DESIGN AND DEVELOPMENT OF A SOLID FUEL FIRED DRYER

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CERTIFICATION.

The undersigned certify that they have read and recommended to the School of Engineering and Engineering Technology for acceptance, a thesis titled "DESIGN AND DEVELOPMENT OF A SOLID FUEL FIRED DRYER" submitted by OCHI CORNELIIUS CHIWENITEM in partial fulfilment of the requirements for the award of Bachelor of Engineering Degree (B.ENG) in Agricultural Engineering.

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DEDICATION

To my late grand mother, Mrs. Nwanyabuife Amu.

ACKNOWLEDGMENT

I am sincerely grateful to the Almighty God the author of life and every good thing, who for Christ's sake has seen me through the rigour of University education without hitches. I owe my life to Him in every aspect of it.

I also wish to acknowledge the assistance of men and women whom God has used to help me especially during this project. They include such people like;

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My parents, Mr. And Mrs. Ochinanwata deserve a heart felt gratitude for all their heart felt support through the duration of my study. May the Almighty reward you with glory in the Hereafter.

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I must also mention the man who helped me so mush during the construction of this project. He is Mr.Yakubu,(Baba Tunde).

May God bless all of you and give you people who will run to you at thee time of your need. Amen.

Cornelius Chiwenitem Ochi.

Minna

ABSTRACT

The design and development of a solid fuel fired dryer has been carried out in this study. Drying takes place inside a drying chamber wherein the material to be dried is placed on plates with air spaces through where hot air from the furnace provides both the latent heart for vaporization of the moisture in the crop and the transportation medium for removal of the vapor from the crop in the drying chamber to the atmosphere.

The study involves; the determination of the volume of air that is required to burn coal at the rate of 5kg/hr and also bring down the flue gas temperature to 43^{0}c, the design of a blower, hopper, conveyor, furnace, drying chamber and the fabrication and coupling of the difference parts to form a unit.

The volume flow rate of air required to burn coal at the rate mentioned above and also bring the flue gas temperature down to 43°C is $43.3873m^3$/min. The blower used to pump this volume of air is made up of a centrifugal fan with wheel diameter of 0.506m and enclosed in a circular casing of diameter 0.6m, inlet area of $0.3083m^2$, outlet area of $0.2977m^2$ and air route which expands into the furnace to an area of $0.3429m^2$. The hopper is of a

capacity of $0.0375m^3$ and rest on the conveyor casing. The conveyor is made up of 2chains with 100 pitches each carrying plates, and are rotated toward the furnace by sets of sprockets and gears.The conveyor collect fuel (coal)from the hopper into the furnace. A metering device is used to regulate the rate at which coal is fed into the furnace. The furnace is of $0.972m^3$ volume and contains a fuel grate which could be removed and ignited outside the furnace through the ash discharge door and replaced. The drying chamber is made up of 3 frames having a zig-zag top surface into which 22 plates are aligned such that there is provision for air to pass under them into drying chamber which is of 0.33m depth and a capacity of $0.19020m^3$. The material to be dried is fed into the drying chamber from the top and discharged after drying through a discharge door at the far end of the dryer. The furnace and drying chamber share the same insulation wall made up of particle board of 0.0127m enclosed with sheet metals.

About ₦14500 was spent to bring this project to the present stage of completion.

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2.0 LITERATURE REVIEW

2.1 TYPES OF FUEL

A fuel is any material that is burnt to provide energy in the form of heat. Most Fuel are derived directly or indirectly from the plant kingdom. They could either be plants of the present, such as wood, or plants that lived millions of years ago, such as coal and petroleum. When Fuels burn, it is carbon (or other elements, as the case may be) of the fuel that combine with oxygen of the air in a chemical reaction in which useful heat is liberated.(Bugaje,1990).

Types of Fuel

Fuel exists in different forms and could be categorized into three major classes namely;

- Solid Fuels.
- Liquid Fuels
- Gaseous Fuels.

2.1.1 Solid Fuels.

Solid Fuels may further be classified into (a) natural solid fuels and (b) prepared solid Fuels

(a) Natural Solid Fuels-These are Fuel that are utilized in the very form they are recovered from nature. They consist of the following; Wood, peat, lignite or brown coal, bituminous or soft coal and anthracite or hard coal.

1. Wood: This consist largely of carbon and hydrogen chemically combined through photosynthesis. Wood used to be a major industrial fuel. The side effect of deforestation associated with its utilization has, however, drastically reduced

could use coal as their basic fuel, thereby giving room for the exploitation of the abundant coal reserve in Nigeria in pursuit of the country's technological advancement.

(2) It would also help to curtail the large percentage of loss in agricultural produce due to lack of affordable and portable drying equipment to local farmers that would supplement sun-drying which is not always sufficiently available during production season.

1.3 JUSTIFICATION OF OBJECTIVES

The above objectives when achieved would have produced another step towards emphasizing along with other researchers like Chinweze (1984) the potentials of coal as a good replacement for petroleum as a source of energy for drying the country's crops. Further more, farmers would now be able to produce as much as they can afford without the fear of failure due to over dependence on sun-drying. That is, an alternative cheap and portable means of drying farm produce would have been produced and this would contribute to the "self-sufficiency in food production", which is our nation goal.

against the material at high temperature or by a large volume exhausted at a lower temperature. Heating the drying air is therefore a common method of speeding up crop drying processes and incidentally of increasing thermal efficiency. Drying temperature employed are usually as high as they can safely be, without causing damage to the material being dried, or leading to inefficient operations in other ways.

Dryers are complex crop processing equipment that provide conditions necessary for faster and more efficient removal of moisture from crops as compared with traditional method of drying. Most dryers employ some kind of furnace for heating air and a fan or blower for blowing it through the product to be dried.

Based on the type of fuel or means used for heating up air used in dryers, they can be classified as solar dryers, solid fuel dryers, liquid fuel dryers, gaseous fuel dryers or electric filament dryers. For this particular design, coal which is a solid fuel is used. The blower, the furnace and the drying chamber are incorporated into a single equipment which would be suitable for drying most of the locally produced crop.

1.2 OBJECTIVES OF THE STUDY

This study aims at designing a dryer for crops that would use heated air stream. The heated air would be generated from a furnace which would run on solid fuel, that is, coal. The capacity and efficiency of the dryer would be investigated to describe its performance for a realistic range of parameters,

(1) It was intended that the results would stimulate the minds of designers toward the development of other systems that

CHAPTER ONE

1.1 INTRODUCTION

Drying of agricultural products is one of the most important post-harvest preservative farm operations practiced today. It means the removal of water from agricultural products with the aim of improving their storage ability or improving their desired properties for further processing operations. Dried food is better preserved because, the micro-Organisms which cause food spoilage and decay cannot grow and multiply without sufficient water, and many of the enzymes which cause undesired change in the chemical composition of food material cannot function in the absence of water. More also, many food processing operations involve the use of powdered or flour-form of agricultural products as is found in bakeries and feed mills.

Although moisture (water) may be extracted from various substances in a variety of ways, the method universally accepted in farm crop dryers is vaporization (the removal of moisture in a stream of drying air) and depends on the fact that the moisture in the crop tends to come into a state of equilibrium with the drying air. The ability of the air to dry crop depends on its relative humidity (the difference between the amount of water vapor a given volume of air already contain and the amount it can carry if saturated) This difference increases rapidly along with temperature.

Removal of a given amount of water from a material by an air stream may be achieved either by supplying a small volume of air if not halted its use in the industry at present. However in rural area of Africa and Asia, wood is still the major energy source for domestic purposes. Wood is also regarded as the origin of all fossil fuel such as peat, coal, petroleum and natural gas. Land plants buried beneath the ground over the ages under mildly reducing-conditions produced peat and various grades of coal. Sea plants (and probably animals) buried over the ages under strongly reducing-conditions were transformed into petroleum crude and natural gas. Th ough wood is a readily available fuel, its calorific value is relatively low about 15-18 MJ/Kg (Bell,1971).

2. Peat: This represents the first stage in the transformation of wood and other vegetable matter under the effect of temperature and pressure beneath the ground over the ages. Peat is brownish and one could even notice traces of wood fibre in it. It contains about 20-30% water and as such must be dried before it could be used satisfactorily as a fuel. The calorific value (C.V.) of air-dried peat is about 16-20 MJ/Kg. (Bugaje,1990).

3. Lignite: This is sometimes called brown coal. It represents the first intermediate stages in coal formation. It is an inferior class of coal containing about 68%carbon. Air-dried Lignite has a calorific value of 20-23 MJ/Kg(Bugaje,1990). It burns with a large smoky flame and is non-caking (that is, when burning, parts do not stick together).

4. Bituminous (or soft) Coal; Bituminous coal represent the next intermediate stage in the development of coal. It contains about 75% carbon with 20-25% volatile matter. Its average calorific value is 30-32 MJ/Kg(Bugaje,1990). It is shiny black in appearance and is of two types; caking and non-caking bituminous coal. The non-caking bituminous coal burns with a

fairly yellow flame with the coal parts sticking together.

5. Anthracite or hard coal; This is the final stage in the development of coal. It has 90-95% carbon with 5-10% volatile matter. It is hard, brittle, non-caking and burns without smoke. It has little impurities and the highest quality among all natural solid fuels. It's calorific value is about 33 to 37 MJ/Kg (Bugaje,1990).

(b) Prepare Solid Fuels:- There are solid fuels produced by processing (physically and/or chemically) any of the above natural solid fuels. They include wood Charcoal, briquetted coal and pulverised coal.

1. Wood Charcoal: This is produced by heating in an inert atmosphere at a temperature of not less than 310°C. The higher the temperature of carbonization, the darker and harder the charcoal produced. Dry wood charcoal contains 85-90% carbon and has a calorific value of about 27 MJ/Kg. As a result of the ecological problem associated with its large scale production, wood charcoal is nowadays rarely used as an industrial fuel. It is only the traditional black-smith industry in Nigeria that uses it as fuel.

2. Coke: Made from bituminous coal by driving off its volatile components. It is hard, brittle and porous. Coke is widely used for steam generation. Metallurgical industries also use coke though as a chemical feed stock. (Bugaje,1990).

3. Briquetted Coal: Made by mixing finely ground coal with a suitable binder and pressed together into briquettes (blocks). This treatment decreases the fuel loss through the grates in furnaces, increases heat efficiently by 20-30%

compared to burning raw coal, reduce air pollution by half at a moderation cost (Bugaje,1990).

4. Pulverized Coal; This is coal that has been ground to very fine powder such that it could float in air. Thus when mixed with appropriate amount of air, the pulverized coal would be in a fluidised form and could flow through burners for combustion like other liquid or gaseous fuels

2.1.2 Liquid Fuels

The most important liquid fuels are petroleum products, alcohol and oil from coal tar.

(a) Petroleum products: Petroleum crude is a dark and viscous liquid which is refined in fractionating columns to obtain various liquid fuels.

These include:

(1) Gasoline (or petrol)

(2) Kerosine

(3) Light gas oil (diesel)

(4) Heavy gas oil

(5) Fuel oil

(6) Asphalt and bitumen

(b) Alcohol: This is a renewable liquid fuel. It is produced by fermentation. It could be used especially in combination with gasoline (the so called gasohol mixture) to power internal combustion engines.

(c) Oil From Coal tar: The major liquid fuel obtain from coal tar is benzole. It is produced by distillation of the coal tar or extraction from coal gas. Benzole can be used in internal combustion engines like alcohol (Bugaje,1990).

.3 **Gaseous Fuels**

Gaseous fuel can be classified into two; natural and ufactured gaseous fuels.

Natural Gas: This has some origin with crude petroleum. It is obtained as associated natural gas (that is, along with crude petroleum and sometimes in coal seams) or non-associated natural gas. It is the most abundant and widely used of all gaseous fuels. It has high calorific value of about 37 MJ/kg is uniform in composition and contains very little undesirable impurities.

Manufactured gas: These are prepared from other source. y include:

1. Producer gas -produced by coal gasification in air.
2. Water gas -produced by coal gasification in air and steam.
3. Wood gas -produced by destructive distillation of wood.
4. Peat gas -produced by destructive distillation of peat.
5. Coal gas -produced by destructive distillation of coal.
6. Refinery gas-by-product of crude petroleum refining (also called petroleum gas).
7. Blast furnace gas-by-product of iron ore reduction.
8. Hydrogen -produced by electrolysis of water.
9. Acetylene -produced by the action of carbides with water, eg, $CaC_2(s) + 2H_2\ 0(l) \longrightarrow Ca(0H)_2(aq) + C_2H_2(g)$.
10. Biogas -produced by biological degradation of cow dung and other animal/vegetable wastes, (Francis and Peter,1990).

2.2 NIGERIAN FUEL RESERVE

Nigeria is blessed with virtually all the conventional Fuel Reserve in varying qualities. These include petroleum crude, natural gas, coal, Uranium, tar sand, wood and other biomass fuels. Petroleum crude occupies an important corner stone of Nigerians economy as it account for about 75% of Nigeria's foreign exchange earnings, 82% of government revenue and over 20% of the Gross Domestic Product (G.D.P). The other Fuels are also making significant contribution to the G.D.P. of the nation. (Fed. Min. of Sc. And Tech.,1987).

1. Petroleum: Nigeria's proven reserve of crude oil is put at 2.7 billion tonnes. This represents 34% and 3.2% of the entire African and world oil reserve respectively (Bugaje,1990). The annual crude oil production, exports and domestic consumption, from 1970-1980 show that Nigeria produces an average of over two million barrels per day (m bd). The production for domestic consumption by local refineries (Port Harcourt, Kaduna and Warri) has risen from 3.4% in 1973 to 6.9% in 1980. With the commissioning of the fourth refinery in port Harcourt, Nigeria is today self-sufficient in refined petroleum product, that is at any point in time when all the refineries are functioning in full capacity. Unfortunately petroleum is not a renewable fuel.
2. Natural Gas; Nigeria has abundant natural gas, both associated (that is, produced along with petroleum crude) and non-associated. The proven reserves of natural gas is put at between 90-100 billion cubic meters, 30% of which is

associated and the remaining 70% non-associated. Unfortunately, most of it is not presently put into economic use and instead it is daily being flared. It is estimated that gas equivalent to 17.5million tonnes of crude oil is flared annually in the country. This represents approximately twice our total annual energy consumption. The effort of the government in promulgating the Gas. Re-injection Decree is not yielded much results. Available statistics show that in 1985,only 6% of the gas produce was re-injected and over 75% was flared. The need to find immediate use for Nigeria natural gas on both economic and environmental ground cannot therefore be over emphasized. Nigeria has an inferred coal reserves of 708.4X 10^6metric tonnes (Nigeria coal corporation,1981). Production of coal in Nigerian rose from 24,000 tonnes per annum in 1916 to 900,000 tonnes in 1959. Thereafter production fell to 550,000 tonnes in 1966 and ceased during the civil war. After the war, production picked up to 334,000 tonnes in 1972 and thereafter progressively declined to 180,000 tonnes in 1980. Coal used to contribute about 40-50% of total commercial energy consumption in the sixties, especially in electricity generation and rail transport. Today, the contribution of coal to power generation in Nigeria is virtually zero and its total share in the nation's energy mix has dropped to 0.23% while petroleum and gas account for 95%. There are effects however to divert coal to other non-energy sectors, such as industrial feed stock in the metallurgical industry (iron ore reduction), fertilizer industry etc.

