CONVERSION OF COKE FIRED FURNACE TO GAS FIRED FURNACE

A Thesis

by

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Submitted to the Department of Metallurgical Engineering, Bangladesh University of Engineering and Technology, Dacca, in partial fulfilment of the requirements for the Degree of Master of Science in Engineering (Metallurgical).

December, 1973

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DACCA.

CERTIFICATE

This is to certify that this experiment was done by the author under the supervision of Dr. M. Ibrahim, Professor and Head, Department of Metallurgical Engineering, Bangladesh University of Engineering and Technology, Dacca and it has not been submitted elsewhere for the award of any other degree or diploma.

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ACKNOWLEDGEMENT

The author expresses his indebtedness and sincere gratitude to the Thesis Supervisor, Dr. M. Ibrahim, Professor and Head, Department of Metallurgical Engineering, Bangladesh University of Engineering and Technology, Dacca for his constant guidance, constructive suggestions and encouragement to carry out the research and to prepare this thesis.

The author is also pleased to extend his heartiest thanks to Dr. Musharrif Husain Khan, Professor and Head, Department of Mechanical Engineering and Mr. Md. Serajul Islam, Associate Professor, Department of Metallurgical Engineering, Bangladesh University of Engineering and Technology, Dacca for their kind help and suggestions in determining some experimental datas.

The author expresses his warm gratitude to Mr. Kazi Md. Mosharuddin, Foundry Instructor, Department of Metallurgical Engineering and Mr.Fazlul Haque, Foreman of Foundry Shop, Bangladesh University of Engineering and Technology, Dacca for their valuable suggestions and help during the experiment.

The author also appreciates the assistance extended to him by other staff members of the department in preparing the burner and the experimental furnace.

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December, 1973.

ABSTRACT

Coke when imported from abroad, becomes a costly fuel for melting metals. Bangladesh imports coke at a very high cost and hence metal casting is very costly. Fortunately, Natural gas of good quality is available in this part of the world. An attempt has been made to replace coke fired furnace to a gas fired furnace. A small gas fired furnace was erected in the Foundry Section of the Metallurgical Engineering Department. About thirty experiments were carried out to melt pig iron and cast iron scrap. Encouraging results were obtained. About 70 pounds of pig iron and cast iron scrap were melted in 80 minutes. It has been observed that the zone of exact combustion was found variable with the velocity of air-gas mixture. Few experiments were also carried out to find the exact height of the combustion zone for the experimental furnace erected.

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CHAPTER - I

INTRODUCTION

It is generally held today that the contemporary way of living in the advanced societies, is almost entirely based on the use of metals. It is very difficult to conceive of modern life without them. The advancement of civilization has been largely brought about by man's ability to employ metallic materials to his service. Primitive man of the 'Stone age'[1] used certain metals before 3500 B. C. for weapons and artefacts which would help in making their life easier and safer.

Toward the end of the 'Stone age' man discovered the art of smelting. It seems likely that the first casting was accidentally produced in the ashes of his campfire. Charcoal served as a reducing agent in the primitive smelting process and the first crude bronzes were probably the result of accidental roasting alloy. About 2500 B. C. with the start of Bronze age,[2] bronze has been identified as the first alloy actually cast by man. However, it was generally accepted as true that the campfire was the original smelting furnace as sketched in Fig. No. 1. It can be imagined that high temperatures would be virtually impossible by such a fire.

Investigations have revealed that some predynastic Egyptian ware had been fired at temperature upto 1100°C to 1200°C. In order to attain such high temperatures, kilns of a suitable design had been evolved. Such kilns were two-tier furnacos having features shown diagramatically in Fig. No. 2.

It was quickly discovered that better results would be obtained if a channel were dug below the fire and lined with stones and clay to provide an air-intake. This arrangement produced the most primitive form of tuyere and provided a crude method of concentrating the air flow. If a fire equipped with this device, were built on the brow of a hill, a fairly powerful draught could be drawn through it. This method of procuring a high temperature was commonly employed in very early times and is still used in many parts of the world. This early type of smelting furnace is illustrated in Fig. No. 3.

The furnaces used by the wandering smiths were quite primitive developed from the early campfires. The stages in the development of the furnaces are naturally very difficult to define precisely but can be shown easily as in Fig. No. 4 (a, b, c). With the 'Sunk furnace' designs, the draught from a bellows would be introduced over the lip in the manner shown for an iron making furnace in Fig. No. 5. The simplicity of these early furnaces made them popular and largely accounted for the dissimination of iron smelting technique among the less advanced people. Furnaces of this simple type continued to be employed in various regions for about two thousand years. Yields from such bowl furnaces were decidedly poor and fuel consumption was surprisingly high, the weight of charcoal consumed being from four to five times the weight of iron producad.

However, the course of developments was irregular and rather uncertain but its general trend may be followed from the furnace diagramatically illustrated in Fig. No. 6. The section shown in this figure displays a hill-side furnace of a rather more advanced type.

In the seventeenth, eighteenth and nineteenth centuries the contemporary revolution in physics and chemistry took place and new developments came at an accelerated pace. Scientific man attempted to expand his knowledge by laboratory experimentation to explain countless phenomena in the art of metallurgy. Scientists in the eighteenth and nineteenth centuries formulated the quantitative conception of chemistry, thus providing a basis for metallurgical work. The devices for burning a fuel economically, with the correct quantity of air, vary widely with the nature of the fuel. The requirement of low cost per unit of heated product has led to the development of a great variety of labour and heat saving devices in connection with furnaces.

