INSPECTION
OF
FIRED HEATERS

OISD - STANDARD-133
First Edition, November 1990
Amended Edition, August, 2000

OIL INDUSTRY SAFETY DIRECTORATE
Government of India
Ministry of Petroleum & Natural Gas
8th Floor, OIDB Bhavan, Plot No. 2, Sector – 73, Noida – 201301 (U.P.)
Website: www.oisd.gov.in
Tele: 0120-2593800, Fax: 0120-2593802
INSPECTION OF FIRED HEATERS

Prepared by

FUNCTIONAL COMMITTEE ON INSPECTION OF FIRED HEATERS

OIL INDUSTRY SAFETY DIRECTORATE
8th Floor, OIDB Bhavan,
Plot No. 2, Sector - 73
Noida – 201301 (U.P.)
Preamble

Indian petroleum industry is the energy lifeline of the nation and its continuous performance is essential for sovereignty and prosperity of the country. As the industry essentially deals with inherently inflammable substances throughout its value chain – upstream, midstream and downstream – Safety is of paramount importance to this industry as only safe performance at all times can ensure optimum ROI of these national assets and resources including sustainability.

While statutory organizations were in place all along to oversee safety aspects of Indian petroleum industry, Oil Industry Safety Directorate (OISD) was set up in 1986 Ministry of Petroleum and Natural Gas, Government of India as a knowledge centre for formulation of constantly updated world-scale standards for design, layout and operation of various equipment, facility and activities involved in this industry. Moreover, OISD was also given responsibility of monitoring implementation status of these standards through safety audits.

In more than 25 years of its existence, OISD has developed a rigorous, multi-layer, iterative and participative process of development of standards – starting with research by in-house experts and iterating through seeking & validating inputs from all stake-holders – operators, designers, national level knowledge authorities and public at large – with a feedback loop of constant updation based on ground level experience obtained through audits, incident analysis and environment scanning.

The participative process followed in standard formulation has resulted in excellent level of compliance by the industry culminating in a safer environment in the industry. OISD – except in the Upstream Petroleum Sector – is still a regulatory (and not a statutory) body but that has not affected implementation of the OISD standards. It also goes to prove the old adage that self-regulation is the best regulation. The quality and relevance of OISD standards had been further endorsed by their adoption in various statutory rules of the land.

Petroleum industry in India is significantly globalized at present in terms of technology content requiring its operation to keep pace with the relevant world scale standards & practices. This matches the OISD philosophy of continuous improvement keeping pace with the global developments in its target environment. To this end, OISD keeps track of changes through participation as member in large number of International and national level Knowledge Organizations – both in the field of standard development and implementation & monitoring in addition to updation of internal knowledge base through continuous research and application surveillance, thereby ensuring that this OISD Standard, along with all other extant ones, remains relevant, updated and effective on a real time basis in the applicable areas.

Together we strive to achieve NIL incidents in the entire Hydrocarbon Value Chain. This, besides other issues, calls for total engagement from all levels of the stake holder organizations, which we, at OISD, fervently look forward to.

Jai Hind!!!

Executive Director
Oil Industry Safety Directorate
NOTES

OISD publications are prepared for use in the oil and gas industry under Ministry of Petroleum and Natural Gas. These are the property of Ministry of Petroleum and Natural Gas and shall not be reproduced or copied and loaned or exhibited to others without written consent from OISD.

Though every effort has been made to assure the accuracy and reliability of data contained in these documents, OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from their use.

These documents are intended only to supplement and not replace the prevailing statutory requirements.
FOREWORD

The Oil Industry in India is nearly one hundred years old. Due to various collaboration agreements, a variety of international codes, standards and practices have been in vogue. Standardisation in design philosophies and operating and maintenance practices at a national level was hardly in existence. This, coupled with feed back from some serious accidents that occurred in the recent past in India and abroad, emphasised the need for the industry to review the existing state of art in designing, operating and maintaining oil and gas installations.

With this in view, the Ministry of Petroleum & Natural Gas, in 1986, constituted a Safety Council assisted by Oil Industry Safety Directorate (OISD), staffed from within the industry, in formulating and implementing a series of self-regulatory measures aimed at removing obsolescence, standardising and upgrading the existing standards to ensure safer operations. Accordingly, OISD constituted a number of Functional Committees of experts nominated from the industry to draw up standards and guidelines on various subjects.

The present document on “Inspection of Fired Heaters” has been prepared by the Functional Committee on “Inspection of Fired Heaters”. This document is based on the accumulated knowledge and experience of industry members and the various national and international codes and practices. This document is meant to be used as a supplement and not as a replacement for existing codes and practices. It is hoped that the provisions of this document, when adopted may go a long way to improve the safety and reduce accidents in the Oil and Gas Industry. Users are cautioned that no standard can be a substitute for the judgement of a responsible, qualified Inspection Engineer. Suggestions are invited from the users, after it is put into practice, to improve the document further.

Suggestions for amendments to this document should be addressed to

The Coordinator,
Functional Committee on “Inspection of Fired Heaters”,
OIL INDUSTRY SAFETY DIRECTORATE
Government of India
Ministry of Petroleum & Natural Gas
8th Floor, OIDB Bhavan, Plot No. 2, Sector – 73, Noida – 201301 (U.P.)
Website: www.oisd.gov.in
Tele: 0120-2593800, Fax: 0120-2593802

This standard in no way supercedes the statutory regulations of PESO, Factory Inspectorate or any other Government Body which must be followed as applicable.
# FUNCTIONAL COMMITTEE ON INSPECTION OF FIRED HEATERS

(Third Edition March-2016)

## List of Members

<table>
<thead>
<tr>
<th>Name</th>
<th>Designation &amp; Organisation</th>
<th>Position in Committee</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sh. Ramesh Kumar</td>
<td>Head Insp. &amp; Engg. Essar Oil Limited</td>
<td>Leader</td>
</tr>
<tr>
<td>2. Sh. L.C.Gopalani</td>
<td>DGM (Insp.), IOCL Panipat Ref.</td>
<td>Member</td>
</tr>
<tr>
<td>3. Sh. R.P.Bhan</td>
<td>DGM (Insp.) HPCL, Vizag Ref.</td>
<td>Member</td>
</tr>
<tr>
<td>4. Sh. D. Arthur Manohar</td>
<td>Ch. Manager (E&amp;I) CPCL, Chennai</td>
<td>Member</td>
</tr>
<tr>
<td>5. Sh. M.K.Sinha</td>
<td>Associate VP (Process) Technip India Ltd. Noida</td>
<td>Member</td>
</tr>
<tr>
<td>6. Sh. Mandip Kapoor</td>
<td>A.G.M, EIL</td>
<td>Member</td>
</tr>
<tr>
<td>8. Sh. K.G. Nandakumar</td>
<td>Sr. Manager (Insp.) BPCL, Kochi Refinery</td>
<td>Member</td>
</tr>
<tr>
<td>9. Sh. Surdeep Bordoloi</td>
<td>Manager (Insp.) Numaligarh Refinery</td>
<td>Member</td>
</tr>
<tr>
<td>10. Sh. M. Subrahmanyam</td>
<td>Chief Engineer, Combustion Engg. &amp; Equipment, Technip India Ltd. Noida</td>
<td>Member</td>
</tr>
<tr>
<td>11. Sh. Y.P.Gulati</td>
<td>Jt. Director (Asset Integrity) OISD</td>
<td>Member</td>
</tr>
<tr>
<td>12. Sh. S.K.Bagchi</td>
<td>Addl. Director (Asset Integrity) OISD</td>
<td>Member-Coordinator</td>
</tr>
</tbody>
</table>

In addition to the above, various other experts from the industry contributed in the preparation, review and finalisation of this document.
FUNCTIONAL COMMITTEE ON
INSPECTION OF STATIC EQUIPMENT
(First Edition April-1990)
List of Members

<table>
<thead>
<tr>
<th>Name</th>
<th>Designation &amp; Organisation</th>
<th>Position in Committee</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sh. R.K. Sabharwal</td>
<td>CMNM-IOC (R&amp;P)</td>
<td>Leader</td>
</tr>
<tr>
<td>2. Sh. R.H. Vora</td>
<td>DGM IOC (Mkt)</td>
<td>Member</td>
</tr>
<tr>
<td>3. Sh. D.P. Dhall</td>
<td>Ch Insp. &amp; AE Manager-BPC (Ref)</td>
<td>Member</td>
</tr>
<tr>
<td>4. Sh. P. Dasgupta</td>
<td>SIPM IOC (R&amp;P)</td>
<td>Member</td>
</tr>
<tr>
<td>5. Sh. I.M. Advani</td>
<td>MGR Insp-(Proj) HPC (Ref)</td>
<td>Member</td>
</tr>
<tr>
<td>6. Sh. V. K. Moorthy</td>
<td>Dy. Suptd.Engg, ONGC</td>
<td>Member</td>
</tr>
<tr>
<td>7. Sh. R.M.N. Marar</td>
<td>Jt. Dir-OISD</td>
<td>Member Coordinator</td>
</tr>
</tbody>
</table>

In addition to the above, various other experts from the industry contributed in the preparation, review and finalisation of this document.
## INSPECTION OF FIRED HEATERS

### CONTENTS

<table>
<thead>
<tr>
<th>SECTION</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2.0 Scope</td>
<td>1</td>
</tr>
<tr>
<td>3.0 Definition and Types of Heaters</td>
<td>1</td>
</tr>
<tr>
<td>3.1 Fired Tubular Heaters</td>
<td>1</td>
</tr>
<tr>
<td>3.1.1 Heating Coil</td>
<td>1</td>
</tr>
<tr>
<td>3.1.2 Furnace and Ducting</td>
<td>2</td>
</tr>
<tr>
<td>3.1.3 Types of Fired Tubular Heaters</td>
<td>4</td>
</tr>
<tr>
<td>3.2 Heaters with Arbor Coils</td>
<td>5</td>
</tr>
<tr>
<td>3.3 Heaters Used in Steam Methane/ Naphtha Reforming</td>
<td>5</td>
</tr>
<tr>
<td>3.4 Pyrolysis Heaters</td>
<td>6</td>
</tr>
<tr>
<td>3.5 Direct Fired Heaters</td>
<td>6</td>
</tr>
<tr>
<td>4.0 Inspection Responsibility</td>
<td>6</td>
</tr>
<tr>
<td>5.0 Inspection Tools</td>
<td>7</td>
</tr>
<tr>
<td>6.0 Inspection of Heaters during Construction</td>
<td>8</td>
</tr>
<tr>
<td>7.0 Checklist of Inspection of Fired Heaters Prior to Commissioning</td>
<td>10</td>
</tr>
<tr>
<td>8.0 Likely Locations of Metal Wastage</td>
<td>12</td>
</tr>
<tr>
<td>8.1 Heating Coil</td>
<td>12</td>
</tr>
<tr>
<td>8.1.1 Deterioration Due to Corrosion</td>
<td>13</td>
</tr>
<tr>
<td>8.1.2 Metallurgical Deterioration</td>
<td>14</td>
</tr>
<tr>
<td>8.1.3 Mechanical Deterioration</td>
<td>15</td>
</tr>
<tr>
<td>8.1.4 Deterioration Mechanism for Steam Methane/Naphtha Reformer Heaters</td>
<td>17</td>
</tr>
<tr>
<td>8.2 Tube Supports</td>
<td>17</td>
</tr>
<tr>
<td>8.3 Refractory Lining</td>
<td>17</td>
</tr>
<tr>
<td>8.4 Casing</td>
<td>18</td>
</tr>
<tr>
<td>8.5 Miscellaneous</td>
<td>18</td>
</tr>
<tr>
<td>9.0 Types &amp; Frequency of Inspection</td>
<td>18</td>
</tr>
<tr>
<td>9.1 Types of Inspection</td>
<td>18</td>
</tr>
<tr>
<td>9.1.1 Onstream Inspection</td>
<td>19</td>
</tr>
<tr>
<td>9.1.2 Planned Shutdown Inspection</td>
<td>19</td>
</tr>
<tr>
<td>9.1.3 Emergency Shutdown Inspection</td>
<td>19</td>
</tr>
<tr>
<td>9.2 Frequency of Inspection</td>
<td>19</td>
</tr>
<tr>
<td>9.2.1 Onstream Inspection</td>
<td>19</td>
</tr>
<tr>
<td>9.2.2 Shutdown Inspection</td>
<td>19</td>
</tr>
<tr>
<td>10.0 Inspection Procedures</td>
<td>20</td>
</tr>
<tr>
<td>10.1 Onstream Inspection</td>
<td>20</td>
</tr>
<tr>
<td>10.2 Planned Shutdown Inspection</td>
<td>21</td>
</tr>
<tr>
<td>10.2.1 Inspection of Radiant and Shock Tubes</td>
<td>21</td>
</tr>
<tr>
<td>10.2.2 Inspection of Convection Tubes</td>
<td>24</td>
</tr>
<tr>
<td>10.2.3 Inspection for Steam Air Decoking</td>
<td>24</td>
</tr>
<tr>
<td>10.2.4 Retiring Limits</td>
<td>25</td>
</tr>
<tr>
<td>10.2.5 Comprehensive Health Assessment of Heaters</td>
<td>25</td>
</tr>
<tr>
<td>10.2.6 Hydrostatic Test</td>
<td>25</td>
</tr>
<tr>
<td>10.2.7 Inspection of Heater Foundation</td>
<td>26</td>
</tr>
<tr>
<td>10.2.8 Structural</td>
<td>26</td>
</tr>
</tbody>
</table>
1.0 INTRODUCTION

Fired heaters are essential components of a chemical / petrochemical / petroleum refining industry. In most processes, failure of a heater in a unit may cause shutdown of the entire unit. The most reliable method to ensure operational safety is proper design, operation of heaters within design limits, periodic inspection and preventive maintenance. In a sound equipment safety programme, inspection and repairs are carried out to good engineering standards.

