

**ENERGY ANALYSIS OF A NON-FERROUS
PISTON FOUNDRY—A CASE STUDY**

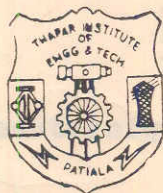
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Guide

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TEJINDER PAUL SINGH

CONTENTS

<u>Sr. No.</u>	<u>Description</u>	<u>Page</u>
<u>CHAPTER I</u>		
	INTRODUCTION	1
1.1	Foundry as an input-output system	1
1.2	Energy as an input	2
1.3	Energy and available forms	4
1.4	Heating in foundry	7
1.5	Probable places of energy loss	8
1.6	Importance of loss prevention and conservation	8
1.7	Energy analysis	11
1.8	Scope of energy analysis	12
1.9	Brief description of unit and product	13
1.10	Broad definition of the problem, its boundaries, procedure and other associated aspects	14
<u>CHAPTER II</u>		
	LITERATURE SURVEY AND PHILOSOPHY UNDERLYING ENERGY ANALYSIS	15
2.1	Literature survey	15
2.2	Procedure of energy analysis	18
2.21	Global Industrial systems	19
2.22	Actual industrial systems	19
2.23	Inputs and outputs of industrial systems	21

<u>Sr. No.</u>	<u>Description</u>	<u>Page</u>
2.24	Energy analysis and systems	21
2.25	Choosing the system	21
2.26	Assigning energy values of subsystems	23
2.27	Combining the energies of subsystems	23
2.28	Simplification of problem for energy analysis	26
2.29	Orders of analysis	26
2.30	Fuels and their energy	28
<u>CHAPTER III</u>		
	DESCRIPTION OF PRODUCT AND PROCESS	30
3.1	Details of the process	30
3.2	Layout of foundry	31
3.3	Process details	33
<u>CHAPTER IV</u>		
	DETAILED ENERGY ANALYSIS	38
4.1	Energy inputs	38
4.2	Outputs	40
4.3	Calculations of energy values	45
4.31	Defining the system	45
4.32	The subsystems	46
4.33	Calculations of energy consumed by each subsystems	48
4.34	Calculations of energy values for individual blanks in each subsystems	51
4.35	Conversion into energy units	72
4.36	Forge section	73

<u>Sr. No.</u>	<u>Description</u>	<u>Page</u>
<u>CHAPTER V</u>		
5.1	Discussion of Results	79
5.11	Casting subsystems	80
5.12	Heat Treatment subsystem	83
5.2	Energy wastage on melting furnaces	84
5.3	Energy wastage on holding furnaces	85
5.4	Temperature loss due to uncovered holding furnaces	90
5.5	Dechlorination unit	91
5.6	Casting of rods for forged piston blanks	92
<u>CHAPTER VI</u>		
	CONCLUSIONS AND RECOMMENDATIONS	93
	BIBLIOGRAPHY	100

ABSTRACT

The whole world is passing through an acute energy crises. The situation is going to worsen in the near future because the finite quantity of fossil fuels are fast exhausting. With the development of science and technology the manual work is being replaced by machines thus increasing the demand for energy.

While on one hand the efforts are on to produce more energy through conventional and non-conventional sources, it is necessary, on the other hand, to use the available energy in the most efficient way and conserve it.

Before we apply any conservation measures, it is necessary to know how much energy should be theoretically used and how much is being used with a breakup of energy consumption at various level. Energy Analysis is the technique for examining the way in which the energy sources are harnessed to perform useful functions.

In this study Energy Analysis of a non-ferrous piston foundry has been conducted. All inputs and outputs of Energy and materials for a period starting January 86, have been collected. The system has been divided into

various sub-systems and energy consumption of each type of piston blank in each sub-system have been calculated. From the manner the sub-systems are linked to each other the total energy consumption of each type of piston blank has been calculated.

The total energy values, thus calculated, are critically examined and areas of energy wastage with quantum of wastage have been found out. Ways and means are then suggested to avoid or atleast minimise the Energy wastage. Scope for further study has also been given.

CHAPTER I

INTRODUCTION

In all manufacturing industries raw materials are converted into finished products with the help of relevant input resources such as materials machines and labour. Thus, any industrial production system can be represented as an input-output system as shown in figure 1.1.

1.1 Foundry as an Input-output system

Taking the case of a foundry the direct materials inputs are various elements, which constitute the desired alloy. Indirect materials are added to the molten alloy for its refinement. casting process involves pouring of this molten metal into moulds of the desired shape and sizes. The alloy solidifies there and required castings are thus produced.

Energy is used in the foundry for performing the following operations:-

i) Energy used in the preparation of material/alloy

Running of induction furnaces and oil fired furnaces involves consumption of energy for heating the alloy to bring it to the molten stage. Further when the molten alloy

INPUTS

OUTPUTS

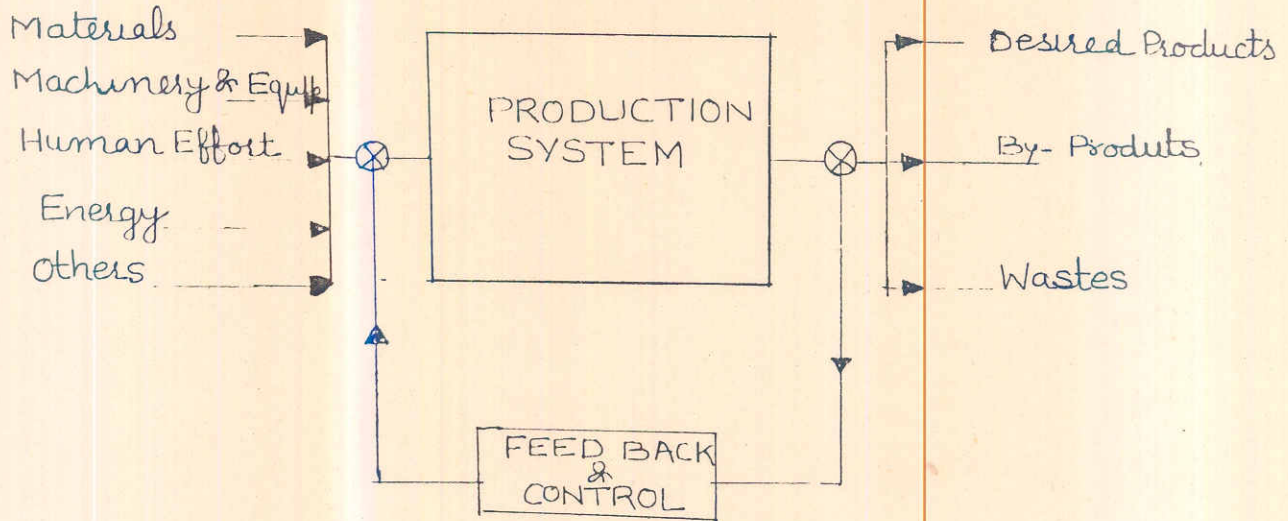


FIG 1.1 INDUSTRY AS AN INPUT-OUTPUT SYSTEM

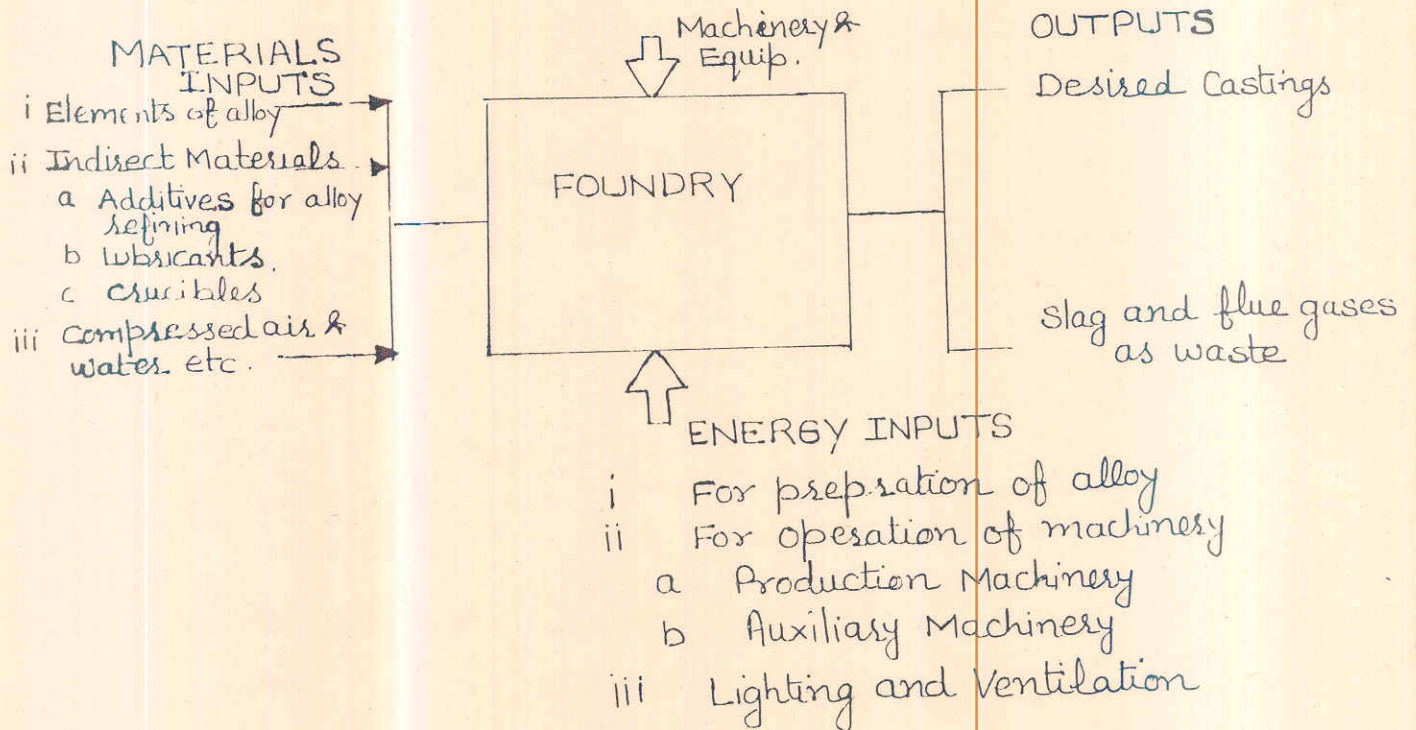


FIG 1.2 FOUNDRY AS AN INPUT-OUTPUT SYSTEM

is transferred to holding furnaces, energy is again used to maintain the molten alloy at the required casting temperature.

ii) Energy used for operating the machinery

(a) Production Machinery

Die casting machines on which actual casting process is carried out, machines for cutting runners and risers and furnaces for the heat treatment of castings are all run by the supply of energy to these machines.

(b) Auxiliary Machinery

Air compressors, water pumps and air cleaning system require energy for their operation.

iii) Lighting and Ventilation ~~output~~

output

The objective output from foundry is the castings of the desired dimensions. The waste may be the slag etc; formed in the process. Figure 1.2 shows foundry as an input-output system.

1.2 Energy as an Input

In all processes energy is supplied at different stages for the conversion of raw materials into finish products. In a machine shop energy is expended to operate the drives of the machine tools, to run air compressors and motors etc. This provides the power needed in the process.

However in a casting process energy is used mainly for heating purposes.

With so much of mechanisation having taken place there is very less manual work left in a manufacturing industry. Mostly it is restricted to loading and unloading of components on machines, charging and emptying of furnaces etc. Rest, virtually everything is done with the help of machines and for that energy is the primary input. Besides this, use is made of energy for providing basic amenities like cold water, air circulation and operating coolers and air conditioners, lighting systems and antipollution equipment etc.

Thus it is seen that in any production system energy enters at different stages in the form of electricity or as fuels.

1.3 Energy and available forms

Energy is available from many sources which can broadly be classified as conventional and unconventional energy resources. Electricity oil and other fuels like coal, coke and wood etc., are the conventional energy sources. The unconventional sources are solar power, wind power and fuel cells etc.

The conventional forms of energy are commonly used. Electricity is by far the most common form followed by oils

and other fuels like coal, coke etc.

During usage, the available form of energy is converted into the desired form. An electric motor converts the electrical energy into mechanical energy in the form of rotation of the motor shafts, which in turn provide rotational motion to spindles of the machines or reciprocative motions to the machine slides, transmission taking place through gear trains or hydraulic or other fluid power units.

For heating purposes the electrical energy is converted to heat energy through heating elements or through induction process by generating eddy currents. The air conditioners or water coolers convert the electrical energy to cooling effect.

Further electrical energy is converted to mechanical motion of the fans which provide cool air and through the lamps and fluorescent tubes to lighting.

The energy of fuel oils is converted into desired form by combustion. The heat energy thus produced is either used directly for foundry processes or it can be converted to some other form.

Fig. 1.3 show the details regarding the conversion of one form of energy into the other and its use.

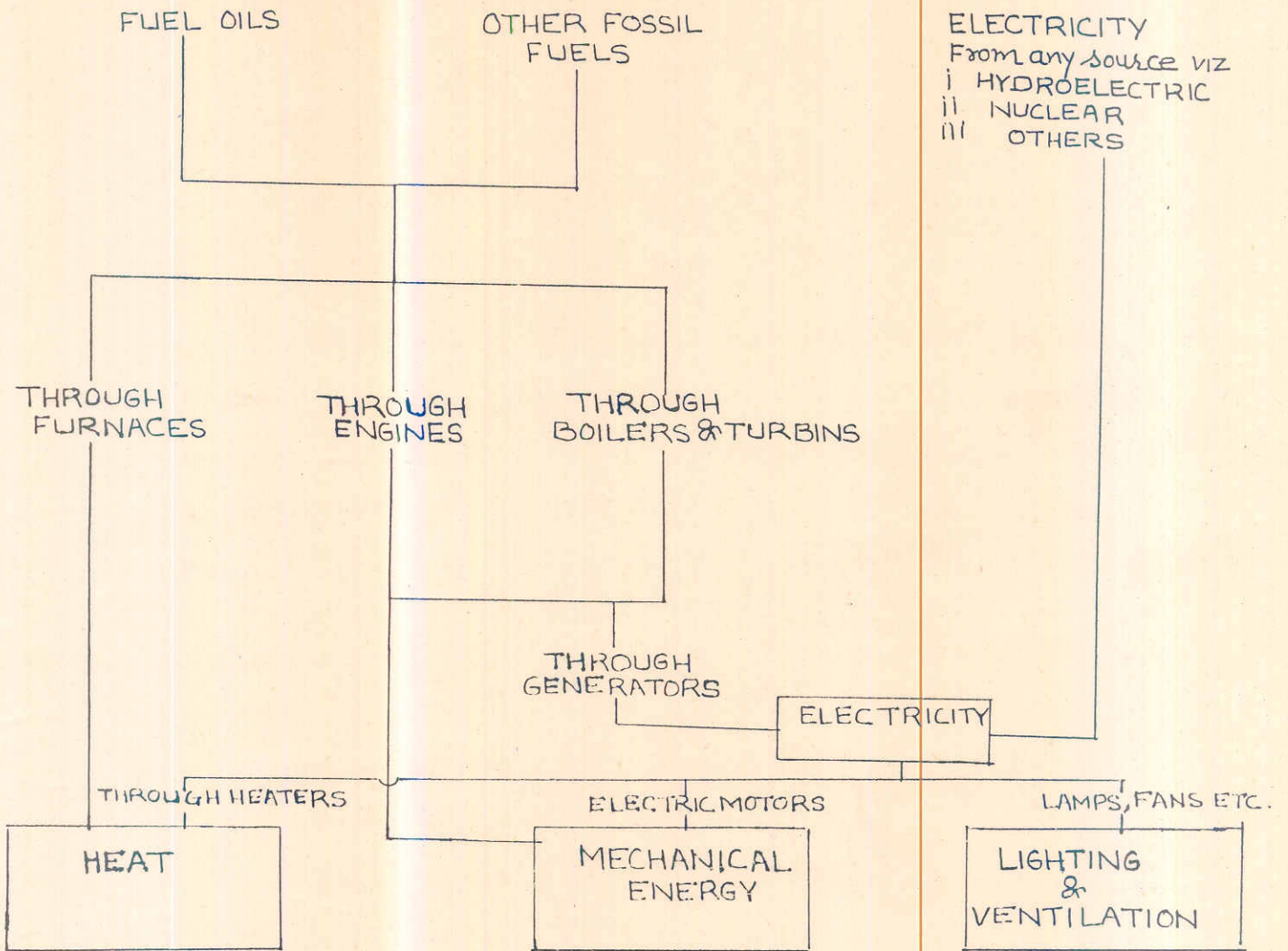


FIG 1-3 CONVERSION OF ENERGY

1.4 Heating in Foundry

In a foundry heating is a process in which maximum amount of energy is consumed. Heating is required to bring the alloy in a molten stage so that it can be made to cast into moulds of desired shape and size.

In foundries both electrically operated and oil fired furnaces are used. For alloy making normally the use is made of induction furnaces, where as the melting of the already available solidified alloy is done on oil fired furnaces.

In the induction furnaces the principle of induction is used. The material to be melted is made secondary of a coil through which current is passed. The heat and the eddy currents thus produced melt the different constituents of the alloy to form material of the desired composition.

Oil fired furnaces use a burner. This burner makes the combustible mixture of the oil and air which gets burnt and produce heat. With the heat thus generated the material to be melted is heated.

Heating is again required to keep the alloy at the required casting temperature till it is poured into moulds. For this purpose Holding Furnaces are used which are normally electrically operated.

Fig. 1.4 show different stages in a foundry where energy is consumed for heating and other operations.

1.5 Probable places of Energy Loss

1. In the melting furnaces if the quantity of alloy made is more than the consumption rate then molten alloy has to be hold at high temperature in melting furnaces thus wasting a energy.
2. In the holding furnaces if the quantity of alloy kept is more than the pouring rate than alloy has to be kept at casting temperature wasting energy.
3. Low efficiency and week insulation of the furnaces.
4. Faulty operations and toolings cause excessive burrs which wasted energy during deburring.
5. Under using the equipment capacity.
6. Excessive breakdown of machinery and equipment to results in non-usage of alloy kept at higher temperatures.
7. Ineffective transport system causes reduction in temperature during transportation.
8. Ineffective or ill designed air cleaning system.

In any foundry the energy loss takes place in one or more of the above places which must be prevented.