Figure No.1

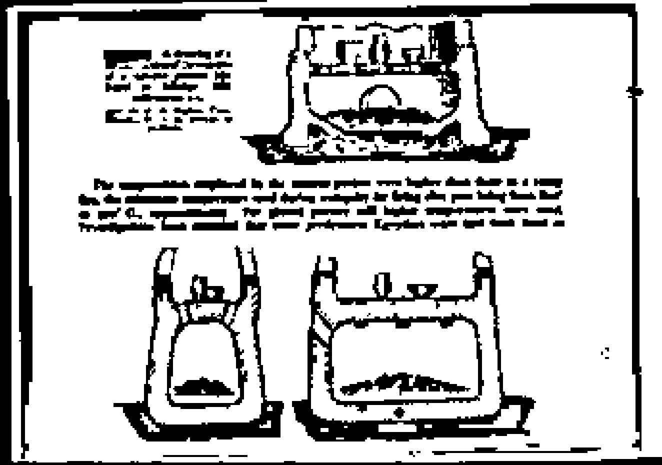

Figure No.2

Figure No.3

Figure No.4

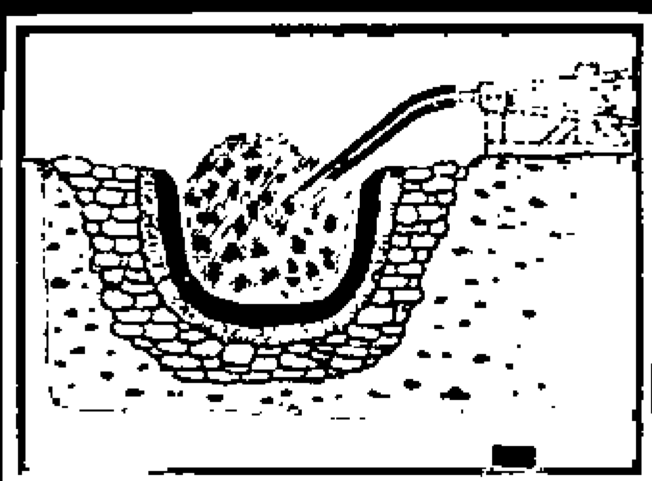

Figure No.5

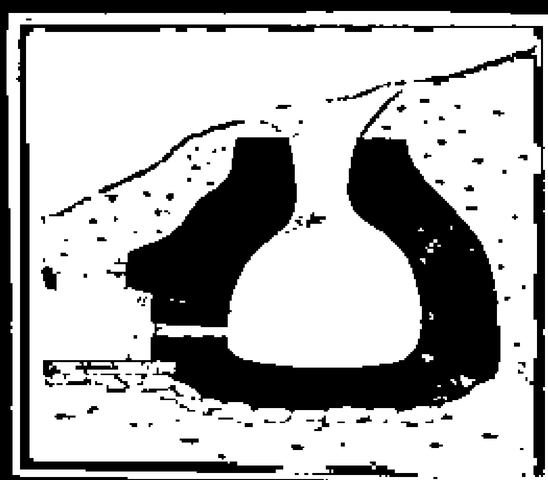

Figure No.6

If economic side is considered obviously natural occuring fuels will be the cheapest among the fuels. The use of natural gas is very common in advanced countries like America, Canada, Soviet Union and others. Even forty years ago natural gas was the important source to develop thermal and electric energy. Now-a-days the production of retort gas and the use of town gas and producer gas are negligible compared to natural gas. Today natural gas amounts 97% of totel energy used in U. S. A. and in Canada, France, U. S. S. R. there has been enormous development in the use of natural gas. In Great Britain specially in the West Midlands area, methane gas is drawn from Granville Colliery and piped into Wellington Gas Works at the rate of 2 million cft. of pure methane per week[3]. There was a scheme that Britain would be importing 35,000 million cft. of Sahara gas per annum.

The following table[4] will give an idea about the use of natural gas in different industrial and heating purposes in U. S. A.

(a) 80% of the air conditioning is gas operated.

(b) 90% of the space and water heating is with gas.

(c) 99% of the cooking is with gas.

However, the basic property of a fuel is its calorific value. The calorific value of a natural occuring gaseous fuel is much more higher than other types and also the gaseous fuel has some advantages over the other types. These are briefly as follows[5]:

(a) The ease and flexibility of application.

(b) Smoke and ash are eliminated and there is no labour involved in fuel or ash handling.

(c) This fuel can be mixed with air in proper proportion without previous preheating and the rate of flow can be accurately measured.

(d) The fuel is easily transported to any number of furnaces.

(e) The combustion may be readily controlled for changes in demand, the oxidizing or reducing nature of atmosphere, the length of the flame and the temperature.

(f) Greater thermal efficiency can usually be obtained when high temperatures are required.

Metallurgical Engineering Department has employed only crucible furnaces for melting purposes. Such furnaces are more generally fired by coke or coal. These pit furnaces usually yield a small quantity of metal. In the pit furnace, only the crucible is heated and there are no other way for utilizing heat that is evolved in the furnace. Furthermore, the availability of good quality of coke is one of the greatest problems in this country. To overcome these difficulties, an attempt has been made to convert a coke fired furnace to a gas fired furnace with suitable devices to make the furnace operation easier, safer and economical.