2.0 SCOPE

This standard covers the minimum inspection requirements for fired heaters used in petroleum industry. Areas to be inspected, Inspection procedures, frequency of inspection, method of repairs and causes of deterioration have been specified in this standard. The inspection requirements during the construction and prior to commissioning of new heaters are also included in brief.

3.0 DEFINITION AND TYPES OF HEATERS

Fired heaters in a petroleum industry are used to add heat to the system. The fuel used may be oil, gas or both. There are two different types of fired heaters commonly used namely, fired tubular heaters and direct-fired heaters.

3.1 FIRED TUBULAR HEATERS

In a fired tubular heater, the hydrocarbon to be heated flows through a heating coil or coils placed inside an enclosure which is fired. Tubular heaters are built with two distinct heating sections namely the radiant section and the convection sections. A fired heater consists of following basic parts namely:

i) Heating Coil
ii) Furnace and ducting
iii) Air Preheater
iv) Stack

3.1.1 Heating Coil

The heating coil which carries the process fluid consists of lengths of tubing connected in series to form a continuous coil or coils. The tube fittings such as return bends and other connections may be of welded construction or rolled-in headers with plugs.

Various sections of heating coil are briefly described below:

(a) Radiant Coil

The radiant coils are located in the radiant section of the furnace where the heat pick up is predominantly from the heating flame and incandescent refractories by thermal radiation. The radiant tubes may be either vertical or horizontal depending on the construction of the furnace.

(b) Convection Coils

“OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines.”
INSPECTION OF FIRED HEATERS

The convection coils are located in the low heat flux zone of the furnace. The section is called so because the predominant mode of heat transfer is due to convection mode between the high temperature flue gas and the tube metal. The restricted flow area in this section increases the flue gas velocity which in turn increases the convective heat transfer co-efficient. Due to lower flue gas temperature, the process side operating temperature in the convection coils will be lower than that of radiant coils. The convection tubes are generally placed horizontal, irrespective of the configuration of radiant tubes.

In some of the heaters, BFW preheat tubes, steam generating tubes and steam superheating tubes, on-board air preheating tubes also are placed in convection section.

(c) Shock Tubes (Shield Tubes)

The rate of heat absorption tends to be high at the entrance to the convection section in heaters, where the convection section is right above the radiant section, because heat is delivered both by radiation and convection. Tubes at this section are called shock/shield tubes.

3.1.2 Furnace and Ducting

The term furnace covers all members that form the housing, supports and any other auxiliary equipment. The furnaces are operated on natural draft or provided with forced and/or induced draft by means of fans or blowers. The various parts of furnace and ducting are briefly described below:

a) Air Duct

Air duct is a conduit, made of steel sheets to convey air from FD fan to the fire box through air preheater (if provided) with the air preheater bypass duct. Section of air duct carrying hot air is normally insulated from outside.

b) Wind Box

The wind box is a chamber surrounding a burner through which air under pressure is supplied for combustion of the fuel. The flow rate of air is adjusted by means of air registers.

c) Burners

Burners are devices through which fuel and air is delivered inside the fire box at the required condition so as to provide ideal firing. Burners may be mounted vertically upwards or downwards or horizontally depending on the construction of the heater.

d) Fire Box

Fire box is a cylindrical or rectangular chamber in which actual combustion of the fuel takes place and the heat transmitted to the surrounding tubular coil by radiation. The walls of the fire box are made of refractory bricks and blocks/castables. Ceramic Fiber blanket or Modules at the fire side. Ceramic Fiber is a fibrous refractory insulation primarily composed of silica and alumina and sometimes zirconia. It can come in various forms like blanket, board, module, rigidized blanket, and vacuum-formed shapes.

e) Tube Supports/Hangers/Guides

“OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines.”
These are metallic members able to withstand high temperatures used to prevent sagging/ bowing / buckling/ swaying of tubes. Horizontal roof tubes of box type heaters are supported by means of hangers and side wall tubes by supports. Vertical tubes are generally provided with tube hangers at the top and guides at the bottom for guiding the expansion. Very long tubes may have intermediate additional guides.

Convection coils are provided with Tube Sheets for supporting and lateral guiding of tubes.

Radiant horizontal tubes are provided with tube Retainers/Locking Bars, to hold tubes in position from lateral shifting.

Radiant arbor coil vertical tubes are provided with tube spacers, to maintain coil verticality during construction and operation.

Radiant manifolds and convection to radiant cross over coils are at times provided with spring supports, to absorb coil expansions.

f) Re-radiation Cone

The re-radiation cone is a hollow inverted cone, made of alloy steels for high temperature service, installed inside the fire box at the top of cylindrical furnaces, by means of hanger rods. This is meant to increase the radiant heat transfer.

g) Bridge Wall

The bridge wall is a refractory wall constructed inside the firebox which divides it into two or more cells so that different heat input is possible in each cell.

h) Convection Section

This is the section of furnace at the flue gas outlet of fire box where secondary heat recovery coils, known as convection coils are placed.

i) Flue Gas Duct

Flue gas duct is a conduit, made of steel sheets used for conveying flue gas from convection section outlet to the stack, through air pre-heater and I.D. fan. The ducts are generally refractory lined from inside or insulated externally.

j) Air Pre-heater

Air pre-heaters are made as waste heat recovery units from the out-going flue gas to heat the combustion air. Both Regenerative (rotary type) and recuperative (stationary type) air pre-heaters like Cast APH, Glass APH, Plate APH, Steam Air Pre-heaters are commonly employed.

k) Soot Blower

It is a device consisting of a long tubular lance with spray nozzles for spraying steam or air to dislodge soot deposits on convection tubes while the heater is in operation. Rotary, stationary and retractable types of soot blowers are commonly employed.

l) Stack

*O/ISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of O/ISD Standards/Guidelines.*
A flue gas stack is a vertical conduit used to discharge products of combustion at a safe height so as not to pollute the surrounding atmosphere beyond the permissible limits. It is also used as a means of creating a draft at its base due to the difference in density between the internal and external gases, in natural draft furnaces.

m) **Duct Expansion Bellows**

Flue gas and combustion air ducts are provided with either fabric or metallic bellows to take care of duct expansions and also help in isolation of equipment like fans/ burner/stack from load and vibrations/ oscillations transfer.

n) **Dampers and Shut-Off Blades:**

Dampers are devices for introducing variable resistance in order to regulate the flow of flue gas or air. Shut - Off Blades are used for isolation of equipment/ heaters and provides positive/ man-safe isolation.

o) **Tube Seals:**

Tube seals are made of fabric cloth and steel clamps and are provided at coil terminals passing through heater shell/ header boxes, to prevent air/ rain water ingress.

p) **Sight Doors/ Peep Holes:**

Peepholes of either cast type or fabricated with glass assembly are provided for viewing radiant tubes and burner flames for proper operation and for light-off.

q) **Explosion doors:**

Explosion doors are devices meant to release accidental over pressures which may occur on flue gas side.

r) **Access Doors/ Inspection Doors:**

The doors are provided at various furnace and ducting sections to facilitate entry and inspection of internals.

s) **Forced Draft & Induced Draft Fans:**

Forced Draft Fans are used to supply combustion air to burners either through Air Pre-heaters or directly.

Induced Draft Fans are used to remove flue gases and to maintain a negative pressure in the furnace.

### 3.1.3 Types of Fired Tubular Heaters

There are many variations in the arrangement of fired tubular heaters, the most commonly used being the box/cabin type and vertical cylindrical type of heaters.

(a) **Box /Cabin Type Heaters**

A box type heater is considered to be any heater in which the radiant tubes are either horizontally or vertically arranged within a rectangular or square box configuration. In this type it is possible to have zones of different heat densities. They may be updraft or...
downdraft with gas or oil fired burners located in the end of side walls, floor, or any combination thereof. In Fig. 2(e) to 2(h) few of the commonly used coil arrangement in box type heaters are shown.

A cabin heater is typically a box heater having a hip / slant arch (radiant roof connecting convection bottom with 45 deg inclination typically) and radiant section having horizontal tubes arranged along radiant walls and roof within a rectangular box. In Figure-2(a) to 2(d) few of the commonly used coil and burner arrangement in cabin type heaters are shown.

(b) Vertical Cylindrical Type Heaters

A vertical cylindrical heater is typically a heater having cylindrical radiant shell with vertical radiant tubes typically and could be with helical coils at times. These heaters are typically bottom fired, with the stack mounted directly on top of the heater. With a bank of heaters, a common stack also may be used. In Fig. 1, vertical cylindrical heaters with vertical coils and helical coils are shown.

(c) Heaters with Helical Coils

These types of heaters are cylindrical with the surface of the radiant section in the form of a coil that spirals up the wall of the heater. See Figure 1(b).

3.2 Heaters with Arbor Coils

Heaters with arbor or wicket (inverted U) coils are used extensively in catalytic reforming units for preheat and reheat service and as heaters for process air or gases. These heaters have a radiant section that consists of inlet and outlet headers connected with inverted or upright L or U tubes in parallel arrangement. The convection sections consist of conventional horizontal tube coils. See Figure 2(h) for box heater with arbor coil having inverted U tubes and inlet and outlet headers.

3.3 Heaters Used in Steam Methane/Naphtha Reforming

In reforming heaters the vaporized feed like naphtha or light hydrocarbons like natural gas is processed in catalyst filled radiant tubes to produce hydrogen. In these heaters the vertical catalyst filled radiant tubes are normally arranged in cylindrical shell or in box with single or multiple parallel rows and operate at high temperatures, typically tube skin temperature ranging from 1500 degF (816 degC) to 1800degF (982 degC). These heaters are constructed with typically licensor specific designs and these designs may vary from one licensor to another.

These heaters are either upfired from floor or down fired from roof or side wall fired at multi-levels to achieve even heat distribution across the entire length of catalyst filled radiant tubes.

Figure 5 (a) shows a typical reforming heater which consists of inlet distribution system (having pigtailed and headers), catalyst tubes and outlet collection system (having sub headers and cold collector/transfer line).
3.4 Pyrolysis Heaters

Pyrolysis heaters are used in high temperature thermal cracking of hydrocarbons. These heaters operate at high temperatures, typically tube design metal temperatures in the order of 1100 degC involved. These heater designs are licensor specific.

The radiant coil assemblies of these heaters are normally having U or W or Y configuration and are arranged in single row having multiple coil assemblies.

These heaters are normally up fired from floor and/or side wall fired at multi-levels to achieve even heat distribution across the entire length of radiant tubes.

Figure 5(b) shows a typical pyrolysis heater.

3.5 Direct Fired Heaters

Heaters in which fuel is fired directly into the fluid stream to be heated are called direct fired heaters. The common examples in refinery use are direct fired air heaters and flue gas generators.

Typical direct fired heaters consist of a steel cylindrical sheet with air/gas inlet and outlet, and the burner(s) mounted at one end. The steel shell is internally refractory lined to protect the shell. General arrangement of a typical direct fired heater is shown in Figure - 3. The shells of direct fired heaters are designed to withstand internal pressures. Such units should be treated as pressure vessels and inspected according to OISD Standard-128 ‘Inspection of Unfired Pressure Vessels’.

4.0 INSPECTION RESPONSIBILITY

The following shall be the responsibility of the inspection team.

To develop an inspection procedure for all heaters outlining the following:

1. Basic design of the furnace
2. Basis for material selection of the parts
3. Design operating conditions as per datasheet
4. Actual operating conditions
5. Design fluid characteristics
6. Actual fluid characteristics
7. Deviations and its effect on deterioration mechanisms
8. Deterioration expected based on actual operating and fluid characteristics
9. Recommended operating windows along with technical services (process engineering) and operations for safe operations of furnaces.
10. Inspection required to be done on stream and off stream to ensure by various agencies to maintain safe operations
11. Methodology for periodic review of on-stream inspection findings with operations and advise corrective actions
12. Methodology for periodic review of off stream inspection recommendations with operations / maintenance for implementation of the recommendations

In addition the following shall be maintained;

(i) Inspector shall obtain base data of the heating coil in addition to the regular stage wise inspection. Base data includes microstructure, observed original thickness etc.

“OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines.”
(ii) Operating dept. to maintain a constant vigilance on the physical condition and operating parameters of the heaters during operation to spot any unsafe condition. Sample check list for observations by the operations department is placed as check list 1 and 2 of this document.

(iii) To maintain a constant vigilance on the physical condition and operating parameters of the heaters during operation to spot any unsafe condition and initiate corrective measures.

(iv) To inspect, measure and record the deterioration of materials and to evaluate the physical condition.

(v) To evaluate and analyse the deterioration rate which forms the basis in determining scheduled repairs/replacements before serious weakening or failure of any part occurs.

(vi) To determine causes of deterioration and to advise remedial measures.

(vii) To predict/recommend short-term and long-term repairs and replacements to enable procurement of materials required well in time.

(viii) To inspect the quality of replacement materials.

(ix) To inspect while doing the repairs for quality of the work and to approve after completion of repairs.

(x) To maintain and update maintenance and inspection records of various parts of the heaters.

(xi) To keep the concerned operating and maintenance personnel fully informed as to the condition of the various heaters.

(xii) To ensure that the heaters are inspected as per schedule of inspection.

(xiii) To provide timely recommendation for spares and consumables.

(xiv) Compliance of IBR statutory norms.

5.0 INSPECTION TOOLS

Following tools are generally required for carrying out inspection of heaters.

i) Ultrasonic Thickness Gauge

ii) Radiography Equipment

iii) Magnetic Particle Testing Kit

iv) Dye Penetrant Inspection Kit*

v) Infrared Scanner for Thermography

vi) Optical pyrometers

vii) Portable Metallographic Equipment

viii) Portable Hardness Tester

ix) Binoculars

x) Magnifying Glass

xi) Magnets

xii) Pit/Depth Gauge

xiii) Inside Calipers

xiv) Outside Calipers

xv) Direct reading calipers of special shapes

*OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines.
xvi) Steel Rule/Tape  
 xvii) Inspector’s Hammer  
 xviii) Broad Chisel or Scraper  
 xix) Wire Brush  
 xx) Thin Bladed Knife  
 xxi) Plumb, Bob and Line  
 xxi) Paint or Crayon  
 xxiii) Portable Lights  
 xxiv) Mirror  
 xxv) OD/ID gauge  
 xxvi) Borescope / Video probe  
 xxvii) Vibration meter  
 xxviii) Theodolite  
 xxix) Portable instruments like gas analysers, pressure gauge, temperature gauge  
 xxx) Portable PMI machine  
 xxi) Go-no-Go Gauge  

*NOTE: When selecting products which will be used for marking or applied on stainless steel and Nickel Chromium micro-alloy tubes, these products should not contain chlorides to prevent stress corrosion cracking. Additionally, any equipment or paint which can/will contact the stainless steel and Nickel Chromium micro-alloy tube surfaces should not be made or coated with low melting point metals like aluminum, zinc, lead and cadmium, to prevent liquid metal embrittlement concerns.*

### 6.0 INSPECTION OF HEATERS DURING CONSTRUCTION

Furnace shall be designed and constructed as per relevant codes and standards. Design shall be checked and certified by persons(s) duly authorised by the user industry. Construction of the furnace both in shop and in field shall be inspected on the basis of an approved quality assurance plan. Various standards such as API-560 and API-530 are used for the design of heaters and heater tubes. Other parts of the heaters, namely the furnace, setting and stack are designed to good Engineering Practices. It is the responsibility of the Inspector to see that the heater is constructed strictly to the design requirements. Proper inspection requires regular checks as it progresses.

Inspection shall be carried out in the following stages:

i) Study of the design, drawings, layout and the tender documents. 

ii) Identification and inspection of materials of construction. All alloy steel and stainless steel materials and weldments used in construction of the heaters shall be 100% checked by PMI before and after completion of welding. QAP shall capture the same. 

iii) Approval of welding procedures in accordance with tender specifications/code requirements. 

iv) Carrying out of welder qualifications tests as per code. 

v) Ensuring that approved welding procedures, welders and welding electrodes are employed. 

vi) Ensuring that proper preheating and post weld heat treatment are carried out, wherever specified. 

vii) Checking the quality of welding by radiographic and other NDT techniques as required.

*OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines.*
viii) Ensuring that the tubes are expanded into headers properly and the tube ends are not damaged, wherever applicable.

ix) Ensure proper welding of Tube Skin Temperature Thermocouple (TST) points.

x) To ensure that all the tubes are properly seated in hangers/anchors.

xi) Checking if the layout and dimensions of all heater parts are strictly as per the drawing and the tolerances laid down in the specifications are not exceeded.

xii) Testing the coils and all the pressure parts hydrostatically according to design requirements. In case hydrostatic test is not practical due to process constraints (such as catalyst incompatibility to water, refractory lined components), pneumatic test shall be carried out as per API 560 guidelines with due safety considerations.

xiii) Ensuring that all load bearing structural steel are in accordance with approved drawings.

xiv) Ensuring that the lining anchors are rigidly welded to the furnace and ducts casing prior to lining.

xv) Ensuring that castable refractory materials are within the shelf life and are mixed and applied according to the manufacturer’s recommendations and in correct thickness.

xvi) Where brick lining is used, the laying of brick lining should be as per recommended procedure.

xvii) Ensuring that all refractory work is free of voids/cracks/bulges etc.

xviii) Checking the quality of insulation material and weather proofing.

xix) Ensuring that all painting jobs are done after adequate surface preparation and the painting procedure meets the specifications.

xx) Ensuring that the explosion doors provided are operable and discharge in a safe direction.

xxi) Checking that escape routes are provided and are free from obstructions.

xxii) Checking the verticality of stack.

xxiii) Ensuring that the refractory drying out operation is carried out as per specifications. Check that during the drying out operation, the heater casing temperatures, coil Tube Skin Temperature (TST) and stack temperatures are within permissible limits.

xxiv) Inspecting the refractory lining and tubes, tube supports after the drying out operation.

xxv) Checking that sight doors being provided are operable and provide adequate view of radiant coil, tube supports and burners.

xxvi) Coil expansion provisions as per design drawings available (at tube support locations, spigot guide locations, floor refractory and header box locations; tube sleeves locations etc.).

xxvii) Convection tube sheets free expansion provision (expansion gaps between tube sheets and support columns, tube sheet to refractory gaps etc).

xxviii) Verify external piping supports/guides connected with heaters allow heater coil movements as per heater coil drawings.

“OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines.”
INSPECTION OF FIRED HEATERS

xxix) No paints/ paint marks, no wrapping of aluminium foils on stainless steel tubes before insulation (cross overs and terminals external to heater).

xxx) Verification of Insulation materials quality used in stainless steel tubes (cross overs and terminals external to heater), chloride content in insulation materials shall be less than 10ppm (to use inhibited insulation materials).

xxxi) Verification of springs installation, deblocking of springs (travel stops removal), Spring Cold readings (travel scale readings & load scale readings/ where load adjustments done).

xxxii) Removal of all temporary supports (like fabric bellows locking strips; coil bundles packing steel etc.).

xxxiii) In case of site assembled APH, ensure all sealing (gasketing & field welding) requirements as per APH vendor, to avoid mix-up of flue gas & air.

xxxiv) Heater coils /tubes resting uniformly at support locations.

7.0 CHECKLIST OF INSPECTION OF FIRED HEATERS PRIOR TO COMMISSIONING

The following information shall form part of the checklist.

<table>
<thead>
<tr>
<th>FURNACE NO:</th>
<th>DATE OF INSPECTION:</th>
</tr>
</thead>
</table>

GENERAL INFORMATION

Plant
Service
Coil I/L & O/L Press
Coil I/L & O/L temp
Coil hydrotest pressure
Fluid Flow Rate
Heat Duty
Max. Heat flux
Max. Allowable Skin Temp.

**Radiant section**

Min/Max. allowable flue gas temp in stack
Max. Temp. of casing
Furnace Type
Draft
Air pre-heater type
Stack type
Purchase order No.
Manufacturer
Serial No.
Drawing Nos.
Erection Contractor
Contractor’s Inspector
Company Inspector

“OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines.”
CHECK LIST

The following shall be the checks required prior to commissioning:

<table>
<thead>
<tr>
<th>Action</th>
<th>Check Mark</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Check if all as built drawings and design calculations are received for records.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Check if all test reports of materials, welding, Radiography, stress relieving etc. are received for records.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Check if tubes, supports and connections are installed in accordance with drawings.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Check external surface of tubes for deposits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Ensure that coils are free of foreign matters internally</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Check proper allowance for expansion of tubes and external cross overs / jump overs.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Check if all skin temperature points are installed and reading accurately.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Inspect all weld joints visually.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Carry out thickness survey of tubes for records.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Check all tubes are placed full seating on their supports.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Check if adequate provision is given in lining for thermal expansion.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Check burner alignments.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Check operability of air registers dampers, oil guns, pilot burners etc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Check steam tracing to avoid oil congealing in pressure gauge/switch lead lines etc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Check ease of operation for burner oil &amp; gas gun changing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. Check operability of explosion doors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. Check and inspect peep doors and their field of view.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. Check accessibility of all furnace parts.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. Check adequate headroom on platforms / walkways</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. Check headers boxes for tightness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20. Check and inspect air preheaters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21. Ensure rotary APH rotates freely and provision for expansion is provided.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22. Check and inspect ducting and ensure adequate provision is given for expansion.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23. Inspect duct lining and insulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24. Test the heater tubes and connected piping hydrostatically</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25. Check and inspect general completion of various sections of heaters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26. Ensure that all construction equipment, scaffolding, temporary supports etc. are removed.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27. Check if refractory lining is dried out by approved procedure.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28. Inspect refractory lining and tubes &amp; tube supports after drying out operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29. Apply a pressure test for furnace and ducting (like smoke test) and check leakage</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

"OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines."
30. Check operability of soot blowers
31. Check steam supply to header boxes, furnace, soot blowers and coils
32. Check that all relief valves are set at the correct pressures
33. Check and inspect structure and all their load bearing welding
34. Ensure all railings, gratings and floor plates are safe
35. Check external painting of all structural elements
36. Check the general cleanliness inside and outside the heater prior to commissioning
37. Check statutory approvals like IBR (if applicable) have been obtained
38. Check operability of the dampers and shut-off-blades
39. Check that coil vents / drains blind flanges and instrument mounting flanges are securely installed
40. Stack field splice are welded/bolted as per approved documents and local in-situ lining (if applicable) is installed
41. Check grouting of base plates and heater / stack anchor bolts for loose/missing nuts
42. Check that spring support locking pins are removed after hydrotest
43. Check proper setting and cold/hot readings of spring hangers
44. Check that sufficient expansion space is available at tube guides / tube extensions through the casing
45. Check the expansion joints or Non Metallic Expansion Joints in ducts
46. Verify PMI reports of coils/ coil supports and ensure 100% PMI for all alloy steels and stainless steel materials and material mismatch, if any, are eliminated.
47. Ensure hydrostatic / pneumatic testing of heater tubes and steam coils
48. Check tube seals installed at all terminal/ crossover & jump over locations (where tubes pass through furnace/ header box casing)
49. Check that all the access doors, observation & inspection doors are gasketted before box-up, for proper sealing.
50. Generate base line data for microstructure of tubes which are operating in creep range of the material.
51. Generate base line data for the supporting system for Hydrogen Reformer tubes in cold and hot condition.

8.0 LIKELY LOCATIONS OF METAL WASTAGE

8.1 Heating Coil

The principal factors contributing to deterioration of the heating coil are as listed below:

a) Type of process
b) Characteristics of charge stock
c) Velocity of flow through Heating Coil
d) Pressure
e) Temperature
f) Combustion products
g) Mechanical damage

The above factors may act singularly or in combination resulting in various forms of deterioration, namely;

“OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines.”
i) Deterioration due to corrosion
ii) Metallurgical deterioration
iii) Mechanical deterioration

8.1.1 Deterioration Due to Corrosion

a) High Temperature Oxidation

Higher tube metal temperatures than the design value may be experienced in heater tubes due to various factors such as high process temperature, flame impingement, high heat flux, internal coking/fouling, flow starvation etc. High tube metal temperature causes high temperature oxidation which is characterised by hard brittle oxide scales on the tube surface, resulting in tube wall thinning.

The most likely locations where high temperature oxidation occurs are the fire sides of radiant and Shock/shield tubes, it may also take place on the convection tubes and refractory side of radiant tubes if the tubes are overheated uniformly due to starvation.

Failure by high temperature oxidation will take place due to tube wall thinning mostly at the fire side of the tube. If the tube is subjected to internal pressure, failure is characterised by severe scaling, bulging and longitudinal cracks. For tubes with internal vacuum, numerous transverse cracks on the oxide scales are observed. In extreme cases cracks may penetrate the tube wall resulting in failure.

b) Sulphidation:

Sulphur attack, like oxidation, proceeds by conversion of the metal to a sulfide scale. The most destructive form of sulphur is Hydrogen Sulphide. Generally corrosion rate is a function of the sulphur content in crude, but other factors such as presence of Naphthenic acids, dissolved oxygen etc. may increase the corrosion rate for the same sulphur content.

