IS 15562 (2005): Design and construction of fuel fired bogie hearth type heat treatment furnaces - Guidelines [MTD 26: Industrical Fuel Fired Furnaces]

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भारतीय मानक

ईंधन तप्त इंजिन टाइप ऊष्मा उपचार भट्टी का डिजाईन और निर्माण — दिशानिर्देश

Indian Standard

DESIGN AND CONSTRUCTION OF FUEL FIRED BOGIE HEARTH TYPE HEAT TREATMENT FURNACES — GUIDELINES

ICS 25.180

BUREAU OF INDIAN STANDARDS
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Industrial Fuel Fired Furnaces Sectional Committee, MTD 26

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Industrial Fuel Fired Furnaces Sectional Committee, had been approved by the Metallurgical Engineering Division Council.

A bogie hearth or car bottom type furnace is the most widely used batch type furnace for heating and heat treatment of a variety of metallic and non-metallic products.

Main reasons for selection of bogie hearth furnace are:

a) Capability to handle various sizes and shapes of products.

b) Ease of handling such products.

c) Techno-economically found advantageous with respect to both operation and maintenance.

d) Double ended version with one additional bogie can ensure operation almost on a continuous basis and eliminate loss of time due to loading and unloading.

This standard is prepared to cover bogie hearth furnaces needed for heat treatment of cast, forged and fabricated metallic products under air atmosphere. Such furnaces may also be designed and built to operate under protective atmosphere, if considered essential, for the heat treatment process.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

DESIGN AND CONSTRUCTION OF FUEL FIRED BOGIE HEARTH TYPE HEAT TREATMENT FURNACES — GUIDELINES

1 SCOPE

This standard covers requirements for bogie hearth type heating and heat treatment furnaces.

2 REFERENCES

The following standards contain provisions which through reference in this text, constitute provisions of this standard. At the time of publication the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below :

IS No.	*Title*
6 : 1983	Specification for moderate heat duty fireclay refractories Group 'A' (*fourth revision*)
8 : 1994	High heat duty fireclay refractories (*fifth revision*)
210 : 1993	Grey iron castings — Specification (*fourth revision*)
1030 : 1998	Carbon steel castings for general engineering purposes (*fifth revision*)
1875 : 1992	Carbon steel billets, blooms, slabs and bars for forgings (*fifth revision*)
1977 : 1996	Low tensile structural steels — Specification (*third revision*)
2042 : 1972	Insulating bricks (*first revision*)
2062 : 1999	Steel for general structural purposes — Specification (*fifth revision*)
3355 : 1974	Grey iron castings for elevated temperatures for non-pressure containing parts (*first revision*)
4522 : 1986	Heat resistant alloy steel and nickel base castings (*second revision*)
6911 : 1992	Stainless steel plate, sheet and strip (*first revision*)
8154 : 1976	Preformed calcium silicate insulation (for temperature up to 650 °C) (*first revision*)
8183 :1993	Bonded mineral wool (*first revision*)
8849 : 1991	Glossary of terms relating to fuel fired industrial furnaces (*first revision*)

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 8849 shall apply.

4 DESIGN CONSIDERATION

4.1 Charge Dimension and Unit Weight

Size, shape and weight of individual charge pieces and the number of pieces to be charged/arranged on the hearth per batch load should be decided.

4.2 Handling of Charge Material

Material to be heat treated may be loaded or unloaded either manually or with the help of a mechanized device. Charge pieces, if large, can be placed directly on refractory hearth. Small components for heat treatment are usually charged/arranged in containers/ fixtures.

4.3 Useful Internal Dimensions of the Furnace

These dimensions are to be decided on the basis of charge dimensions, arrangement of charge pieces on hearth for uniform heating and the free space to be provided from circulation of the products of combustion (POC) around the charge before leaving the furnace. Typically, the length of the hearth should be at least two times its useful width.

For ease of charge loading/unloading, height of the bogie hearth (top of the refractory lining) should be 900 mm to 1 000 mm from shop floor level. Guideline data indicating internal dimensions of the furnace based on nature and loading pattern of charge stock are furnished in Table 1.

4.4 Operating Temperature

Up to 750-800°C operating temperature, provision for re-circulation of products of combustion (POC) by way of selecting appropriate burner system (excess air firing/high velocity burner) would be desirable for better convective heat transfer. For operating temperature beyond 800°C, radiation being predominant, suitable combustion equipment should be selected.