1.6 Importance of Loss prevention and conservation

Almost all the countries of the world are passing through an acute energy crises with no visible solution for

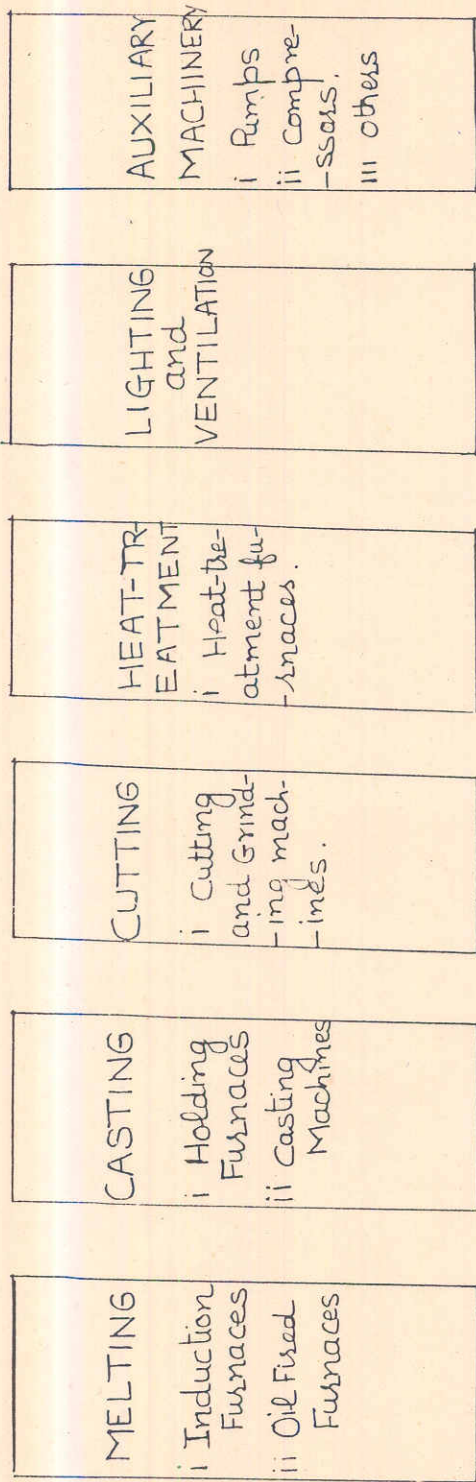


FIG 1.4 STAGES OF ENERGY CONSUMPTION IN FOUNDRY

the time being (7). Frequent power cuts, long queues for diesel, kerosene and LPG etc. clearly indicate that the country is passing through an energy crisis. The speakers at the Eleventh World Energy Conference held at Munich from September 8 to 12, 1980 gave a clear cut warning of anticipated energy shortage in the world in the near future (13). The reasons why we have to face this energy dearer situation are

- i) Due to development of science and technology most of the manual work has been replaced by machines.
- ii) Slowly the finite quantity of the fossil fuels are exhausting and there are predictions about the dates, on which the fuel supply from particular source will be exhausted. Some oil wells have already exhausted (5,8,11).

While on one hand the efforts are on to produce more energy through conventional and unconventional sources, it is also necessary to use the available energy in the most efficient way so that minimum amount of energy is used to carry out a particular work (17). As the largest amount of energy is used in the industrial sector so it is imperative that preventing energy loss in industry will go a long way towards energy savings at national level (12).

To efficiently use the available energy it is of utmost importance to know the areas where the energy loss is taking place. This energy loss should be quantitatively known and then energy conservation means are to be applied to bring down the energy losses (3). The conservation means can be provided in the form of

1. Improving the technology of the process.
2. Making the production planning process based on energy consumption.
3. Providing heat exchangers etc.
4. Providing better insulations etc.
5. Efficient working and awareness regarding energy dearer situation.
6. Improving the design of the equipment.

1.7 Energy Analysis

Before we apply any conservation measures in the form of improving the design of the equipment, using heat exchangers, redesigning of processes or recycling etc., it is of prime importance to know how much energy should be theoretically used and how much is being used with a break-up of Energy consumptions at various levels. This is necessary to pin point the areas of Energy loss and the possible reasons for the loss. The technique for examining the way in which the energy sources are harnessed to perform useful

functions is called Energy Analysis.

1.8 Scope of Energy Analysis

The energy analysis deals not only with the energy consumption of industrial operations on smaller machines and actual manufacturing processes but also takes into account the ancillary operations and services that are needed to support the present day industry. Here the attempt is to arrive at the Gross Energy requirement which is defined as the energy associated with all the operations needed to support the production of the commodity. A simple example of driving a vehicle from one place to the other will reveal the complexity involved in such calculations. The main consumption of energy is the fuel required to make the vehicle move. However in order to provide the fuel, further energy must have been expended in the oil refinery to produce it from crude oil and yet more to deliver it to the petrol station. In addition the vehicle itself had to be manufactured and involved energy expenditure not only in the construction of vehicle but also in the back up industry that supply the parts and raw materials to the vehicle industry. Further more during the ride use is made of road whose construction and maintenance also requires the expenditure of energy.

For some of the factors listed above the energy expenditure will be small but for others it will be much more significant. A fundamental problem lies which of these operations should be included in the energy of drive. For that purpose the system boundaries are to be decided first and the energy entering into the product at different points within that system is calculated. Combining energies of different stages give the energy requirement of the product.

1.9 Brief Description of the Unit and Product

The unit under study is situated in Punjab and manufactures pistons of almost all vehicles, compressors and engines available in India. The pistons are produced with casting or forging operations carried out in the foundry. Subsequently these castings and forgings are machined to finish pistons in the machine shop.

The material of the pistons, the Aluminium alloy is prepared in the foundry itself. The main constituent of alloy are Aluminium and Silicon. The alloy is prepared and melted in induction furnaces and oil fired furnaces respectively. The molten alloy is then transported to holding furnaces near the die casting machines. After casting, the runners, risers and burrs are removed and heat treatment is carried out. The piston blanks made

thus are then sent to the machine shop after inspection.

1.10 Broad definition of the problem, its boundaries, procedure and other associated aspects

The attempt is to do detailed Energy Analysis of the foundry operations and calculate the energy requirement of each type of piston blank at all stages in the foundry. The energy requirements thus arrived at would be critically examined to find out the areas of energy losses. To avoid or atleast minimise such energy losses, the ways and means would be suggested and tried out to reflect the quantum of savings which could be effected.

To carry out the energy analysis the input-output data for the study period of one year from January 86 to December 86 has been taken.

The inputs include direct materials, indirect materials and energy inputs. Energy inputs to the foundry are in the form of Electricity, Light diesel oil and LPG. The output from the foundry is the piston blanks of various types.

CHAPTER II

LITERATURE SURVEY AND PHILOSOPHY UNDERLYING ENERGY ANALYSIS

For many years the energy consumption calculations for production plants, machines and processes have been done by engineers but Energy Analysis, as the subject is known these days, is comparatively new. In the space of last about 20 years the energy analysis has progressed from a minor academic research work to an essential tool of management. Although for over a hundred years the engineers have taken a close interest in the energy consumption of the machines they have designed and built but the real start of Energy Analysis subject can be said to be after the 1960's.

2.1 LITERATURE SURVEY

In 1960's the people became more aware of the environmental considerations. Second factor was that the fossil fuels available from the earth were gradually finishing and it was predicted that by which time the particular sources will be exhausted. But the main factor which made the industrialist more energy conscious was the increasing cost of energy. Due to this it became necessary to know how much energy is consumed and that resulted in

the development of the subject Energy Analysis.

As the awareness regarding energy shortage and importance of Energy saving and loss prevention measures spread more and more sections of people started adopting the Energy Analysis technique to know the amount of Energy they are using on a particular product or process. A comparison of such values to theoretical minimum showed that at how much efficiency they are working. This followed the conservation measures and resultant savings.

Till date energy analysis of almost all sectors have been done. This includes mines, metal processing industry, agriculture sector and even the domestic sector and hospitals (18). A study was conducted to find out quantity of different commercial fuels for cooking with respect to utensils (made of different materials) and time for cooking operations and investigates energy requirements of various utensils for cooking under varying cooking media (D. Malathi and K.R. Swammathan 1986) (10).

The most of the work done has been in the industrial sector. Energy Analysis of an integrated aluminium complex using the Energy usage diagram has been done (Mohan K Iyer 1986) (9). The audit system based on the cost audit principles provides an easy review and control of expenditure.

Energy saving measures in refrigeration plant operations have been highlighted after conducting a study for refrigeration plant performance analysis (4).

Examination of the most energy intensive industries and methods by which the fuel efficiency can be improved has been done (1).

In transport sector also Energy Analysis has been of immense value. Energy Analysis of transportation systems of developing countries have been done and compared with that of the developed countries. The figures suggest considerable scope for transport energy savings. The more energy intensive systems are marked (6).

An analysis of Energy consumption patterns for rural areas has been done. The Indian Energy Scenario has been highlighted (2).

The assessment of potential impact of information technology on energy use in advanced economics have been made through Energy Analysis (19).

Historical trends of energy consumption of some large energy consuming industries have been compiled and analysed. The Energy Analysis show that Energy intensities have remained fairly stable in case of textiles. These have declined in case of inorganic heavy chemicals

and paper board iron and steel. A steady upward trend has been shown in case of non ferrus, basic metal and cement. (16).

In chemical industries also the energy analysis has found its use. For example an analysis of Sulphuric acid plant showed that a large amount of heat energy go as a waste in a contact process sulphuric acid plant. If this heat is recovered it is possible to achieve an energy efficiency of 90 per cent (14).

In 1987 an extensive energy analysis was conducted at IFFCO, KALOL (15). The management of the plant thus identified various areas for energy efficiency improvement. The implementation of various energy conservation schemes has brought down the specific energy consumption.

Gross energy requirements of the products and materials ranging from metals, resins, fibres, metal castings and forgings, gases, salts, plastics, bricks, electrodes cement water and wood etc. have been calculated and tabulated. Different energy values are given for these products when these were produced from different raw materials using different methods.

2.2 Procedure of Energy analysis

First and fore-most requirement of energy analysis is the detailed and accurate description of present

industrial energy consumption and the way in which the contributing operations are linked. For example a recycling operation in any system will need extra energy for the recycling but at the same time it will reduce the requirement for virgin raw material.

2.21 Global industrial systems

In all industrial operations the materials are processed. These processes may involve change of state as producing petrol from crude. Washing clothes and transportation are also example of processes. The fuels and materials requirements of processes can be traced back to some previous processing stage. In this way moving backward we can reach a stage where the material was extracted from earth. Similarly we can trace out when after varying uses the product finally goes back to the earth.

If in our approach we decide the natural boundries for the industrial system as discussed above the system is called the Global Industrial System and is shown in figure 2.1. In figure 2.2 the part of materials input which ~~is~~ actually acts as fuel is shown separately as fuel input.

2.22 Actual industrial systems

Unlike the global system, choosing the boundries for smaller component systems raises some problems but once the boundries -

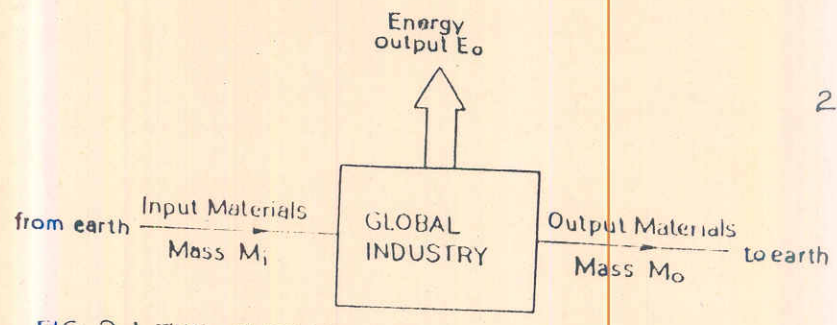


FIG 2.1 THE GLOBAL INDUSTRIAL SYSTEM.

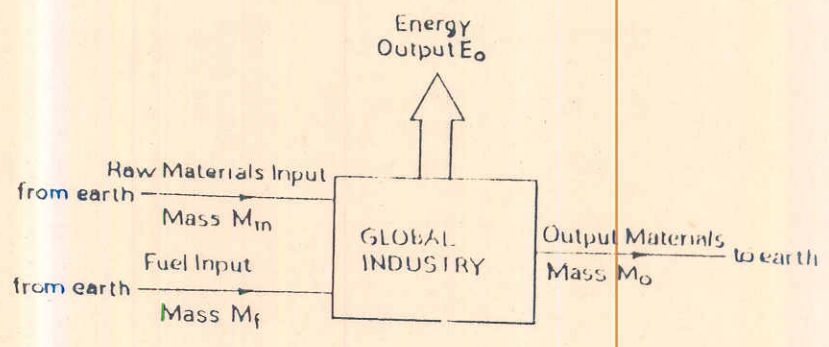


FIG. 2.2

have been drawn the behaviour of the enclosed system is identical to the global system.

2.23 Inputs and outputs of the industrial systems

The inputs and outputs of the systems should be clearly defined. Here the systematic approach of fig. 2.3 and 2.4 will be used. The material inputs, fuel inputs, the desired outputs and waste outputs should be clearly differentiated. Representation as shown in Fig. 2.4 should be adopted.

2.24 Energy analysis and systems

Generally the problem for energy analysis is related to product rather than the equipment or operations. For example the problem may be to find out the energy needed to produce one Kg. of steel. So the first task is to convert the product oriented system to operation oriented one. For this a system is to be chosen which includes all the operations needed to produce the commodity. In the system will come the whole series of operations or sub-systems. For each of these sub-systems the materials and energy inputs will be evaluated. These are then combined to obtain a description of the whole system.

2.25 Choosing the system

There is no such thing as correct or absolute value

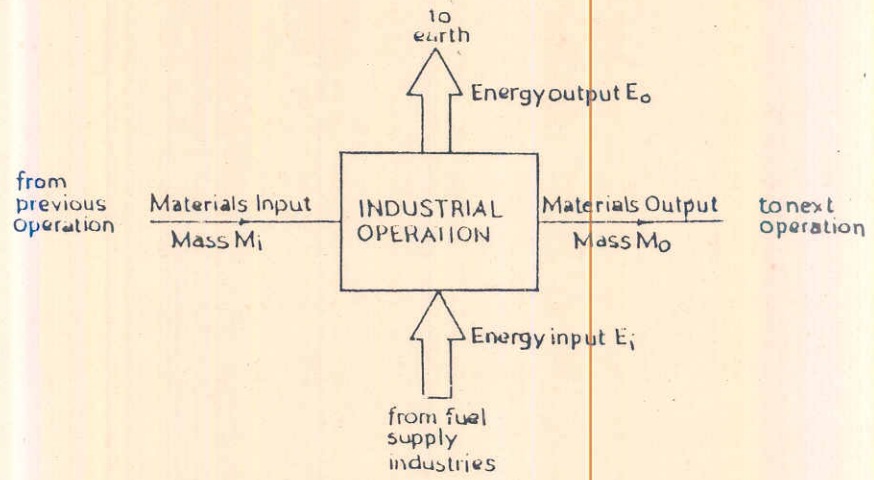


FIG 2.3

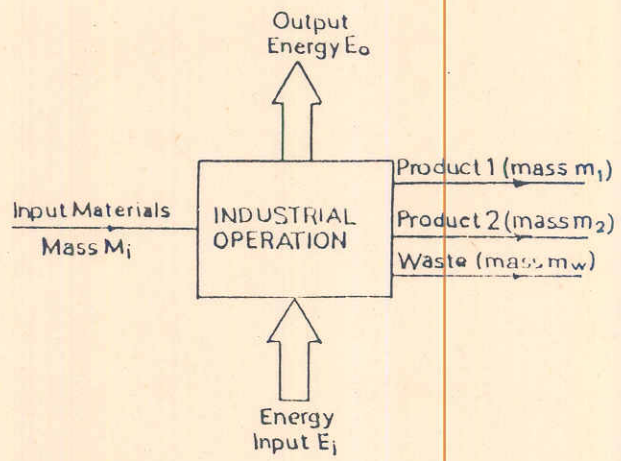


FIG. 2.4

for the energy needed to produce a kilogram of any commodity. The values obtained depend critically upon the system boundaries chosen. The choice of system and the identification of the component sub-systems is the most difficult problem before the analyst. Care is to be taken as to which operations are to be included or excluded depending upon the significance and energy content of each and the definition of the problem. A plant operator may only be interested in the energy content of the fuels actually consumed by his plant, whereas the company policy decisions require information concerning not only the energy requirements to run the plant but also that needed to construct the plant in the first place and maintain it thereafter.

2.26 Assigning energy values to sub-system

Using the procedure described earlier we can represent each sub-system as in figure 2.4. Inputs and outputs of materials and energies can be written for each sub-system. The final stage of analysis is the combination of the energies associated with each of the sub-systems into a single value which represents the energy for the whole system.

2.27 Combining the energy of sub-systems

The overall energy of the system is not always the simple sum of all the values of the sub-systems. Rather

it depends upon the way in which the individual sub-systems are linked. Three types of sequences occur very frequently. They are

- i. Multiple Feeds
- ii. Linear Sequences
- iii. Feed back loops

i. Multiple Feeds

The arrangement is shown in Figure 2.5. A number of operations feed materials to a single process. Typical example is the feeding of iron coke and lime stone to a blast furnace. The system energy will be, therefore be the sum of energies of each sub-system.

ii. Linear System

The arrangement and the system is shown in Figure 2.6. The system energy in this case also is the sum of the energies of individual sub-systems. The important difference, however, is that in the linear type there is no independent production element. If the conversion efficiency of any sub-system changes the effect of this change will pass along the chain of supply.

iii. Feed Back Loops

Figure 2.7 shows a feed back system. Here operations 4 and 2 of a linear sequence of operations labelled 1 to 5 are linked with a feed back loop via an additional operation 6. If f be the mass which is returned by feed back loop

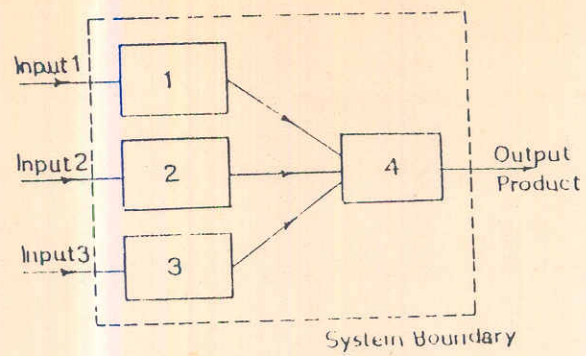


FIG. 2.5c MULTIPLE FEEDS.

