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What's Inside

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Pulverized Coal Fiered Re-heating Furnace Design and Concept

Kamal Aggarwal
Hon. Sec. General, AIIFA

The hot working of steel requires heating/re-heating the steel to give a shape without any damage to the internal structure of steel. Basically, the heating/re-heating operation is intended to raise the temperature of raw material from room temperature to working temperature (1050^{0}C to 1200^{0}C).

A re-heating furnace is an instrument where chemical energy of fuel (Solid, Liquid or gas) is converted into heat energy to heat the steel to increase its plasticity to make it convenient for shaping it in desired shape.

The major issues in billet/ingot/scrap heating are the production rate, (which exactly coincided with the mill rate), minimum scale loss and high furnace life and energy conservation. All these factors have direct relation with the selection of type of furnace (single zone/multizone, top firing/side firing) and selection and installation of fuel and combustion system. It is observed that proper selection of combustion system is normally ignored either due to non-availability or due to improper information.

Basic Element of a Furnace

Heating chamber: It is an enclosed area to contain the material and retain the heat.

a) **Hearth:** It is the moving or stationary support on which charge (raw material) moves.

b) **Roof:** The main function of roof is to contain the flame and helps in heat transfer to charge (raw material) by means of radiation.

c) **Wall:** To complete the encloser and retain the heat in-side the encloser, side walls are required.,

d) **Doors:** To view the stock as well as move the stock due to pile-up or any other obstruction during moving of stock.

- **Facilities for Development of Heat:** The combustion of fuel is usually employed to develop the required furnace temperature. Here we are talking on designing of Pulverized Fuel Fired Furnaces, hence we shall be restricted to that only. In this case following systems shall be required:

  - **Pulverizer:** To pulverize the coal to desired level of fineness.
  - **Coal Transportation:** Installation of coal transportation system- screw feeder with blower to transport the coal to furnace through burner or designing the system in such a way that the powdered coal could be easily fed to the furnace.
  - **Properly Sized Blower:** Proper size of blower should be selected which could transport the desired amount of coal at desired pressure and velocity in case transportation is required and also to full fill the combustion criteria of fuel by producing proper turbulence.
  - **Properly Designed Burner:** Proper air fuel turbulence can be given and a properly shaped (length and diameter) flame could be generated.

    - **Means for Distribution of Heat and Removal of Gases:** Flue duct and Chimney plays an important role of creating draft which ultimately facilitate the movement of gases from one end to other end.
    - **Air Pollution Control Device:** When coal as fuel is used the removal of ash particulate as well as unburned carbon if any, is most important to prevent the environment as social cause as well as it is legal regulation also.

Design Consideration for Continuous Pusher type Re-heating Furnace:

The design of furnace depends on many parameters:

- Required Tonnage per hr. (Production rate and hearth loading), (Single zone/multizone)
- Raw Material Type, Size and Chemical Composition. In case of multi size Raw Material use, %age of use of different Raw material for different products & product type
- Type of Fuel and Combustion Equipment's
- Type of Auxiliary Equipment's
- Heat Recovery System
- Draft requirement and Chimney Size (Height and Diameter)
- Refractory and Insulation etc.

Furnace Size and Capacity:

The first step in designing a continuous pusher type furnace is to decide and freeze the size of furnace, i.e., length (effective length) and width of furnace (effective width) as per production requirement. On conceptual basis furnace is divided into three zones, viz. Preheating, Heating and Soaking. However, based on the number of combustion zone furnace is again divided into single zone or multi zone (may be top fired. Side fired or bottom fired). The decision of single/multi zone furnace is based on production rate as well as size of raw material also.

The first thing is to decide the length of the RHF. It is generally decided on required tonnage/hr based on the size of raw material and its heating time (0-1200°C).

Helweg gave an equation for calculating the character of the soaking at the discharge end of furnace. The minimum specific value for heating time, or alternatively for corresponding length of hearth required is given by the equation given below:

$$t \geq \frac{18\, l^2}{D} \qquad \text{or} \qquad ?L = 0.3\,\frac{l^2}{D}\,V$$

Where;

t = Heating time in furnace, minutes,

l = Vertical thickness of material of the charge,

D = diffusivity of the charge, square meters per hour, some time it is called "temperature conductivity" equals

$$\frac{\text{Thermal conductivity } ((\text{Kcal per } (m3,hr,0C)}{\text{Specific heat } (\text{Kcal}/kg0C) \text{ x Density } (kg/m3/ft)}$$

?L = corresponding length of furnace, meter,
V = Velocity of charge over the hearth, meter per hour,