Table 1 Guideline Data for Internal Dimensions of the Bogie Hearth Furnace

(*Clause* 4.3)

Sl No.	Internal Dimension	Compact Loading of Charge Stock on Hearth	Charge Stock Like Welded Vessel Placed Loose on Hearth
(1)	(2)	(3)	(4)
i)	Length, m	Up to 15	Up to 30
ii)	Width, m	Up to 4	Up to 7
iii)	Height, m	Up to 4	Up to 7
iv)	Hearth surface area, m^2	Up to 50	Up to 160
v)	Inner volume of furnace, m^3	Up to 100	Up to 1 000
vi)	Loading/batch, t	Up to 200	Up to 200
vii)	Specific hearth loading, t/m^2	Up to 4	Up to 4

For operating temperature limit of maximum 500-550°C, indirect heating can be opted along with provision of effective re-circulation of POC by means of suitable fan.

4.5 Rate of Temperature Rise

Selection of suitable burners, their placement and combustion control system should take into account the desired maximum and minimum rate of temperature rise and also the rate of cooling inside the furnace, if called for, by the heat treatment process.

4.6 Connected Heat/Fuel Load in kcal/h

Requirement of heat or fuel usage should be calculated based on:

a) Maximum charge load/bath,

b) Operating temperature,

c) Heating rate,

d) Summation of various losses through inner lining, leakages through gaps around door/ openings and between fixed and moving hearth, and

e) Heat loss through the flue gas leaving the furnace.

Connected fuel load of the furnace should be about 20 percent more than the calculated fuel usage.

5 CONSTRUCTIONAL FEATURE

The bogie hearth or car bottom type heat treatment furnace include following two basic arrangements:

a) Fixed or stationary part of the furnace, and

b) Moving (bogie hearth or car bottom) part of the furnace which normally moves over a pair of rail.

5.1 Furnace Casing

Mild steel plate of at least 5 mm thickness duly reinforced with mild steel sections conforming to IS 1977 or IS 2062 should be used for the construction of furnace casing. Selection of size and placement of such steel sections are primarily based on the dimensions of the furnace and the type of its construction. Bottom support plate for the fixed portion of the furnace hearth should be 8 mm thick mild steel plate conforming to IS 1977 or IS 2062.

5.2 Structurals for the Bogie

Structurals for the bogie consist of the base plate, preferably of 8 mm thickness, and a rigid framework with steel sections conforming to IS 1977 or IS 2062. In order to protect this under-structure from conducted heat, it is advisable to maintain an air gap of approximately 100 mm between the base plate and the structural frame work by putting steel sections as inserts. Furnace with total bogie, length not exceeding 4 000 mm base support frame, can be fabricated as one rigid structure mounted on two pairs (four numbers) of wheel and bearing.

Where the total length of the bogie exceeds 4 000 mm, it is recommended that the bogie structure support frame should be fabricated in segments which are bolted/ welded to a single rigid construction. Each segment is provided with two pairs (four numbers) of wheel bearing assembly. This will ensure proper alignment and uniform loading of bogie under-structure and the wheels on the rails. This will also allow absorption of shock due to load impact and expansion of understructure due to variable heat and load conditions.

5.3 Hearth Support Wheels

Support wheels may be either cast or forged steel conforming to IS 1030 or IS 1875 duly annealed, machined and rim hardened to about 280-320 BHN. Depending upon the load connection envisaged on individual wheels, shock/impact during loading/ unloading, size of wheel/bearing/shaft, etc, should be selected.

5.4 Rails for Bogie Movement

Sleepers (mild steel channel) conforming to IS 2062 should be grouted on shop floor (foundation) at intervals to support a pair of rails to enable bogie movement in and out of the furnace. Depending upon the load concentration envisaged on individual wheel and bearing assembly, standard rails of 30-45 kg/m size may be selected.

5.5 Castings

Cast parts being more resistant to wear due to heat are used to cover areas around door openings, sand troughs and dipper plates for sealing the gap between the fixed and moving part of the furnace. Curb angles around the periphery of the bogie and fixed hearth, which act as retainer for the refractory lining work, should be made of cast iron or heat resistant cast iron. Selection of the grade of castings to cover the above stated areas of both fixed and moving hearth will depend on the operating temperature of the furnace and the extent of exposure with maximum operating temperature of 650-700°C, cast iron conforming to grade FG 200 of IS 210 may be used. Above 700 °C and up to 1 000 °C operating temperature, heat resistant cast iron conforming to IS 3355 may be used.

5.6 Door

Vertical rise and fall type suspended door, normally counter weighted and operated by a motorized drive mechanism (small doors can be manually operated) is commonly used. For sealing the gap around the door periphery, sand troughs or fibre/asbestos packed mountings can be provided. For large size doors, clamps, either manually or pneumatically operated, can be provided for better sealing. For small single ended bogie hearth furnace, door could be constructed fixed on to the moving bogie, if otherwise, not found inconvenient.

5.6.1 *Accessories for Door Support Movement*

Standard accessories include link or roller chain, appropriately sized pulleys, sprockets, bearing blocks and shaft in addition to structurals for door mast, support beam, etc.

5.6.2 *Mechanized Door Drive*

Door operation may be mechanized by means of electrodrive or hydraulic/pneumatic cylinders with limit switches, etc, and generally designed for a door operating speed of 2 m/min. Door drive mechanism can either be placed on shop floor for ease of maintenance or on door mast at an elevated level with accessibility for maintenance.

5.7 Drive/Haulage Mechanizm for Moving Bogie Hearth

For smaller furnace with maximum hearth loading of 4-5 t per batch, steel wire rope ties at the front and back (over a pulley) of the bogie hearth and wound around a winch to be rotated manually can be used. For bogie hearth with larger batch loading capability, following commonly adopted motorized drive/haulage mechanism can be recommended.

5.7.1 *Rope and Drum Type*

Steel wire rope wound around the rope drum is driven by an electric motor through reduction gear unit, electromagnetic brake, cutoff limit switches, etc. Two ends of the steel wire rope would be ties at the front and rear (over a pulley) of the moving bogie hearth. Normally, the haulage speed of such a mechanism is recommended as 3-4 m/min.

5.7.2 *Rack and Pinion Type*

Cast or fabricated rack would be fitted underneath the bogie structure and is meshed with a cast and heat treated wheel pinion is driven (rotated) by an electric motor, reduction gear unit, electromagnetic brake, cutoff limit switches, etc. Such a drive mechanism is suitable for higher haulage speed of up to 10 m/min. For high haulage speed, however, suitable control to achieve acceleration and deceleration during bogie movement is recommended.

5.8 Inner Lining of the Furnace

Generally, heat treatment furnace should be lined inside with low thermal mass type, that is, less dense refractory and insulation material to minimize heat storage by the inner lining. Actual configuration of inner lining will be decided on the basis of maximum operating temperature and the operating practice desired by the heat treatment shop. For a furnace with 800 to 1 000°C maximum operating temperature, typical lining configuration is suggested below as guideline.

5.8.1 *Burner Blocks*

Can be prefired, dense quality shapes containing 35-58 percent alumina (Al_2O_3) or shapes made out of suitable quality refractory castable duly cured for attaining required bonding and strength. For installation of burner blocks, instruction furnished by the burner manufacturer should be followed.

5.8.2 Areas around the burner block can be lined with either IS 8 Grade 1 quality firebricks or suitable quality refractory castable.

5.8.3 Fixed portion of the furnace hearth and the lower part (approximately 250-300 mm high from hearth top) of the side wall all around should be lined with IS 8 Grade 1 firebricks duly backed by hot and cold face insulation bricks similar to IS 2042 Type 1 and Type 2 quality should be used primarily to withstand any possible impact during loading/unloading of charge material.

5.8.4 *Side Walls*

Either conventional lining with refractory/insulaltion bricks or with ceramic fibre blankets could be used. The thickness of lining should, however, ensure skin temperature within 45°C above ambient for Alternative 1, and 35°C for Alternative 2.

Sl No. *Alternative* 1

i) 230 mm thick insulating firebricks

ii) 115 mm thick cold face insulation to IS 2042 Type quality insulation bricks

iii) 40 mm thick insulating block

Sl No. *Alternative* 2

i) 25 mm thick 1 260°C grade 128 kg/cm³ density ceramic fibre blanket

ii) 50 mm thick 1 260°C grade 96 kg/cm³ density ceramic fibre blanket

iii) 50 mm thick 1 260°C 64 grade kg/cm³ density ceramic grade blanket

iv) 75 mm thick mineral wool blanket

5.8.5 *Furnace Roof*

For a furnace having internal width of 2 000 mm the arch type roof can be constructed with 230 mm thick insulating firebricks backed by 115 mm cold face insulation bricks conforming to IS 2042 Type 2 insulating bricks and 25 mm thick layer of insulating castables.

5.8.5.1 *Suspended type furnace roof construction*

Furnace with relatively larger internal width above 4 000 mm, suspended type roof construction is preferred to ensure higher stability and life of roof refractory lining. For furnace having side walls lined with ceramic fibre blanket (Alternative 2 *see* **5.8.4**) suspended type roof construction with ceramic fibre blanket would be considered advantageous. Following alternative lining configuration can be suggested as guideline. High tolerance in the skin temperature measured on furnace roof can be allowed, depending upon the design/construction for Alternative 1 the skin temperature should be 60°C above ambient temperature whereas for Alternative 2 the same should be within 45°C above ambient temperature.

Sl No. *Alternative* 1

i) 175 mm thick special shape bricks of IS 8 Type 1 quality to be suspended at intervals by special shape hanger bricks of same quality

ii) 75 mm thick cold face insulation bricks conforming to IS 2042 Type 2 quality

iii) 75 mm mica/vermiculite base insulation bricks

iv) 25 mm thick layer of insulating block

Sl No. *Alternative* 2

i) 25 mm thick 1 260°C grade 128 kg/cm³ density ceramic fibre blanket

ii) 50 mm thick 1 260°C grade 96 kg/cm³ density ceramic fibre blanket

iii) 50 mm thick 1 260°C grade 64 kg/cm³ density ceramic fibre blanket

iv) 75 mm thick mineral wool blanket

5.8.6 *Bogie Hearth*

Curb/retainer blocks for the hearth refractory lining all around should be special shape of IS 8 Type 1 quality firebrick. Depending upon the size/shape of charge pieces and method of loading/unloading, IS 8 quality refractory support blocks or piers may have to be provided. As guideline, following typical lining configuration can be suggested :

a) 150 mm thick IS 8 Type 1 quality firebrick,

b) 75 mm thick hot face insulation brick similar to IS 2042 Type 1 quality,

c) 150 mm thick cold face insulation brick similar to IS 2042 Type 2 quality, and

d) 40 mm thick insulating block.

Tolerance limit for skin temperature measured under the hearth lining support plate can be 60°C above ambient temperature.

5.8.7 *Door*

Either conventional with refractory/insulating bricks or with ceramic fibre blanket can be recommended.

Sl No. *Alternative* 1

i) 115 mm thick insulating firebricks

ii) 115 mm thick cold face insulation bricks conforming to IS 2042 Type 2 quality or mica/vermiculite base insulation bricks

iii) 40 mm thick insulating block

Sl No. *Alternative* 2

i) 25 mm thick 1 260°C grade 128 kg/cm³ density ceramic fibre blanket

ii) 50 mm thick 1 260°C grade 96 kg/cm³ density ceramic fibre blanket

iii) 75 mm thick mineral wool blanket

5.8.8 *Passage for Escape of the Flue Gases*

For the escape of flue gases (POC) from the furnace, either single or multiple flue ports would be provided in the inner lining of the furnace. Areas around such flue openings are usually lined with IS 8 Type 1 quality firebricks duly backed with insulation bricks in case of conventional refractory lining furnace. For the escape of flue gases beyond the furnace, either underground passages will be provided or steel encased ducts to be constructed above the mill floor. These would normally be lined inside with firebricks conforming to IS 6 quality duly backed by a layer of insulation bricks and building quality red bricks.

Chimney/stack would normally be lined inside with firebricks similar to IS 6 quality backed by refractory/ grog (broken bricks) wherever considered necessary.

6 BURNERS

For achieving desired rate of temperature rise and temperature uniformity for heat treatment process, selection of burners for firing fuel oil or gas is considered extremely important.

Heat treatment furnaces generally call for operation at varying temperatures throughout the cycle and also operate often with reduced loading. Hence, fuel demand will be less during major portion of the heat treatment cycle. Since the selection of burner capacity must be based on the fuel requirement at maximum temperature and loading, the combustion system must turndown during lower demand. To compensate corresponding loss in burner velocity and thus also the penetration capability of furnace atmosphere and uniform distribution of heat throughout the load being heat treated, firing of burners with excess air is common for heat treatment furnaces. High velocity burners with excess air firing capability would therefore be commonly selected. Excess air firing, will, of course, increase fuel consumption.

Burners are selected based on available fuel (oil or gas), fuel oil grade, type of fuel gas (also cleanliness and calorific value of gas) and the temperature or air for combustion. Accordingly, burners can be chosen exclusively for oil firing, gas firing or combination burner for firing either oil or gas as fuel.

Burners with excess air firing capability and high velocity burners are considered advantageous for heat treatment operation. In the event, preheated combustion air or fuel gas would be used, burners selected should be suitable for the same.

6.1 Oil Burners

Low medium air pressure oil burners in which atomizing and combustion air have separate piping and maintain stable flame, even with excess air firing, should be used. As a compromise, self-proportioning oil burners with single air inlet may also be used.

6.2 Gas Burners

Nozzle mixing gas burners in which combustion air and fuel gas are kept separate within the burner itself, but the nozzle orifices are designed to provide mixing of fluids as they leave the burner are considered more suitable for heat treatment process. Such burners have high excess air firing capacity and high velocity.

6.3 Oil and Gas Combination Burners

Periodic changes in the supply of fuel as well as price picture may sometime call for changing of fuels. Hence, combination burners for firing either fuel oil or fuel gas are also available for selection.

6.4 Burner Lighting-Up

Every burner should have a pilot ignition and an observation port so that the main flame can be seen by the operator. The pilot ignition port may be used for lighting up the burner manually by a hand held torch.

Alternatively, burners can be provided with automatic light-up system either by a pilot flame using LPG/ natural gas or spark ignited light oil pilots. Direct electric ignition of burner main flame is also used. Figure 1 illustrates a typical gas fired pilot flame ignition system for nozzle mixing gas burners. For sake of overall safety, interrupted type pilot should be used.

7 SUPPLY OF AIR

For complete combustion of either fuel oil or fuel gas, required volume of air should be provided to the burners. In case of oil firing, this total volume of air would include required volume of air for bath atomization and combustion of the fuel oil. In case of fuel gas firing, the total air to be supplied is for the purpose of combustion of the fuel gas. As guideline for determining the theoretical air requirement for complete combustion of fuel oil or fuel gas, if may be mentioned that for every 890 kcal heat release 1 m^3 of air would be necessary to ensure complete combustion of the fuel.

7.1 Combustion Air Supply

In case of low/medium pressure oil burners and nozzle mixing gas burners, it is necessary to provide a blower motor unit for supplying total quantity of air required for the combustion of fuel oil or fuel gas. Based on the type of fuel to be used (oil or gas) and its pressure required at the burner, the pressure rating of the blower may vary between 600-1 000 mm W.C. depending upon the recommendation of the burner supplier. The overall volumetric capacity of the combustion air blower should be 30 percent higher than the theoretical air requirement.

Use of recuperators will increase the combustion air blower pressure by 100-250 mm.

7.2 Atomizing Air Supply

For low/medium pressure air atomized burners, the air for atomizing the fuel can be supplied by a common blower for providing both atomized and combustion air or by two separate blowers. The delivery pressure of the blower should be selected to ensure correct atomizing and combustion air pressure at the burner inlet.

8 FUEL SUPPLY SYSTEM

For supply and distribution of fuel oil or fuel gas to individual burners, a network of piping interconnecting the source of supply in the heat treatment shop and individual burners in the furnace would be necessary. Fuel to the burner should always flow through suitable filters. It is recommended that in case of heavy fuel oil, requiring heating, filter to be provided after every heating stage.

8.1 Fuel Oil Supply and Preparation Unit

To ensure efficient combustion, it is necessary that the fuel oil is supplied to the burners through a ring main uniformly and at constant pressure. For this, the viscosity of the available fuel is important. For efficient atomization, viscosity of the fuel oil should be in the range of 80-100 seconds on Redwood I scale. Figure 2 illustrates a schematic piping network for fuel oil and air to a low air pressure sealed in type oil burner including an oil preparation unit in the system. For light distillate fuel oils, a composite fuel oil pumping unit (without heating) can be used. For heavy grade furnace oil and LSHS fuel oil, a composite heating cum pumping unit should be used. In addition, out flow heaters in the day tank and heat tracing of distribution piping network (in case of LSHS fuel oil) may be necessary besides other precautionary measures like flushing the ring main system with light oil before shutting off the burner.

8.2 Fuel Gas Supply System

Fuel gas supply pipeline to the heat treatment shop will have an outlet with isolating valve for the furnace. Generally, fuel gas is made available at higher pressure than required and hence it is necessary to use pressure regulating valve to ensure that gas pressure at the burner will remain constant irrespective of the flow rate of the gas. Figure 1 illustrates a schematic piping network for supply of fuel gas to a nozzle mixing gas burner.

9 FUEL GAS EXHAUST SYSTEM

To ensure temperature uniformity inside the furnace, it is also necessary to allow the escape of flue gases out of the furnace (*see* **8.2**) in a controlled manner over and above ensuring adequate circulation through the burner firing system.

9.1 Stack/Chimney

To include a natural draft or pressure difference necessary for pulling the flue gases out of the furnace, a stack/chimney of adequate height can be provided. Depending upon the diameter and height of such a chimney, it can either be self supporting or supported from stop columns.

9.2 Damper in the Flue Passage

To regulate and control the flue gas flow through the stack/chimney and ensure a positive pressure inside the furnace chamber, a damper is commonly provided in the flue passage connected to the stack/chimney. Depending upon the maximum flue gas temperature, such dampers can either be alloy steel fabricated conforming to Grade X 02Cr19Ni10 of IS 6911 or cast alloy steel conforming to IS 4522.

10 RECUPERATOR

Depending upon the operating temperature, time-temperature cycle to be followed for the heat treatment process and the required continuity of furnace operation, it would be necessary to decide whether or not a recuperator to preheat the combustion air will be techno-economically desirable. Accordingly, the burner and control system will be selected.

During heat treatment process, the volume of air and flue gas as well as the temperature of flue gas may vary widely. Hence, the extent of air preheat through recuperator may also vary between 150-400 °C.

Exit flue gas temperature being generally low in a heat treatment furnace, a tube type convective recuperator, suitably designed for incorporation in the flue passage leading to the chimney (before the damper) can be recommended. Incorporation of a recuperator will generally call for an appropriate protective device in the control/instrumentation system.

11 OUTPUT AND SPECIFIC FUEL CONSUMPTION

Furnace efficiency or output rate with respect to specific hearth output (kg/m^2 . h) and heat requirement (specific fuel consumption in kcal/kg) will primarily depend on the heat treatment cycle being followed. Accordingly, these values are to be calculated and agreed upon mutually based on a specified time-temperature cycle for heat treatment.

12 CONTROL/INSTRUMENTATION

In a conventionally followed combustion control system other than in a pulse fired system which allows controlled and sequential firing of individual burners all the burners in a giving zone are controlled simultaneously in unison and at different turndown condition throughout the heat treatment cycle.

In order to achieve uniform heating of charge within specified tolerance limit, optimum utilization of fuel being used and also to safeguard trouble-free operation of the furnace, following loop functions are required to be controlled/monitored. Type and extent of instrumentation should be based on the nature of heat treatment process, furnace size, fuel being used and the selected firing equipment (burners/accessories) .

12.1 Furnace Temperature

Depending upon the internal length/width of the furnace, number and arrangement (placement) of burners in the furnace, measurement and controlling of temperature may have to be carried out in one or more independent control zones. For furnace having internal length of 2 000 mm or less, heat input through burners and furnaces temperature can be controlled in a single zone. For heat treatment furnace up to 1 000 °C maximum operating temperature, Ni-Cr/Ni-A1(Chromel-Alumel) thermocouples can be used for sensing measurement of temperature. The thermocouple tip should project inside the furnace by about 100 mm from refractory hot face. Depending upon the time temperature cycle to be followed for the heat treatment process, the thermocouple may be connected to a temperature controller (ON-OFF)PI/PID type, at option with programmer attached to the controller, which may operate the valve actuators to regulate the flow of fuel and air to the burners.

12.2 Fuel/Air Ratio

For optimum furnace performance, it is essential that the ratio of fuel to air is maintained at the desired level. Fuel/Air ratio can be controlled in three different ways as given in **12.2.1, 12.2.2** and **12.2.3.**

12.2.1 *Area Control*

This is achieved by use of constant pressure and variable areas. A simple mechanism can be used to cause the areas of fuel and air valves to vary in proportion to one another. This requires that the two valves with identical (or known) flow characteristics are mechanically linked to produce directly proportional movement.

12.2.2 *Pressure Control*

The system works on the principle of constant areas and variable pressure. The flow through a constant resistance is proportional to the square root of the pressure different across that resistance. Therefore, if the fuel and air pressure are kept equal (or proportional) then the fuel and air flow rates should be proportional throughout the entire firing rates.

This is more accurate than the area control system and adaptable to different arrangements like oil/air ratio or gas/air regulator, etc (for illustration *see* Fig. 1 and Fig. 2).

12.2.3 *Mass Flow Control*

In case of preheating of combustion air or fuel gas, their volume will change with the change in their temperatures. In a mass flow ratio control system, compensation for changing temperature is added to the basis fuel/air ratio control module to take care of the changing mass and the flow rates of fuel and air will be separately regulated through a separate ratio controller in which the desired fuel/air ratio can be preset.

In addition to fuel economy, incorporation of a proper fuel/air ratio control system will ensure other benefits like less pollution, better safety, improved temperature uniformity and product quality.

12.3 Furance Pressure

Uncontrolled furnace pressure may affect the air/fuel ratio and cause wastage of fuel. In order to obtain and maintain a positive pressure (over temperature pressure) inside the furnace, the damper in the fuel passage connecting the chimney can be operated either manually or through an automatic pressure control system comprising of a sensor, pressure transmitter, PI type controller and an actuator to operate the damper. Furnace pressure can either be indicated or continuously recorded through an indicator or recorder.

12.4 Fuel Flowmeter

To keep a close control over the fuel oil or fuel gas fed to the furnace, on oil or gas flow meter can be incorporated. By obtaining proper flow signal, the fuel flow can also be integrated and totalized in a multi-zone control system.

12.5 Gas Analyzer

Exit flue gas from the furnace should be analyzed preferably once in every operating cycle with portable gas analyzer to ensure correct combustion condition inside the furnace.

12.6 Temperature Recorder

The furnace should be provided with a system of continuous recording of temperature either through a single or multipoint temperature recorder, depending upon its size and number of independent temperature control zones.

12.7 Recuperator Protection

In the event, a recuperator is used for preheating the combustion air, a suitable protection device against accidental overshooting of recuperator element temperature should be incorporated. The protection device generally comprise of thermocouple to measure the temperatures of flue gas entering the reccuperator and temperature of preheated air, suitable controllers, dilution air line, motorized flow control valve in the dilution air line, motorized bleed off valve in the preheated combustion airline, etc.

12.8 Alarm/Annunciation of Faults

Audio-visual alarm/annunciation system to indicate faults like accidental overshooting of temperatures, loss of pressure in utility flow, etc, with automatic shut off can be incorporated.

Instead of using individual stand alone controllers and recorders to control/monitor above stated process loops, a programmable logic controller (PLC) can also be used, if desired in a furnace with multizone control system.

13 SAFETY CONTROLS

13.1 The objective of a combustion safety system is to stop the flow of fuel if the flame should suffer such a condition that it might get extinguished as otherwise the furnace (or the entire building) may be filled with an explosive mixture of fuel and air. It is, therefore, advisable to incorporate safety controls to interrupt fuel supply in the event of :

a) low atomizing air pressures and supply in case of liquid fuel firing,
b) low and high fuel pressure,
c) low and high fuel temperature,
d) power failure, and
e) failure of any safety interlocks in safeguarding the process parameters.

Usually manual reset type valves are used for automatic shut off of fuel supply. Such valves will not open on their own but will have to be manually reset for opening upon restoration of operating condition.

13.2 Since the operating temperatures in heat treatment furnaces are low and varying, it is advisable to install UV type flame monitoring device with the burner. For gas firing, it may also possible to use flame rod.

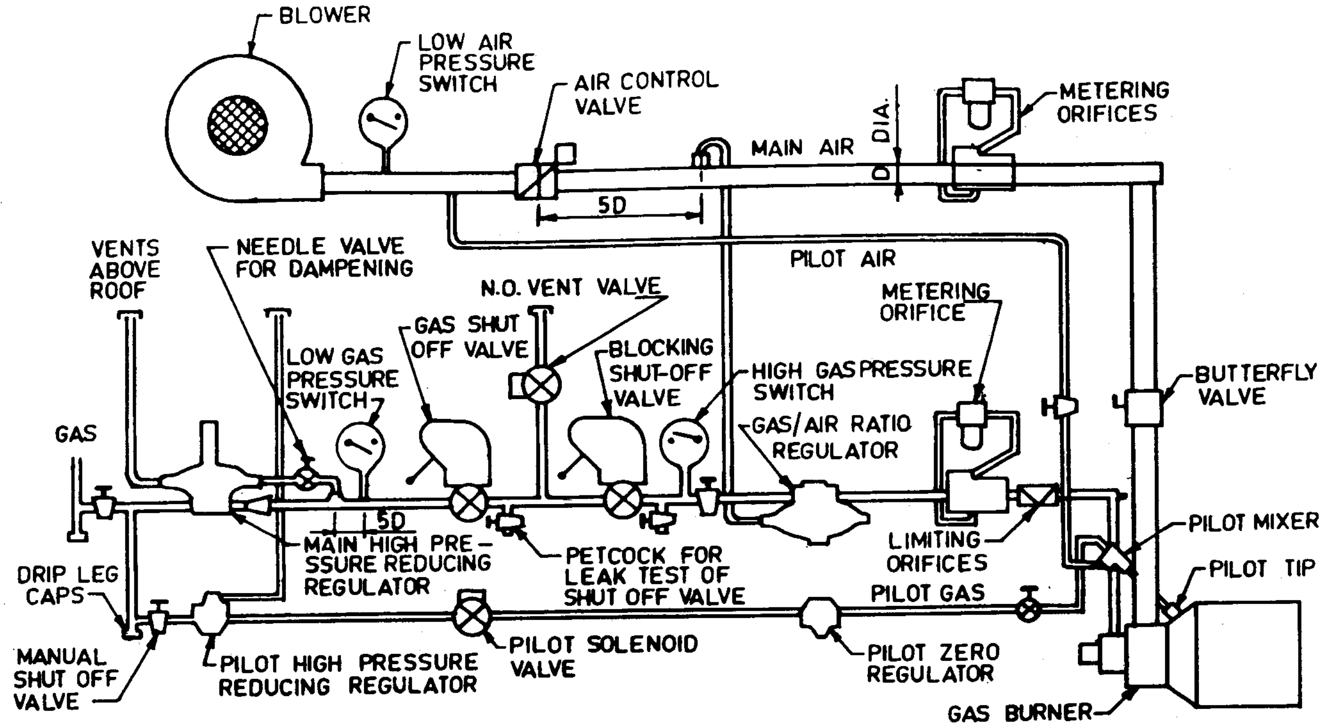
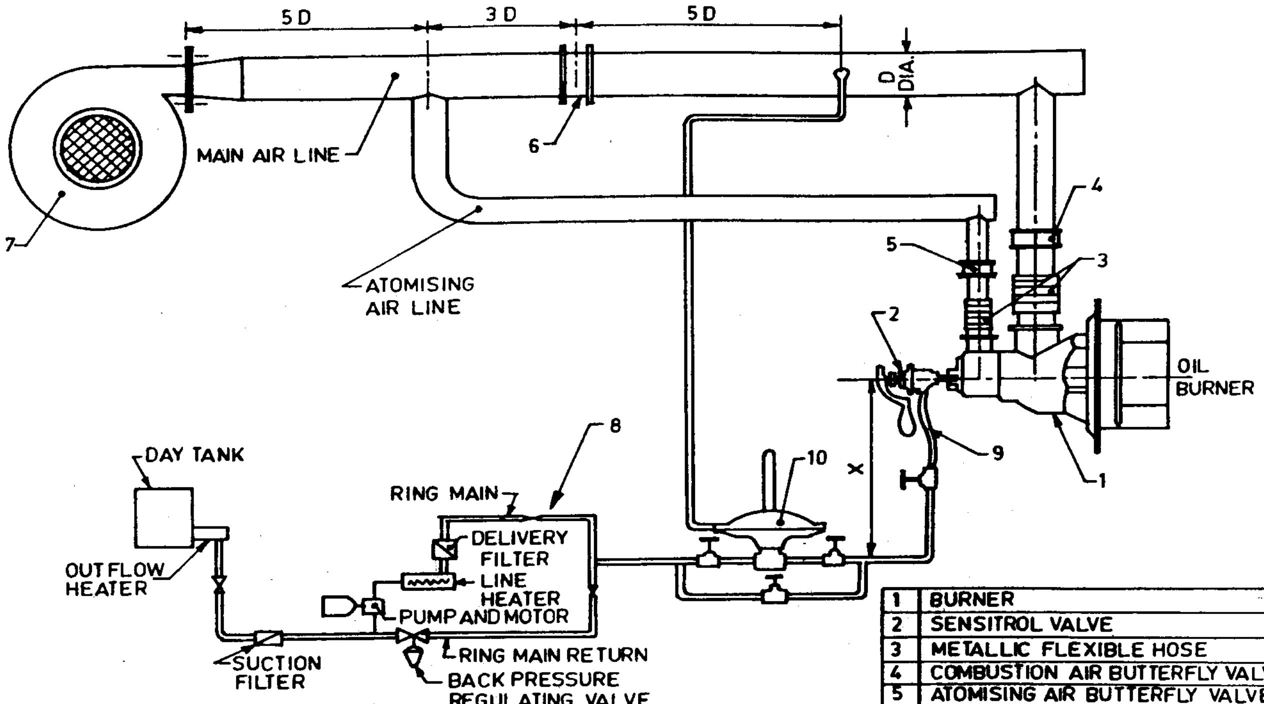


FIG. 1 SCHEMATIC DIAGRAM OF AIR AND GAS PIPING FOR BURNER WITH AIR/GAS REGULATOR AND AUTOMATIC GAS PILOT IGNITION SYSTEM



NOTE:
1. OIL PIPE LINE DEAD LEG SHOULD BE MINIMUM
2. X - SHOULD NOT BE MORE THAN 12"

1	BURNER
2	SENSITROL VALVE
3	METALLIC FLEXIBLE HOSE
4	COMBUSTION AIR BUTTERFLY VALVE
5	ATOMISING AIR BUTTERFLY VALVE
6	ZONE AIR CONTROL VALVE
7	COMBUSTION AIR BLOWER
8	HEATING AND PUMPING UNIT
9	FLEXIBLE HOSE
10	AIR AND OIL RATIOTROL

FIG. 2 SCHEMATIC DIAGRAM OF AIR AND OIL PIPING WITH OIL/AIR RATIO REGULATOR

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