CHAPTER - II

NATURAL GAS

The origin of natural gas is closely associated with that of petroleum, it is always found in or near the petroleum fields. But the pipe lines are being constantly extended to furnish gas to large consuming centres. In the past large volumes of natural gas were wasted during drilling operations for petroleum. Now-a-days, the tendency is toward the use of the gas for different purposes.

Natural gas consists largely of methane with decreasing amounts of Ethane (C_2H_6) and Propane (C_3H_8) and relatively small amounts of isomers, napthenic and aromatic hydrocarbons, carbon dioxide and nitrogen, in some places small but recoverable amounts of helium are found.

During the last century natural gas has come to be recognised as one of the world's most valuable and versatile sources of energy. The United States, Italy, France and Holland have all highly developed gas fields and pipelines have been laid all over these countries to feed industries and other commercial and domestic fuel markets.

The purity of natural gas makes it ideal for many industries such as steel industry, glass and ceramics, pharmaceuticals, etc. It is also used as a raw material for the petrochemical industry. Natural gas also helps agriculture of a nation because it is a feed stock for fertilizer production. Natural gas can be used with equal advantages in power generation and direct process heating. With the advancement of technology the range of its application is widening.

The gas is distributed in steel pipe of upto 30 inch diameter at a pressure of 55 atmospheres[6]. On long distance lines there are pressure booster stations at intervals which can raise the pressure to some 15 atmospheres. The pipe lines are protected against corrosion by layers of cellulose wrapper and asphalt and also by anodic protection. Internal protection is assured now by removal of water vapour, hydrogen sulphide and organic sulphur compounds before distribution. Large cities are by passed and are served by branch-lines of small diameter, also cathodically protected, working at pressure of 13 atmospheres. Public service is at a pressure of about 10 inch water gage.

Since natural gas does not contain carbon monoxide, it is not poisonous and its distribution suffers less from leakage danger than manufactured gas. But it is odour-less and leakage which might lead to the formation of an undetected explosive mixture must be guarded against. The addition of a number of organic sulphur compounds, has been tried including ethyl mercaptan but the present choice is a cyclic sulphide called by the trade name Calodorant C, the amount required being about 1 pound per million of cft. of gas. It is important that the amount be sufficient to be detected at a dilution in air of 4 percent since the explosive range begins at this concentration. One difficulty is the absorption of odour in dust in the mains and in damp soil surrounding a pipe line.

The currently known reserves of natural gas deposits in Bangladesh are 9.03 million million cft. and are spread over seven gas fields of which two biggest ones are in Comilla district and rest five are in the district of Sylhet. Out of seven, gas fields three viz., Rashidpur, Kailas Tila and Bakhrabad are untapped and other four are being tapped.

The reserves of individual gas fields along with their chemical composition and calorific value are given in Table[7] (next page).

Among the four tapped gas fields, Titas is the biggest having a deposit of 2.25 million million cft. Since this gas does not contain Hydrogen sulphide, therefore, there is no danger for Sulphur pick up in the molten iron.

The Titas field in Brahmanbaria in the district of Comilla is supplying raw materials to Ghorasal Fertilizer Factory, fuel to Ashuganj and Siddhirganj Power Station. It is also supplying fuel to Industrial, Commercial and Domestic Consumers in and around Dacca city. But unfortunately the response from industries

	Untapped			Tapped			
Q Place	Rashidpur	Kailas Tila	Bakhrabad	Hobiganj	Haripur	Chhatak	Titas
Quantity (million million cft.)	0.74	0.60	3.70	1.28	0.44	0.02	2.25
Composition (Volume %) Methane(CH_4)	98.2	95.7	95.2	98.8	95.4	99.05	97.2
Ethane (C_2H_6)	1.2	2.6	1.4	1.5	2.67	0.25	1.8
Propane (C_3H_8)	0.2	0.9	0.8	-	0.3	-	0.5
Butane & Higher Hydro-Carbon (C_4H_{10})	0.1	0.4	0.3	-	0.78	-	0.2
Nitrogen (N_2)	0.3	0.2	0.4	0.7	0.37	0.67	0.3
Carbon Monoxide (CO)	-	-	1.3	-	-	-	-
Carbon Dioxide (CO_2)	-	0.2	0.6	-	0.48	0.03	-
Hydrogen Sulphide (H_2S)	-	-	-	-	-	-	-
Calorific Value Btu/cft.	1014	1050	1022	1020	1052	1007	1039

has been very poor. The reasons for poor response are manifold-lack of knowledge of modern techniques and developments in industrial process and above all the capital shyness of industrialists. Though natural gas is the cheapest of all the available fuels, industries need some initial investments for pipe laying and conversion materials for switching over to natural gas. Conversion equipments usually are to be imported from abroad which needs foreign exchange.

CHAPTER - III

COMBUSTION DEVICES FOR GASEOUS FUELS

In well-designed furnaces the combustion device or heat liberating device and the furnace are properly adapted to each other and form an integral combination which generates and utilizes heat. It is very difficult to say that where heat generation stops, the heat generation is begun in combustion device and should be finished in the furnace[8]. For that reason it is necessary to study 'Combustion Devices' or 'Burners' seperately.