Wood Fuel:- Nigeria is presently using over 80 million cubic meter of wood fuel annually (about 43 billion kg) with about 90% of its heating value being wasted. The rate of wood consumption far exceeds the replenishing rate to such an extend that desert encroachment as a result of this massive deforestation is today a recognised nation problem. The consumption of this fuel, however, is largely in domestic heating services. The industries hardly use wood as fuel in Nigeria.

Other sources:- Nigeria has other source of energy which include nuclear fuels, solar energy, hydro - power, tar sand etc. At present, the Nigeria Uranium Mining Company (NUMCO) is prospecting for uranium is part of Bauchi and Adamawa states. Solar energy is also virtually available every where in the country and research and development effects are going on towards its efficient harnessing. It is estimated that the total annual energy consumption of the country (about $21x10^9$ kwh) could be met by converting 1% of total solar energy incident on the country at a conversion efficiency of 0.1%. Hydro-power is yet another source and is currently being utilized in a number of hydroelectric dams in Kanji, Jebba and Shiroro. Tar sand reserves has also been reported in parts of Ondo state. This is, however, yet to be put into economic use (Federal Ministry of Science and Technology, 1987).

THE CONCEPT OF DRYING

Drying of food implies the removal of water from the foodstuff. In most cases drying is accomplished by vaporizing the water that is contained in the food, and to do this the latent heat of vaporization must be applied. There are, thus, two important process-controlling factors which enter into the unit operation of drying.

(a) The transfer of heat to produce the necessary latent heat of vaporization.

(b) The movement of water or vapor through the food materials and then away from it to effect the separation of water from foodstuff(Charm,1970). Drying processes fall into three categories.

1. Air and contact drying under atmospheric pressure. In air and contact drying, heat is transferred through the foodstuff either from heated air or from heated surfaces. The water vapor is removed with the air.
2. Vacuum drying; In vacuum drying advantage is taken of the fact that evaporation of water occurs more readily at lower pressures than at higher ones. Heat transfer in vacuum drying is generally by conduction, sometimes by radiation.
3. Freeze drying; In freeze drying, the water vapor is sublimed off from frozen food. The food structure is better maintained under these conditions. Suitable temperatures and pressure must be established in the dryer to ensure that sublimation occurs. (Spicer,1974).

2.4.0 DRYING EQUIPMENT

In an industry so diversified and extensive as the food industry, it would be expected that a great number of different types of dryers would be in use. This is the case and the total range of equipment is much too wide to be described in this review. However the principle of mass and heat balance form the fundamentals in drying processes and dryers in general. Common drying equipment are;

2.4.1 Tray Dryers

In tray dryers the food is spread out, generally quite thinly, on trays in which the drying takes place. Heating may be by an air current sweeping across the trays, by conduction from heated trays or heated shelf on which the trays lie, or by radiation from heated surfaces. Most trays are heated by air which also moves the vapor.

2.4.2 Tunnel Dryers

This may be regarded as development of the tray dryers in which the tray on trolley move through a tunnel where the heat is applied and the vapor removed. In most cases air is used in tunnel drying and the material can move through the dryer either parallel or counter current to the air flow.

2.4.3 Roller or Drum Dryers

In these the food is spread over the surface of a heated drum. The drum rotates with the food being applied to the drum at one point of the circle. The food remains on the drum surface for the greater part of the rotation, during which time the drying takes place, and is then scraped off. Drum drying may be regarded as conduction drying.

2.4.4 Fluidized Bed Dryers

In fluidized bed dryer, the food material is maintain suspended against gravity in an upward moving - flowing air stream. They may also be a horizontal air flow to convey the food through the dryer. Heat is transferred from the air to the food materials, mostly by convention.

2.4.5 Spray Dryers

In a spray dryer, liquid or fine solid material in a slurry is sprayed in the form of a fine dispersion into a current of heated air. Drying occur very rapidly , so that this process is very useful for materials which are damaged by exposure to heat for any appreciable length of time. The dryer body is large so that the particles can settle, as they dry, without touching the walls on which they might otherwise stick.

2.4.6 Pneumatic Dryers

In a pneumatic dryer, the solid food are conveyed rapidly in an air stream, the velocity and turbulence of the stream maintaining the particle in suspension. Heated air accomplishes the drying, and often some form of classifying device is included in the equipment. In the classifier, the dried material is separated. The dried material passed out as product and the moist remainder is re-circulated for further drying.

2.4.7 Rotary Dryers

The foodstuff is contained in a horizontally inclined cylinder through which it travels, being heated either by air flow through the cylinder wall or by conduction of heat from the cylinder walls. In some cases, the cylinder rotates, and in other the cylinder is stationary and a paddle or screw rotates within the cylinder conveying the material through.

2.4.8 Trough Dryers

The material to be dried are contained in a trough-shaped conveyor belt, made from mesh, and air is blown through the bed of materials. The movement of the conveyor continually turns over the materials, exposing fresh surface to the hot air.

2.4.9 Bin Dryers

In bin dryers, the foodstuff is contained in a bin with perforated bottom through which warm air is blown vertically upwards, passing through the materials and so drying it.

2.4.10 Belt Dryers

The food is spread as a thin layer on a horizontal mesh or solid belt and air passes through or over the material. In most cases the belt is moving, though in some designs the belt is stationary and the material is transported by scrapers.

2.4.11 Vacuum Dryers

Batch vacuum dryers are substantially the same as tray dryers, except that they operate under a vacuum, and heat transfer is by conduction or by radiation. The trays are in a large cabinet which is evacuated. The water vapor reduced is generally condensed, so that the vacuum pump has only to deal with non-condensible cases. Another type consists of an evacuated chamber containing a roller dryer.

2.4.12 Freeze Dryers

The material is held on shelves or belt in a chamber which is under high vacuum. In most cases, the food is frozen before being loaded into the dryer. Heat is transferred to the food by conduction or radiation and the vapor is removed by vacuum pump and then condensed. In one process known as accelerated freeze drying. Heat transfer is by conduction, sheets of expanded metal are inserted between the foodstuff and heated plates to improve heat transfer and moisture removal. The food must be shaped so as to present the largest possible flat surface to the expanded metal and the plates to obtain good heat transfer. A refrigerated condenser may be used to condense the water vapor. (Earle,1992).

CHAPTER THREE

3.0 HEATED AIR DRYING

3.1 Heated Air Drying Mechanism

As mentioned in section 2,3 drying involves the evaporation of the moisture contained in foodstuff. When heated air is used, the hot air provides the latent heat for vaporization for water contained in the foodstuff and the water thus evaporated is removed from the foodstuff by the air (Earle, 1992). The rate of removal of the water depends on the conditions of the air, the property of the food and the design of the dryer.

Drying rate in air drying falls into two periods, that is, the constant-rate and the falling-rate drying periods.

1. In constant-rate drying period, the drying behaves as though the water were at a free surface. Water in foodstuff held by very weak forces retaining surface moisture is removed during this period.
2. However, in food, after a period of constant rate, it is found that water then comes out more slowly. This is referred to as falling-rate drying. Here moisture held inside the foodstuff has to travel to the surface before evaporation. More so, the force holding moisture gets increasingly stronger up to very strong chemical bonds as drying progresses. The rate of drying is generally determined by the rate at which heat energy can be transferred to the water in order to provide the latent heat. In air drying the rate of heat transfer is given by.

$$q = h_s A(t_a - t_s).$$

Were q is the heat transfer rate in KJ Kg^{-1} S^{-1}; h_s is the surface heat transfer coefficient in Jm^{-2} S^{-2} $°C^{-1}$; A is the area through which heat flow is taking place, m^2; ta is the air temperature and t_s is the temperature of the surface which is drying, °C (Earle, 1992).

As drying proceeds the character of the heat transfer situation changes. Dry materials begin to occupy the surface layers and conduction must take place through these dry surface layers which are poor heat conductors so that heat is transferred to the drying region progressively more slowly.

Conclusively, it could be said that heat energy needed for drying is transferred under the driving force provided by a temperature difference between the air and the material to be dried, and the rate of transfer is proportional to the temperature difference and to the properties of the transfer system characterized by the heat transfer coefficient.

3.2 Heated Air Production Technique

Heated air required for drying is produced by passing air through a furnace where in the air is heated up by the principle of heat transfer.

$$M_1C_1\theta = M_2C_2(T_f - T_i)$$

Where M_1 is the mass of the fuel burnt in the furnace, C_1 is the specific heat capacity of fuel, θ is the temperature of the furnace, M_2 is the mass of air passed into the furnace, C_2 is the specific heat capacity of the air, T_i is the initial temperature of the air and T_f is the final temperature of air (all the parameters are in their S. I. units).

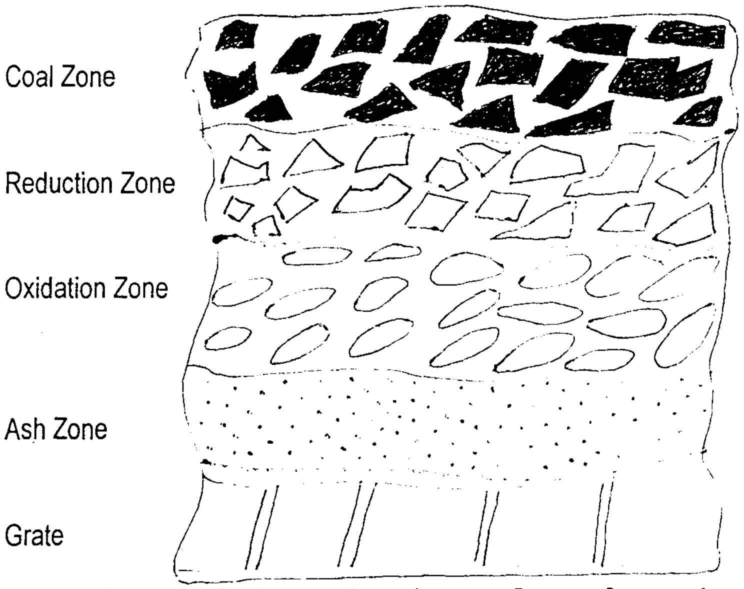
In this particular design, attention was focused on production of drying air with a temperature of about 43°C which could be increased depending on the properties desired to be preserved in the foodstuff. Since the calorific value of coal is relatively high as compared with other solid fuels, an attempt was made to bring down the temperature of the air to this level by suppling a large volume of air to mix up with air needed for complete combustion and then be exhausted at the temperature value required.

3.3 Mechanism of Coal Combustion on Grates.

Grate is a bed on which Coal is placed and air is supplied for combustion. It is located right at the furnace of heat generation plants. The grate could either be moving or stationary bed and usually perforated so as to allow primary air pass upward through it and ash (after combustion) to drop into the ash pit.

Successful combustion of coal on grates involves 5 operational stages namely:

1. Distillation of the volatile matter from coal at the topmost layer (coal zone).
2. Reaction of the fixed carbon of the coal. The carbon combines with the incoming carbon dioxide from below to form carbon monoxide (reduction zone).
3. Complete combustion of all carbon monoxide and expelled volatile matter by the secondary air supplied over the fire (over fire zone).
4. Ash disposal as it falls through the grates (ash zone).



$(Vm + CO) + O_2 \rightarrow CO_2$

Distillation of volatile mater (Vm)

$C + CO_2 \rightarrow 2\,CO.$

$C + 0_2 \rightarrow CO_2$

Fig. 3.3.1 Machanism of coal combustion on crates.

If coal is added on top of the one already burning, smoke from the volatile matter in the coal is likely. If the new coal s fed under the burning one, smoke will be burnt away as it is mitted, but this creates a dilemma in designing feeding mechanism nd ash outlet. A new way of solving the problem is by so called everse combustion where the new coal is fed in on top but the ombustion proceeds downward by a forced draught.

In this design, coal is fed in from the top while combustion roceeds sideways. Complete combustion is by deflecting air at the ther end of the combustion chamber to create the over fire zone.

.4 Theoretical Volume of Air Required to burn 1kg of Coal

Composition of Coal per 100kg

Material	C	H	O	N	S
Weight (kg)	65.45	4.75	10.8	1.6	0.95
molecular weight	12	2	32	28	32
Mole	5.45	2,37	0.337	0.057	0.029

Source: Nigerian Coal co-operation, 1981. The combustion aterials in Coal are carbon (C), Hydrogen (H) and sulphur (S).

a) Stoichiometric method. The reactions involved are:-

(1) $C + O_2 \quad - \quad CO_2$

12 32 44

(2) $H_2 + \frac{1}{2} O_2 - \quad H_2O$

2 16 - 18

(3) $S + O_2 \quad - \quad SO_2$

32 32 64

Source: Harker and Allen, 1972

Mass of oxygen required is found as follows:

For carbon = $\frac{0.6545x32}{12} = 1.7453kg$

For Hydrogen 6.0475 x 16 = 0.3800 kg

For Sulphur = $\frac{0.095x32}{32} = 6.0475x16 = 0.3800kg$

Suming up to 2.1348kg

:. Total oxygen required for burning 1kg of Coal = 2.1348kg

But 0.1080 kg of oxygen is available in the coal (Chukwu, 1987)

:. Oxygen to be supplied = 2.1348 - 01080 = 2.0268kg/kg Coal.

Air = 23% w/w oxygen.

Thus weight of air to be supplied is $\frac{2.0268x100}{23} = 8.8122kg/kg$ Coal.