The rate of corrosion of sulphur increases with temperature. Therefore, areas of heater tubes subjected to higher temperature such as the fire side of radiant tube may suffer higher corrosion, while all internal surfaces of heater coils are prone to sulphur attack. Erosion and pitting type cavitation attack is found on internal surfaces of return bends. Pitting type corrosion is observed beneath sulphur rich internal deposits. Where discontinuous layer of coke is present, the parent metal adjacent to the edge of the coke layer suffers preferential attack.

c) Naphthenic Acid Corrosion:

Organic acids such as Naphthenic acids cause corrosion of heater tubes in the temperature range 230-425 degree C. Naphthenic acid corrosion is significant when the TAN value of crude is more than 0.5. This type of corrosion is more pronounced in locations of high velocity, turbulence and impingement such as the return bends, weld joints between the return bend and straight tube, downstream of weld joints between the return bend and straight tube, etc. Corrosion by Naphthenic acid is characterised by sharp edged stream lined grooves or ripples resembling erosion effects.

d) Low Temperature Acidic Corrosion

The flue gas of fired heaters contains $\text{SO}_2$ and $\text{SO}_3$. At low temperatures (less than dew point), this may combine with moisture and condense as acids which is corrosive. Depending on the flue gas outlet temperature, locations such as air pre-heater, stack, duct, ID fan, the convection tubes external surface etc. are prone to acidic corrosion.
Combustion products containing sulphates deposited on various metallic components of the heater also form acids during shutdowns/idle time of the heater leading to corrosion.

e) Fuel Ash Corrosion

If the fuel fired in the heaters contains more than 100 ppm of total vanadium and sodium, the deposits formed on the tube support surfaces are corrosive at temperature higher than 650 degree C. External surface of radiant tubes /convection shock tubes & radiant/convection shock tube supports may be affected by this type of corrosion, known as fuel ash corrosion.

f) Miscellaneous Types of Corrosion

Other impurities such as chlorides, wet phenols etc. may cause corrosion of heater tubes. Chlorides cause pitting type corrosion, inter granular corrosion and stress corrosion cracking on austenitic stainless steels. Generation of polythionic acids from wet sulphide scales during down time may also pose stress corrosion cracking problems in sensitized Austenitic Stainless Steels.

Convection coils made of studded tubes are prone to pitting type internal corrosion in corrosive oils, due to differential temperatures between studded and bare areas.

8.1.2 Metallurgical Deterioration

Metals and alloys subjected to high temperature for long periods undergo metallurgical deterioration. While metallurgical changes rarely cause loss of tube metal thickness, they result in general reduction in mechanical strength or change in ductility which may eventually cause complete failure of the tube.

Areas subjected to high tube metal temperatures are prone to metallurgical deterioration. The time of exposure to the temperature and hence the operating history of the tube also is a factor. A brief description of various forms of metallurgical deterioration is given below:

a) Grain Growth:

In general the smaller the grain size in a metal or alloy, higher the tensile strength and lower the rupture and creep strength. Therefore, any change in grain size is detrimental for given operating conditions. Mild steels undergo grain growth above 600 degree C and austenitic stainless steel above 900 degree C. Grain growth also is a function of time of exposure at high temperature, degree of cold work and type of steel.

b) Graphitization

Certain ferritic steels when operated for long period in the range of 440 degree C may suffer graphitization in which the carbide which gives the strength to the steels decompose into iron and graphite. Replacement of hard, strong carbide with soft, weak iron and brittle graphite lowers the strength of steel.

c) Carburization

Diffusion of elemental carbon into solid steel when in contact with carbonaceous materials in petroleum oils is called carburisation. Carburisation increases rapidly with increase in temperature and increased time of exposure. Carburization is often found where coke and gaseous hydrocarbons rich in CO, CO₂, Methane and Ethane are present at temperatures typically higher than 600 degree C. The presence of hard, brittle carburized structure may result in spalling or cracking of the tubes.
d) High Temperature Hydrogen Attack

At high temperatures (above 230 degree C) hydrogen may dissociate to atomic hydrogen and penetrate the steel surface. The source of hydrogen may be from the process steam or evolved by thermal cracking of hydrocarbon. The carbon in the steel migrates to the grain boundaries where the carbon and the hydrogen combine to form methane. This reaction causes internal pressure at the grain boundaries to build up high enough to cause inter granular cracks. This phenomenon is generally known as high temperature hydrogen attack which also results in decarburization. Material selection for hydrogen service is done based on API 941.

e) Hardening

When ferritic steels are heated above 727 degree C, austenite, a solid solution of iron and carbon begins to form. If the steel is cooled rapidly - and this critical rate of cooling varies widely with the steel compositions - martensite, an extremely hard and brittle substance is formed. In carburised furnace tube even the slow cooling of the furnace is fast enough to cause hardening which is often accompanied by cracking through the tube wall.

f) Liquid Metal Cracking/Embrittlement

This is a form of environmental cracking where molten metal penetrates the grain boundaries of the steel. Austenitic stainless steel tubes of series 300 are susceptible to this type of mechanism from molten aluminum, zinc and cadmium. Firebox temperatures are adequate for these metals to be molten since these metals have relatively low melting points. Care should be taken to avoid contact of stainless steel surfaces with a low melting point metal during maintenance outages including incidental contact such as using marking pens containing zinc and galvanized or aluminum scaffolding poles rubbing against tubes.

g) Metal Dusting

Metal dusting is a catastrophic form of carburization which can lead to rapid metal wastage in both ferritic and austenitic alloys. Typically this damage mechanism appears in the form of localised pitting, or grooving, along the inner walls of pipe and tubes. Environments with high carbon activity (greater than 1) and low oxygen partial pressures can be prone to this type of damage if temperatures become high enough for carbon diffusion to occur in the base metal. Depending on the type of alloy, this temperature may be as low as 800°F (427°C) and as high as 1400°F (760°C).

8.1.3 Mechanical Deterioration

Mechanical deterioration of heater tubes and tube supports may take place due to over stressing, weakening, poor workmanship, vibration, abrasion etc. Various forms of mechanical deterioration are indicated in the following paragraphs:

a) Creep & Stress Rupture

Creep is defined as the plastic deformation of metals held for long period of time at stresses lower than the normal yield strength. Creep rate increases with increase of stress or temperature. Loss of thickness due to corrosion will result in increase in stress of tubulars and hence the creep rate. Stress rupture takes place when the creep rate is very high. Metallurgical deteriorations also result in loss of creep strength of the material.

b) Bulging

“OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines.”
Localised hotspots such as those caused by flame impingement reduce the mechanical strength of the material at such spots, resulting in bulging due to internal pressure.

c) Sagging

Sagging is due to decreased structural strength of tube on overheating, unequal metal temperature, improper spacing or failure of tube supports.

d) Bowing

Bowing is due to unequal metal temperature or restriction to free thermal expansion at the ends which induces excessive stresses.

e) Thermal Stresses

If a dissimilar metal is welded to the furnace tube such as skin points and tube guide supports, the differential co-efficient of expansions will cause thermal stresses. When the temperature around such locations fluctuates, the stresses will fluctuate resulting in thermal fatigue and failure at weld HAZ. This phenomenon is also possible in thick walled heater tubes due to higher differential skin temperatures at the inside and outside surface of the tubes.

f) Thermal Shock

Thermal shock is a phenomenon caused by a sudden change in temperature either from hot to cold or from cold to hot. The stresses resulting from the sudden unequal expansion or contraction of the different parts may cause distortion only or distortion plus cracking. Thick metals are more susceptible to cracking than thin ones. The most likely time of temperature shock is during unit start-ups when the process fluid is more likely to reach a dry point within the tubes. Heating or cooling rates should be controlled to avoid thermal shock.

g) Erosion Corrosion

Erosion corrosion is a degradation of material surface due to mechanical action, often by impinging liquid, abrasion by a slurry, particles suspended in fast flowing liquid or gas, bubbles or droplets, cavitation, etc.

h) Thermal Fatigue

Metal that operates under cyclic temperature conditions, especially over a wide range, may develop cracks from thermal fatigue. Cracks start at the surface of the material where the stresses are normally higher, progressing slowly at first and then more rapidly with each cycle of temperature change. Thermal fatigue is often found at locations where metals that have different coefficients of expansion are joined by welding. Other common locations for thermal fatigue are in convective tubes where the tube fins can promote cyclic temperature swings, tubes with two-phase flow, and bracing/weld attachments which do not allow for thermal expansion.

f) Vibration

Vibration of heater tubes is caused by two phase flow, flow fluctuation, rapid evaporation and improper tube supports. Vibration will cause tube metal wear at the tube/tube support contact points. Rolled in headers may develop roll leaks due to vibration.

g) Mechanical Cleaning

"OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines."
Damage to a tube during mechanical decoking can take place if the cleaning tool was operated in one place for long period. Machined surfaces of header fittings can be damaged by decoking tool. Undue force used in header fitting can result in cracks, excessive wear or distortion of the fitting. Repeated hammering of ferritic alloy steel at one location causes cracking of tube.

8.1.4 Deterioration Mechanism for Steam Methane/Naphtha Reformer Heaters

Due to high thermal and mechanical stresses and high operating temperatures, steam methane/naphtha reformer heater tubes and pigtails are susceptible to creep and stress rupture. Generally, the failures due to stress rupture occur at the hottest, most highly stressed portion of the tube. The hottest areas are normally near the bottom and top of the tubes for down-flow systems and up-flow system respectively. If flame from burners or from combustion products gets deflected off walls and the same impinges upon the tube, stress rupture can occur in the hottest parts of the tube.

Creep rupture failure of Steam methane/naphtha reformer heater tubes can be different from most other heater tubes. The tubes of these heaters have a thick wall with a large thermal gradient across it such that there are significant thermal stresses in the region between the ID and mid-wall. These thermal stresses are high enough to promote creep initiating where the combination of stress and temperatures are above a threshold and propagating to the inner diameter. Finally, the cracks propagate to the outer diameter which results in the failure of the tubes.

For better reliability of pigtails and tubes of these heaters the mechanical stresses from thermal growth should be minimized. Special support and hanger system of steam methane/naphtha reformer heaters is designed in such a way that it allows the tubes to grow in service and reduces the stress on the pigtails and headers. Failure of the support system can produce high stresses on the pigtails and tubes to the extent of promoting creep rupture. Without adequate support, tubes can bow in service, resulting in further increase of the stresses. Stress level at the bends of the bowed tubes is higher than the stress levels in the straight portion of the tubes. Tube bowing, tube movement, sagging of the pigtails under its own weight, and thermal expansion of a pigtail loop induce bending stresses on pigtails. The pigtails are susceptible to thermal fatigue, if the movement is cyclic because of swings in operation or number of start-up and shutdown operations.

8.2 TUBE SUPPORTS

i) The tube supports are subjected to much higher temperature than the tubes. Hence they are more prone to high temperature oxidation and fuel ash corrosion.

ii) Austenitic stainless steel tube supports such as type 304, 309, 310 etc. and nickel chromium alloys are prone to sigma phase formation and loss of ductility.

iii) Failure of tube supports may take place due to mechanical overloading caused by bowing of tubes, lifting of tubes from some supports, loss of strength of supports, and tube vibrations. Inadequate expansion gaps at Intermediate Tube Sheet (ITS) ends (gaps between ITS and support columns, Gap between ITS and refractory hot face etc.) may also result in overloading of the supports.

8.3 REFRACTORY LINING

i) At high temperatures, refractories will deteriorate as a result of long time exposure, by spalling, failure of binding material, melting and loss of structural strength.

"OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines."
ii) Rapid cooling of furnaces such as during emergency shutdowns will cause thermal shock and cracking of lining.

iii) When fuel ash containing vanadium is in contact with refractory, a fluxing action takes place producing a molten slag and gradual reduction in thickness.

iv) All the expansion gaps in the refractory brick lining shall be packed with ceramic fibre strips whenever the heater is cooled and started back during shutdown and start-up; the gap otherwise permit the corrosive flue gas to reach the metallic casing, condense and corrode the casing metal.

8.4 CASING
i) Failure of internal refractory lining causes overheating of underlying steel casing. This will be revealed by local hot spots.

ii) Cracks in refractory lining allow the flue gas to come in contact with steel. The low temperature of the casing promotes acidic corrosion.

iii) External surface of the casing are subject to atmospheric corrosion, particularly in case of heaters which are located in coastal areas and at downwind of cooling towers.

iv) Inadequate stiffening of the casing may result in warping / local deformation of casing.

v) Radiant roof, breeching roof, duct roof surfaces are subjected to corrosion due to rain water stagnation/ water seepage inside (due to blocked drain holes/ damaged sealing).