Perhaps the first factor in considering the control of combustion of gases is the composition and properties of gases themselves. The burning velocity of hydrogen is much higher than that of any other component and its concentration affects both the rate of burning of the mixture and the stability of any flame. In an aerated burner, therefore, the amount of primary air possible will decrease with increasing hydrogen content. Flame stability in aerated flames can be defined as the range between the minimum rate of supply of gas which causes the flame to die down and the maximum rate which causes the flame to blow off the end of the burner.

Attempts have been made to define the combustion characteristics of rich gas by the use of certain emperical relationships and standardized tests. The combustion diagrams of Fuide[6*] and his assistants are prepared by the operation of a simple tubular burner with increasing air/gas ratios and the plotting of the observations against thermal input. A typical set of curves for coal gas and water gas shows considerable difference in their behavior. These are shown in Fig. No.:- 7 .

(A) Horizontal-Retort gas,

(B) Vertical - Retort gas,

(C) Carburetted-Water gas.

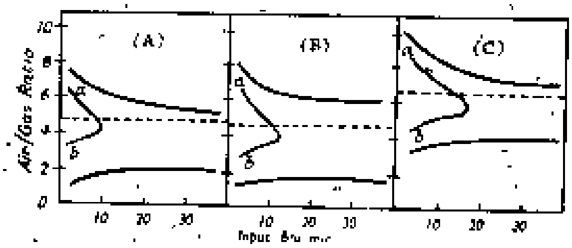

Fig No 7 Combustion Diagrams of Town Gas
(A) Horizontal-retort gas (B) Vertical-retort gas.
(C) Carburetted water gas.
---- Theoretical air requirement

The idea of the above curves will be clear from the following statements :

(a) The disappearance of luminosity is given by the bottom full curved lines.

(b) The blow-off point of flame is the upper full curved line.

(c) The back-fire area is to be the left of the curved line ab.

Any where in the area between these three lines the conditions are such that the gas will burn without luminosity, but the hight of the inner cone will decrease in the direction of increasing air/gas ratio.

(d) The theoretical air requirements is represented by the dashed line.

These diagrams, therefore, give a considerable insight into the performance of gas in an aerated burner and can be used to define the limits of conditions of gas input and degree of aeration to give a satisfactory performance and a stable flame.

The performance of a burner depends upon the combined resistance of the air ports and the burner tubs as well as upon the flame speed of the aerated mixture. These observations relate to gas burners using gas under pressure and induced primary air. In industry, where air under pressure may be used, the full measure of control is obtained by adjustment of the air pressure. Generally speaking, greater the amount of primary air supplied, the shorter the flame produced i.e., greater is the rate of combustion.

The area of the flame ports should increase with decreasing calorific-value of the gas. The area of the air ports should be equal to or up to twice the area of the flame ports and the adjustment should then be made by means of an air shutter or a screw throttle. In the case of natural gas having a calorific value of the order of 1000 Btu/cft. the same rules apply and the diameter of gas orifice is less.

In domestic heating or cooking the emphasis is on complete combustion and therefore, on short, well aerated flames. In industry there are so many different requirements that no generalisation is possible. It may be necessary to obtain intimate mixing for the development of a high temperature in a confined space or delayed mixing for the heating of large surfaces or spaces or any intermediate condition.

Gas burners are generally classified as :-

(a) Natural Draught Burner,

(b) Pre-heated Air Burner,

(c) Low-pressure Blast Burner,

(d) High-pressure Gas Burner,

(e) Pre-mixing Burner,

(f) Surface Combustion Burner.

(a) Natural Draught Burner : This type is essentially an injector burner of the bunsen type, the gas being slightly above and the air at, atmospheric pressure. A portion of the air is supplied with the gas as primary air, the remainder being induced by the furnace draught as secondary air.

(b) Pre-heated Air Burner : This type takes the form of one or more ports and is supplied with pre-heated air from a heat recovery appliance, recuperator or regenerator. It is generally used on large furnaces. The gas is delivered at low pressure and the air is supplied either by natural draught or at low pressure after passing through the pre-heater.

(c) Low-pressure Blast Burners : With these burners the gaseous fuel is supplied at pressures between 2 inch and 8 inch water gage and with air pressure varying from a few inches to 5 or 6 pound per square inch gage. They may be used with either cold or pre-heated air. The gas and air supplies are generally seperately controlled. Maintenance of the correct air/gas ratio may be assisted by coupling the air, and gas valves together through a proportioning mechanism.

(d) High-pressure Gas Burner : In this type of burner air is supplied in more than two stages according to the class of fuel and condition of use. Gas pressure may be from 1 to 10 pound per square inch gage. Alternatively, the similar type of burner may be operated by means of high pressure air, used as an injector to entrain gas supplied at low pressure.

(e) Pre-mixing Burner : This is a popular type of burner in which the gas and the air are mixed and then delivered to the throat. It has the advantage that the combustible mixture can be distributed by suitable mains to a number of different points in the furnace to produce the required temperature distribution. The aeration of the gas is affected in an injector mixer by the use of high pressure air, the gas pressure being stabilised by the use of a governor.

(f) Surface Combustion Burners: These are the multi-jet burners in which the gas and air are sub-divided into a number of small streams, producing in effect a series of films of flame. The flame volume is easily controlled. Excessive local temperature in the body of the flame is also avoided.