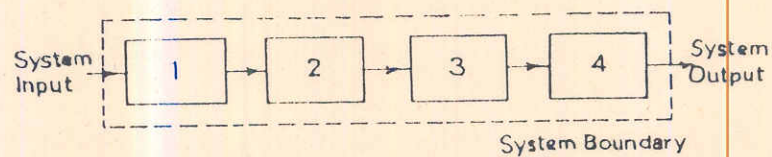


FIG. 2.6 LINEAR SEQUENCES.

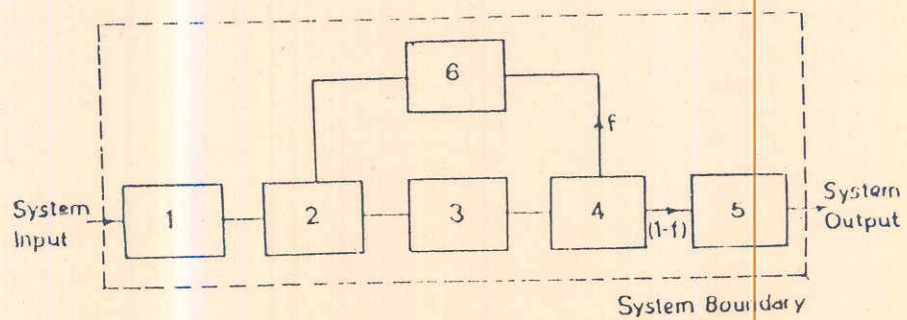


FIG. 2.7 LINEAR SYSTEM WITH SINGLE FEEDBACK LOOP.

and, (1-f) goes directly to operation 5.

2.28 Simplification of problem for energy analysis

In real industrial systems the operations are complex and interlinked. The Energy analysis approach as described earlier cannot be directly applied to the problem. Rather the problem has to be simplified first and reduced to the form where the systematic approach can be applied. Complex operation can be broken down to a series of simpler operations. Less energy intensive operations can be neglected without any appreciable error.

2.29 Orders of analysis

This term can be best explained by an example i.e. the production of oil in the oil refinery. Let us assume that the whole of the oil industry is fueled by oil only. This system is shown in figure 2.8. Mass M of crude is converted to finished oil fuel M with an energy input $m = fM$ where f is a suitable multiplier. However, the oil fM must have been produced at an earlier stage by the expenditure $fxfM$ quantity of fuel. If we go further then at some even earlier stage $(f.fM)f$ amount of energy must have been expended to produce $f.fM$ amount of oil. Proceeding this way we arrive at fig. 2.9. If we consider only the block A where an output of M is produced by an input of $(M+fM)$, this is the first order analysis. If

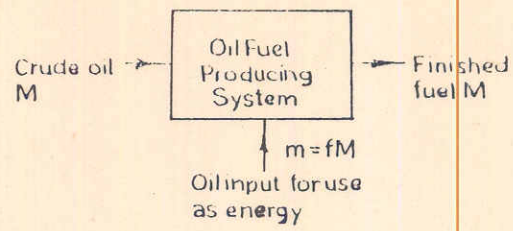


FIG. 2-8 SIMPLE OIL-FUEL PRODUCING SYSTEM.

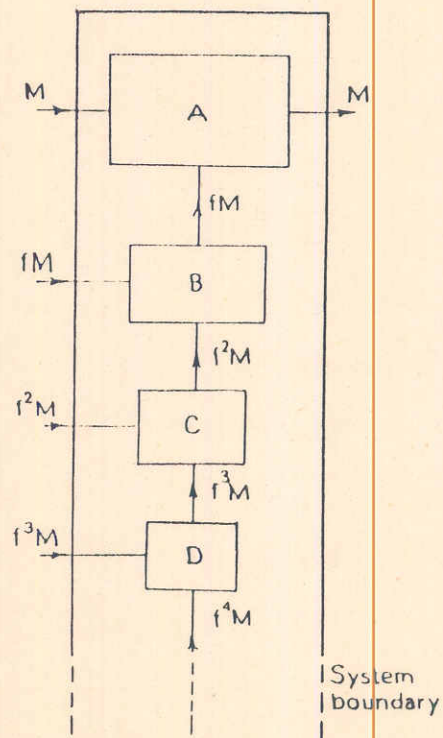


FIG. 2-9 OIL-FUEL PRODUCING SYSTEM SUCH THAT ALL INPUTS ARE DERIVED FROM RAW MATERIALS IN THE GROUND.

block B is also considered then it becomes the second order analysis and so on. With the increasing orders the contribution of energy to the system becomes smaller and so normally second order analysis gives sufficiently accurate results.

2.30 Fuels and their energy

There are two types of fuels, primary fuels and secondary fuels. Primary fuel is a naturally occurring raw material and is used as a fuel without modifying its chemical structure. Coal natural gas and oil fuels are all primary fuels. A secondary fuel is a source of energy which is derived from the primary fuel, Coke, electricity and gas are all secondary fuels.

The energy content of a fuel is the energy present in the fuel that is actually available to the ultimate consumer. But at some earlier stage some energy must have been expended to produce this fuel. This is called the fuel production and delivery energy. So the total energy associated with any fuel includes both these energies Table 2.1 represents production energy of fuel, energy content of fuel and energy content of fuel and energy production efficiency for different fuels.

CHAPTER III

DESCRIPTION OF PRODUCT AND PROCESS

The industry under analysis is situated in Punjab and manufactures pistons of almost all Indian vehicles, generator sets, engines and compressors. Monthly production at present varies between 1,20,000 to 1,30,000 pistons.

The material used for pistons is aluminium alloy. Figure 3.1 shows the flow of material in various departments of the factory. The alloy is prepared in the foundry from different constituent elements. From this alloy piston blanks of various types are either cast or forged in the foundry. After removing the extra material, the piston blanks are sent to machine shop where they are machined to finish products. After careful inspection, they are packed and sent to the required destinations outside the factory.

Since the area of analysis, here is foundry only, therefore a detailed description of only foundry shop is given here.

3.1 Details of the process

The piston blanks are either cast or forged. Forging

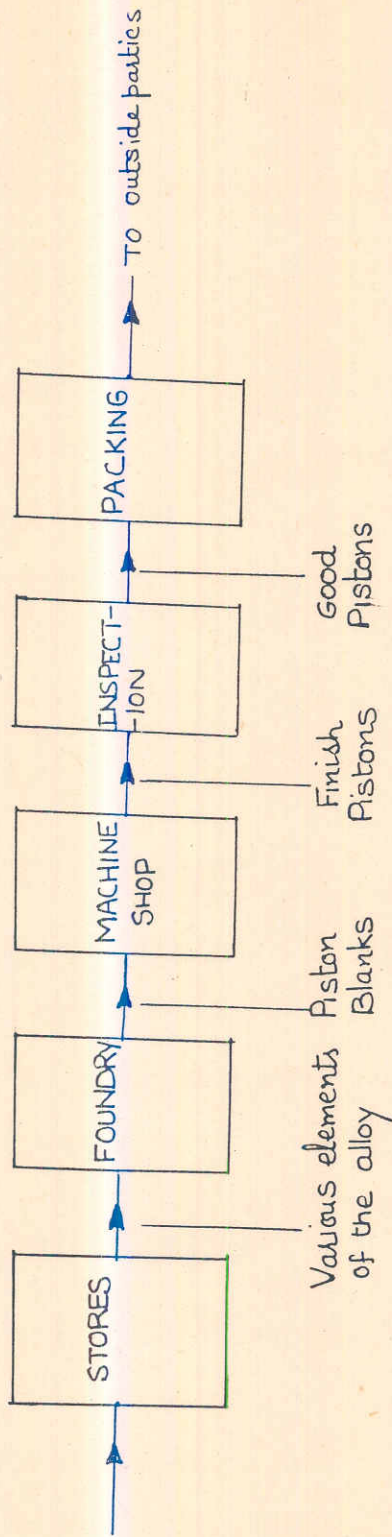


FIG 3.1 MATERIAL FLOW IN THE FACTORY

is done only in a few types of pistons. Mostly the pistons are made by casting process.

Casting process is of two types namely hand casting and machine casting. In case of hand casting the different tools of the die are assembled and de-assembled manually during casting. In machine casting the dies fitted on hydraulic machines and the different tools are moved with the hydraulic actuators. Machine casting is comparatively a newer process and is slowly replacing the hand casting process.

For forged pistons firstly long rods of the required alloy are cast. These are then cut to the required weights and forged by hydraulic presses.

After casting or forging the extra material is removed and the piston blanks thus manufactured are heat treated in aging furnaces. These are then sent to machine shop for machining.

3.2 Layout of foundry

Figure 3.2 shows the layout diagram of the foundry. There are two numbers of coreless induction furnaces located on a higher platform near the entrance. Three numbers of oil fired furnaces are situated as shown in the diagram.

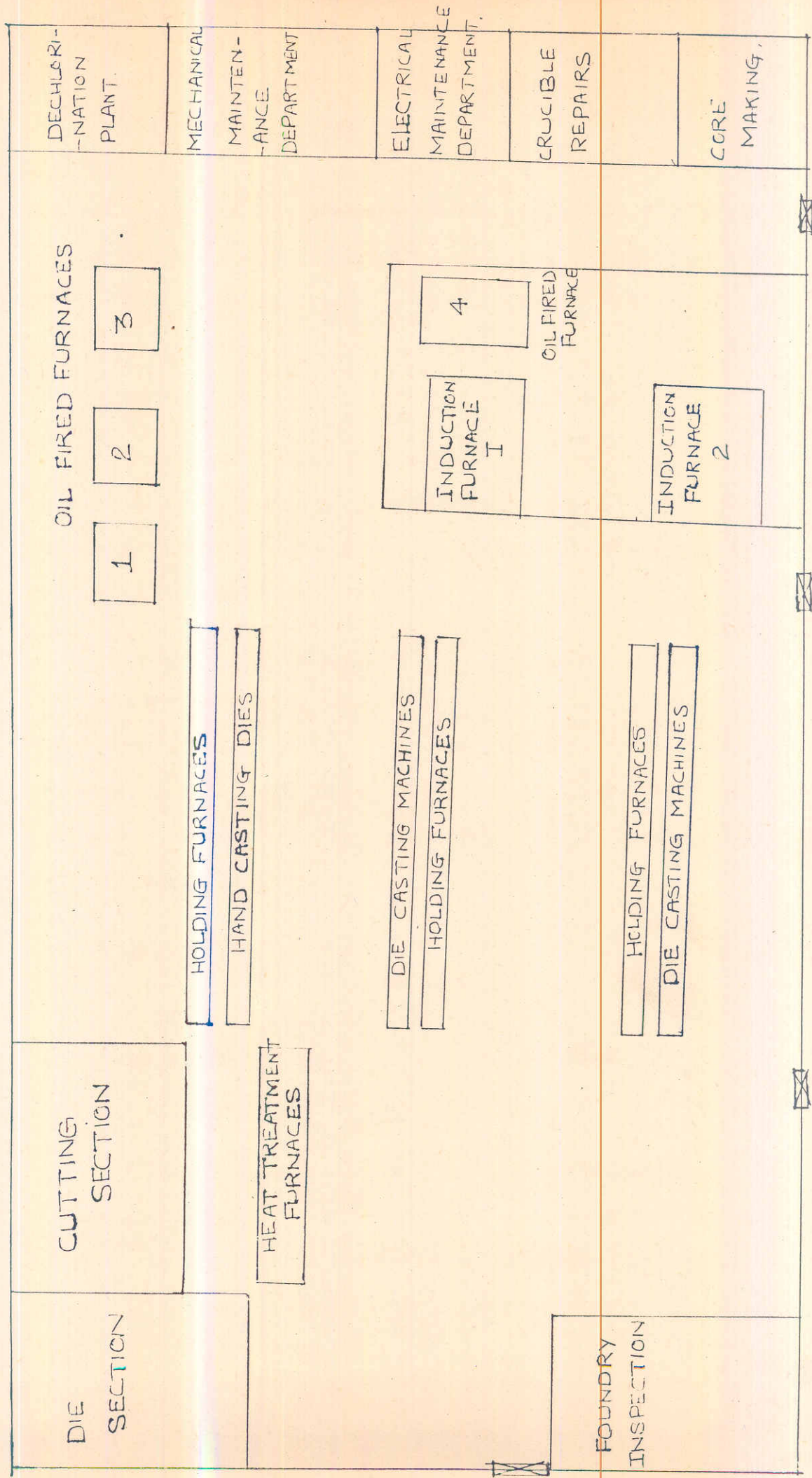


FIG 3-2 LAYOUT OF FOUNDRY

Out of these two are the direct heating types and third of crucible type. The die casting machines and hand casting moulds are placed in three casting lines. Holding furnaces are also situated in lines parallel to the lines of die casting machines and hand casting moulds.

Cutting machines are kept next to the casting area. Heat treatment furnaces are lined up near the cutting section. Foundry Inspection Department is situated next to the heat treatment furnaces.

Forge plant is housed in a separate building near the foundry building. There are two hydraulic presses 550 tones and 150 tones, a double chamber rotary heating furnace, a stock cutting machine, a hydraulic unit for the operation of presses and a pickling unit situated as shown in the layout diagram.

3.3 Process Details

Figure 3.3 shows the flow of material in the foundry. In figure 3.4 the details of operations done on the piston blank are shown in a material type flow process chart.

Alloy making is carried out on induction furnaces. Mainly three types of alloys are used. We will name them alloy²⁴, alloy³⁸ and Alloy^{Q4}here. The difference between alloys is the composition of different ingredients mainly

aluminium and silicon. Alloy 24 has more silicon than alloy 12A and 3B and alloy 3B has more silicon than alloy 12A. With the increase in the silicon content the casting temperature increases.

From induction furnaces the alloy is taken at a temperature higher than the casting temperature. This temperature is called Tapping temperature. Tapping temperature in case of Alloy 24 is more than Alloy 12A and 3B and tapping temperature of alloy 3B is more than that of alloy 12A. This is done to keep into account the temperature loss during transportation.

The alloy is then transported to the holding furnaces with the help of Fork lift Trucks. Holding furnaces are electrically operated and control temperature of alloy automatically, within the required limit.

After filling in the holding furnaces the alloy refining is done by adding certain additives. These chemicals react with the impurities and bring them on the surface in the form of slag or slurry which is manually removed. chlorine gas also one of the additives.

After the alloy is refined and it has attained the required casting temperature the casting process is started. All parts of the die are assembled, the required quantity of

MATERIAL FLOW

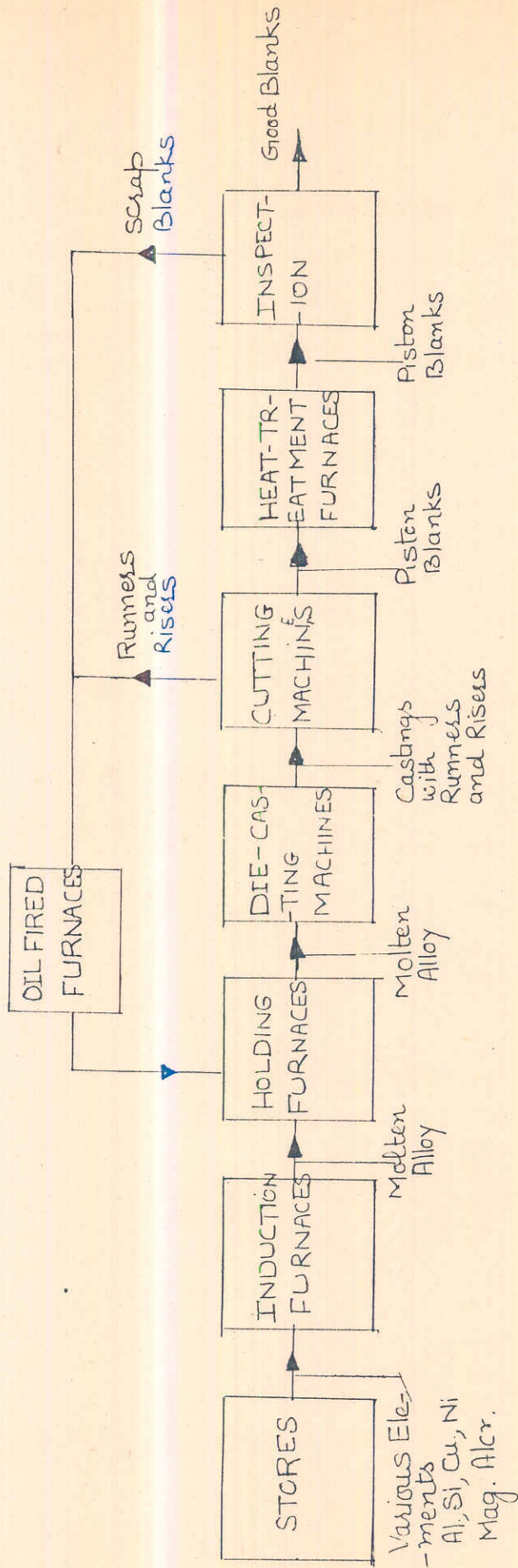
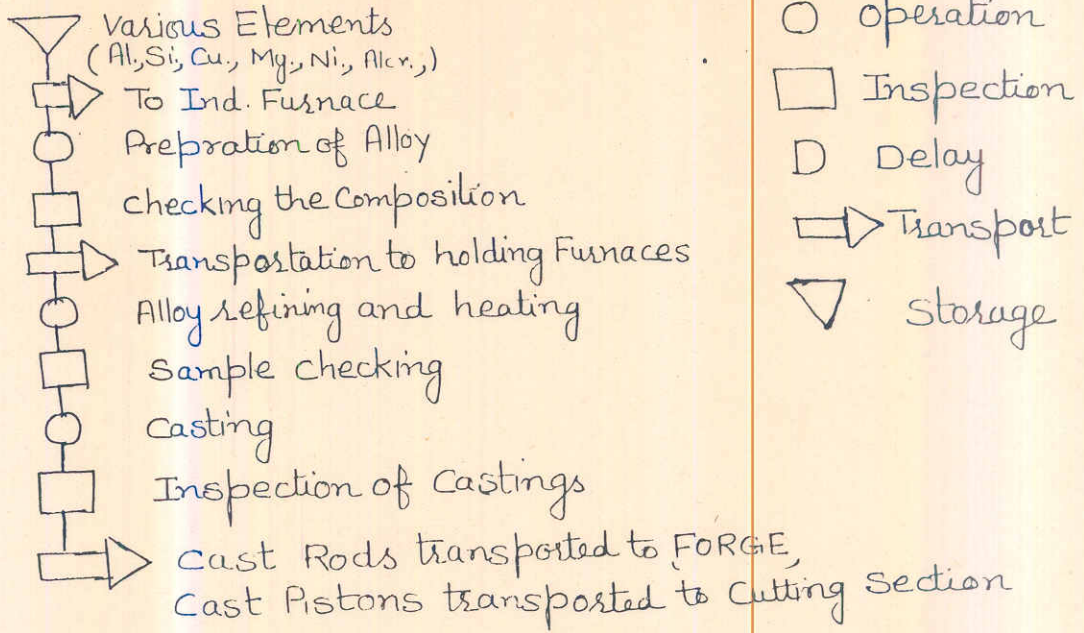


FIG 33 MATERIAL FLOW IN FOUNDRY

(Material Type)



- Symbols
- operation
 - Inspection
 - D Delay
 - ⇒ Transport
 - ▽ Storage

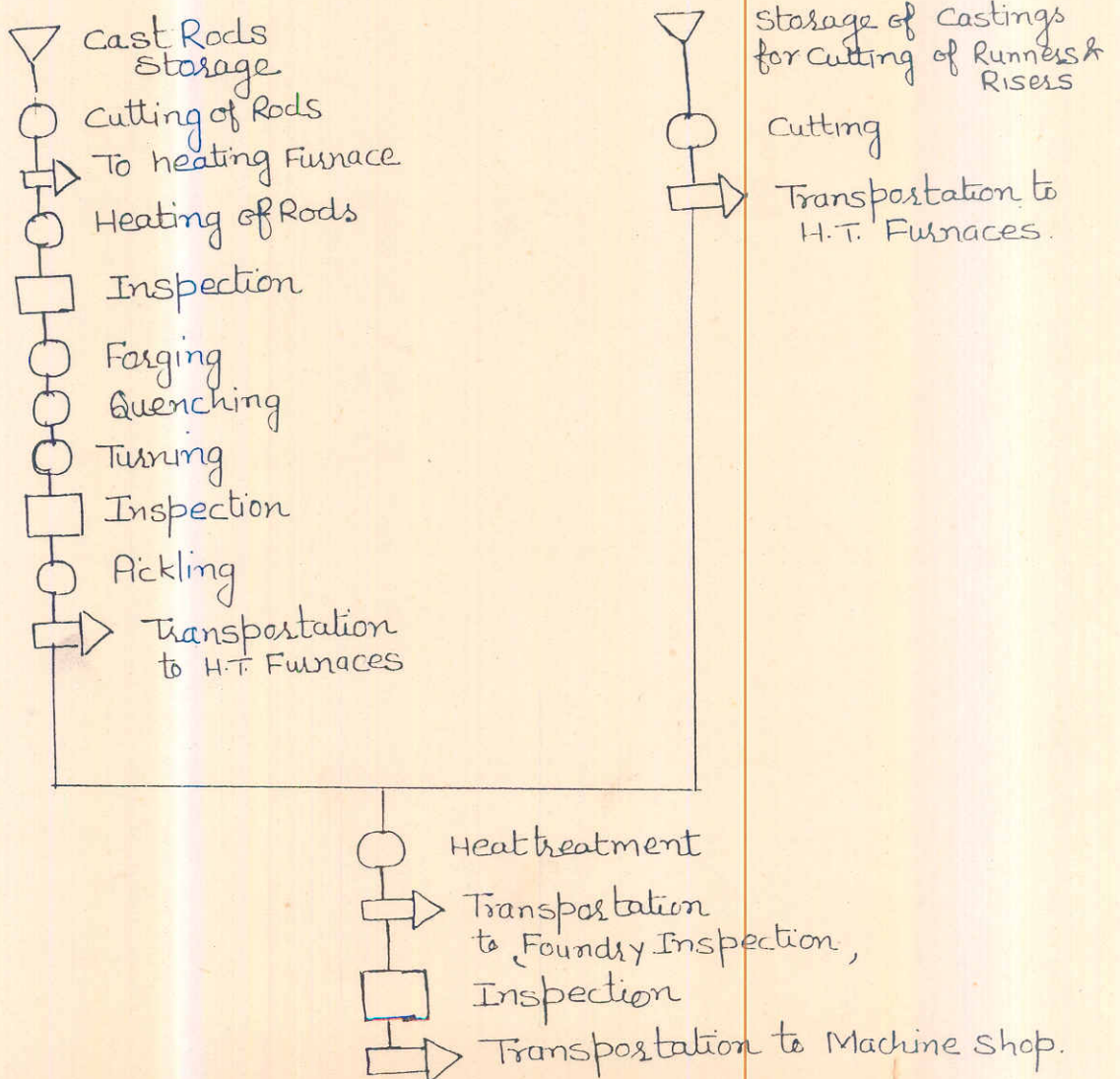


FIG 3.4 FLOW PROCESS CHART

molten alloy is taken from the holding furnace with the help of a casting spoon and poured into the closed die. The alloy solidifies in the moulds and after a specified time the die parts are opened and castings are taken out.

The castings are then sent to the cutting section. Here the runners and risers of the castings are cut and burrs etc. are filed.

In case of forged type blanks the long rods after casting are cut to sizes on a cutting machine. These cut pieces are then heated in a double chamber rotary furnace upto the forging temperature. The rods are forged one by one firstly on pre-forge press 150 tones and then on main forge press 550 tones. The forgings thus made are again heated and quenched in water. This is necessary for the subsequent heat treatment. The quenched forgings are then machined on lathes. Pickling in caustic soda solution and nitric acid is done after that to detect defects.

Cast blanks after removal of runners and risers and forged blanks after pickling are then heat treated to remove the work stressed and attain the required degree of hardness.

After heat treatment the blanks are inspected for all dimensional, heat treatment and metalurgical defects. The good blanks are sent to the machine shop and the scrap blanks are melted.

CHAPTER IV
DETAILED ENERGY ANALYSIS

The data has been collected for a period of one year from January 1, 1986 to December 31, 1986. The data includes all energy and material inputs and the material outputs during the study period. Other relevant data regarding the process details, to be used in the energy calculations have also been collected.

4.1 Energy Inputs

Energy inputs to the foundry are mainly in the form of electricity, light diesel oil and LPG. Table 4.1 show the electricity consumption by different sections of the foundry in each month during the study period.

TABLE 4.1
Electricity input to the foundry during January to December, 1986

Month	Electricity consumption in Kwh					Total foundry
	Forge	Induction furnaces No.1	Induction furnaces No.2	Dechlorination	Heat Treatment	
Jan.	48666	51260	44480	23350	49543	494944
Feb.	47866	67090	65410	24421	56213	403684
March	42630	63900	64780	25196	55941	489349
April	32600	60350	59150	24342	56222	438240
May	34000	67410	67870	21021	55143	518065
June	30920	69010	27250	26262	52219	507290
July	42450	48310	24970	23214	51023	509317
Aug.	39660	42460	44760	24913	48914	434864
Sept.	33100	78700	72230	25913	50500	559552
Oct.	40570	71290	67780	24563	55447	486700
Nov.	25400	74600	66120	23053	50213	501400
Dec.	54530	85680	83050	25586	56020	551835
Total.	422392	780130	687850	291834	637398	5895240

Table 4.2 shows the light diesel oil and LPG input to the foundry during the study period.

TABLE 4.2

Light Diesel Oil and LPG input to foundry during
January to December, 1986

Month	LDO (Litres)	LPG (Kg.)
January	93474	2550
February	61583	300
March	69346	2503
April	56459	-
May	64094	1697
June	61505	-
July	67183	1000
August	30812	1000
September	43147	1900
October	46298	2700
November	34718	3000
December	42431	3000
Total	671050	19550

The materials inputs to the foundry are different constituents of the alloys. Table 4.3 show the total input of these.

TABLE 4.3

Direct materials input to the foundry during
January to December, 1986

S.No.	Material	Quantity (Kg.)
1.	Aluminium	1274569.00
2.	Silicon	244644.78
3.	Copper	15963.10
4.	Nickle	14708.70
5.	Magnesium	41380.15
6.	Al.Cr.	6025.00
7.	Alloy 124 rods	35750.00
8.	Alloy 138 rods	1219.10

Indirect materials inputs to the foundry form a long list but they have a negligible contribution to energy values. Hence for the convenience of analysis these inputs will not be considered.

4.2 Outputs

Output from foundry is the piston blanks of various types varying in size shape and composition. Table 4.4 to 4.10 show the blanks output in numbers during the study period. The other details contained in these tables are,

1. No. of good blanks produced
2. No. of scrap blanks produced
3. Weight of each blanks
4. Weight of runners and risers of each blank.
5. Total number of good and scrap blanks.
6. Total weight of castings and forgings i.e. Blank weight plus runners and risers weight of each type.

As three types of alloys are used for the production of piston blanks namely alloy 124, alloy 138, alloy 244 and mainly three types of process are employed namely machine casting, hand casting and Forging so tables 4.4 to 4.10 contain the above details with a distribution depending upon alloy type and process of manufacturing. This is as under:

- a) Table 4.4 for alloy 124 with Machine casting process
- b) Table 4.5 for alloy 124 with hand casting process
- c) Table 4.6 for alloy 138 with Machine casting process

- d) Table 4.7 for alloy 138 with hand Casting process
 e) Table 4.8 for alloy 244 with machine casting Process
 f) Table 4.9 for alloy 244 with hand casting process
 g) Table 4.10 for Forge piston blanks.

TABLE 4.4

Details of blanks of alloy 124 made with machine casting process

S. No.	Type of Piston blank	No. of good blanks a	No. of scrap blanks b	Blank Weight Bw Kg.	Runners and Riser weight Rw	Total No. of Blanks (a+b)	Total Blank weight Bw+Rw
1.	Amb 5RV	18302	895	0.435	0.415	19197	0.850
2.	Amb SS(HCR)	19278	1607	0.435	0.415	20885	0.850
3.	Amb SS	16169	810	0.435	0.415	16979	0.850
4.	Escorts 335	40015	6733	1.600	1.410	46748	3.010
5.	Escorts 228/342	15235	1084	1.880	0.880	16319	2.760
6.	Ford 3600	66914	2429	1.835	1.065	69343	2.900
7.	Hind Trekkers	48379	2412	0.885	0.945	50291	1.830
8.	Int Harv.	69599	2329	0.945	0.885	71928	1.830
9.	Jeep Jellinue	9655	1797	0.580	0.280	11452	0.860
10.	Koel 80	55198	2268	0.850	0.525	57466	1.375
11.	Koel 87.5	14050	347	1.023	0.452	14397	1.475
12.	Maruti 800	64234	11873	0.231	0.254	76107	0.485
13.	Perkins P6	35733	736	1.512	1.238	36469	2.75
14.	Rustm YDA	4551	149	2.240	1.500	4700	3.740
15.	Rustm YWA	2404	103	1.510	1.190	2507	2.70
16.	Silver Plus	18553	335	0.510	0.127	18868	0.277
17.	Willy's Jeep	14620	845	0.605	0.190	15465	0.795
18.	Zeter 95	12377	538	1.280	0.590	12915	1.870
Total		525266	37290			562550	

TABLE 4.5

Details of blanks of alloy 124 made with hand casting process

S. No. blank	Type of Piston	No. of good blanks	No. of scrap blanks	Blank weight		Runners and Riser weight		Total No. of blanks	Total Blank weight
		a	b	Bw Kg.	Rw Kg.	(a+b)Kg	Bw+Rw Kg		
1.	Ambassador	217838	10952	0.435	0.415	228790	0.850		
2.	Elgi 50	1329	174	0.133	0.108	1503	0.241		
3.	Koel 85	6640	236	0.890	0.870	6876	1.760		
4.	Koel AV-33	3347	64	0.640	0.507	3411	1.147		
5.	Standard Herald	12313	931	0.280	0.260	13244	0.540		
6.	Tata AC	10235	897	0.295	0.415	11132	0.710		

TABLE 4.6

Details of blanks of alloy 138 made with machine casting process

S. No. blank	Type of Piston	No. of good blanks	No. of scrap blanks	Blank weight		Runners and Riser weight		Total No. of blanks	Total Blank weight
		a	b	Bw Kg.	Rw Kg.	(a+b)	Bw+Rw Kg		
1.	Agrom	11515	2315	1.700	1.550	13830	3.250		
2.	Bajaj Chetak	93093	3405	0.240	0.266	96498	0.506		
3.	Eicher	25138	6201	2.305	2.200	31339	4.505		
4.	Garelli Moped	9396	138	0.105	0.135	9534	0.240		
5.	Majestic Moped	123734	7657	0.094	0.096	131391	0.190		
6.	Peugeot	83814	6311	1.022	0.463	90125	1.485		
7.	Rajdoot	276182	20967	0.250	0.152	297149	0.402		
Total		622872	46994			669866			

TABLE 4.7

Details of blanks of 138 alloy made with hand casting process

S. Type of Piston No. blank	No. of good blanks	No. of scrap blanks	Blank weight		Runners and Riser weight		Total No. of blanks (a+b)	Total Blank weight Bw+Rw Kg
			a	b	Bw Kg.	Rw Kg		
1. Atlas Moped	7846	463	0.096	0.158	8309	0.254		
2. Bajaj Cub	6471	1044	0.155	0.209	7515	0.364		
3. Bajaj scooter	113719	11816	0.225	0.279	125535	0.504		
4. Bajaj 125	2585	399	0.220	0.212	2984	0.432		
5. Girnar	29354	1138	0.220	0.289	30492	0.509		
6. Jawa 70	3468	361	0.370	0.500	3829	0.870		
7. Tata Rods	151888	18226	5.150	-	170114	5.150		
8. MWM Rods	4495	900	9.86	-	5395	9.86		

TABLE 4.8

Details of the blanks of 244 alloy made with Machine Casting Process

S. Type of Piston No. Blank	No. of good blanks	No. of scrap blanks	Blank weight		Runners and Riser weight		Total No. of blanks (a+b)	Total Blank weight Bw+Rw Kg
			a	b	Bw Kg.	Rw Kg		
1. Cento J-100	11047	1039	0.175	0.246	12086	0.421		
2. Ind Suzuki, AX-100	3425	512	0.170	0.160	3937	0.330		
3. Lamby 57	37819	2643	0.272	0.132	40462	0.404		
4. TVS Moped	293275	14929	0.092	0.090	308204	0.182		
5. Vijay 57	77653	5259	0.270	0.107	82192	0.377		
Total	423438	24406			447844			

TABLE 4.9

Details of blanks of 244 alloy made with hand casting process

S. No.	Type of Piston blank	No. of good blanks a	No. of scrap blanks b	Blank weight Bw Kg.	Runners and Riser weight Rw	Total No. of blanks (a+b)	Total Blank weight Bw+Rw
1.	Mac 62	2977	794	0.305	0.205	3771	0.510
2.	Rajdoot 350CC	4255	1218	0.313	0.337	5473	0.650
3.	Vikram 66	7112	1316	0.335	0.275	8428	0.610
Total		14344	3328			17672	

TABLE 4.10

Details of the blanks of 124 and 138 alloy made with forging process

S. No.	Type of Piston blank	No. of good blanks a	No. of scrap blanks b	Blank weight Bw Kg.	Runners and Riser weight Rw Kg.	Total No. of blanks (a+b)	Total Blank weight Bw+Rw Kg.
1.	Ruston MWM 138	7660	1330	3.170	1.760	8990	4.93
2.	T-55 124	5120	671	3.930	1.270	5791	5.2
3.	Tata 90 138	30288	1479	1.320	1.255	31767	2.575
4.	Tata 92 138 4 Rv	7970	837	1.394	1.181	8807	2.575
5.	Tata 92 138 5 Rv	252336	10867	1.405	1.170	263203	2.575
Total		303374	15184			318558	
		138 298254	14513				
		124 5120	671				

4.3 Calculations of Energy Values

4.3.1 Defining the system

Our study is restricted to operations taking place inside the foundry. Therefore the system boundaries are decided considering the foundry boundaries. Figure 4.1 show various inputs and outputs of the system. Here the attempt is not to calculate the absolute value of energy associated with each type of blank, rather it is to know how much energy is spent on individual blank inside the foundry, only.

The system includes

- (a) All direct materials inputs
- (b) All energy inputs from fuels and Electricity
- (c) All materials outputs

The system excludes

- (a) Indirect materials input
- (b) Energy consumed on administrative and other functions
- (c) Energy consumed on the production and delivery of raw materials
- (d) Energy consumed on transportation of raw materials, outside the foundry building

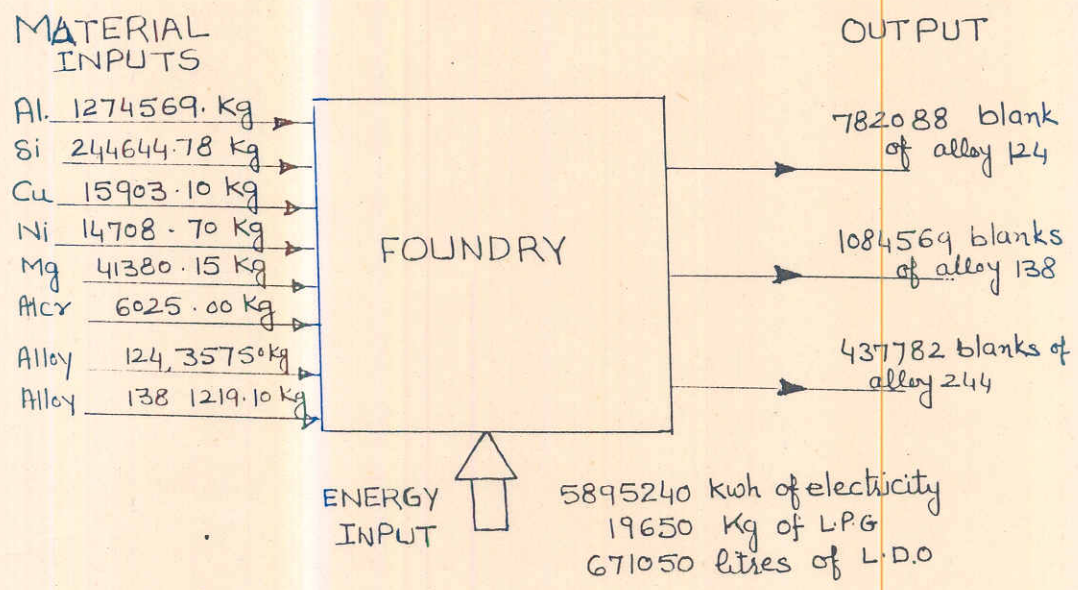


FIG 4.1 THE SYSTEM

- (e) Energy consumed on the manufacture of casting machines and other equipment used in the foundry.

