

OISD STANDARD - 134
Third Edition, October 2010

**FOR RESTRICTED
CIRCULATION**

**INSPECTION
OF
HEAT EXCHANGERS**

OISD - STANDARD-134
Third Edition October 2010



Oil Industry Safety Directorate

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INSPECTION OF HEAT EXCHANGERS

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INSPECTION OF HEAT EXCHANGERS**

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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**

FOREWORD

The Oil Industry in India is more than 100 years old. As such a variety of practices are in vogue because of collaboration/ association with different foreign companies and governments. Earlier, standardisation in design philosophies, selection, operating and maintenance practices at a national level were hardly in existence. This, coupled with feed back from some serious accidents that occurred in India and abroad, emphasised the need for the industry to review the existing state of art in designing, selecting, operating and maintaining oil and gas installations.

With this in view, the then Ministry of Petroleum and 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 comprising of experts nominated from the industry to draw up standards and guidelines on various subjects.

The present standard "Inspection of Heat Exchangers" has been thoroughly revised (Third Edition) by the functional Committee constituted for its revision. This document was originally prepared in March 1990 & amended (Second Edition) in August 1999. This document is based on the accumulated knowledge and experience of industry members and the various national and international codes and practices, is meant to be used as a supplement and not as a replacement for existing codes standards and manufacture's recommendations. It is hoped that the provision of this standard, if implemented objectively, may go a long way to improve the safety and reduce accidents in the Oil and Gas Industry. The users of this document are cautioned that no standard can be a substitute for a responsible and experienced engineer. Suggestions are invited from the users after it is put into practice to improve the standard further. Suggestions for amendment, if any, should be addressed to:

The Coordinator
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This standard in no way supersedes the statutory regulations of CCE, Factory Inspectorate or any other statutory body which must be followed as applicable.

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

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(Third Edition October - 2010)**

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(First Edition - March 1990)

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

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INSPECTION OF HEAT EXCHANGERS

1.0 INTRODUCTION

Safety in hydrocarbon industry comes thorough continuous efforts at all stages and as such, it can be ensured by observing that plant and equipment are designed, constructed tested and maintained as per Engineering Standards and subsequently modifications and repairs are conforming to the same standards.

2.0 SCOPE

This standard covers minimum inspection requirements, types of inspections, inspection frequencies, inspection procedures and repair methodology for heat exchangers in hydrocarbon industry.

Electric immersion heaters, plate heat exchangers, steam heating coils provided in storage tanks and pressure vessels are excluded from the scope of this document. Steam boilers (fired and waste heat recovery) are not covered by this document.

3.0 DEFINITIONS

3.1 AUTHORIZED PERSON

A qualified and experienced person authorized to perform heat exchanger inspections by the owner organization.

3.2 APPLICABLE STANDARD

Applicable standard refers to the original standard of construction, unless the original standard of construction has been superseded or withdrawn from publication. The applicable standard means the current edition of the appropriate standard.

3.3 COOLER

A Cooler cools the process fluid, using water or air, with no change of phase.

3.4 CHILLER

A Chiller uses a refrigerant to cool process fluid to a temperature below that obtainable with water.

3.5 CONDENSER

A condenser condenses a vapour or mixture of vapours using water or air.

3.6 DEFECT

A defect is an imperfection of a type or magnitude exceeding the acceptable criteria.

3.7 HEAT EXCHANGER

A heat exchanger is a device that transfers heat from one fluid to another without allowing them to mix.

The details about **Types Of Heat Exchangers** are enclosed at **Annexure-I**

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3.8 HOLD POINT

A point in the repair or alteration process beyond which work should not proceed until the required inspection has been performed and documented.

3.9 IN-SERVICE / ON STREAM

Heat exchanger that has placed in operation after commissioning process streams

3.10 MAXIMUM ALLOWABLE WORKING PRESSURE (MAWP)

The maximum internal pressure permitted in the heat exchanger for continued operation at the most severe condition of coincident internal or external pressure and temperature (Minimum or Maximum) expected during operation.