The degree of soaking, defined as temperature gradient within the mass of charge, ?Φ is related to the rate of temperature increase on surface of charge, ?Φ[1] is given by the equation,

$$?\Phi = \frac{l^2}{2D}\,.\,\Delta\Phi 1$$

As **thumb rule mild steel** requires (in general 100 mm x 100 mm billet as standard) 30-35 minutes per sq. inch for billet (gas and oil-fired furnace) and ***40-45 minutes per sq. inch (for pulverized coal furnace based on calorific value of coal).*** However, in case of alloy steel it takes 45-50 minutes per sq. inch for 100 mm x 100 mm billet for gas or oil-fired furnace, however we don't recommend pulverized coal in this case due to quality reasons. As discussed above, a 100 mm x 100mm ingot/billet shall take approximately 160 minutes to 180 minutes depending on quality and calorific value of coal to reach a temperature for ambient 25°C to 1200°C and shall utilizes 180 Kcal/kg theoretically. The typical hearth loading in different type of furnaces are given below**:**

Type of Furnace	Kg/m3/hr
Heat Treatment Furnace	150 – 200
Annealing Furnace	195 – 293
Forging Furnace	290 – 390
Continuous Reheat Furnace	190 – 490

Typical Hearth Loading Rates (in good operating practices)

The size and productivity of pusher type furnaces are again limited by the fact that not more than 200 to 250 number of billets can be pushed easily through a furnace due to piling up phenomenon. These drawbacks of limitation have given a serious thought for having high productivity rates. Another dimension of thought appeared for new concept for increasing the productivity by increasing the width of furnace to increase the hearth load area. The concept of increasing the width as per billet or ingot size also increases the %age hearth utilization.

Since the active/effective length of the furnace in pusher type furnaces are the number of billets/ingots occupied in the furnaces placed in between distance of half of the side door discharging door to half of the flue duct area in more or less all cases, the productivity depends on geometrical dimensions of billets/ingots.

The dimension of the working space of Pusher type Reheating Furnaces are determined on the basis of furnace productivity, the dimension of billets, and heating time. Let "P" be the given productivity and "t", the heating time (hrs). To provide the productivity, the mass of metal charged into furnace must be

Mass of metal to be charged in furnace "G" = P t

For given dimensions of a billet (width "a", thickness "b", and length "l", meters), we can find out the mass of a billet" g" and number "n" of billets the furnace should accommodate:

Number of billet "n" = G/g

With "n" < 200, furnaces are usually of the one row type, for which:

Length of furnace "L" = a x n meter,

For two row furnace length "L" = $\frac{an}{2}$ meters

In case n/2 is < 200, furnace shall be of the three row one, The**final length** of furnace shall be "L" in case of end discharge and "L" + approximately 1.5 meter in case of side discharge.

The width of a furnace is determined as the length of a billet plus the gap left between the billet ends and inside furnace wall or between two billets. Hence the effective width of a billet is usually width of billet + 0.25 meter.

Width of furnace one row furnace "B" = 2l +2 x 0.25 meter, and Width of furnace two row furnace "B" = 2l +3x 0.25 meter etc.

The productivity of a continuous pusher type furnace can be increased by increasing hearth loading in three ways:

1. Increasing the hearth area (length x width)
2. Increasing the weight of pieces by increasing cross section area of billets/ingots
3. Increasing the thermal heat load, it means increasing the number of burners and number of combustion zones.

We should also know that each of the above is having its own limitation also for example.

a) For increasing the hearth area in case length cannot be increased more than 100' to 120' due to piling up phenomenon for 100 mm x 100 mm billets/ingots. In case of width, it shall depend on length of the pieces, a single piece can be taken as long as 10 to 12 meters however 7 to 8 pieces of size of 0.35 meters could only be put up due to operating limitation of furnaces or length has to cut after heating and passing with roughing stands in required number of pieces.

b) For increasing the cross-section area i.e., mainly increasing the thickness of Raw material it is always recommended that in case the thickness is around 150mm or above one should think of top – bottom firing for reducing the scale losses which generally increases in case of top firing only.

c) For increasing the no. of zone i.e., two zones to three zones or side firing the flame size viz length and width and the flame of the combustion zone plays very important role, even in single zone furnace the volume plays very important role.

Once the **length and width of the furnace is freezed as per size, type and composition of the furnace for a desired productivity (i.e., tonnage/hr), thenext step is zoning of the furnace as per type of fuel and selection of combustion equipment.**

In a good **Pulverized Coal Fired Re-heating Furnace** the hearth loading and heat utilization is shown in figure given below.

Production Rate	Million Calorie			
	10 T/hr	5 T/hr	3T/hr	1T/hr
Heat to Stock	1760	880	530	176
Waste Gas Loss	2520	1760	1510	1290
Structure Loss	1760	1760	1760	1760
Heat Loss Input	6040	4400	3800	3226
Specific Heat Consumption	604	880	1267	3226

Effect of Furnace Loading on continuous furnace performance

Now the first thing is to select the type of coal and its composition and accordingly the equipment for grinding the coal. Mainly three types of coal are of important in pulverized coal firing system as per ranking:

1. Anthracite, 2. Bituminous and 3. Sub bituminous

Knowing the cola analysis (proximate analysis) for knowing the %age of moisture (internal and surface), volatile mater (gases + tar (hydro-carbon) %age of calorific value helps in designing the combustion chamber of the furnace.