Density of air at s.t.p. = 1.290kg/m^3 (Chukwu, 1987).

:. Volume of air required to burn 1kg of coal is 8.8122/1.29 = 6.831m^3/kg.

Mole Method

The reactions involved are (Harker and Allen, 1972)

1kmol C + 1 kmol O_2 $\rightarrow$ 1 kmol CO_2

1komol H_2 + ½ kmol O_2 $\rightarrow$ 1 kmol H_2O

1komol S + 1kmol O_2 $\rightarrow$ 1 kmol SO_2

kmol Oxygen required to burn combustible elements in coal (basis: 100kg Coal)

Component	% Weight	÷ by	kmol	kmol O_2 required
C	65.45	12	5.454	5.454
H	4.75	2	2.375	1.188
O	10.8	32	0.23375	-0.3375
N	1.6	28	0.0571	--
S	0.95	32	0.0297	0.0297
				6.3342

:. Air to be supplied = $\frac{6.3342}{21} = 30.163kmol/10kgcoal$

(1 kmol is equivalent to volumes $22.4m^3$ and air is 21% v / v 0_2)

. Weight of air to be supplied = 30.163 x 28.93 = 872.6 =62kg/100kg coal (28.93 is the mean molecular weight of air). Weight of air for kg of coal = 8.7262. Volume of air to be supplied = 30.161 x 22.4 = 675.6064 m^3 /100kg coal or 6.756512 m^3/kg Coal.

.5 RATE OF COAL COMBUSTION

Because of economic limitations the rate for this design is kg of coal per hour.

. Rate of combustion = $\frac{5}{60x60} = 0.001389 kg/s.$

.6 VOLUME OF FLUE GAS and EXCESS AIR USED

Composition of dry flue gas

From section 3.4 the theoretical (or stoichiometric) air required is 30.163kmol/100kg coal.

This air contains 0.79 x 30.163 = 23.8288.N_2

In addition the flue gas contains 5.4454 kmol C.,0. 0297 kmol so_2 from combustion of 0.0297 Sulphur), 0.0571kmol N_2 (From coal).

Total = 29.361 kmol/100kg coal.

100kg coal contain 2.375 kmol of H Which form 2.375kmol of $H_2 0$ apour. kmol of wet flue gas is 29.361 + 2.375.

The volume of flue gas.

=31.736 x 22.4.

=710.8864 m^3/100kg coal

=7.10.89 m^3/kg coal

SO_2 = 0.297 x 64 = 19.008kg

CO_2 = 5.454 x 44 = 239.976kg

= (23.8219 + 0.0297) 28 = 667.8448Kg

= 2.375 X 18 = 42.75kg

weight of flue gas = 969.5788 kg/100kg coal 9.70kg/kg Coal.

3.7 Temperature of Flue Gas And Excess Air Used For 1 Kg Coal

Heat generated by combustion of 1kg of coal is equal to its calorific value which is equal to 28,466 kJ/kg (Chukwu, 1987). Specific heat capacity of coal =1.260kJ/kg (Incropera and Witt. 1972).

Mass of Coal to be combusted = 1kg

$Q = MCP\ \theta = MCp\ (t - ta)$

where Q is quantity of heat generated, M is mass of coal to be burnt, Cp is the specific heat capacity of coal, θ is change in temperature, t is the final temperature of the furnace and ta is the ambient temperature = 28°C.

Substituting and rearranging $\frac{28{,}466}{1.26} = t - 28^\circ C$

$t = 22620.06349°c$

(Assuming complete combustion)

The temperature of flue gas is calculated with the application of law of conservation of energy $M_c\ C_c\ \theta_c = M_{fg}\ C_{fg}\ \theta_{fg}$.

Where $M_c\ C_c \theta_c$, are mass, calorific value and temperature of coal respectively and $M_{fg}\ C_{fg}\ \theta_{fg}$ are parameters for flue gas.

$$M_c\ C_c\ \theta_c = [M_{so_2}\ C_{so_2} + M_{co_2}\ C +_{co_2} \cdot M_{N_2}\ C_{N_2} + M_{H_2O}\ C_{H_2O}] \times t_{fg} - t_a$$

$M_{so_2} = 0.19008$ kg

$M_{co_2} = 2.39976$ kg

$M_{N_2} = 6.678448$ kg

$M_{N_2} = 6.678448$ kg

$M_{H_2O} = 0.4275$ kg

$C_{co_2} = 871$ J/kg.k

$C_{so_2} = 623$ J/kg.k

C_{N_2} = 1041 J/kg.k

C_{H_2O} = 4177 J/kg.k

Source: M Graw Hills Hand Book of Heat Transmission, 1958.

$$t - 28 = \frac{1x1260x22620.06349}{(0.19008x623+2.39976x871+6.78448x1041+0.4275x4177)} = 2577.69°C$$

t = 2631 . 678701°C = 2603.69

The excess air required to bring the temperature of exhaust gas (drying gas) to 43°C is calculated from the relation.

$$M_C \; C_C \; \theta_C = (M_{fg} \; C + M_{air} \; C_{air}) \; 43.$$

Where M_{air} is mas of air and C_{air} is specific heat capacity of air =1007J/kg.k

$$\frac{1x1260x22620.06649}{43} = \frac{28501280}{43}$$

$$= (10946.54267 + M_{air}x1007) = \quad 662820.4651 - 10946.54267$$

$$M_{air} = \frac{651873.9234}{1007} = 647.3425kg$$

:.Total air to be supplied to 1 kg of coal and bring the temperature to 43°C is 647.34 25 + 8.8122 =656.1547 kg/kg coal.

CHAPTER FOUR

4.0 DESIGN OF SOLID FUEL-FIRED DRYER

4.1.1 Design Of Blower

Fans or blowers are used for non-positive movement of air. The capacity of a fan is identified by the volume of air moved in cubic meter per minute or hour at a certain pressure of head. The head is made up of the static and velocity pressure. The static head is utilized in overcoming the friction of the air with its contents in the duct and the velocity head is the pressure required to produce the flow.

Fans may be classified as radial flow (centrifugal) or axial flow (propeller). With radial flow fans the air is moved in the direction of the radius of the fan wheel, and with axial fans, the flow is parallel to the axis of rotation of the blade. Radial flow fans can be constructed with blades which are straight, forward curved or backward curved (Chukwu, 1987).

In this design centrifugal fan is to be used to blow air into the furnace and to drying chamber. This is because it has no possibility of overloading the power source (Henderson and perry, 1955).

Basic fan Laws express the relationship between the flow rate and power to drive the fan, it also expresses the relationship between the flow rate and the wheel diameter.

The relationship are as shown below:

(1) Change of speed with definite fan size, duct system, and gas density.
   - (a) The capacity changes directly as the speed ratio.
   - (b) The static pressure varies as the square of the speed ratio, and
   - (c) The hp required to drive the fan varies as the cube of the speed ratio.

(2) Fan-Size change with the fan operated with constant blade tip speed, unchanging air density, uniform fan proportions and

a fixed point of rating.

(a) The discharge volume and the required power (b hp) vary as the square of the wheel diameter's ratio.

(b) The discharge pressure remains constant, and

(c) The speed (rpm) varies inversely as the ratio of the wheel diameter (Severns and Fellows, 1958).

Effect of Speed Variation Using Fan Law 1

From table on radial blade fans let the characteristics of fan A be as follows:

At 1010 rpm

cmm = 186.497 (cubic meters per minute)

bhp = 15.73 (brake horse power)

sp = 0.254m (static pressure)

outlet velocity = 009.6m/min

Diameter of wheel = 1.06045m

outlet area = $0.2977445m^2$

inlet area = $0.3083351m^2$

For this design, the volume flow rate is calculated as follows:

656.1547kg of air is needed for 1kg of coal.

$\therefore$ 656.1547x5 = 3280.7735 kg/5kg = 3280.7735/1.29 = 2543.235271 $m^3/hr = 42.38725452m^3/min$

The characteristic of fan A above will change as follows:

with cmm = $42.38725452 = 186.497 \times \frac{x}{1010}$

x = 229.5540 rpm

sp = $0.0254 \times \left(\frac{229.5540}{1010}\right)^2 = 0.01312m$

bhp = $15.73 \left(\frac{229.5540}{1010}\right)^3 = 0.1847$

The Characteristics of the new fan will be:

cmm = 42. 3873

Rpm = 229.5540

Sp = 0.01312m

bhp = 0.1847

Diameter of wheel = 1.06045 m

Outlet area = $0.2977445m^2$

Inlet area = $0.3083351m^2$

Outlet velocity = 609.6m/min.

With the second Law

$$42.3873 = \left(\frac{x}{1.060x5}\right)^2 x186.497$$

x = 0.50555906m

= 0.506m

where x is diameter of wheel

sp = constant = 0.01312m

$$bhp = 0.1847 \times \left(\frac{0.500}{1.06045}\right)^2 = 0.04198$$

$$rph = 229.5540 \times \frac{1.06045}{0.506} = 481.507619$$

For fans operating at constant tip speed and at fixed point of rating, pressure remains fixed (Sevens and Fellows 1988). Consequently, velocities through fan inlet, impeller, and fan outlet are identical for each size of fan. The effective area of each fan varies with the square of the wheel diameter; hence volumetric capacity is a function of velocity and area is directly proportional to outlet area, power input varies in proportion to delivered volume, since pressure and efficiency undergo no change.

Therefore the outlet area of the fan B is given by:

$$\text{Outlet area A, } = 0.2977 \times \frac{42.3873}{186.497} = 0.06766m^2$$

$$\text{Inlet area is given by } A_2 = 0.3083 \times \left(\frac{0.506}{1.060497}\right) = 0.07019m^2 = \frac{\pi d^2}{4}$$

Where d is diameter of inlet d = 0.2989m

The impeller eye (d), is given by 0.5_2 where , is impeller eye and d_2 is impeller diameter = 0.506m

di = 0.506x0.5 = 0.253m

The blade width of the wheel is given by 0.35 d_2

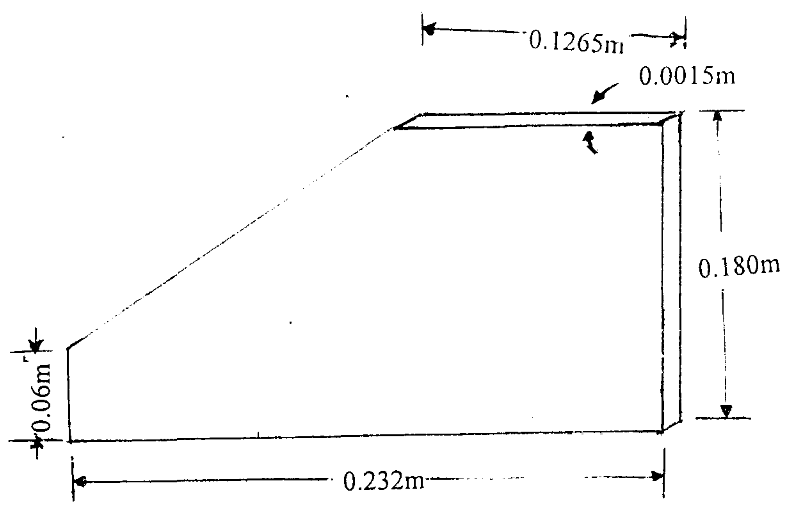
Blade width = 0.35 x 0.1771m

= 0.1769m

Number of blades = 8 (chosen for ease of dismantling and repair).

Height of blade = 0.18m (giving room for thickness of sheet metal).

Thickness of plate to be used is 0.0015m.



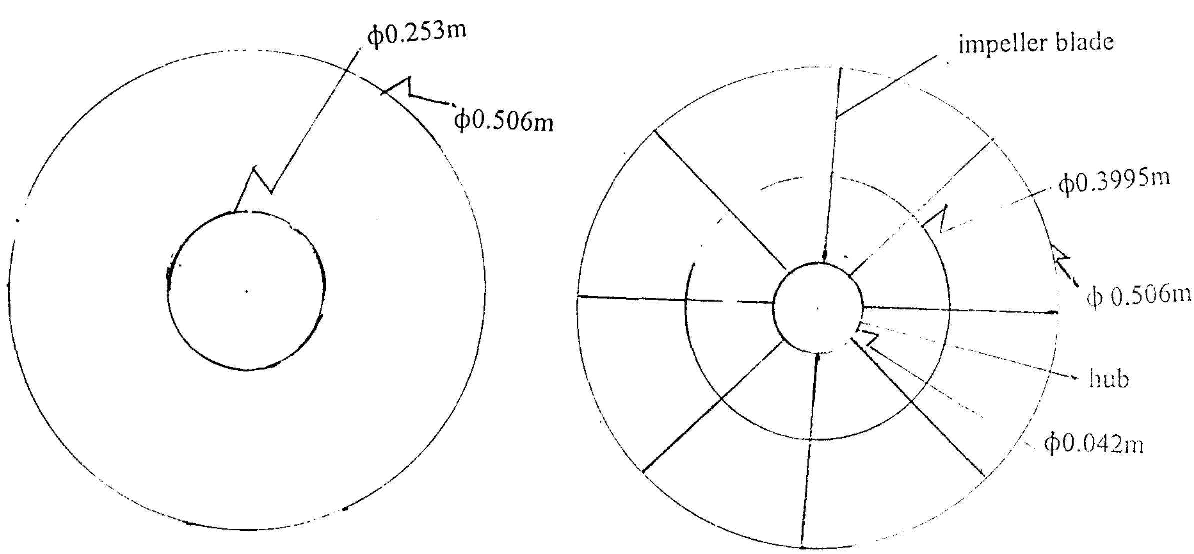


Fig. 4.1 Fan Dimensions

From the relation of area of similar figures the dimension f the outlet of the fan can be established.

$$\frac{A}{A_1} = \left(\frac{L}{L_1}\right)^2$$

$$\rightarrow \frac{3.295}{0.7284} = \left(\frac{1.9797}{L^1}\right)^2$$

L′ = 0.9306 = 28.3632cm = 28cm

width = $\frac{Area}{Length} = \frac{0.7284}{0.9306} = 0.7828$

= 23.8586 =24cm

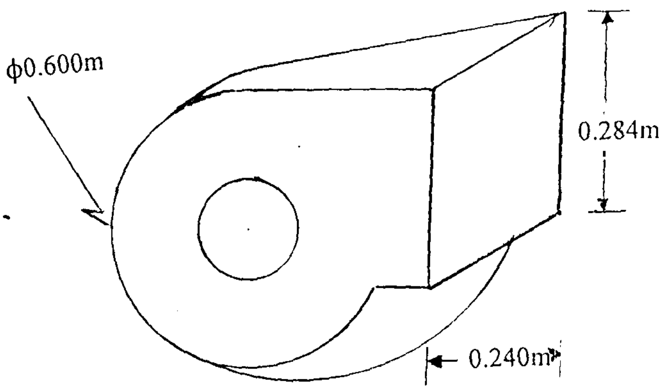


Fig. 4.2 Blower

The Length of the standard fan L is found from table 10 appendix).

Total area of fan components (A)

$A = 8\ (A_1 + A_2 + A_3 + A_4) + A_5$

where A_5 is area of hub.

1.2 Design of Belt and Pulley (Blower Belt and Pulley)

Electric motor speed = 1440 rpm

The choice is based on availability.

Belt selection: A, V-belt (based on the usual load of drive 75 - 5 kw power)

Determination of the maximum power of belt

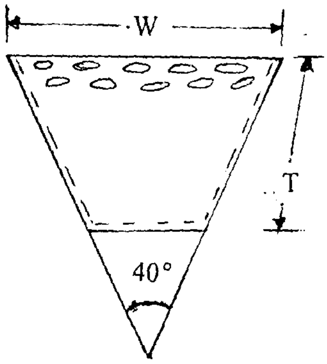


Figure: 4.3 standard selection V-belts.

For V-belt A, the following are the data of its sections.

Usual load of drive 0.75 - 5 kw.

Recommended minimum pitch diameter d = 75 mm

Nominal top width w = 13mm

Nominal thickness T = 8mm

Weight per meter = 0.106 kg/m

(i) Belt speed = S = π dp N (DESIGN DATA PSG TECH 1982)

were dp = minimum pulley pitch diameter

N =motor speed

$$S = \pi \frac{(0.075)1440}{60} = 5.6540 \text{m/s}$$

$$\text{Speed ratio} = \frac{1440}{481.5} = 2.991$$

ii) Small diameter correction factor for arc of contact variation

F_b = 1.14 (based on 5 speed ratio range) (DESIGN DATA PSG TECH 1982)

iii) Calculation of the equivalent pitch diameter d_c

$d_e = d_p \times F_b$

= 0.075 x 1.14 = 0.08 55m = 85.5mm

This value is within the expected range since it is greater than the minimum of 75mm.

v) Calculation of the maximum power in kilowatt of the belt (A section) For V-belt A the maximum power is given by

$$kw = (\quad (0.45S^{-0.09} - \tfrac{19.62}{d_e} - 0.765 \times 10^{-4} S^2)S$$ (DESIGN DATA PSG TECH 1982)

where S = belt speed = 5.6549 m/s

de = equivalent pitch diameter = 0.0855m

kw = maximum power in kw at 180 arc of contact for a belt of average length.

$$Kw = (0.45(5.6549)^{-0.09} - \frac{19.62}{85.5} - 0.765\times10^{-4}(5.6549)^2 \times 5.6549$$

$=0.8658$ kw.

This power is suitable for the belt type since it is within range of the usual load of drive of 0.75 - 5 kw.

Selection of the driver and the driven pulley speed n_1 and n_2 respectively.

$\frac{n_1}{n_2} \leq 9/\eta$ (Design Data PSG Tech 1982)

where η is efficiency = 0.98

$\frac{n_1}{n_2} = \frac{9}{0.98} = 9:0.98$

This means that the ratio of the speed of the driver to the ven pulley is 9:1 approximately.

) Determination of the diameter of the larger pulley D.

$D = d \frac{n_1}{n_2}\eta$

$D/d \leq 9$ ------(*)

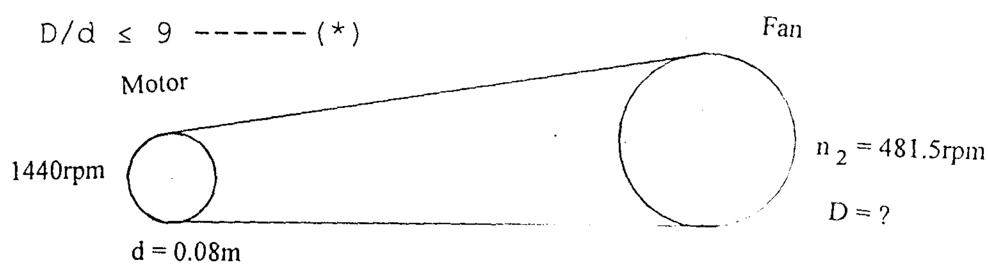


Figure 4.4 Fan and Puller diameters and speeds

$$D = 80 \times \frac{1440}{481.5} \times 0.98 = 234.467\text{mm}$$

The diameter ratio $D/d = \frac{234.467}{80}$

$= 2.931$

This is within the range of the equation(*) above and is satisfactory.

(vii) Determination of the ratio of center distance to larger pulley diameter.

With the knowledge of D/d the value of C/D = 1.0 (DESIGN DATA PSG TECH 1982)

This is the recommended C/D ratio (read from the table of given speed ratio of 3).

(viii) Calculation of c. (centre distance, mm)

C = C/D x D

=1 x 234.467

=234.467mm.

(ix) Calculation of Cmin and Cmax

minimum centre distance C min = 0.55 (D f d) x T

But T = nominal belt thickness = 8mm

Cmin = 0.55 [234.467 + 80] + 8 = 180.957mm

maximum centre distance Cmax = 2 (Dfd)

Cmax = 2 (234.467 + 80) = 628.934mm.

(x) Calculation of the nominal pitch length of belt, L,

$$L = 2C + \frac{\pi}{2}(D+d) + \frac{(D-d)^2}{4C}$$

$$L = 2 \times 234.467 + \frac{\pi}{2}(234.467 + 80) + \frac{(234.467+80)^2}{234.467}$$

=1384.661 mm.

The value of L is used to calculate C to check if the condition Cmin ≤ C ≤ Cmax holds.

(xi) Calculation of the actual value of C

$$C = AX \sqrt{A^2 - B}$$

$$\text{Where } A = L/4 - \pi\frac{(D+d)}{8}$$

$$B = \left(\frac{D-d}{8}\right)^2$$

$$\frac{1384.661}{4} - \pi \frac{(234.467+8)}{8} = 250.949\text{mm}$$

$$B = \frac{(234.467-8)^2}{8} = 6410.9127\text{mm}$$

$$C = 250.949 + \sqrt{250.94^2 - 6410.9127}$$

$$= 488.782 \text{ mm}$$

Checking the condition Cmin ≤ C ≤ Cmax

180.957 ≤ 488.782 ≤ 628.934.

The condition is satisfied, C is within range.

xii) Calculation of the number of belt required from table (Design data PSG TECH 1982)

correction factor for industrial service Fa = 1.2

Rating for A, V-belt = KW = 0.94

Correction factor = Fc = 0.94.

The arc of contact on smaller pulley.

Arc of contact angle $f = 2 \cos^{-1} \frac{D-d}{2C}$

$$= 180° - 60° \frac{D-d}{c}$$

$$B = 2 \cos^{-1} \frac{(234.467-8)}{2\text{x}488.782}$$

= 153.2098.

The correction factor arc of contact Fd = 0.93

Number of belts

$$= \frac{P\text{x}F_a}{KW\text{x}F_c\text{x}F_d} = \frac{0.8658\text{x}1.2}{0.94\text{x}0.94\text{x}0.93}$$

=1.2643 = 1 belt

1 Belt is to be used.

<u>Design of Fan shaft</u>

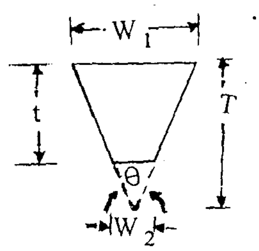


Figure: 4.5 Belt Dimensions

Top Width of Belt W_1 = 13mm

Nominal depth of belt t = 8mm

Sheave groove angle θ = 40°

Density of Leather belt = $970 kg/m^3$

Determination of the bottom width of belt

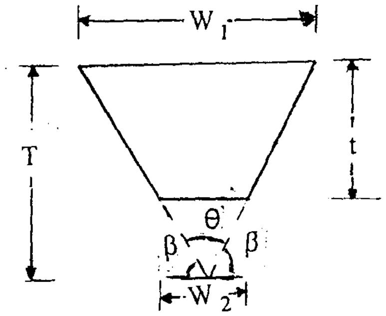


Figure: 4.6 Belt Dimension.

Belt Dimension

From figure 4.6 $\beta = \frac{180-\theta}{2} = \frac{180-40}{2} = 70°$

$T = ½\ W_1 \tan 70 = 6.5 \tan 70° = 17.86mm$

From similar triangles, $W_2 = \frac{tw_1}{T} = \frac{8x13}{17.86} = 5.82mm$

Belt cross sectional area can be obtained as

$$A = \frac{(W_1 + W_2)t}{2} = \frac{(13+82)}{2}8 = 75.29mm^2$$

mass per unit length = M = ρxA = 970 x 75.29mm[1]

= 0.073 kg/m

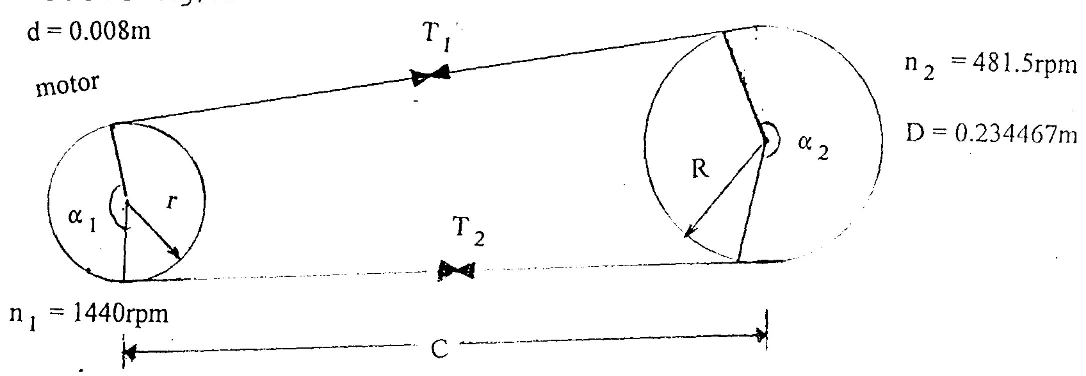


Fig.4.7 Fan - Motor, V-belt and Pulley

Belt velocity = Dn_2 = $\frac{(234.467x10^{-3}x481.5)}{60}$ = 1.8816 m/s.

The maximum tension for leather belt (T)

$T_1 = 2 \times 10^6 \ N/m^2$

To express T_1 = Maximum tension x Belt Cross-sectional area

$= 2 \times 10^6 x 75.29 x 10^6$

$= 150.58N$

Determination of the arc of contact $\propto$

$= 180 \pm 2 \sin^{-1} \frac{117.2335 - 4}{488.782}$

$= 180 \pm 26.7902$

$180 + 26.7902$

$\propto_2 = 206.790 \ 2°$

$180 - 26.7902$

$\propto_1 = 153.2098°$

Determination of the allowable tension ratio for the V-belt (R)

$R = \ell^{\mu \propto} \ \text{Cosec} \ (\theta/2)$

where μ = fraction between belt and pulley

α = Arc of contact in degree

θ = Sheave grove angle.

$R_1 = \ell^{\mu \propto} \ \text{Cosec} \ (\theta/2) = \ell^{0.23 x 153.2098 \text{Cosec}(\frac{\theta}{2})}$

$= \ell^{(0.25 x \pi/180 x 153.2098) 1/\sin 20}$

$= 7.0609$

$R_2 = \ell^{\mu \propto} \ \text{Cosec} \ (\theta/2)$

$= \ell^{(0.25 x \pi/180 x 206.7902) 1/\sin 20}$

$= 13.9870$

The lower value 7.0609 is the allowable tension ratio for V-belt on pulley and it is the one that governs the design.

The centrifugal force, $T_c = MV_2$

where M = belt mass/unit length

V = belt velocity

$Tc = 0.073 \times (1.8816)^2$

$Tc = 0.2585$ N

Determination of belt Tension on the slack side T_2

Given

$$\frac{T_1 - T_C}{T_2 - T_C} = R$$

$$T_2 = \frac{T_1 - T_C}{R} + T_C$$

$$= \frac{150.58 - 0.2585}{7.0609} + 0.2585$$

$= 21.5478$N

Power transmitted by belt

$$P = \frac{(T_1 - T_2)}{1000} V$$

$$= \frac{(150.58 - 21.5478)}{1000} 1.8816$$

$= 0.2428$ kw

Loads on Fan shaft

Fan blade and hub (Galvanised sheet)

density of steel = $7850 kg/m^3$

Total mass of materials used for fan

$= 2.997 \times 10^{-4} m^3 \times 7850$

$= 2.3548$ kg.

Weight = 23.1059 N.

Gross volume of disc used for pulley = $\frac{\pi D^2}{4}(W_1 + 2Y)$

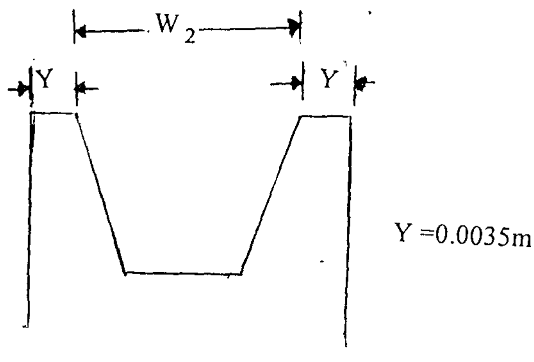


Figure 4.8 Cross-section of pulley

$$\pi x \frac{234.467^2}{4}(13+2x3.5)$$

$= 863541.7323\ mm^3$

Volume of groove on pulley = π D (Belt cross-sectional area)

$= \pi \ x\ 234.467\ x\ 750.29$

$= 55458.5993 mm^3$

Net volume of pulley = 863541.7323 - 55458.5993

= 808083.133

$8.0808\ x\ 10^{-4} m^3$

Material for pulley is aluminum with density of 27 $2710 kg/m^3$

Weight of pulley = $8.0808\ x\ 10^{-4}$ x 2710 x 981 = 21.483N.

It is assumed that the bore of the pulley will have the approximate weight of the pulley collar.

Calculation of shaft diameter.

Vertical Loading

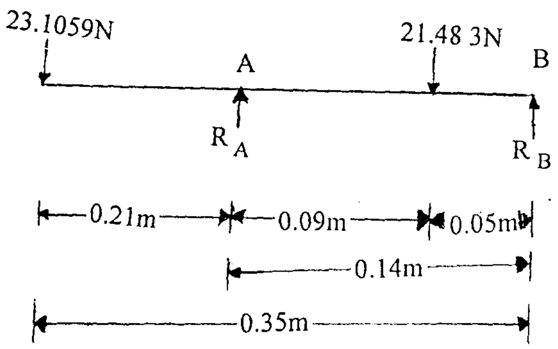


Fig. 4.9 vertical loading of shaft

$\Sigma vf = R_A + R_B - (23.1059 + 21.483) = 0$

$R_A + R_B = 44.5889N$

$\Sigma B = 0 = 21.483 \ x\ 0.05 + R_A \ x\ 0.14 - 23.1059 \ x\ 0.35$

$= 0.14 R_A = 1.07415 - 8.087065$

$0.14 R_A = 9.161215$

$R_A = 9.161215/0.14 = 65.4725N$

Substituting, $65.43725 + R_B = 44.5889$

$R_B = 44.5889 - 65.43725 = -20.84835$ N

Calculation of shear forces to draw shear force diagram

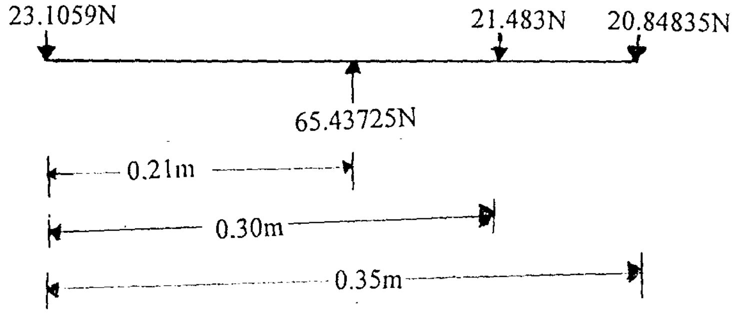


Fig. 4.10 Shaft Loading

$0 \leq x \leq 0.21$

$x: F_1 = -23.1059$

$0.21 \leq x \leq 0.30 \; x: F_2 = F_1 + 65.43725$

$= 42.33135$N

$0.30 \leq x \leq 35 \; x: F_3 = 4\ (F_1 + F_2) - 21.483$

$= 42.33135 - 21.483$

$= 20.84835$N

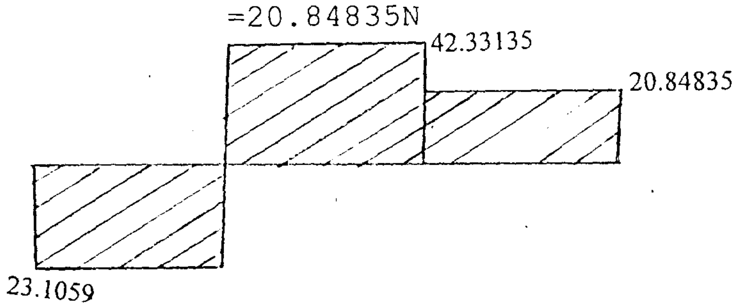


Fig.4.11 Share force diagram

Bending Moment

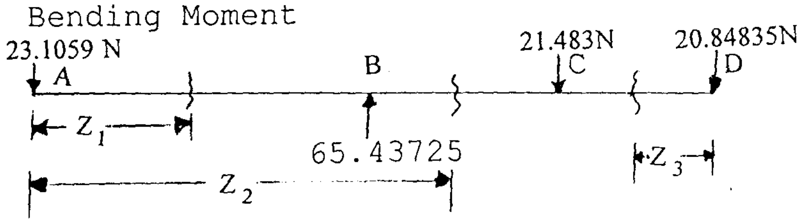


Fig. 4.12 Shaft sectioning

$M_A = 0 \; M_1 - 23.1059Z_1 = 0$

$M_1 = 23.1059Z.$

$0 \leq 1 \leq 0.21$

For $Z_1 = 0$ $M_1 = 0$

For $Z, = 0.21$

$M_1 = 23.1059x0.21 = 4.852239NM$

$\Sigma M_B = 0$

$M_2 - 23.1059Z_2 + 65.43725\ (Z_2 - 0.21)$

$M_2 = 23.1059\ Z_2 - 65.43725\ (Z_2 - 0.21)$

$0.21 \leq Z_2 \leq 0.30$

For $Z = 0.21$

$M_2 = 23.1059 \times 0.21 - 65.43725\ (0.21 - 0.21)$

$= 4.852239$ Nm

For $Z_2 = 0.30$

$M_2 = 23.1059 \times 0.30 - 65.4725\ (0.30 - 0.21)$

$= 1.04\ 24175$ NM

$\Sigma Mc\ M_3 - 20.84835Z_3 = 0$

$0 \leq Z_3 \leq 0.05$

$M_3 = 20.84835\ Z_3$

For $Z_3 = 0$ $M_3 = 0$

$Z_3 = 0.05,\ M_3 =$

$M_3 = 20.84835 \times 0\ .\ 05 = 1.0414275$

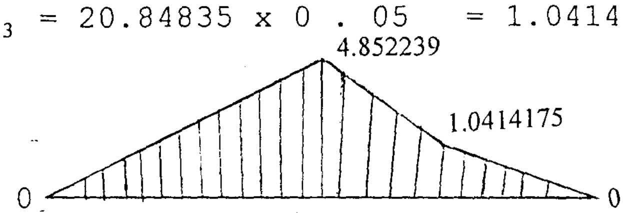


Fig.4.13 Bending moment diagram

Horizontal loading

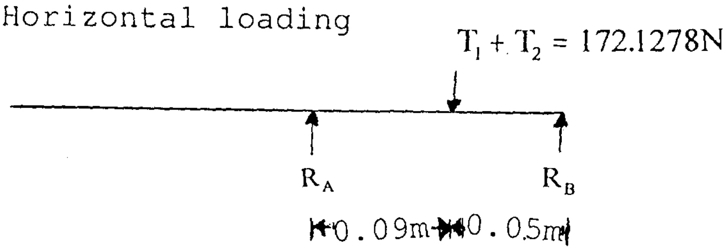


Fig. 4.14 Horizontal loading of shaft

$\Uparrow \Sigma M_A = 0,\ 172.128 \times 0.09 - R_B \times 0.14 = 0$

$R_B = \frac{172.1278 \times 0.09}{0.14}$

$= 110.6535857$

Substituting in equation (1)

$R_A = 172.1278 - 110.6536$

$= 61.4742N$

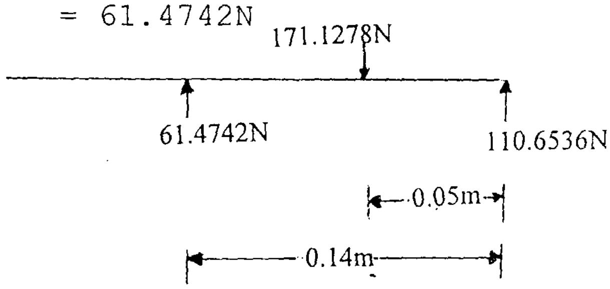


Figure 4.15 Shaft loading

Horizontal shear force diagram

$0 \le x \le 0.09$: $F_1 = 61.4742$ N

$0.25 \le x \le 0.14$ $F_2 = F_1 - 172.1278$

$= 61.4742 - 172.1728$

$= -110.6536N$

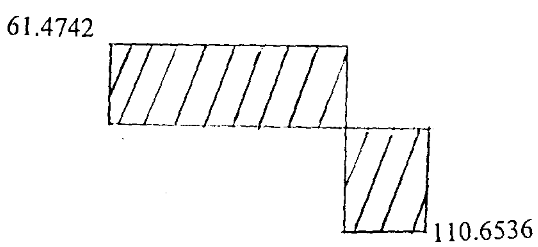


Figure 4.16 Horizontal shear Force diagram

Horizontal bending moment.

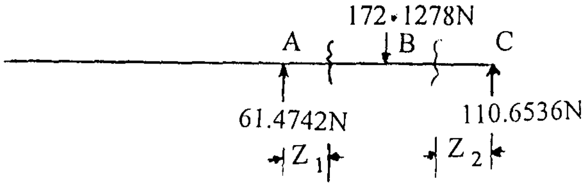


Figure 4.17 Shaft sectioning

$\Uparrow \Sigma M_A = 0 \quad M_1 + 61.4742\ Z_1 = 0$

$M_1 = -\ 61.4742\ Z_1$

$0 \leq Z_1 \leq 0.09.$

For $Z_1 = 0 \quad M_1 = 0$

$Z_1 = 0.09$

$M_1 = -\ 61.4742 \times 0.09$

$= -\ 5.532678NM$

$\Sigma M_C \Uparrow = 0 \quad M_2 - 110.6536\ Z_z$

$M_2 = 110.6536\ Z_2$

$0 \leq Z_2 \leq 0.05$

For $Z_2 = 0, \ M_2 = 0$

For $Z_2 = 0.05 \ M_2 = 110.65\ 36 \times 0.05$

$= 5.53268$

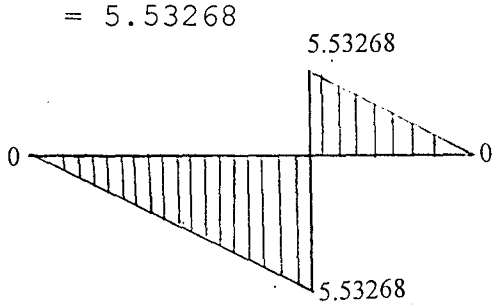


Fig. 4.18 Horizontal bending moment diagram

The maximum bending moment at point B is 4,852239

That at c is given by

$$M_B = \sqrt{1.0414175^2 + 5.53268^2}$$

$= 5.62984$

So bending moment is maximum at C

Torsional moment for the belt is given by

M_t = $(T_t - T_2)$ R where R - radius of the larger pulley.

M_t = (150.58 - 21.54 78 x 1.172335)

= 151.2689642 NM.

The diameter of the shaft is given by the equation

$$d\frac{16}{\pi Ss}\sqrt{(K_bM_B)^2 + (K_tM_t)^2}$$ (Design data PSG Tech. 1982)

Where

Ss= allowable stress = 40 x 10^6Nm for steel shaft with key ways

K_b= combined shock and fatigue factor for gradually applied bending moment = 1.5.

K_t = Combined shock and fatigue factor applied to torsional moment for gradually applied load. 1.0

M_B = Maximum bending moment = 5.62984 Nm

M_t = Maximum torsional moment = 151.2689642 Nm

$$d^3 = \frac{16}{\pi x 40x10^6}\sqrt{(1.5x5.62984)^2 + (1.0x151.268642)^2}$$

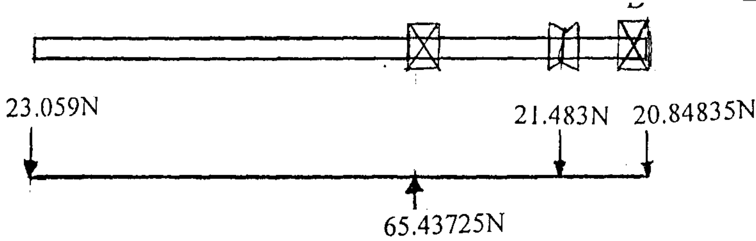
= 1.9290 x 10^{-5}

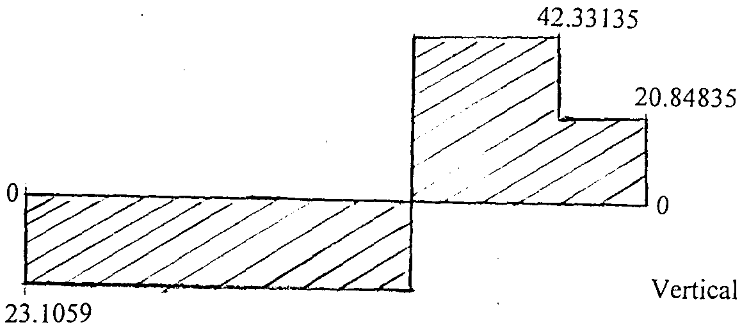
$$d = \sqrt[3]{1.9290x10^{-5}}$$

= 0.026819 cm

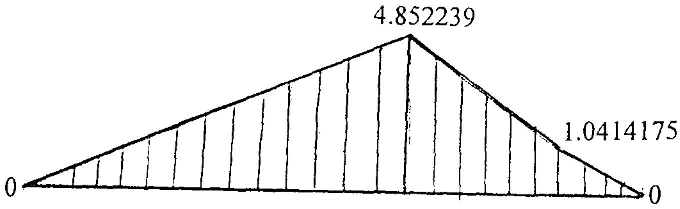
For safety

d = 28.00mm

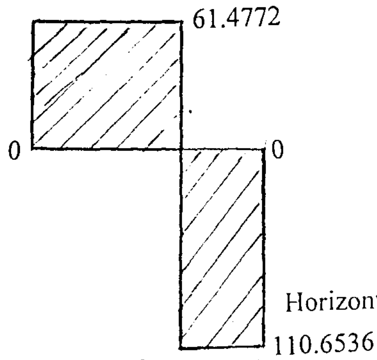




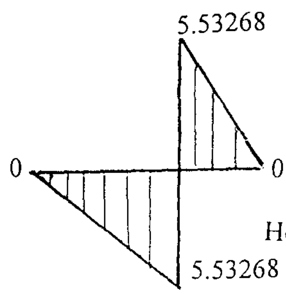
Vertical Shear Force Diagram



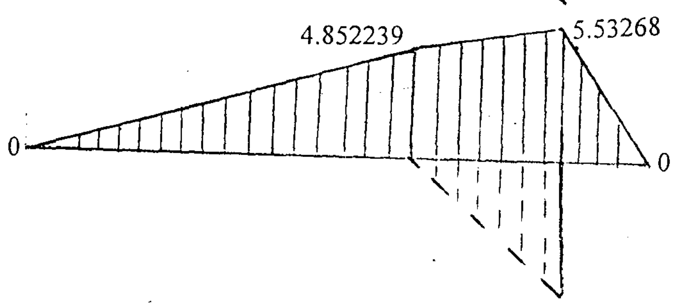
Vertical B.D.M.



Horizontal Shear Force Diagram



Horizontal B.D.M.



Resultant B.M.D.

Torsional Rigidity for the shaft

$Q = 584\ M_t\ L/Gd^4$ (Laughlin, 1978)

where

θ = angle of twist

M_t = torsional moment (mm)

L = Length of shaft

G = torsional modulus of elasticity Nm^{-2}

d = shaft diameter

$$\theta = \frac{584 \times 151.2689642 \times 0.35}{80 \times 10^9 \times 0.026819^4}$$

$= 0.7471°$

Therefore the angle of twist for the torsional rigidity is within the allowable range, since permeable angle of twist ranges from about 0.3 degrees/m for machine tool shafts to about 3 degree/m for line shaft.

4.1.3 Design of blower Casing

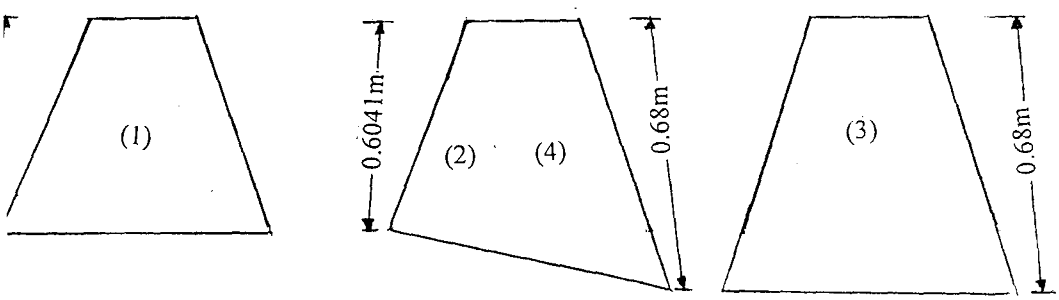
The impeller diameter = 50.6 cm = 506mm with allowance of 4mm from the casing, the diameter of casing is 600mm.

The outlet dimension for the blower is 280mm by 240mm.

Therefore the width of the blower casing is 240 mm + 3mm 243 mm. Sheet metal thickness is 1.5mm.

4.1.4 Design Of Air Route.

The air route is made up of 4 plates welded together to form rectangular cross-section. The inlet has same dimensions as the fan outlet while the subsequent sections gradually expands to join the combustion chamber with outlet as specified below.(Fig. 4.20).



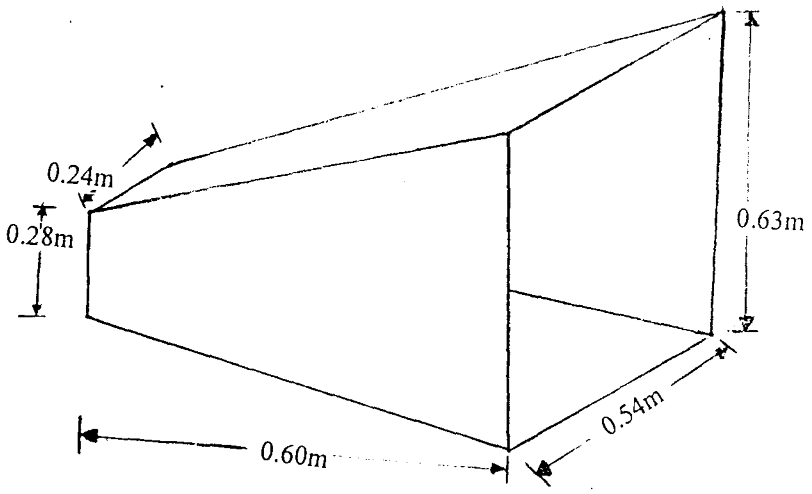


Fig. 4.20 Blower Air Route

The outlet is designed so that it allows about 20% of the total air supplied by the fan to come in contact with the combustion grate directly.

.2.0 Design Of Furnace

In the design of a dryer furnace, two major areas are taken into consideration.

These areas are:

3) The volume of the furnace space or combustion grate
4) The furnace casing or the insulation wall thickness.

.2.1 Design Of Combustion grate

The main parameter to be considered in the design of the combustion grate is the thermal load of the furnace space.

This is given by

$$qf\frac{MQ}{V}, KJ/m^3 - hr$$

ρQ, KJ/m^3 -hr (Chukwu, 1987)

where qf = thermal load of the furnace space in KJ/m^3-hr

Q = Calorific value of the fuel being considered =28,466 kJ/kg for coal

V = Volume of furnace space, m^3 for coal

P = density of fuel = 1, 350 kg/m^3 for coal

M = mass of fuel burnt in one hour, kg

qf = 1350 x 28, 466

= 38429100 KJ/M^{3-} hr

The volume of the furnace grate is given as

$$V = \frac{MQ}{qf}$$

Feed rate for this particular design is 5 kg/hr

$$\therefore \quad V = \frac{5x28,466}{38429100} = 0.0037037m^3$$

When coal chips with average dimensions of 0.02m x 0.025m and 0.03m, minor, intermediate and major diameters respectively falling from a height of about 0.3m to 0.06m is considered, the volume occupied is 0.0075m^3/kg coal (experimentally determined). This is due to air spaces left in between the coal chips in the container.

Therefore a volume of 0.009m^3 is used for the grate to accommodate to variation in temperature for drying.

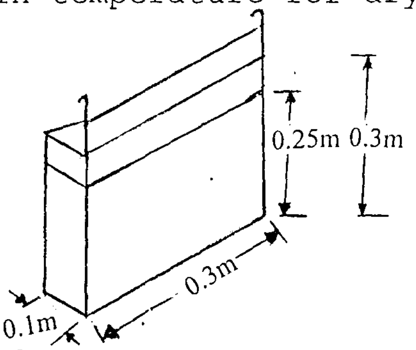


Fig: 4.21 Combustion Grate

4.2.2 Design Of Furnace Casing/Wall Thickness

The dimensions of the furnace casing are as follows:

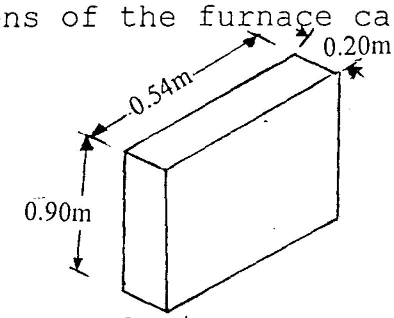


Fig: 4.22 Furnace Casing

The thickness of the insulation wall is a major factor to be considered in the control of heat loss in any heat production chamber. Depending on the thermal conductivity of the insulating material, the heat loss from a chamber can be controlled by varying the thickness of the insulating material.

The insulating material to be used in this design is particle board (fibre board) with thermal conductivity of 0.052 $JM^{-1}\ S^{-1}\ C^{-1}$ (Earle 1992). The rate of heat loss here is to be maintained at less than 1.0%. The rate of heat loss is given by Forgers equation $q = UA\ \Delta t$

where q = rate of heat loss, JS^{-1}

A = Area of insulation wall, M^2

Δt = the temperature difference between the mediums

U = the overall heat-transfer coefficient otherwise called overall conductance of the combined layers.

$$A\ \Delta t = q\ (1/u)$$

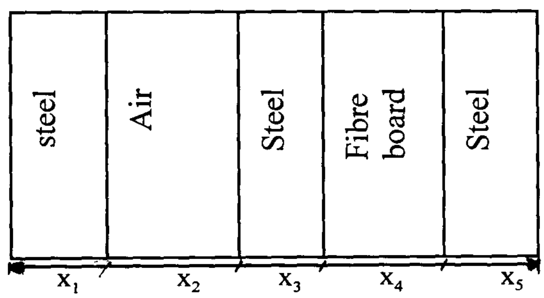


Fig. 4.23 Furnace Casing Wall thickness

$$1/u = x_1/k_1 + x_2/k_2 + x_3/k_3 + x_4/k_4 + x_5/k_5$$

X_1, x_2, x_3, x_4 and x_5 represent the thickness of the layers making up the insulation wall, that is, steel grate, air, inner steel sheet, fibre board and outer steel sheet respectively. K_1, K_2, K_3, K_4 and K_5, are the corresponding thermal conductivities of the layers.

X_1 =0.003m

x_2 =0.07m

x_3 =0.0015m

x_4 =0.0127m

x_5 =0.0015m

k_1 $=k_3 = k_3 = 45\ JM^{-1}\ S^{-1}\ °C^{-1}$

K_2 $=0.0260\ JM^{-1}\ S^{-1}\ °C^{-1}$

k_4 $=0.052\ JM\ S^{-1}\ °C^{-1}$

$$1/U = \frac{0.003}{45} + \frac{0.07}{0.026} + \frac{0.0015}{45} + \frac{0.0127}{0.052} + \frac{0.0015}{45} = 2.9367$$

A =Area of Grate wall facing the furnace casing

A =0.1 x 0.3 = 0.03

Δt =22620.06340 - 28°c

=22592.00349

q =A Δt/ $1/U$

= 0.03 x 22592.06349/2.367

= 231.3646 Js^{-1}

= 832.9126 KJ/hr

Q = 28466 x 5 = 142330 KJ/hr

percent heat loss

= q/Q x 100 = $\frac{832.9126}{142330}$x100 = 0.5852%

:.The insulation material to be used is 0.0127m = ½ inch fibre board since the heat loss than 1.0%.

4.2.3 Design Of Ash Discharge Door

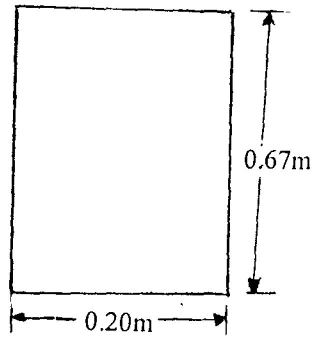


Fig.4.24 Ash discharge door

The dimensions are so chosen so as to allow for removal and replacing of the combustion grate and enough space for sweeping out ashes.

4.3.0 Design Of Hopper

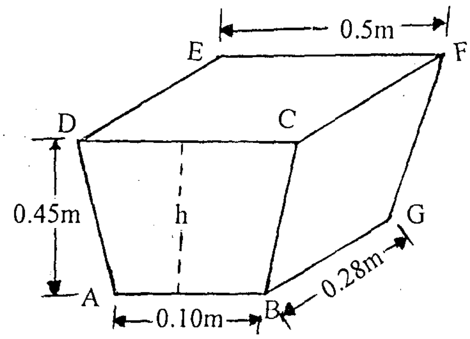


Fig. 4.25 Hopper

The design of hopper is motivated by the desire to keep the equipment running for 5 hours before reloading fuel.

The feed rate is 5kg/hour which occupies $0.0075m^3$.

25kg will be used up for 5 hours therefore the volume of the hopper will be $0.0075 \times 5 = 0.0375m^3$.

The area for the side A B C D is $0.0375/0.28 = 0.1339m^2$.

0.28m is chosen for side AG to allow feeding of the grate without waste or side drops.

Area A B C D is given as $\frac{1}{2}(AB + CD)\,h = 0.1339$

AB =0.10

h =0.45

$$CD = \frac{0.1339x2}{h} - AB$$

$$= \frac{0.1339x2}{0.45} - 0.10 = 0.49524m \cong 0.5m = 50cm$$

4.4.0 Design Of Fuel Conveyor

The design of the fuel conveyor is based on the desire to convey 5kg of fuel into the combustion chamber per hour. Therefore it is designed to convey about 0.0833kg of fuel per minute into the furnace. This is about 124.4607 cm^3/min.

4.4.1 Design Of Conveyor Pulley and Belt

The specifications on the belt design is as obtained in section 4. 1. 2.

Belt speed is $= \dfrac{\pi(0.075)4815}{60} = 1.8909m/s$

481.5 rpm is speed of the small sprocket which is equal to speed of fan shaft.

Speed ration $= \dfrac{481.5}{100} = 4.815$

100 rpm is the speed of conveyor pulley.

Maximum power in kilowatt of the belt is kw = 0.45

$$(1.8909)^{-0.09} - \frac{19.62}{85.5} - 0.765x10^{-4}(1.8909)^2 1.8909$$

= 0.36905 kw

The diameter of the larger pulley is determined as follow.

$$D = 80 \; x \; \frac{481.5}{100} x0.98 = 377.495mm$$

diameter ratio $= \dfrac{D}{d}$

$$= \frac{377.495}{80} = 4.7187$$

which is satisfactory.

The minimum center distance = 0.55 [377.495 + 80] + 8 =259.6239 mm maximum center distance

= 2 (377.495 + 80) = 914.99 mm

The actual center distance is dependent on other design arameters in the equipment as a whole.

.4.2 Design/Selection Of Sprocket And Chain

Because of economic reasons the design space of the conveyor s limited to the dimensions shown below:(fig.4.26).

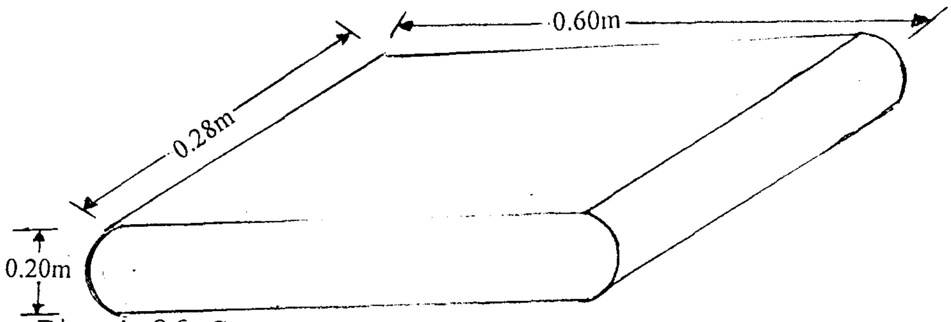


Fig.4.26 Conveyor

Therefore sprockets with inbuilt ball bearing were selected. The diameters are 0.10m each and they have 18 teeth each. ney run with 2 chains with pitch length of 0.013m.

Each has a total of 100 pitches which gives a center distance f 49.4cm = 0.494m.

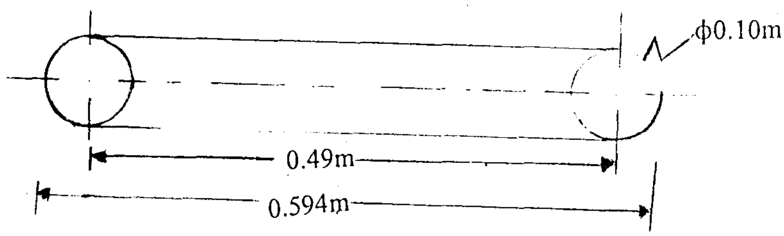


Fig.4.27 Conveyor Sprockets and Chains

The shaft diameter is based on the bore on the sprockets.

4.3 Design Of Conveyor Plates And Plates' Support

The plate dimensions are based on the pitch of the chain ince each pitch have one plate attached to it) and the width of e conveyor.

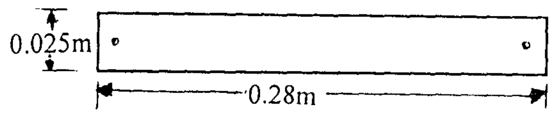


Fig.4.28 Conveyor Plate

The plates' support are triangular bars of length = 0.4m.

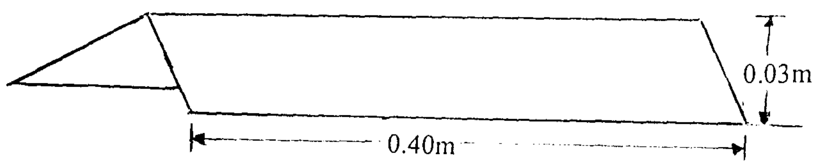


Fig. 4.29 Conveyor Frame

4.4.4 Design/Selection Of Conveyor Gears System

Fro controlled rate of feeding which is 5kg per hour, only one plate in the conveyor is allowed to carry fuel into the combustion chamber (This is achieved with the aid of the metering device described later in this section). It is desired that the chain pitch that carries this plate gets into the furnace at most once in a minute.

To achieve this a set of epicyclic gear system is used to reduce the speed of the conveyor to this desired speed. The system is made up of 2 pairs of gear with one paired with the conveyor sprocket.

The speed of the first gear is equal to the speed of the conveyor's pulley in section 4.4.1 which is 100 rpm, that is, it has same shaft as the pulley. It has 11 teeth and drives another gear with 69 teeth (selection is based on availability).

The speed of the larger gear is calculated as shown below.

Number of teeth of smaller gear (Z_1) = 11

Number of teeth of larger gear (Z_2)= 69

Speed of smaller gear (n_1) = 100 rpm

Speed of the larger gear (n_2) to be determined.

$n_1\ z_1 = n_2 z_2$ (Yisa, 1998)

$$n_2 = \frac{n_1 z_1}{z_2} = \frac{100x11}{69} = 15.942rpm$$

This speed is transmitted to the Conveyor as follows.

The Conveyor sprocket has 18 teeth and will carry the Chain through one revolution per minute if it revolves at $^{100}/_{18}$=5.556 r.p.m.(The chain has 100 pitches).

This is the maximum rpm required for this design.

To produce this speed, the number of teeth in the smaller gear to transmit the reduced speed of pulley to the conveyor sprocket is determined as follows.

$$Z_1\ \frac{n_2 z_2}{n_1}$$

Where n_1 n_2 are the speeds of the gear and sprocket respectively, while Z_1 and Z_2 are the number of teeth on the gear and the sprocket respectively.

n_1 = 15.942 rpm (same shaft with larger gear above)

n_2 = 5.556 rpm

z_2 = 18

$$Z_1 = \frac{5.556x18}{15.942}$$

$$= 6.27 = 6.$$

A gear with 5 teeth is selected since gears are found with odd number of teeth. This will produce sprocket speed as follows.

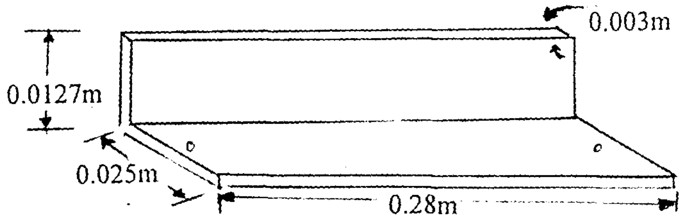
$$n_2 = \frac{n_1 z_1}{n_2} = \frac{5x15.941}{18} = 4.28rpm$$

This is acceptable since it is less than the maximum required (that is 5.556 rpm)

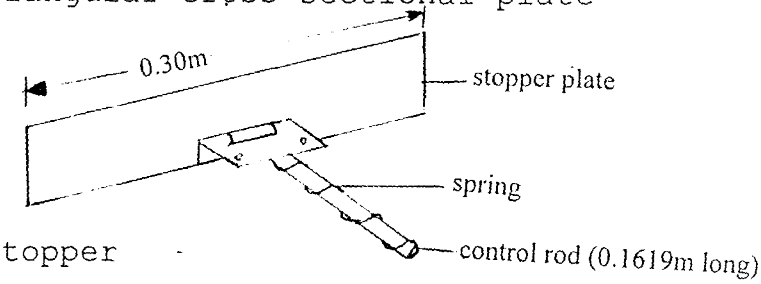
.4.5 **<u>Design Of Metering Device</u>**

The metering device is made up of the following components.

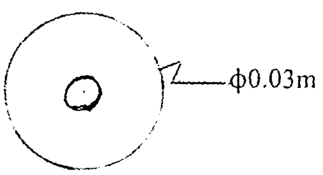
3) One plate from the conveyor has a triangular cross-section which helps to open the stopper(figs. 4.30, 4.31, 4.32 and 4.33).



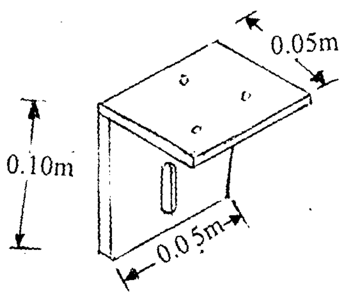
(1) Fig.4.30 Triangular cross-sectional plate



(2) Fig. 4.31 Stopper



(3) Fig.4.32 Washer



(4) Fig. 4.33 Hanger

It then empties its content into the furnace grate. The per is made up of the stopper plate hinged to the main frame he dryer at one side and at the other side a control rod is lso hinged to the plate. The rod has a spring into which it is nserted and is also handed or inserted into the hanger's bore. he washer is bolted to the roof or top cover of the furnace so hat the device operates to stop every other plate of the conveyor rom carrying coal into the furnace except the plate described bove.

The fifth part of the metering device though separated from thers is the calibrated stopper inserted under the fuel hopper ase. The calibration is supposed to be done alongside with xperimentation of the machine on completion. It would help to chieve different drying temperature ranges in the dryer. But ince the machine could not be completed, the calibration could ot be done. (fig. 4.34).

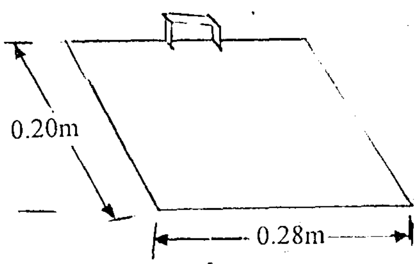


Fig. 4.34 Stopper

.5.0 Design of Drying Chamber

The design of the drying chamber was motivated by the desire o get a capacity that could dry at least 50 kg of grain at once. addy rice was used as a basis or point of reference for this esign. The capacity is about $0.19020m^3$ which will accommodate bout 62.7989 kg of paddy rice. (Bulk density of paddy rice is $20.37\ kg/m^3$) (Mohscnin, 1978).

The chamber has the following dimensions(fig. 4.35).

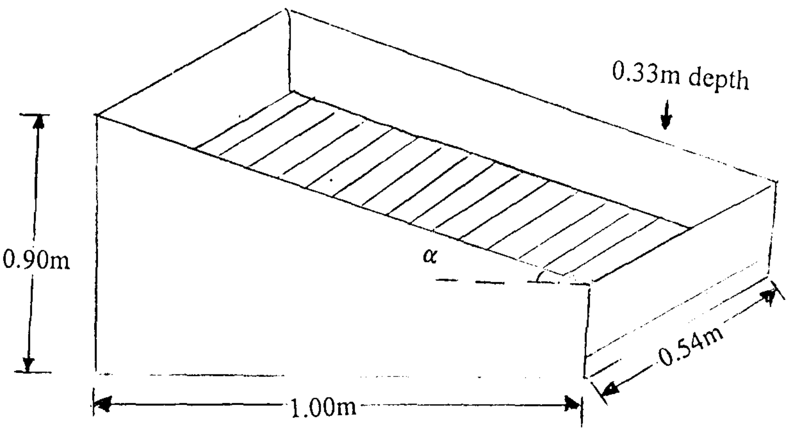


Fig. 4.35 Drying Chamber

∝ = 25°, so chosen to accommodate drying of grains with wide ange of angle of repose and to suit the dimensions of the ombustion chamber. The depth of the drying chamber was so chosen s recommended by Ian Carrutas, 1980 for air flow rate of about .7 to 1.0m^3S^{-1} at a temperature of about 43°c, that is 0.33m.

.5.1 Design Of Drying Plates

The drying chamber has 22 plates so arranged that they lie n each other giving a clearance of 0.02m to allow air from the urnace into the drying chamber.

The dimensions are as shown below:(fig. 4.36).

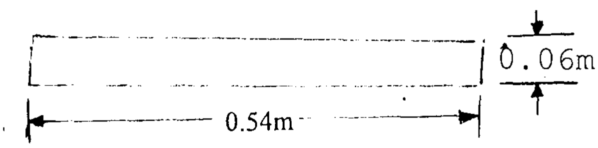


Fig.4.36 Drying plate

.5.2 Design Of Drying Plate Frames

The frames for the drying plates are three in number, one on ach side of the drying chamber wall and one in the center of the rying plate.

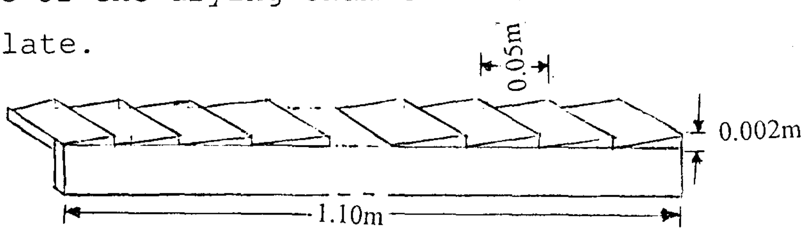


Fig. 4.37 Drying Plate Frame

.5.3 The Design Of Drying Chamber Casing/Wall Thickness

The drying chamber wall has the following dimensions(Fig. 4.38),

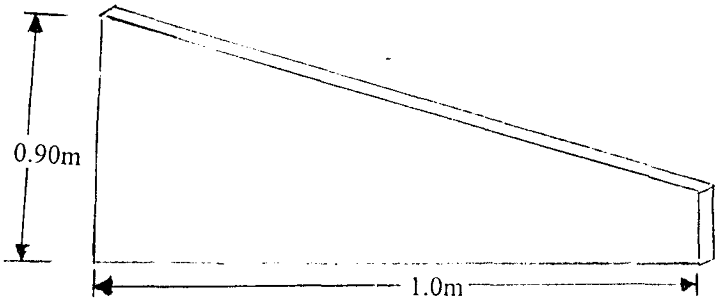


Fig. 4.38 Drying chamber casing

The thickness is as calculated in section 4.2.2.

.5.4 Design Of Material Discharge Door

The dimensions of the discharge door is in conformity with he dimensions of the width of the drying chamber(fig. 4.39).

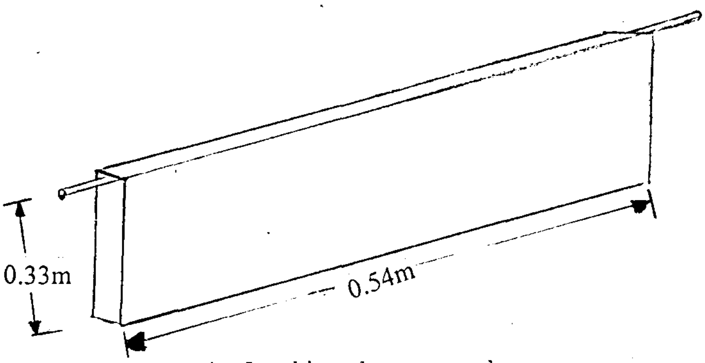


Fig.4.39 Material discharge door.

CHAPTER FIVE

5.0 TESTING OF THE SOLID FUEL FIRED DRYER

The testing of the solid fuel fired Dryer was supposed to be carried out on completion. This would have been done in order to verify the design claims, such as developing a dryer that runs on solid fuel (that is, coal) with a flue gas temperature of 43°c and could also achieve other temperature ranges depending on the quality desired to be preserved in the crop to be dried, just by making little adjustments in the metering device.

Unfortunately, the testing could not be done due to financial handicap which has impeded the completion of the development of the project.

5.1 EFFICIENCY OF THE DRYER

The efficiency of the dryer is supposed to be calculated based on the comparism of certain parameters in practical terms with the design calculated values. Such parameters as the calculated flue gas flow rate, its temperature and velocity, would have been compared with the values achieved practically in the dryer. But the inability to complete the development of the dryer could not allow these practical values to be obtained and so it was not possible to calculate the efficiency of the dryer.

CHAPTER SIX

6.0 COST ANALYSIS OF THE DRYER

In this chapter the cost analysis of the equipment is carried out. It is based on the present market value of the materials used for the development of the equipment since from conception the availability of materials was highly considered to ensure that all the materials used were available locally, though better quality of work could be achieved with precise machining of certain parts like the conveyor chain which is not achievable locally. Therefore the availability of the material for development of the equipment, cheap fuel, and the fact that it is an equipment that would meet one of the most important needs of our local farmers, have made the belief that it is quite economical acceptable.

The table below shows the costing of the materials at their present market value.

Part List Chart for Costing the Solid Fuel Fired Dryer.

Part No.	Description	Quantity	Unit Cost ₦ K	Total Cost ₦ K
1.	1.5mm thickness sheet metal (gauge 16)	2	2000.00	4000.00
2.	0.5mm thickness sheet metal (gauge 22)	2	750.00	1500.00
3.	Particle board	1	850.00	850.00
4.	Flat bar (3mm thickness)	2	130.00	260.00
5.	Angular bar (3.81cm wide)	3	750.00	2250.00
6.	2.54cm angular bar	1	550.00	550.00
7.	Fan Hub	1	50.00	50.00

Part No.	Description	Quantity	Unit Cost	Total Cost
8.	Bolt and Nut	300	5.00	1500.00
9.	Flat Bar (4mm Thickness)	½ length	300.00	150.00
10.	Blower Shaft	1	300.00	300.00
11.	Blower Shaft Bearing	2	200.00	400.00
12.	12cm Diameter Gear	1	200.00	200.00
13.	3 cm Diameter Gear	3	50.00	150.00
14.	Conveyor Shaft Bearing	4	150.00	600.00
15.	Conveyor Shaft (Rear)	1	50.00	50.00
16.	Conveyor Shaft (Front)	1	150.00	150.00
17.	Conveyor Sprocket	4	200.00	800.00
18.	Conveyor Bearing Housing	1	50.00	50.00
19.	Conveyor Shaft	1	50.00	59.00
20.	Conveyor Chain	2	200.00	400.00
21.	Hinges	5	10.00	50.00
22.	0.635 cm Thickness Metal Rod	1	150.00	150.00
23.	1.27 cm Thickness Metal Rod	1	200.00	200.00
24.	Grate Net	1	1000.00	1000.00
25.	Bolters	3	20.00	60.00
26.	Spring	2	25.00	50.00
27.	Rivet Pin	150	20.50	375.00
28.	Washer	300	20.50	750.00
29.	Binding Wire	2	500.00	40.00
30.	Electrodes	2 packs	150.00	1000.00
31.	Rectangular Pipe	1	120.00	120.00
32.	8cm Diameter Pulley	1	80.00	80.00
33.	8cm Diameter pulley with Inbuilt Bearing	1	150.00	150.00
34.	Pulley Belts	2	150.00	300.00
				18585.00

MACHINING COST

Part No.	Description	Quantity	Unit Price	Total Cost
	Cutting of Plate	72	20.00	1440.00
	Turning of Shaft	1	150.00	150.00
	Cutting of Gear	2	200.00	400.00
				1990.00

Total material and Machining Cost = 18585 + 1990.00 = ₦20575.00

Labour Cost = 30% of total cost

= 0.3 x 20575

=₦6172.50

Total cost of the dryer

= 20575 + 61747.50.

= ₦26747.50

The actual amount spent to bring the machine to the resent stage of completion it about ₦14500 and would need about ₦3000 to bring it to final completion. The reduction in cost is due to the fact that many of the parts used were craps.

Economic Analysis of the Dryer. In analysing any investment economically, the true worth of the investment is regarded as how much income it will generate and how soon after the original capital outlay (Chukwu, 1987).

Therefore it is desirable that an investment generates large share of total income in the early years of it's life. For the Solid Fuel Fired Dryer the income is viewed as saving, accruing from, (1) choosing coal a solid fuel as a source of energy instead of other conventional energy sources, (2) the opportunity offered farmers to produce crops at the time when maximum yield is possible without considering the problem associated with weather conditions at time of harvest.

To completely analyse the dryer economically therefore, data are to be collected for at least a period of one year to know what savings could be made using this type of dryer or any other type in a farm for wide variety of crops grown within the period of maximum production (agronomical period). Moreover, the efficiency of the dryer is a major factor especially when calculating the pay back period.

Therefore within the limit of time, and the stage of completion of this project, a full economic analysis could not be made.

CHAPTER SEVEN

7.0 CONCLUSION AND RECOMMENDATIONS

7.1 CONCLUSION

With only bolting of a few parts left, the design and development of a solid fuel fired dryer has been made. As could be seen in this report, it involved;

1. The study of coal as a source of energy.
2. The design of a blower with a predetermined capacity.
3. The design of a furnace
4. The design of a fuel hopper
5. The design of fuel conveyor
6. The design of drying chamber.

The dryer has a capacity of $0.190202m^3$per batch and runs on coal at a feed rate of 5kg coal/hr and flue gas temperature of 43°c. A blower with 0.506m wheel diameter and air flow rate of $42.2873m^3$/min supplies the combustion and drying air through the furnace into the drying chamber. A Continuous conveyor conveys coal from the hopper into the furnace where combustion takes place in the grate inside the furnace. The dryer when completed should be able to solve the problem associated with drying during raining period and also provide a boost in re-emphasizing the potentials of coal as a good replacement for petroleum as a source of energy for operating most farm equipment. Therefore it could be said that with this dryer adopted, a good step would have been taken in making this country self-sufficient in food production and also a good means of utilizing our coal reserve.

7.2 Recommendations

This same project could be improved upon to burn coal at different rates and so achieve different temperature ranges, making it adaptable to any condition of drying desired.

The conveyor could be improved upon to allow adjustment and so could use other solid like palm kernel husk, rice husk and sawdust.

Other materials such as clay could be used as the insulation material for the furnace and drying chamber walls especially when drying at high temperature is required to prevent pyrolysis.

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Table 9. Capacity Table of Radial-blade
No. 600 Type E Fan with HE Wheel
(Courtesy of American Blower Corp., Detroit, M

Outlet Velocity	1 in. SP Rpm	1 in. SP Bhp	2 in. SP Rpm	2 in. SP Bhp	3 in. SP Rpm	3 in. SP Bhp	4 in. SP Rpm	4 in. SP Bhp	6 in. SP Rpm	6 in. SP Bhp	SP Bhp	10 in. SP Rpm	10 in. SP Bhp	14 in. SP Rpm	14 in. SP Bhp
1000	331	0.75	457	1.52	550	2.27									
1200	341	0.91	463	1.80	555	2.67	634	3.60							
1400	356	1.10	470	2.06	562	2.95	642	4.24	772						
1600	373	1.36	481	2.43	566	3.49	647	4.75	780		9.85				
1800	389	1.64	492	2.78	579	4.02	661	5.50	787		10.68	1002	14.04		
2000	407	1.94	504	3.16	589	4.49	668	5.90	793		11.96	1010	15.23	1189	21.39
2200	423	2.27	522	3.67	602	5.10	674	6.58	801		13.22	1013	16.61	1196	23.47
2400	442	2.69	540	4.19	617	5.71	683	7.27	811	1[illegible]	14.33	1019	18.04	1198	25.39
2600	451	3.16	556	4.77	631	6.34	700	8.10	818	1[illegible]	15.35	1024	19.77	1202	27.17
2800	430	3.67	573	5.36	649	7.14	712	7.70	831	1[illegible]	16.57	1035	20.80	1205	29.13
3000	500	4.26	591	6.08	662	7.86	729	9.83	842	13[illegible]	17.74	1044	22.28	1211	31.15
3200	519	4.91	607	6.81	680	8.80	746	10.88	855	14[illegible]	19.16	1053	23.84	1216	32.97
3400	538	5.62	626	7.65	698	9.69	765	12.03	870	16[illegible]	20.59	1061	25.30	1227	34.10
3600	558	6.22	644	8.47	714	10.72	778	13.03	886	17.[illegible]	22.16	1072	26.91	1233	37.18
3800	577	7.23	663	9.52	732	11.79	795	14.16	904	19.[illegible]	23.54	1086	28.88	1243	39.22
4000	599	8.19	685	10.65	749	13.01	812	15.51	922	20.[illegible]	25.60	1099	30.91	1251	41.70
4200	621	9.24	701	11.79	768	14.27	836	17.20	935	22.[illegible]	27.24	1112	32.76	1261	44.25
4400	641	10.37	721	13.06	788	15.68	850	18.28	952	23.[illegible]	29.25	1125	34.63	1271	46.43
4600	663	11.63	741	14.41	807	17.06	864	19.66	969	25.[illegible]	31.38	1145	37.44		
4800	685	12.99	760	15.94	825	18.72	883	21.55	958	27.[illegible]	33.51	1158	39.66		
5000	707	14.46	791	18.21	844	23.24	901	23.40	1003	29.[illegible]	35.52	1172	42.45		
5200									1021	31.[illegible]	38.28	1192	44.79		
5400									1041	33.[illegible]	40.51	1205	47.50		
5600									1056	35.9[illegible]	43.08	1222	49.73		
5800									1075	38.4[illegible]	45.61	1243	53.24		
6000									1095	41.2[illegible]	48.67	1258	55.93		
6200									1113	44.0[illegible]	51.48	1275	59.41		
6400									1132	46.8[illegible]	55.34				
6600									1152	50.0[illegible]	57.80				

...2 8¼ in. x 20 7/16 in. outside. Area 3.295 sq ft or 474 sq in. ...ensions see Table 10.

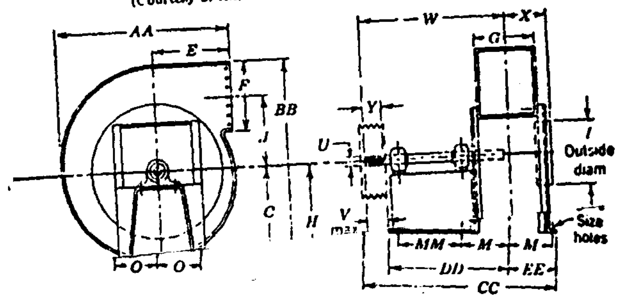
Standard wheel { 41 3/4 in. diameter. 10.93 ft circumference.

5 3/16 in. diameter outside. ...rea 3.319 sq ft or 478 sq in.

Table 10. Dimensions of Radial-blade Fans

Type E Fans with HE Wheels

(Courtesy of American Blower Corp., Detroit, Mich.)



Arrangement 1-B consists of housing, overhung fan wheel, two bearings located on drive side, and the running gear support is a tapered box type pedestal with straight top. The shaft is extended beyond the outer bearing and key-seated to overhang the sheave or pulley.

This is the most popular arrangement as it permits the application and removal of belts without dismantling the bearings and shaft.

Pulley or sheave shown in the above diagram is for illustration purposes only and is not included as regular equipment.

Fan Size	C	E	F	G	H	I	J	M	N	Keyway, HE Wheel	U, HE Wheel
250	12 7/16	12	9 7/8	8 9/16	17	10 1/2	10 3/16	7 5/8	6 7/16	3/8 × 3/16	1 7/16
300	15 11/16	14 1/2	12 7/16	10 3/4	21	13 3/16	12 3/4	8 11/16	7 7/8	3/8 × 3/16	1 11/16
350	17 1/2	16	13 7/8	11 15/16	23	14 5/8	14 5/16	9 5/16	8 7/8	1/2 × 1/4	1 15/16
400	19 3/4	18	15 5/8	13 1/2	26	16 1/2	16 3/16	10 1/16	9 5/8	1/2 × 1/4	1 15/16
450	22 3/16	20	17 1/2	15 1/8	29	18 1/2	18 3/16	11 1/8	10 7/8	1/2 × 1/4	2 3/16
500	24 15/16	22 1/2	19 11/16	16 15/16	32 1/2	20 3/4	20 1/2	12 1/8	12 1/8	5/8 × 5/16	2 7/16
550	27 3/8	24 1/2	21 5/8	18 5/8	35 1/2	22 13/16	22 1/2	12 15/16	13 5/8	5/8 × 5/16	2 7/16
600	30 1/8	27	23 3/4	20 7/16	38 1/2	25 3/16	24 3/4	13 7/8	14 5/8	5/8 × 5/16	2 11/16
700	33 3/16	30	26 1/4	22 5/8	42 1/2	27 11/16	27 1/4	16 3/16	16 1/2	5/8 × 5/16	2 11/16
750	36 9/16	33	28 7/8	24 7/8	47	30 3/8	30	17 5/16	19 1/4	3/4 × 3/8	2 15/16
800	40 3/16	36	31 11/16	27 5/16	51 1/2	33 3/8	33	19 9/16	19 7/8	7/8 × 7/16	3 7/16
900	44 5/16	40	34 7/8	30 1/16	56 1/2	36 3/4	36 3/8	20 15/16	21 3/4	7/8 × 7/16	3 7/16

Fan Size	O	T	W	X	AA	BB	CC	DD	EE	MM	Dimension V, HE Wheel* SAO	Dimension V, HE Wheel* D	Y
250	7 1/16	5/8	27 1/2	8 1/16	25 3/4	32 1/8	36	21 3/4	8 1/2	13 1/4	5 1/4	4	4
300	8 1/2	5/8	30 11/16	9 1/16	31 7/8	40	40 1/4	23 13/16	9 9/16	14 1/4	6 3/8	4 1/2	4 1/2
350	9 3/4	5/8	33 5/16	9 13/16	35 5/8	44 1/4	43 1/2	25 15/16	10 3/16	15 3/4	6 3/16	5	5
400	10 1/2	5/8	37 1/16	10 9/16	39 7/8	50	48	29 3/16	10 15/16	18 1/4	6 11/16	5 1/2	5 1/2
450	12	3/4	30 3/4	11 5/16	44 9/16	55 15/16	53	32 1/8	12 1/4	20	8 1/8	6	6
500	13 1/4	3/4	45 5/8	12 3/16	50 1/8	62 13/16	58 7/8	36 1/8	13 1/4	23	9	6 1/2	6 1/2
550	14 3/4	3/4	48 15/16	12 15/16	54 13/16	68 13/16	63	38 15/16	14 1/16	25	9 1/2	7	7
600	15 3/4	3/4	53 7/8	13 15/16	60 3/8	75 1/8	68 7/8	42 7/8	15	28	9 5/16	7 1/2	7 1/2
700	18	7/8	56	15 11/16	66 3/4	82 7/8	73 3/4	45 11/16	17 11/16	27 1/8	9 7/8	7 13/16	8
750	20 3/4	7/8	57 1/4	16 15/16	73 1/2	91 7/16	76	46 13/16	18 13/16	27 1/8	9 1/2	8 7/16	8
800	21 3/8	7/8	63	18 9/16	80 1/2	100 5/16	84	50 9/16	21 1/16	28 5/8	11 1/2	9 7/16	9
900	23 1/4	7/8	67 1/4	19 13/16	89	110 5/16	89 5/8	53 15/16	22 7/16	30 5/8	12 3/8	10 5/16	10

* SAO = ball bearings; D = sleeve bearings.