CHAPTER - IV

EXPERIMENTAL SET UP

A schematic diagram of the experimental set up is shown in Fig. No.:- 8 . It mainly consisted of a burner, a furnace body, two blowers and necessary instrumentation and pipelines.

A modified high pressure gas burner design was adapted for the experimental set up. A detailed diagram of the burner is shown in Fig. No.:- 9 . It consisted of a 2 inch diameter mild steel pipe 6 inch long through which natural gas was supplied. Primary air was supplied in a 4½ inch outer diameter, 4 inch inner diameter cast iron pipe of 24 inch long. This gave a good air/fuel mixture. The secondary air entered through a 12 inch diameter mild steel pipe with 1¼ inch thick refractory lining on the inside of the pipe, 32 inch long. The free end of the 12 inch diameter pipe was supported by and flushed with the furnace body. The 4½ inch diameter cast iron pipe was supported by three screws. The three pipes (2 inch, 4½ inch and 12 inch diameter) were assembled concentrically. The air was supplied through the wall of the pipes.

A pit furnace body was designed and constructed to suit the burner. In designing the furnace the following points[9] have been kept in mind.

(a) <u>Robustness of the furnace structure</u> :- Besides a mechanically stable frame work, good quality refractories and good workmanship are essential.

(b) <u>Ease of control</u> : All valves, damper controls and instruments should be situated in a convenient and as far as possible central position to give ready accessibility for control purposes.

(c) <u>Ease of maintenance</u> : This implies accessibility, the use of readily replaceable parts and means for inspection and cleaning.

(d) <u>Insulation</u> : This must be regarded as an essential feature of almost any type of furnace.

(e) <u>Provision for adequate draught</u> : A chimney is not necessarily the

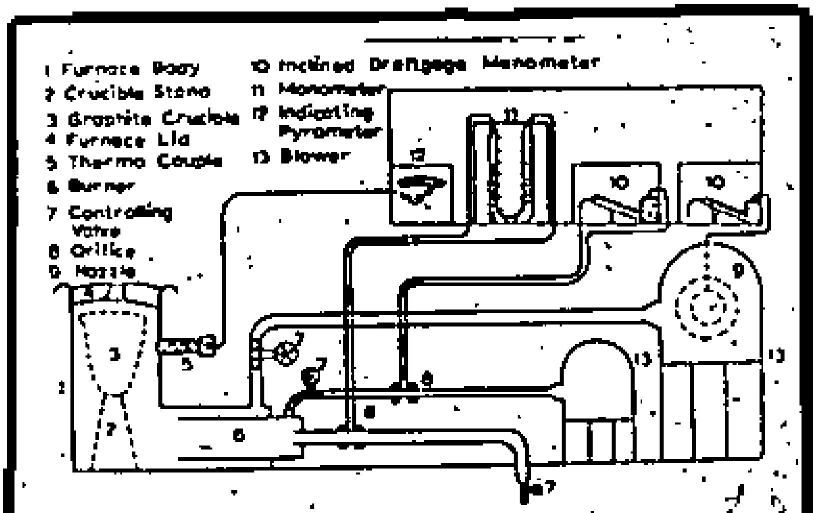

Fig. No. 8

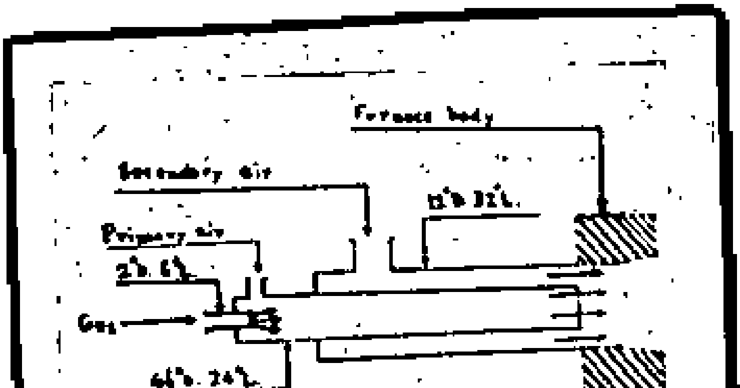

Fig No- 9

most efficient means of providing draughts. Fans should be carefully rated for the duty intended. Flues, dampers and sight holes should be so arranged and constructed as to reduce the possibility of air inleakage to a minimum.

A sectional diagram showing the main parts of the furnace and the burner in the assembled condition is shown in Fig. No.:- 10 whereas a cross-section of the furnace is shown in Fig. No.:- 11 . Main particulars of the furnace is given below :

(a) Outer shell 27 inch diameter 44 inch high was made of 1/16 inch mild steel sheet.

(b) Refractory lining of 6 inch thick was provided giving a working space diameter of 15 inch.

(c) A circular block of 6 inch diameter and 25 inch high, was made of chrome brick to support the crucible in the furnace.

(d) A crucible of 80 pounds capacity was utilised to carryout the experiment.

The whole furnace was built on concrete foundation over ordinary brick soiling.

(e) The furnace was provided with a refractory dish shaped lid of 22 inch diameter and 5 inch high.

The lid consisted of a reinforced circular casting with a 6 inch hole at the centre for the exhaust gases. Outer shell of the casting was a steel cylinder made of 1/16 inch plate provided with hooks to handle the lid and the reinforcements were done by 19 numbers, 3/8 inch diameter mild steel rods and arranged diametrically on the shell.