The velocity of propagation of flames, approximate relationship between air/fuel ratio, coal volatile matter inflammability limits and flame speed are few parameters which play very important role for designing the chamber. A relationship of the above is given below:

V M of coal %	Inflammability limit lb air/lb coal		Max. flame speed ft/s	Air/Fuel ratio at max. speed lb air/ lb coal
	Upper	Lower		
15	1.8	2.7	13	2.3
20	1.7	7.0	23	3.8
30	1.5	14.0	43	4.5

Note: it is at 5% ash, more ash means decrease in flame speed and inflammability limits.

For better grindability not more than 3% free H2 water is recommended. As per volatile matter and ash is concerned, low ash and around 20-25% VM is good for pulverized coal firing system.

As per fineness of the coal/size of coal is concerned in pulverized coal firing system for reheating furnace design, it requires more fineness. Finer particle will require less time for combustion (a three-stage reaction viz. vaporization or heating of particle to release of moisture + volatile matter, drying of coke and finally combustion). The requirement of fineness is given below;

Type of Coal	%age to pass
Bituminous & Sub bituminous coal	65 to 75% should pass through 200 mesh size sieve
Anthracite coal	75-85% should pass through 300 mesh size sieve

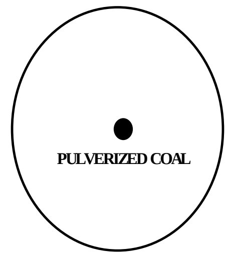
It should be noted that it is more difficult to grinded the coal having high ash content and anthracite coal. However, only bituminous and sub bituminous coal is recommended in pulverized coal firing furnaces, in case anthracite is required to be burned, only, higher volatile matter anthracite is recommended for pulverized coal firing system.

The experiments have shown that combustion of coal taken fraction of seconds around 0.4 to 0.5 second for a size of 0.0025 inches. As discussed earlier the sizing of the chamber should be calculated as per the velocity of air and residence time of coal particle (which is put into the furnace) to size appropriate combustion chamber. As thumb rule one can take 50 to 60 Kcal/ft3/s heat release for combustion volume. It can increase in case ash and volatile matter is high. As discussed earlier the combustion of coal powder taken place in three steps (viz. heating of water + VM burning of VM and finally burning of coke left after removal of water and VM). One should also keep it in mind while designing furnace chamber that one volume of coke needs approximately 14000 volumes of air under atmospheric condition; in consequence each particle of coke needs an air volume of 24 times of its own diameter. For furnace conditions, grows to about 35 times as illustrated in figure above.

The amount of air required for combustion of coal is generally calculated based on elemental constituents of coal (% carbon, % Hydrogen, % Sulphur and % Oxygen). For a coal having composition as 84 % carbon, 11 % Hydrogen, 3.5 % Sulphur and 4.0 %Oxygen shall require 10.4 m3 air per Kg of coal theoretically. However, for practical burning of coal requires extra air. This extra air depends to be 25 to 35 % in pulverized coal fired furnaces depending on furnace configuration and operating practices.

One has to size the different zones i.e., preheating heating and soaking zone as per the required thermal load in the furnaces. In general, 30-35% against 65-70% in taken in two zone furnaces. However, 30-35% in each zone taken in case of three zone furnace.

It is important to mention here that the type of flame and turbulence is determined by the content of volatile matter.



AIR TO FUEL VOLUME RELATION OF A COAL PARTICLE

Type of Coal	Flame Shape
High VM coal	Short and self-induced turbulence
Medium VM coal	Short and externally induced turbulences
Low volatile coal =+ Anthracite	Long or U type flame

Note : In RHF low volatile, anthracites coal can be burned reasonably.

It should be noted that short flame requires turbulent flow while long flame requires parallel (stream line) flow.

The thermal and temperature condition of pusher type continuous furnaces are time invariable. However, the temperature can vary substantially along the length of furnace, its variation determining the number and purpose of furnace zones. The RM (metal) is charged into a zone having lowest temperature and when moving in the direction of opposite to that of waste gases, is gradually heating.

Design of chamber must obtain correct coal/air ratio, velocity, as per the size of particle and heat load distribution. The design of zones details the thermal mapping of furnace. The rate of flame propagation in powdered coal air mixture is shown in figure. The volume and sizing of zones much depend on it.

The preheating zone the first in the path of metal has a temperature which varies along its length. In this zone the metal is gradually heated before entering to the high temperature zone i.e. heating zone. Most of the cases to avoid excessive thermal stress material is heated up to 550oC.