8.5 Miscellaneous
i) The burner mounting plates are prone to distortion and oxidation due to flame back up. Burner tips are subjected to erosion and oxidation.

ii) Flue gas ducts, breeching and stack are prone to acid dew point corrosion on steel parts.

iii) Settlement of foundation may cause cracks to develop in brick or concrete stacks. Sections of stack lining exposed to rain are damaged in a short period.

iv) Air preheater elements and casing may be affected by acid dew point corrosion if flue gas temperature is low. The cast iron elements of APH may develop cracks under thermal shock inducing conditions, such as on stream water washing and/or due to restricted flow over some part of APH due to blockages in flue gas path.

v) Improper operation of furnaces can cause after burn explosion in the convection section / flue gas duct/stack and related deterioration.

vi) Externally insulated ducts and pipelines may corrode if water seeps into the insulation.

vii) Chocking in convection section can cause pressurization in the box.

viii) Steam condensation due to passing of soot blower steam inlet and/or purge steam valves causes corrosion of heater components.

9.0 TYPES & FREQUENCY OF INSPECTION

9.1 Types of Inspection
Generally there are three types of inspection of fired heaters that are in service

“OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines.”
INSPECTION OF FIRED HEATERS

i) Onstream inspection

ii) Shutdown inspection

iii) Emergency shutdown inspection

9.1.1 Onstream Inspection

Onstream inspection is carried out when heater is in service. All external parts of the heaters such as structurals, ducting, insulation/painting, external surface of stacks etc. can be visually inspected on stream. The heater tubes, tube supports, internal refractory lining etc. are visually inspected through the peep doors. The observations recorded during onstream inspection are of importance for effective shutdown inspection.

9.1.2 Planned Shutdown Inspection

During planned shutdowns, all parts of the heaters are thoroughly examined and corrective action taken for a safe run until the next planned shutdown.

9.1.3 Emergency Shutdown Inspection

Emergency shutdowns are taken due to tube failure or failure/malfunction of any other part. Inspection is generally limited to the failed part. However, it can be extended to other parts which were found in unsatisfactory condition during on stream inspection.

9.2 Frequency of inspection

The frequency of inspection of fired heaters is established with due consideration for safety and efficient operation of the heaters. The rate of deterioration of heater parts may dictate the time interval between two inspections. On the other hand shutdown of some other part of the process unit may render the heater available for inspection. The following frequency of inspection of fired heaters shall be followed:

9.2.1 Onstream inspection

i) Visual inspection of firing conditions flame pattern, tubes and tube supports of radiant section shall be carried out daily.

ii) Monitoring of tube skin temperatures, process fluid temperatures, pressure drop across the coils, flue gas temperatures and drafts at various sections shall be carried out daily.

iii) Thermographic survey for hot spots on internally lined heater casing, ducts and stack shall be carried out at least once in three months and report maintained to compare the deterioration in the refractory/ insulation/ lining.

iv) High temperature locations in heater tubes of radiant section can be measured either by thermography or optical pyrometers. The frequency of such measurement shall be decided for each installation based on severity of heater operation.

v) Onstream inspection of all other parts of the heater such as ducting, structurals, refractory etc. shall be carried out every fortnight.

vi) Spring travel scale movements shall be monitored during each start-up and also in case of increase in load/capacity during operation.

9.2.2 Shutdown Inspection

All parts of the fired heaters shall be thoroughly inspected in open and clean condition during each turn around of the unit in which the heaters are located.

"OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines."
10.0 INSPECTION PROCEDURES

Before undertaking for inspection of fired heaters, the Inspector should know the complete previous history of the heater tube supports and other parts. He should also be aware of the design and normal operating parameters, vulnerable locations of deterioration etc.

10.1 Onstream inspection

Onstream inspection shall be carried out to determine the extent of general damage and deterioration of the heater. Findings of onstream inspection forms a basis to determine the repairs to be carried out during the next planned shutdown of the heater. It also helps to identify and rectify unsafe conditions arising out of faulty operation. The following points shall be checked during periodic onstream inspection:

i) The main burners shall be checked to ensure that flame does not touch the arch or the tubes. Where more than one burner is used, the flames should be kept as uniform in length and size as possible.

ii) The radiant tubes shall be inspected for hot spots, flame impingement, excessive oxidation bowing and sagging, and the exact locations recorded.

iii) Metal skin temperatures of the radiant coil shall be checked and the possibility of any excessive coking evaluated. Specified skin temperature limit of the tubes shall not be exceeded.

iv) All radiant tubes and cross overs shall be checked for any sign of vibration and the tube locations recorded for future reference.

v) The tube supports/hangers/guides shall be checked for displacement or any deterioration.

vi) The lining of the furnace shall be checked for cracks and spalling. Hot spots observed on the furnace casing will also indicate deterioration of the lining.

vii) Breeching and ducts shall be visually inspected for any signs of external oxidation/paint failure which may be as a result of overheating of the metal after the internal refractory lining has failed.

viii) The heater operating data shall be monitored and compared with the design conditions to spot any abnormal operating conditions so that immediate correction could be made. Some indications of faulty operation are:

<table>
<thead>
<tr>
<th>Indication</th>
<th>Probable Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Positive pressure at top of firebox</td>
<td>1) ID fan not running. Excessive firing rates. Stack damper closed.</td>
</tr>
<tr>
<td>2) Excessive temperature in firebox</td>
<td>2) Overfiring</td>
</tr>
<tr>
<td>3) High flue gas pressure</td>
<td>3) a) Heat release too high b) Incorrect combustion air flow c) Fouled up convection section</td>
</tr>
</tbody>
</table>

“OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines.”
## INSPECTION OF FIRED HEATERS

| 4) Variation in outlet temperature | 4) a) Unequal flow distribution of multi-pass heaters  
   b) Flame impingement |
|-----------------------------------|---------------------------------------------------|
| 5) High pressure drop in coils    | 5) a) Coke build up/fouling  
   b) High flow rate  
   c) High Vaporisation |
| 6) Low pressure drop in coils     | 6) Low flow rates |
| 7) High flue gas pressure drop    | 7) Excessive fouling across convection bank / air preheater |

**ix)** The oxygen level in the flue gas shall be monitored to avoid excessive oxidation of the tubes or after burning in the convection and air preheater sections.

**x)** Check for any flue gas leakage from the furnace and flue gas passage ways.

**xi)** Check for any leakage of oil from rolled end headers and plugs.

**xii)** Check the operability of soot blowers.

**xiii)** Visual inspection shall be made of all load carrying structural steel members to check any unusual conditions such as deflection, bending, corrosion which might result in substantial weakening of the structural and the cause may be determined.

**xiv)** The stacks shall be externally inspected for cracks on the shells of concrete/brick stacks and hot spots and external corrosion of steel stacks. Check, if any unusual vibration of the stack exists.

**xv)** Temperature of flue gas down stream of APH shall be monitored to prevent dew point corrosion

**xvi)** Casing shall be checked for hot spots/perforations

**xvii)** Floor casing/burner housings shall be checked for warping/bulging

**xviii)** Expansion joints on flue gas/air ducting shall be inspected for leaks

**xix)** Insulated APH casing and air ducting shall be periodically inspected (after opening pockets of insulation) for detection of external corrosion.

**xx)** Heater floor shall be checked for fallen objects.

### 10.2 PLANNED SHUTDOWN INSPECTION

#### 10.2.1 Inspection of Radiant and Shock Tubes

**a)** Visual Inspection

---

"OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines."
i) The nature of external deposits on the tubes shall be checked prior to cleaning. Sulfur compounds on external deposits may lead to external corrosion during down time.

ii) On heaters with fittings of the removable U-bend or plug type, the tubes shall be visually checked internally for the nature and the thickness of internal deposits. On welded coils, the coke thickness shall be determined by radiography at selected locations.

iii) The tubes shall be visually checked for excessive sagging or bowing and the cause ascertained. Moderate sagging or bowing of radiant tubes are quite common and the same is not considered serious unless it affects the mechanical cleaning or jam and wedge against other tubes. Tubes sagged/bowed by more than 1.5 times outside diameter of the tube should be replaced. However, in case of reformer and pyrolysis heater tubes bowing and sagging limits shall be governed as per the licensor’s recommendations.

iv) The tubes shall be visually inspected to locate bulging, scaling, cracking or splitting etc. All the above types of deterioration are due to high tube metal temperature and are observed only at the fire side of the tubes. Excessive scaling indicates loss of thickness and the decision to replace the tube may be considered based on the rate of thickness loss, life of tube, anticipated length of next run etc. Typically diametrical creep from 1 to 5% on tube is allowed. However, in case of reformer and pyrolysis heater tubes the creep limits shall be governed as per the licensor's recommendations.

v) The tubes shall be examined for external corrosion and mechanical damage. The points resting on the tube supports/guides are prone to mechanical wear and localised corrosion. If the construction of the radiant tubes do not permit visual inspection at the refractory side of the tubes, tubes removed for replacement may be used as samples to study the refractory side corrosion rates.

vi) Leaking rolls and plugs shall be visually checked. The external surface of the fitting body and holding members shall be examined for cracking, distortion and mechanical wear. The plug or U-bend seat in the fitting shall be examined for enlargement, out of roundness, width of seat and damage to the seating surface.

vii) When welded coil are used all weld joints should be inspected carefully. Visual inspection may be supplemented by dye penetrant, magnetic particle and radiographic inspection as the condition may warrant.

viii) Any welding on the tube such as skin points and tube spacers etc. shall be carefully examined for cracks. Welds of dissimilar metallurgy on the tubes are prone to cracking due to thermal fatigue particularly if subjected to flame impingement.

ix) Internal visual inspection of the tubes with plug type fitting shall be carried out by holding light at one end and viewing from the other. This will reveal deteriorations such as pitting type corrosion, erosion thinning of tube ends, mechanical damage caused by cutters etc.

x) Where severe internal corrosion is anticipated it is recommended to split open representative tubes which are removed for some other reason and make a thorough internal survey to determine the corrosion rates of tubes at various geographic locations of the heater. Internal deposits, where present, shall be scrape cleaned and the tubes examined to locate pitting underneath. Return bends and downstream locations of weld joints shall be checked for erosion and streamlined pitting type attack.

xi) After mechanical cleaning of the tubes, all tubes shall be internally inspected for coke deposit and to the extent possible, mechanical damages. Similarly external inspection of the tubes shall be carried out after steam air decoking to determine any deterioration on tubes due to overheating.

“OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines.”
xii) In heaters having stainless steel tubes arrangements shall be made for passivation before exposing it to atmosphere. However, in case of thermally stabilized grade stainless steel tubes the passivation requirements shall be as per licensor recommendations.

xiii) If stainless steel tubes have been used in inlet ends of heater tubes (to mitigate severe corrosion at inlet ends) Radiography or critical thickness survey shall be carried out to detect any grooving taking place downstream of S.S. sleeve.

b) Determination of Tube Wall Thickness

i) Ultrasonic thickness readings of the tubes shall be taken at four or more predetermined locations along the length/height of the tube. At each location, tube thickness is measured at 3-4 spots along the circumference and the same are recorded. Typical tube thickness data entry forms with locations of gauging points are shown in Fig. 6 & 7. The previous thickness readings at the corresponding locations may be compared with the present thickness and the corrosion rate and remaining life of each tube determined. The locations to be gauged shall include areas closest to the flame, downstream of each weld joint, adjacent to tube supports, return bends of welded coils, and portion of tube inside the header.

Intelligent pigging of heaters to determine the condition of the convection and radiation sections tubes should be done where the heater indicates susceptibility to corrosion during normal operation and hence loss of thickness.

ii) Further, the minimum thickness of the coil shall be determined at the following areas:

a) Excessively oxidised areas
b) Bulged locations
c) Return bends
d) At locations of hot spots as recorded from onstream inspection.

c) Other Type of Examinations

i) Hardness Testing: Spot checking of hardness of tubes at selected areas may reveal metallurgical changes such as carburisation, decarburisation and hardening of tubes at external surface.

ii) O.D. Measurements: Outside diameter measurements on tubes shall be carried out at predetermined locations and the readings compared with those of previous inspection to check minor bulges, creep and external thickness loss.

iii) Metallurgical examination: Heater tubes exposed to high temperatures undergo metallurgical changes that are detrimental to tube life. Most metallurgical tests are destructive hence metallurgical examination of discarded heater tubes which are suspected to have been exposed to high temperatures often throw light on the condition of the other existing tubes. However, with spot metallographic equipments, it is possible to detect most metallurgical deteriorations such as grain growth, hardening, decarburisation etc. of tubes in service also.

iv) Magnetic Test for Carburization in pyrolysis heaters: Pyrolysis heater tubes are susceptible to carburization on the internal surface which is detrimental to overall life of the tubes. Magnetic permeability measurement is one of the NDE methods to evaluate the extent of carburization in heater tubes of austenitic metallurgy. Austenitic tubes are essentially nonmagnetic. Carburized areas of the tubes become magnetic, and if these areas are large, they can be detected with a magnet. A magnet on a string dropped down a tube will indicate areas that are magnetic but will not indicate the depth of carburization. There are several commercially available devices that are used for measuring the ferrite
content of austenitic welds which may be suitable for identifying localized areas of magnetism in heater tubes. Some instruments and field services can relate the degree of magnetism to the depth of carburization.

