WELCOME

BOILER MAINTENANCE

BOILER MAINTENANCE

1.0 INTRODUCTION

1.1Background

- Maintenance is derived from the word "maintain" which has the following meanings ; carry on, preserve, support, sustain, keep up and keep supplied

1.0 INTRODUCTION

- For boiler system, it means :-
  - to ensure safe operation by regular inspection
  - to keep the boiler in operation
  - to keep the boiler in operating condition
  - to restore boiler efficiency
  - to repair the damaged parts and keep it tight
  - to clean the boiler

1.2 Maintenance Objectives

- From the definition, boiler maintenance is any work done on the boiler system so as to meet certain objectives. These objectives are :-
  - to keep the boiler in operation so as to meet the design load
  - to maintain full reliability and maximize availability by zero unplanned down time and optimize planned down time
  - to meet safety and regulatory requirements

1.3 Types of Maintenance (Generic)

Type	***Rate***	***Requirement***
1. Routine	**Daily, Weekly, Monthly or Yearly (incl. regulatory inspection)**	**Require Procedure and Instruction including record keeping**
2. Predictive	**depend on plant maintenance philosophy and program**	**Requires special tool or program i.e. RBI, CBM**
3. Preventive	**depending on O & M requirements**	**Regular inspection and test during operation or shutdown**
4. Reactive (Corrective)	**when boiler system fail and damage**	**May require stock of part and external expertise**

2.0 BOILER MAINTENANCE PROGRAM

2.1 Background

- To ensure boiler system is continuously reliable, special planned program for maintenance must be set up.
- In general, the program should consists of the following basic items;
  - Written inspection and overhaul procedure
  - Maintenance scheduling inclusive planned, predictive & preventive

2.1 Background (cont.)

- Equipment database inclusive histories, lesson learnt.
- Spare part inventories.
- Personnel training for competency.
- Equipment improvement planned.

2.1.1 Inspection and overhaul procedure

- A procedure or instruction can be usually being designed for each of the following operations during overhauls;
  - Equipment in service prior to overhaul.
  - Equipment out of service.
  - Equipment in service following an overhaul.
- Overhaul can be divided into two types;
  - Partial - usually confine to rotation or reciprocating equipment.

2.1.1 Inspection and overhaul procedure (cont.)

- Complete - complete dismantling performed to examine every possible cause of future equipment failure or to verify the capability of the equipment to perform its function.

- Inspection can be made during normal operation to check performance as it may indicate physical condition.

2.1.2 Maintenance scheduling

- The schedule should include a comprehensive maintenance and equipment activities.
- The schedule must be take consideration on production requirements, equipment capability, operating experience and equipment performance.
- Schedule must flexible and intervals between inspections should be subject to constant review.

2.1.3 Equipment database

- The database is to make available the information required to determine equipment maintenance performance and charting the maintenance program for the specific equipment.
- SAP system in Petronas is one of example of implementation.

2.1.4 Spare parts inventories

- The equipment database should list the major parts repaired or replaced during an overhaul so that spare parts inventories can be intelligently reviewed and spare parts kept to a reasonable minimum.

2.1.5 Personnel training for competency

- Training for operation and maintenance personnel is required to be able plant to recognized, identify and report any indication of impending equipment failure. So that, unscheduled down time can be avoided.
- Any indication of failure must be addressed for immediate action but also as bases for future overhauls.

2.1.6 Equipment improvement planned

- Every overhaul, an effort must be made to improve any inherent equipment defects i.e. by a change of material, lubrication, environment, temperature or any other means. Changes must be justified economically or in the interests of safety.

3.0 GENERAL MAINTENANCE CHECKS, INSPECTION & EXAMINATION

Problem	Method of Measuring	Possible Causes
Dimensional Changes	Measure important dimensions Measure weight of component Measure clearance	Erosion Corrosion Abrasive wear Permanent deformation due to over-stress Cavitation Substandard material

3.0 GENERAL MAINTENANCE CHECKS, INSPECTION & EXAMINATION

Problem	***Method of Measuring***	***Possible Causes***
Distortion	Measure important dimensions	obstructed expansion Overheating & unequal expansion Over-stress Substandard material Poor design

3.0 GENERAL MAINTENANCE CHECKS, INSPECTION & EXAMINATION

Problem	***Method of Measuring***	***Possible Causes***
Appearance of crack	After dye penetrate test, measure length of cracks and record its position Radiograph weld	Fatigue Thermal stress Water hammer Improper welding Poor design

3.0 GENERAL MAINTENANCE CHECKS, INSPECTION & EXAMINATION

Problem	Method of Measuring	Possible Causes
Deposits	photograph Sketch location of deposit Record results of chemical analysis	Incomplete combustion Dusty condition Rust deposit Upstream sootblowing deposit soot down stream

3.0 GENERAL MAINTENANCE CHECKS, INSPECTION & EXAMINATION

Problem	***Method of Measuring***	***Possible Causes***
High vibration level	Record vibration readings Record plant offsetand gap readings (for alignment) Measure clearance	Unbalance Misalignment Lack of clearance Lube oil property change Foundation setting

3.0 GENERAL MAINTENANCE CHECKS, INSPECTION & EXAMINATION

Problem	Method of Measuring	Possible Causes
Blockage	Record location of blockage Photograph	Accumulation of scales on steam side Failure of sootblowers Accumulation of soot Foreign matter Damaged strainer not replaced

3.0 GENERAL MAINTENANCE CHECKS, INSPECTION & EXAMINATION

Problem	Method of Measuring	Possible Causes
Sudden failure	Record events leading to sudden failure briefly	Wrong assembly No lubrication; water hammer Material failure

4.0 GUIDELINES ON BOILER MAINTENANCE ACTIVITIES

4.1 Furnace

- Inspection of the following parts :-
  - front wall tubes including the area of the burner
  - side wall tubes including peephole area
  - rear wall tubes including the boiler nose area
  - furnace floor area
- Water washing to remove deposits from all the walls

4.1 Furnace

- Repair the burner cell refractory
- Repair the furnace floor area
- Scaffolding erection in the furnace
- Cut the water wall tube for mechanical and chemical inspection
- Repair the water wall tubes
- Removal of fire bricks and refractory materials from furnace

4.2 Secondary Superheater and Reheater

- Inspection of the following :-
  - secondary superheater tubes
  - screen tubes
  - secondary reheater tubes
  - manhole and sootblower area
  - boiler roof
- Waterwashing of tubes
- Removal of slag - by mechanical or chemical means
- Replace or repair the tube

4.3 Heat Recovery Area

- Inspection of the following :-
  - Primary superheater/reheater tubes
  - Screen tubes
  - Manhole area
  - Sootblower area
  - Economizer tubes
- Removal of combustion products from hopper
- Water washing of HRA
- Repair the expansion joint
- Replace or repair the tubes

4.4 Forced Draft Fan Ducting

- Inspection of the following :-
  - FD fan suction screen
  - Steam air preheater area
  - Hot air ducting from air preheater to windbox
- Cleaning of suction screen
- Cleaning of steam air preheater steam tubes (externally) and tightening of leaking joints.
- Strengthening of hot air ducting and burner windbox guide vanes.

- 4.5 Steam Drum
- Inspection of the following :-
  - Drum internal surfaces
  - All pipe fittings/joints inside the drum
  - Feed pipe, girth plates, baffles, scrubbers, chevron driers, separator
  - Gauge glasses
  - Isolation valves

4.5 Steam Drum

- Wipe clean the drum internal surface
- Removal of deposits by vacuum cleaning
- Inspection by Inspector of Machinery before reassemble
- Overhaul the gauge glass and isolating valve.

4.6 Header

- Inspection of the following :-
  - Superheater inlet and outlet header
  - Reheater inlet and outlet header
  - Waterwall header
  - Economizer inlet and outlet headers
- Removal of handhole or by cutting header cap for inspection and reweld.

4.7 Tubes

- Cutting of tubes for inspection and rewelding.
- Replacing worn-out tubes.

4.8 Forced/Induced Draft Fan

- Inspection of the following :-
  - Impeller and shaft
  - Suction part and impeller gap
  - Casing and ducting
  - Suction screen
  - Bearing
  - Fluid coupling

4.8 Forced/Induced Draft Fan

- Water washing of the fan impeller, shaft and casing.
- Cleaning and easing of the damper, greasing and casing.
- Checking bearing clearances and renewing lubricating oil.
- Overhaul the fluid coupling and realignment.

4.9 Valves and Fittings

- Overhaul of the following valves :-
  - All the safety valves
  - Boiler main stop valve and its bypass
  - Feedwater control valve and its bypass
  - All burner inlet and outlet isolating valves
  - Boiler and drum blowdown valves.
  - High Pressure dosing valves.

4.9 Valves and Fittings

- Overhaul of the following valves :-
  - Sootblower steam isolating, bypass and control valves
  - Steam oil heater valves.
  - Steam traps and its bypass and isolating valves
- Overhauling the drum gauge glasses.
- Cleaning and easing of the boiler explosion door.

4.10 Economizer

- Check interior of tubes and headers where possible for corrosion, oxygen pitting and scale.
- Check exterior of tubes and headers for corrosion, erosion and deposits. Check particularly at soot blower locations for impingement and leakage.
- Check for cleanliness and security of vent and drain connections and valves.
- Check exterior economizer casing for leaks and tightness and doors.

4.11 Water Columns

- Check gauge glasses for leaks, cleanliness and visibility.
- Check illuminators, reflectors, and mirrors for cleanliness and breakage.
- Check operation and condition of gauge cocks and valves. Inspect chains and pulleys if used. Repair or replace as necessary.
- Ensure that water column is free to expand with boiler.
- Check water column piping to drums for leaks, internal deposits, and missing insulation.
- Check condition of high and low water alarms and trips.

4.12 Feedwater Regulator

- Examine valve externally for leaks, operability, and cleanliness. Do not dismantle if operation has been satisfactory. Check connecting lines and mechanisms for proper function.

5.0 OPERATING CHECKS RELATING TO MAINTENANCE

5.1 Leakage

- Check for any flue gas, steam drum or water leaks
- Check for steam leaks at superheater headers and tube joint
- Check for air leaks around doors, seals and tubes joints
- Operating Checks Relating to Maintenan

5.0 OPERATING CHECKS RELATING TO MAINTENANCE

5.2 Refractory

- Check condition of burner throat refractory
- Check condition of pit refractory (if applicable)
- Check for slag build up on refractory
- Check for missing insulation on headers and drum

5.3 Burner

- Check for burner wear by noting flame shape and completeness of combustion
- Check ease of operation of burner vanes. This will indicate burner mechanism condition

5.4 Superheater Tubes

- Check for a change in pressure drop through the superheater indicating internal condition of the tubes

5.5 Boiler drums

- Check the steam quality. This will indicate the condition of steam scrubbers and separators
- Check for noises in drums. This may be caused by loose connections of drum internal piping

5.6 Economiser and air pre-heater

- Check for a variation in temperature differences over both units at constant load, indicating deposits or buildup
- Check for a decrease in pressure drop over any part of the system at constant load indicating a misplaced or bypassed baffle

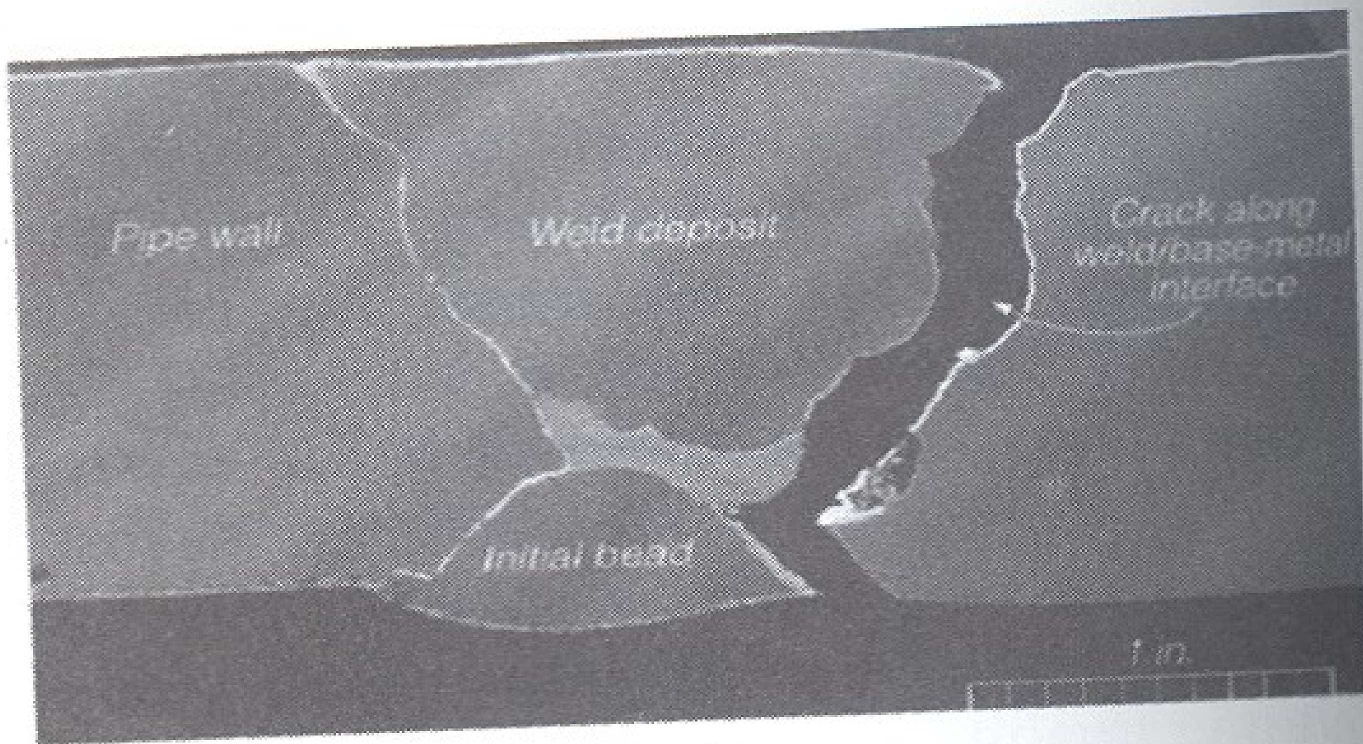
5.7 Furnace and Casing

- Check the extent of expansion and contraction of pressure parts during startup and shutdown
- Check that header support hangers are always in tension. Looseness will indicate an obstruction to free expansion and contraction.

Internal Inspection

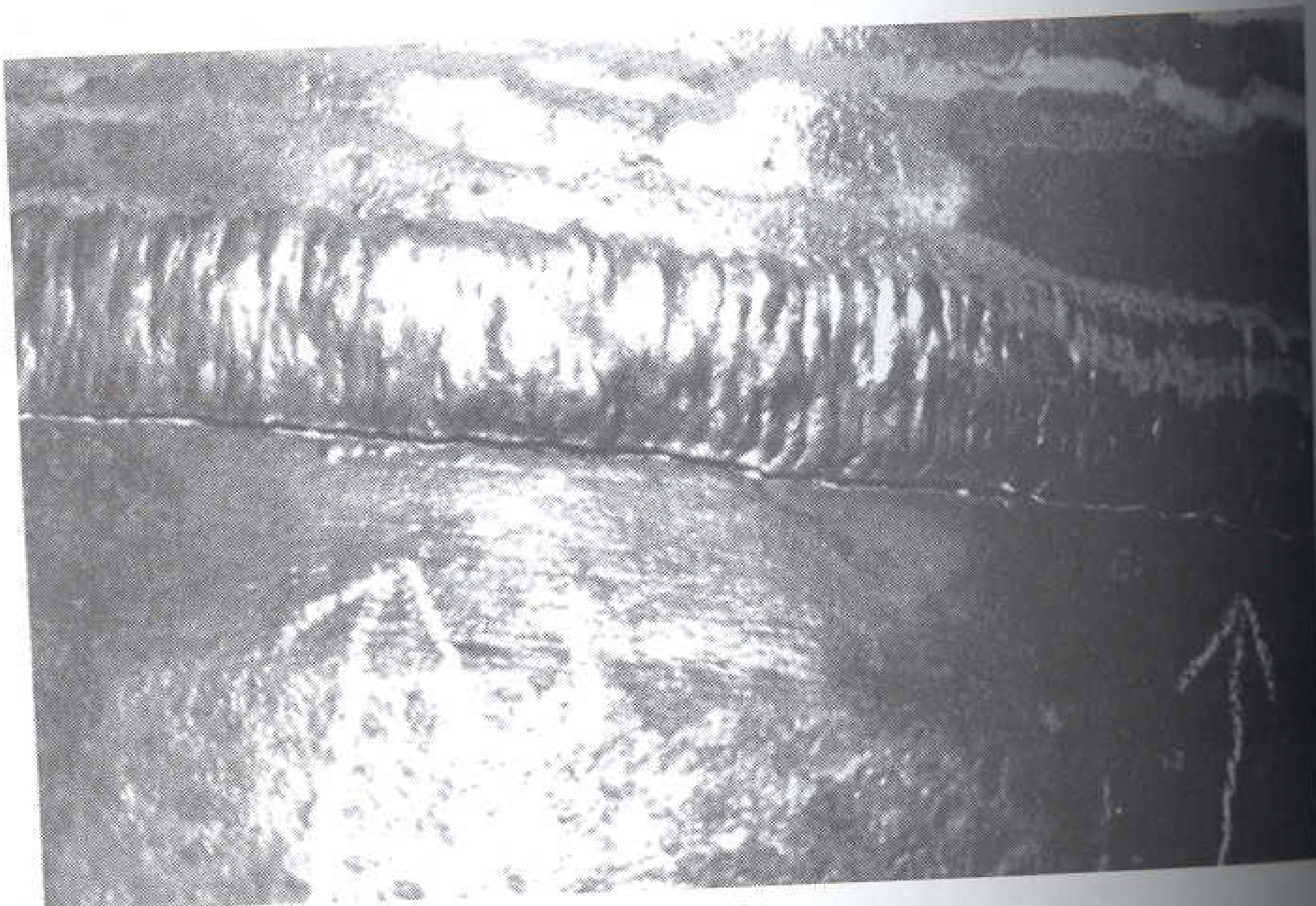
- What to check for?
  - Wear
  - Deterioration
  - Corrosion
  - Scale
  - Oil
  - Crack
  - Grooving
  - Thinning
  - etc
- All the above technique is using Visual test or and NDT

Welding crack



(a)

Visual inspection of crack



(b)

failures. (a) Longitudinal weld

Typical internal inspection

Where	What to inspect
Longitudinal seam of drums	Crack and grooving
Unstayed heads	Groove at fillet weld
Manholes and opening	Corrosion thinning & crack
Welded nozzles and atachment	Weld washout, crack, deterioration

Typical internal inspection

Where	What
Stay & stay bolts	Crack and even tension
Waterline in drums	Oil and pitting
Tubes and plate expose to fire	Bulging or blistering
Tube to shell weld joint	Crack or pitting

External Inspection

- Check for any abnormalities or damage in the following area:
  - Platform and ladders
  - Insulation
  - Skin Temperature using Infrared Thermography
  - Any leakage or seepage at PSV and other valves and flanges
  - Any sign of water under insulation

How?

- Nondestructive Test
  - Visual Test
  - Dye Penetrant Test (DPT or dyepent)
  - Magnetic Particle Inspection (MPI) or WFMPT (wet flourecence magnetic particle testing)
  - Radiography
  - Ultrasonic Test (UT)
- Other advanced NDT such as Remote Field Eddy Current (C Steel boiler tubes) and IRIS (Internal rotating Inspection System), Hardness Test , Plastic replica and metallography

Non Destructive Testing

Equipment and samples

Example of damages found during visual inspection in boilers

Figure 14-3. Thin-lipped burst caused by rapid overheating.

FIGURE 2-15 Thick lip fracture from creep in a power plant superheater tube. (Courtesy of R. B. Pond, Jr.)

Thin and thick lipped burst

Figure 10-1. Oxygen-pitted boiler feedwater pipe.

Figure 14-2. Deposit accumulation restricted heat transfer, leading to long-term overheating.

Scales in boiler tube resulting in failure

Scales in boiler tube resulting in failure

PROCESS HEATERS/FURNACES

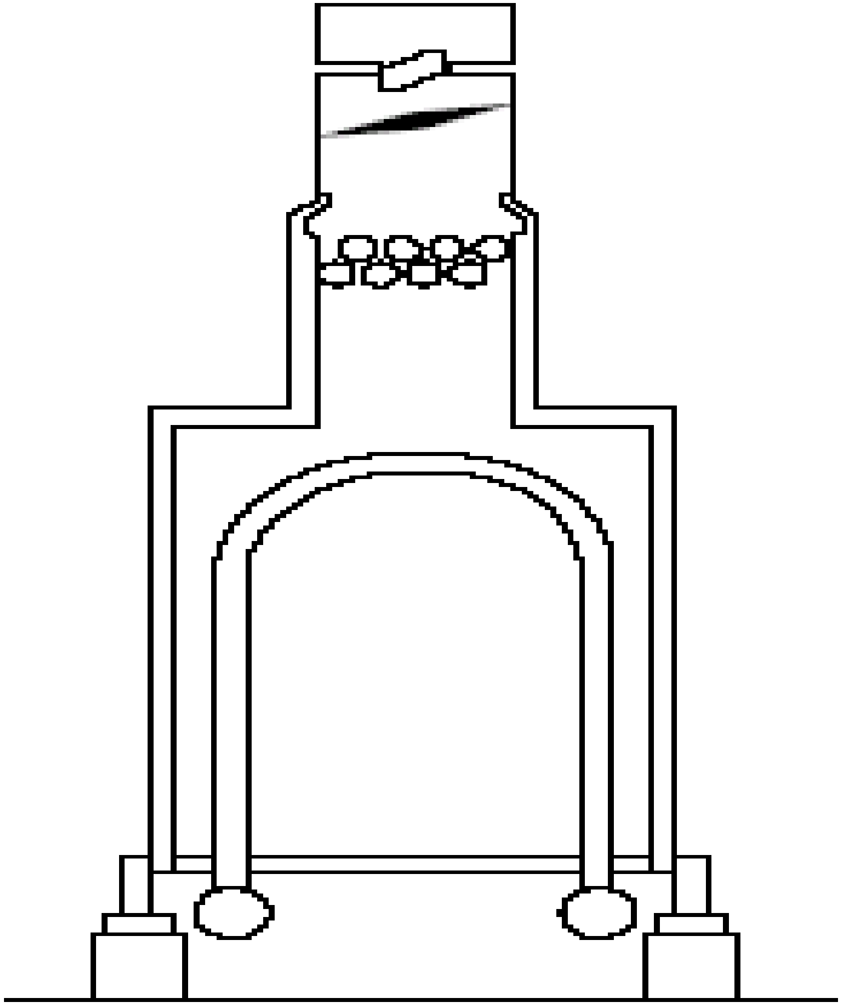
FIRED HEATERS

- A fired heater is a device in which heat liberated by the combustion of fuel within an internally insulated enclosure is transferred to fluid contained in tubular coils. Heat transfer occurs primarily by radiation in the combustion chamber and by convection in the convection chamber.

- Fired heater size is determined in terms of its design heat absorption capability or duty, in Btu/hr. Duties range from about a half million Btu/hr to about one billion Btu/hr.

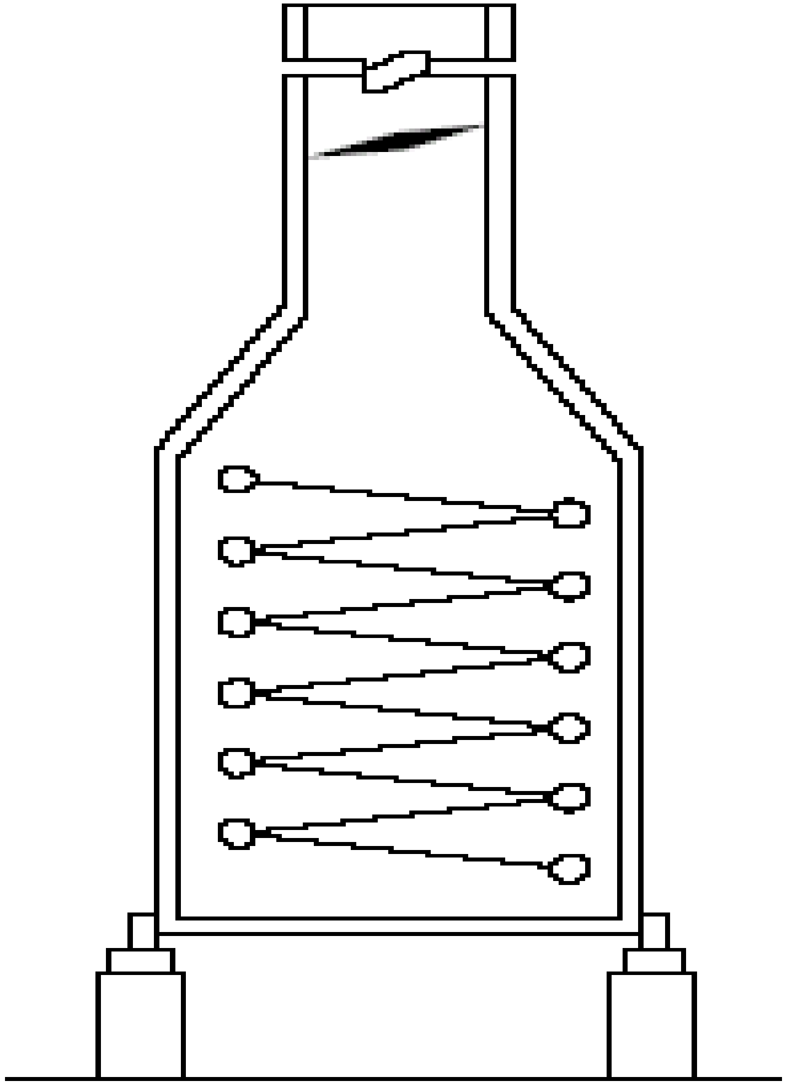
- Examples of **service categories** are column reboilers, fractionating column feed pre-heaters, reactor feed pre-heaters, heating of heat transfer media such as heating oil, heating of viscous fluids and fired reactors.

- The two examples of **orientation categories** are vertical and horizontal.



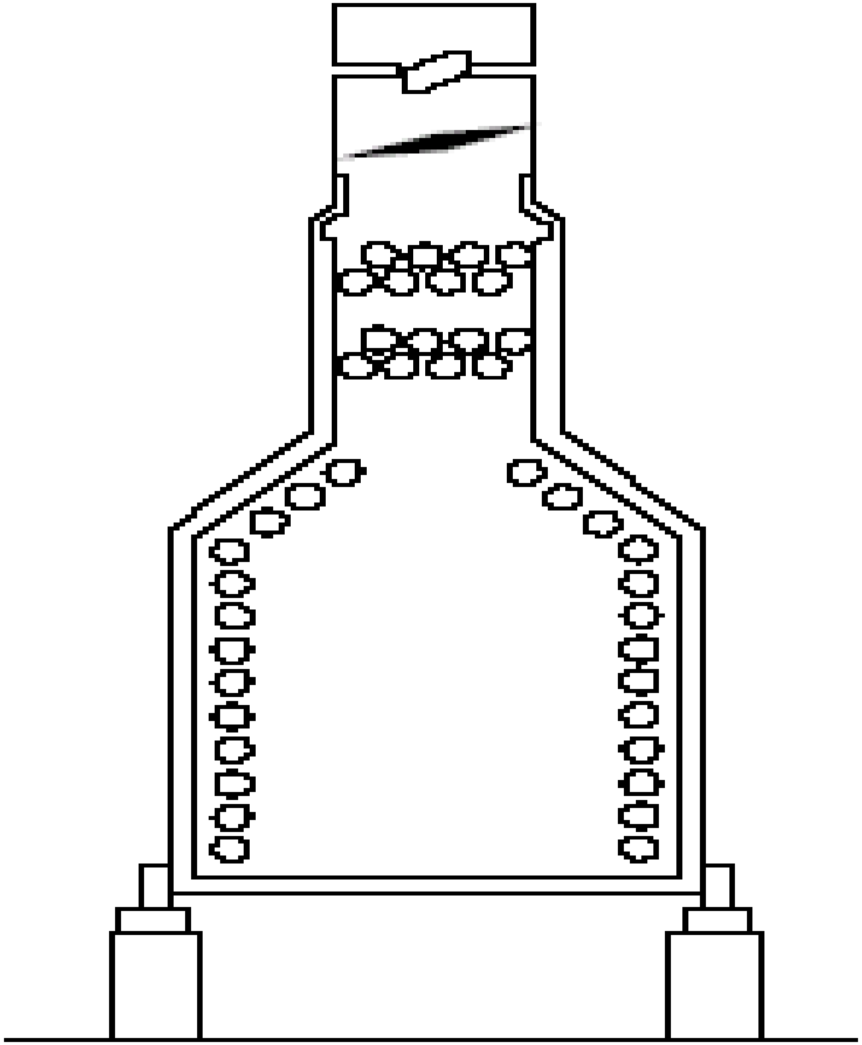
TYPE A—BOX HEATER WITH ARBOR COIL

Suitable for heating large flows of gas under conditions of low pressure drop. Typically used in catalytic reformer charge heaters.



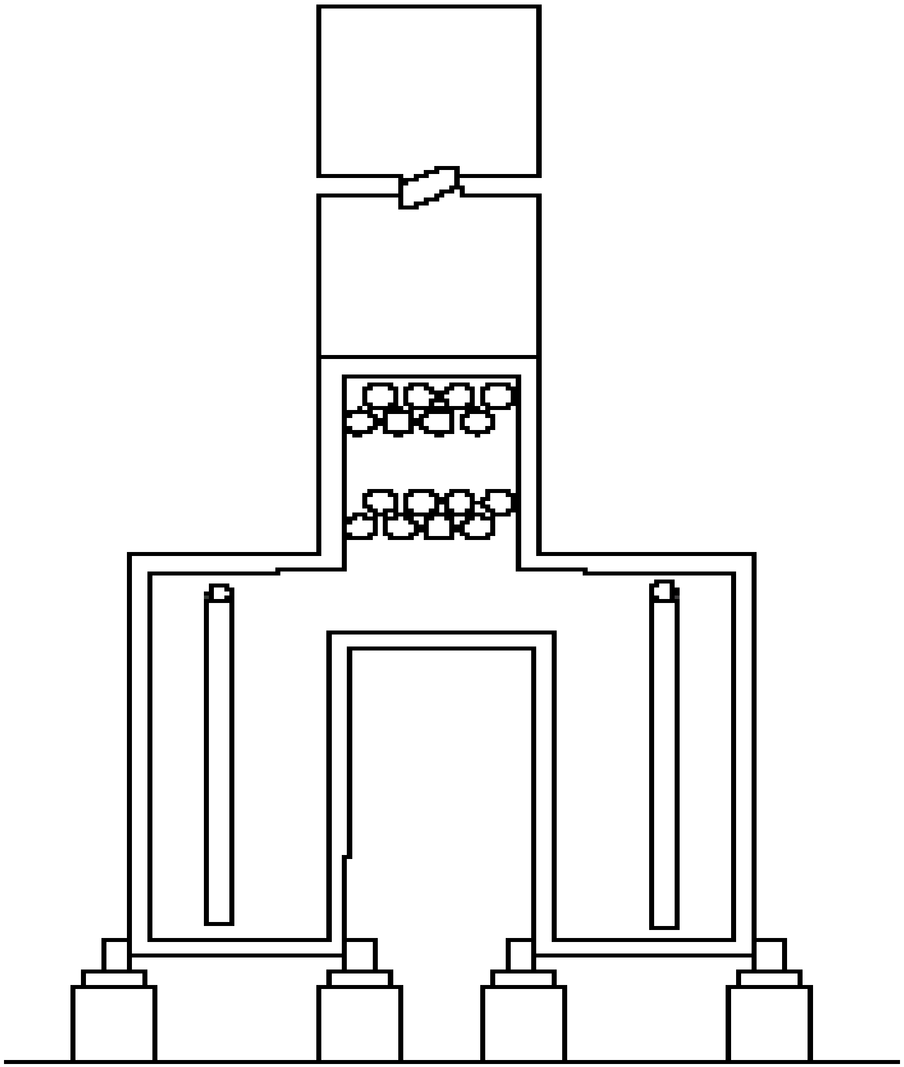
TYPE B—CYLINDRICAL HEATER WITH HELICAL COIL

The tube coil is inherently drainable. One limitation is that generally only one flow path is followed by the process fluid.



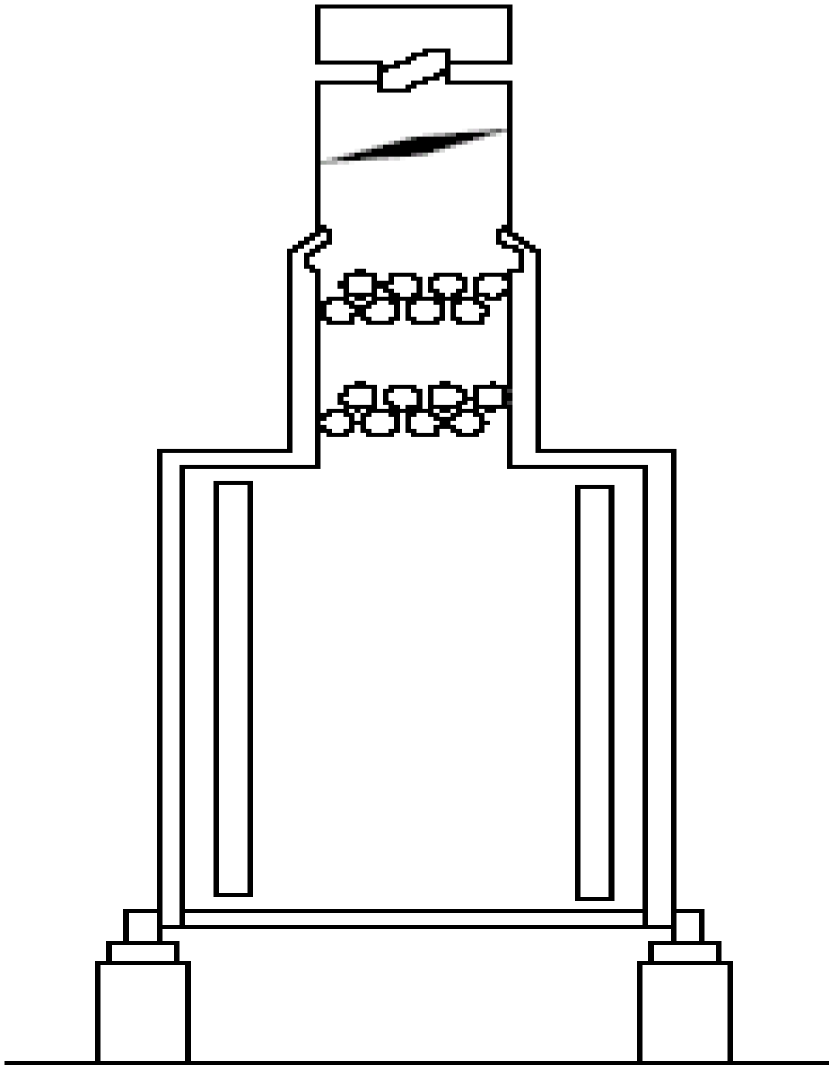
TYPE C—CABIN HEATER WITH HORIZONTAL TUBE COIL

Can be fired from the floor or from the side. Tubes are laid horizontally in the radiant section.



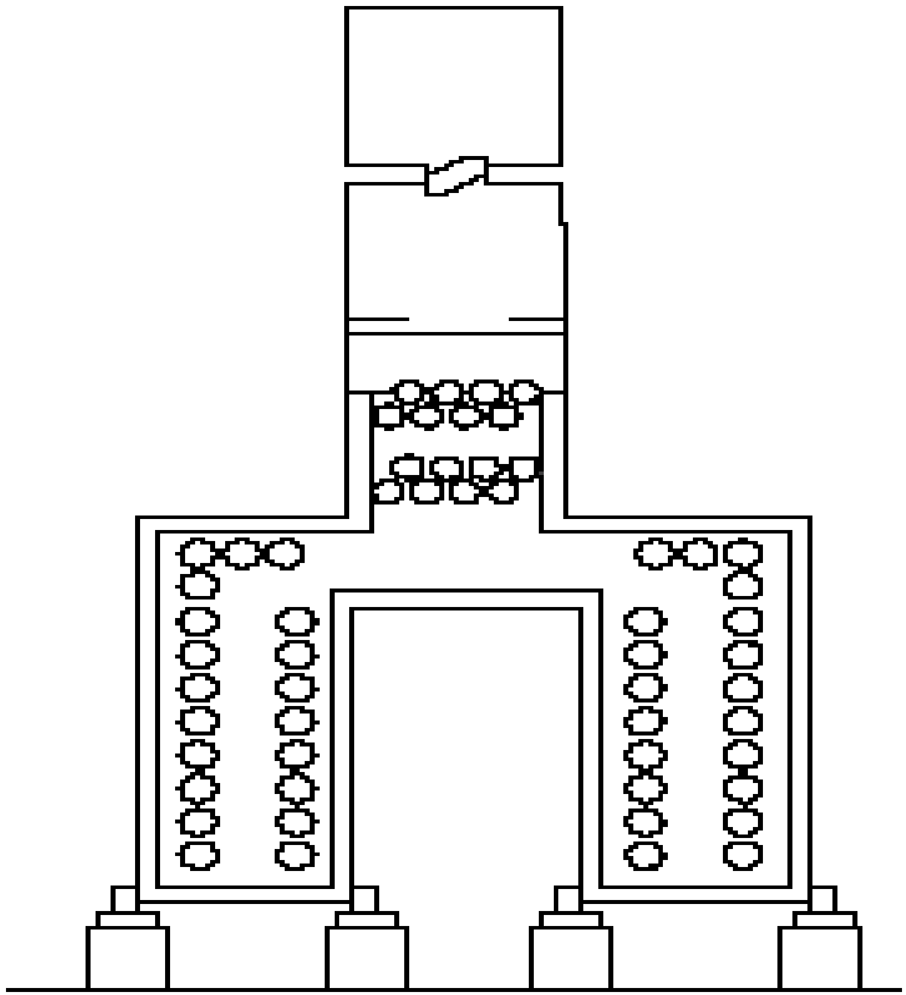
TYPE D—BOX HEATER WITH VERTICAL TUBE COIL

Yields a highly uniform distribution of heat transfer rates about the tube circumference. Firing is normally from both sides of the row.



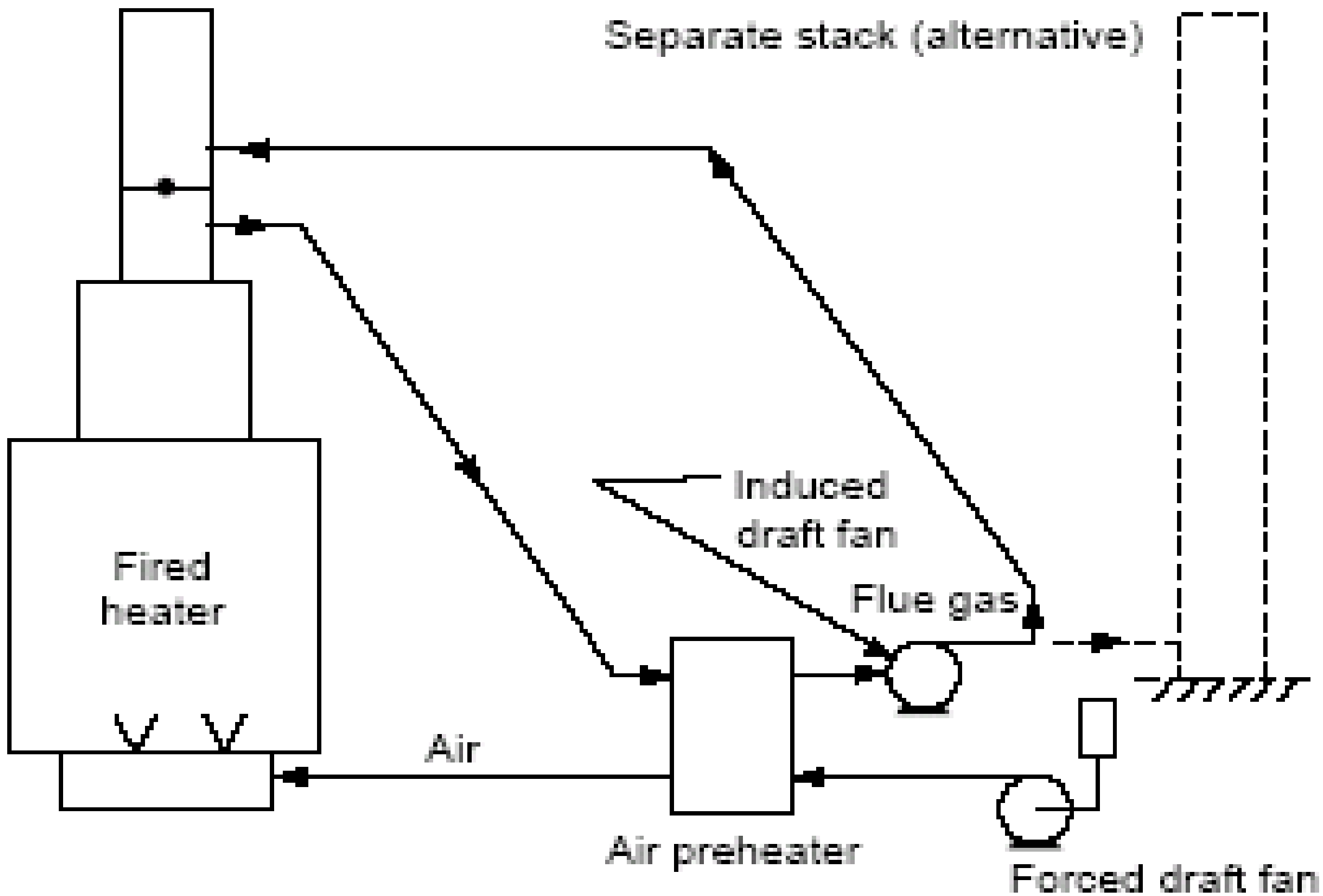
TYPE E—CYLINDRICAL HEATER
WITH VERTICAL COIL

Firing is from the floor. It features both radiant and convection sections. It is an economical high efficiency design. The first few rows of tubes in the convection section are subject to radiant heat transfer in addition to convective heat transfer. These tubes are subject to the highest heat transfer rates in the heater and are called shock or shield tubes.



TYPE F—BOX HEATER WITH HORIZONTAL TUBE COIL

Vertically fired from the floor. Economical, high efficiency design.



Air Preheat System Using Regenerative, Recuperative, or Heat Pipe Unit

- **FURNACE FLUE GAS TEMPERATURES**

1. FLAME - 1816 deg C

2. RADIANT EXIT OR BRIDGE WALL - 788 deg C

3. STACK - 204 deg C

- **HEAT DISTRIBUTION IN RADIANT SECTION**

1. FLAME RADIATION - 14%

2. HOT GAS RADIATION - 28%

3. CONVECTION - 6%

4. REFRACTORY REFLECTION - 12%

TOTAL = 60%

- **HEAT DISTRIBUTION IN CONVECTION SECTION**

1. CONVECTION = 25%

- **HEAT LOSS IN HEATER**

1. FLUE GAS - 13%

2. REFRACTORY - 2%

TOTAL = 15%

Process	Internal Scale	Typical Metallurgy	Typical Corrosion Allowance	Typical Failure Causes
Crude	Coke	9 Cr	1/8"	1, 3
Vacuum	Coke	9 Cr	1/8"	1, 3
Coker	Coke	9 Cr	1/8"	1, 3
Naphtha Hydrotreating	Inorganic	1-1/4 Cr to 9 Cr 347 SS	1/8"- 3/16" 1/16"	1,2
Kerosine/ Diesel Hydrotreating	Inorganic	347 SS	1/16"	1,2
Hydrocrackers	Inorganic	347 SS	1/16"	1,2,3,4
Catalytic Reformers	Clean	2-1/4 Cr to 9 Cr	1/16"	1,4
Reboilers	Clean	CS	1/8"	1

<u>**TYPICAL FAILURE CAUSES**</u>

1) Overheating caused by low flow or flame impingment
2) Hydrogen sulfide attack
3) Sulfur attack
4) Long Term Creep Deformation

Performance monitoring

- Data that provide an indication as to how well the heater is being fired -

1. Process stream flow rate
2. Fuel firing rate
3. Process stream temperatures
4. Flue gas temperatures
5. Flue gas draft profile
6. Flue gas sampling
7. Tube skin temperatures

Maintenance Program for heaters

1. **VISUAL INSPECTION**

   Operating burners should be checked visually once per shift. Any unusual situation, such **as** flame impingement on **tubes** and supports, improper flame dimensions, oil drippage, uneven heat distribution, smoky combustion, and so forth, should be noted and corrected **as** soon **as** possible.

2. CHECK BURNERS WITH ORIGINAL DESIGN

The following items should be checked with the original design to ensure compatibility with the present operating conditions:

a. Fuel pressure.

b. Fuel characteristics (heating value, composition, viscosity, sulfur content, etc.)

c. Gas tip and oil guns (orifice size, drilling angle, and tip and gun position).

d. Burner size.

e. Turndown.

Replacement either **of** burner tip or gun or of complete burner should be considered if the original burner cannot be operated satisfactorily.

3. BURNER CLEANING

Users should establish their own cleaning schedules based upon their experience; however, the following should be noted:-

a. Oil guns normally require more frequent cleaning than gas tips. Oil guns should be cleaned at least once a week when burning No. ***6*** oil.

b. Gas tips are typically cleaned when the gas pressure **drop** across the burner has increased approximately **30** percent above the design pressure for a given fuel and heat release. **Gas** tips are cleaned when irregular flame patterns develop from a burner tip.

4. BURNER BLOCK

The burner block should be inspected. Cracks and spalled sections shall be repaired to a smooth surface commensurate with the original design. Repairs should be accomplished with a plastic refractory comparable to the existing material and having at least the same temperature rating. Burner blocks requiring extensive repair should be replaced.

5. AIR REGULATING DEVICES

Air dampers and registers should be operable at all times.

6. REMOVAL OF UNUSED BURNERS

As many burners **as** practicable should be in operation to achieve good heat distribution. Unnecessary burners should be removed and the burner openings sealed to prevent air leakage. Remaining bumers should be arranged to provide good heat distribution.

Gas tips and oil guns should be removed on shutdown burners. No metallic burner components should be exposed to the hot flue gas. Burner tiles may be left in place.

Burners may be removed from the outside when the heater is in operation. Burner openings should be covered with carbon steel plate insulated from the heat of the furnace. Burners may be blanked from the inside of heater after shutdown.

7. BURNER REPLACEMENT OR MODIFICATION

Burners should be replaced or modified if the burners have deteriorated where substantial maintenance is required. They should be replaced if satisfactory combustion with optimum excess air operation cannot be maintained.

Burners should be replaced or modified if the existing burners are unsuitable for the new operating requirements.

These requirements may be environmental, fuel change, heat release, process, etc.

The burner manufacturer should be consulted when burner replacement or modification is required.

8. SPARE PARTS

The number of spare parts depends on burner design, fuel, plant location and operation, and maintenance experiences. It is recommended that 10 percent of all tips, oil guns, and burner tiles **as** a minimum should be purchased **as** spares.

9. CLEANING THE CONVECTION SECTION

Deposits on the convection tubes when burning fuel oil are generally sulfur, vanadium, sodium and ash. These need to be removed or the efficiency of the heater will be reduced. This is done by manual lancing, rotating soot blowers or retractable soot blowers.

Water washing is also done to remove deposits. Permanently installed alloy steel headers and nozzles are positioned in the convection section. Water is injected through these and the contact of water with the hot tubes vaporizes the water thus dislodging the deposits.

Water washing can also be done during turnarounds after suitably protecting the refractory in the radiant section.

10. Tube replacement

a. Radiant section : Tubes can be lowered into the furnace through the access doors on top of the radiant section. As far as is possible, tubes shall be replaced in one piece from return bend to return bend without intermediate welds. In case it is not possible, sectional replacement can be considered.
b. Convection section : Tube replacement here is difficult since the tubes have to be inserted through the intermediate tube sheets.

11. Refractory repair

The primary consideration is the skin temperature of the casing. In case alternate materials are used, calculations must be made to ensure required skin temperature of the casing.

Repairs along the roof of the heater are difficult and may require the use of plywood shoring. The plywood shoring is left in the heater and allowed to burn up during operation.

12. Damper repairs

Problems associated with dampers are mainly with the bearings. These require periodic greasing. In case of manual control, the wire ropes and pully systems used should be kept in good condition.

13. FD/ID fans

These fans should be subjected to regular preventive and predictive maintenance. ID fans should be inspected at shutdowns due to the high temperatures involved. FD fan vane control mechanisms should be inspected and kept in good condition by lubrication.

14. Air pre-heaters

Inspection through manways should be done at every shutdown. These are generally cast and replacement is in modules or sections.

15. Skin thermocouples

Regular replacement of tube skin thermocouples should be done to maintain the accuracy of temperature measurements.

16. Thermowells

Thermowells should be removed for inspection at every shutdown. There are instances of leaks through the thermowells resulting in hydrocarbon leaks at the thermocouple wiring area.

17. Tubes

Tubes should be inspected for relevant failure mechanisms and the remaining life should be calculated.

DECOKING OF FURNACE TUBES

Steam/Air Decoking

The steam/air decoking method is used to remove coke in furnace tubes. The decoking operation in thermal cracking is comparable with the regeneration steps in cat. cracking and heat forming.

This method is nowadays generally applied in thermal cracking units instead of the former mechanical cleaning method by means of turbines. The advantages of steam/air decoking over turbining are:

1) lower operating costs;
2) shorter shutdown times, since less dismantling and mounting of tube fittings are required;
3) cleaner operation;
4) negligible damage to the tubes;
5) the furnace can be made cheaper, as far fewer tube fittings need be installed or even none at all.

A disadvantages of steam/air decoking is that if the temperature in the tubes is not carefully controlled, overheating of the tubes may occur. Proper control will eliminate this disadvantage.

DECOKING OF FURNACE TUBES

2. Decoking by pigging

Decoking of furnace tubes can be accomplished by means of using pigs. These pigs are made of foam with metal studs on the outer surface. These are propelled through the tubes with water as the medium. Coke is collected in drums by filtering the effluent water.

PHOTOGRAPHS OF DECOKING ACTIVITY AT PPTSB.

Inspection

The reason for inspection of a furnace or boiler is to determine by comparison with the initial inspection at the time of construction or with basic records the effect that corrosion, erosion and other factors have had on the equipment. Inspection helps to maintain the safety and efficiency of continued operation and forecasts maintenance and replacements, based on the indicated rate of deterioration.

The inspector must be concerned not only with the pressure parts of the furnaces and boilers but also with related non-pressure parts, including the combustion chambers, burners, flue gas ducts, stacks and all kind of internals.

Causes of Deterioration in Furnaces

Deterioration of the coils is influenced by:

- Type of process
- Characteristics of feed
- Velocity of Flow
- Pressure
- Temperature
- Combustion products
- Mechanical deterioration
- Climate condition

Methods of Inspection

A. Visual inspection of furnaces and coils

Externally:
- Sagging or bowing
- Bulging
- Oxidation or scaling
- Cracking or splitting
- External corrosion
- External deposits
- Leaking rolls
- Damage or distortion of fittings
- Corrosion of fitting
- Condition of refractory and burners

Internally:
- Selective spot-type or pit-type corrosion
- Thinning of tube ends
- Cutting or other cleaning damage
- Loosening of the tube roll and flare
- Erosion.