The primary air was supplied by a centrifugal blower driven directly by

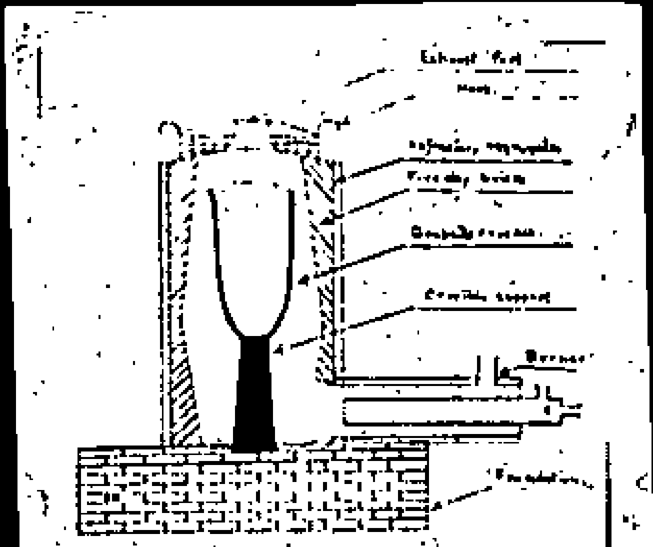

Fig. No. 10

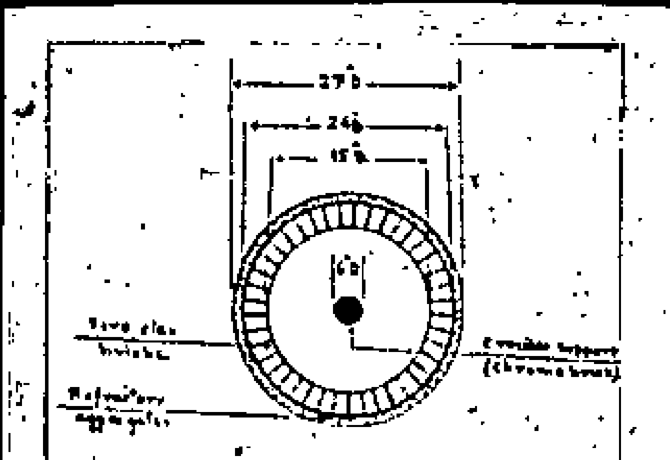

Fig. No. 11

3/4 h.p. motor whereas the secondary air was supplied by another centrifugal blower driven directly by 3 h.p. motor. The primary air and the gas were measured by orifices and inclined draft gages. The secondary air was measured by a A. S. M. E. long radius nozzle of 4 inch diameter.

CHAPTER - V

EXPERIMENTS AND RESULTS

The furnace was fired at low temperature. Few cracks were developed and subsequently were patched by fire clay cement. The furnace was then heated to a temperature of about 700° to 800°C. This resulted in a few cracks which were also patched up. The furnace was then fired at elevated temperature but no noticeable cracks developed. The furnace was then ready for experimental firing.

The initial firing produced the flame above the mouth of the furnace. The air supply was increased and the flame came down within the furnace hearth. These are shown in Fig. Nos. 12(a, b), 13(a, b). First set of experiments did not yield much result but provided useful information about various factors like crucible stand height, air fuel ratio. Table No. 1 shows the results of the first set of experiments. The temperature developed in this set was estimated to be around 1100°C.

In the first set of experiments, once a mild steel rod was put at the exhaust opening of the furnace lid. The rod was found in the plastic state after few minutes giving an idea that the zone of maximum temperature would be near the exhaust opening. So in the second set of experiments the height of crucible stand was raised from 15 inch to 27 inch. Simultaneously the furnace height was also increased by few inches. About six experiments were conducted in this set as shown in Table No. 2.

In the second set of experiments, the diameter of the gas opening was same and the heating period was increased from 60 to 90 minutes. The first few experiments showed no melting indicating no appreciable change of crucible temperature. The refractory lining of the exhaust port was found in spongy state and it was assumed that the heat was not being stored within the furnace hearth due to high velocity of exhaust gases. Some refractory bricks were placed in the annular space between the furnace wall and the crucible. Under similar conditions

(a) (b)

Figure No. 12 - Flame is shown with full air and full gas supply, (a) with lid and (b) without lid.

(a) (b)

Figure No. 13 - Flame is shown with full air and reduced gas supply, (a) with lid and (b) without lid.

of heating the iron in the crucible was noticed to be in the spongy state indicating that the temperature was higher than the previous conditions. The crucible stand height was then raised by 3 inch and heating was continued for 90 minutes but no sign of melting was observed.

The second set of experiments gave an idea that the combustion zone or the zone of maximum temperature varied with the velocity of air-gas mixture. To reduce the velocity of the Titas gas a 2 inch diameter pipe was put in place of 1½ inch diameter pipe just before the burner where mixing of gas and air was arranged as shown in Fig. No. 9. The crucible height was also varied from 15 inch to 24 inch and the heating time was increased to two hours. The first two experiments did not show any melting while the third heating with 24 inch crucible height showed melting as noted in Table No. 3. The furnace temperature may now be considered to be about 1150°C. The metal got melted but even by increasing the duration of heating, the molten metal did not attain the fluidity for sound casting.