3.11 REBOILER

An equipment which uses steam or any hot fluid to heat process fluid (hydrocarbon).

3.12 SHALL

Indicates mandatory requirement.

3.12 SHOULD

Indicates recommendation or that which is advised but not mandatory.

3.13 STEAM HEATER

An equipment which uses steam to heat either water or process fluid.

3.14 STEAM GENERATOR / WASTE HEAT BOILER

An equipment which produces steam from water using hot process fluid (that requires cooling) or hot gases produced in chemical reaction.

3.15 REPAIR

The work necessary to restore a heat exchanger to a condition suitable for safe operation at the design conditions.

4.0 ROLE OF INSPECTION

The Authorized Person(s) performing the inspections shall be suitably qualified and experienced. The requisite criteria for deciding the qualification and experience shall be decided by the individual organization. Typical role of inspection personnel inter-alia is;

- I) To prepare and implement inspection schedules to meet requisite standard, statute and / or quality requirements.
- II) To measure and record the corrosion/ deterioration rates and to evaluate the current physical condition of the heat exchanger for soundness for continuation in service.
- III) To co-relate the corrosion/ deterioration rate with design life for further serviceability of the heat exchanger.

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- IV) To investigate the causes of deterioration and recommend remedial measures, such as short term and long term repairs/ replacements.
- V) To perform various stages of inspections and maintain inspection records & heat exchanger history.

5.0 STAGES OF HEAT EXCHANGER INSPECTION

5.1 PRE-COMMISSIONING INSPECTION

The pre-commissioning inspection of heat exchanger shall be performed to ensure that all examinations and tests during fabrication, erection and hydro-testing have been carried out in line with the design standard / approved procedure. This inspection also includes the scrutiny of all the related records.

A Typical Check list For Inspection Prior To Erection & Commissioning is placed at **Annexure V**.

5.2 IN SERVICE (EXTERNAL) INSPECTION

- 5.2.1 All heat exchangers shall be subjected to external visual inspection for any possible leak through the joints or any other possible deterioration.
- 5.2.2 The inspection shall determine the condition of insulation, painting, supports, earthing connections, and general alignment.
- 5.2.3 Any deviation in the above or any sign of leakage from flanges and threaded joints shall be investigated to identify the cause so as to take corrective measures.
- 5.2.4 Special attention shall be given to heat exchangers in humid areas such as area near to cooling tower and in area where corrosive chemical vapours are present, to check for external corrosion and thickness reduction due to exposure to corrosive stream.
- 5.2.5 Whenever there is plant upset, the heat exchangers which experience excessive pressure / temperature fluctuations/ surges shall be externally inspected immediately.

5.3 OUT OF SERVICE (COMPREHENSIVE) INSPECTION

- 5.3.1 The out of service inspection of heat exchangers shall be carried out to assess the integrity of shell, tube bundle, end covers & other components and to determine the corrosion rate (metal loss) to estimate the remaining life of exchanger parts. The inspection strategy/ program shall be designed based on the likelihood and consequences of damages because of the prevailing internal service/ environment conditions. The appropriate NDT techniques such as Liquid penetrant test (LPT), Magnetic particle test (MPT), Ultrasonic test (UT), Radiography etc. shall be deployed for condition assessment of shell & covers and eddy current testing, IRIS (Internal rotary inspection system) , RFET (Remote field electro-magnetic testing) for tubes.
- 5.3.2 The thickness measurements for all major components (shells, covers, nozzles, tube bundle assembly etc.) shall be measured. Adequate number of thickness measurement locations (TMLs) shall be defined to establish general or localized corrosion rates of different parts of the heat exchangers.
- 5.3.3 Inspection for corrosion under insulation (CUI) shall be considered for externally insulated heat exchangers subject to moisture ingress and operating between (-) 4⁰ C & 120⁰ C or under intermittent service. This inspection shall require removal of insulation from suspected zones.