Co-relation between magnetic permeability and depth of carburization may differ for different tube metallurgy. Hence the instruments should be calibrated on an operating tube sample as per NACE.

10.2.2 Inspection of Convection Tubes

The guidelines for inspection of radiant and shock tubes given in 10.2.1 are equally applicable for convection tubes also, depending on their accessibility for inspection. However, the following additional points should be borne in mind while inspecting the convection tubes:

i) External corrosion of the convection tubes will be more when compared to radiant tubes due to lower flue gas temperature at locations where external deposits are observed.

ii) The external deposits on convection tubes shall be cleaned during shutdown opportunities.

iii) Due to lower heat flux in convection section, deteriorations due to high tube metal temperature will be of less magnitude as compared to radiant tubes.

iv) Excessive sagging or bowing of convection tubes may result in blockage of the flue gas passage way which will affect the heater performance.

v) Studded tubes shall be inspected visually for external corrosion especially below the stack openings

vi) Convection tubes shall be inspected for erosion marks opposite/adjacent soot blower openings.

10.2.3 Inspection for Steam Air Decoking

An improperly operated steam air decoking process may cause damage to the tubulars. The following shall be observed carefully during steam air decoking:

a) It shall be ensured that

i) adequate steam flow and pressure during the spalling operation exists.

ii) correct pressure and flow of air during burning exists.

iii) all passes are spalled simultaneously and steam flow distributed uniformly.

iv) the tube skin temperatures are correctly monitored. The furnace firing conditions shall also be monitored periodically.

v) the amount of coke collected in knock out drum is monitored to judge the effectiveness of the process.

vi) visual inspection of the tubulars after steam air decoking is carried out.

vii) UT measurement of bends and coil hydro test is also recommended based on heater configuration and past experience.

"OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines."
Cleaning of tubulars can also be carried out by other methods such as high pressure water jet blasting, mechanical pigging etc. During mechanical pigging special attention to be made to the following:
   a) Ensure that all the pigs launched are received at their designated locations(s)
   b) Coke removed during pigging shall be checked for metal content.
   c) Visual inspection of the tubulars to be carried out

10.2.4 Retiring Limits

All heater tubes which do not have sufficient thickness to last till the next shutdown shall be replaced. An elaborate method of estimating tube skin temperature, minimum allowable thickness and calculation of remaining life of heater tubes as given in API RP-530 shall be used. Tubes which indicate severe grain growth shall also be renewed.

10.2.5 Comprehensive Health Assessment of Heaters

It is recommended to remove representative samples of tubes for comprehensive health assessment based on the following:
   i) Tubes are nearing end of life based on calculations with actual pressures, tube metal temperatures and measured thicknesses.
   ii) Creep damage detected from measurement / metallography.
   iii) Tube failures / leaks have occurred.
   iv) Unusual operating conditions / upsets are suspected to have taken place.

Heater tubes operating in creep zone should be considered for comprehensive health assessment after 100,000 hours of operation.

10.2.6 Hydrostatic Test

The heater coils shall be hydrostatically tested with potable water at a pressure of one and half times the design pressure corrected for maximum operating skin temperature or one and half times the heater feed pump shut off pressure, whichever is higher. Hydrostatic test pressure shall be maintained for minimum one hour duration to test for leaks. Testing may be done with kerosene or suitable oil in services where water ingress is not desirable. The tube metal temperature during hydrostatic testing shall always be at least 17 Degrees C more than the minimum design metal temperature (MDMT) but need not exceed 48 Degree C.

Hydrostatic test shall be carried out whenever replacement of any tube/fitting is done and in every major maintenance/inspection shutdown and in every decoking shutdown. However, if it is not practical to carryout hydro test due to process reasons (water being a poison to systems) or due to constructional features of the furnace an alternate leak test shall be performed as per API 560 guidelines. The individual components getting replaced shall be hydro tested outside and all the weld joints shall be 100% RT or UT checked.

Deminereralised water shall be used for hydrostatic testing of stainless steel heater tubes to avoid chloride stress corrosion cracking. The test pressure shall be held for at least one hour after all joint leaks have been eliminated.

Dry Air/Nitrogen shall be blown inside the austenitic SS tubes after hydro test to avoid any accumulation of water to prevent chloride SCC.

“OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines.”
During the time the heaters are under test pressure, an inspection shall be carried out from inside the combustion chamber/convection box to locate any possible leak. All heater fittings shall be examined thoroughly to see that tube rolls are tight and that the plugs or U-bends and their holding members are properly seated and tight.

All the safety consideration during hydro testing of the heater coil shall be followed.

_The furnace coil to be taken upto hydrotest pressure, hold it for 60 minutes and then bring down the pressure to test pressure divided by 1.5. Carry out inspection at the reduced pressure._

10.2.7 Inspection of Heater Foundation

i) Check the foundation for settlements with reference to a reference point and compare with the previous inspection.

ii) Visually inspect the foundation concrete for calcination and flaking. Calcination takes place due to dehydration at high temperature, resulting in weak porous structure of concrete. Corrosion of the reinforcement steel will cause cracking of the concrete. Such conditions require corrective measures.

10.2.8 Structural

i) Visual inspection of all load bearing structures shall be carried out for signs of overloading such as deflection, buckling and corrosion. The cause of excessive deflection should be ascertained and corrective measures taken.

ii) All ladders, platforms and stairs shall be inspected for paint failure and external corrosion.

iii) All riveted/ bolted/ welded connections on structural members shall be checked for cracks and any other type of deterioration.

10.2.9 Air duct

i) Visual inspection of the air ducts shall be carried out for any signs of external corrosion. Light hammer testing of the duct plates shall be carried out to locate thinned out areas.

ii) Mechanical damage and buckling of the duct shall be checked. Settlement of foundation will cause damage to the ducts.

iii) Check the tightness of all bolted joints.

iv) The dampers shall be examined for corrosion and cracking and its operability shall be checked. The calibration of damper position indicator shall also be checked.

v) Expansion joints shall be visually examined. Leaky non metallic bellows shall be replaced. Metallic expansion bellows having cracks shall be repaired/replaced.

10.2.10 Burners

i) The burners shall be inspected for oxidation, corrosion, erosion and clogging.

ii) The air registers shall be examined for their physical condition and adjustability.

iii) The alignment of the burners shall be checked after installation.

iv) Burner throat, wind box shall be checked for debris.

“OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines.”
10.2.11 Tube supports, Hangers and Guides

The tube support / hangers / guides /tube spacers /locking bars shall be examined (by NDT as per requirement) for cracks, oxidation, missing sections and missing/broken or oxidised bolts. Ferritic/Austenitic SS supports are prone to formation of sigma phase and subsequent weakening. Presence of sigma phase can be determined by studying the microstructures of representative tube supports. It should be borne in mind that failure of tube supports in operation may cause damage to the tubes and accordingly unsound support should be replaced or reinforced.

Intermediate tube sheets in convective section shall be inspected visually and by NDT, if necessary, for detection of any crack.

Inspection of spring supports:

The spring supports shall be periodically inspected visually for their proper positioning, functioning, and distortions, if any, and to ensure that supports are not damaged or obstructed by items such as temporary scaffolding, additional equipment or debris that might have fallen into the unit.

Threaded items require greasing at intervals to suit the environment, but no longer than 2 years.

Lubricating/ occasional spray over the area of moving parts, with particular attention paid to spacer washer between the load adjuster block and the lever side arms (in constant hangers) and bearings with medium grade lubricating oil.

Protective coatings should be periodically inspected for rusting/ corrosion and if necessary repaired.

10.2.12 Fire Box and convection Box

i) The steel casing plates shall be examined for any signs of overheating such as oxidation and buckling and corrosion. Where the casing is made of bolted panels, the joints shall be checked for flue gas leakages. The peep doors and manholes shall be checked for any deterioration. The explosion doors shall be checked or their fitness and operability.

ii) The refractory lining shall be visually inspected for breakage, cracks, spalling and slagging. Spalling of refractory lining causes seepage of flue gas towards the steel casing overheating it. Slagging will result in loss of overall thickness of the lining. Refractory surface subject to very high temperatures will become plastic, forming a hard glazed surface.

The condition of refractory lining and its supporting members in high temperature zones like at the top of vertical furnaces need special attention and their periodic inspection by locally cutting the furnace casing may be considered.

iii) Insulation of furnaces is provided as a back up material to the refractory lining. Deterioration of the insulation will be revealed by overheating of the steel casing. External insulation and insulation protection of other components such as ducting and piping shall be visually inspected for deterioration.

iv) The expansion joints on refractory lining shall be free of debris and free of expand.
v) The burner throats shall be examined for coke build up, cracks, breakage etc.

vi) Re-radiation cone and its hanger rods, bolts and support baffles shall be examined for oxidation, cracks and weakening.

vii) Refractory / Metallic corbels shall be visually inspected for damage

10.2.13 Flue Gas Ducts

i) The flue gas ducts shall be visually examined for any signs of overheating as indicated by paint failure and external corrosion.

ii) Flue gas ducts are also prone to internal corrosion due to condensation of acidic flue gases, and also down time corrosion due to deposits. The casing plates shall be light hammer tested to locate thinned out area.

iii) Internal visual inspection shall be carried out to locate damage to internal lining, if any.

iv) The dampers shall be inspected to check the operability and for corrosion. Calibration of damper position indicator shall also be checked.

v) The tightness of all packed joints shall be checked. The physical condition of the expansion joints also shall be checked.

vi) Insulated air ducting shall be visually examined, after removal of insulation in pockets, for detecting external corrosion and thinning

vii) Inspection will be guided by Thermography which should be done before shutdown.

10.2.14 Soot Blowers

i) The soot blower lance pipe shall be checked for internal choke up, corrosion and erosion of the spray nozzles.

ii) The operability of the soot blower shall be checked. The position of spray nozzles should be such that they do not cause direct impingement on the tubes. Check the gland packing for leakage and evidence of warpage. The steam shut off valve also shall be checked for leakage.

iii) Soot blower relief valves shall be inspected and tested as per OISD Standard 132.

iv) Soot Blower impingement plates/liner plates shall be checked for erosion/corrosion.

10.2.15 Air preheaters

i) The rotating element of rotary air preheaters shall be removed and the air and flue gas compartments shall be inspected for any type of deterioration.

ii) Rotary and circumferential seals shall be inspected for corrosion.

iii) Deposits on the rotary elements shall be cleaned by water washing or any mechanical means. They shall be inspected for corrosion or mechanical damage.

iv) Dust collectors shall be inspected for leakage corrosion, erosion and detachment.

v) In tubular type of air preheaters, fouling of tube at the flue gas side causes high fire box pressure. Cleaning of the tubes may be carried out by water washing or air blowing, or
mechanical means. Water washing of APH tubes made of cast iron should be avoided when the tubes are hot as it will cause cracking of the tubes due to thermal shocks.

vi) The tubes and the casing shall be inspected for corrosion/mechanical damage. The casing and covers shall be checked for buckling due to after burns. The tightness of packing between air and flue gas side shall be checked.

vii) It shall be ensured that the wash water from air preheater does not cause damage to the lining and casing plates of the ducts and air preheater.

viii) APH casing shall be inspected for signs of external corrosion, after pockets of insulation are removed at the selected locations.

ix) Refractory lining inside APH shall be inspected for spalling/cracks.

x) Casing shall be visually and ultrasonically examined, for corrosion due to condensed flue gas products.

xi) Glass tubes of glass type air preheaters to be checked for any breakage.

xii) Water washing shall be done following proper procedure to avoid thermal shocks.

xiii) Air test or Smoke test should be carried out to detect any leaks in glass tubes or CI tube panels.

10.2.16 Inspection of Direct Fired Heaters

The inspection of direct fired heaters, as far as the burners and refractory lining are concerned, is similar to that for a tubular heater.

The external, cylindrical casing of some of the direct fired heaters may be designed to withstand internal pressure. Such units should be treated as a pressure vessel and inspected according to OISD Standard 128.