As most of furnaces (pulverized coal fired) arc of two zone, top fired in nature (productivity in the range of 8 MT/hr to 15 MT/hr), the temperature of gases in the high temperature zone (where combustion is taking place) is usually maintained at a level of 1250 to 1350oC, but it drops to (650oC to 850oC at the end of the preheating zone. A preheating zone increases substantially the coefficient of fuel utilization.

The high temperature zone (heating/welding zone) is the second zone in the path of material heating. Here in principle the surface of metal is heated quickly to the final temperature (1150oC to 1250oC)

The soaking or holding zone is the third in the path of metal and it serves two purpose heating as well as temperature equalization. In single zone it acts heating + soaking, however in two zones it should be utilized as temperature equalization.

The **height of the furnace** is decided generally by combustion volume and shape and size of furnace. The rate of heat input or fuel charging rate shall be as per production rate. Hence once the amount of fuel rate is calculated as per desired rate of heat input or temperature increase the required amount of air could be calculated and hence one can calculate the combustion volumerequired. In general, the heating volume requirement varies from type, size of raw material and number of combustion zones. As thumb rule a single zone furnace requires about **50 to 60 Btu per ft3 per second, however it can go up-to 100 Btu per ft3 per second.**

Different type and grade of steel require different temperature of rolling. The table given below indicates the same.

Types of Steel	Temperature o C
Carbon and Low alloy steels (up to 0.45% C)	1200 – 1220
Carbon low and medium alloy steel (up to 0.65% C)	1180 – 1200
Carbon & medium alloy steel (up to 0.9% C)	1140 – 1160
Carbon & alloy steel tool and bearing (up to 1% C)	1120 – 1140
Carbon & alloy steel tool and high manganese (up to 1.3% C)	1100 – 1120
Nirchrome and Stainless Steel	1180 – 1220
High speed steel	1180 - 1200

A particular design of continuous furnace is selected according to type of rolling mill and kind of fuel. The type of rolling mill generally determines the productivity of furnace, the thickness of billet to be rolled, the temperature of metal heating, the grade of metal. As discussed earlier the length and width and number of zones of furnace decide the productivity. As discussed, the type of fuel determines the design of burner and use of recuperators. The designed capacity of furnace shall meet the rolling mill capacity.

The approximate data for selection of continuous furnace and heating methods are given in table below:

		Cross section (mm)	*Ingot/Billet Length	Heating Method	Zones Characteristics				No of Row
					No. of Zones	Soaking zone	Heating Zone	Pre-heating Zone	
Small mill	2-4	Scrap based, 16 mm to above thickness 100 x 100	1000 - 1500	One way	Single	Front	----- -----	-----	Single/ Multi row
Small Mill	5-6	100 x 100 or 110 x 110	1000-1500	One way	Single	Front	-----	-----	Single
Medium	7-8	100 x 100 or 110 x 110	1500-2000	One way	Single/ Two	Front	Top/Side	-----	Single/ Multi row
Medium	10-12	100 x 100 or 110 x 110 or 125 x 125	1500-3000	One way	Single/ Two	Front	Top/Side	-----	Single/ Multi row
Large	15-20	110 x 110 or 125 x 125 or 150 x 150	1500-3000	Two way	Three	Front	Top/Side/Bottom	Top/Side	Single/ Multi row
Large	Above 20	150 x 150 or 200 x 200 or above	1000-3000 or above	Two	Three/ Four	Front	Top/Side/Bottom	Top/Side	Single/ Multi row

✼ In case of small mills these can be as short as 300 mm length piece.

It should be noted here that in case of Pulverized coal firing furnace there is heating capacity limitation. Energy efficient furnaces with minimum scale loss could have maximum capacity of 15 MT/hr. However, in case of more tonnage productivity, one has to use mixed firing system (Coal + Oil or Coal + Gas). Also, bottom firing in pulverized coal furnaces are next to impossible. In case of side firing, it is also not recommended in furnaces having width less than 5-6 meter as the chances of flame impingement on walls.

- **During calculation of numbers of burners as per required thermal load in different zones, one should keep in mind that the two burners flame should not impingent on each other**

Burner for Pulverized Coal Firing system:

During selection or designing of burner, designer should keep in mind that powder coal will not burn in open air, whereas well atomized oil, with some difficulty and gaseous fuels, rapidly, do so. Accordingly, the flame should be surrounded by brick work at its root. The successful design of burner with and without hot air should always be as simple as possible. The action of powdered coal on brickwork in furnace varies greatly with amount and composition of **Ash** and **furnace temperature**. Special attention must be given **during selection of refractory materials and design of flue off take and waste gas duct.** Ready accessibility for cleaning is must.

The **powdered coal flame is generally one of high calorific intensity,** and therefore in general, suitable safeguards against overheating of raw material should be taken during selection of combustion system (burner and blower). Required velocities should be maintained during re-heating furnace operation where constrains are there. Flame intensities and flame length can be varied with powder coal in very much the same manner as with oil and gas.

Strength and Durability of the Furnace:

The methods and materials used in furnace construction have an important bearing on fuel efficiency. The design of the structural frame work of the furnace is based on the well-known principle of mechanical construction. A special point in its bearing on fuel efficiency is that robustness is essential, since repeated cooling and heating structural membranes together with the concomitant expansion and construction of refractory material used can, in course of time, induce a remarkable degree of distortion of frame work.

Foundation design should take care of overheating. In case non-ventilated hearth sufficient brickwork should be made with proper insulation to overcome the problem of overheating. However it is not good practice to provide excessive brick work. There must be correct combination of suitable refractories and thermal insulation material to give mechanical stability. In highly productive furnaces the hearth should be strong and proper ventilation or brick work should be made so that the reinforced concrete cracking should not occur. The hearth should be mechanically supported and air-cooled from below. Limiting thickness are D/6 for furnaces, D is the shortest dimension of the hearth in feet.

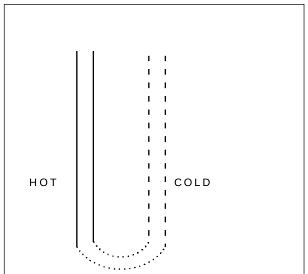
Adequate insulation **of hearth in** modern practices is a must. Also, now a days material capable of withstanding the heaviest hearth loads are available. Another most important is thing is fixation of rails or water-cooled skids. Proper care must be taken so that material should skid without damaging the hearth and minimum water cool mark development.

Providing the abutment of the **arch, or skewback**, should be adequately supported by a strong frame work with tie rods, the arch must rise on heating. During selection of refractory, one should know the expansion characteristics of the refractory to be used and also the operating temperature of the furnace roof. A furnace width 15 feet or more should not be spanned by single arch. However, it should be suspended in nature. Roof 9" thick are generally insulated with advantage, except in special cases over combustion chambers where the temperature in roof construction attention should be devoted to choose of brick shape to give uniform stress and reasonable gas tightness to overcome leakage of hot gases.

The **side walls** in heat treatment furnaces and re-heating furnaces does not have much bear to say. However, side wall forms support for the roof, so its correct construction is of importance in relation both to the thrust of the roof and of the hearth. In long furnaces vertical expansion joints for horizontal expansion are often provided. The joints are filled with cardboard or wooden strips when furnace is being erected.

Buckling tendency of furnace wall of larger extent is restricted by binding; it stands to reason that thickness of bonded portion should grow with extent of unsupported wall.

Furnace doors should be tight, light durable and heat proof. There are many types of doors available, hinges type, swing type lifting type etc. Opening in side wall generally causes inefficiency, particularly in re-heating furnaces. Bad fitted doors at discharging side having a gap of 1" wide and about 24" long along its top edge will give heat loss approximately to the tune of 50,000 kcal per hour due to escaping of hot gases.



COLUMN OF HOT & COLD AIR

The most important is the binding material for side wall, roof etc. It is seen that fireclay mortars are generally employed; it is not appreciated. Mortars are of two types, i) hot settling mortars and ii) Air settling mortars. Hot settling mortars do not acquire the property of bonding until a certain temperature has been reached. Air settling mortars are preferred.

A **well-designed recuperator** should be used to recupe the energy from flue gases to put again in furnace for energy conservation. Due to ash content in flue the design of recuperator is important as well as it requires frequent cleaning. Proper design means the no of tubes should be calculated based on flue gas temperature and the area required to heat. Every 16°C to 20 °C recovery of temperature means 1% of fuel saving. It means if 200°C rise in combustion air is gained a 10% reduction in fuel consumption shall be gained.

Dampers are the most important part of furnace, as it functions to regulate the draft. In general, two numbers of dampers should be provided in flue duct, one before recuperator and the other after recuperator near chimney.

Once thermal mapping is finalized the next step is maintaining this thermal condition in the furnace by creating proper draft and chimney.

Draft and Chimney:

To understand draft, we assume a column of hot air and cold air as shown in diagram. A column of hot air weighs less than a column of cold air of equal height, which is shown as dotted line to form a u tube. This dotted column corresponds to outside atmosphere. The difference in weight produces a pressure difference which is known as draft. It is commonly expressed in terms of inches or mm water column or gauge.

The pressure required to supply air to a furnace and to remove the flue gases from the furnace is draft. The chimney and draft play very- very important is called draft. Role in furnace operation, hence its design is also very important. Since the pressure required is low, draft is usually expressed as inches/mm of water gauge (i.e.) wg) which is the height of water in a U type gauge equivalent to the pressure in the furnace, flue or chimney.

The draft produced by a chimney is proportional to the height of the chimney and to the density of the chimney gases. The density of the gas is determined by their composition and temperature.

Water column Draft = H x (qc – qh) in mm

Where, H= Height of stack or chimney (in meter)

qc = Density of Air (Kg/m^3)

qh = Density of hot Air (Kg/m^3)

$$\text{Density} = \frac{1.293 \times 273}{273+Tc}$$

$$\text{Hence draft} = H \times \frac{1.293 \times 273}{273+Tc} - \frac{1.293 \times 273}{273+Th}\ \text{mm}$$

OR

$$\text{draft} = 352.989 \times \frac{1}{273+Tc} - \frac{1}{273+Th}\ \text{mm}$$

A natural draft is produced by a chimney; the resultant flow of gas is controlled by dampers. An artificial draft is produced by fans and is controlled by the speed of fans, variation in the pitch of the blades or by dampers.

The Chimney height required for a given draught (and temperature) is cal calculated from the formula given below.

$$\text{Height of chimney "H"} = \frac{\textit{Draft reqired in mm water}}{\frac{1.293 \times 273}{273+Tc} - \frac{1.293 \times 273}{273+Th}}\ mm$$

Chimney is designed to give velocity to hot gases to create draft in furnace and flue line. Hence the velocity of flue gas become an important parameter. Velocity in chimney is calculated by

$$\text{Velocity "v"} = \sqrt{2gh}$$

Where, "V" = velocity in m/s

"g" = Acceleration due to gravity (9.8 m/s)

"h" = Height of column equivalent to draft of h in mm

$$\text{Density of air} = \frac{1.293 \times 273}{273+Tc}$$

The amount of flow is calculated based on combustion product which is flue gas,

Flow rate "Q" = v x Area of chimney duct or

$$A = \pi r^2$$

$$\text{So, (diameter of chimney) "r"} = \sqrt{\frac{Q}{\pi}}$$

A chimney is designed to give minimum5 m/s velocity for small furnaces and 15 m/s in bigger furnaces.

Energy Efficiency Using Motor & Variable Speed Drives

P. Mishra
Sr. Executive Director, AIIFA

Electricity is increasingly important in today's modern society. Most primary energy sources are converted into electricity to meet relentless demands. The inefficient use of energy means that three-fifths of our energy capacity is lost. Greater energy efficiency also helps to reduce carbon emissions. The efficient use of energy is regarded as a solution to the energy crisis. From producer to consumer, there is great potential to save energy.

Energy is lost at each step of the chain:

- During extraction and transportation of primary energy resources, such as oil and gas, potential energy is wasted by inefficient drilling practices and processing operations.
- Cumbersome and inefficient propulsion systems use more fuel than necessary to transport coal, oil and gas.
- Significant amounts of potential energy are also lost when primary resources are converted into electrical power and delivered to consumers via transmission and distribution systems.

Energy saving potential for industry is enormous in motor/drive systems alone:

- 67 percent of all industrial electricity is used to run motors
- About 90 percent of industrial motor driven applications cannot adjust their output or use very crude methods to do so

How to Reduce Electrical consumptions

Plan the installation with;

- Use of high-efficiency motors
- Correct motor sizing to match load requirements
- Use variable-speed drives to match speed and torque to load
- Replacing inefficient throttling devices and wasteful mechanical transmissions
- Optimize systems, including motor-driven equipment, distribution and end-use equipment to deliver required energy service more efficiently
- Proper maintenance and repair
- Maintaining acceptable levels of power quality

Many operators buy motors that are too large for the task in hand, often because they anticipate expansion of their operations and want to avoid buying another larger motor at a later date, to deal with an increased load. It is better to run a small motor at full capacity than to run a larger motor below capacity, especially if its speed is controlled by "throttling".

Applications for VSD's

Historically;

- VSDs were primarily DC and were used solely for the purpose of machine control - paper plants, rolling mills, extruders
- VSDs used to control motor speeds and torques to manage line speed and process variables like thickness, grain formation and winding tightness

While process control still remains a major reason for use of VSDs in industry, scope of usage includes applications previously run at fixed speed. Reason for VSDs here is to save energy and reduce operating costs.

Few businesses know how to identify the motor-driven applications within their plant or processes that can benefit from a variable-speed drive or high efficiency motor. Proper care must be taken while selecting correct size of VSD/Motor, as;

- ❍ Variable-speed drives (VSDs) do not make motors more efficient.
- ❍ Losses of a VSD add to basic motor losses due to harmonics
- ❍ Since waveforms delivered by a VSD to motor are not perfectly sinusoidal, there is additional heating of motor
- ❍ Most motors have lower efficiencies when speed deviates from a "base" speed

Yet, **VSDs can help make an overall application, system, or process more energy efficient than without them.**

VSDs are used to save energy by controlling speed of motors in several applications or processes. VSDs lead to savings from:

- ❍ Better machinery or equipment uptime
- ❍ Lower switchgear and cabling costs
- ❍ Better process control
- ❍ Higher productivity and quality

Drives reduce the output of an application, such as a pump or a fan, by controlling the speed of the motor, ensuring it runs no faster than it needs. Many motors are oversized to cope with a maximum demand that rarely or never occurs. The drive brings the motor speed down to match the actual demand needed by the application. This often cuts energy consumption by 50 percent and in extreme cases by as much as 90 percent.

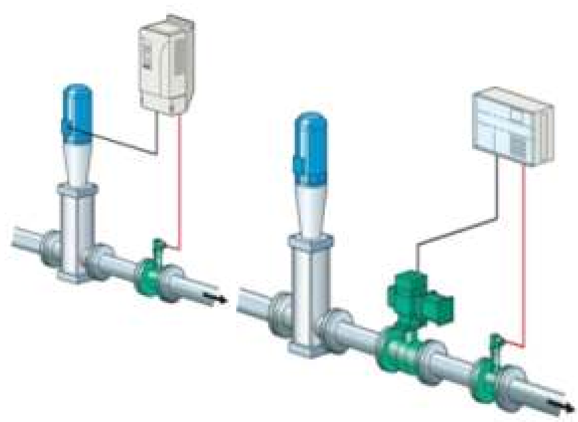
Replacing traditional mechanical-speed controls

Previous fixed-speed applications are now using variable-speed to deliver significant energy and other operational cost savings. These savings also occur when traditional mechanical-speed controls like fluid couplings, gear-shifting, and eddy-current clutches are replaced with direct-driven, VSD-controlled motors

These conversions from fixed to variable-speed applications fall into several categories. Here we describe two categories:

- ❍ Pumps and fans
- ❍ Compressors

When other control methods are used, such as dampers, vanes or valves, the motor runs at full speed and the flow of the output are mechanically restricted. For instance, the flow through a pipeline may be reduced by a valve. This is wasteful, because the motor keeps running at its nominal speed regardless of the demand.The pump delivers maximum output and the excess is reduced at the valve, where the surplus energy is wasted through friction.



Analogy with an automobile

- ❍ Using motors without VSDs is like driving a car with gas-pedal floored and then controlling speed using the brake only.

- This results in high gas usage, an uneven ride, worn brake pads, and short engine life.
- That may sound like a ridiculous way of running any machine - but until VSDs became economical, reliable and user-friendly, that is how most motors were run.

Outputs were throttled, braked, "slipped" in clutches, or bypassed

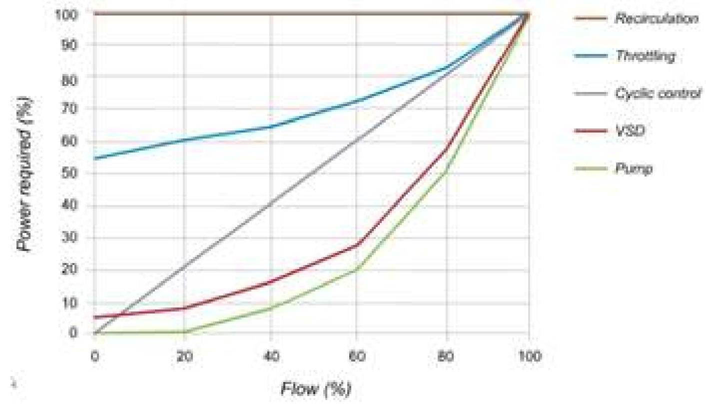
Pumps & Fans

- About 25 present of industrial "motor system" energy usage is for pumps
- About 14 present of industrial "motor system" energy usage is for fans

Traditionally, liquid or air flow from a pump or blower was controlled with throttle valves, vanes, orbypass mechanisms. If process demanded less flow than that delivered by the pump or blower, flow was redirected/bypassed elsewhere. Centrifugal pump, fan or blower applications are attractive for conversion to variablespeed, this is due to "affinity laws" that define relationship between speed, flow, head, and power. In a centrifugal pump (or fan), while flow rate is directly proportional to speed, power required is proportional to cube of speed. So, if flow is reduced by a third by slowing down pump, you reduce power consumption to (not "by") 30 present - a 70 present reduction in power used.

Centrifugal fans or pumps, by contrast, are variable torque applications. The requirement for torque (and hence current) increases with the square of the speed. The voltage again varies in proportion to the speed, so power actually varies in proportion to the cube of the speed. Hence, by reducing the speed by a certain percentage, the power reduces by the cube of the speed change. So 80% speed results in (0.8)3 = 51% power.

So, if flow is reduced by a third by slowing down pump, you reduce power consumption to (not "by") 30 present - a 70 present reduction in power used.



(Please note that this calculation only gives an approximate estimate of your possible savings)

Use of variable-speed also allows pump users to exploit smart benefits and solve old problems:

- Water hammer
- Cavitation
- Shaft shear at starting

All are mitigated once running the motor with variable-speed. Using controlled speed on pumps (or blowers) also allows users to eliminate control valves and vanes. This reduction in moving parts means higher system reliability and lower failure rates.

Compressors

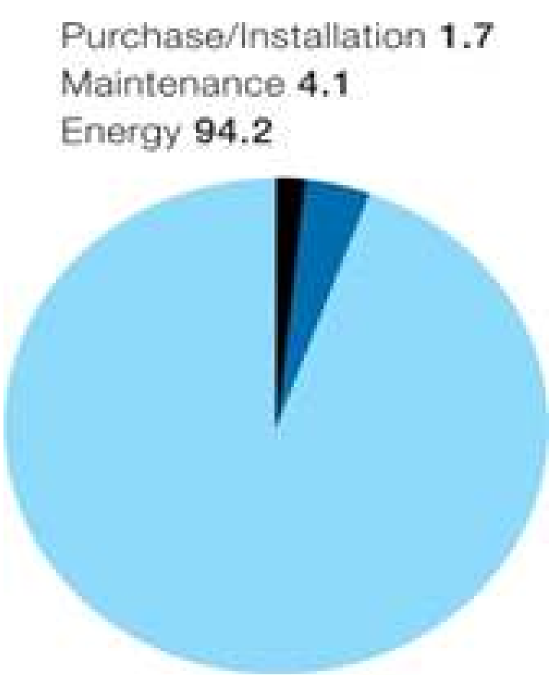
Industrial "motor system" energy use - Compressed air ~ about 16 present, advent of VSDs allows plant engineers to match delivery pressure by compressor modulation. Significant energy savings achieved by tightly controlling delivery pressure within a very narrow band close to "required" pressure. Alternative is to maintain accumulator pressure well in excess of required/ application pressure to compensate for pneumatic load variability and line losses. This is poor in terms of energy consumption. For example, operating a system at 120 psig (pounds per square inch, guage) instead of 100 psig requires 10 present more energy in addition; higher pressure leads to higher line losses due to leakage.

Variable-speed systems allow air compressors to manage delivery pressure precisely and deliver exactly what is needed for application while compensating for line losses and coping with variability of demand. If several compressors feed into a single header, it is common to see several units run at fixed speed delivering base or minimum load while a variable-speed unit caters to process variation. This arrangement often makes most economical sense.

Motor

Consider life cycle cost when purchasing a motor

- Initial investment may account for only 1 percent of total life cycle operational cost
- Energy consumption is about 94 percent (rest is maintenance)
- Motor purchasing price corresponds to 8 to 12 weeks of its electricity consumption
- Reliable motors with high efficiency level ensure lowest life cycle costs



Low-voltage motor

Payback time for energy efficient motors can be as low as one year

Improvements, but room for much more

The steel industry is the largest industrial energy consumer and the largest source of industrial CO2 emissions, accounting for 15 percent of industrial CO2 emissions from fuel combustion. Much of this thermal energy is used to create the enormous amounts of heat needed to manufacture iron and steel.

It's no surprise that energy efficiency is nothing new to the sector, where the cost of energy can be as much as 20-40% of operating costs. Improvements since 1975 have in fact helped reduce the energy needed to produce a ton of crude steel by nearly half.

However, large gaps in energy efficiency exist between the world's best producers and countries where there is much room for improvement. According to Global Trends in Energy Efficiency, steel industry energy consumption could be reduced by as much as 40 percent if the world's main producers had the same energy efficiency as the world's best performers. Savings are typically 5-20% and come throughout the energy system including reduced consumption, minimizing distribution losses and improving generation efficiency.

There are many electrical and thermal opportunities to improve the energy efficiency of integrated and secondary iron and steel making plants. These solutions complement core processes and support systems, rather than changing the way iron and steel are made. In addition to reducing energy costs and environmental impact, many of these solutions provide additional operational benefits such as improved productivity and quality, and reduced maintenance burdens.

Energy Manager

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Summary

Although the cost of the electrical equipment amounts to only a small fraction of the total investment in a modern, highly automated plants, the correctchoice of systems helps to determine a plant's overall performance and profitability.

When all of the intermediate energy losses are taken into account, an end-user who saves one unit of electricity removes the need for 2-3 units of electricity generation.

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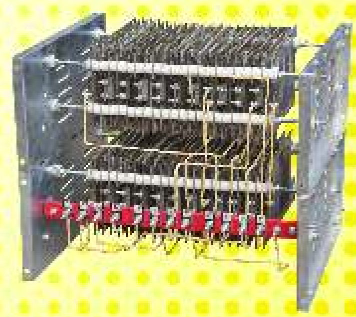

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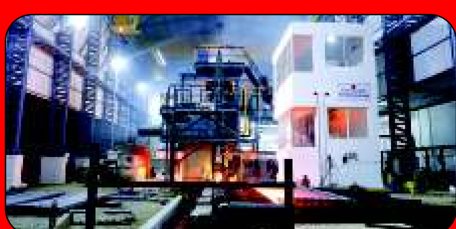

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