During the third set of experiments, the exhaust port lining of the lid was softened and it dripped down on the crucible. The lid lining shape was then made conical to facilitate the easy escape of the exhaust gases and chrome brick aggregate was used for the lining. The gas pipe in the burner was replaced by a 3 inch diameter pipe. To reduce the velocity of gas, a 3 inch mild steel circular plate with 19 drilled holes (3/8 inch diameter) was introduced in the gas pipe. The crucible stand height was varied between 22 inch and 25 inch and the gas supply was then raised from 19 cu.ft. per minute to 22.4 cu.ft. per minute. This set of experiments showed some promising results when the crucible with metallic charge was heated for 90 minutes as shown in Table No. 4. A good casting metal was obtained by increasing the heating time from 90 to 105 minutes. This experiment thus provided an idea that the reduced velocity of gas supply gave a better mixing and kept the zone of maximum temperature within the furnace body i.e., at about a height of 25 inches from the bottom of the furnace. Reduced gas supply at 25 inches crucible height did not yield molten metal whereas the metal got melted when the crucible height was brought down to 22 inches.

Results of the fifth set of experiments, tabulated in Table No. 5, show that an excellent fluid metal was obtained at a crucible height of 25 inches. More volume of metal was found melted under similar conditions with longer heating period. These experiments were performed with primary and secondary air as shown in Fig. No. 9. To find the exact effect of the primary air, some experiments were conducted without it. The metal was not melted even with 75 minutes heating but was melted after few minutes when primary air supply was resumed as shown in Table No. 5, Experiment Nos. 5 and 6. This gave an idea that the primary air helps better mixing and hence good combustion. It also lowers the exact zone of combustion.

Few experiments were also conducted by increasing gas supply from 22.4 cu.ft. per minute to 26 cu.ft. per minute. Excellent fluid metal was obtained with shorter heating period. As many as 70 pounds of metal was melted in 80 minutes time as shown in Table No. 6.

To know the melting temperature of the furnace and the exact ratio of the air and the gas, some experiments were conducted. For temperature record, a Platinum - 13% Platinum/Rhodium thermocouple was inserted into the furnace lining. Few holes were made in the furnace lining near the crucible stand height level. These holes were provided with mild steel pipes for easy insertion of the thermocouple. A temperature gradient of 10°C per inch was found to exist in the horizontal as well as vertical direction. As such a correction factor of about 50°C may be added to get the crucible temperature from the observed temperature.

The Titas gas that was used, contains predominantly (97.2%) methane gas and chemically correct air fuel ratio by volume comes to 10:1. Relationship between percentage of excess air and the furnace temperature is evident from the results of the experiments listed in Table No. 7. About 60% excess air produced the highest furnace temperature for a particular gas supply.

It was observed that the lining of the experimental furnace (gas fired) was used for about 25 heats without any major patch up, whereas a coke fired furnace usually stands about 15 heats before the lining requires patching or replacement. The reason might be that the ash of the coke reacts with the furnace lining and erosion by the ash at high velocity severely damages the lining. Exhaust gas heat loss in the coke fired furnace is less than the gas fired furnace since the retention time of the products of combustion is more in coke fired furnace due to the presence of coke around the crucible. This is the reason that the experiment No. 5 of Table No. 2 shows that after packing the annular space by refractory bricks, the spongy metal was observed. The same function of increasing the retention time was performed by the furnace lid in addition to radiant heat transfer to the metal from the lid refractory surface. The crucible stand height for maximum heating depends on the design of the furnace, velocity of air-gas mixture and also their proportions and is to be determined experimentally for a particular furnace.

Table Nos. 8, 9 and 10 show some economic aspect of the coke and the gas fired furnace. It was observed that the gas fired furnace is economical not only on fuel cost but also will have a higher production capacity because of the shorter heating time required and low maintenance cost because of the larger number of heats between the refractory repair works. Moreover, there is no danger of picking up of sulphur and phosphorus by molten metal from natural gas whereas some objectionable impurities like sulphur and phosphorus are picked up by the molten metal from coke. Over and above all these, coke is to be imported at high cost. So the conversion of coke fired to gas fired furnace is advocated.

This project may be continued to determine experimentally the effect of various design and operating factors and suggest an analytical model for design purposes.

TABLE NO. 1

(1st set of experiments)

Serial Nos.	Weight of Metals in lbs.	Height of crucible stand in inches.	Heating time in minutes	Gas consumption in cu.ft. per min.	Results.
1	20 (Pig Iron)	10	60	19	No melting
2	20 (Cast Iron Scrap)	15	60	19	No melting
3	5 (Copper)	15	25	19	Melting
4	10 (Lead & Antimony Alloy)	15	10	19	Melting
5	10 (C.I.Scrap)	15	60	19	No melting

TABLE NO. 2

(2nd set of experiments)

Serial Nos.	Weight of Metals in lbs.	Height of crucible stand in inches.	Heating time in minutes	Gas consumption in cu.ft. per min.	Results
1	25 (C.I.Scrap)	18	60	19	No melting
2	25 (C.I.Scrap)	21	90	19	No melting
3	15 (C.I.Scrap)	21	90	19	No melting
4	15 (C.I.Scrap)	24	90	19	No melting
5	15 (C.I.Scrap)	24	90	19	Spongy state (Annular space was packed by refractory bricks)
6	15 (C.I.Scrap)	27	90	19	No melting

TABLE NO. 3
(3rd set of experiments)

Serial Nos.	Weight of Metals in lbs.	Height of crucible stand in inches	Heating time in minutes	Gas consumption in cu.ft. per min.	Results
1	20 (C.I.Scrap)	15	120	19	No melting
2	20 (C.I.Scrap)	20	120	19	No melting
3	20 (C.I.Scrap)	24	120	19	Melted but not fluid enough for sound casting.

TABLE NO. 4

(4th set of experiments)

Serial Nos.	Weight of Metals in lbs.	Height of crucible stand in inches	Heating time in minutes	Gas consumption in cu.ft. per min.	Results
1	20 (Pig Iron)	22	90	22.4	Melted but fairly fluid.
2	20 (Pig Iron)	22	105	22.4	Melted but dull fluid.
3	20 (Pig Iron)	25	105	22.4	Melted and sufficiently fluid for good casting.
4	30 (Pig Iron)	25	105	22.4	Melted but fairly fluid.
5	20 (Pig Iron)	25	105	19	Spongy state
6	20 (Pig Iron)	22	105	19	Melted but dull fluid.

TABLE NO. 5

(5th set of experiments)

Serial Nos.	Weight of Metals in lbs.	Height of crucible stand in inches	Heating time in minutes	Gas consumption in cu.ft. per min.	Results
1	13 (Pig Iron)	25	75	22.4	Excellent fluid metal for sound casting.
2	25 (Pig Iron)	25	90	22.4	Excellent fluid metal for sound casting.
3	30 (Pig Iron)	25	100	22.4	Excellent fluid metal for sound casting.
4	40 (Pig Iron)	25	105	22.4	Excellent fluid metal for sound casting.
5	13 (Pig Iron)	25	75	22.4	No melting (without primary air)
6 (subsequent)	13 (Pig Iron)	25	30	22.4	Excellent fluid metal for sound casting (with primary air).

TABLE NO. 6

(6th set of experiments)

Serial Nos.	Weight of Metals in lbs.	Height of crucible stand in inches	Heating time in minutes	Gas consumption in cu.ft. per min.	Results
1	20 (Pig Iron)	25	40	26	Excellent fluid metal for sound casting.
2	41 (Pig Iron)	25	50	26	Excellent fluid metal for sound casting.
3 (subsequent)	25 (Pig Iron)	25	25	26	Melted and sufficiently fluid for sound casting.
4	70 (Pig Iron)	25	60	26	Melted and sufficiently fluid for sound casting.

TABLE NO. 7

Sl. Nos.	Gas consumption in cfm.	Air required (theoretical) in cfm.	Air Supplied Primary in cfm.	Air Supplied Secondary in cfm.	Air Supplied Total air in cfm.	Excess air supplied in cfm.	% of excess air	Wall temp. in Centigrade.
1	26	260	25	285	310	50	19.23	1060
			50		335	75	28.85	1080
			75		360	100	38.46	1110
			100		385	125	48.00	1135
			125		410	150	57.70	1150
2	22.4	224	25	285	310	86	38.40	1040
			50		335	111	49.70	1060
			75		360	136	60.70	1080
			100		385	161	71.85	1080
			125		410	186	83.40	1070
3	19	190	10	285	295	105	55.27	980
			20		305	115	60.53	1000
			25		310	120	63.15	995
			50		335	145	76.30	970
			75		360	170	89.50	960
			100		385	195	102.63	950
			125		410	220	115.80	945

TABLE NO. 8

Fuels used	Weight of Metals in lbs.	Melting time in minutes	Total fuel consumption
Solid (coke)	70	90	100 pounds
Liquid* (Diesel)	70	70	3½ gallons
Natural Gas(Titas)	70	60	2100 cu.ft.

* Data taken from Foundry Section, B.U.E.T., Dacca.

TABLE NO. 9[7*]

100 cft. of gas (1000 Btu/cft.)	Equivalent (Thermal)
Price	6.5 gallons of Furnace Oil
For Industry Tk. 2.92 for 1000 cft.[x]	6.1 gallons of Diesel Oil 6.1 gallons of Kerosine Oil 6.1 gallons of Petrol
For Power Generation Tk. 1.60 for 1000 cft.[x]	91.7 pounds of Indian Coal 177.4 pounds of Wood.

[x] Includes Tk. 0.40 per 1000cft. as Govt. Excise Duty.

TABLE NO. 10

Name of the furnace	Cost per heat in Taka	Ratio of Cost
Coke fired pit furnace	$\frac{13 \times 100}{80} = 16.25$	2.65
Gas fired pit furnace	$\frac{2.92 \times 2100}{1000} = 6.132$	1.00

CHAPTER - VI

CONCLUSION

A coke fired pit furnace was successfully converted to a gas fired furnace. As much as 70 pounds of metal was melted and excellent fluid metal was obtained for sound casting with 60% excess air. The zone of maximum temperature varied with air/fuel ratio and gas velocity and was found to be at a height of 25 inches from the bottom of the furnace. A maximum combustion temperature of 1200°C was attained with air-gas ratio of 16:1 i.e., 60% excess air.

The heating time was less for gas fired furnace for the same charge. In melting 70 pounds of metal, gas fired furnace required 60 minutes whereas in the coke fired furnace it took 90 minutes. The cost ratio of gas fired and coke fired operation comes to 2.65:1.

The overall economic consideration advocates the conversion of coke fired to gas fired operation.

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