


Figure (6.7) : (a) Flow control for a reciprocating pump ,(b) Alternative scheme for a centrifugal compressor or pump.

6.8.4 Heat exchangers

Figure (6.8 a) shows the simplest arrangement, the temperature being controlled by varying the flow of the cooling or heating medium. If the exchange is between two process streams whose flows are fixed, by-pass control will have to be used, as shown in Figure (6.8 b).

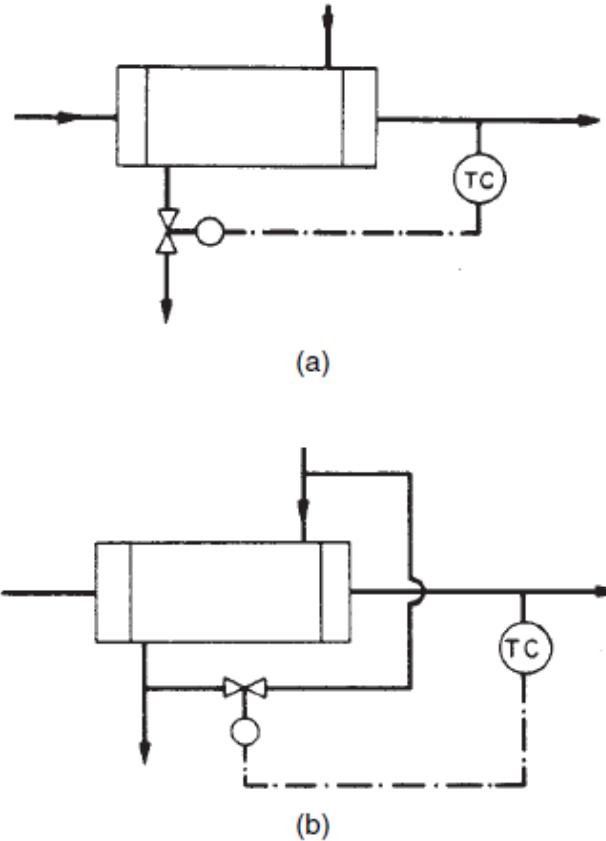


Figure (6.8) : (a) Control of one fluid stream ,(b) By-pass control .

6.8.5 Condenser control

Temperature control is unlikely to be effective for condensers, unless the liquid stream is sub-cooled. Pressure control is often used, as shown in Figure (6.6 d), or control can be based on the outlet coolant temperature.

6.8.6 Reboiler and vaporiser control

As with condensers, temperature control is not effective, as the saturated vapour temperature is constant at constant pressure. Level control is often used for vaporisers; the controller controlling the steam supply to the heating surface, with the liquid feed to the vaporiser on flow control, as

shown in Figure (6.9) An increase in the feed results in an automatic increase in steam to the vaporiser to vaporise the increased flow and maintain the level constant.

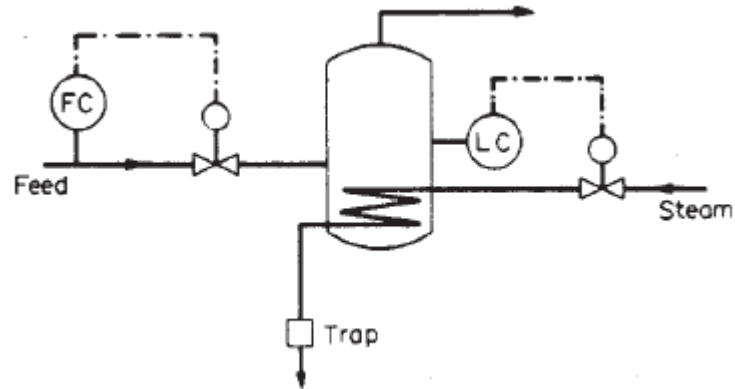


Figure (6.9) :Vaporiser control .

6.8.7 Cascade control

With this arrangement, the output of one controller is used to adjust the set point of another. Cascade control can give smoother control in situations where direct control of the variable would lead to unstable operation. The (slave) controller can be used to compensate for any short-term variations in, say, a service stream flow, which would upset the controlled variable; the primary (master) controller controlling long-term variations. Typical examples are shown in Figure(5.10 e) and (5.13)¹.

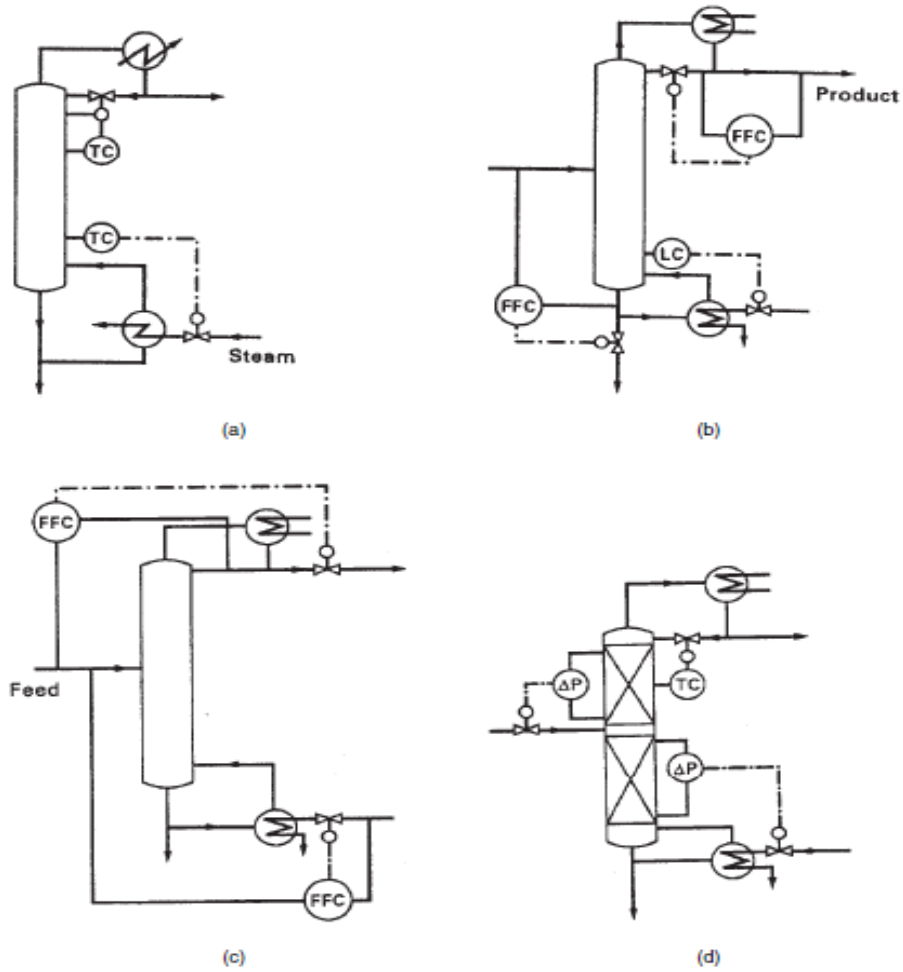


Figure (6.10) : (a) Temperature pattern control. With this arrangement interaction can occur between the top and bottom temperature controllers ,(b) Composition control. Reflux ratio controlled by a ratio controller, or splitter box, and the bottom product as a fixed ratio of the feed flow ,(c) Composition control. Top product take-off andboil-up controlled by feed ,(d) Packed column, differential pressure control.

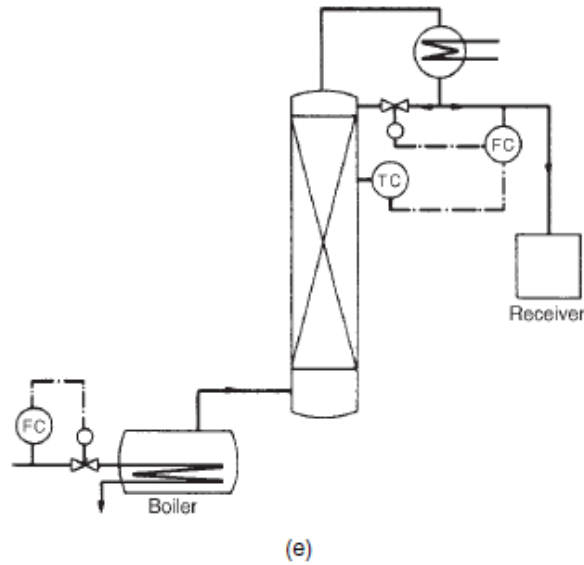


Figure (6.11) : (e) Batch distillation, reflux flow cascaded with temperature to maintain constant top composition.

6.8.8 Ratio control

Ratio control can be used where it is desired to maintain two flows at a constant ratio; for example, reactor feeds and distillation column reflux. A typical scheme for ratio control is shown in Figure (6.12).

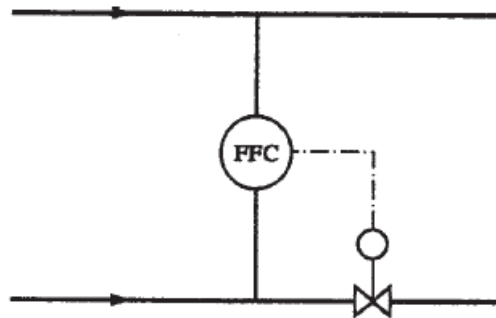


Figure (6.12) : Ratio control .

6.8.9 Distillation column control

The primary objective of distillation column control is to maintain the specified composition of the top and bottom products, and any side streams; correcting for the effects of disturbances in:

1. Feed flow-rate, composition and temperature.
2. Steam supply pressure.
3. Cooling water pressure and header temperature.
4. Ambient conditions, which cause changes in internal reflux.

The compositions are controlled by regulating reflux flow and boil-up. The column over all material balance must also be controlled; distillation columns have little surge capacity hold-up and the flow of distillate and bottom product (and side-streams) must match the feed flows. Shinskey (1984) has shown that there are 120 ways of connecting the five main parts of measured and controlled variables, in single loops. A variety of control schemes has been devised for distillation column control. Some typical schemes are shown in **Figures 6.10** a, b, c, d, e; ancillary control loops and instruments are not shown. Distillation column control is discussed in detail by Parkins 1959, Bertrand and Jones 1961 and Shinskey 1984 Buckley *et al.* 1985. Column pressure is normally controlled at a constant value. The use of variable pressure control to conserve energy has been discussed by Shinskey 1976.

The feed flow-rate is often set by the level controller on a preceding column. It can be independently controlled if the column is fed from a storage or surge tank. Feed temperature is not normally controlled, unless a feed preheater is used. Temperature is often used as an indication of composition. The temperature sensor should be located at the position in the column where the rate of change of temperature with change in composition of the key component is a maximum; see Parkins 1959.

Near the top and bottom of the column the change is usually small. With multicomponent systems, temperature is not a unique function of composition.

Top temperatures are usually controlled by varying the reflux ratio, and bottom temperatures by varying the boil-up rate. If reliable on-line analysers are available they can be incorporated in the control loop, but more complex control equipment will be needed. Differential pressure control is often used on packed columns to ensure that the packing operates at the correct loading; see Figure (6.10 d). Additional temperature indicating or recording points should be included up the column for monitoring column performance and for trouble shooting^[3].

6.8.10 Reactor control

The schemes used for reactor control depend on the process and the type of reactor. If a reliable on-line analyser is available, and the reactor dynamics are suitable, the product composition can be monitored continuously and the reactor conditions and feed flows controlled automatically to maintain the desired product composition and yield. More often, the operator is the final link in the control loop, adjusting the controller set points to maintain the product within specification, based on periodic laboratory analyses^[3]. Reactor temperature will normally be controlled by regulating the flow of the heating or cooling medium. Pressure is usually held constant. Material balance control will be necessary to maintain the correct flow of reactants to the reactor and the flow of products and unreacted materials from the reactor. A typical reactor control scheme is shown in Figure (6.13)^[3].

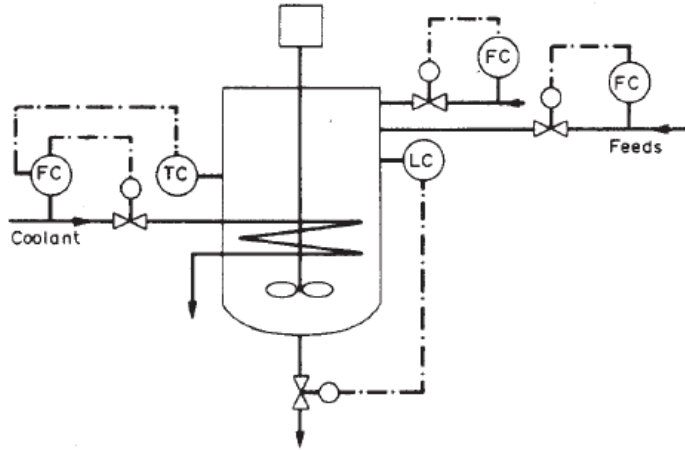


Figure (6.13) A typical stirred tank reactor control scheme, temperature: cascade control, and reagent: flow control .

6.8.11 Alarms and safety trips , and enter locks

Alarms are used to alert operators of serious, and potentially hazardous, deviations in process conditions. Key instruments are fitted with switches and relays to operate audible and visual alarms on the control panels and annunciator panels. Where delay, or lack of response, by the operator is likely to lead to the rapid development of a hazardous situation, the instrument would be fitted with a trip system to take action automatically to avert the hazard; such as shutting down pumps, closing valves, operating emergency systems.

The basic components of an automatic trip system are:

1. A sensor to monitor the control variable and provide an output signal when a preset value is exceeded the instrument.
2. A link to transfer the signal to the actuator, usually consisting of a system of pneumatic or electric relays.
3. An actuator to carry out the required action; close or open a valve, switch off amotor. A description of some of the equipment (hardware) used is given by Rasmussen 1975.

A safety trip can be incorporated in a control loop; as shown in Figure (5.14 a). In this system the high-temperature alarm operates a solenoid valve, releasing the air on the pneumatic activator, closing the valve on high temperature. However, the safe operation of such a system will be dependent on the reliability of the control equipment, and for potentially hazardous situations it is better practice to specify a separate trip system; such as that shown in Figure (5.14 b). Provision must be made for the periodic checking of the trip system to ensure that the system operates when needed.

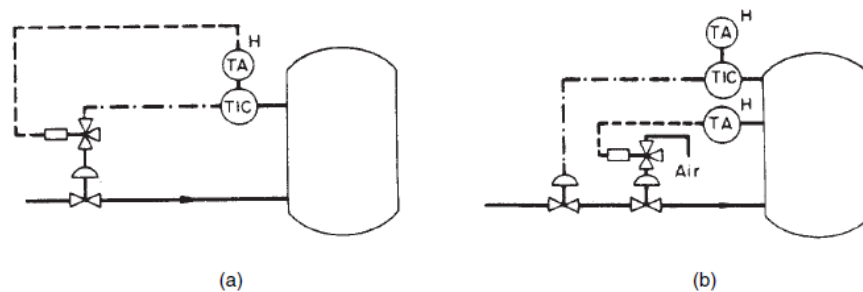


Figure (6.14) : (a) Trip as part of control system ,(b) Separate shut-down trip .

6.8.12 Interlocks

Where it is necessary to follow a fixed sequence of operations for example, during a plant start-up and shut-down, or in batch operations interlocks are included to prevent operators departing from the required sequence. They may be incorporated in the control system design, as pneumatic or electric relays, or may be mechanical interlocks. Various proprietary special lock and key systems are available.

6.8.13 Computers and microprocessor in process control

Computers are being increasingly used for data logging, process monitoring and control. They have largely superseded the strip charts and analogue controllers seen in older plant. The long instrument panels and mimic flow-chart displays have been replaced by intelligent video display units. These provide a window on the process. Operators and technical supervision can call up and display any section of the process to review the operating parameters and adjust control settings. Abnormal and alarm situations are highlighted and displayed.

Historical operating data is retained in the computer memory. Averages and trends can be displayed, for plant investigation and trouble shooting. Software to continuously update and optimise plant performance can be incorporated

in the computer control systems.

Programmable logic controllers are used for the control and interlocking of processes where a sequence of operating steps has to be carried out: such as, in batch processes, and in the start-up and shut down of continuous processes. A detailed discussion of the application of digital computers and microprocessors in process control is beyond the scope of this volume. The use of computers and microprocessor based distributed control systems for the control of chemical process is covered by Kalani (1988).

7. Safety & Loss Preventions

7.1 Introduction

Any organization has a legal and moral obligation to safeguard the health and welfare of its employees and the general public. Safety is also means working without accidents, believes that all accidents can be prevented, and efficient production.

All manufacturing processes are to some extent hazardous, but in chemical processes there are additional, special hazards associated with the chemical used and the process condition.

7.2 Identification of Hazardous

The hazard of Chemicals is divided into the reaction heats, flammability, explosiveness, toxicity, corrosiveness and chemical interaction.

7.2.1 Toxicity

Most of the materials used in the manufacture of chemicals. The potential hazard will depend on the inherent toxicity of the material and the frequency and duration of any exposure. Toxic substance must first be absorbed into organism before having a biological effect. In case of man and animals three portals of entry.

1. Inhalation.
2. Ingestion.
3. Skin contact.
4. Eye contact.

7.2.2 Flammability

Flammability is the ease with which a substance will ignite, causing fire. To cause the combustion of a substance is subject to quantification through fire testing.

The hazard caused by a flammable material depends on a number of factors:

1. The flash point of the material.
2. The autoignition temperature of the material.
3. The flammability limits of the material.
4. The energy released in combustion.

1. The Flash Point:

The flash- point is a measure of the ease of ignition of the liquid. It is the lowest temperature at which the material will ignite from an open flame. The flash-point is a function of vapor pressure and the flammability limits of the material for acetone -20°C.

2. Auto Ignition Temperature:

The auto ignition temperature of a substance is the temperature at which it will ignite spontaneously in air, without any external source of ignition for acetone 465°C.

3. The Flammability Limits:

The flammability limits of a material are the lowest and highest concentrations in air, at normal pressure and temperature, at which a flame will propagate through the mixture. They show the range of concentration over which the material will burn in air, if ignited. Flammability limits are characteristic of the particular material, and differ widely for different materials for acetone UFL 2.5% , LFL12.8%.

7.3 Safety Considerations

7.3.1. Fire Hazard

A fire hazard is any situation in which there is a greater than normal risk of harm to people or property due to fire. Fire hazards can take the form of ways that fires can easily start, such as a blocked cooling vent, or overloaded electrical system, ways fires can spread rapidly, such as an insufficiently protected fuel store or areas with high oxygen concentration. Fire hazards include things which, in the event of fire, pose a hazard to people, such as materials that produce toxic fumes when heated or objects that block fire exits.

7.3.2 Fire Fighting Equipment



Figure 7.1 Fire Fighting Equipment

7.3.3 Fire Protection Systems

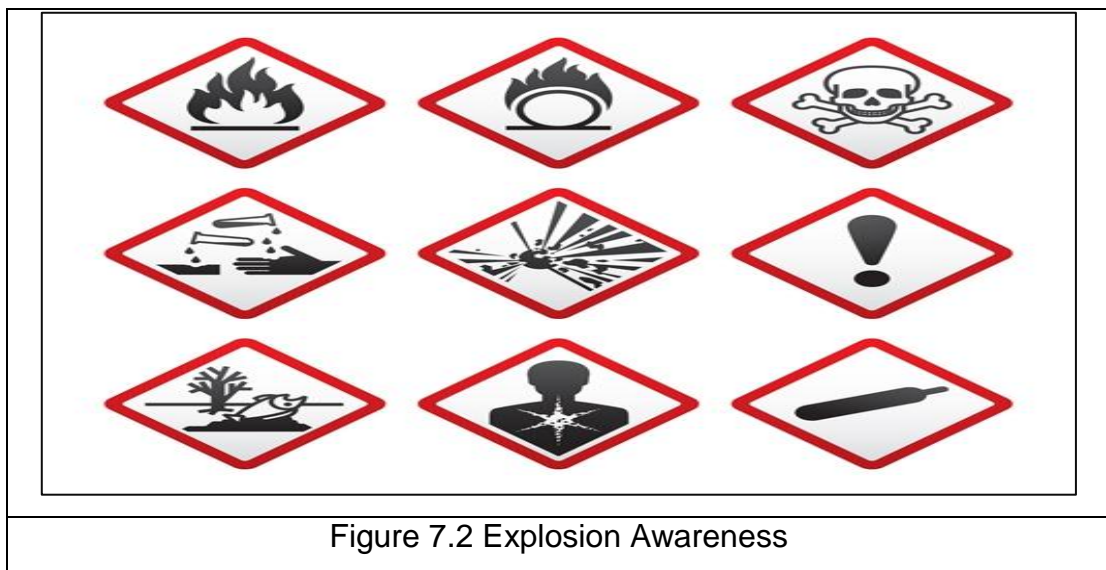
1. Foam
2. Water spray
3. Chemical and special agent extinguishing systems :
 - Dry Chemical Systems
 - Carbon Dioxide Systems
 - Inert System

- Vaporizing Liquids (Halon System)

7.3.4 Emergency Action

In the event of a fire, wear full protective clothing-approved self-contained breathing apparatus with full face piece operated in the pressure demand or other positive pressure mode. Use water spray to blanket cool fire, cool fire exposed containers, and to flush non-ignited spills vapors away from fire.

7.4 Explosion Hazard



Explosion is the second hazard that can occur in our plant. The violence of the explosion depends on the rate at which the energy is released. And there are three types of energy:

- Physical energy.
- Chemical energy.
- Nuclear energy

Explosion Kinds:

There are two kinds of explosions:

1. Deflagration: in a deflagration the flammable mixture burns relatively slowly. For hydrocarbon air mixture the deflagration velocity is typically of the order of 1.0m/s.
2. Detonation: in a detonation the flame front travels as a shock wave followed closely by a combustion wave which releases the energy to sustain the shock wave.

7.5 Environmental Effects

Acetone evaporates rapidly, even from water and soil. Once in the atmosphere, it's degraded by UV light with a 22-day half- life. Acetone dissipates slowly in soil, animals, or waterways since it's sometimes consumed by microorganisms; however, it is a significant issue with respect to ground water contamination, since its highly soluble in water. Environmental half-life is about 1 to 10 days. But acetone may pose a significant risk of oxygen depletion in aquatic systems due to the microbial activity consuming it.

7.6 General Safety Rules:

7.6.1 Working Practices

1. Employees must not use any equipment unless they have been trained and authorized to do so.
2. Employees must report immediately any fault or damage to equipment.
3. Employees must use all substances, chemicals; liquids etc. in accordance with all written instructions and should familiarize themselves with relevant Hazard Data Sheets and Risk Assessments.

4. Employees must return all substances, chemicals, liquids etc to their designated safe storage area when not in use.

7.6.2 Working Conditions/Environment

1. Employees must make proper use of all equipment and facilities provided to control working conditions/environment.

2. Employees must keep all areas clear and in a clean and tidy condition.

3. Employees must dispose of all rubbish, scrap and waste materials using the facilities provided. Chemical, radioactive and biological waste must be disposed of through the Safety Office in accordance with the relevant Code of Practice.

4. Employees must clear up any spillage of liquids immediately.

7.5.3 Personal Equipment Protective

1. Employees must use all items of protective clothing/equipment provided as instructed.

2. Employees must not misuse or willfully damage any of protective clothing/equipment provided.

3. Employees must report any damage, loss, fault or unsuitability of protective clothing/equipment to their supervisor.



Figure 7.3 Personal Protective Equipment (PPE)

8. Conclusions

This work reports on the purification process of butene to use in the production of polyethylene. The main conclusions of this work are presented.

- 1- The presented some information related to the process of using this material in the chemical engineering process.
- 2- Material balances around the process were presented to understand the effects of changing in quantities on the production process. In this point, small error in calculation was presented. This error was around 0.95 % which is within the applicable ranges.
- 3- Energy balances as well was prepared in this work to clarify the heat loss and heat gain within the manufacturing process.
- 4- A special design for heat exchanger was evaluated in this work to help and understand the design process in chemical plants.
- 5- The last conclusion in this work can be related the study of safety procedures in such chemical process to avoid and prevent accident which may be happened in such chemical manufacturing.

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