4.32 The Sub Systems

The system as defined above is divided into different subsystems. Firstly the total energy consumed by each subsystem during the study period will be calculated. Then energy consumed by each type of blank in each sub-system will be calculated. Energy values thus calculated for a blank in each subsystem will be added to arrive at the total energy value.

The subsystems are decided on the bases of different sections and processes in the foundry. These are

1. Melting
 - a) Alloy making
 - b) Remelting
2. Casting
3. Fettling (Cutting of Runners & Risers)
4. Heat Treatment
5. Forge
6. Auxiliary operations of lighting and ventilation etc.

Figure 4.2 show how the subsystems are connected and the material flow through each subsystem.

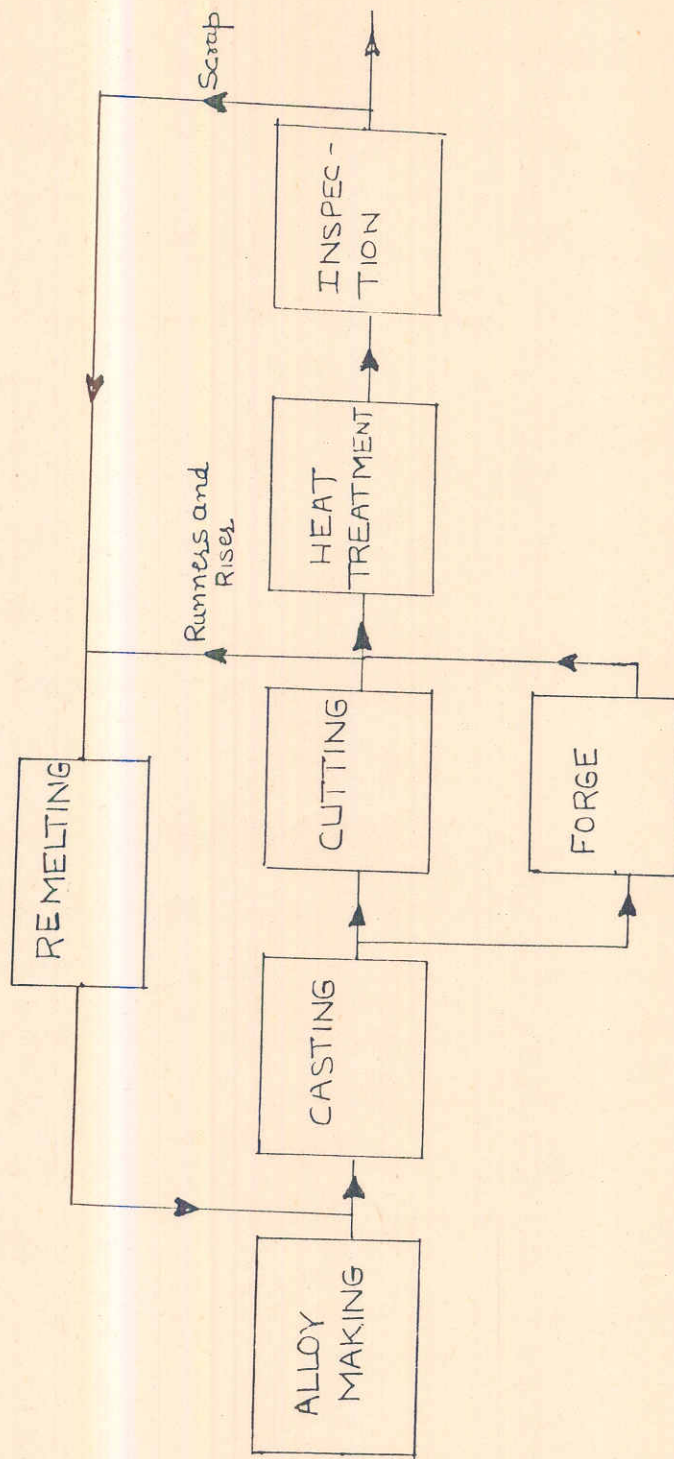


FIG 4.2 SUB-SYSTEMS

4.33 Calculation of Energy consumed by each subsystems

Table 4.1 shows the energy (electricity) consumption for different sections of the foundry. As different meters are not installed for every sub-system as made in our study, so while for some sub-systems the energy consumption is directly available from the meters, for others it has to be calculated from the wattage of the total equipment in that sub-system. These energy values are arrived at as under:

1. MELTING

(a) Alloy Making

Electricity consumption on two induction furnaces as available from table 4.1 is

$$780130 + 687850 = 1467980 \text{ Kwh.}$$

As all returning material added at the induction furnaces is in the molten stage, melted on oil fired furnaces, so all energy consumption on induction furnaces is assumed to be consumed on fresh materials i.e. for alloy making.

(b) Remelting

From Table 4.2 the total diesel oil consumption is 671050 litres.

Electricity consumption by a 2 Kw motor of the oil fired furnace in running for 4129.13 hours (Time calculated

in later sections)

$$= 4129.13 \times 2 = 8258.26 \text{ Kwh.}$$

2. PETALING (Cutting of runners and risers)

The machines and their wattages are as under:

S.No.	Machine	Quantity	Wattage	Total Wattage
1.	SA ₁	2	15 KW	30 KW
2.	SA-20	2	6 KW	12 KW
3.	SA-2	2	7.5 KW	15 KW
4.	Power Hacksaws	5	1.5 KW 1.5 KW	7.5 KW

Total Running time of machines per day is 16 hours.

Total electricity consumed in one year

$$= 65 \times 25 \times 12 \times 15 = 31200 \text{ units}$$

(days) (Months) (Hrs)

3. HEAT TREATMENT

Table 4.1 show the electricity consumption for heat treatment as 637398 Kwh.

4. AUXILIARY OPERATIONS

The auxiliary operations include lighting, fans and dechlorination unit. The different appliances used and their wattages are as under:

50

S.No.	Applicance	Quantity	Wattage	Total Wattage
1.	Ceiling Fans	40	80	3.200
2.	Tubelights	120	40	4.800
3.	Mercury Lamps	125	250	31.250
4.	Cabin fans	50	80	4.000
5.	Coolers and Ped Fans.	10	250	2.500
				45.750 Kw

Considering 24 hours working 25 days a month for
12 months.

$$\text{Total energy consumed} = 45.75 \times 24 \times 25 \times 12 = 329400 \text{ KW}$$

$$\begin{array}{l} \text{Electricity consumption of Dechlorination as} \\ \text{given by table 4.1} \end{array} = 291834 \text{ KW}$$

621234 Kwh

5. CASTING

$$\begin{array}{l} \text{Energy consumed} = \left(\begin{array}{l} \text{Total energy} \\ \text{consumed by} \\ \text{foundry} \end{array} \right) - \left(\begin{array}{l} \text{Energy consumed by alloy} \\ \text{making + Remelting +} \\ \text{Auxiliary operations +} \\ \text{Casting + heat treatment} \end{array} \right) \\ \text{by casting} \end{array}$$

$$= 5895240 - (1467980 + 8258 + 31200 + 637398 + 621234)$$

$$= 2848370 \text{ Kwh.}$$

6. FORGE

Electricity consumption from Table 4.1 = 422392 Kwh
LPG consumption from Table 4.2 = 19650 Kg.

Distribution of Energy consumption among sub-systems

Having calculated the energy consumption by each sub-system we fill these values in figure 4.2 to arrive at figure 4.3.

4.34 Calculation of Energy Values for individual blanks in each sub-system

For calculating the energy consumption values for individual blank in each sub-system the following details will be needed.

1. Total weight of good blanks of each type of alloy, total weight of good blanks of all alloys and weight of individual type of good blanks.
2. Runners-risers weight of good and scrap blanks of each type, RR weights of blanks of each alloy and RR weight of all alloys.
3. Total alloy made of each type
4. Total metal recirculated of each type of alloy for remelting.

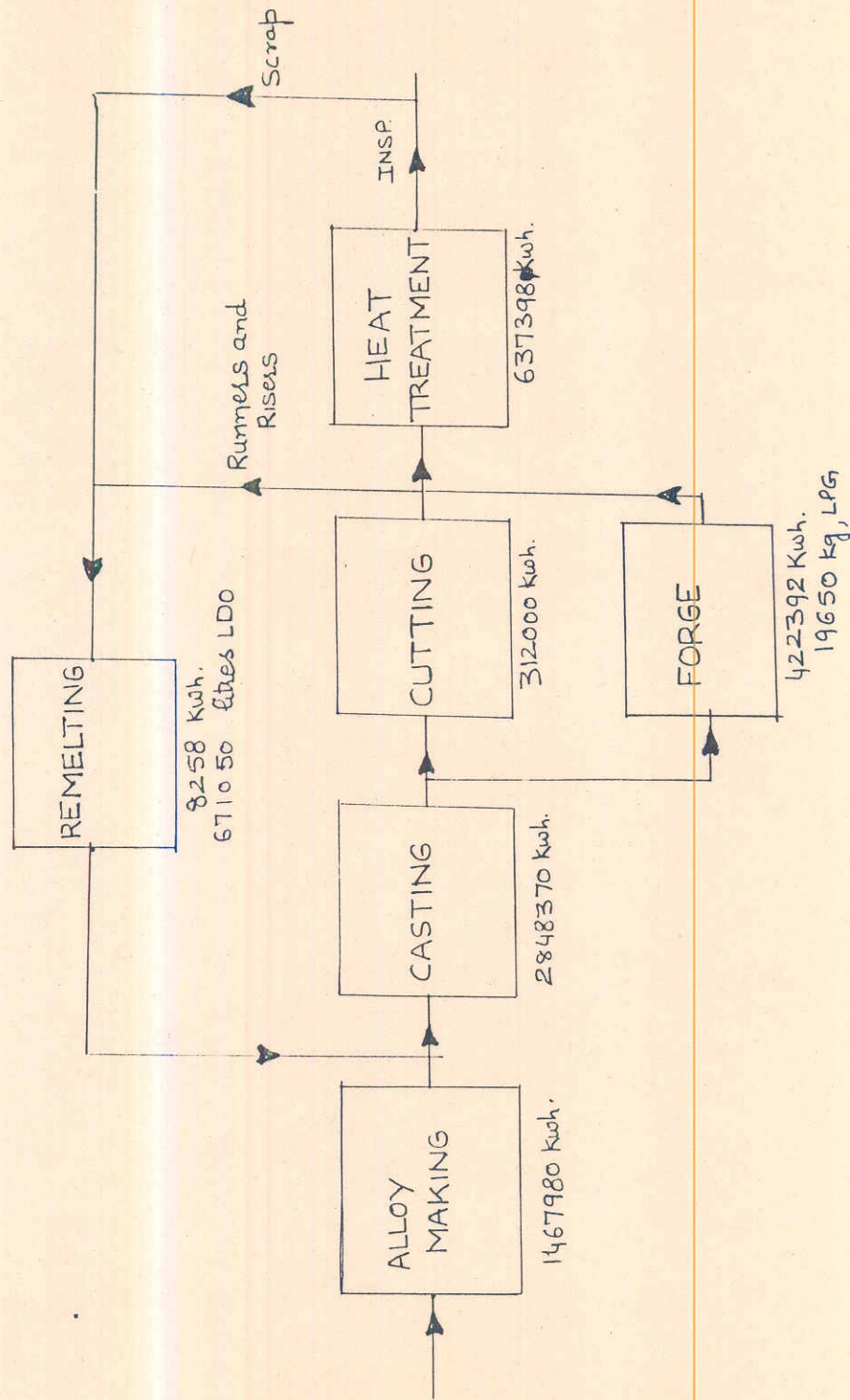


FIG 4.3. ENERGY CONSUMPTION OF SUB-SYSTEMS

5. Production per shift and number of shifts a particular blank was produced during the study period.
6. Number of blanks of each type per charge of heat-treatment and thus number of charges made during the study period out of the total production made.

Calculations tables 4.11 to 4.17 show the above details. Different tables contain information regarding different alloys and manufacturing processes. Values in these tables have been arrived at by suitable multiplications or additions of values of different columns of tables 4.4 to 4.10. This is evident from the tables.

TABLE 4.11

Details of the blanks of alloy 124 made with machine casting process

S. No.	Type of Piston	Weight of good blanks a x Bw	Weight of scrap blanks b x Bw	Weight of good+ scrap blanks (a+b)Bw	Runners & Riser weight of good + scrap blanks Rw(a+b)	Total weight (Rw+Bw)x (a+b)	Material Recirculated $R_w(a+b)+b \cdot Bw$	Production per shift P	No. of production shifts $\frac{a+b}{P}$	No. of blanks per Char-ge of heat treatment $\frac{a+b}{H}$
1.	Amb 5RV	7961.37	389.32	8350.69	7966.75	16317.45	8356.07	200	95.98	700
2.	Amb SS HCR	8385.93	699.04	9084.97	8667.27	17752.25	9366.32	200	104.42	700
3.	Amb SS	7033.51	352.35	7385.86	7046.28	14432.15	7398.64	200	84.89	700
4.	Escorts 335	64024.00	10772.80	74796.80	65914.68	140711.48	76687.48	80	584.35	250
5.	Escorts 228/342	28641.00	2037.92	30678.92	14360.72	45039.64	16398.64	100	163.19	250
6.	Ford 3600	122787.19	4457.21	127244.40	73850.20	201094.70	78307.51	100	693.49	300
7.	Hind Trekker	42815.41	2134.62	44950.03	47524.99	92475.02	49659.61	150	335.27	500
8.	Int. Harvester	65771.05	2200.92	67971.96	63656.28	131628.24	65857.19	140	513.77	400
9.	Jeep Jellinue	5599.90	1042.26	6642.16	3206.56	9848.72	4248.82	200	57.26	500
10.	Koel 80	46918.30	1927.80	48846.10	30169.65	79015.75	32097.45	150	383.10	350
11.	Koel 87.5	14373.15	354.98	14728.13	21235.57	35963.70	21590.55	125	115.17	350
12.	Maruti 800	14838.05	2742.66	17580.71	19331.17	36426.89	21588.84	200	380.53	400
13.	Perkins P6	54023.29	1112.83	55141.12	45148.62	100289.75	46261.46	110	331.53	300
14.	Ruston YDA	10194.24	333.76	10528.00	7050.00	17578.00	7383.76	100	47.00	250
15.	Ruston YWA	3630.04	155.53	3785.57	2983.33	6768.90	3138.86	100	25.07	250
16.	Silver Plus	2782.95	50.25	2830.20	2396.23	5226.43	2443.48	300	62.89	800
17.	Willy's Jeep	8845.10	511.22	9356.32	2938.35	12294.67	3449.57	150	103.10	500
18.	Zeter 95	15842.56	698.64	16531.20	7619.85	24151.05	8308.49	100	129.15	300
		524472.04	31964.17	556436.21	431066.59	987502.80			4210.16	1500.59

TABLE 4.12

Details of the blanks of alloy 124 made with hand casting process

S. No.	Type of Piston	Weight of good blanks a x Bw	Weight of scrap blanks b x Bw	Weight of good+ scrap blanks (a+b)Bw	Runners & Riser weight of good + scrap blanks R _w (a+b)	Total weight (R _w +B _w)x (a+b)	Material Recirculated R _w (a+b) + b.BW	Production per shift P	No. of Production shifts $\frac{a+b}{P}$	No. of blanks per char-ge of heat treatment $\frac{a+b}{H}$	No. of No. of char- ges
1.	Ambassador	94759.50	4764.12	99523.65	94947.85	194471.50	99712.00	150	1525.27	700	326.84
2.	Elgi 50	176.75	23.14	199.89	163.32	362.23	185.48	150	10.02	500	3.00
3.	Koel 85	5909.60	210.04	6119.64	5982.12	12101.76	6192.16	100	68.76	350	19.64
4.	Koel AV-33	2142.08	40.96	2183.04	1729.37	3912.41	1770.33	100	34.11	400	8.52
5.	Std. Herald	3447.64	260.68	3708.32	3443.44	7151.76	3704.12	125	105.95	300	44.14
6.	Tata AC	3019.32	264.61	3283.94	4619.78	7903.72	4884.40	150	74.21	300	37.105
	Total	109454.89	5563.55	115018.43	110884.88	225903.36			1818.32		439.24

TABLE 4.13

Details of the blanks of alloy 138 made with machine casting process

S. No.	Type of Piston	Weight of good blanks a x Bw	Weight of scrap blanks b x Bw	Weight of good+ scrap blanks (a+b)Bw	Runners & Riser weight of good + scrap blanks RW(a+b)	Total weight (RW+Bw)x (a+b)	Material recirculated RW(a+b) + b.Bw.	Production per shift P	No. of blanks per charge of heat treatment (H)	No. of blanks charges	
1.	Agrom	19575.50	3935.50	23511.00	21436.50	44947.50	25372.00	70	197.57	250	55.31
2.	Bajajchetak	22342.32	817.20	23159.52	25668.46	43827.98	26485.66	300	321.66	500	192.99
3.	Eichers	57943.09	14239.30	72236.39	68945.80	141182.19	83239.10	50	626.78	150	208.92
4.	Garelli Moped	986.58	14.49	1001.07	1287.09	2288.16	1301.58	300	31.78	600	11.91
5.	Majestic Moped	11630.99	719.75	12350.74	12613.53	24964.27	13333.28	350	375.40	800	164.23
6.	Pengeot	85014.04	6449.84	91463.88	41727.87	133191.75	48177.71	125	721.00	350	257.50
7.	Rajdoot	69045.50	5241.75	74287.25	45166.64	119453.89	50408.39	250	1188.59	600	495.24
	Total	266538.02	31471.83	298009.85	216845.89	514855.74			3462.78		1386.1

TABLE 4.14

Details of the blanks of alloy 138 made with hand casting process

S. No.	Type of Piston	Weight of good blanks a x Bw	Weight of scrap blanks b x Bw	Weight of good+ scrap blanks (a+b) Bw	Runners & Riser weight of good + scrap blanks Rw(a+b)	Total weight (Rw+Bw) x (a+b)	Material recirculated Rw(a+b) + b.Bw.	Production per shift P	No. of Production shifts $\frac{a+b}{P}$	No. of blanks per charge of heat treatment (H)	No. of blanks charges
1.	Atlas Moped	753.21	44.44	797.66	1312.82	2110.48	1357.27	200	41.54	800	10.38
2.	Bajajcub	1003.00	161.82	1164.82	1570.63	2735.46	1732.46	170	44.20	500	15.02
3.	Bajaj scooter	25586.77	2658.60	28245.37	35024.26	63269.63	37682.86	150	836.90	500	251.07
4.	Bajaj 125	568.70	87.78	656.48	632.60	1289.08	720.38	170	17.55	500	5.967
5.	Girnar	6457.88	250.36	6708.24	8812.18	15520.42	9062.54	150	203.28	500	60.98
6.	Jawa 70	1283.16	133.57	1416.73	1914.50	3331.23	2048.07	125	30.62	400	9.56
7.	Tata Rods	78223.20	96863.90	876087.10	--	876087.10	93863.90	70	2430.20	--	--
8.	MWM Rods	44320.70	8874.00	53194.70	--	53194.70	8874.00	30	179.83	--	--
Total		862196.62	106074.47	968271.10		1017538.1			3784.12		352.97

TABLE 4.15

Details of the blanks of alloy 244 made with machine casting process

S. No.	Type of Piston	Weight of good blanks a x Bw	Weight of scrap blanks b x Bw	Weight of good+ scrap blanks (a+b) Bw	Runners & Riser weight of good + scrap blanks Rw(a+b)	Total weight (Rw+Bw) x (a+b)	Material recirculated Rw(a+b) + b.Bw	Production per shift P	Production shifts $\frac{a+b}{P}$	No. of blanks per charge of heat treatment (H)	No. of charges
1.	Cento-J-100	1933.22	181.82	2115.04	2973.15	5058.19	3154.97	250	48.34	400	30.21
2.	Ind Suzuki AX-100	582.25	87.04	669.29	629.92	1299.21	716.96	225	17.49	400	9.83
3.	Lamby 57	10286.76	718.89	11005.65	5340.98	16346.63	6059.87	250	161.84	500	80.92
4.	TVS Moped	26981.30	1373.46	28354.76	27738.36	56093.12	29111.82	300	1027.34	800	385.20
5.	Vijay 57	20966.31	1419.93	22386.24	8871.58	31257.97	10291.51	200	414.56	500	165.82
Total		60749.84	3781.14	64530.98	45553.99	110084.97			1669.57		671.98

TABLE 4.16

Details of blanks of 244 alloy made with hand casting process

S. No.	Type of Piston	Weight of good blanks a x Bw	Weight of scrap blanks b x Bw	Weight of good scrap blanks (a+b) Bw	Runners & Riser weight of good scrap blanks Rw(a+b)	Total weight (Rw+Bw)x (a+b)	Material Recirculated $Rw(a+b) + b.Bw.$	Production per shift P	No. of Production shifts $\frac{P}{a+b}$	No. of blanks per charges of heat treatment H	No. of blanks charges $\frac{a+b}{H}$
1.	Mac 62	907.98	242.17	1150.15	773.05	1923.21	1015.23	100	37.71	500	7.54
2.	Rajdoot	1331.81	381.23	1713.04	1844.40	3557.45	2225.64	150	36.48	600	9.12
3.	Vikram	2382.52	440.86	2823.38	2317.70	5141.08	2758.56	100	84.28	400	21.07
	Total	4622.32	1064.26	5686.58	4935.15	10621.74			158.47		37.73

TABLE 4.17

Details of the blanks of 124 and 138 alloy made with forge process

S. No.	Type of Piston	Weight of good blanks a x Bw	Weight of scrap blanks b x Bw	Weight of good scrap blanks (a+b) Bw	Weight of good+ scrap blanks (a+b) Bw	Runners & Riser weight of good + scrap blanks Rw(a+b)	Total weight (Rw+Bw)x (a+b)	Material Recirculated Rw(a+b) + b.Bw	Production per shift P	Production shifts $\frac{a+b}{P}$	No. of blanks per charges of heat treatment	No. of charges
1.	Ruston MWM	24282.20	4216.10	28498.30	15822.40	44320.70	200385.50	300	29.96	250	35.95	
2.	T-55	20121.60	2637.03	22758.63	7354.57	30113.20	9991.60	300	19.30	250	23.16	
3.	Tata 90	39980.16	1952.28	41932.44	39867.58	81800.00	41819.60	700	45.38	500	63.53	
4.	Tata 92 4RV	11110.18	1166.77	12276.95	10401.06	22678.02	11567.84	700	12.58	500	17.61	
5.	Tata 92 5RV	354532.08	15268.13	369800.21	307947.51	677747.72	323215.64	700	376.00	500	52.64	
Total		450026.22	25240.32	475266.54	381393.12	856659.67			483.22		666.65	

TABLE 4.18

Total weights of each alloy and gross weight of all alloys

		Wt. of Good blanks	Wt. of scrap blanks	Wt. of good plus scrap blanks	R.R. Weight	Total weight
A L L O Y 1 2 4	Hand casting	109454.89	5563.55	115018.48	110884.88	225903.36
	Machine casting	524472.04	31964.17	556436.21	431066.59	987502.80
	Total	633926.93	37527.72	671454.69	541951.47	1213406.16
A L L O Y 1 3 8	Hand casting	862196.62	106074.47	968271.10	49266.99	1017538.10
	Machine casting	266538.02	31471.83	298009.85	216845.89	514855.74
	Total	1128734.64	137546.30	1266280.95	266112.88	1532393.84
A L L O Y 2 4 4	Hand casting	4622.32	1064.26	5686.58	4935.15	10621.74
	Machine casting	60749.84	3781.14	64530.98	45553.90	110084.97
	Total	65372.16	4845.40	70217.56	50489.05	120706.71
T O T A L	Hand casting	976273.83	112702.28	1088976.16	165087.02	1254063.20
	Machine casting	851759.90	67217.14	918977.04	693466.38	1612443.51
	Total	1828033.73	179919.42	2007953.20	858553.40	2866506.71

Calculation of Energy consumed by blanks in each sub-system

1. Alloy Making

As the figure 4.4 indicates 633926.93 Kg. of alloy 124, 1128734.64 Kg. of alloy 138 and 6337216 Kg. of alloy 244 were made on induction furnaces. These figure have been taken from table 4.18 and is the weight of the good blanks sent out of foundry.

During its normal working it is observed that 400 Kg. of alloy 124, 350 Kg. of alloy 138 and 300 Kg. of alloy 244 can be tapped per hour from the induction furnace. Therefore working hours of the furnace during the study period for each type of alloy are

Alloy 124	$\frac{633926.93}{400}$	=	1584.81 Hours
Alloy 138	$\frac{1128734.64}{350}$	=	3224.95 Hours
Alloy 244	$\frac{65372.16}{300}$	=	217.90 Hours
Total		=	5027.66 Hours

Electricity consumption for each type of alloy

Alloy 124	$\frac{1467980 \times 1584.81}{5027.66}$	=	462734.02 Kwh.
Alloy 138	$\frac{1467980 \times 3224.95}{5027.66}$	=	941623.34 Kwh
Alloy 244	$\frac{1467980 \times 217.90}{5027.66}$	=	63622.60 Kwh

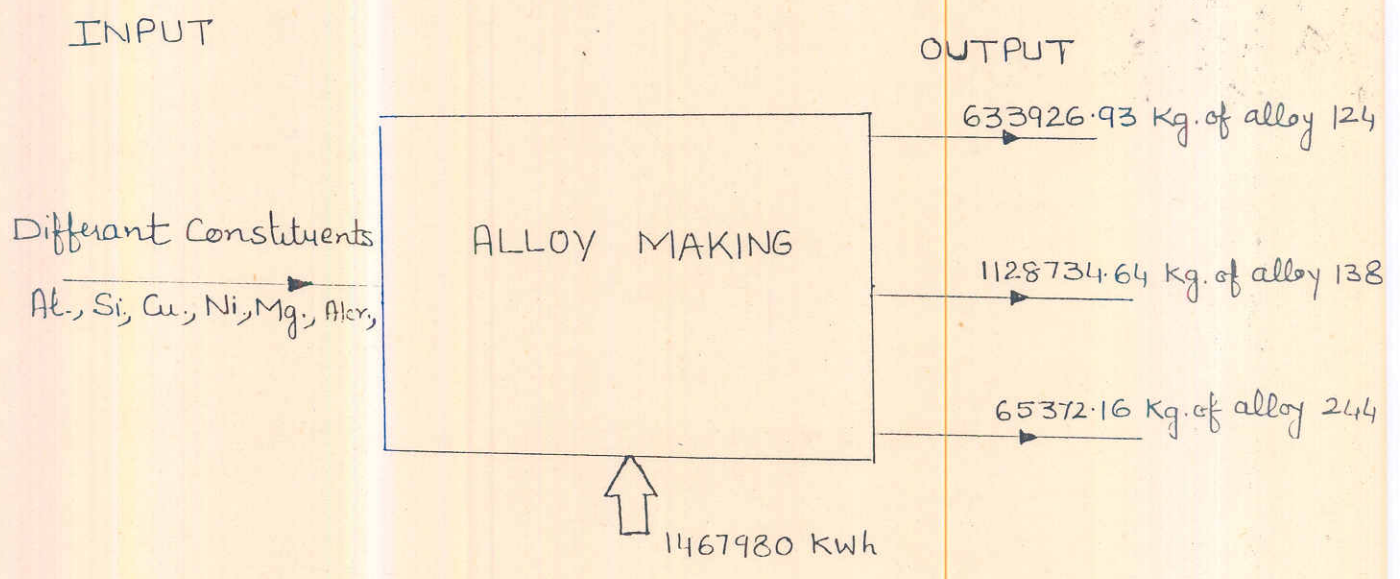


FIG 4.4. ALLOY MAKING SUB-SYSTEM

Energy consumed per Kg. of alloy making

$$= \frac{\text{Total Electricity consumption for the alloy}}{\text{Total weight of alloy}}$$

$$\text{Alloy 124} = \frac{462734.02}{633926.93} = 0.7248 \text{ Kwh/Kg.}$$

$$\text{Alloy 138} = \frac{941623.32}{1128734.64} = 0.8342 \text{ Kwh/Kg.}$$

$$\text{Alloy 244} = \frac{63622.60}{65372.16} = 0.9724 \text{ Kwh/Kg.}$$

For calculating the energy consumption for alloy making for individual blank of each type, the blank weight is multiplied by the energy consumption per unit weight

e.g. Amb 5 RV alloy 124

$$\begin{aligned} \text{Energy for alloy making} &= 0.7298 \times 0.435 \\ &= 0.3174 \text{ Kwh} \end{aligned}$$

Similarly in case of alloy 138 and 244 the blank weight is multiplied with 0.8342 and 0.9724 respectively.

These calculated values are written in column No.1 of tables 4.19, 4.20, 4.21, 4.22, 4.23, 4.24 and 4.25.

2. Remelting

Shows
Figure 4.5, Remelting as input-out system.

Alloy Remelted

Alloy	Hand casting	Machine casting	Forge	Total
124	116448.47	463030.76	9991.6	589470.74
138	155341.48	248317.72	396641.85	800301.03
244	5999.42	49335.13		55334.55
		Gross		1445106.32

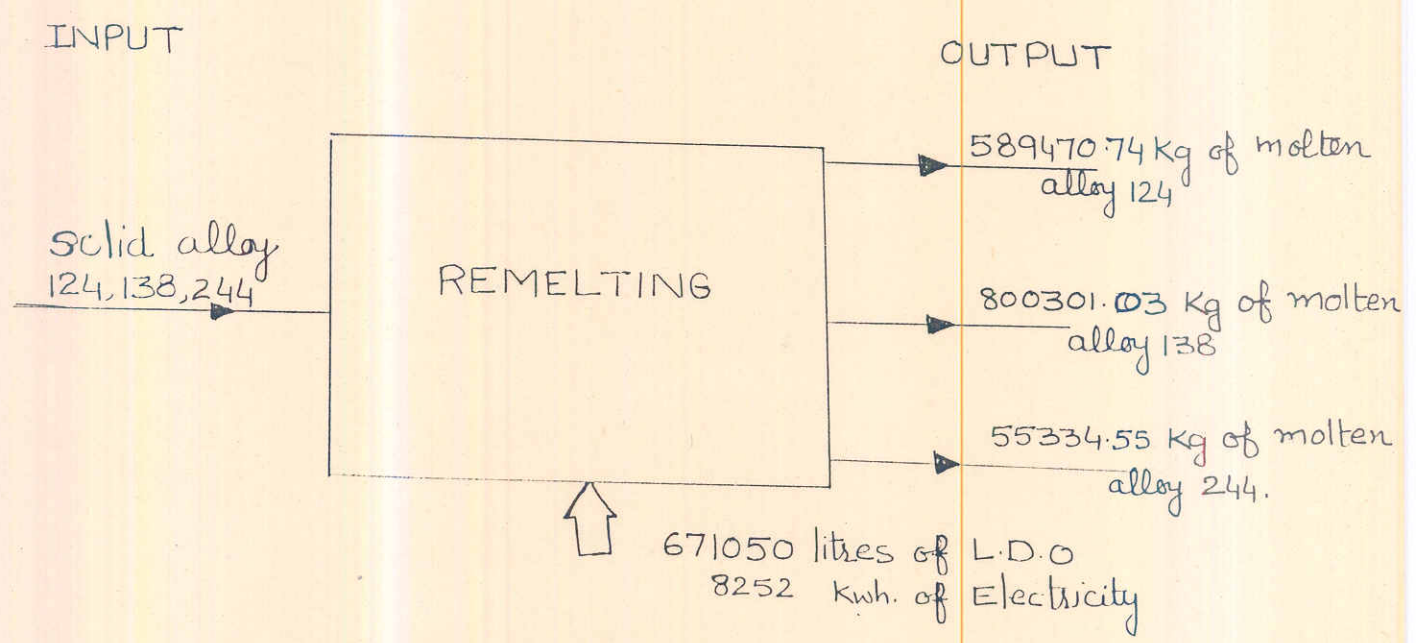


FIG 4.5 REMELTING SUB-SYSTEM

The above values are taken from table 4.12 to 4.18.

Alloy 124 and 138 are remelted on direct heating type oil fired furnaces. The output is

Alloy	Output
124	400 Kg.
138	350 Kg.

Alloy 244 is remelted on crucible type oil fired furnace and the output is 150 Kg. per hour.

In both the above type of furnaces a 2 Kw motor operates the blower.

Total furnace working hours

124	$\frac{589470.74}{400} = 1473.67$ hours
138	$\frac{800301.03}{350} = 2286.57$ hours
244	$\frac{55334.55}{150} = 368.89$ hours
	<hr/>
Total	$= 4129.13$

Electricity consumption = $4129.13 \times 2 = 8258.26$ Kwh.

Energy consumption for each type of alloy

Alloy	Electricity consumption	LDO Consumption
124	$\frac{8258.26 \times 1473.67}{4129.13} = 2947.34$	$\frac{671050 \times 1473.67}{4129.13} = 239495.06$

3. Casting

Figure 4.6^{Shows} casting as an input-out system.

The basis for the division of the total electricity consumption of casting section into blanks of various types has been taken as production per shift.

There are two processes with which the blanks are cast. One is the hand casting and the other is machine casting. In case of machine casting a hydraulic unit operates the actuators of the hydraulic casting machines.

$$\text{Energy consumption by hyd. unit} = \frac{25 \text{ Kw} \times 25 \text{ days} \times 24 \text{ hrs} \times 12 \text{ Month}}{= 1,80000 \text{ Kwh}}$$

$$\text{Energy consumption for other casting operations} = 2848370 - 180000 = 2668370 \text{ Kwh}$$

$$\text{Energy consumption by a blank at casting stage} = \frac{2668370}{\text{Total No. of shifts}} \times \frac{\text{No. of shifts of the blank}}{\text{No. of good blanks}}$$

$$= \frac{2668370}{15103.42} \times \frac{\text{No. of shifts of the type}}{\text{No. of good blanks}}$$

Additional energy for machine casting blanks

$$= \frac{180000}{\text{Total No. of shifts of machine casting blanks}} \times \frac{\text{No. of shifts of the type}}{\text{No. of good blanks}} \quad (9332.51)$$

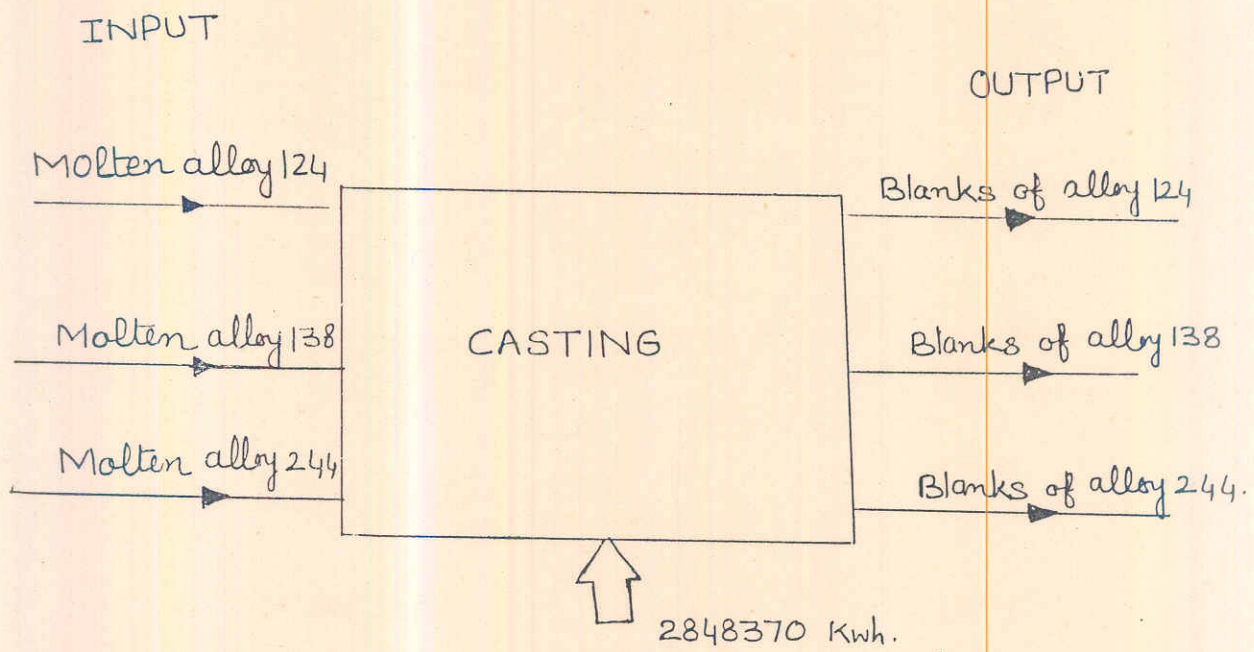


FIG 4.6 CASTING SUB-SYSTEM

Example

Ambassador 5RV alloy 124 Machine casting

$$\text{Energy consumption} = \frac{2668370}{15103.42} \times \frac{95.98}{18302} = 0.9265 \text{Kwh}$$

$$\text{Energy consumption by Hyd. Unit} = \frac{180000}{9332.51} \times \frac{95.98}{18302} = 0.1011 \text{Kwh}$$

Similarly the above energies have been calculated for all types of blanks and tabulated in column No.4 of Tables 4.19 to 4.25.

4. Cutting

The cross section of the runner and risers is directly proportionate to the weight of the runners and risers. Therefore the Cutting Energy is also proportionate to the weight of the runners and risers.

$$\begin{aligned} \text{Energy used for cutting of runner and riser of a blank} &= \frac{\text{Total energy} \times \text{Wt. of RRs of (Good+scrap) blanks}}{\text{Total weight of RRs of all types} \times \text{No. of good blanks}} \\ &= \frac{312000}{858553} \times \frac{\text{Wt. of RRs of Good + scrap blanks}}{\text{No. of good blanks}} \end{aligned}$$

Example Amb 5 RV alloy 124

$$\text{Energy used for cutting of runners and risers} = \frac{312000}{858553} \times \frac{7966.75}{18302}$$

$$= 0.1581 \text{ Kwh}$$

Similarly the energy consumed for cutting of runners and risers of blanks of all other types have been calculated and tabulated in column No.5 of tables 4.19 to 4.25.

5. Heat Treatment

Process of heat treatment involves heating the blanks at a particular temperature for a specified time followed by air cooling. The piston blanks are kept in a box which is charged in the furnace. The electricity consumed for one charge is almost same for charges of all types. Therefore the energy consumed by one blank will depend upon the number of blanks per charge. column 9 of tables 4.11 to 4.17 show the number of piston blanks per charge of heat treatment and the column 10 show how many charges of the type were heat treated during the study period of one year. The sum of such charges is 4388.61 Nos.

$$\text{Energy consumed at heat treatment by one blank of the type} = \frac{\text{Total consumption by heat treatment}}{\text{Total No. of charges}} \times \frac{\text{No. of charges of the type}}{\text{No. of good blanks}}$$

$$= \frac{637398}{4388.61} \times \frac{\text{No. of charges of the type}}{\text{No. of good blanks}}$$

Example Amb 5 RV

$$\begin{array}{l} \text{Energy consumption} \\ \text{at heat treatment by} \\ \text{one Amb 5 RV blank} \end{array} = \frac{637398}{4388.61} \times \frac{27.42}{18302} = 0.2175 \text{ Kwh}$$

Similarly the above values of energy consumption at heat treatment by blanks of all types have been tabulated after calculations in column NO.6 of tables No. 4.19 to 4.25.

6. Auxiliary operations

The basis of division of energy consumption of auxiliary operations of lighting, fans and dechlorination etc. into blanks of various types is ^{again} given the production per shift.

$$\begin{array}{l} \text{Energy contribution} \\ \text{of auxiliary operat-} \\ \text{ions consumption to} \\ \text{one blank of the type} \end{array} = \frac{\text{Total energy consum-} \\ \text{ption of auxiliary} \\ \text{operations}}{\text{Total No. of} \\ \text{shifts.}} \times \frac{\text{No. of shifts of} \\ \text{the type}}{\text{No. of good blanks}}$$

$$= \frac{621234}{15103.42} \times \frac{\text{No. of shifts of the type}}{\text{No. of good blanks.}}$$

Example Amb 5 RV

$$= \frac{621234}{15103.42} \times \frac{95.98}{18302} = 0.2157 \text{ Kwh}$$

Similarly energy contribution of auxiliary operations consumption to blanks of all types have been calculated. Column No.7 of tables 4.19 to 4.25 show such values.

7. Total Energy consumption

We have calculated the energy consumption of all type of blanks in each subsystem namely alloy making, remelting, casting, cutting of runners and risers, heat treatment and auxiliary operations. The sum total of these energy consumption values give the total energy consumption. Column No.8 and 9 of tables 4.19 to 4.25 show such values for electricity and LDO respectively.

4.35 Conversion of energy units

Table 4.26 show the energy values associated with 1 KW of electricity, One litre of LDO and one Kg. of LPG.

Table 4.26

		Production & delivery energy	Energy content	Total energy
1.	Electricity 1KW	11.40	3.6	15.00
2.	Light Fuel Oil 1 litre	8.29	40.18	48.47
3.	LPG 1 Kg.	-	-	58.19

Values of column No.9 and 10 have been converted to energy units and added. These are tabulated in column No.10.

4.36 Forge section

Total No.of shifts = 483.22

Total energy consumption = 422392

Energy per blank = $\frac{422392}{483.22} \times \frac{\text{No.of shifts of the type}}{\text{No.of good blanks}}$

Example Ruston MWM

Energy consumption at Forging stage = $\frac{422392}{483.22} \times \frac{29.96}{7660} = 3.4188 \text{ Kwh}$

and

= $\frac{19650}{483.22} \times \frac{29.96}{7660} = 0.1590 \text{ Kg. of LPG}$

Similarly the forging energy of all other types have been calculated and tabulated in table 4.25.

Column No.3 and 4 of table 4.25 show the casting energy attributable to each type of forged blank. These values have been taken from table NO.4.21.

Last column of table 4.25 show the addition of column 3,4,5,6 and converted to energy units and thus given the total energy consumption of the forged blanks.

TABLE 4.19

Energy consumption of piston blanks of 124 alloys made with Machine casting process

S. No.	Type	Alloy Making	Remelting		Casting		Cutting	Heat Treatment	Auxiliary Operations	Total	
			Elect.	Oil	General	Hyd. Unit				Elect.	Oil MJ
1.	Amb 5RV	0.3174	2.28x10 ³	0.18549	0.9265	0.1011	0.1581	0.2175	0.2157	1.9385	0.18549
2.	Amb SS(HCR)	0.3174	2.42x10 ³	0.1973	0.956	0.1044	0.1633	0.2247	0.2227	1.9918	0.1973
3.	Amb (SS)	0.3174	2.28x10 ³	0.1859	0.9275	0.1012	0.1583	0.2178	0.2159	1.9403	0.1859
			0.00228								
4.	Escorts 335	1.16768	0.00958	0.77	2.5800	0.28	0.5986	0.6787	0.6006	5.9151	0.77
5.	Escorts 228	1.3720	0.00538	0.437	1.8924	0.2065	0.3425	0.6222	0.44057	4.8815	0.437
6.	Ford 3600	1.3391	0.00585	0.475	1.8310	0.1998	0.4010	0.5017	0.4262	4.7046	0.475
7.	Hind Trekker	0.6458	0.00513	0.4168	1.224	0.1336	0.3569	0.3019	0.2849	2.9522	0.4168
8.	Int. Harvester	0.6896	0.00473	0.3845	1.304	0.1423	0.3323	0.3752	0.3035	3.1516	0.3845
9.	Jeep Jellinue	0.4232	0.0022	0.1787	1.047	0.1143	0.1206	0.3444	0.2437	2.2954	0.1787
10.	Koel 80	0.6203	0.0290	0.2356	1.226	0.1338	0.1986	0.4032	0.2854	2.8702	0.2356
11.	Koel 87.5	0.7465	0.00768	0.6240	1.4482	0.1580	0.5492	0.4251	0.3371	3.6717	0.6240
12.	Maruti 800	0.1685	0.00163	0.1365	1.046	0.11419	0.1093	0.4297	0.2435	2.1128	0.1365
13.	Perkins P-6	1.1034	0.00647	0.5257	1.639	0.178	0.4591	0.4940	0.3815	4.2614	0.5257
14.	Ruston YDA	1.6347	0.00811	0.6590	1.82	0.1980	0.5629	0.5999	0.4237	5.2473	0.6590
15.	Ruston YWA	1.1019	0.00652	0.5298	1.9424	0.2011	0.4509	0.6053	0.4289	4.6370	0.5298
16.	Silver Plus	1.1094	0.00658	0.5346	0.598	0.065	0.0469	0.1845	0.1392	1.14958	0.5346
17.	Willy's Jeep	0.4415	0.00117	0.095	1.2458	0.136	0.0730	0.3072	0.2900	2.4946	0.095
18.	Zeter 95	0.934	0.00335	0.2722	1.84	0.2008	0.2237	0.5051	0.4283	4.1352	0.2722

TABLE 4.20

Energy consumption of piston blanks of 124 alloys made with hand casting process

S. No.	Type	Alloy Making	Remelting		Casting General	Cutting	Heat Treatment	Auxiliary Operations	Total		Energy MJ
			Elect.	Oil					Elect. Kwh.	Oil Litres	
1.	Ambassador	0.3174	0.0028	0.2275	1.2370	0.1583	0.2179	0.2879	2.2213	0.2275	44.34
2.	Elgi 50	0.0970	0.00069	0.0560	1.3320	0.0443	0.3278	0.3101	2.1118	0.0560	34.39
3.	Koel 85	0.6495	0.00466	0.3786	1.8295	0.3273	0.4295	0.4259	3.66636	0.3786	73.34
4.	Koel AV-33	0.4670	0.00264	0.21452	1.8005	0.1876	0.3697	0.4191	3.2465	0.21452	59.09
5.	Std. Herald	0.2043	0.00150	0.12188	1.5202	0.1016	0.5206	0.3539	2.7021	0.12188	46.43
6.	Tata AC	0.2152	0.00238	0.19339	1.2809	0.1640	0.5265	0.29821	2.4891	0.19339	46.68

TABLE 4.21

Energy consumption of piston blanks of 138 alloys made with hand casting process

S. No.	Type	Alloy Making	Remelting		Casting General	Cutting	Heat Treatment	Auxiliary Operations	Total		Energy MJ
			Elect.	Oil					Elect. Kwh.	Oil Litres	
1.	Atlas Moped	0.0800	0.000988	0.08028	0.9353	0.0604	0.1921	0.2177	1.4864	0.08028	26.18
2.	Bajaj Cub	0.1293	0.001529	0.12424	1.2067	0.0882	0.3371	0.2809	2.0437	0.12424	36.67
3.	Bajaj Scooter	0.1876	0.00189	0.15357	1.3002	0.1119	0.2668	0.3027	2.1719	0.15357	40.00
4.	Bajaj 125	0.1835	0.00159	0.12919	1.1994	0.0799	0.3352	0.2792	2.0788	0.12919	37.44
5.	Girnar	0.1835	0.001764	0.14333	1.2234	0.1090	0.3017	0.2848	2.1041	0.14334	38.509
6.	Jawa 70	0.3086	0.00374	0.3039	1.5599	0.2006	0.4003	0.3631	2.8362	0.3039	57.27
7.	Tata Rods	4.296	0.003531	0.2869	2.8267			0.6583	7.7847	0.2869	130.67
8.	MMM Rods	8.22	0.01128	0.9165	7.0681			1.6455	16.9448	0.9165	298.59

TABLE 4.22

Energy consumption of piston blanks of 244 alloys made with hand casting process

S. No.	Type	Alloy Making	Remelting		Casting General	Cutting	Heat Treatment	Auxiliary Operations	Total		Energy MJ
			Elect.	Oil					Elect. Kwh.	Oil Litres	
1.	Mac 62	0.2965	0.00454	0.3689	2.2379	0.0943	0.3678	0.5210	3.52204	0.3689	70.71
2.	Rajdoot 350CC	0.3043	0.00696	0.5655	1.51469	0.1575	0.3112	0.3526	2.6472	0.5655	67.11
3.	Vikram 66	0.3257	0.00517	0.4201	2.0936	0.1184	0.4302	0.4874	3.4604	0.4201	72.26

TABLE 4.23

Energy consumption of piston blanks of 138 alloys made with Machine casting process

S. No.	Type	Alloy Making	Remelting		Casting General Hyd. Unit	Cutting	Heat Treatment	Auxiliary Operations	Total		Energy MJ
			Elect.	Oil					Elect.	Oil	
1.	Agram	1.4181	0.0125	1.015	3.0312	0.3309	0.6765	0.7057	6.8725	1.015	152.28
2.	Bajajchetak	0.2002	0.00162	0.1316	0.6100	0.06659	0.1002	0.1420	1.4216	0.1316	27.70
3.	Eichers	1.9228	0.01892	1.5373	4.4050	0.4808	0.9967	1.0255	10.0567	1.5373	225.36
4.	Garelli Moped	0.0875	0.00079	0.0641	0.5975	0.0652	0.0497	0.1391	1.12379	0.0641	19.96
5.	Maj.Moped	0.0750	0.0061	0.4956	0.5360	0.0585	0.0370	0.1247	1.03	0.04956	17.85
6.	Pangeot	0.8525	0.00328	0.2665	1.5198	0.1659	0.1809	0.3538	3.5256	0.2665	65.80
7.	Rajdoot	0.2085	0.00104	0.0845	0.7603	0.0830	0.1635	0.1770	1.6537	0.0845	28.90

TABLE 4.24

Energy consumption of piston blanks of 244 alloys made with Machine casting process

S. No.	Type	Alloy Making	Remelting		Casting General Hyd. Unit	Cutting	Heat Treatment	Auxiliary Operations	Total		Energy MJ
			Elect.	Oil					Elect.	Oil	
1.	Cento J-100	0.1701	0.0038	0.3087	0.7730	0.0843	0.0978	0.1799	1.706	0.3087	40.55
2.	Ind.Suzuki-AX-100	0.1653	0.0027	0.2193	0.9020	0.0984	0.0668	0.2099	1.8619	0.2193	38.55
3.	Lamby 57	0.2644	0.00213	0.1730	0.7560	0.1091	0.0513	0.1760	1.6626	0.1730	25.217
4.	TVS Moped	0.0894	0.00132	0.1072	0.6188	0.0510	0.03437	0.1440	1.129	0.1072	22.1309
5.	Vijay 57	0.2625	0.00176	0.1430	0.9431	0.1029	0.0415	0.2195	1.88136	0.1430	35.15

TABLE 4.25

Energy consumption of piston blanks of 124 and 138 alloys made with forging process

S. No.	Type	Number of good blanks	Casting energy per blanks		Energy due to forging operations Elect. (Kwh)	LPG (Kg.)	In Energy Units
			Elect. (Kwh)	LDO (Litres)			
1.	Ruston MWM	7660	8.4724	0.45825	3.4188	0.1590	209.83
2.	T-55	5120	-	-	3.2950	0.1532	58.338*
3.	Tata 90	30288	3.89235	0.14345	1.3096	0.0609	88.52
4.	Tata 92 4 RV	7970	3.89235	0.14345	1.3797	0.06418	89.76
5.	Tata 92 5RV	252336	3.89235	0.14345	1.3025	0.06059	88.40

* The rods of the required size were purchased from outside. Therefore the casting energy figures are not available.

CHAPTER V

DISCUSSION OF RESULTS

5.1 From energy calculations tables 4.19 to 4.25 it is seen that a TVS Moped piston blank has the lowest energy consumption as 22.13 MJ while the Eichers piston-blank has the highest value as 225.36 MJ which is about ten times that of a TVS piston-blank. But the weight of an Eichers piston-blank, 2.305 Kg., is about 25 times that of a TVS piston blank. Thus it can be inferred that a TVS piston blank consumes about 2.5 times energy per unit weight as compared to an Eichers piston blank. Figure 5.1 shows the variation of energy per unit weight with blank weight.

The graph shows that the energy per unit weight decreases with the increase in blank weight. This indicates that the smaller piston-blanks are more energy intensive and the production process and the other parameters are more suitable to bigger piston-blank and it is uneconomical from the energy point of view to manufacture smaller piston-blanks.

Further, it is seen that energy per unit weight increases very rapidly below a blank weight of about 0.850 Kg. The above variation of the energy consumption are because of the reasons that the capacity of the equipment is suitable for bigger

about 115 Kg. of alloy is unnecessarily heated throughout the shift.

The reason for the steep rise of energy per unit weight below a blank weight of about 850 gms is, that above this weight almost the full quantity of molten metal from the holding furnace is utilised whereas below this it is not used. For example a Kirloskar 80mm dia blank with a blank weight of 0.850 Kg. has 1.375 as the weight of casting, including runners and risers. The production per shift is 150 piston blanks.

$$\text{Total alloy used} = 1.375 \times 150 = 209.50 \text{ Kg.}$$

We have assumed in our study that electricity consumption on each holding furnace in one shift is the same. This is because of the automatic switching on and off of the holding furnaces. Let this energy consumption be, C. Let the total weight cast in one shift from one holding furnace be W. Then energy consumption per unit weight is $\frac{C}{W}$. More the weight cast less is the energy consumption per unit weight as C is constant. This is the reason why smaller blanks are more energy intensive.

The slow decrease in energy per unit weight with the increase in blank weight beyond a blank weight of about 0.850 i.e. above the value where complete 200 Kg. of alloy can be consumed is because the more the blank weight the more is the consumption of alloy per shift. Thus with the same amount of

energy consumption on one holding furnace more weight is cast per shift of blanks with higher weight.

To bring down the energy consumption per unit weight in case of smaller pistons either we have to increase the weight cast or reduce the value of Constant C. But the weight of blanks cast cannot be increased as the production rate depends upon so many other parameters. Reducing the value of constant C means using a furnace with lesser capacity.

Size of Holding Furnace

The above discussion indicates that the capacity of holding furnaces should match the consumption rate of the type. For maximum savings in energy we can arrive upon the following sizes.

1. Wt. of Maj. Moped blank	= 0.190 Kg.
Production per shift	= 350 blanks
Consumption per shift	= 0.190 x 350 = 66.5 Kg.
Optimum size of holding furnace	= 75 Kg.

Thus depending upon the consumption rate of various types of blanks we can have holding furnaces sizes as 75 Kg., 100 Kg., 125 Kg., 150 Kg., 175 Kg. and 200 Kg.

Now depending upon the cost of each type of crucible and their inventory carrying cost we can decide upon the number of sizes to be used.

5.12 Sub-Group Heat Treatment

In the heat treatment subsystem the energy consumption is on running the heat treatment furnaces. We have assumed in our study that energy consumption on one charge of piston blanks irrespective of the type is the same. This is because all types are heated for almost the same duration of time. Thus energy consumption per charge is constant. Let this be H. Now energy consumption for heat treatment per unit weight depends upon the weight of piston blanks per charge. Table 4.11 to 4.17 show the number of blanks per charge of heat treatment.

As a comparison let us take the details of two types of blanks

	Weight of blanks	Number of blanks per charge	Total weight per charge
Garelli Moped	0.105	800	84 Kg.
Agrom	1.700	250	425 Kg.

Similarly if we calculate the weight per charge of heat treatment for other types of piston blanks. We will conclude that smaller pistons consume more energy per unit weight.

Here again, the same reasoning, that the equipment must have been chosen to cover the whole range of products holds good.

To reduce this energy per unit weight we have to modify the process. Different types of Blanks of the same alloy can be put in different racks and stocked one above the other to make the total weight approximately equal to that of one type of bigger piston blanks.

Considering the blanks of above example if we stock 5 types of smaller blanks of the same alloy one above the other then approximate total weight = $84 \times 5 = 420$ Kg.

To implement the above proposal the size and design of heat treatment boxes and their handling equipment has to be changed.

But there are practical difficulties in the implementation of the above process. As the blanks are to be sent out of the foundry for machining every day, so whatever blanks are produced in one shift have to be charged for heat treatment. Normally the availability of smaller blanks of the same alloy is not so much as to make complete charge as calculated above. Hence the energy consumption per unit weight for heat treatment will remain more for smaller piston blanks with the present size of heat treatment furnaces. To reduce it we have to go in for the equipment of lesser capacity.

5.2 Energy wastage on melting furnaces

It is normally observed that the consumption rate of alloy is not properly matched with its generation rate in the

the induction furnace. Due to this reason the alloy after being made has to be kept in the induction furnace and electricity is consumed to keep it at the require tapping temperature.

Electricity consumption on Induction furnace as per data table No.4.1 = 1467980 Kwh.

No.of working hours during the study period as calculated earlier = 5027.66

The wastage of the furnace at the maximum step = 200 Kw.

Total consumption during the year = 5027.66 x 200 = 1005532 Kwh.

Wastage for holding the alloy = 1467980 - 1005532 = 462448 Kwh.

Holding time = $\frac{462448}{200} = 2312.24$ hours

Thus the alloy after being ready had to be kept for 2312 hours in the induction furnaces before it could be tapped for pouring into the holding furnaces in the process 462448 Kwh of electricity were wasted. A better material planning can minimise this loss.

5.3 Energy wastage on holding furnaces

It has already been shown that lot of energy is consumed because of the size of the holding furnaces. Still more energy is wasted because of unnecessary holding of metal at the casting temperature.

Total number of working shifts as calculated earlier are 15103.42 shifts.

One working shift means that one holding furnace kept on running for one shift. The holding furnaces switch on and off automatically to maintain the alloy within the pre-set temperature range. From experience we know that average time for which the holding furnace remains switched on is about 5 minutes and then remain switched off for 10 minutes. Thus out of 8 hours shift working the furnace remain switched on for $\frac{480}{3}$ 160 minutes.

The wattage of one holding furnace = 40 Kw.

$$\begin{aligned} \text{Total consumption in the study period} \\ &= \frac{40 \times 160}{60} \times 15103.42 \\ &= 1611031.465 \end{aligned}$$

Energy consumption for running the hydraulic unit as calculated earlier = 1,80000 Kwh.

Total energy consumption = 1791031.46

$$\begin{aligned} \text{Energy wasted} &= 2848370 - 1791031.46 \\ &= 1057338.54 \end{aligned}$$

$$\text{Holding time} = \frac{1057338.54}{40} \times 3 = 79300 \text{ hours.}$$

The wastage of energy for heating the alloy unnecessarily for 79300 hours is very high. This shows that 37 per cent of the total available time the casting has not been done, only 63 per cent of the time is utilised.

The reasons for the above holding are

1. Alloy not ready due to high or low temperatures.
 2. Breakdown of equipment.
 3. Stoppage of casting process due to metalurgical or other casting ~~process~~. defects
 4. Breakdown of tooling.
1. Low or high temperatures

To achieve the desired quality of castings the metal has to be poured at the required temprature. To maintain the molten alloy at this pre-set level in the electrically heated holding furnaces, heating elements of the furnace are automatically operated with the help of pyrometers which are fixed in the pannels, meant for supplying electricity to the furnaces. The pyrometer indicates and controls the temperature senced by the thermocouples. But if due to any reasons the temperature drops down or increases beyond the required range the casting process has to be stopped. The reasons for the temperature variations can be following.

1. Tapping temperature of alloy on melting furnaces is either too high or too low

If the tapping temperature from the melting furnace is

too high then after pouring in holding furnaces, you have to wait till the temperature drops down and then casting process can be started. In case of low temperature the alloy has to be heated in the holding furnaces and the casting process is started after attainment of required temperature.

2. Slag Formation

The thermocouple senses the temperature of the heating zone as shown in the figure 5.2.

The slag formation in acts as an insulation and while the temperature of the heating zone reaches the required level the temperature of the alloy remains much below. This can be avoided

1. By avoiding or minimising the slag formation.
2. Usage of thermocouples or pyrometers which directly give the temperature of the molten alloy.

2. Breakdown of Machinery

Due to breakdown of machinery and equipment the casting process is stopped. But during the time the repair work goes on, the molten alloy has to be kept at the required casting temperature. This results in wastage of energy.

3. Stoppages due to metallurgical defects

To produce the castings of the desired quality, a number of parameters have to be controlled. They are temperature of

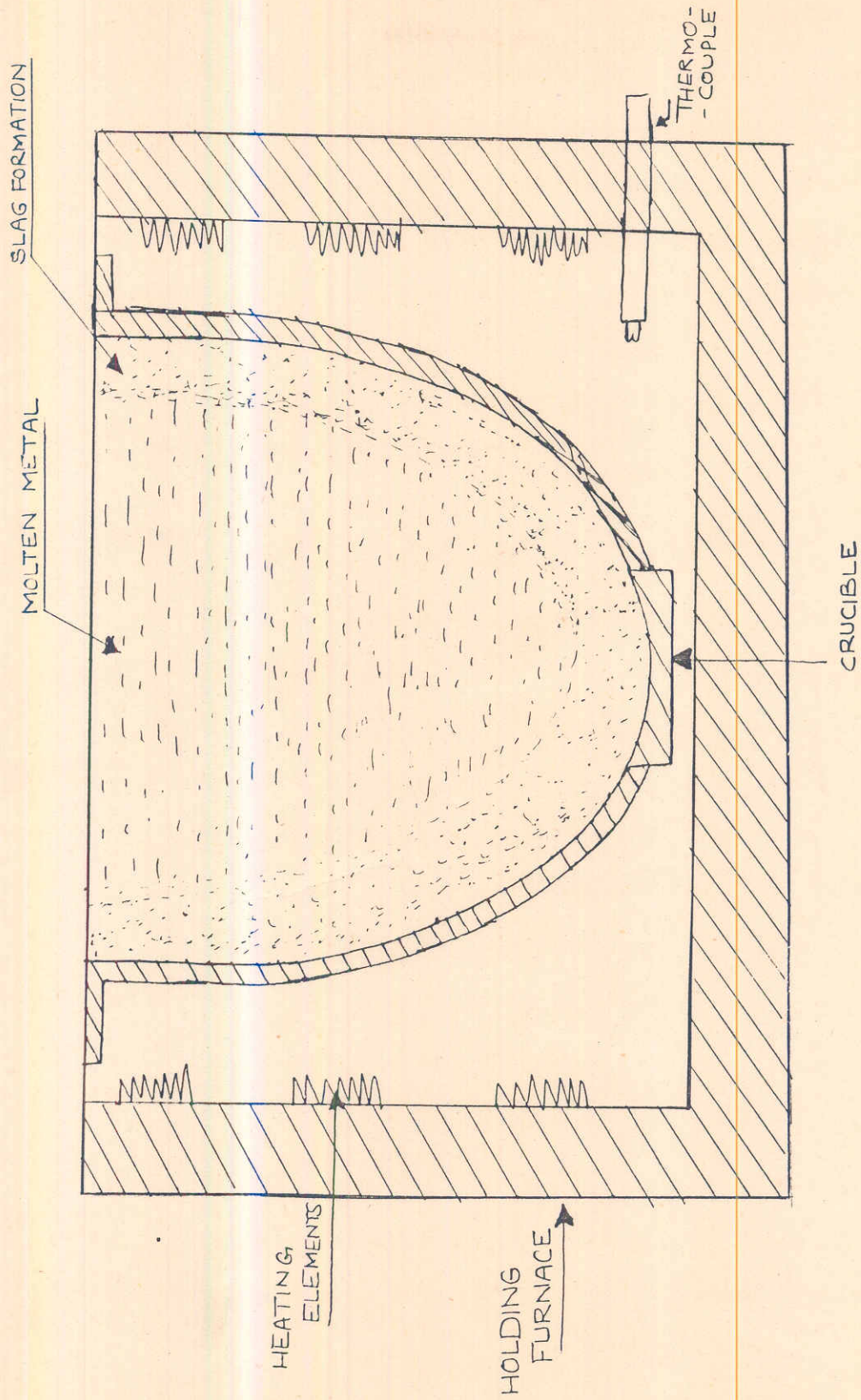


FIG 5.2. HOLDING FURNACE DETAILS

alloy, temperature of die parts, die and tool paints and coatings, cooling cycles and total time cycles etc. If any one of these parameters is not properly maintained, the quality of castings goes bad and the casting process has to be stopped till that parameter is brought to the required value. Before starting the casting process in the beginning of the shift all these parameters should be checked and maintained because any stoppage afterwards will not only effect the production but also waste energy.

5.4 Temperature loss due to uncovered holding furnaces

We have seen that a holding furnace remains switched on for one third of the time. Normally the working range of temperature is $\pm 10^{\circ}\text{C}$. e.g. if the required temperature is 770°C , we can work between 760°C to 780°C , a total variation of 20°C . Therefore in 5 minutes working the temperature increased by 20°C and the furnaces gets switched off. Within another ten minutes the heat is lost to the atmosphere and temperature drops down to 760°C , and the furnace again switches on.

The top end of the furnace is about 75cm diameter. This remains open throughout because from this open end the metal is taken out with the help of casting spoons. Because of this open end the temperature loss takes place very rapidly.

Because of the same reason the temperature loss takes place during transportation of the alloy also. The crucible

carried by fork left containing the molten alloy is also uncovered. Due to this anticipated temperature loss the alloy is tapped from the induction furnaces at a temperature about 30°C higher than the casting temperature. To achieve this more energy is consumed on the induction furnaces.

5.5 Dechlorination Unit

For refining the alloy some chemicals are added to the molten alloy in the holding furnaces. Chlorine gas is one of these chemicals. As inhaling of chlorine is harmful to health therefore a dechlorination unit exists in the foundry as shown in the Layout. From this dechlorination unit a pipe of about 400 mm dia meter comes to the other extreme of the foundry. For each holding furnace one pipe of 150 mm diameter branch out from 400 mm diameter pipe. Over every holding furnace there is a suction hood. The suction blower of the dechlorination plant is run by a motor of 75 Kw. With this the chlorine fumes coming out of the holding furnaces are sucked and neutralised.

Normally the alloy refining operations are carried out in the foundry on 3 to 4 holding furnaces out of a total of 30 holding furnaces at a time. There is a butterfly valve on the suction hood of every holding furnace. This valve is to be opened in case the chlorine is passed to the metal. But for the proper operation of the butterfly valve a loose clearance has to be provided which reduces the suction effectiveness. Thus the suction effectiveness^{of} such a big blower is reduced because of

30 connections coming out of the main pipe.

A lot of energy spent on running the 75 Kw motor of the suction blower is thus wasted. If we use smaller blowers for a set of 5 holding furnaces it will be more effective and at the same time consume less energy.

5.6 Casting of Rods for Forge Piston blanks

Table 5.25 show that out of a total weight of 5.2 Kg. of a rod for Tata blanks 1.6 Kg. is the weight of the riser which goes as a waste. In gravity die casting employed in the foundry this cannot be avoided.

Actually gravity die casting is not a suitable process for casting of rods. The rods should be made by continuous die casting process. As the melting furnaces are already available in the foundry we should look into the possibility of going in for the other equipment used for continuous casting.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

The results show that energy is being wasted in most of the operations in the foundry. In melting operations more energy is spent than required because of holding the alloy after it has been prepared in the induction furnaces or oil fired furnaces. A total of 462448 Kwh of electricity has been wasted in one year which is 31 per cent of the total electricity consumed on induction furnaces. Thus, about one-third of the total running time of induction furnaces was wasted on unnecessary holding the metal.

It is not possible to totally eliminate the holding of the prepared alloy, but it can be minimised by a better material planning. From the total number of blanks being cast on a particular day and the consumption rate of each type the total alloy requirements can be calculated. For example if the furnaces have been filled at 6.30 AM we can make out that after how much time the next filling is required. This time can be arrived at considering the die with the highest consumption rate. At this time all the furnaces of that type of alloy should again be filled. So the alloy should be ready just before that taking into account the margins required for

the safe working. A study can be conducted to evolve a formula keeping in view the different parameters on which holding depends, to minimise holding.

In casting the wastage of energy as shown earlier is firstly because of the size of the holding furnaces and secondly because of unnecessary holding of alloy in the event of stoppage of casting operation. In the first case it is recommended to use holding furnaces of the smaller sizes. To completely eliminate the energy loss due to bigger size of the holding furnaces, we have to use at least six sizes of holding furnaces. This may not be particularly feasible, because it is very difficult to keep inventory of spares of six types of holding furnaces. The inventory carrying cost might surpass the energy savings. Thus a study can be conducted to arrive at a breakeven point between the number of furnaces and the cost of keeping the inventory.

In case of alloy 244 ^{no} number piston blank has weight more than ^{Kg} 0.65. Therefore atleast for alloy 244 we can use furnaces of smaller sizes.

The second reason of wastage of energy in casting, the holding of alloy during the time when casting is not going on can be minimised.

- i) by reducing the breakdown of machinery through better preventive maintenance.

- ii) by properly painting the die parts, using the exact composition of the materials required and using lubricants before and during working. This will avoid the metallurgical defects.
- iii) by proper control of temperature on (a) melting furnaces while tapping the alloy (b) By regular removal of slag from the holding furnaces to avoid the effect of slag on temperature control.

The slag formation occurs when the chemicals are added to refine the molten alloy. Even if we take care to remove this slag regularly, some quantity of it will definitely deposit on the walls. The crucibles of the furnaces are replaced on every Sunday. Thus on first working day, Monday there is no slag on the walls and as a result the temperature of the molten alloy remains controlled within the set limit. But during the next days of the week the slag deposits get increased. The difference of temperature between the set values and actual readings occurs.

As slag formation cannot be totally eliminated so the only way to control the temperature is to look for and use the thermocouples which directly gives the temperature of the alloy, instead of that of the heating chamber.

Due to all above reasons the casting operations were stopped, while the alloy was ready to be cast, for 79300 hours

wasting a total of 1057338.54 Kwh. which is 37.1 of the total consumption. This must be minimised.

One more area in casting, which wastes energy as shown earlier is heatless from the uncovered holding furnaces. It is recommended to cover the holding furnaces with temperature resistant steel sheets with reflections on the lower sides. These sheets can be covered with refractory or other insulating materials. These covers can be made to move up and down automatically for the insertion of casting spoons, or these can be made to rotate on hinges. Similarly the crucible of fork lift track can be covered.

A study can be conducted to find out the expenditure to be done on covering the holding furnaces and the resultant energy savings.

Heat Treatment

To avoid the wastage of energy in heat treating the smaller sized piston blanks, it is recommended to change the design of the boxes and their handling equipment so that four to five types of small sized piston blanks of the same alloy can be put together for heat treatment. This system will avoid the wastage when 4-5 types of such piston blanks are available.

To completely avoid this wastage it is recommended to use smaller sized heat treatment furnace for smaller blanks. Depending upon the total number of such pistons available throughout the year, the cost of the equipment and other related factors, a study can be conducted regarding the purchase of the equipment.

As present dechlorination plant is not effective and at the same time consumes lot of energy. Everytime a 75 Kw motor runs. It is recommended to use 4 to 6 smaller plants for a set of holding furnaces. Only that plant in the area where the metal refining is going on can be switched on at a time. This will save a lot of energy.

Rod casting consumes lot of energy because of the weight of the riser. It is suggested that either the continuous casting process should be employed or the rods should be purchased from a party who employs continuous casting process.

Suggestions for further study

Through the present study all the areas where energy is being wasted have been highlighted with the quantum of energy being wasted in each area. The suggestions have also been given regarding employing the ways to avoid these energy losses. To prove the practicability of these suggestions further studies can be conducted.

Scope of further work

1. Optimum size and number of sizes of the holding furnace:
Considering the consumption rates of alloys for all types of blanks, cost of crucibles and their inventory carrying cost it can be calculated that what should be the size of the holding furnace for a particular consumption rate range. Also the number of sizes of crucibles can be calculated.
2. Material Planning for Minimising holding in melting furnaces:
Considering all the parameters on which alloy holding in melting furnaces depend, a linear programming problem can be made and holding can be minimised.
3. Covering of holding furnaces:
A study regarding how much energy will be saved by providing moveable covers on the holding furnaces and the cost of providing and maintaining covers, can be done.
4. Changing the design of heat treatment boxes and their handling system. The cost involved and the anticipated energy savings can be studied.

Also cost involved in the purchase of smaller sized heat treatment furnace and the savings which could be made by its use can be studied.

5. Dechlorination plant:

If we use 4 or 6 smaller plant instead of the present plant what would be the savings and other benefits.

6. Rod casting:

Continuous casting process should be used for rod casting. For a rod about 400 mm long, gravity die casting process is not recommended. A study can be conducted regarding the purchase of machinery and equipment used in continuous casting process and the benefits and energy savings which could be affected through it.

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