10.2.17 Inspection of Stacks

i) The foundation and anchor bolts of the stacks shall be examined for deterioration.

ii) Stacks are prone to after burning due to carryover of unburnt fuel. This may be indicated by localised overheating of plates of steel stacks, and cracking of the outer shells of concrete/brick stacks. Thorough external visual inspection of the stacks will reveal such conditions. Concrete stacks may also develop cracks due to expansion of corrosion products of the steel reinforcements. Such conditions need repair depending on their seriousness.

iii) The internal lining of all stacks shall be inspected for cracks, wear and for structural soundness by using Bosun’s chair or scaffolding.

iv) A close inspection of welds of flue gas stacks shall be carried out to locate preferential acidic corrosion and stress corrosion cracking.

v) Ultrasonic thickness survey of steel stacks shall be carried out. Thickness survey adjacent to the ladders will usually suffice for stacks with ladders. For stacks without ladders, thickness survey may be done by using painters trolley/scaffolding. During the first major maintenance/inspection outage of the heater, thickness survey of steel stacks shall be carried out. Subsequent thickness survey shall be done at least in every alternative shutdown or based on the expected corrosion rate, a safe frequency of

“OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines.”
inspection may be decided. The remaining thickness shall be compared with the pre-established minimum allowable thickness and repairs carried out as necessary.

vi) The stiffening rings, lugs, wind breakers, ladders and landing on the stacks shall be thoroughly inspected for corrosion.

vii) The caps on brick and concrete stacks shall be checked for any deterioration. Failure of the caps may cause loose bricks to fall down.

viii) The stack painters trolley cable and damper operating wire ropes shall be inspected for corrosion and mechanical damage before each usage.

ix) Guy lines of guyed stacks shall be visually inspected for corrosion and weakening of the strands. Binoculars may be used to inspect the guy wires. These wires should be greased in every shutdown. The stack and bottom connections of guy wires are particularly prone to service corrosion.

x) Lightning rods and their grounding cables shall be inspected visually to ensure that they are not broken and that electrical continuity exists.

xi) During inspection of stacks following accessibility also to be checked as per CPCB emission regulation part three:
   a) Availability /no./location of sampling ports for manual sampling.
   b) Installation / strength of working platform for drawing samples.

10.2.18 Inspection of Auxiliary Equipment:

i) Duct Expansion Bellows:

Fabric bellows shall be visually inspected for surface defects or damage to fabric layers. Especially in the early days of operation, monitor the outer fabric layer for any discoloration or damage, indicative of excessive heat or movements. When the system is operating, check that the bolt heads do not touch the outer layers of the expansion joint, to prevent damage to fabric layers.

ii) Tube Seals:

Tube Seals shall be visually inspected for damages if any to outer fabric cloth and to ensure proper positioning of clamps/ fixing wires for leak tightness.

iii) Dampers and Shut Off Blades:

Dampers:

Though dampers do not generally require any maintenance, it is however advisable to check following items once a year for correct adjustment:

a) Check that shaft seals are fully pressed against the frame. If not, hand tighten the seal retainer plate and lock the nuts with counter nuts.

b) Clean the linkages pivots from dust. If the backlash in the pivots exceed 0.3mm, then replace the eyebolts (Note: Do not lubricate the eyebolts).

c) Inspect blade seals, shaft seals and bearings and replace as per damper vendor recommendations.

d) Where pneumatic actuators are provided, check for their smooth operation.

e) When the damper remains in a specific position for a long time while in operation, the operability of the system should be checked through “crack open test” without disturbing the routine operation. This test ensures that the damper is not jammed due to “stay put”
condition during operation. This test may be performed once in a month and test procedure shall be as per damper vendor recommendations/maintenance manual.

**Shut Off Blades:**

The SOBs should be inspected to ensure integrity of its components.

a) Blade seals: While in service, check for leakage across to duct while the blade in closed position. Inspect blade seals and replace as per damper vendor recommendations.

b) Bearings: While in operation, check for excessive noise, heat or vibrations or any indication of misalignments/ binding.

c) Check for excessive wear on stem teeth, stem nut and clean/grease these items periodically.

d) Where electro-mechanical actuators are provided, check for their overheating and smooth operation. Check amperage of the motor during operation to detect any overloading.

**Electromechanical / Intelligent Actuators:**

Electromechanical / Intelligent Actuators should be operated at certain interval to ensure reliability and correct operation of the actuators. All the settings should be cross checked with respect to the design and ensure proper setting for reliable operation. Required maintenance of the gear box, stem and other accessories should be carried out during the trial. All electrical connections should be checked and verified by carrying out maintenance on the actuator and power source.

**11.0 METHODS OF REPAIRS AND INSPECTION DURING REPAIRS**

Repairs/replacements of damaged heater parts are carried out to ensure that the heater is in fit condition for uninterrupted service until the next planned shutdown of the unit. Method of repairs and inspection requirements during repairs are given hereunder:

**11.1 Tubes & Fittings**

i) Damaged tubes with rolled in fittings shall be fully replaced. After removal of the damaged tube, the fitting shall be inspected for damage such as nicks, cuts and out of roundness of the tube seat. The clearance between the replacement tube OD and tube sheet I.D. of the header shall be checked to ascertain whether the same is within the permissible limits. The expansion given on tube I.D. also shall be checked to ensure adequacy of leak proof joint.

ii) Depending on the extent of damage, the rolled headers shall be either replaced or repaired. Small cracks and isolated deep pitting on the headers may be weld repaired. In alloy steel fittings, the weld heat input should be limited to avoid stress relieving of the header.

iii) In coils of welded construction, while the damaged section of the tube alone would require replacement, it would be a good practice to replace the tube from weld joint to weld joint. In such cases, it shall be ensured that no weld joint be located at areas prone to flame impingement. As far as possible, the root of the welds should be flush with ID of the tube to avoid coke formation at downstream of the excess weld metal. Use of TIG welding for the root run is preferable. In case of Alloy Steel tubes, radiography shall be carried out after stress relieving wherever applicable. Hardness checks shall be done on the welds and HAZ of alloy steel tubes. Stress relieving procedures/cycle shall be reviewed and set up shall be examined. A details procedure for inspection of welding is covered in OISD Standard 128 on pressure vessels.
11.2 Furnace and Stack

Repairing of furnace settings, ducts and stacks involve routine repairs or replacement depending on the condition of the individual part. Refractory repairs shall be inspected with respect to materials being used, method of mixing etc. Replacement works of casing shall be inspected with respect to materials being used, set ups etc.

12.0 INSPECTION OF REFORMER TUBES

In the past, the cast form of austenitic stainless HK-40 alloy tubes (25Cr-20Ni) was used in the reformer. With passage of time, this alloy was modified to IN519 (24Cr-24Ni-1.5Nb) and currently HP-Micro alloys (25Cr-35Ni-Nb-Si, Microalloys Ti,Zr,W,Cs) are being used for better resistance to carburization and for greater creep strength in Reforming operations.

Reformer heater tubes are susceptible to creep and stress rupture due to high thermal and mechanical stresses and high operating temperatures. Failures generally occur due to stress rupture at the hottest, most highly stressed portion of the tube. The hottest areas are normally near the bottom or outlet of the tube, since the temperature of the gas inside the tubes rises during reaction by about 500°F (260°C), from about 900°F (482°C) at the inlet to about 1400°F (820°C) at the outlet. If flame from burners or from combustion product, gets deflected off walls and impinging upon the tube, stress rupture can occur in the hottest parts of the tube.

Reformer heater tubes can fail by creep rupture that is different from most other heater tubes. The tubes have a thick wall with a large thermal gradient across it such that there are significant thermal stresses in the region between the ID and mid-wall. These thermal stresses are high enough to promote creep initiating where the combination of stress and temperatures are above a threshold and propagating to the inner diameter. Finally, the cracks propagate to the outer diameter resulting in rupture failure in a longitudinal direction. Minimizing mechanical stresses from thermal growth are critical to tube reliability. Reformer heaters have an elaborate support and hanger system designed to allow the tubes to grow in service and to reduce the stress on the pigtails and headers. If the support system is not functioning as designed, it can produce high stresses on the pigtails and tubes to the extent of promoting creep rupture. Without adequate support, tubes can bow in service, further increasing stresses. Bowed tubes have higher stress levels at their bends than do straight tubes.

Some cast tube materials may embrittle after exposure to high temperatures. Weld materials that embrittle during postweld cooling have high residual stresses. Weld material with a carbon-silicon ratio that does not match that of the base metal fissures easily during welding. Any micro-fissures not detected during fabrication can propagate during subsequent heating, thermal cycles, or continual high stresses from bowing or localized heating. Welding flux must be removed from tube welds. Grit blasting is recommended for flux removal. Flux of lime with fluorides is corrosive if the combustion gases are reducing (because of very little excess air) and sulfur is present.

Another main damage mechanism can be overheating of tubes by catalyst degeneration or by operating upsets. This results in bulging and final rupture in axial direction.

Design Life of Reformer Tubes

Reformer tubes are manufactured of heat-resistant austenitic alloys by the centrifugal casting process. A design life of 100,000 operating hours has been the normal time-based criteria for considering retirement of tubes however tube retirement can be decided by condition-based assessment rather than time-based assessment. The life is generally limited by creep failures. In practice there are several factors contributing to the loss of creep properties thereby making it difficult to run the tubes up to the design life of 100,000 hours. These factors are

i) Thermal shocks due to reformer tripping.

ii) Localized overheating due to damaged catalyst.

iii) High Thermal Gradient along the length of the tubes.

iv) Non uniform firing of the burners.

"OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines."
v) Restrictions in the free expansion and contraction of the tubes.
vi) Bowing of the tubes
vii) Inadequate induced draft in the furnace.

Since accidental failure of a reformer tube is a very expensive affair in terms of fire hazard and production loss, reformer tubes are normally replaced based on periodic condition assessment.

On-stream Inspection
As on-line skin (thermocouple) temperature measurements are generally not provided to the reformer tubes, more frequent on-stream inspection is necessary to assess the condition and ensure the reliability of reformer tubes.

The burner alignment shall be adjusted to ensure that the flame does not impinge on the tubes. Every day, reformer shall be inspected for firing condition, flame pattern, hot spots, bulging, oxidation, bowing and sagging. Basically, the overheating problem due to Flame impingement, Gas flow restriction, Burner associated issues etc. can be detected with Infrared thermography, which is one of the most useful inspection tools to help locate problems in steam reformers while the process units are online and fired. Single point (spot) pyrometer survey is very useful to plant personnel and do help tremendously in “trending” reformer tube skin temperatures.

Shutdown Inspection
All tubes shall be physically inspected by the various available non-destructive examinations for reformer tubes. Specific attention shall be given to the bottom half of the tube which is subjected to extreme operating temperatures and also not fully accessible for on-stream inspection in case of reformer operating with top fired burners.

i) **Tube Wall Thickness Measurement**

Ultrasonic thickness measurements shall be done at four or more predominant locations along the height of the tube. The locations shall be close to the tube welds, hot spots recorded from on-stream inspection, bulged spots and other suspected areas. Wherever creep damage occurs, an apparent decrease in wall thickness is evident.

ii) **Diametrical Growth - CREEP**

As creep damage occurs, the tube bulges. Each material has its own nominal value of diameter change where creep is considered to have occurred. Manual strapping of the tube is performed to assess diametrical growth, and the results are tabulated per tube, at specific locations on the tube (normally at burner locations). The bulging of the tubes in the bottom half portions needs to be monitored very closely. For a particular design operating pressure and temperature, the maximum allowable bulging normally is 2% for HP- micro alloyed tubes.

Diametrical growth (OD and ID) may provide a very general indication of tube condition; however, using diametrical growth as a stand alone method for measuring creep damage may lead to a significant false call on the actual condition of the tube. Only through the application of other assessment techniques, the true condition of the tube is to be determined.

iii) **Thorough Transmission Ultrasonic Attenuation (UT)**

This technique transmits sound from the outside of the tube from an ultrasonic transducer (transmitter) to a detector sensor. Creep voids and fissures in the tube attenuate and scatter the signal and allows for identification of damaged areas. The amount of attenuation and scattering is assumed to be a function of the degree of damage. But as the surface of the tubes is rough and the material grain structure is coarse, this makes it difficult to apply normal frequency ultrasonic signals. Further the primary disadvantage of this technique is the influence of tube surface condition that affects the ultrasonic signal and gives the impression of creep damage. Hence there is a possibility that this technique can falsely identify areas of damage and in other instances it can clear (pass) tubes which can then prematurely fail in service and have to be replaced. The technique can be carried out manually over the tubes or with automated crawlers which travels over the tubes.

“OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines.”
INSPECTION OF FIRED HEATERS

When this technique is applied periodically with baseline examination data, the trend of results can be an indicative measure for the rate of deterioration of the tube. A grading of percent transmission is made to draw some conclusions about the degree of fissuring, which attenuates transmission of the ultrasound. Since tubes vary in the amount of equiaxed and columnar grains, the calibration standard used should reflect the tubes being inspected. Without an adequate standard, the judgment of percent transmission may be in error.

iv) Ultrasonic Shear Wave / TOFD

Ultrasonic time-of-flight diffraction (TOFD) has also been used to compliment through transmission tube inspection. TOFD is a method that detects diffracted waves coming from the tips of flaws and is best used to detect severe flaws, such as fissures in reformer tubes. Assessment of degradation using these ultrasonic techniques may be accomplished by performing a baseline examination and recording trends over a period of time. TOFD-based technique suffers less from false-calls. A “snapshot” inspection may not adequately assess damage because of the many variables involved.

v) Radiography

Random radiographic examination is normally used as a supplementary technique to confirm the presence of severe cases of creep damage in reforming tubes. However, tight cracks cannot readily be seen unless they are normal to the film. When catalyst is in the tubes, the tight cracks will be harder to find because of the varied film densities and the catalyst edges that are present. It is desirable to remove the catalyst from the tubes, but this is not normally practical or economical when the catalyst is not scheduled for replacement. Radiography may not be as sensitive to initial fissuring and tight cracks as is ultrasonic inspection. If radiographs do show cracks, the cracks can be judged on the basis of the number of cracks and how wide they appear to be on the radiograph. Normally, dark, wide cracks on a radiograph indicate that the cracks are open to the inside diameter of the tube and requires tube replacement.

vi) Eddy Current

Eddy current inspection of reformer tubes is employed from the outside of the tube to identify crack-like defects. The principal behind eddy current inspection is that a defect changes the energy flux induced in the material through a magnetic field. For austenitic stainless steels, the energy field penetrates, up to 1 inch deep which is greater than the wall thickness of most tubes. This technique is performed externally; hence catalyst need not be removed and allows rapid inspection of tubes at travel speeds of up to 1 ft/s. External eddy current technique has a reduced sensitivity to damage located towards the inner tube diameter of tube wall. Eddy current measurements suffer from changes in the magnetic properties of the alloy, such as the oxide layer, the de-carburized zone at the outer diameter and carburization. This technique can be used more reliably from the tube inside also. The magnetic field is then closer to the most damaged area.

vii) Replication

Replication is useful for in-situ metallography assessment of reformer tube on outside tube surfaces, to detect overheating that causes micro-structural changes. Replication is a "spot" type assessment and is normally used as a supplementary technique. Only the advanced stages of creep damage can be assessed utilizing in-situ replication. There are many combinations of inspection techniques available from various inspection companies that can detect and quantify the effects of the creep damage mechanisms. The inspections are carried out in a single, simultaneous scan, with custom-designed hardware and software combining multiple NDT techniques. These are available on crawler units that are able to travel up and down the reformer tube. Some inspection techniques are available from the outside, some from the inside. Each inspection technique has its specific advantages and disadvantages such as removal of the catalyst. The end-user is to choose the best inspection technique(s) for the situation.

"OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines."
The tube internal inspection is carried out by a suitable technique like remote visual inspection or internal laser mapping of the ID growth quickly during a turn around when the reformer catalyst is being changed. Access is required only from the top of the tubes where the catalyst is discharged /loaded and no access to the reformer box itself is necessary.

13.0 DOCUMENTATION

Forecasting the future repairs to any part of the heater is based on the past history, present condition, the design and operating parameters. Therefore, maintenance of accurate information regarding each fired heater is very important. The records to be maintained shall be in general consist of the following:

i) A heater data sheet covering the design, operating and the constructional aspects of the heater. (See for example Anneuvre II, Sheet 1)

ii) A history card showing the shutdown period of the heater and the reason for shutdown.

iii) A detailed inspection report indicating inspection finding, work carried out and forecast for next shutdown. Information such as history of individual tubes, thickness readings on tubes, tube support replacement history etc. shall be presented in the form of tables and sketches. Annexure II, sheets 2, 3 & 4 show typical forms used to record tube history and thickness reading of box type heater, vertical heater and convection section tubes respectively. Sheet 5 of Annexure II is a sketch showing replacement history of tube supports of box type heater.

iv) A reference card indicating work to be carried out during shutdown of the heater based on previous inspection data and onstream inspection shall also be maintained.

14.0 REFERENCES

i) API RP 571 Damage Mechanisms Affecting Equipment in the Refining Industry

ii) API guide for inspection or refinery equipment chapter V preparation of Equipment for safe Entry and Work.


iv) API RP 573 - INSPECTION OF FIRED BOILERS HEATERS AND HEATERS

v) API STD 560 - Fired Heaters for General Refinery Service

"OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines."
Fig. 1(a) CYLINDRICAL HEATER WITH VERTICAL COIL

Fig. 1(b) CYLINDRICAL HEATER WITH HELICAL COIL

Fig. 1 TYPICAL VERTICAL CYLINDRICAL HEATERS

“OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines.”
Fig. 2 TYPICAL CABIN / BOX HEATERS

“OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines.”
INSPECTION OF FIRED HEATERS

Fig. 2(e) BOX HEATER WITH DOWN FIRED BURNERS VERTICAL

Fig. 2(f) BOX HEATER (TWIN CELL) WITH TUBE COIL DOUBLE FIRED BURNERS

Fig. 2(g) BOX HEATER (TWIN CELL WITH COIL UP HORIZONTAL TUBE COIL

Fig. 2(h) BOX HEATER WITH ARBOR FIRED BURNERS

Fig. 2 TYPICAL CABIN / BOX HEATERS

“OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines.”
Fig. 3 DIRECT FIRED HEATER

"OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines."
Fig. 4 Box-type Heater with Horizontal Tube Coil
Showing Main Components

"OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines."
Fig. 5(a) TYPICAL STEAM METHANE REFORMING FURNACE

"OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines."
Fig. 5(b) TYPICAL ETHYLENE CRACKING (PYROLYSIS) FURNACE

*OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines.*
ANNEXURE I

INSPECTION CHECKLIST FOR FIRED HEATERS IN SERVICE
(STRIKE OUT IF NOT APPLICABLE)

UNIT___________ HEATER NO._______________ DATE______________

1. DATE IF PREVIOUS INSPECTION

2. REASON FOR INSPECTION
   i) Planned Shutdown  (ii) Onstream
   (iii) Breakdown     (iv) Forced Shutdown

3. INSPECTION OF TUBULARS
   (A) Radiant Section
      (i) Visual Inspection prior to cleaning
      (ii) Visual Inspection after cleaning
      (iii) Hammer Testing
      (iv) Ultrasonic Thickness Gauging
      (v) Radiography
      (vi) Metallography
      (vii) Visual Inspection for Roll/Plug Leaks
      (viii) Visual/Ultrasonic Inspection of fittings.

   (B) Convection Section
      (i) Visual Inspection prior to cleaning
      (ii) Visual Inspection after cleaning
      (iii) Hammer testing
      (iv) Ultrasonic Thickness Gauging
      (v) Other types of inspection
      (vi) Visual Inspection for Roll / Plug Leaks.
      (vii) Visual / Ultrasonic Inspection of fittings.

4. INSPECTION OF FURNACE AND TESTING
   (i) Tube supports/hangers guides
   (ii) Re-radiation cone assembly.
   (iii) Burner assembly
   (iv) Refractory Lining.
   (v) Central Baffle Walls.
   (vi) Plenum Section
   (vii) Convection Zone
   (viii) Furnace casing
   (ix) Explosion Doors
   (x) Soot Blowers
   (xi) Air Preheater Elements.
   (xii) Fluegas Ducts/ Breeching
   (xiii) Stack External

"OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines."
(xiv) Stack Internal
(xv) Dampers
(xvi) Damper Operating Mechanisms/Wire Ropes
(xvii) Load Bearing Structures
(xviii) Foundation
(xix) Ladders/Platforms/Railings/Roofing
(xx) External Insulation
(xxi) External Painting
(xxii) Fuel Piping to heater
(xxiii) Steam Piping to Heater
(xxiv) Process Piping to/from heater.

5. INSPECTION DURING REPAIRS

(A) Tubulars
   (i) Correct tube removed?
   (ii) Inspection of new replacement tubes
   (iii) Inspection of headers/clearances
   (iv) Inspection of tube expansion
   (v) Inspection welding
   (vi) Roll plug leaks

(B) Furnace & Setting
   (i) Tube Supports
   (ii) Refractory Lining
   (iii) Casing Repairs
   (iv) Burner Alignment
   (v) Soot Blowers
   (vi) Stack
   (vii) Miscellaneous Jobs per job list

6. INSPECTION PRIOR TO BOX UP

   (i) Hydro-test of tubulars
   (ii) All tubes clear of refractory material?
   (iii) All construction materials/scaffolding removed?
   (iv) Box up
   (v) Leak test of furnace.
## ANNEXURE II (Sheet 1)

### HEATER DATA SHEET

#### General Information
- Supplied by: 
- Project No.: 
- In use from: 

#### Technical Data
- **Type**: 
- **Total Duty**: 
- **Max. Radiant Flux**: 
- **Density**: 
- **Coking Allowance**: 
- **Coil Pressure Drop (Clean)**: 

#### Inlet/Outlet Conditions (Designs)
- **Temperature**: 
- **Pressure**: 
- **Liquid Flow**: 
- **Vapour Flow**: 
- **Pressure Drop**: 
- **Min. Furnace Draft/Location**: 

#### Flue Gas Temperature
- **Radiant Outlet**: 
- **Convection Outlet**: 
- **APH Outlet**: 

#### Air Temperature
- **APH Outlet**: 

#### Thermal Efficiency
- **100% Oil Firing**: 
- **100% Gas Firing**: 

#### Coil Design
- **Design Pressure (kg/cm²g)**: 
- **Tube metal Temp.(°C)**: 
- **Temp. Allowance**: 
- **Corrosion Allowance (mm)**: 
- **Hydro test Pr. (kg/cm²g)**: 

#### Tubes
- **No. of flow passes/ Tubes per pass**: 
- **Tubes Material**: 
- **Tube Size**: 
- **Wall Thickness mm**: 
- **Overall Tube Length m**: 
- **Bare tubes/studded tubes**: 

#### Tube Supports
- **Location**: 
- **Material**: 
- **Tube Retainers**: 

#### Stack
- **Location**: 
- **I.D./Thickness**: 
- **Length of Stack**: 
- **Lining**: 

---

"OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines."
Fig. 8 CONVECTION TUBE THICKNESS ENTRY FORM

DEVELOPED VIEW ON TYPICAL VIEW OF SINGLE PASS OF CONVECTION COIL & CONNECTING CROSS OVER, TEN PASSES REQUIRED.
"OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines."
**CHECK LIST 1**

**Fired Heater Operator Rounds Checklist**

<table>
<thead>
<tr>
<th>Unit:</th>
<th>Date:</th>
<th>Heater ID:</th>
<th>Employee ID:</th>
</tr>
</thead>
</table>

**ROUTINE SURVEILLANCE ACTIVITIES**

<table>
<thead>
<tr>
<th>Activity</th>
<th>OK</th>
<th>Comments</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Check external condition of the heater for the following:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Smoke from stack (visible plume other than water vapor).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Stack vibration.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Stack and draft damper positions.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Hot spots or bulges on shell.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Air leaks on shell or ducting.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Check fuel system for the following:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Proper fuel pressure to burners.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Proper fuel pressure to pilots.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Verify that excess oxygen, combustibles, and draft are within acceptable ranges by checking field devices, if applicable.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. View burner and pilot flame through sight glasses on burner front plate for the following:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13a. Burner tip condition.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13b. Burner tip condition and color.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13c. Burner tip plugging.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. View internal firebox components through sight ports on heater casing for the following:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Burner flame pattern (shape, length, and color).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. Flame impingement on tubes or tube supports.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. Tube condition (color, external scale, or hot spots).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. Tube hanger/supports condition (color, or, tubes out of position, or hot spots).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20. Refractory condition (damage evident by lots of refractory on floor).</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Activity Number** | **Additional Comments**
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

"OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines."
CHECK LIST 2

HEATER PERFORMANCE
To be performed every shift
- DRAFT
- STACK DAMPER POSITION
- O2
- CO
- STACK TEMPERATURE
- FUEL PRESSURE
- PILOT FUEL PRESSURE
- PREHEAT AIR TEMPERATURE

BURNER INSPECTION
To be performed every shift
- UNSTABLE FLAME
- BAD FLAME PATTERN
- PLUGGED TIPS
- COOL BURNER TILE
- PILOT TIP NOT GLOWING
- PILOT AIR NOT WORKING
- AIR REGISTER STUCK OR NOT WORKING
- AIR REGISTER OPEN WHILE BURNER OFF

FIREBOX INSPECTION
To be performed every shift
- RADIANT SECTION
  - TUBE BULGING, BOWING, SAGGING
  - TUBE COLOR
  - TUBE EXTERNAL SCALING
  - TUBE HANGAR COLOR UNIFORMITY
  - TUBE HANGAR DISTORTION
  - WALL REFRACTORY COLOR
  - FLOOR REFRACTORY DAMAGE
- CONVECTION SECTION
  - TUBE BULGING, BOWING, SAGGING
  - CONVECTION TUBE COLOR
  - CONVECTION TUBE SCALING
  - NOTICEABLE AFTERBURNING
- EXTERNAL
  - HOT SPOTS ON HEATER SKIN
  - SIGHT PORTS FUNCTIONAL (SEAL)
  - EXPLOSION DOORS, FLANGES, HOLES, LEAKING AIR IN BOX

"OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines."