CLEANER PRODUCTION AUDIT FOR THE UTILITY OF CEYLON PETROLEUM CORPORATION.

By

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DECLARATION

The content described in this thesis was practically implemented by me at the Ceylon Petroleum Corporation and the Faculty of Applied Sciences under the supervision of Miss. Enoka P. Kudavidanage and Mr. N.R. Amarasinghe.

And the report described on this thesis has not been submitted by any one for another degree.

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Affectionately Dedicated

To

My Parents

And

Teachers

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ABSTRACT

The Petroleum Refinery is the single crude oil refining unit in Sri Lanka located at the Sapugaskanda owned by Ceylon Petroleum Corporation. The refining process of the crude oil and produce the valuable petroleum products is a huge process and it is carried out in several kind of units established in the Refinery.

The study was carried out to identify the resource wastage of utilities in terms of waste and present it in a CP audit. Each of the units and their processes have been carefully studied by this project and identified to discover that there are so many resource wasting points Such as pipe leaks, tank overflows, evaporation etc. The resource wastages were quantifies and presented in a material balance.

It was identified that the wastages are due lack of proper monitoring system, unidentified equipment break downs and mainly neglect .

The causes of the waste generation and the all possible prevention methods that can be implemented have been studied and reported in this working period. As well as the annual cost that spent by the CEYPETCO for each wastage points has been evaluated statistically.

CONTENT

LIST OF ABBREVIATIONS.

Bbls	-	Barrels
B.F.D	-	Boiler Feed Water
C.D.U	-	Crude Distillation Unit
CEYPETCO	-	Ceylon Petroleum Corporation
F	-	Furnace
G.O	-	Gas Oil
H.P	-	High pressure
IGPN	-	Imperial Galleries per minute
L.P	-	Low pressure
L.P.G	-	Liquid Petroleum Gas
M.P	-	Medium pressure
MT/D	-	Metric tons per day
Psig	-	Pounds per squire inches gauge
R.W.I.T.U	-	Raw water intake and treatment unit
S.B.P.S	-	Special Boiling Point Solvent
S.R	-	Straight run off
T.G	-	Turbo Generator
T.P	-	Turbo pump
U.N	-	United Nations
WHB	-	Waste heated boiler
Wk	-	Week
UNEP	-	United nation Environment Program
MT	-	Metric ton
CP	-	Cleaner Production
MW	-	Mega Watt
CEB	-	Ceylon Electricity Board

LIST OF FIGURES.

CHAPTER 01
Introduction

1.1 The Petroleum Refinery

The Petroleum Refinery is the single crude oil refining unit of Sri lanka located at the Sapugaskanda, owned by Ceylon Petroleum Corporation. This refining unit is extended over quite a large area approximately 165 acres and fair numbers of employs are working at present.

The main function of the process is to convert the raw crude oil into valuable petroleum products.

1.2 Brief history of the Refinery

The Refinery was established in 1969 to process 38000 Barrels of crude oil and to produce petroleum products to meet the demand at that time. With the increase in demand , Refinery was de bottlenecked to process 50000 barrels of crude oil in 1979.

In 1992 , the crude distiller unit was modified so that different variety of crude oil can be processed. Further, processing capability of other units were also increased wherever possible to increase the production and to meet the changing specification of the products.

However , the countries demand for the petroleum products can be processed in the Refinery and the deficit of around 50% is imported as petroleum products.

1.3 Refinery delivery system

The each fuel produced by the Refinery are stored in the Refinery tanks and then are pumped into the tanks located at the Kolonnawa oil storage unit, through the underground pipe lines. (Operation manual ,1992)

And then products are further transported by browsers and wagons to 14 of small oil storage units located at various regions of the country. And by its storage oil distributed throughout the island . Small Ships are also used for transportation process up to Galle and Trinco ports from the Colombo with refined oil.

1.4 Concept of the Cleaner Production and their application

Used in conjunction with other elements of environmental management, cleaner production is a practical method for protecting human and environmental health, and for supporting the goal of sustainable development.

Production with no regard for environmental impacts creates water and air pollution, soil degradation, and large-scale global impacts such as acid rain, global warming and ozone depletion. To create more sustainable methods of production, there needs to be a shift in attitudes away from control towards pollution prevention and management.

The United Nations Environment Program (UNEP) introduced the concept of cleaner production in 1989, and defined it as 'the continuous application of an integrated preventive environmental strategy applied to processes, products and services to increase eco-efficiency and reduce risks to humans and the environment'.

Cleaner production activities include measures such as pollution prevention, source reduction, waste minimization and eco-efficiency. They involve better management and housekeeping, substitution of toxic and hazardous materials, process modifications, and reuse of waste products. At its heart, the concept is about the prevention, rather than the control, of pollution.

The concept of cleaner production questions the need for a particular product, and looks at other ways to satisfy the demand. It is a slowing down of the rate at which we use resources, and a gradual shift from linear to more circular processes, similar to those found in nature. The eventual goal of clean production is to achieve a 'closed loop' operation in which all excess materials are recycled back into the process.

The four elements of cleaner production are:

1. The precautionary approach - potential polluters must prove that a substance or activity will do no harm;
2. The preventive approach - preventing pollution at the source rather than after it has been created;
3. Democratic control - workers, consumers, and communities all have access to information and are involved in decision-making;
4. Integrated and holistic approach - addressing all material, energy and water flows using life-cycle analyses.

The benefits of cleaner production include decreased waste, the recovery of valuable by-products, improved environmental performance, increased resource productivity, increased efficiency, lower energy consumption, and an overall reduction in costs.

Implementing cleaner production can be as straightforward as adopting better housekeeping practices, or it may involve more complex measures associated with processes and products. The more sophisticated options may include switching to renewable energy sources, increasing material efficiency, and re-using and recycling by-products. The product itself can be designed to reduce consumption of resources, to prolong its useful life, and to allow disassembly and recycling of its component parts.

Cleaner production requires a new way of thinking about processes and products, and about how they can be made less harmful to humans and the environment. For successful implementation, the concept must be effectively communicated within the organization. Employees at all levels, including senior management, should be actively involved.

The cost of complying with environmental legislation can be significantly reduced by companies that adopt cleaner production techniques. The latter are often more cost-effective than control technologies. The costs of dealing with wastes are reduced, and there is potential for new markets to be discovered through innovations or the sale of by-products.

Cleaner production can reduce environmental risks and liabilities and lead to greater competitiveness. By demonstrating a commitment to cleaner production, companies can also improve their public image and gain the confidence of consumers.

1.5 Scope of the study

The refining process of the crude oil which is carried out in the Refinery is a huge process. In addition to crude oil which is the major material involved in the process there are some sort of utilities such as water , air , electricity and steam that are used in the main refining process separately. Due to several causes, these utilities can be lost as refinery waste from several points of the Refinery. So due to this reason the refinery loose lot of money in terms of resource wastage. by minimizing those waste, that money can be saved and the efficiency of the refining process also can be enhanced.

Taking this point in to consideration, This project was aimed assess wastage points in the refinery premise. all the points that waste can be happened which involving the utilities, by studying about the available utility systems. Not only that, the effluence amount of waste of each points was evaluated statistically and calculated the cost spent by the Refinery for that waste per day. And also all the causes for that kind of waste generation was discovered and the suggestions or prevention method for that, has been given in this report.

1.6 Aim of this study

The major objective of the cleaner production audit is to promote the efficiency of the refining process and minimized the environmental damage by reducing the refinery loses.

a) To identify the resources wastage points in the utility process.
b) To quantify the resources wastage in CP audit
c) To suggest implementation measures to minimize resources wastage

CHAPTER 02

Refining process and Utilities

2.1 Refining units and their process

The primitive objective of this refining process is to gain valuable products and byproducts from raw crude oil, which mined from the earth crust. So that to achieve this task, mainly the crude oil is processed several chemical and physical treatments and converted its high complex hydrocarbons into several fractions. (Thuman ,1990)

This process is taken place in the processing units of the petroleum refinery and uses several kinds of columns, reactors, vessels, tanks and pipelines to achieve this task. As mentioned above, the basic refining process can be categorized into four major processes.

1. Fractional Distillation processes
2. Terminal Cracking processes
3. Catalytic processes
4. Treatment processes.

Each processes is carried out in several specific units established in the plant throughout the whole day. Also the major processing units of the plant are: (Rao ,1997)

1. Crude Distillation unit
2. Naphtha unifier unit
3. Platformer unit
4. Gas oil unifier unit
5. Visbreaker unit
6. Merox unit
7. Vacume distillation unit
8. Bitumen blowing unit
9. Depropernizer unit
10. Special boiling point solvent unit

2.1.1 Crude Distillation Unit

The Crude Distillation unit is principle unit in the process section of the Refinery. The main task which carried out of this unit is to fractioning raw crude oil into four major fractions called "Distillates". Such as:

1. Naphtha 2. Kerosene 3. Gas Oil 4. Long Residue

The crude oil is supplied to the unit by charge pumping which is electrically driven by a high tension motor. Before entering the C.D.U, the crude oil desalted by using desalter to prevent corrosion and is preheated by two preheaters. (Shah Dinesh,1994)

The preheated crude oil is passed through two furnaces to create some sort of crude vapor and then the steam of crude is passed to distillation column as a mixture of vapor and liquid. And also the low pressure steam is added to the column as a striping steam to reduce the partial pressure of the crude vapor. And our C.D.U unit is flexible to process different type of crude ranging from *Tapis Blend* to *Arabic* medium. (Operation manual ,1990).

The various temperature profile is maintained from top to bottom of the main column which temperature of the column is reduced along from top to bottom. So that the fraction which having with highest boiling point is concentrated in the bottom and the products which having with lowest boiling point is concentrated at the top of the column. (Shah Dinesh,1994)

The bottom product is drawn off from the bottom as long residue by electric pump and split it into two streams of which one is diverted to the Visbreaker unit and the other goes to the Vacumn distillation unit. (CEYPETCO-CDU,1992)

The heavy Gas oil is taken from the bottom pump around came from the bottom part of the unit called "Gas oil stripper". And the light Gas oil is drawn off from the tray No 14 and both of them is diverted to the gas oil unifiner unit. And one part of

S.R Gas oil is used to create Auto Diesel after mixing with light vacumn gas oil came from vacuum distillation unit.(Thuman,1990)

The Kerosene products is drawn off from the tray No 24 and spitted it into two streams, which one is directly used as illuminate Kerosene without any treatment and the other is diverted into the Kerosene merox unit. (Operation manual ,1992)

Naphtha is extracted from the top of the column and diverted it into the Naptha stabilizer for stabilization process. In Naptha stabilizer the L.P.G is separated from the S.R Naptha then the L.P.G is diverted to the depropenriser unit and remained Naptha is sent to Naptha unifiner. (Thuman,1990)

2.1.2 Unifiner units

There are two types of unifiners established in the plant premism.

1. Naptha Unifiner 2. Gas oil Unifiner

The main task which carried out of these units is to reduce sulfur content contaminated in S.R naptha and Gas oil. Here this task is performed by the reactions of H_2 gas (gained from platformer unit) in Ni/Mo catalytic medium in the reactors.

Before entering the reactors, the feed entered to heaters for vaporizing. and then the vaporized charge enters the reactor at top and passes down over a Co/Mo catalyst bed, where H_2 is consumed trough hydrogenation and desulphurization(Shah Dinesh,1994)

Here not only S, the N_2 ,O_2, Halide, Olefins, and even metal also can be removed as H_2S ,NH_3, H_2O and so on respectively. All the removed gaseous byproducts are diverted into the flue gas system. (Operation manual ,1995)

2.1.3 Naptha unifiner

As mentioned above the S.R naptha is fed it from C.D.U and desulphurization process is taken place. In addition to the dsulp hurization process, here the SR naptha is divided into two fractions in the striping column of this unit as

1 Heavy naptha
2 Light naptha

The heavy naptha having with the Octane number ranges from 45 to50 and the light naptha is ranges from 60 to 70 .So then the heavy naptha with low octane number is pumped to the plat former unit to increase its octane number. (Shah Dinesh,1994)

And also the one part of heavy naptha is mixed with light naptha derectly and create chemical naptha. The light naptha stream is divided into two streams which one is diverted directly to S.B.P unit and the other stream is mixed with platformate outlet . (CEYPETCO-Unifiners,1992)

2.1.4 Platformer

The feed stock of this unit is the heavy naptha with low octane number. The main objective of this unit is to increase octane number of the heavy naptha from 45-50 up to 90-95.

The platform means , the platinum reforming. So by using the reforming process in the platinum catalytic media , the low – aromatic compound is catalytically converted in to high aromatic compound. This process is called as "Platformate". (Thuman,1990)

In the platformate process , the reaction shown below can be taken place. They are

1. Dehydrogenation
2. Isomerization
3. Dehydro cyclation
4. Hydro cracking

Those are the most common reaction occurring in the platforming reactors. The Hydrogen gas and L.P.G is generated during these reaction as a side products. The Hydrogen gas is diverted into the unifiner and consumed itself for other reaction which is occurred in the platformer unit. (Operation manual ,1992)

L.P.G is pumped into the Depropernizer. The main product of this unit is heavy naptha with high aromatic compounds and high Octane value (90-95). This out let then mixed with light naptha (45-50 Oct.) and maintained the octane number 90 and produced Gasoline.(Rao,1997)

2.1.5 Gas oil Unifiner

There are two Gas oil unifiners in the Refinery called O4 and O7. Approximately the feeding capacity of O7 and O4 are 1000 MT/D and 300 MT/D respectively. The same process carried out in the Naptha unifiner is occurred in this unit. The S.R or S.R Kerosene and cracked Gas oil from Visbreaker are fed in to this unit with Hydrogen gas (from plat former) and it will react in Co/Ni catalytic media and de sulphurization process is occurred. (CEYPETCO-Unifiners,1992)

Here also, in addition to the Sulfur , the Nitrogen gas ,Oxygen , Halide , Olefin and metal also can be removed as several kind of gaseous products. These gaseous by products is then diverted into flue gas system. Here the Sulfur reduction is carried out from 0.8% up to 0.1%. And the desulphurized gas oil came from O4, O7 unit is then mixed with S.R gas oil (0.5% sulfur content) and maintained sulfur percentage at 0.5%, then transported to storage tanks as "Super Diesel". (Rao,1997)

In addition, at present, the unit is used to produce Kerosene products too, like low aromatic white spirits, Aviation turbine fuel (Jet fuel) and illuminating Kerosene.

2.1.6 Visbreaker

After the mixing of long residue (produced by C.D.U) with heavy vacuum gas oil(from vacumn distillation unit) is fed into the Visbreaker unit. The main task of this unit is to convert high viscosity fuel oil into visbroken residue with lower viscosity, visbroken gas oil , full range naptha and gases, (CEYPETCO-Visbreaker,1992)

Normally this conversion takes place under the influence of temperature. That means the thermanal cracking is carried out in this unit. The cracked naptha produced by this unit is further stripped to heavy and light naptha. And then diverted it into the naptha Stabilizer. And also the cracked gas oil produced by this unit is divided in to two streams which one goes to gas oil unifiner for hydrotreating and the other mixed with cracked residue and produced fuel oil (blended).

As mentioned above the cracked residue stream is directly lined up into cracked gas oil and then produced blended fuel oil. (Operation manual ,1992)

2.1.7 Vacumn Distillation unit

A part of the long residue product of the crude distiller, has to be made heavier in order to serve as a feed stock for bitumen manufacturing. This is the main objective of this unit. So the long residue produced by the C.D.U is fed in to this unit. This process is taken place in low pressure vucumn column and during this process , the long residue feed stock is stripped in to three main out let such as

1. Light vacumn gas oil
2. Heavy vacumn gas oil
3. Short residue

The light vacumn gas oil is combined to the S.R gas oil came from C.D.U and produced the Auto Diesel. Where as the heavy vacumn gas oil products join with Visbreaker feed stock. (CEYPETCO-Vacumn distilation,1990) There is a provision to run down heavy gas oil to storage. The short residue (Vacumn bottom product) is used as a feed stock to the bitumen blowing unit.

2.1.8 Bitumen Blowing unit

The feed stock of this unit is short residue came from vacumn distillation unit. In this unit the air is pumped in to the column and due to that case air bubble goes from the bottom to upwards through the short residue and the air is mixed properly and react with short residue. (Shah Dinesh,1994)

Due to the chemical inversion occurred during the mixing with air, the high viscosity bitumen is generated. And after the part of short residue came from Vacumn Distillation unit is mixed with bitumen, then pumped to storage as "Blown Asphalt".

2.1.9 Depropernizer

The L.P.G came from naptha stabilizer and platformer is fed into this unit. In this unit the gaseous part which having with high cations are removed and sent it to Flue gas system. The remained gaseous products with low carbon atoms is diverted to the L.P.G merox unit.(CEYTCO-Depropernizer,1995)

2.1.10 Merox units

There are two kind of merox units can be identified in our Refinery. Such as

1. L.P.G Merox unit
2. Kerosene Merox unit

The merox process is a catalytic chemical treatment for petroleum distillates to convert high corrosive mercaptans to less corrosive disulphide without reducing the sulphure content of the stock. (CEYPETCO-Merox,1995)

This merox process utilize by the selectively prepared catalysts, which promote the oxidation of mercaptants to disulphide with air, being the source of oxygen. As well as an alkali solution such as NaOH also requires for this process . In the L.P.G merox unit the effluent of the depropernizer unit is fed to this unit and after merox process occurred , the non corrosive L.P.G with disulphide is diverted to storage.

As well as in the Kerosene Merox unit , the S.R kerosene is fed directly into this unit and merox process is occurred. After that the non corrosive kerosene is pumped to storage as a "Jet- Merox,1995)

2.2 Refinery Utilities

The main objective of the Refinery is to refine crude oil and produced valuable products and by products. So to achieve this task, several physical and chemical changes are taking place in several units established in the refinery premism. (CEYTCO-Utilities,1990)

In addition to this refining process , to implement this process satisfactionery, several utilities are needed. The required utilities that aid to the refining process can be categorized in to four major types. (Operation manual ,1995)

1. Water
2. Steam
3. Electricity
4. Air

The raw water drawn off from kelani ganga is presettled, clarified and filtered in the plant and pumped to the Refinery to be used as.

1. Cooling water
2. Boiler feed water
3. Drinking water
4. Process water

To prepare each utilities, the number of unit have been established inside or out side of the Refinery area. Such as

1. The raw water intake and treatment unit
2. Demineralizer unit
3. Drinking water system
4. Cooling water system
5. Instrument and tool air system
6. Steam and power generation system
7. Steam condensing and condensate system

2.2.1 Raw water intake and treatment unit

2.2.1.1 River water pump house

The river water is withdrawn directly from the kelani ganga at the pump house located in the river. So then the water is pumped to the presettling stage and further clarification and filtration section. (Operation manual ,1995)

2.2.1.2 Settling and Clarification

After the pump house the river water is delivered to a presettling basin of concrete construction to allow presettling of silt and sand. The settled sludge is collected and discharged by gravity to the sewer system for ultimate disposal in the river down stream of the plant. Here chlorine injection is done in the presettling stage for oxidation of organic matters and ferrous ions. (CEYTCO-Utilities,1990)

The ion removing purpose is carried out by the cascade aerator located immediately down stream of the presettling basin. Then water is

Pumped to the clarification stage. This stage consist of to parallel or single operating concrete-steel clarifiers of the stage blanket type.

The dilute solutions of process chemicals are also added for the following purposes in this stage.

1. Pre-lime 5% solution for alkalinity adjustments.
2. Alum 7% solution for actual clarification.
3. Coagulant aid !% solution in the clarification
4. Post lime 5% solution for alkalinity adjustment to reduce corrosion in transfer lines.

And the clarified water then is diverted to the filtration stage.

2.2.1.3 Filtration stage

This consists of five sand filters in parallel and water filtration process is occurred. So the filtered water is collected in concrete basin and from this basin delivered to the refinery . The filtered water for chemical dilution and other pretreatment services are taken via Refinery transfer pump. (CEYTCO-Utilities,1990)

2.2.1.4 Sludge disposal system

All spillages, overflows, drain and waste lines originating from the clarification and filtration system are collected in a suitable concrete basin . Two vertical pumps are installed for disposal of this sludge back in to the river at a down stream location. (Operation manual ,1995)

2.2.2 Demineralizer unit

Before the water is fed to the boilers, it should be treated for removing ions / Minerals for preventing corrosions. This task is occurred by the demineralizer unit. The demineralizer is a mixed bed ion- exchanger resign which consist of vessels, pipe work, operating valves and an air compressor. (CEYTCO-Utilities,1990)

The purpose of the mixed bed demineralizer is to prepare boiler feed water of a suitable quality (low hardness, low silica content) for the boilers. This is achieved by removing vertically all dissolved water (mainly inorganic cations and anions) by a process called ion- exchange or Demineralization. The demineralizer consist of a mixture of cation exchange resin (Dark brown beads) and anion exchange resin (slightly yellow beads) .

The cation exchange resin consist of a complex organic structure to which sulphonic acid groups are attached. The H ions of these acid groups can reversible inter change with other positive ions (cations)

Ex:

Ca^{++}, Mg^{++}, Na^{+} and K^{+}

The anion exchange resin consist of a similar structure to which a quaternary ammonium base group is attached. The negative charged OH^{-} ions of this base group can reversibly interchange with other negative ions.

Ex:

Cl^{-}, $SO4^{--}$,$CO3^{--}$

The reaction which take place in cation exchanger can be summarized as

$$2R\text{-}H^{+}Ca^{++} \rightleftharpoons 2R\text{-}Ca + H^{+}$$

$$R\text{-}H + Na^{+} \rightleftharpoons R\text{-}Na + H^{+}$$

Anion exchanger Reactions can be summarized as

$$2R\text{-}OH + CO_3^{--} \rightleftharpoons 2R\text{-}CO_3 + OH^-$$

$$R\text{-}OH + Cl^- \rightleftharpoons R\text{-}Cl + OH^-$$

The intake of the Demineralizer consist of treated water is prepared at Kelani river water intake and treatment plant and is routed via the two treated water basin at the Refinery site. Practically all cations and anions have been removed , resulting in virtually pure water with a pH of 7 and a very low conductivity. (CEYTCO-Utilities,1990)

2.2.3 Steam and Power generation system

2.2.3.1 Boilers

The equipment which steam generated is generally called as Boilers. Water is boiled by heat, generated from burning fuel oil and gas in the boiler and steam is generated as a result. There are two type of Boilers available in the Refinery.

1. If the heat is generated with the purpose of making steam, such kind of boilers called as "Fired Boilers".
2. Steam generation using waste heat of a pressure heater is called as "Waste heated Boilers"

The generated steam by the Boilers is used for several applications. These application can be categorized in to three main grop. (O peration manual ,1995)

1. As inert gases- Stripping steam, Clearing steam
2. Heating purposes- Tracing steam
3. Mechanical energy- Atomizing steam, Turbine steam (H.P steam)

The steam generating installation consists of three boilers made by the separate designers in the Refinery. They are assembled as "Package Boilers" with force – draft fan , fire equipment, economizing and feed water preheater.

They are designed for a capacity of 60000, 100000 and 82500 lbs respectively of steam per hour each and an operating pressure 530 psig. And it can only be fired with fuel oil as well as fuel gas. (CEYTCO-Utilities,1990)

2.2.3.2 Turbines

The turbine is of the single case extraction condensing type with nine impulse stages. The steam produced by boilers with 550 psig pressure called *high pressure* steam are admitted to the turbine and after the first stage, the part of steam is extracted with 250 psig and produced as *medium pressure* steam. And again the steam interaction is taken place from the end point of the turbine which the pressure of 50 psig to produce *low pressure* steam. (Operation manual ,1995)

This medium and low pressure steam are used for various applications in the Refinery process. In addition to the three kind of steam generation the major task of the turbine is to convert thermal energy in steam to the mechanical energy. This mechanical energy is used for

1. Pumping purpose as Motive power.
2. Electricity generation

The pumps which are driven by turbine is called as "*Turbine pumps*" and the equipment which generate electricity by using turbine called as "*Turbo generator*". In this plant two kind of electricity generators are used

1. Turbo generator - driven by steam
2. Diesel generator- driven by a diesel engine

Normally two turbine generators are available in the Refinery which only one is operated and the other one as stand-by. Each one generates 4 MW Max electric capacity.

Two Diesel generators are available of which one is operated and the other is as standby. Both have the capacity which generate 2MW each of electric power. Because of the electricity gained from national grid is not reliable, this own electricity generation is used by the plant. But in addition to those sources some portion of power is also used from national grid for non critical operations. (Shah Dinesh,1994)

2.2.4 Steam and Condensate system

In every Refinery it is a common practice to reduce operating cost. One of the cost centers in utilities is boiler feed water treating. As a consequences if one makes if possible to return as much as possible condensate to the boiler feed water system , the quantities of makes-up water can be reduced considerably. And also condensation of low pressure steam, which we have in excess, is a very attractive way of saving in boiler feed water cost. (CEYPETCO-Utilities,1990)

The system that is allocated for such kind of process is called as *steam and condensate system.*

2.2.5 Cooling water system

The working of the plant needs cooling , mainly in the heat exchangers and condensaters. This cooling is done by a mass quantity of water in the cooling water system. The cooling water system is a cyclic process by which water is used to cool the plant and then the hot water is cooled in the cooling tower and recycled. During the cyclic process some of water is lost as (Shah Dinesh,1994)

1. Windage loss-At the cooling tower
2. Blow down loss- The water is not recycled
3. Evaporation
4. Pipe leaks

The loses of water is substituted by the make-up water from the Kelani river. And the make-up water is treated with $Ca(OH)_2$ +Cl_2 water.

Cooling water pump play an important role in Refinery cooling water system since so many units used cooling water as their cooling medium. A cooling tower is installed at the plant and hot cooling water from process units is fed to the top of the tower through the underground pipe lines. In the cooling tower a forced circulation air draft cools the water and cold water is fed to process units through under ground pipe lines.(CEPTCO-Utilities,1990)

Majority of cooling water that is fed to process units, such as trim coolers and surface condensers is returned to the tower except in few cases. Similarly a considerable portion of cooling water is used to cool motor pumps and turbo pumps is returned to the tower except in few cases. (CEYPETCO-Utilities,1990)

Cooling water loses occurred at drain point where it gets mixed with oil and in the cooling tower due to evaporation. In addition to those loses unaccountable loses occurred due to underground leaks . To compensate all these loses make-up water is fed to the cooling tower.

2.2.6 Drinking water system/ Portable water system

In general portable water shall be free from pathogenic organism and confirm to U.N World health organization or U.S public health department prescription for appearance tasted and bacteriological acceptability. And Filtered water is delivered from two basins to an elevated concrete tank. And after proper chlorination through a Hypochlorite automatic dozing device including a chemical tank with mixture, a dosimetric pump and the automatic devices for control hypochlorite addition indirect proportion to water rate. (Shah Dinesh,1994)

Down stream in the elevated storage, an activated Carbon pressure vertical filter is installed for elimination of chlorine excess and portable water taste control. The rate of portable water requirement is 33 IGPN. In case of insufficient pressure in portable water network a centrifugal pump will start operation. (CEYPETCO-Utilities,1990)

2.2.7 Instrument and tool air system

The compressed air is used in the Refinery to achieve too major tasks. The one is to operate the hand-drillers in drilling purposes at the work shops. And the other is for controlling values established along the pipe lines. The system which allocated for the work shops. And the other stream is treated by two treatment units .The one is oil filter which remove the oil particles contaminated in the air. And the other unit is Dehydrification system which remove the water vapor in the air and produced de-humid air. Both of units are aided to prevent the corrosion which may be occurred in the pipe lines. Such kind of treated air is called as "*Instrumental air*" and it uses for controlling the pnumetic valves established along the pipe lines. (Shah Dinesh,1994)

2.3 Application of Cleaner Production in industry

Governments and business leaders alike now recognize that industrial development needs to become environmentally sustainable, and the pressures on business to reduce environmental pollution and waste are mounting. As awareness of environmental threats has grown, and new regulations to protect the environment have been developed, new challenges and opportunities have arisen for industry.

The way ahead for industry must involve the use of cleaner technologies and environmental management systems. These production systems focus on the minimization of waste, reuse and recycling of materials, environmental friendly design and reductions in energy consumption. Cleaner production is about a new way of thinking within industry, and it involves innovation in management as much as in technology. (Operation manual ,1995)

Implementation of cleaner production is carried out within a wide span of industrial production sectors, e.g.: chemical, pharmaceutical, textile, pulp and paper, industrial laundry, tanning, graphics, food, latex products, electronics. The overall aim of the cleaner production options has been to reduce consumption of raw materials and chemicals as well as the basic resources: water and energy. Further, emphasis is placed on substitution of hazardous chemicals.

A series of services has been developed that fulfill all needs, when the demand is environmentally sound optimization or revision of production processes. All services are based on identification of the best available technology from a technical, economic and environmental point of view. (Mccaslin,1992) The services comprise:

a) Water minimization and reuse in industry
b) Utilization of by-products
c) Industrial wastewater treatment
d) Hygienic concerns
e) Process simulation of production units and processes
f) Substitution of hazardous chemicals
g) Environmental management systems
h) Data monitoring and reporting
i) Interaction between regulation of industries and the public sewer system

CHAPTER 03
Methodology

3.1 Identification of the Refining process

At the beginning of the project period, the first requirement was to study the units established in the Refinery, their processes, the type of crude used in the Refinery and the products produced by the refinery which is summarized in chapter 2. And by using these information, summarized plant flow diagram was prepared including all the units established in the refinery.

After referring of the technical manuals, step three was to visit the plant. At the plant premism, each of the units were carefully observed and collected more information from the engineers, managers and plant operators, employed in the refinery. Here the study was covered about the process occurred inside of each units, produced products and by products.

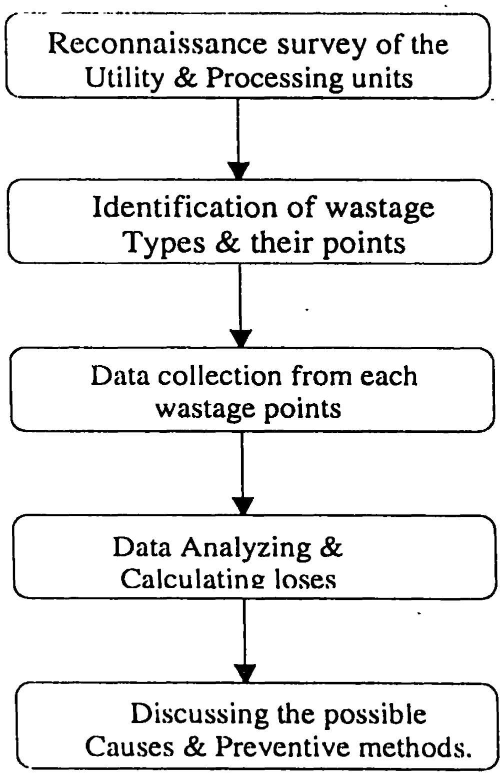


Figure 3_1. Overall methodology steps

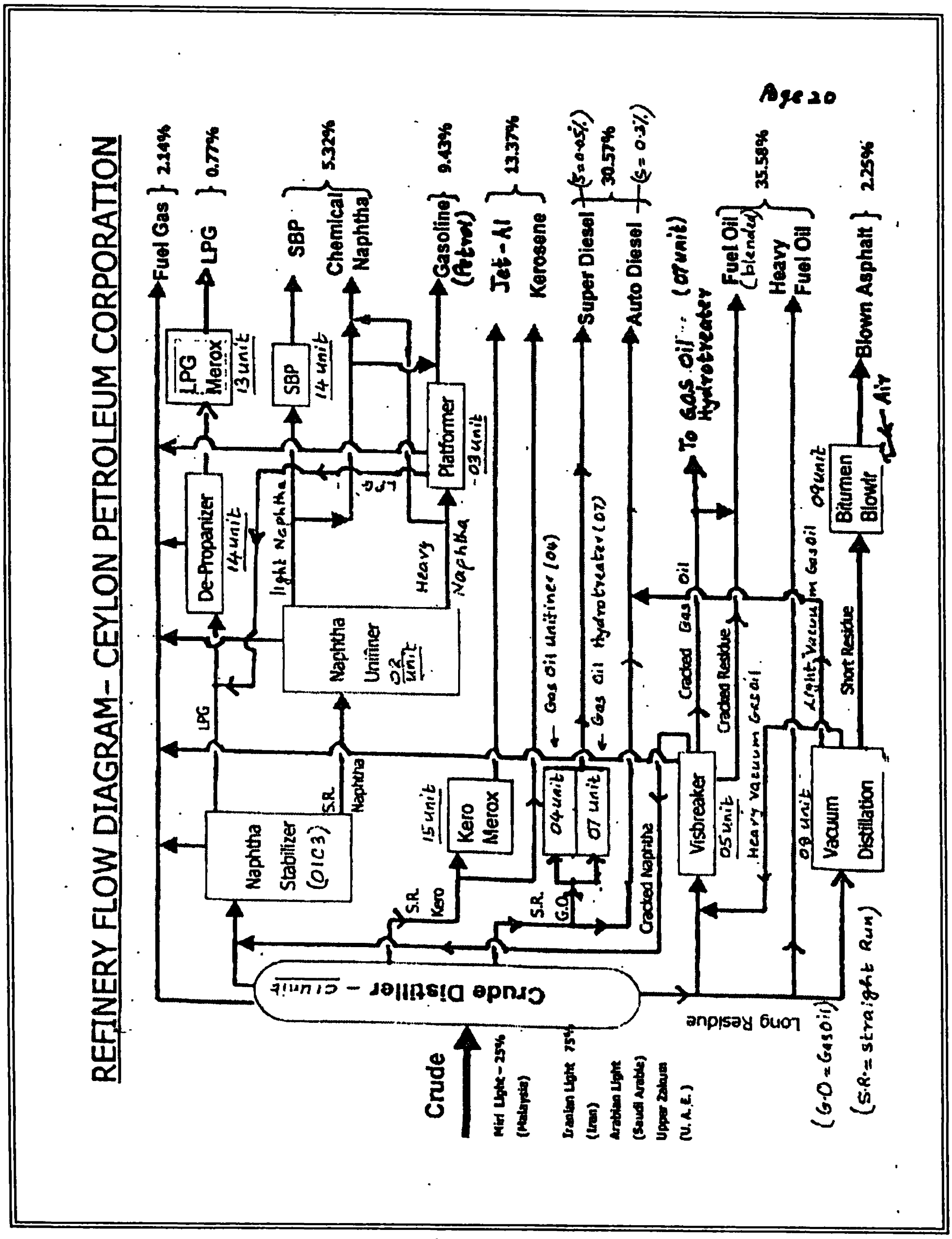


Figure 3_2. Overall Refining Process

3.2 Identification of the Utilities

As same as identification of the refining process, at first, few overview was taken from the external supervisor about the utilities and their processes through the questions "what are utilities, How they are utilized in the refining process and what are the utility systems available in the refinery" to be used in the audit.

Then the study was carried out on each system by using the operating manuals in the technical library and relevant field observations. During the field visits each system was carefully observed and studied. All the resource usages and wastages were measured and quantified

Here this study pointed out of five major utility systems namely

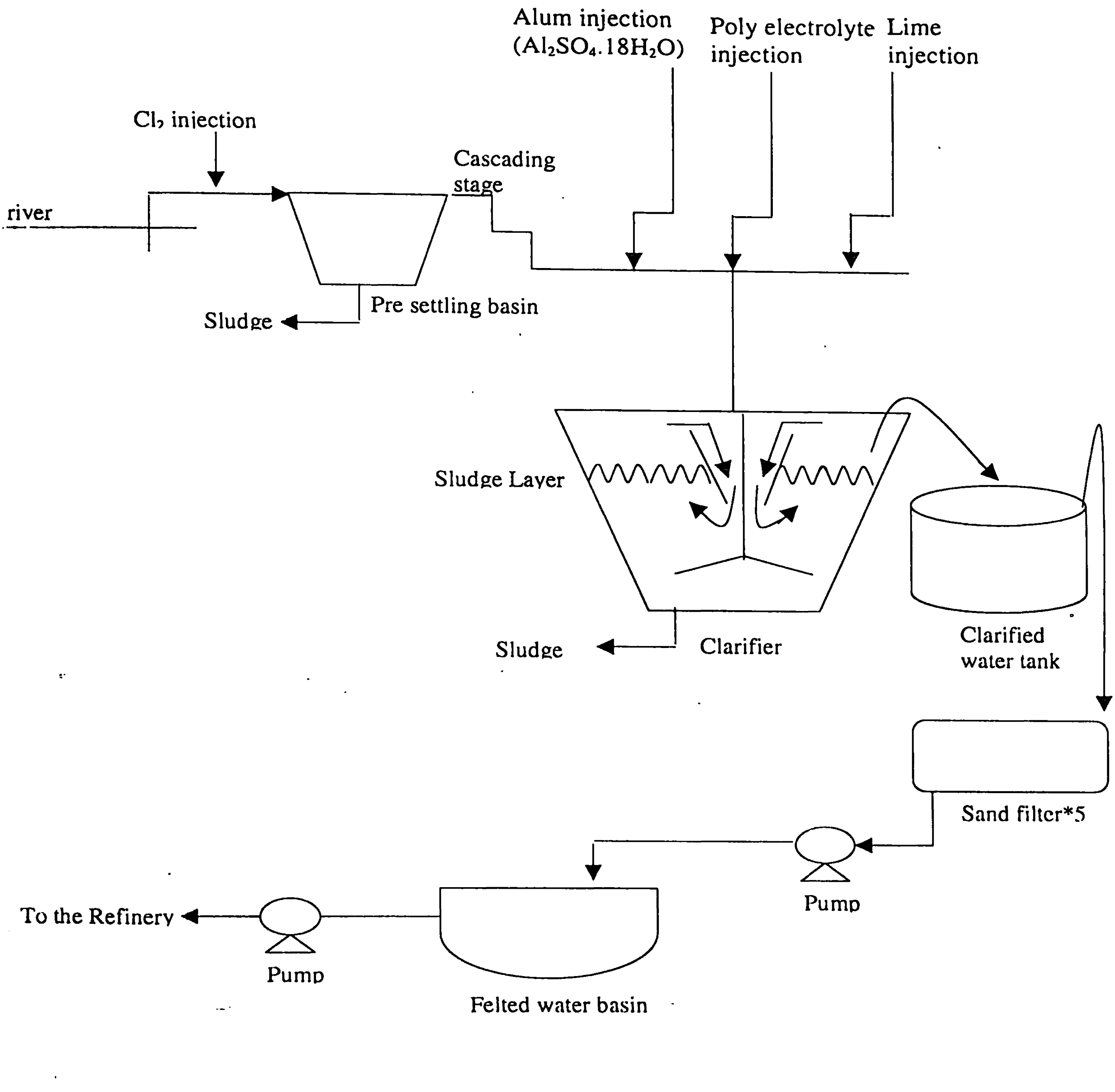
1. Raw water intake and treatment system
2. Drinking water system
3. Cooling water system
4. Steam and Condensate system
5. Instruments and tool air system

After the study, flow diagram was prepared and which will be shown under each units. Each unit is described in the next section

3.2.1 Raw water intake and treatment system.

The pipe house, pre settling stage , clarification stages, receiving tanks, sand filters, water basins located at the Gonawala were visited and monitored for each stage. In addition to monitoring of each stage, the process occurred each stages, the chemicals used and their reactions were studied and quantified.

After studying the systems, a flow diagram was created including all the stages and their processes. In addition to those studies, all the wastage points of this system were detected and the causes and the prevention methods of this loses were studied. The more details about the loses will be discussed in the next section.



gure 3_3. Raw water intake and treatment system

3.2.2 Drinking water system

Each stages of this system, namely motor/turbo driven pumps, basins, activated carbon filter, chlorine injection stage were carefully monitored and studied.

In addition to studying the processes of each stages, the types of possible loses that can be happen were identified and their points were detected.

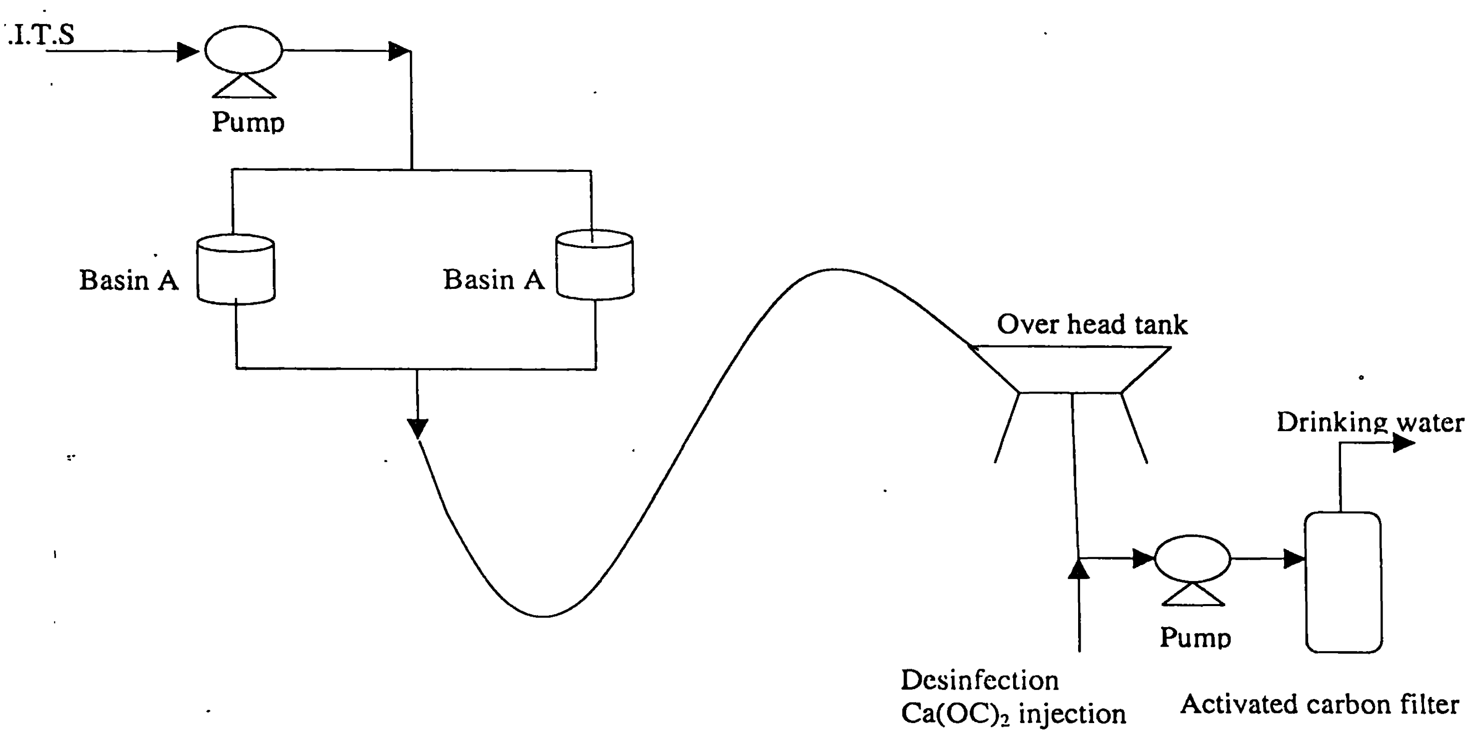


Figure 3_4. Drinking water system

3.2.3 Cooling water system.

Like in the previous section, at first each of the units of this system and their processes were carefully monitored, specially cooling tower, cooling water pond, recycling transfer lines, heat exchangers and trim coolers. After studying of this system, a flow diagram was drawn and it is shown below.

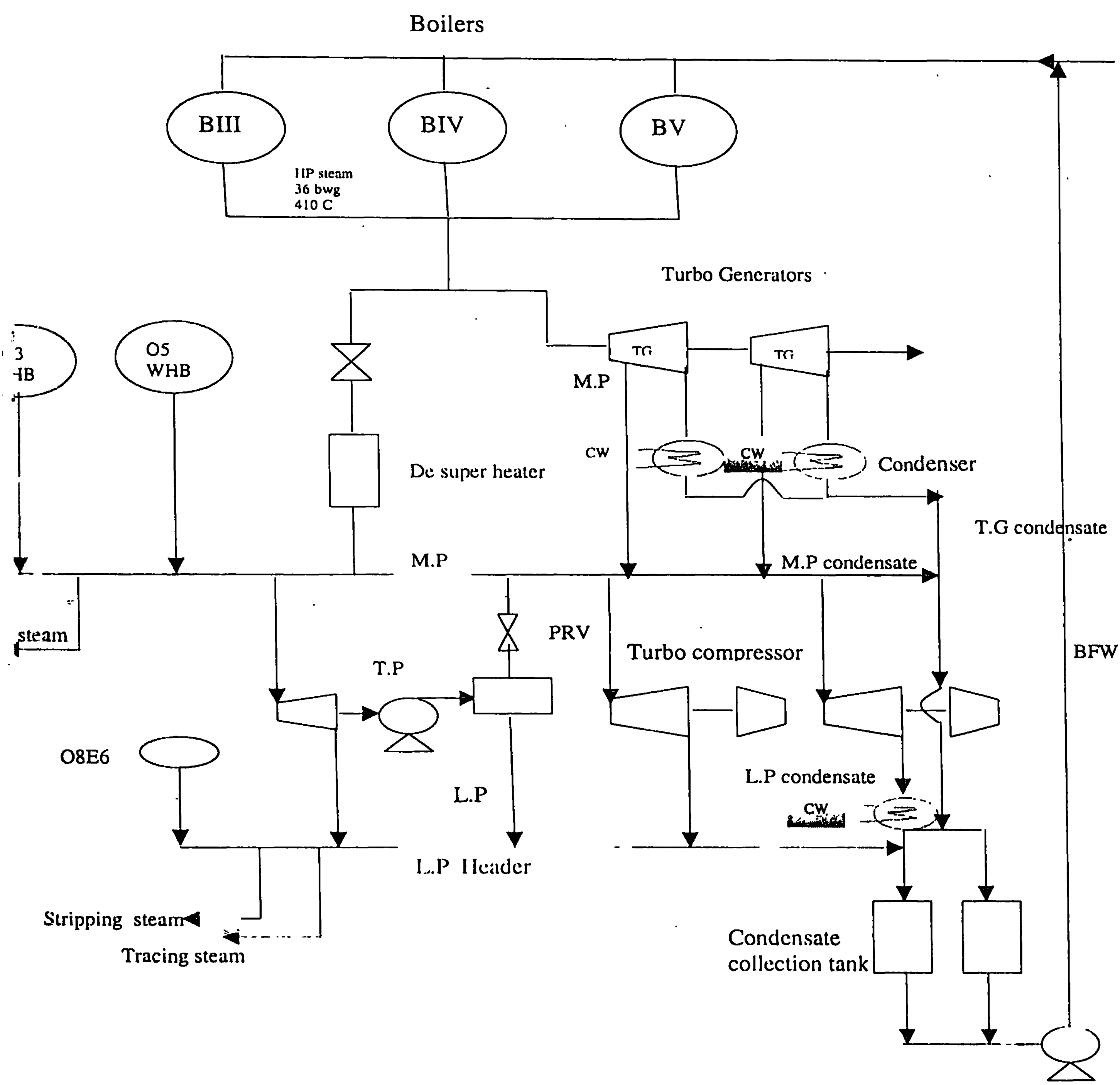
It was pointed out that all possible loses of this system including cooling tower and it will be discussed more in the discussion section.

3.2.4 Steam and Condensate system

The boilers, turbines, steam transfer lines, steam traps and steam condensers. All the mentioned units of this system firstly was monitored and then studied more for the types of boilers used in the refinery, the fuels used for that boilers & the processes occurred in boilers, the properties of the steam produced by this boilers.

In addition to the process of steam and condensate system , the structure of the steam condensers and turbines were also studied. Together with that the tasks of the steam traps and their structure were also studied.

Finally the damaged steam traps, pipe leaking points were detected. Eventually a flow diagram of this system was created and it is shown below.

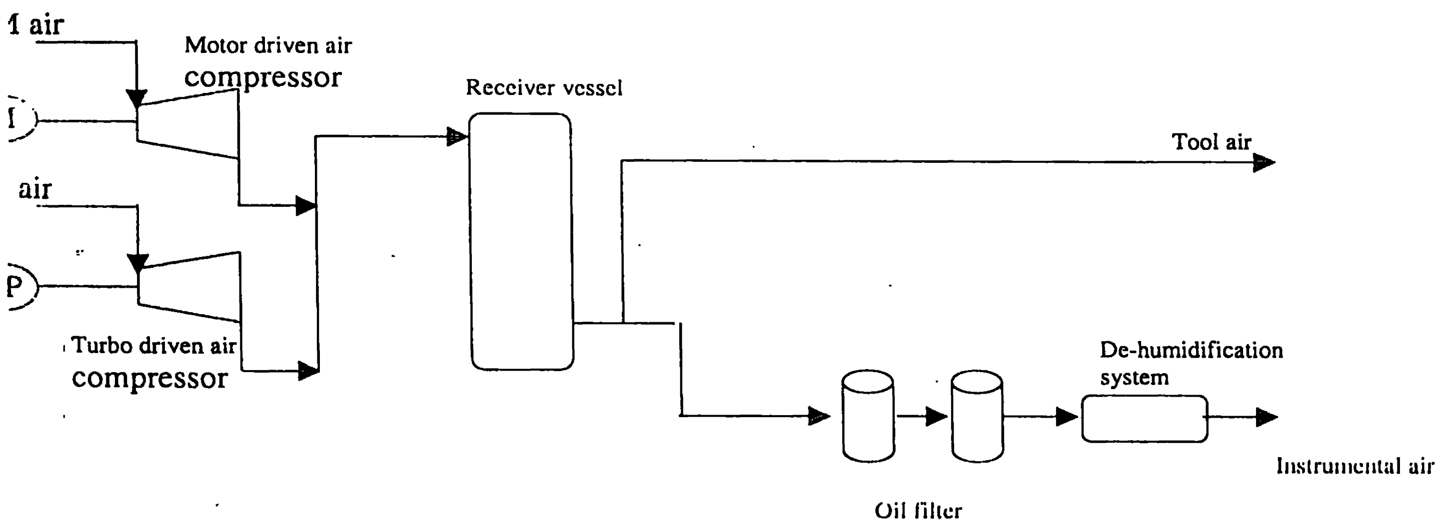


ıre 3_5. **Steam and Condensate system**

3.2.5 Instrumental and tool air system

In this the units, which are mentioned are the turbo driven and motor driven compressors, receiver vessels, oil filters and De humidification system. The process occurred ,the structures and the flow path ways of this units were identified to create the following flow diagram.

The flow diagram is shown below.



igure 3_6. Instrumental and tool air system

All the possible loses and the places where that loses can happen were detected and their causes and prevention methods were noted.

3.3 Quantification

Here aim was to categorized and quantify wastage at each utility system.

The following loses were detected over the four major utility system as illustrated below.

1. Drinking water system
   - Pipe leaks
   - Over flows
   - Excess chlorine

2. Cooling water system
   - Pipe leaks
   - Evaporation loses
   - Windage loses
   - Blow down loses

3. Steam and condensate system
   - Boiler blow down loses
   - Pipe leaks
   - Condensate loses

4. Instrumental and tool air system
   - Pipe leaks

3.3.1 Drinking water system

Above three forms of loses have been detected in this system.

1. Pipe leaks
2. Tank over flows
3. Excess chlorine

3.3.1.1 Pipe leaks

The leaking points were identified at following locations. Such as

1. Canteen
2. Labotary
3. Administration building
4. Utility room
5. Army matrix
6. Training centre
7. Housing scheme
8. Workshop
9. Control room
10. Material department
11. Security points

The quantity of drained water for a period of 15 minutes was collected and measured. This was carried out every first and third weeks during four months period. All the gathered data are shown on the table1_1 in appendix I . The total water loses from all points has been calculated for each day. Eventually the average water loses in 15 minutes has been calculated using above values.(total water loses for each day.)

The cost , of loses per day has been calculated using the drinking water production cost of the refinery.

3.3.1.2 Tank over flows

In this , All the water storage places in the refinery were identified as follows

1. Canteen
2. Labotary
3. Administration building
4. Utility room
5. Army matrix
6. Training centre
7. Housing scheme
8. Workshop
9. Control room
10. Material department
11. Security points

The quantities of the over flowing water was collected in every time water is pumped. This was carried out in every first and third week during the four month period. The gathered data for each days is shown on table 1_2 in appendix I.

The total over flow water quantity was calculated for each day of the weeks. By using these values, the average overflowing water quantity per day has been calculated.

The cost of the drinking water loses has been calculated by using the average water lose and the production cost of drinking water per metric ton.

3.3.1.3 Excess Chlorine

The aim of this was to find the quantity of excess Chlorine that is injected before the carbon filter. Normally Chlorine is injected as $Ca(OCl)_2$. The purpose of this injection is to kill the pathogenic bacteria constituted in the drinking water.

At the chlorine injection stage, $Ca(OCl)_2$ is injected haphazardly by operators. This cause huge loses in this stage. To find this, the dissolved excess chlorine amount was checked in the drinking water. To achieve this task , several water samples were taken from several location in the Refinery and the dissolved Chlorine concentration was checked. This was carried out during every week of the four month period.

The obtained data is shown on the table 1_3 in appendix I. Using that data , The average chlorine concentration was calculated(the normal dissolved chlorine concentration should be nill).

Using the dissolved excess chlorine , the equalent amount of used excess $Ca(OCl)_2$ was calculated(using stoikiometric ratio of the reaction). The cost spent of the refinery excess $Ca(OCl)_2$ has been calculated using excess amount of $CaOCl)_2$ and the cost of 1 MT of $Ca(OCl)_2$.

3.3.2 Cooling water system

Four types of loses were identified in this system. Such as

1. Pipe leaks
2. Windage loses
3. Blow down loses
4. Evaporation loses

Normally the pipe leaking can happen along the transfer lines and the other loses are available in the cooling tower.

As mentioned in the above coming utility section, the purpose of this system is to cool the hot water from the several processing units in the plant. Mainly the hot water is cooled in the cooling tower. The hot water is drained from top of the column and it will fall in to the pond-established bottom of the tower. Mean while of the water is drained, the air stream is blown from the bottom in a counter current direction of the water. Due to this mechanism the heat is transferred . from water to air. Due to this high pressure air stream, some drops of water is blown away and it is called as "*Windage loses*".

During draining water can evaporate from the drained droplet and from the cooling pond established under the tower. These loses are called as "*Evaporation loses*". Due to evaporation, the salt concentration of the cooling pond can increase. So this water with high salt is not recycled again due to corrosion problems and it will be discarded as blow down loses.

Due to all mentioned loses, the water level of the cooling pond goes down and it is filled by the make-up water, daily. The quantity of the make-up water is equivalent to the total loses of the system.

So the make-up water was calculated in every weeks of the month and by using these values the average make-up water quantity was calculated. All the obtained data is shown at the table 3_1 in the appendix III session.

Every pipe leaking points in this system was identified and collected the drained water quantity from each points. This was carried out every first and third weeks during four months period. The gained data is shown at the table 3_2 in the appendix III session. And here the total water quantity was calculated each day. By using these values & the average water loses was measured.

Normally the other types of loses such as windage, evaporation and blow down loses were difficult to measure separately without having engraining knowledge. So by using the make-up water quantity and total pipe leaking loses, the total windage, evaporation and blow down loses was calculated. The cost that spent for these loses was also calculated by using the cost that spent to produce 1 MT of cooling water.

3.3.3 Steam and Condensate system

Three types of wastage forms have been identified.

1. Boiler blow down loses
2. Pipe leaks
3. Condensate loses

3.3.3.1 Boiler blow down loses

Normally the main task of the boiler is to produce high pressure steam from the water in boiler called as "Boiler feed water". Normally the salt concentration of this B.F.W is increased due to the evaporation occurred in the boilers during steam generation.

So every ten days, the high salt concentrated water is drawn off from the boilers in to the refinery sewer system. Eventually, it is disposal without any treatment. So here huge quantity of water loses can be happened and this kind of loses is called as *Blow down water loses*.

During the project period, this effluented boiler blow down water was collected in certain time period and measured the water quantity. This was carried out every weeks of the four months period and all the obtained data is shown on the table 2_7 in appendix II session.

By using those data , the average water loses per day was calculated. The cost that spent for these loses was also calculated by using the quantity of blow down loses and the B.F.W cost.

3.3.3.2 Pipe leaks

There are three types of steam used in the refinery.

1. High pressure steam
2. Medium pressure steam
3. Low pressure steam

Each type of steam is transferred among each unit through the pipe lines/transfer lines. So according to the steam types, this transfer lines have been categorized as

1. H.P Transfer lines
2. M.P Transfer lines
3. L.P Transfer lines

The pipe leaks can occurr along the transfer lines due to several reasons. Normally there are no any pipe leaks seen in H.P transfer lines. Because if it is happened it will be very dangerous. But number many pipe leaks were identified in M.P and L.P transfer lines. During this project period, each of the leaking points in M.P and L.P transfer lines were detected and its diameters were measured. By using this estimation chart, the annual heat loses were estimated .

All the diameters that were taken from M.P and L.P transfer lines are shown on separate tables 2_5 & 2_6 in the appendix II session. Each estimated heat loses also included in the tables. As well as the cost spent by the refinery for steam loses were also calculated using the current fuel oil price.

3.3.3.3 Condensate loses

As mentioned above, the steam produced by the boilers, is transferred to the transfer lines. During the steam transferring some portion of steam can be condensated . So if this condensate is persist further, the transfer lines can be damaged . Therefore to prevent these damage, the generated condensate has to be removed.

The equipment that is used to remove the condensate at the transfer lines from the steam is called steam traps. During this project period several kind of damaged steam traps were detected. Due to they are not work properly , they can not separate condensate from the steam perfectly . As a result of that their effluent condensate is mixed with steam. Therefore due to this reason a fraction of the condensate is thrown in to the refinery sewage system. So during this project period, the amount of condensate, effluented from each damaged steam traps, was collected in certain time period and its quantity was measured. This was carried out every second and fourth week over four months. All the obtained data was shown at the table 2_1 & table2_2 in appendix II. The effluent quantity of condensate in each M.P and L.P steam traps, is shown separate in the total effluented amount of condensate was calculated each day. By using these values eventually the effluented average condensate quantity were separately calculated in each M.P and L.P steam traps. And by using these values (the average loses and the fuel oil cost) the cost spent for these lost was calculated.

3.3.4 Instrumental and tool air system

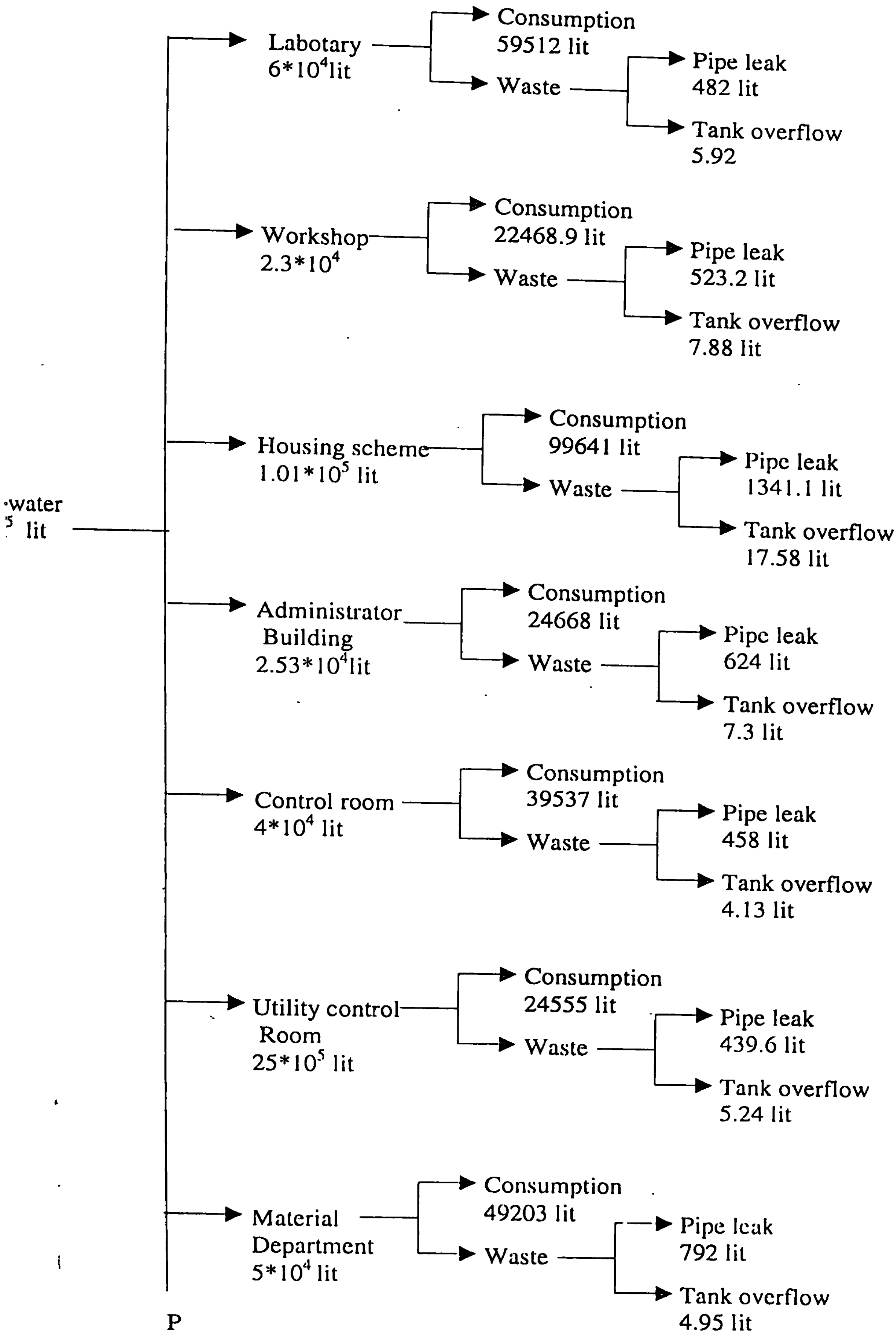
The air that is compressed by the turbo and motor driven compressors, is transferred through the transfer lines among each units. Like steam transfer lines , this transfer lines can also be cracked/damaged due to several causes.

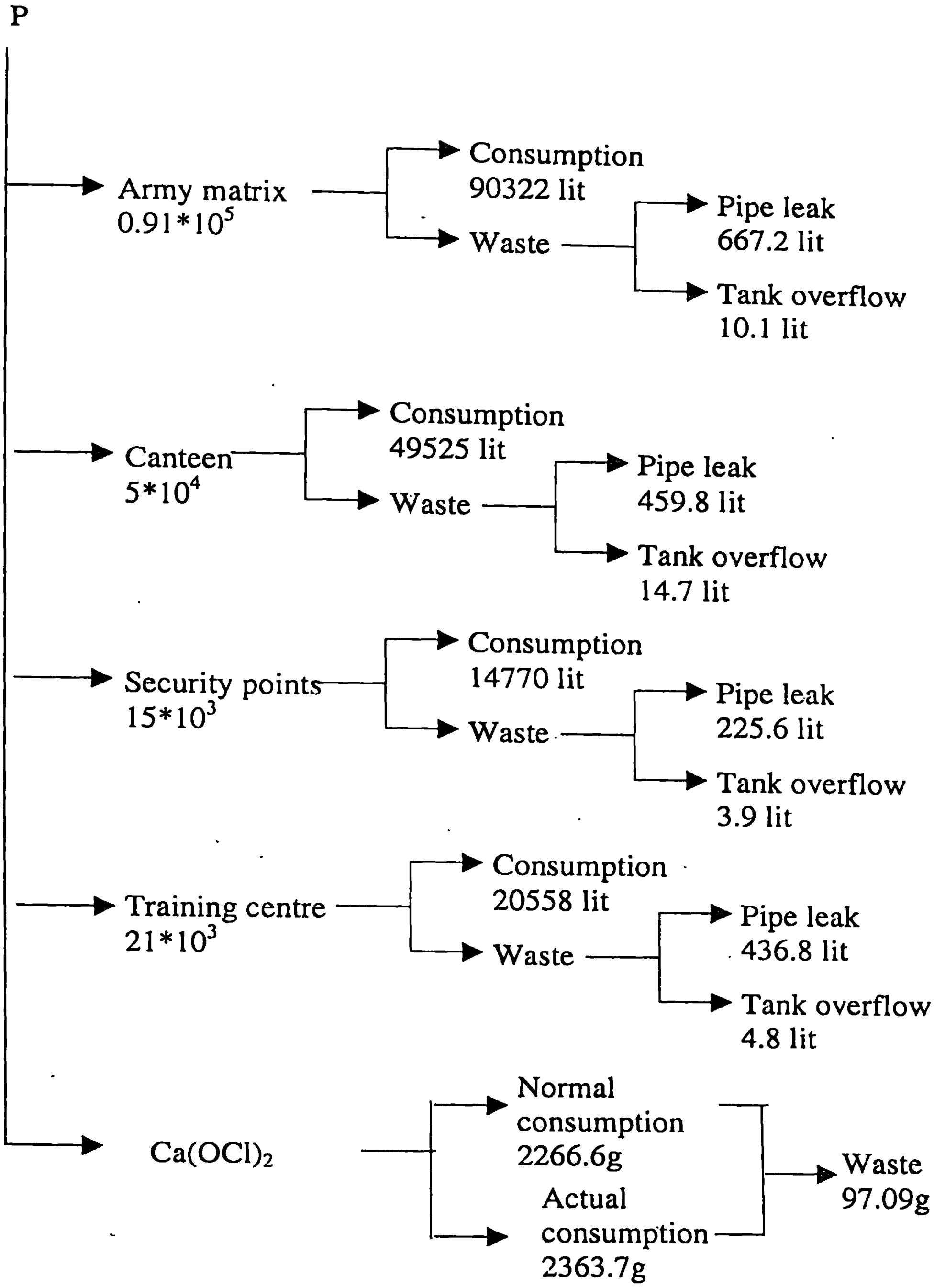
Therefore the air can be leaked from these leaking points . In the project period , these leaking points, located in several work shops were identified and their diameters were measured. The results are given in table 3_3 in the appendix III session . The quantity of air loses that can be effluented from each leaking points was estimated using estimation chart. The cost that spent for these loses was also calculated using the production cost of 1000Ft3 of air and total air loses.

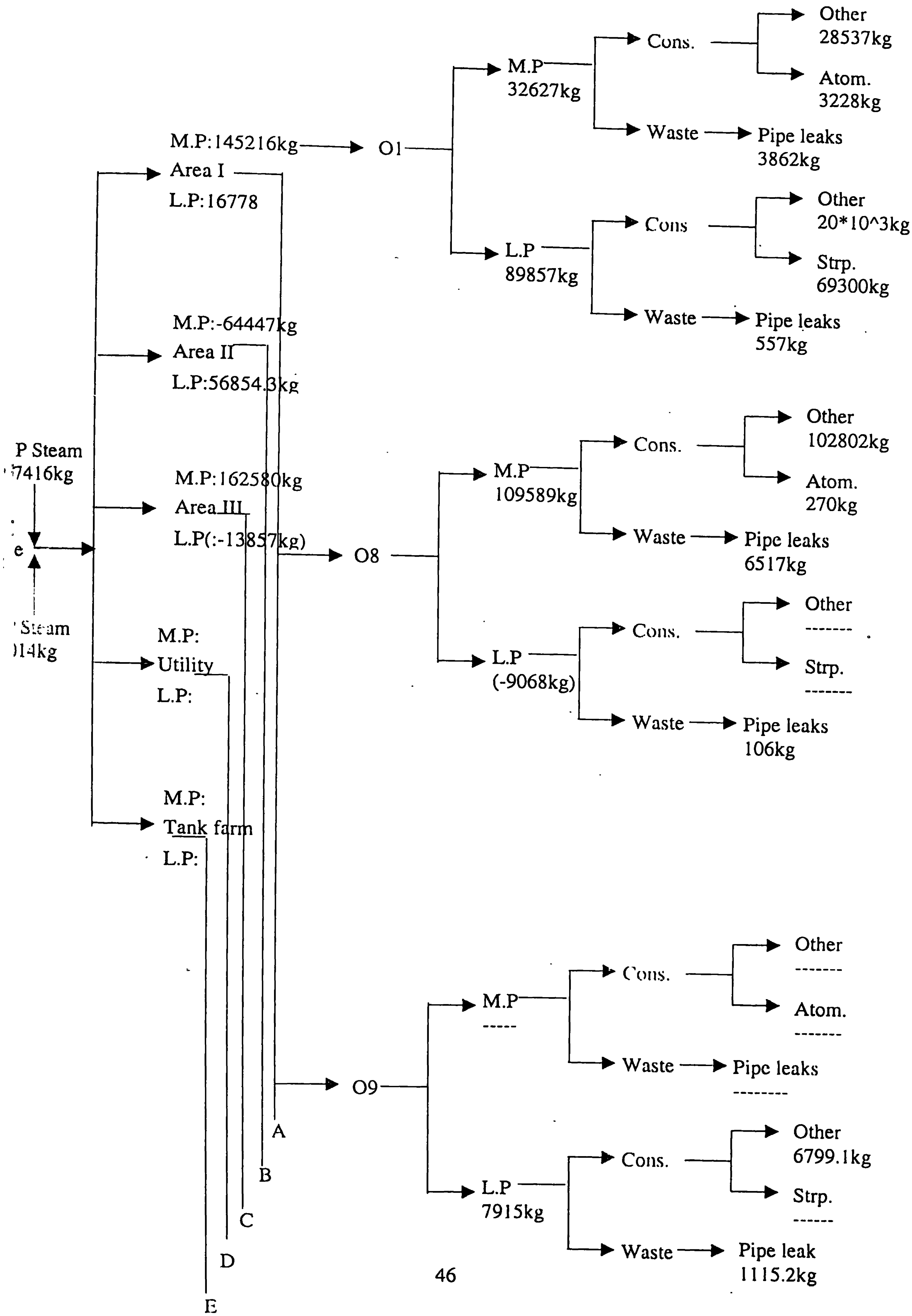
3.4 Material balance

The main objective of this session is to show the production , consumption and waste of each utility system quantity wise in hierarchical manner. So all the produced ,consumed and wasted quantities are given from the diagram shown below.

Summarized material balance




P
Army matrix
0.91*10^5
Consumption
90322 lit
Waste
Pipe leak
667.2 lit
Tank overflow
10.1 lit
Canteen
5*10^4
Consumption
49525 lit
Waste
Pipe leak
459.8 lit
Tank overflow
14.7 lit
Security points
15*10^3
Consumption
14770 lit
Waste
Pipe leak
225.6 lit
Tank overflow
3.9 lit
Training centre
21*10^3
Consumption
20558 lit
Waste
Pipe leak
436.8 lit
Tank overflow
4.8 lit
Ca(OCl)2
Normal consumption 2266.6g
Actual consumption 2363.7g
Waste
97.09g



P Steam
'7416kg
e
' Steam
)14kg
M.P:145216kg
Area I
L.P:16778
M.P:-64447kg
Area II
L.P:56854.3kg
M.P:162580kg
Area III
L.P(:-13857kg)
M.P:
Utility
L.P:
M.P:
Tank farm
L.P:
A
B
C
D
E
O1
M.P
32627kg
Cons.
Other
28537kg
Atom.
3228kg
Waste
Pipe leaks
3862kg
L.P
89857kg
Cons
Other
20*10^3kg
Strp.
69300kg
Waste
Pipe leaks
557kg
O8
M.P
109589kg
Cons.
Other
102802kg
Atom.
270kg
Waste
Pipe leaks
6517kg
L.P
(-9068kg)
Cons.
Other

Strp.

Waste
Pipe leaks
106kg
O9
M.P

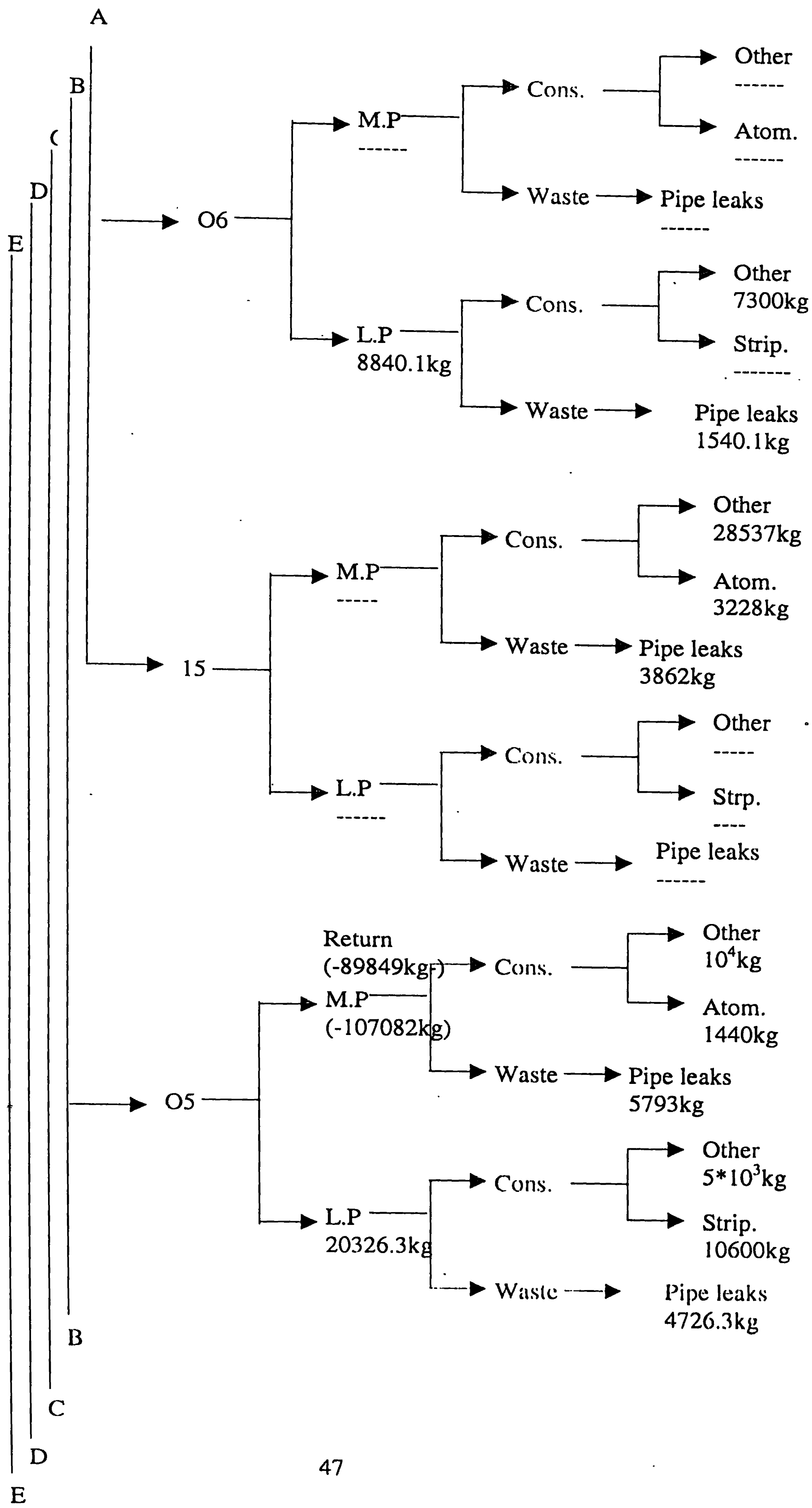
Cons.
Other

Atom.

Waste
Pipe leaks

L.P
7915kg
Cons.
Other
6799.1kg
Strp.

Waste
Pipe leak
1115.2kg


A
B
C
D
E
O6
M.P

Cons.
Other

Atom.

Waste
Pipe leaks

L.P
8840.1kg
Cons.
Other
7300kg
Strip.

Waste
Pipe leaks
1540.1kg
15
M.P

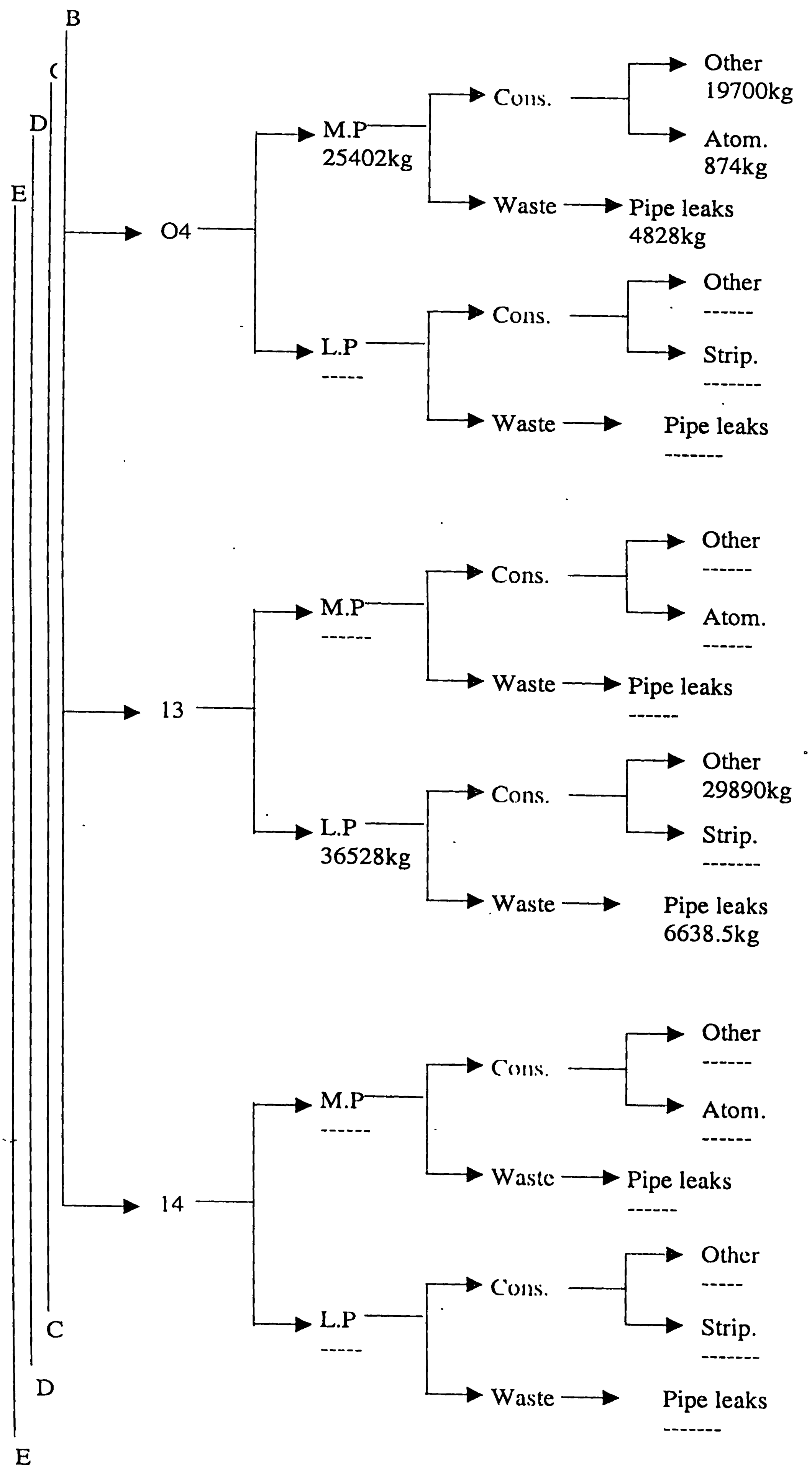
Cons.
Other
28537kg
Atom.
3228kg
Waste
Pipe leaks
3862kg
L.P

Cons.
Other

Strp.

Waste
Pipe leaks

O5
Return
(-89849kg)
M.P
(-107082kg)
Cons.
Other
10^4kg
Atom.
1440kg
Waste
Pipe leaks
5793kg
L.P
20326.3kg
Cons.
Other
5*10^3kg
Strip.
10600kg
Waste
Pipe leaks
4726.3kg
B
C
D
E


B
C
D
E
O4
M.P
25402kg
Cons.
Other
19700kg
Atom.
874kg
Waste
Pipe leaks
4828kg
L.P

Cons.
Other

Strip.

Waste
Pipe leaks

13
M.P

Cons.
Other

Atom.

Waste
Pipe leaks

L.P
36528kg
Cons.
Other
29890kg
Strip.

Waste
Pipe leaks
6638.5kg
14
M.P

Cons.
Other

Atom.

Waste
Pipe leaks

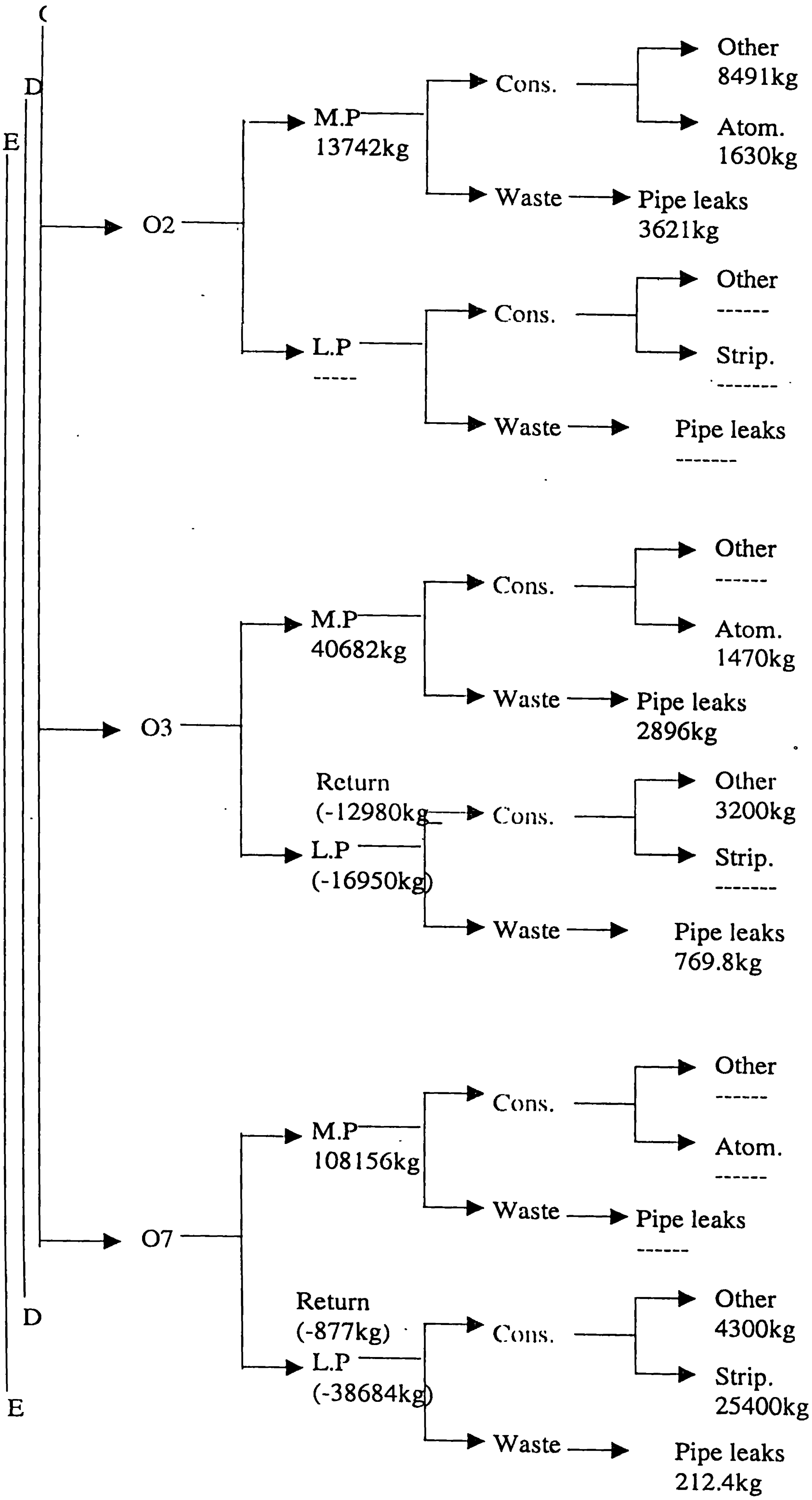
L.P

Cons.
Other

Strip.

Waste
Pipe leaks

C
D
E


C
D
E
O2
M.P
13742kg
Cons.
Other
8491kg
Atom.
1630kg
Waste
Pipe leaks
3621kg
L.P

Cons.
Other

Strip.

Waste
Pipe leaks

O3
M.P
40682kg
Cons.
Other

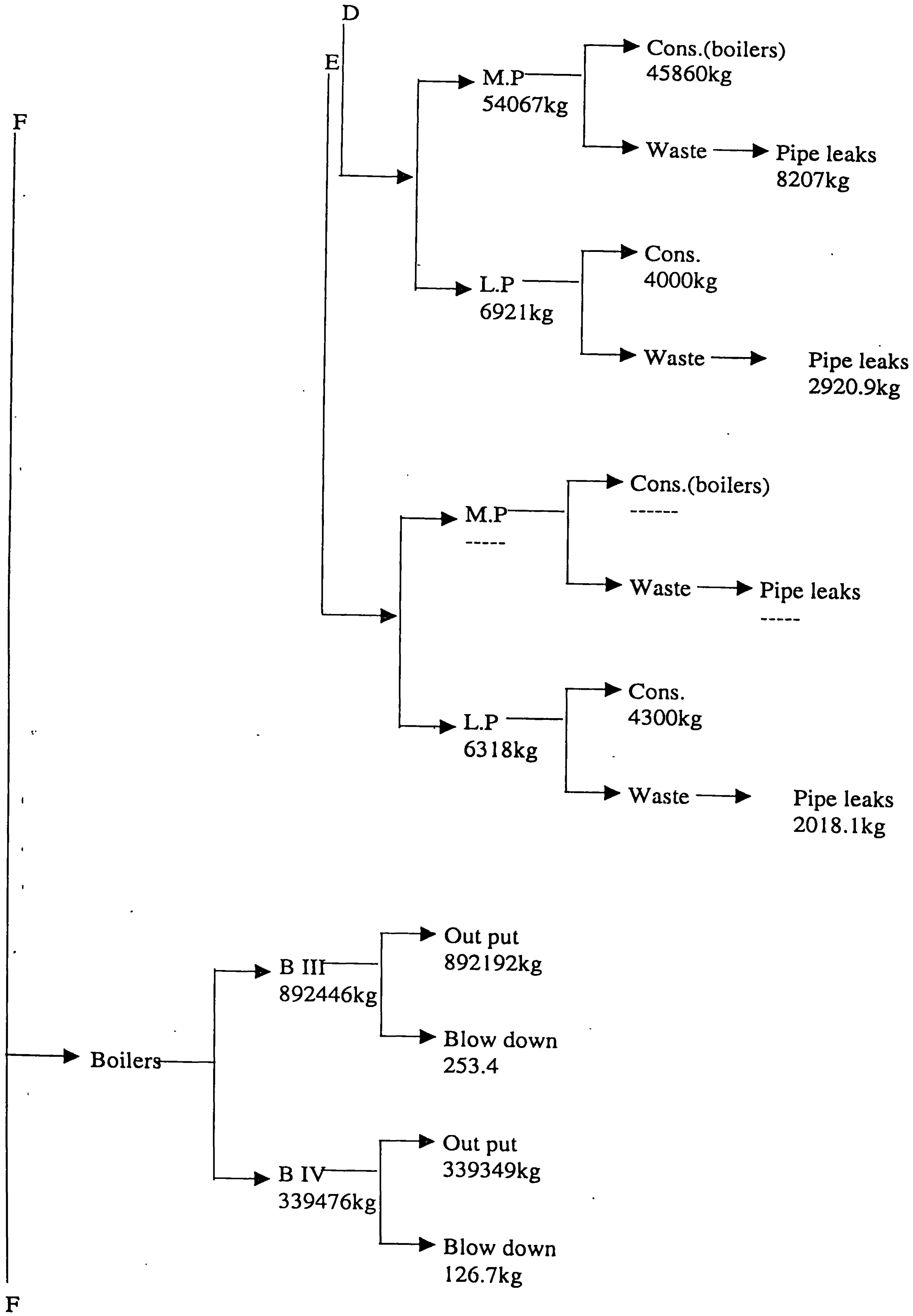
Atom.
1470kg
Waste
Pipe leaks
2896kg
Return
(-12980kg
L.P
(-16950kg)
Cons.
Other
3200kg
Strip.

Waste
Pipe leaks
769.8kg
O7
M.P
108156kg
Cons.
Other

Atom.

Waste
Pipe leaks

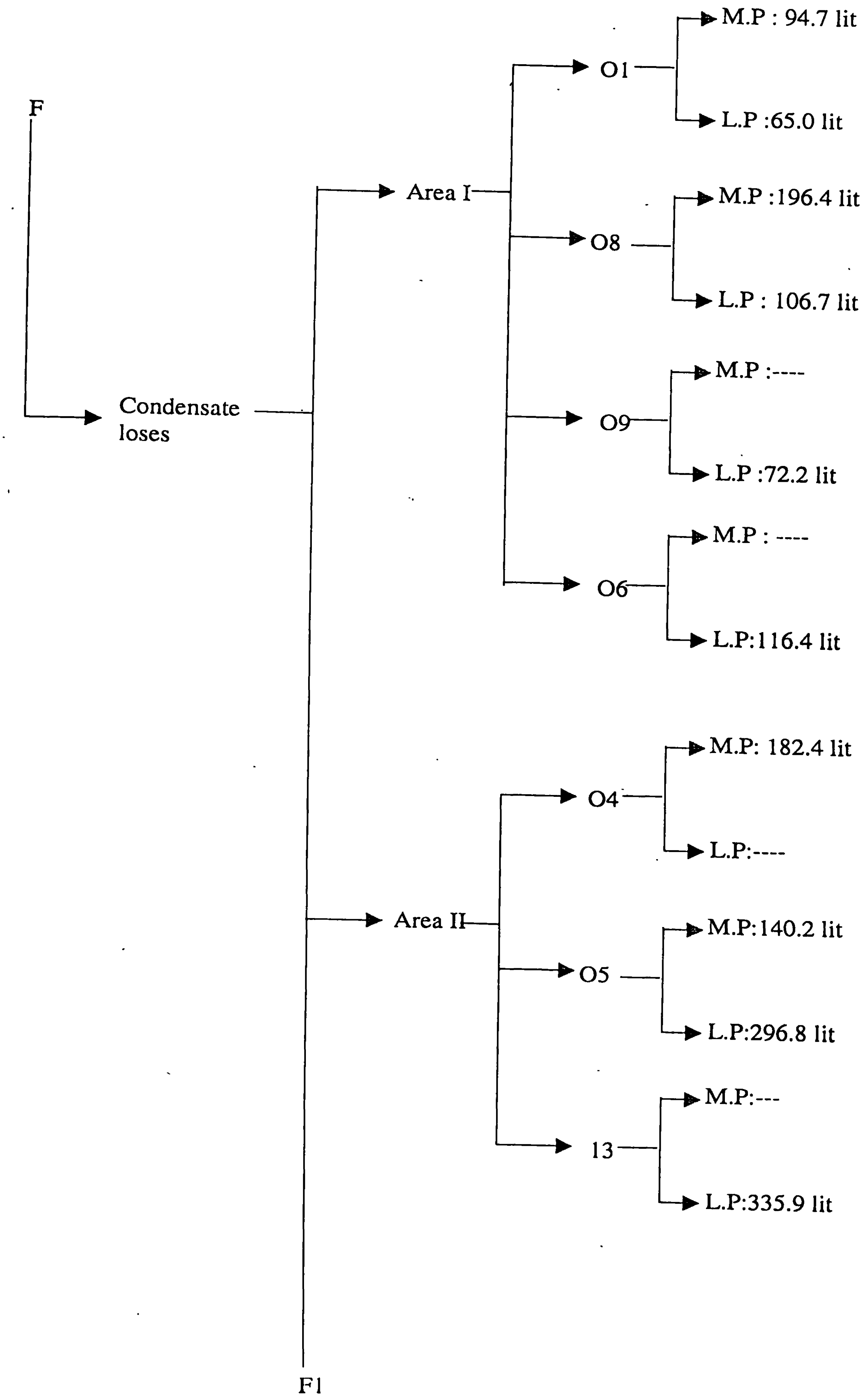
Return
(-877kg)
L.P
(-38684kg)
Cons.
Other
4300kg
Strip.
25400kg
Waste
Pipe leaks
212.4kg
D
E

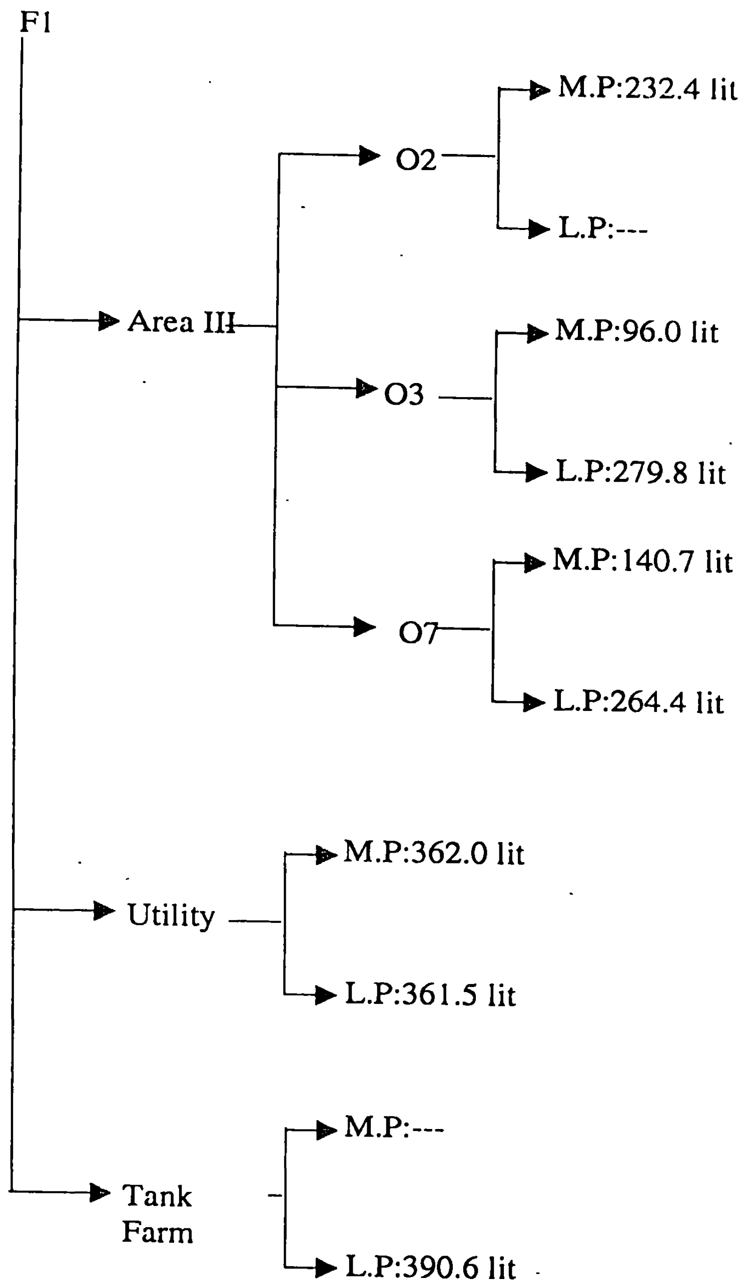

D
E
F
M.P
54067kg
Cons.(boilers)
45860kg
Waste
Pipe leaks
8207kg
L.P
6921kg
Cons.
4000kg
Waste
Pipe leaks
2920.9kg
M.P

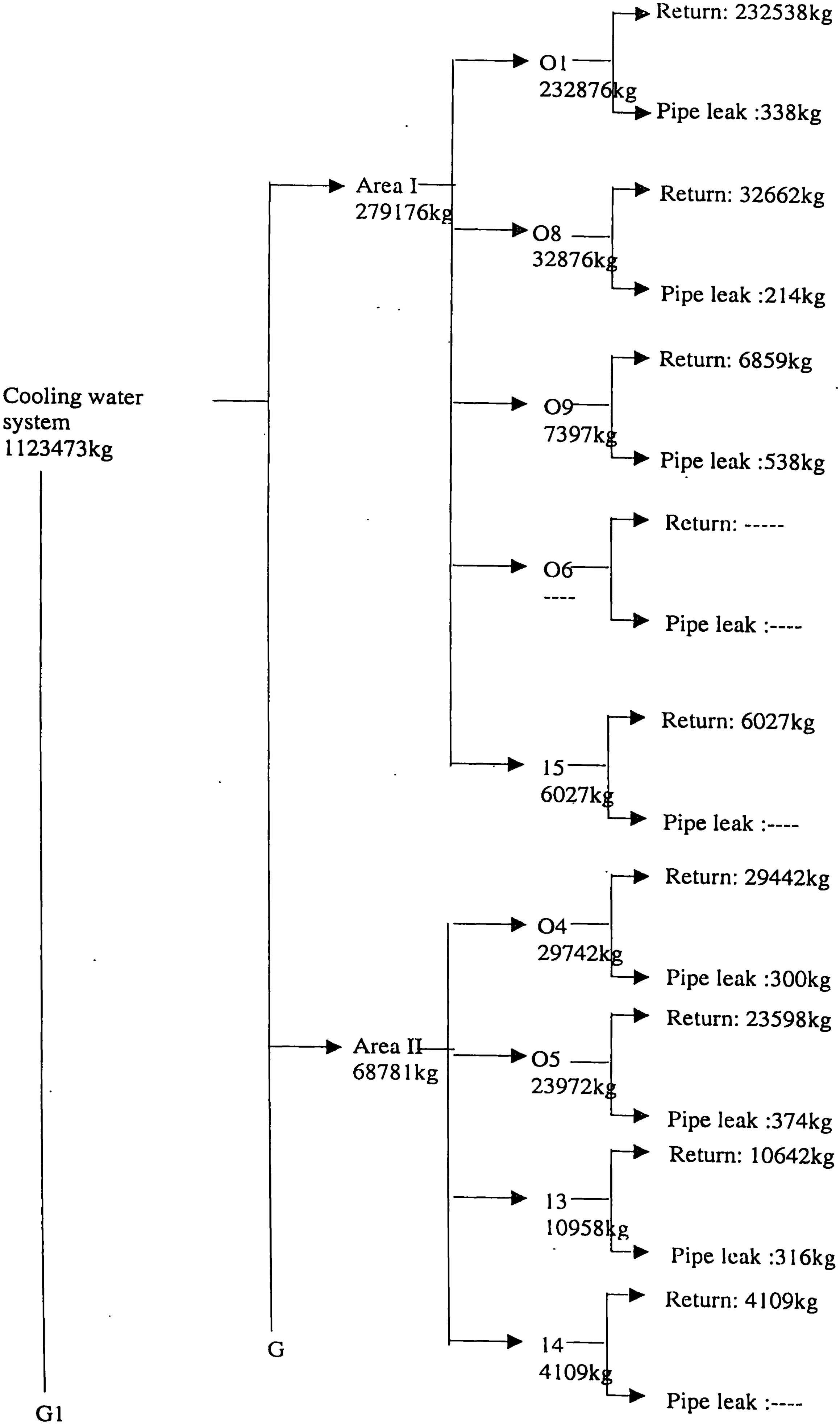
Cons.(boilers)

Waste
Pipe leaks

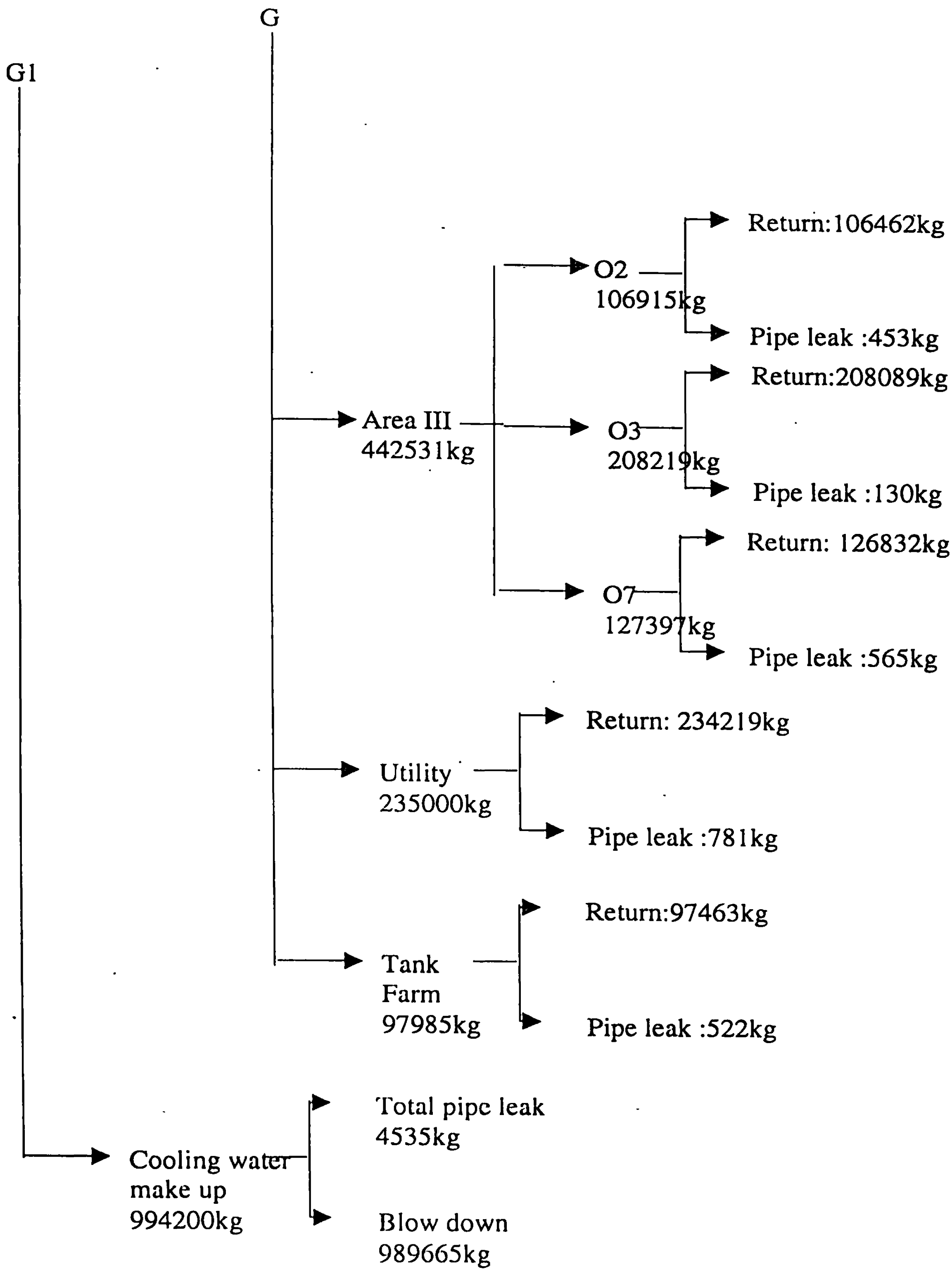
L.P
6318kg
Cons.
4300kg
Waste
Pipe leaks
2018.1kg
Boilers
B III
892446kg
Out put
892192kg
Blow down
253.4
B IV
339476kg
Out put
339349kg
Blow down
126.7kg
F

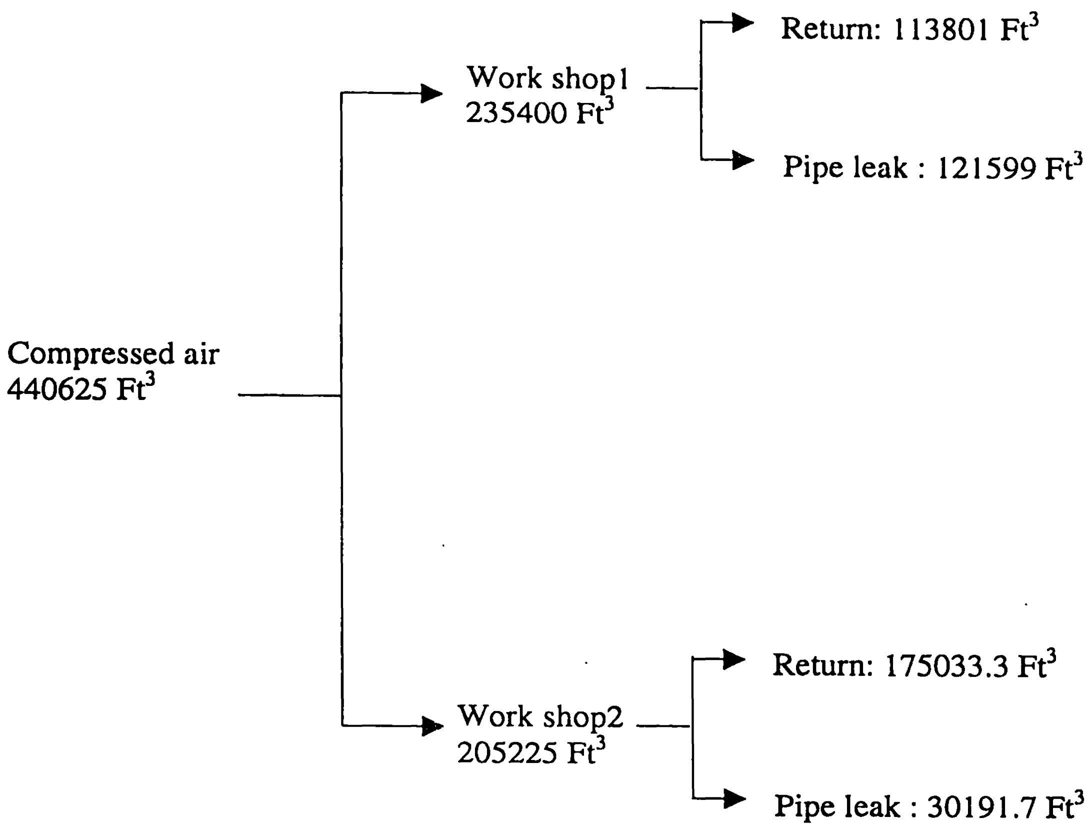

F
Condensate loses
Area I
O1
M.P : 94.7 lit
L.P :65.0 lit
O8
M.P :196.4 lit
L.P : 106.7 lit
O9
M.P :----
L.P :72.2 lit
O6
M.P : ----
L.P:116.4 lit
Area II
O4
M.P: 182.4 lit
L.P:----
O5
M.P:140.2 lit
L.P:296.8 lit
13
M.P:---
L.P:335.9 lit
F1


FI
Area III
O2
M.P:232.4 lit
L.P:---
O3
M.P:96.0 lit
L.P:279.8 lit
O7
M.P:140.7 lit
L.P:264.4 lit
Utility
M.P:362.0 lit
L.P:361.5 lit
Tank Farm
M.P:---
L.P:390.6 lit


Cooling water system
1123473kg
G1
G
Area I
279176kg
O1
232876kg
Return: 232538kg
Pipe leak :338kg
O8
32876kg
Return: 32662kg
Pipe leak :214kg
O9
7397kg
Return: 6859kg
Pipe leak :538kg
O6

Return: -----
Pipe leak :----
15
6027kg
Return: 6027kg
Pipe leak :----
Area II
68781kg
O4
29742kg
Return: 29442kg
Pipe leak :300kg
O5
23972kg
Return: 23598kg
Pipe leak :374kg
13
10958kg
Return: 10642kg
Pipe leak :316kg
14
4109kg
Return: 4109kg
Pipe leak :----


G
G1
Return:106462kg
O2
106915kg
Pipe leak :453kg
Return:208089kg
Area III
442531kg
O3
208219kg
Pipe leak :130kg
Return: 126832kg
O7
127397kg
Pipe leak :565kg
Return: 234219kg
Utility
235000kg
Pipe leak :781kg
Return:97463kg
Tank
Farm
97985kg
Pipe leak :522kg
Total pipe leak
4535kg
Cooling water
make up
994200kg
Blow down
989665kg



The material balance accounts for only four major systems, out of the several utility systems. They are .

1. Drinking water system
2. Cooling water system
3. Steam and Condensate system
4. Instrumental and tool air system

Here the clarified water stream come from the pump house located at the Gonawala, this is splitted in to three streams are one stream goes towards the drinking water system and the other two streams diverted to cooling water system and boilers (as B.F.W).

In the drinking water system , the allocated water quantity for this system , is distributed further to the labotaries, workshops, housing scheme, administration building, control room , utility room , material in the army matrix, canteen , security points and training centre. As shown above the diagram , the larger portion of drinking water has been allocated for the housing scheme. Because its. water consumption rate is higher than the others. And in every point , one portion of water has been consumed and the other portion has been wasted. Two type of waste have been identified here

1. Pipe leaking
2. Tank overflow

Each of the wasted water quantities of the material balance were taken from the measured average values during the project work. Normally the water loses from pipe leaking is comparatively higher than the water amount effluented from tank overflowing.

In addition to the water loses of the drinking water system, there are other type of loses that can be happen e.g. $Ca(OCl)_2$ loss. This loses was also included as a part of the drinking water system of the material balance . Here in this diagram, the actual consumption of $Ca(OCl)_2$ is higher than the normal consumption rate. There are several causes for that. The main cause is the carelessness of the plant operators. In the material balance , the excess amount of $Ca(OCl)_2$ addition per day has been calculated using normal and actual consumed values.

The next utility system described in the material balance is steam and condensate system. According to the diagram, here, only two type of steams were considered. They are M.P steam and L.P steam. The H.P steam was not considered here. Because there are no any possible waste points in this H.P steam pipe lines. This steam has been distributed over five areas of the refinery such as

1. Area I
2. Area II
3. Area III
4. Utility section
5. Tank farm

In this each of area use both M.P and L.P steam except tank farm. In the tank farm the only L.P steam is used. If we consider the L.P and M.P steam values used in each area , some are positive values which denote the "consumption" and some are negative values which denote the "production" of this steam .

The O1,O8,O9,O6 and 15 are the units which are established in area I . So the total M.P and L.P steam are further diverted in to these units. The diverted amount of each units is shown in the diagram. No steam type is used in 15 unit. Only L.P steam is used in O9 and O6. There is a L.P steam production occurring in O8, instead of steam consumption.

There are four units established in area II namely

1. O5
2. O4
3. 13
4. 14

No steam is used in unit 14 ,only M.P and L.P steams have been used in O4 and 13 units respectively. M.P steam production occurred in O5 unit, instead of the steam consumption . The O2, O3 and O7 are the units that established in the area III.

Both M.P and L.P steam can be wasted in pipe leaks in every section. Also the M.P steam can be consumed as two types.

1. Turbine steam
2. Atomizing steam

The L.P steam can be consumed as tracing and stripping steam. Not only the steam , some portion of water can also be wasted in each area of this system, as

1. Condensate loses- From damaged steam traps
2. Boiler blow down loses- From Boilers

The condensate loses of each area are illustrated in the same hierarchy of the steam and condensate system. Also the total water intake for each boilers in the refinery and their produced steam quantity and the blow down loses were also included in this diagram.

The next utility system is the cooling water system. The portion of water that was gained from Kelani Ganga, is diverted in to this system. As shown in the diagram , this water amount is diverted in to the same units described in the steam and condensate system. The amount of cooling water addition , the amount of cooling water returned from each units and the loses are described in the diagram.

Here, the loses can occur as Pipe leaks, windage, evaporation and blow down . Except pipe leaking, the other loses occur in the cooling tower. The total have been calculated in this material balance by using make-up water and total pipe leaking quantities.

The next utility system is the instrumental and tool air system. The generated compressed air by the two compressors , is distributed over three workshops called workshop I ,II, III . According to this material balance the one portion of the produced air is consumed in this work stations to work several instruments such as hand drillers and for controlling pneumatic valves, the other portion is lost as waste . Only one wastage type can be seen here. Which is pipe leaks.

3.5 Calculations and Comparison

This section is allocated for all the calculations which were used to calculate the loses and the cost spent for that loses in each system. Each of the calculation methods are described under each system.

3.5.1 Electricity system

Normally the electricity requirement of the refinery is achieved from two Diesel and Turbo generators and also from the national grid. Specially, the turbo and diesel generators produce the electric power by working its normal efficiency rate . But if those generators work its maximum efficiency, the consumed fuel oil can be saved and also the generated electric power can be promoted. The produced electricity and its fuel consumption rate was obtained in current and maximum mode of each generator .

By using these values, the total cost that spent for the diesel and turbo generators was calculated in each current and maximum mode, separately. And also here, the consumed C.E.B electricity rate of each mode and the spent cost for this power were also calculated separately. By using these values the total cost spent for the turbo, diesel generators and for the C.E.B power were calculated each mode. After balancing the cost of each mode , the profit that can be gained by working in maximum mode was calculated .

3.5.2 Drinking water system

Three type of water loses and the cost spent for each loses were calculated. And the type of loses and their calculation method is described below.

The types of loses

1. Pipe leaks
2. Tank overflows
3. Excess $Ca(OCl)_2$

3.5.2.1 Pipe leaks

According to the data shown in the table 1_1 in appendix session, the total effluented water quantity from each leaking point of each days was calculated separately. By using each values , the average water loses was calculated. Refinery drinking water production cost for 1000 litre was taken from the refinery budget . By using these values, eventually the cost that spent for the pipe leaking loses was calculated .

3.5.2.2 Tank over flow

According to the data shown on the table 1_2 in appendix I session , the total daily water loses effluented from each location was calculated separately. By using these values, the average water loses was calculated. Then the refinery drinking water production cost value for 1000 litre was taken from the refinery budget. By using these values, the cost that spent for that loses was calculated.

3.5.2.3 Excess $Ca(OCl)_2$

According to the data shown at the table 1_3 in appendix I session , the total dissolved Chlorine concentration of each day was calculated . The average dissolved Chlorine value was calculated by using that total values. By subtracting this actual value from the normal value of dissolved chlorine concentration of drinking water, the excess dissolved chlorine concentration was calculated . According to the stoichiometric ratio of the reaction of $Ca(OCl)_2$ with H_2O, the equelent excess $Ca(OCl)_2$ additon per day was calculated . Also the cost of 1 Kg of $Ca(OCl)_2$ value was taken from the material department. By using these two value, the cost spent for that excess $Ca(OCl)_2$ loss was calculated.

3.5.3 Cooling water system

Here four types of water loses and the cost spent for each loses were calculated. The type of loses and their calculation methods are described below.

Types of losses

1. Windage loses
2. Blow down loses
3. Evaporation loses
4. Pipe leaking

3.5.3.1 Pipe leaks

According to the data on the table 3_2 in appendix III session the total water loses effluence from every point was calculated each day. By using these total values , then the average water loses was calculated. The cost that spent by the refinery to prepare cooling water, was taken from the refinery budget. By using these value, the cost spent for that loses was calculated. And in addition to this values , the average cooling water make-up of the refinery was also calculated by using the data on the table in appendix session .

3.5.3.2 Windage , Blow down and evaporation loses

Normally these loses are difficult to find separately without having engineering knowledge . The total windage , blow down and evaporation loses were calculated instead of finding them separately, by using the average make-up water quantity and total pipe leaks loss.

3.5.4 Steam and condensate system

Three type of loses and the cost spent for each loses were calculated. The type of loses and their calculation methods are described below.

Here also three types of loses were identified

1. Pipe leaks
2. Condensate loses
3. Boiler blow down loses

3.5.4.1 Pipe leaks

Here according to the table 2_5 & table 2_6 shown in the appendix II session , the pipe leaks loses are measured separately for the M.P and L.P steam. Here according to the diameter of each leaking point , the annual heat loses were estimated in KCal, by using figure 7.2-Estimation chart.

Eventually, the total heat loses that effluented from every leaking point was calculated . Also after finding the current fuel oil price of fuel oil , the annual and daily wastage cost were calculated.

3.5.4.2 Condensate loses

Like pipe leaking ,here also, the condensate loses were quantified separately for M.P and L.P steams. So according to the table 2_1 & table 2_2 in the appendix II session , the total condensate loses from each points was calculated each day and by using those values, the average condensate loses was calculated for each M.P and L.P steam. Also here, the cost spent for water demineralization was taken from the refinery budget. By using these values the cost spent for M.P and L. P steam condensate loses were calculated .

3.5.4.3 Boiler blow down loses

According to the data shown on the table, the average blow down loses was calculated. And also the production cost for 1MT of boiler feed water was taken from the refinery budget and then using these values the wastage cost was calculated.

3.5.5 Instrumental and tool air system

The only the waste type that was formed in this system is pipe leaks. Here also , like steam leaks , according to the diameter of each leaking point, the annual wasted air quantities were estimated. By using each values, the average wasted air volume was calculated, also the cost spent for producing 1000FT3 of air was taken from the refinery budget and then by using these value, the annual and daily wastage cost were calculated.

CHAPTER 04
Calculation and Results

During the project period the resources wastages have been calculated in following units.

1. Electricity system
2. Drinking water system
3. Cooling water system
4. Steam and condensate system
5. Instrumental and tool air system

4.1 Electricity system

Normally as mentioned above the chapter 02, the electricity requirement of the refinery is achieved by

1. Diesel electricity generator
2. Turbo electricity generator
3. National Grid

The usual electricity consumption rate of the refinery is 5.8MW. This rate currently is achieved by supplying 1.5 MW from diesel generator, 3.5MW from turbo generator and remained 0.9 from C.E.B. But if we consider the efficiency of the diesel and turbo generator of the refinery , the current electricity production rate is not the maximum rate of those generators. That means considering the diesel generator , its current electricity production rate is 1.5 MW., but if it works in its maximum efficiency, it can produce 2 MW electricity production. And also as same as the diesel generator , the current electricity generation rate of the turbo generator is 3.4MW, but its maximum electricity production rate is 3.8 MW. So the current and maximum rate of diesel and turbo generators and their fuel consumption rate is shown at table 3_4.

According to the table 3_4 , it is clear if the both generator work with its maximum efficiency, the fuel oil consumption rate can be reduced. Also the refinery electricity consumption rate can be achieved only by both generators themselves without invoking national grid power supply (generated from C.E.B.). If these generators of the electricity system are worked in their maximum efficiency, the huge additional benefit can be gained to the refinery. The amount of additional benefit can be calculated as follows.

1. Current mode

1.1 In diesel generator

Daily electricity generation	= 1.5*24 MWhr
In KWhr	= 1.5*24*1000kWhr
Daily fuel oil consumption	= (35g/1kWhr)*1.5*24*1000kWhr
	= 235*1.5*24*1000g
	= 8460kg

1.2 In turbo generators

Daily electricity generation	= 3.4*24 MWhr
In kWhr	= 3.4*24*1000kWhr
Daily fuel oil consumption	= (440g/1kWhr)*3.4*24*1000kWhr
	= 35904kg

1.3 C.E.B electricity

Daily gained electricity load	= 0.9MW*24 hr
	= 21.6MWHr

2. Maximum mode

2.1 In diesel generators

Daily electricity generation	= 2*24MWHr
In kWHr	= 2*24*1000kWHr
Daily fuel oil consumption	= (225g/1kWHr)*2*24*1000kWHr
	= 25*2*24*1000g
	= 10800kg

2.2 In turbo generators

Daily electricity generation	= 3.8*24MWHr
In kWHr	= 3.8*24*1000kWHr
Daily fuel oil consumption	= (430g/1kWHr)*3.8*24*1000kWHr
	= 430*3.8*24*1000kg
	= 39216kg

2.3 C.E.B electricity

Daily gained electricity	= 0

3. Cost evaluation

3.1 Fuel oil

Current fuel oil price	= Rs. 26.00/Lit
Specific gravity of fuel oil	= 0.95
Density of fuel oil	= $0.95*1000kgm^{-3}$
	= $950kgm^{-3}$
The mass of the fuel oil 1lit.	= $950kgm^{-3}*10^{-3}m^{3}$
	= $950*10^{-3}kg$
The cost of 1kg of fuel oil	= (Rs. $26.00/950*10^{-3}kg$)
	= Rs. 27.36

3.2 C.E.B electricity

Average monthly electricity bill	= Rs. 4315674.00
Average used unit	= 231700kWHr
The cost per 1 unit	= Rs. 4315674/231700kWHr
	= Rs.18.62/KWHr
Cost for 1MWHr	= (Rs.18.62/1kWhr)*1000kWHr
	= Rs. 18620

3.3 In current mode

The cost of 1kg fuel oil	= Rs.27.36
Cost of C.E.B electricity 1MWHr	= Rs. 18620.00

3.3.1 In diesel generator

Daily cost	= (Rs. 27.36/1kg)* 8460kg
	= Rs. 231465.60

3.3.2 In turbo generator

Daily cost	= (Rs.27.36/1kg)*35904kg
	= Rs.982333.44

3.3.3 For C.E.B electricity

Daily cost	=(Rs. 18620/1MWHr)*21.6MWHr
	= Rs.402192

3.4 In maximum mode

3.4.1 In diesel generator

Daily cost = (Rs.27.36/1kg)*10800kg

= Rs.295488

3.4.2 In turbo generator

Daily cost = (Rs.27.36/1kg)*39216kg

= Rs. 1072949.70

3.4.3 For C.E.B Electricity

Daily cost = Rs. 0.00

3.5 Benefit of maximum load operation against current operation mode

3.5.1 In current mode

Total cost per day = Rs.231465.60+Rs982333.44+Rs402192

= Rs.1655991

3.5.2 In maximum mode

Total cost per day =Rs. 295488+Rs.1072949.70

= Rs.1368437.70

3.5.3 The profit per day

= Rs. 1615991-Rs.1368437.70

= Rs.247553.30

4.2 Drinking water system

In this system three type of loses have been identified.

1. Pipe leaks
2. Tank Overflows
3. $Ca(OCl)_2$ loses

4.2.1 Pipe leaks

As the data shown in the appendix session , the water loses rate that can be effluented from the pipe leaks is 4.5Lit per minute. So the cost that spent by the refinery for the water loses can be shown as follows.

The waste water quantity per minute	= 4.5 Lit/min
The waste water quantity per day	=(4.5lit/1min)60min*24Hr
	= 6480lit/day
The cost spent for 1000lit	= Rs.61.54
Cost spent for 1lit	= Rs.61.54*10^{-3}
The additional cost spent for the waste water per day	= Rs.61.54*10^{-3}*6480lit
	= Rs.398.77

4.2.2 Tank over flow

According to the data shown in the appendix session , the average water quantity that can be effluented from the tank overflow is about 86.5lit/day. So the total cost that spent by the refinery per day for these loses, can be calculated as follows.

The waste quantity per day	=86.5lit
The cost spent for 1000lit.	=Rs.61.54
The cost spent for 1lit	= Rs. 61.54*10^{-3}
The additional cost spent for the waste water per day	= Rs. 61.54*10^{-3}*86.5lit
	= Rs. 5.32

4.2.3 Excess $Ca(OCl)_2$

According to the table in the appendix session , the average dissolved chlorine in the drinking water is 0.2ppm.

So according to this value, the amount of injected excess $Ca(OCl)_2$ per day should be calculated and the cost spent for that. The calculation can be done as follows.

Normal dissolved chlorine amount in drinking water	= Nill
Actual dissolved chlorine amount	= 0.2ppm
Excess chlorine amount	= 0.2ppm
0.2ppm means	= 0.2kg of $OCl^-/10^6$kg of water
Number of OCl^- mol dissolved in 10^6kg of water	= $0.2*10^3$g/51.5mol$^-$g
Concentration of OCl^-	= $(0.2*10^3/51.5mol)/10^3m^3$
	= $(0.2*10^3/51.5mol)/10^3*10^3dm^3$
	= $3.88*10^{-6}$ mol dm $^{-3}$

The formula of the reaction

$$Ca(OCl)_2+2H_2O \longrightarrow Ca(OH)_2+2HOCl$$

$$2HOCl \longrightarrow 2H^+ +2HOCl^-$$

According to the stoikeometric ratio , the excess $Ca(OCl)_2$ concentration	= $0.5*3.88*10^{-6}$mol dm^{-3}
Average drinking water consumption per day	= 350MT
	= $350*10^3$kg
The volume of water	= $350*10^3$kg/10^3kgm^{-3}
	= $350m^3$
	= $350*10^{-3}dm^3$

Excess $Ca(OCl)_2$ mol per day =$(0.5*3.88*10^{-6}mol/1dm^3)*350*10^3dm^3$

	= $679*10^{-3}$mol
Excess $Ca(OCl)_2$ mass	= $679*10^{-3}$ mol*143gmol^{-}
	= 97.09g/day

The cost of 1kg of Ca(OCL)	= Rs.373.25
The cost spent for that loss per day	= (Rs. 373.25/1000g)*97.09g
	= Rs. 36.23

4.3 Cooling water system

The four types of waste have been identified in this system.

1. Pipe leaks
2. Windage loses
3. Blow down loses
4. Evaporation loses

Except pipe leaks, the other loses are difficult to measure separately without having engineered knowledge. So as a result of that, the total windage, blow down and evaporation loses have been measured by using make-up water and total pipe leaks.

4.3.1 Pipe leaks

According to the data in appendix session, the average water loses in 15 minutes about 47.241 lit/15min. so the cost spent for this waste per day can be calculated as follows.

The waste water quantity per min.	= 47.24lit/15min
The waste water quantity per day	= (47.24lit/15min)*60*24
	= 4535lit/day
The cost spent for 10^3 lit to make cooling water	= Rs. 75.00
The cost spent for 1lit	= Rs.$75*10^{-3}$
The additional cost spent for the waste water per day	= Rs.$75*10^{-3}$*4535lit
	= Rs. 340.12

4.3.2 Total Windage, Blow down and evaporation loses

Because of some engineered knowledge is needed to calculate these loses separately, here the total windage, blow down and evaporation loses have been calculated by using make-up and total pipe leaking quantities. According to table 1_2 in the appendix session, the average make-up water quantity used per day is 994.2lit. And the total water quantity effluented by the pipe leak is 4535lit/day.

Make-up water quantity =Pipe leak loses+Evaporation loses+Blow down loses+ Windage loses

4841lit =4535lit+Evaporation +Blow down+Windage loses

The total windage, evaporation and blow down loses per day =4841lit-4535lit

=306lit/day

The cost spent for that loses per day =Rs.75*10^{-3}*306lit

=Rs.22.95

4.4 Steam and Condensate system

Three types of loses have been identified in this system

1. Pipe leaks
2. Condensate loses
3. Boiler blow down loses

4.4.1 Pipe leaks

The pipe leaks have been identified in M.P and L.P steam separately. And according to the data in the table, the daily wastage loss occurred from L.P steam leaks can be calculated as follows.

The annual heat loses from L.P steam	= $4888800*10^3$ Kcal
The daily heat loss	= $4888800*10^3$Kcal/365
	= $13393.97*10^3$Kcal
Thapa janana value of fuel oil	= 10278Kcal/kg
The pric of 1kg of fueloil	= Rs. 27.36
The daily wastage cost	= (Rs. 27.36/10278Kcal)*$13393.97*10^3$Kcal
	= Rs. 35654.70

And also according to the data in table, daily wastage loss in M.P steam leaks can be calculated as follows.

The annal heat loses	= $10836000*10^3$Kcal
The daily heat loses	= $10836000*10^3$Kcal/365
	= $29.687*10^6$Kcal
The calorific value of fuel oil	= 10278Kcal/kg
The price of 1kg of fuel oil	= Rs. 27.36
The wastage cost per day	= (Rs.27.36/10278Kcal)*$29.687*10^6$Kcal
	= Rs. 79028.40

4.4.2 Condensate loses

As same as the pipe leaks, this condensate loses also have been identified in M.P and L.P steam transfer lines. According to the data in table2_2, the cost spent for that condensate loses in L.P steam and M.P steam can be calculated as follows.

The average wasted L.P condensate 15 min	= 24114ml/15min
The average wasted L.P condensate per day	= (24114ml/15min)*60*24
	= 2313.5lit/day

And the average wasted M.P condensate per 15 min	= 15.1lit/15min
And the average wasted M.P condensate per day	=(15.1lit/15min)*60*24
	= 1449.5lit
The total M.P and L.P wasted condensate per day	= 2313.5lit+1449.5lit
	= 3763lit
Demineralizer water cost per 1 MT(1000kg)	= Rs.74.58
For m^3 ($1000dm^3$) of water	= Rs.74.58
For 1 lit	= Rs.0.074
So the wastage cost per day	= Rs.0.074*3763lit
	= Rs.278.46/day

4.4.2 Boiler blow down loses

According to the data in table 2_7, the wastage cost for the boiler blow down loss can be calculated as follows.

The A.V.G boiler blow down water quantity	= 1.32lit/5min
The A.V.G boiler blow down water quantity per day	= (1.32lit/5min)*60*24
	= 380.16lit/day
The cost spent to produce 1MT(1000kg) of B.F.W	= Rs.143.65
For 1 m^3 ($1000dm^3$)	= Rs.143.65
The cost spent for 1 lit	= Rs.143.65*10^{-3}
	= Rs.54.60

4.5 Instrumental and tool air system

According to the data in table 3_3, the wastage cost spent for the air pipe leaks can be calculated as follows.

The total annual air loses effluented from identified leak points	= $55400 * 10^3$ FT^3
The cost spent to produce $10^3 FT^3$ of compressed air	= Rs. 94.50
The annual wastage cost	$= (55400 * 10^3 * Rs.94.50)/10^3 Ft^3$
	= Rs.5235300
The cost spent per day	= Rs.5235300/365
	= Rs.14343

CHAPTER 05

Discussion

According to the survey, several point of loses have been detected & the causes and the method to prevent these loses occurred in five major utility system of the refinery.

1. Electricity system
2. Drinking water system
3. Cooling water system
4. Steam and condensate system
5. Instrumental and tool air system

5.1 Electricity system

As mentioned in the result section, because of the electricity power of the national grid is not reliable, the required electricity power of the refinery is generated from its own turbo and diesel generator. In addition to the electricity power generated from those generator, few portion of electricity is taken from the national grid for non critical operation. In the normal sense, to achieve refinery requirement of 5.8MW , 1.5 MW gained from the Diesel generator , 3.4 MW gained from the turbo generator and the remained amount (0.9MW)gained from the national grid for non critical application. According to the calculation , the total cost spent for this generation is Rs. 1615991 per day. But if we carefully inspect these electricity generation , this cost can be reduced. That mean , if we consider the power generation rate of the diesel and turbo generator , is not its maximum rate. If it works with its maximum rate, the fuel consumption spent for generating each electricity power, can be reduced (see table). Not only that according to that table, the electricity power gained currently from the national grid , can be minimized up to zero level. This is huge benefit for the refinery Because of the CEB price is the highest price that spent for the electricity by the refinery. According to the calculation, if both generators work with its maximum efficiency, the cost spent (Rs.1615991) in normal day can be reduced up to Rs.1368437.

5.2 Drinking water system

During this survey period three type of loses were identified and studied for the causes and prevention methods that.

1. Excess chlorine
2. Pipe leaks
3. Tank overflows

5.2.1 Excess chlorine

This waste can be happen in the clarification stage in drinking water system. This Chlorine loses is effluented as $Ca(OCl)_2$. Usually this $Ca(OCl)_2$ is injected to the drinking water system for killing the pathogenic organism constituted in the drinking water. But due to the haphazardly injection carried by the plant operators, huge amount of $Ca(OCl)_2$ can be wasted . Actually this waste occur due to the carelessness of those plant operators.

In some refineries some Hypochlorite automatic dozing devices have been installed to prevent these loses. But in most of time, they are not worked properly due to lack of proper maintenances services. According to the calculation the normal $Ca(OCl)_2$ loses in Sapugaskanda refinery is 97g/day. But this loses can be reduced by establishing the automatic hypochloric dosing devices instead of manually injection occurred by the plant operators. And also by replacing the damaged (unworkable) dozing devices or repairing them under proper maintenances , these loses can be saved. If the proper monitoring system is implemented, to check weather the proper chlorine concentrate is in the drinking water and to check weather those dozing devices is worked properly, these loses can be minimized .

5.2.2 Pipe leaks

Number of pipe leaking points have been identified in the several location at the refinery . According to the calculation, the wasted water amount effluented from the pipe leaking is 7200lit/day. The cost spent for that is Rs. 398.00 per day. The large amount of water as pipe leaks has been effluented from the housing scheme. According to this survey, the main causes for that pipe leaks is corrosion. Due to the corrosion , the metal transfer lines has been damaged and from that damages large water quantity was effluented. And the other cause is the damaged valves and seals. The large amount of damage valves were found in several location from these valves also, the large amount of water was effluented. And also the lack of proper maintenances system is another cause for these loses. Only few leaking points that had been maintained during the project period in the refinery. If the proper maintenances system is established in the refinery and if the transfer lines are designed with non corrosive material and / or cathodic protection, and if this system is installed various leak detection devices, these water loses can be controlled.

5.2.3 Tank overflow

Here the effluented water loses from tank overflows has been measured in several location . According to the calculation, the normal effluented water loses per day is 86.5lit and the cost spent for that loses is Rs.5.32 per day. The main causes is for such kind of loses is the carelessness of the operators. Most tank filling in the refinery is operated by the operators manually. So due to their carelessness, huge waste amount can be lost. To prevent these loses, automatic level controllers have been installed in few points of the refinery. By using these devices, automatically water valve is closed when the tank is filled. But most of these controllers are not worked properly. So if the proper maintenance system is introduced to maintain such controllers, and replace all the points with automatic level controllers instead of manually operating by operators, this loses can be minimized.

5.3 Cooling water system

Four types of loses were identified during this survey period involved of this system.

1. Pipe leaking loses
2. Windage loses
3. Blow down loses
4. Evaporation loses

According to the calculation, the total water loses occurred from this system is 48411it /day. The pipe leaking loses was the highest loses compared with other loses. And the amount of this is 4535lit/day.

5.3.1 Pipe leaks

As mentioned above the pipe leaking in the drinking water system , all the transfer lines in this system is made by the metals. So corrosion is the major cause to damage these pipe lines. Here some of pipe leaking point is appeared because it is located at on/above the ground level. But the pipe leaks that is located at under the ground level are disappeared and it is difficult to detect. Due to the absence of pipe leaking detection equipment, specially to detect under ground pipe leak and lack of maintenance, the large amount of waste can be effluented.

Here also, in addition to the damaged transfer lines, the water can be lost from damaged valves and seals. If the modern leak detection system is introduced, to detect the all leaking point and replace the damaged transfer lines with new one in active maintenance system and introducing non corrosive metal for the transfer lines of this system, this loses can be saved.

5.3.2 Blow down, Evaporation and Windage loses

Here due to the lack of engineered knowledge, these loses were not able to calculate separately. But finding the make-up water quantity and the total pipe leaking loses, the total blow down+ evaporation+windage loses were estimated. According to the calculation, the water loses of this type is about 306lit/day. Actually the main causes for the blow down loses is the evaporation. When the water falls from the top of the tower, some portion of water can be evaporated. So due to this evaporation , salt concentration can be increased. So this water with high salt concentration is not suitable to recycled back. So it is thrown to the sewer system. But if this blow down water is treated and reused without discarding , additional benefit can be gained.

And the main causes of the windage loses is the air stream, blown counter current direction of the water fallen. So due to the air blow, some drop let of water can be thrown away with air. Actually by covering the top of the cooling tower, this kind of loses can be prevented in some extent.

The causes of the evaporation loses is also the blow down air. But this type of loses is difficult to prevent. Actually, the wastage water loses from windage+blow down and evaporation is comparatively lower than the pipe leaks

5.3.3 Steam and condensate system.

Three type of loses have been studied in this system.

1. Pipe leaks
2. Condensate loses
3. Boiler blow down loses

5.3.3.1 Pipe leaks

Normally there three type of transfer lines available in the steam and condensate system.

1. H.P Transfer lines
2. M.P Transfer lines
3. L.P Transfer lines

But there are no visible pipe leaking points in the high pressure transfer lines. Because of this is very dangerous to persist such kind of leaking points in the H.P lines. But there are several pipe leaking points that have been identified separately in L.P and M.P transfer lines. But there are no maintenances of this leaking points this is because maintenance of pipe leaking cannot be done during the refining period. Pipe leaking will only be recovered in shut-down period after the four years. So during four years, So huge steam loses can be effluented from these leaks. According to the calculation the M.P and L.P steam loses are 41521kg and 20606kg per day. The amount of M.P steam loses is comparatively higher than the L.P steam due to the high pressure. Normally the daily cost spent for that M.P and L.P steam loses is Rs.79028.00 and Rs. 35654.00 respectively.

It was difficult to measure the effluented steam amount from the pipe leaks. So according to a chart, the effluented steam loses was estimated by measuring the diameter of each leak point. The main causes of the pipe leaking is also corrosion . Due to the corrosion , the pipe transfer lines can be damaged. The salt concentration of the boiler feed water directly cause corrosion. Therefore it is important to control the salt concentration of the B.F.W by demineralizing, to control corrode . And also due to lack of modern leak detection devices in the maintenance period (shut-down period), some leaks can be missed to recover, specially underground leaks. By introducing the modern leak detection devices, this loses can be controlled. Also most of the materials in this transfer lines are corrosive metals. By replacing this metal with non corrosive metal this can be controlled.

5.3.3.2 Condensate loses

There are huge of condensate loses points that have been identified during the project period. The condensate loses is effluented from damaged steam traps. The transferred steam can be condensated in the transfer lines. The purpose of the steam trappers is to separate condensate from the steam. But if this steam traps are damaged, the proper separation does not happen . That is some portion of steam can be mixed with condensate. So this condensate with mixed steam are not recycled back to the condensate system. And is thrown away to the sewer system. But if the steam traps are maintains properly and damaged traps are replaced with new ones , these loses can be saved. Not only condensates, some amount of steam also can be lost from this damaged steam traps. According to the calculation , the total condensate loses that can be wasted from these steam traps is 3763 lit/day in L.P and M.P steam.

5.3.3.3 Boiler blow down loses

The main cause of the boiler blow down loses is the increasing salt concentration of B.F.W. If the B.F.W is not demineralized properly in the demineralizer, the salt concentration of the boiler water can be increased within few days due to the evaporation. So due to the corrosion problems in the steam transfer lines, this water has to be removed. But if the proper demineralization process is occurred, the terms(times) of boiler blow down can be reduced. And also if the effluented blow down water is treated and reused for another task such as firing water, additional benefit can be gained.

5.4 Instrumental and tool air system

The only major wastage form that has been detected in this system is pipe leaking. As mentioned above in the steam and condensate system, here also the effluented air quantity was difficult to measure. So using the diameter of each leaking point, the wasted air quantity was estimated by using estimation chart. According to the calculation, the amount of estimated air quantity is 151780Ft^3 per day.

Here all the transfer lines are made in metals. So here also the major cause for the pipe leaks is the corrosion. This corrosion can be controlled by reducing the humidity of the air at the air compressing stage. And also the salt concentration of the air also directly cause corrosion. Normally the effluented air quantity from some leaks is comparatively higher than the effluented steam and water quantity from leak which equalent diameter. So the loss may be comparatively increased. But the number of leaking point of this system are very low compared with other leaks.

CONCLUSION

- ✓ Waste generation is unavoidable in Industry.
- ✓ But the quantity can be minimized through reducing wastage.
- ✓ People can be motivated to do this only if the wastage is given a monetary value .
- ✓ This CP audit achieved that objectives and the report can be of great practical value for Ceypetco.
- ✓ The calculated values are estimations, but the methodology is applicable for any industry.

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APPENDIX I

Table 1_1 -Drinking water system- Pipe leak loses

Location	Point	Waste quantity(Lit/15 min)									
		Feb 3rd wk	Mar 1st wk	Mar 3rd wk	Apr 1st wk	Apr 3rd wk	May 1st wk	May 3rd wk	Jun 1st wk	Jun 2nd wk	Jun 3rd wk
1. Labotary	P1	2.0	2.0	1.5	1.5	1.8	1.5	1.8	---	---	---
	P2	3.5	3.0	--	---	----	3.5	3.8	3.8	4.0	3.0
	P3	2.0	2.0	1.7	1.5	2.0	2.0	2.4	---	---	---
2. Workshop	P1	2.5	3.0	4.0	3.0	3.4	3.7	3.2	3.5	3.7	3.9
	P2	4.5	4.5	4.5	4.0	3.1	---	---	---	---	---
3. Housing Scheme	P1	3.5	3.0	3.0	3.2	3.1	3.8	---	---	---	---
	P2	4.0	4.5	4.3	4.6	4.4	5.0	4.9	4.7	4.6	4.7
	P3	2.5	2.5	2.2	2.5	2.3	---	---	---	---	---
	P4	4.0	4.0	4.0	4.2	4.1	5.0	4.9	4.8	4.7	4.8
	P5	2.0	2.0	2.0	2.0	2.1	2.7	2.6	2.5	---	---
4. Admin. Building	P1	2.0	2.5	3.0	2.0	3.3	3.1	3.4	2.8	3.0	2.8
	P2	4.0	3.0	4.0	3.5	4.2	3.9	4.1	3.2	3.5	3.2
5. Control room	P1	3.5	4.0	3.5	3.8	3.0	2.7	---	---	3.3	3.0
	P2	1.5	2.5	2.0	2.2	2.0	1.8	2.3	2.5	2.2	2.0
6. Utility con. Room	P1	0.5	0.5	0.5	0.3	0.5	0.4	0.3	0.5	0.8	0.6
	P2	2.5	1.5	2.5	1.7	2.3	2.1	2.0	2.2	---	----
	P3	2.5	2.0	3.0	2.0	2.7	2.5	2.2	2.3	2.5	2.4
7. Material Dept.	P1	1.5	1.5	1.3	1.0	1.5	1.4	1.2	1.3	2.5	2.7
	P2	0.5	1.0	0.5	0.5	0.8	0.6	0.5	0.7	2.0	2.1
	P3	3.5	4.0	3.2	3.0	3.4	3.3	3.2	3.3	---	---
	P4	2.5	3.0	3.0	3.0	3.3	3.2	3.1	3.2	3.0	3.2
8. Army Matrix	P1	4.5	4.5	4.0	4.3	5.0	4.0	5.0	4.0	4.5	4.0
	P2	2.5	3.0	2.0	2.7	2.5	2.0	3.0	2.5	3.0	2.5
9. Canteen	P1	1.5	2.0	2.3	1.6	1.3	1.5	1.5	---	---	---
	P2	3.5	4.0	4.2	3.9	3.2	3.5	3.5	3.7	3.5	3.2
10 Security Points	P1	2.5	2.0	2.0	2.0	1.7	2.2	2.2	2.0	1.7	2.2
	P2	0.5	0.5	1.0	1.0	----	---	---	---	---	---
11. Training Centre	P1	4.5	4.5	5.5	4.0	4.5	4.0	5.0	4.5	5.0	4.0

Table 1_2-Drinking water system-Tank Overflow water loses

Location	Waste water quantity (lit)										A.V.G waste per day at a time (lit)	Terms of water filling per day	Total waste quantity per day (lit)
	Feb 3rd Wk	Mar 1st Wk	Mar 3rd Wk	Apr 1st Wk	Apr 3rd Wk	May 1st Wk	May 3rd Wk	Jun 1st Wk	Jun 2nd Wk	Jun 3rd Wk			
1. Canteen	4	3	7.0	6.5	5.5	3.5	4.5	5.0	4.0	6.0	4.9	3	14.7
2. Workshop	3.5	4.5	4.0	5.3	2.5	3.0	5.1	4.3	3.2	4.0	3.94	2	7.88
3. Housing Scheme	9.0	10.3	7.5	6.0	10.3	10.0	8.5	9.3	8.5	8.5	8.79	2	17.58
4. Admin. Building	6.5	8.0	7.3	5.5	6.0	7.7	8.5	10.0	6.5	7.0	7.3	1	7.3
5. Control room	3.2	5.5	6.2	4.5	3.0	2.3	1.5	5.6	6.5	3.0	4.13	1	4.13
6. Utility room	4.2	6.5	5.0	4.5	5.7	6.9	8.0	4.1	3.0	4.5	5.24	1	5.24
7. Material Dep.	4.5	5.5	2.0	3.5	6.3	7.0	5.0	5.5	3.2	7.0	4.95	1	4.95
8. Army Matrix	5.3	6.5	7.2	8.0	4.1	2.5	3.3	7.5	6.1	6.0	5.05	2	10.1
9. Lab rotary	6.5	6.0	5.2	8.3	7.2	3.5	2.3	7.3	6.2	6.7	5.92	1	5.92
10. Security points	3.2	4.5	5.1	2.3	4.2	3.8	4.0	4.3	5.5	2.1	3.9	1	3.9
11. Training Centre	4.0	3.2	5.6	7.3	2.5	4.2	4.9	3.3	4.3	4.7	4.8	1	4.8

Total 86.5 lit

Table 1_3-Drinking water system- Drinking water Chlorine concentration

Date	Dissolved Chlorine amount (ppm)
Feb 2nd week	0.3
Feb 3rd week	0.1
Mar 1st week	0.3
Mar 2nd week	0.3
Mar 3rd week	0.08
Mar 4th week	0.06
Apr 1st week	0.3
Apr 2nd week	0.2
Apr 3rd week	0.1
Apr 4th week	0.2
May 1st week	0.3
May 2nd week	0.09
May 3rd week	0.07
May 4th week	0.3
Jun 1st week	0.3
Jun 2nd week	0.2
Jun 3rd week	0.1
Jun 4th week	0.3

Total 3.6 ppm

A.V.G 0.2 ppm

APPENDIX II

Table 2_1-Steam and Condensate system- Condensate losses [L.P steam]

Plant area	Location	Damaged steam traps	Effluented water quantity (ml/15 min.) Feb 3rd week	Mar 2nd week	Mar 4th week	Apr 2nd week	Apr 4th week	May2nd week	May 4th week	Jun 2nd week	Jun 4th week
Area I	O1	St1	300	265	400	350	320	382	458	432	376
		St2	225	235	282	335	300	362	383	365	335
	O8	St3	250	300	275	305	365	382	332	325	325
		St4	400	435	565	355	392	565	495	583	545
		St5	230	225	300	373	325	365	365	325	303
	O9	St6	275	300	332	320	383	323	395	396	306
		St7	350	345	473	383	458	420	420	472	420
	O6	St8	325	300	370	453	376	486	400	433	432
		St9	330	300	400	403	485	472	402	432	423
		St10	325	325	370	450	475	380	300	542	532
Area II	O5	St1	300	235	343	302	425	473	325	595	432
		St2	550	555	743	663	672	673	670	600	775
		St3	265	253	335	375	396	300	365	325	342
		St4	700	672	873	765	840	800	852	880	869
		St5	830	800	983	892	972	880	970	890	1072
	13	St6	975	900	1076	1035	982	880	976	976	1092
		St7	1100	1025	1205	1076	1063	1200	969	972	1088
		St8	1000	1200	1200	1232	1200	1272	975	885	1025
		St9	225	283	345	400	383	300	300	325	356
Area III	O3	St1	375	435	525	470	502	505	382	376	525
		St2	480	400	560	492	583	673	583	672	569
		St3	515	470	625	654	670	670	673	625	750
		St4	235	432	432	383	396	380	302	323	356
		St5	840	885	935	942	953	963	892	845	986
	O7	St6	975	883	1083	1082	1040	1045	1063	892	1070
		St7	800	882	983	1092	983	992	983	825	925
		St8	783	675	865	743	923	852	825	685	842
Tank farm		St1	880	900	990	983	925	765	842	750	992
		St2	927	992	880	883	985	984	754	942	1060
		St3	900	930	995	1175	892	970	763	982	835
		St4	975	875	833	925	883	772	880	933	972
		St5	300	470	460	565	332	380	383	445	365
Utility		St1	300	542	583	490	300	302	300	386	332
		St2	313	453	457	425	373	300	321	376	400
		St3	325	265	325	365	323	383	372	425	583
		St4	340	583	520	492	433	225	325	420	500
		St5	522	600	673	525	575	675	700	677	753
		St6	433	543	589	600	542	600	650	525	583
		St7	245	300	375	370	370	372	323	381	385
		St8	250	300	335	365	323	353	330	393	300
		St9	235	335	365	350	400	300	400	275	242
		Total	20903	23268	24843	25448	24795	24745	23425	23906	25643

Table 2_2-Steam and Condensate system- Condensate losses [M.P steam]

			Effluented water quantity (ml/15 min.)								
Plant area	Unit	Damaged steam traps	Feb 3rd week	Mar 2nd week	Mar 4th week	Apr 2nd week	Apr 4th week	May2nd week	May 4th week	Jun 2nd week	Jun 4th week
Area I	O1	St1	900	1001	970	970	1000	1000	977	1063	1000
	O8	St2	430	400	480	672	770	585	675	490	432
		St3	586	542	542	690	652	682	675	655	670
		St4	789	765	762	800	880	970	1100	890	832
Area II	O4	St1	892	863	890	970	1080	1002	1040	972	972
		St2	850	970	900	974	970	960	1000	1000	797
	O5	St3	673	605	670	789	890	889	800	701	725
		St4	680	673	680	690	750	765	800	672	700
Area III	O2	St1	992	975	909	1000	900	1020	1070	1370	900
		St2	765	632	700	600	780	672	790	770	785
		St3	607	593	630	675	673	672	780	860	670
	O3	St4	907	970	903	1100	1058	1000	1100	900	1070
	O7	St5	700	777	765	892	902	715	957	895	780
		St6	600	583	570	570	635	700	701	670	785
Utility		St1	971	875	980	900	1000	1092	1100	932	1000
		St2	597	650	643	682	720	750	700	873	675
		St3	983	900	1100	977	1200	1032	1000	975	958
		St4	973	1132	1350	983	1300	1075	1032	975	900
		Total	13895	13906	14240	14934	16160	15581	16297	15663	15245

Table 2_3-Steam and Condensate system-Atomizing steam consumption

Unit	Fuel oil consumption (MT/D)															
	Feb 3rd wk	Feb 4th wk	Mar 1st wk	Mar 2nd wk	Mar 3rd wk	Mar 4th wk	Apr 1st wk	Apr 2nd wk	Apr 3rd wk	Apr 4th wk	May 1st wk	May 2nd wk	May 3rd wk	May 4th wk	Jun 1st wk	Jun 2nd wk	A.V.G fuel oil consumption (MT/D)
O1 (F1,F2)	16.01	15.91	15.32	14.29	17.65	16.10	16.92	16.35	15.23	17.01	15.50	17.23	16.35	15.43	17.65	15.32	16.14
O2 (F1,F2)	9.01	7.72	8.35	7.26	8.67	9.01	9.52	7.65	8.32	8.55	7.67	9.03	7.62	6.03	7.75	8.32	8.15
O3 (F1,F2)	8.31	6.32	6.55	7.63	7.32	7.56	8.31	6.57	7.23	7.55	6.35	8.91	7.0	6.33	7.78	7.92	7.35
O4 (F1,F2)	4.36	3.35	3.21	4.58	5.53	4.31	5.01	3.67	3.78	4.32	4.14	4.35	4.67	5.11	5.21	4.32	4.37
O5 (F1,F2)	6.54	6.53	6.32	7.76	7.17	8.32	7.16	7.65	8.53	6.32	6.35	7.10	7.53	8.10	7.65	6.32	7.20
O7 (F1,F2)	8.67	6.77	7.15	7.36	8.57	8.63	7.53	6.02	6.77	8.56	7.06	7.65	7.83	6.05	7.65	8.31	7.53
O8 (F1)	2.01	0.76	0.65	1.13	1.45	1.63	2.0	2.01	0.79	0.91	1.53	2.16	2.13	0.97	0.86	0.75	1.35
B3	5.71	3.13	3.76	4.56	4.78	4.73	5.01	3.41	4.18	4.65	5.01	3.26	3.17	4.07	4.83	4.65	4.30
B5	40.55	40.76	41.75	41.52	41.88	42.01	41.76	40.00	42.89	41.73	42.6	42.78	40.11	42.75	4083	41.12	41.56

Unit	A.V.G Fuel oil consumption (MT/D)	Required Atomizing steam quantity (MT/D)
O1 (F1,F2)	16.14	3.228
O2 (F1,F2)	8.15	1.63
O3 (F1,F2)	7.35	1.47
O4 (F1,F2)	4.37	0.874
O5 (F1,F2)	7.20	1.44
O7 (F1,F2)	7.53	1.506
O8 (F1)	1.35	0.27
B3	4.30	0.86
B5.	41.56	8.312

Total 19.59 MT/D

Table 2_4-Steam and Condensate system-Stripping steam consumption

Unit	Required Stripping steam quantity (MT/D)															
	Feb 3rd wk	Feb 4th wk	Mar 1st wk	Mar 2nd wk	Mar 3rd wk	Mar 4th wk	Apr 1st wk	Apr 2nd wk	Apr 3rd wk	Apr 4th wk	May 1st wk	May 2nd wk	May 3rd wk	May 4th wk	Jun 1st wk	Jun 2nd wk	A.V.G Required Stripping steam (MT/D)
O1	68.5	65.5	71.3	67.6	69.9	71.2	68.5	67.3	70.2	68.8	69.0	71.3	70.9	68.0	70	71.2	69.3
O5	9.7	10.0	9.9	11.3	10.7	11.4	9.9	10.5	11.7	11.4	10.3	10.7	9.8	11.1	10.6	11.7	10.6
O7	24.7	25.3	24.9	26.7	25.3	24.7	25.0	26.0	25.3	25.7	25.5	24.3	26.7	26.2	26	25	25.4
O8	9.8	11.1	10.3	10.2	11.2	9.5	9.7	10.4	10.6	10.0	9.6	11.2	9.7	11.5	10.2	10	10.3

Total 115.61 MT/D

Table 2_5-Steam and condensate system- Pipe leak loses [L.P Steam]

Plant Area	Unit	Total No of Leaks	No. of Leaks	Diameter(mm)	Annual heat losses (Kcal) $*10^3$
Area I	O1	2	1	3	31500
			1	5	100800
	O8	1	1	2	25200
	O9	1	1	6	264600
	O6	1	1	4	50400
		1	1	7	315000
Area II	O5	2	1	4	50400
			1	9	567000
		1	1	8	504000
	13	3	1	7	315000
			2	3	315000*2
		2	2	3	315000*2
Area III	O3	2	1	4	50400
			1	3	31500
		1	1	5	100800
	O7	1	1	4	50400
Utility		3	2	3	31500*2
			1	2	25200
		1	1	5	100800
		1	1	8	504000
Tank Farm		2	1	7	315000
			1	5	100800
		2	2	3	31500*2

Table 2_6-Steam and Condensate system- Pipe leak loses [M.P Steam]

Plant Area	Unit	Total No of Leaks	No. of Leaks	Diameter(mm)	Annual heat losses (Kcal) $*10^3$
Area I	O1	1	1	7	1008000
	O8	1	1	6	945000
		1	1	5	786000
Area II	O5	1	1	3	189000
		2	1	4	315000
			1	7	1008000
	O4	1	1	6	945000
		1	1	4	315000
Area III	O3	1	1	5	756000
	O2	1	1	6	945000
	O7	2	1	5	756000
			1	5	756000
Utility		1	1	5	756000
		3	2	3	189000*2
			1	7	1008000

Total loss 10836000*10^3KCal

Table 2_7-Steam and Condensate system- Blow down water loses

Date	Blow down water quantity(lit/5min.)
Feb 3rd week	1.41
Feb 4th week	1.0
Mar 1st week	1.35
Mar 2nd week	1.5
Mar 3rd week	0.95
Mar 4th week	1.66
Apr 1st week	0.91
Apr 2nd week	1.31
Apr 3rd week	1.0
Apr 4th week	1.47
May 1st week	1.53
May 2nd week	0.91
May 3rd week	1.32
May 4th week	1.65
Jun 1st week	1.6
Jun 2nd week	1.55

APPENDIX III

Table 3_1-Cooling water system- Daily Make-up water quantity

Date	Make-up water (MT)
Feb 3rd week	4800
Mar 1st week	4850
Mar 2nd week	4830
Mar 3rd week	4875
Mar 4th week	4860
Apr 1st week	4930
Apr 2nd week	4014
Apr 3rd week	4831
Apr 4th week	4874
May 1st week	4977
May 2nd week	4977
May 3rd week	4950
May 4th week	4975
Jun 1st week	4908
Jun 2nd week	4900
Jun 3rd week	4816
Jun 4th week	4873
Jul 1st week	4950
Jul 2nd week	4800

A.V.G 4841 MT

Table 3_2-Cooling water system- Pipe leaking loses

Area	Unit	Point	Pipe leaking water loses(Lit/15min)									
			Feb 2nd wk	Feb 3rd wk	Mar 1st wk	Mar 3rd wk	Apr 1st wk	Apr 3rd wk	May 1st wk	May 3rd wk	Jun 1st wk	Jun 2nd wk
Area I	O1	P1	1.5	1.0	1.6	1.2	1.4	1.4	1.3	1.2	1.0	1.2
		P2	2.4	2.5	2.0	2.0	2.3	2.1	2.2	2.2	2.3	2.4
	O8	P1	2.0	2.5	2.3	2.5	2.2	2.0	2.1	2.3	2.0	2.4
	O9	P1	2.25	2.7	2.7	2.0	2.5	2.4	2.4	2.1	2.0	2.3
		P2	3.3	3.2	3.0	3.8	3.2	3.5	3.3	3.4	3.0	3.0
Area II	O4	P1	3.0	3.6	3.7	2.8	2.8	2.9	3.1	3.3	3.1	3.0
	O5	P1	1.0	1.7	1.2	2.0	1.6	1.5	1.3	1.2	1.4	1.0
		P2	2.5	2.3	2.5	2.7	2.6	2.7	2.7	2.6	2.5	2.0
	13	P1	3.2	3.0	3.6	3.6	3.5	3.1	3.3	3.4	3.2	3.1
Area III	O2	P1	2.7	2.7	2.0	2.3	2.4	2.3	2.0	2.4	2.6	2.3
		P2	2.4	2.2	2.7	2.5	2.5	2.4	2.3	2.3	2.2	2.0
	O3	P1	1.0	1.2	1.7	1.4	1.5	1.5	1.4	1.3	1.2	1.3
	O7	P1	2.9	2.7	2.1	3.2	2.7	2.5	2.7	2.8	2.7	2.6
		P2	3.1	3.5	3.2	3.5	3.0	3.0	3.2	3.4	3.0	3.1
Utility		P1	3.5	3.0	3.6	3.4	3.2	3.1	3.2	3.4	3.5	3.0
		P2	2.1	2.0	2.2	2.6	2.5	2.4	2.4	2.0	2.3	2.2
		P3	2.6	2.6	2.3	2.6	2.8	2.7	2.7	2.6	2.4	2.5
Tank Farm		P1	2.8	2.0	2.3	2.0	2.4	2.5	2.0	2.1	2.2	2.3
		P2	3.0	3.2	3.0	3.4	3.3	3.5	3.2	3.0	3.2	3.0
		Total	47.25	47.6	48.2	49.2	48.4	47.5	46.8	47	45.8	44.7

A.V.G Loses : 47.24 Lit/15min

Table 3_3-Instrumental and Tool air system- Pipe leak

Location	No. of Leaks	Diameter(mm)	Annual air losses (Ft^3)
Workshop 1	1	3.17	8880000
	1	6.35	35500000
Workshop 2	1	3.17	8800000
	1	1.58	2220000

Total annual losses 55400000 Ft^3

Table 3_4-Electricity system

Working mode	Electricity Production					Electricity Consumption (MW)
	Diesel Generator		Turbo Generator		C.E.B (MW)	
	Load (MW)	Fuel Consumption (g/kWhr)	Load (MW)	Fuel Consumption (g/kWhr)		
Current	1.5	235	3.4	440	0.9	5.8
Maximum	2.0	225	3.8	430	0	5.8

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