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5.3.5 Corrosion rate and remaining life of shell and covers shall be established as per **Replacement Strategy for Heat Exchanger Parts** given in **Annexure II**.

5.3.6 **Hydrostatic Pressure Testing**

- a) Hydrostatic pressure testing shall be carried out for heat exchangers in the following conditions;
- i) Whenever heat exchanger is opened. However, for fixed bundle heat exchangers having water on tube side and where the channel cover is opened for visual inspection, the hydrostatic pressure testing requirement is not mandatory.
 - ii) After any major alteration / re-rating / replacement.
 - iii) After chemical cleaning involving metal loss.
 - iv) Exchangers which are taken out of service for more than six months.

The heat exchanger shall be hydrostatically tested in accordance with applicable design rules of construction. However, the hydrostatic pressure test hold time shall not be less than 30 minutes post stabilization.

- b) Austenitic stainless steel heat exchangers shall be hydrostatic pressure tested using water having chloride content less than 50 ppm. Passivation requirements of Austenitic stainless steel heat exchangers prior to their exposure to atmosphere are covered under clause 7.2.1(b) of this document.
- c) Hydrostatic pressure test shall not be carried out at metal temperatures near the ductile-to-brittle transition temperature of the material.

The Guidelines on various Hydrostatic Test Procedures are given in **Annexure III**.


6.0 FREQUENCY OF INSPECTION

The heat exchanger inspection frequency regime shall be arrived at in such a manner that it provides adequate information necessary to declare that all the sections/ components, including the mountings, are safe to operate until the next scheduled inspection.

The following factors shall be considered while arriving at the inspection frequency regime for heat exchangers:

- a) The nature of the fluid/s handled along with their pressure/s and temperature/s.
- b) The risk associated with operational shutdowns and start-ups.
- c) Corrosion rates/ trends and remaining corrosion allowance.
- d) Increased corrosion rate due to exposure of surfaces to changed environments.
- e) Findings and recommendations of previous inspections.
- f) The location of heat exchanger such as in isolated, high-risk and highly corrosive areas.
- g) Life of sacrificial anodes provided for protection of exchanger parts in sea water service.

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- h) The potential of air, water and other environmental consequences.
- i) Corrosion prevention and leak detection systems.
- j) Applicable statutory requirements such as IBR, Factory Act, etc.
- k) Operating requirements such as desired cleanliness, fouling, maintenance of required heat transfer rate etc.

Identification and evaluation of potential degradation mechanisms are important in assessment of probability or likelihood of heat exchanger failure. Combining the assessment of likelihood and the consequences of failure in the form of a risk matrix may also be considered.

6.1 In-Service Inspection

All heat exchangers shall be externally visually inspected, once in two years as per the approved procedures. Insulated heat exchangers, vulnerable to CUI, shall be inspected by removing insulation pockets at select locations.

6.2 Out of Service Inspection

The maximum interval between the two consecutive out of service inspections shall not exceed five years or statutory inspection interval, whichever is earlier.

For heat exchangers having specific type of construction like Breech-Lock, Packinox or other type, the recommendations of process licensor/ OEM shall be applicable. The necessary waiver/ exemption from statutory authorities, if required, shall be taken in such cases.

7.0 INSPECTION CHECKS

7.1 In-Service Inspection

- a) Visual inspection shall be carried out for any possible leak from the flanges & threaded joints and tell-tale holes in reinforcing pads.
- b) The ladders, platforms, foundation, pipe connections, fittings, external paint shall be inspected for any visible deterioration and mechanical damage.
- c) Thickness measurement shall be carried out for the exchangers handling corrosive/ erosive streams.
- d) The insulated exchanger surfaces which are prone for corrosion under insulation (CUI) shall be checked for metal loss through visual inspection/ thickness gauging. Inspection window shall be provided to facilitate the above inspection activity. The opening of insulation pockets itself may be a source for water ingress, hence care should be taken to properly seal the insulation pockets.
- e) The operating conditions in relation to design parameters shall be checked. Any changes in fluid stream should be noted and their effect on the existing metallurgy shall be assessed.
- f) The exchanger should be checked for fouling/ choking. Infrared thermal imaging should be deployed to detect hot spots due to fouling of streams. The discolouration or burning of paint may also indicate hot spots.

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- g) The tubes of air-fin-coolers shall be visually inspected for warping & distortion of tubes, external fouling & mechanical damage to fins.

7.2 Out of Service Inspection

The out of service inspections shall include both external and internal inspections of heat exchanger. **A General List Of Tools For Inspection** is attached at **Annexure-IV**.

7.2.1 General considerations

The following precautions shall be taken before opening the heat exchangers;


- a) Special precautions shall be taken to prevent overheating due to oxidation of pyrophoric iron at locations where presence of sulphide scale is expected.
- b) Heat exchangers of austenitic steel shall be passivated for polythionic acid neutralisation before exposing to atmosphere. Care shall be taken to ensure chloride content in water used for making passivation solution, shall not exceed 150ppm.
- c) All the temporary piping connections used for depressurising or steaming of heat exchanger shall be made after considering all process and safety aspects.

All the accessible parts of heat exchangers shall be inspected for fouling deposits, scaling etc. prior to cleaning. If corrosion is observed beneath these deposits, then all such deposits shall be analysed.

The Likely Areas Of Metal Loss or Deterioration along with **Commonly Used Materials Of Construction of Parts** are detailed in **Annexure-VII**.

7.2.2 Shell, Channel and Covers

- a) Detailed visual inspection of inside/ outside surfaces and welds shall be done for signs of pitting, grooving, scaling, crack, erosion of impingement attack etc.
- b) Thickness survey of shell, nozzles and components etc. shall be carried out.
- c) Shell sections near tube sheet/s, baffle location, inlet impingement plates and outlet nozzle shall be checked for possible erosion/ corrosion.
- d) In case of non ferrous baffles, the carbon steel shells shall be checked internally for localized grooving due to galvanic corrosion.
- e) The gasket seats of all the nozzles, shell, channel and shell cover flanges shall be visually examined for corrosion or damage.
- f) The pass partition plates of channel head and floating head cover shall be inspected for corrosion and warping. Thinning of partition plate edges, which may take place due to galvanic corrosion or erosion, shall be checked.
- g) Condition of sacrificial anodes, if provided, in channel and floating head side shall be checked for reuse or replacement.
- h) Condition of painting of channel section, floating head section shall be checked after thorough cleaning.

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- i) Drain nozzles and other small bore connections shall be examined for thinning and grooving.
- j) Weld and heat affected zones (HAZ) shall be examined for presence of cracks, due to stress corrosion cracking (SCC) in sour, caustic and amine services.
- k) Exchangers in Hydrogen service shall be checked for damages like hydrogen blistering, hydrogen induced cracking etc.
- l) Exchangers in Naphthenic acid / degraded sulpholine environment shall be checked for possible damages on account of corrosion / erosion.
- m) Area of internal corrosion shall be marked on outside shell, shell cover and channel head in order to monitor on stream.
- n) Internal lining, if provided shall be checked for any damage like corrosion/ erosion/ cracking. Integrity of lining shall be checked by pneumatic testing.

7.2.3 Tube Bundle

- a) Tube bundles shall be inspected visually immediately after pulling out and before cleaning. The colour, type, amount and locations of deposits often help to pinpoint corrosion problems.
- b) The baffles shall be checked for hole enlargement and tubes in corresponding locations shall be checked for grooving.
- c) Tube ends shall be checked for corrosion and thinning.
- d) Non ferrous tubes and tube sheets shall be visually checked externally for selective leaching such as de-zincification, de-nickelification etc.
- e) Internal condition of tube surface should be checked by visual aids like boro- scope/ fiberscope/ video scope. Alternatively, selective tubes may be removed and split open to assess the internal surface condition.
- f) Internal condition of the tube in the peripheral or adjacent rows may be examined by radiography when the tube bundle is out of the shell.
- g) In case a number of tubes are found leaking during hydraulic testing it is advisable to remove at least one leaky tube at random for carrying out thorough investigation for establishing reasons of failure and deciding the residual service life of tube bundle.
- h) Baffles, tie rods, tube sheets, sealing strips etc. shall be visually inspected for corrosion and distortion.
- i) Gasket surfaces of tube sheets shall be checked for damage like pitting, grooving, denting etc.
- j) Tube wall thickness shall be determined by measuring inside and outside tube diameter.
- k) In case of stainless tube bundles, tubes should be checked for pitting and stress corrosion cracking by dye penetrent testing.

7.2.4 Inspection of Miscellaneous Items

- a) The condition of the saddle support shall be inspected.
- b) The backing ring shall be checked for corrosion, pitting, grooving or mechanical damage viz. warping.

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- c) The fasteners shall be checked for elongation, thinning and damaged threads. Clause. Metallic bellows if provided to be inspected for cracks, mechanical distortion, flexibility etc.
- d) The gasket shall be checked for scratches, damage and integrity. The use of particular type of gasket as specified by manufacturer shall be ensured. Gasket shall be properly positioned before tightening of bolt.

7.2.5 Inspection of Specific Type of Heat Exchangers

a) Inspection of Breech Lock Type Exchangers

The following components shall be cleaned thoroughly using chloride free solvents and mechanical tools.

- i) Gasket seating surfaces such as tube sheet to shell, tube sheet to channel box and diaphragm to shell barrel
- ii) Lock ring and barrel acme threads
- iii) Split ring, split ring grooves
- iv) Inner and outer compression rings
- v) Internal flange
- vi) Weld joints of Shell, Channel, Partition plate etc.

After cleaning, these shall be checked by liquid dye penetrant/ magnetic particle testing.

Diaphragm shall be checked visually for distortions.

Bundle shall be checked for fouling, distortion / deformation, tube ends thinning etc. The bundle sealing arrangement (Lamiflex seal) shall be renewed each time the bundle is removed from the shell since during removal it is likely to get damaged.

The procedure for assembly & tightening of bolts should be as per OEM guidelines.

b) Inspection of Packinox Heat Exchanger

The following inspection plan / strategy shall be deployed for assessment of various parts of Packinox heat exchanger. Acceptance criteria's for the pressure parts shall be as per the construction code.

	Top Bellow	Bottom Bellow	Bundle Welded Wall	Bundle Cross Channel leakage	Spray bar	Top head	Support cleat welds	Int. surface of shell
Visual	Yes	Yes	Yes		Yes	Yes	Yes	Yes
LPT	Yes	Yes	Yes					
MPT							Yes	
UT						Yes		
Pneumatic at 0.2 bar				Yes				

The details of **Inspection Methodology for Packinox Heat Exchanger** are placed at **Annexure-VI**.


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c) Inspection of Double Pipe (Pipe-in Pipe) Exchangers

For inspection of these heat exchangers, inner tubes shall be pulled out completely, where ever the construction permits, cleaned and inspected visually for pitting, scaling or any other type of corrosion. Inner surface of outer tubes shall be checked by aided visual inspection. Thickness measurement shall be done on both inner and outer tubes. In case it is not possible to pull out the tube, the condition of internal tube shall be examined by suitable NDT techniques.

d) Inspection of Air Fin Coolers

- i) The cooler assembly shall be visually checked for internal/ external fouling of tube bundles, corrosion, pitting, distortion and any visible damage to the fins.
- ii) The Internal Inspection of tubes for finding out fouling and corrosion is to be carried out either by opening the channel cover or a few plugs on sample basis. The number and location of plugs to be opened shall depend upon the extent of fouling and tube end corrosion.
- iii) After tube cleaning of internal surface of the tube to be thoroughly inspected for erosion-corrosion, tube ends thinning. The ID measurement is to be carried out and recorded. The tubes should be internally inspected for health assessment using advanced NDT techniques like Internal Rotary Inspection System (IRIS), Eddy Current Testing, Remote Field Electromagnetic testing (RFET) etc.
- iv) The header compartments and their cover plates shall be inspected for corrosion, erosion, deposits etc. Thickness gauging of header box and cover plates along with nozzles shall be carried out.
- v) The gasket surfaces shall be inspected for corrosion and mechanical damage.
- vi) If tube ends are welded to tube sheets, the welding shall be checked for cracks, corrosion etc by visual/ Penetrant Testing technique.
- vii) The accessible exterior of the tube between tube sheet and the start of the fins shall be checked for possible corrosion due to moisture condensation.
- viii) The external fouling of the bundle shall be cleaned by pressurized air, dry ice blasting or pressurized washing solution using suitable surfactant. After cleaning off external fouling, the fins of top and bottom rows shall be straightened by combing process .
- ix) After repair and box up, the air fin cooler assembly shall be subject to hydrostatic/ pneumatic testing as recommended by the manufacturer.
- x) In case of tube leak, the identification of the leaky tube shall be carried out by visual inspection, vacuum / pressure testing of individual tubes. After plugging of leaky tubes in standard manner, re-testing shall be carried out.

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7.2.6 Inspection of Box Cooler

- a) Visual inspection shall be carried out on external surface of cooler pipes after cleaning.
- b) Thickness measurements of pipes shall be carried out and recorded.
- c) The Box and the supporting system of cooler coil shall be visually inspected for corrosion/damage etc.
- d) In case, the coils are provided with external coating same shall be visually checked for coating damage. Coating thickness survey shall be carried out.
- e) If sacrificial cathodic protection system is provided, the condition of anode and electrical continuity shall be checked.
- f) After repair and box up, the box cooler shall be subject to hydrostatic testing at the recommended pressure.

8.0 REPAIRS

The recommendations for necessary repair of heat exchanger shall be given by Inspection engineer. The stage-wise Inspection during repair shall be carried out in accordance with the approved procedure.

The repairs of shell & covers shall be carried out in line with the procedures given in "OISD standard 128 - Inspection and Repair of Pressure Vessel". In case of severe metal loss, re-rating of exchanger shall be carried out as per the details given in subsequent clause 9.

The re-tubing of the bundle shall be decided based on followings.

1. Condition of Tube, tube ends, baffles, tie rods
2. Established bundle life in service
3. No of tubes plugged per pass
4. Service criticality

Bundle shall be fully or partially re-tubed depending upon tube condition and service criticality. During partial re-tubing, it is preferred to re-tube complete pass rather isolated tubes since it might adversely affect the roll joints of adjoining tubes.

The different Tube to Tube sheet Joints design & the qualification procedure is e detailed in **Annexure VIII**.

8.1 Hydrostatic Testing

After satisfactory repair & inspection, the heat exchanger shall be hydrostatically tested as per clause 5.3.6.

The **Guidelines On Pressure Testing Of Heat Exchangers** are placed at **Annexure-III**.

8.2 Replacement Strategy for Exchanger Parts

The **Replacement of Shell, End covers & Tube Sheet** shall be based on criteria given in the **Annexure-II**.

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9.0 RE-RATING OF HEAT EXCHANGERS

Re-rating the heat exchanger by changing the temperature rating or the MAWP shall be done only after all the following requirements are met:

- a) All re-rating shall be established in accordance with the requirements of the code to which the heat exchanger was built or by computing using the appropriate methods in the latest edition of the applicable code.
- b) Current inspection records verify that the heat exchanger is satisfactory for the proposed service conditions and that the appropriate corrosion allowance is provided.
- c) Re-rated heat exchanger shall be pressure tested in accordance with the code to which it was built or the latest edition of the applicable code for the new service conditions.
- d) Heat exchanger shall be checked to affirm that required pressure relieving devices are present; are set at appropriate pressure; and have the appropriate capacity at set pressure.
- e) All heat exchanger components in the system, such as valves, flanges, bolts, gaskets etc. are adequate for the new combination of pressure and temperature.
- f) Appropriate engineering records are updated.
- g) A decrease in the minimum operating temperature is justified by impact test results, if required by the applicable code.

10.0 RECORDS AND DOCUMENTATION

The design data and history card, in hard or soft form, for each equipment, shall be maintained. The design data card shall contain information like design data, material of construction, corrosion allowance, manufacturer details etc. The history card shall contain information on all inspection observations, repairs/ replacement details, test records, recommendations etc. This data will help in forecasting the future repairs/replacement of exchanger parts and ordering long delivery items.

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11.0 REFERENCES

This standard shall be read in conjunction with the following standards, codes and publications:

- I) API 661 Air Cooled Exchangers for general refinery service.
- II) API RP 572 , Inspection of Pressure Vessels (Towers, Reactors, Heat Exchangers and Condensers)
- III) API 510 - Pressure Vessel Inspection Code
- IV) API RP 571- Damaged Mechanism Affecting Fixed Equipment in The Refining Industry.
- V) NACE RP 0170 – Standard Recommended Practice Austenitic Stainless Steel and other Austenitic Alloys from Polythionic Acid Stress Corrosion Cracking during Shutdown of Refinery Equipment.
- VI) Standards of Tubular Exchanger Manufacturers Association (TEMA).
- VII) Corrosion Engineering - Fontana and Greene.
- VIII) Corrosion Handbook-Uhlig
- IX) ASME Section VIII Boiler and Pressure Vessel Code
- X) Chemicals Engineer's Handbook by Parry

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Annexure-I**TYPES OF HEAT EXCHANGERS****1. Box cooler**

The simplest heat transfer equipment is a length of steel pipe submerged in a tank of water. The liquid to be cooled flows inside the pipe. The coil in the water tank is commonly called box cooler. It is generally built from long steel pipes which are flanged at inlet and outlet ends and connected together by means of return bends. Cooling water enters from the bottom of the box and passes through the overflow outlet at the top. Box coolers are mainly used for cooling very hot streams like distillation tower bottoms or asphalt. Two disadvantages of submerged pipe coils are low rate of heat transfer and relatively large area required to get the needed cooling.

2. Double Pipe Exchanger

The double pipe unit is completely enclosed and allows the heat transfer element, the pipe, to be surrounded by a faster moving coolant. The double pipe provides counter flow, that is, the hot and cold fluids flow in opposite direction which is a very desirable feature for efficient heat transfer. A variation of double pipe unit is extended surface exchanger, best known as fin tube cooler. Double pipe exchangers are compact and can easily be stacked for connection in parallel or series.

3. Air Fin cooler

Air cooled exchangers are usually designed and fabricated as per API 661. They are exclusively constructed with tubes mostly in horizontal position stacked in layers and their ends rolled and/or welded to tube sheets enclosed by header compartments. Air is circulated by a fan placed either above or at the bottom of the steel framework in which the entire assembly is fixed. These coolers are used for condensing vapour or cooling fluids by blowing air and are installed where water is scarce or from economic viability up to certain optimised temperature.

4 Shell and Tube Exchanger

Although the type of exchangers mentioned above are widely used, the major portion of heat exchange is done with shell and tube exchangers. In general, a shell and tube exchanger consists of a shell, a tube bundle, a channel head, floating head cover and shell cover. Commonly used shell and tube type exchangers are as follows:

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a) Floating Head Exchangers

The exchanger consists of a cylindrical shell flanged at both ends, a tube bundle with a tube sheet at each end, a channel with cover, a floating head cover and a shell cover. (The diameter of floating tube sheet is smaller than the shell diameter so that tube bundle can be inserted into the shell). The diameter of the stationary tube sheet is large enough to bear on the gasket surface of one shell flange. The channel is bolted onto this shell flange so as to hold the stationary tube sheet in position. Similarly, the floating head cover is bolted onto the smaller (floating) tube sheet. The shell cover is thereafter bolted in its place. Suitable partition arrangements in several tube side passes. The flow through the shell is directed by baffles as desired. The floating tube sheet is free to move in the shell. This type of construction permits free expansion and contraction with changes in temperature. This type of exchanger is most commonly used.

b) Fixed Tube Sheet Exchanger

The simplest and least expensive type of shell and tube equipment is the fixed sheet type exchanger. It consists of two tube sheets welded to the shell with the tubes rolled into the tube sheets, with channel head on either side. Since the tube bundle cannot be pulled out, this type of exchanger is suitable for services where there is little possibility of fouling on the outside of the tubes, otherwise chemical cleaning will need to be done. Also, temperature conditions should be such that the stresses due to differential thermal expansion between shell and the tube does not over stress shell or tube, otherwise expansion bellows will need to be provided on shell to take care of this differential thermal expansion.

c) U-tube Exchanger

The U-tube construction offers several advantages over fixed tube sheet exchangers. In this type of exchanger, each tube is permitted to expand and contract independent of the other tubes. The U-tube bundle is usually equipped with welded shell cover. One disadvantage of the U-tube exchanger is that tubes are difficult to clean internally. The other disadvantage is that replacement of leaky tubes in the inner row involves unnecessary cutting of good tubes in the outer rows.

d) Double Tube Sheet Exchanger

In certain services where even minute leakage of one fluid into another cannot be tolerated, a double tube sheet construction can be employed. In the tube bundle, two tube sheets are installed with approx. 1" or less gap between them and the tube ends rolled into both the tube sheets. The zone between the tube sheets can be made pressure tight. Any roll leakage from either shell or tube side passes into the zone

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between the tube sheets, can be drained off. This can be done only in U-tube exchangers.

e) **Re-boiler/ Kettle Shell**

The primary use of this exchanger is boiling the fluid for distillation. The kettle shell is used in the re-boilers or chillers. The fluid to be heated in the shell and the heating medium, generally steam, is in the tubes. The shell of the kettle tube re-boiler has large vapour space over the tube bundle. A kettle type re-boiler has several advantages over standard heat exchanges in similar service. It has a lower pressure drop and can handle widely fluctuating load. The same type of construction is used in some chillers. For this service a volatile cooling medium such as propane is in shell and fluid to be cooled in tubes. The latent heat of vapourisation is absorbed from the cooled medium.

For the purpose of this standard, the term 'Heat Exchanger' shall mean all the heat changing equipments as defined above.

f) **Compact and Non-Tubular Heat Exchangers**

There are two major types gasketed and brazed/ welded –plate fin compact and non tubular heat exchangers :-

i) **Plate and Frame Exchangers**

In this type of compact heat exchanger a series of corrugated alloy material channel plates, bounded by elastomeric gaskets are hung off and guided by longitudinal carrying bars, then compressed by large diameter tightening bolts between the two pressure retaining frame plates. The frame and channel plates have portholes which allow the process fluids to enter alternating flow passages. Gaskets around the periphery of the channel plate prevent leakage to the atmosphere and also prevent process fluids from coming in contact with the frame plates.

ii) **Brazed –Plate Fin Heat Exchangers**

Brazed aluminium –plate-fin heat exchangers are also known as core exchangers or cold boxes specially meant for application below -45 deg C .Core exchangers are made –up of a stack of rectangular sheets of aluminium separated by a wavy, usually perforated aluminium fin .Two ends are sealed off to form a passage .Aluminium half pipe are type headers are attached to the open ends to route the fluids in to the alternating passages. Fluids usually flow at this 90 deg angle to each other. Design conditions range in pressures from full vacuum to 96.5 bar g & in temperature from -269 deg C to 200 deg C.

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Annexure-II**REPLACEMENT STRATEGY FOR HEAT EXCHANGER PARTS****A. SHELL AND END COVERS**

The replacement strategy for pressure parts like shell and end covers shall be based on the criteria of availability of half the remaining life for next run length. The available remaining life shall be calculated as under;

- (I) Remaining life of the **exchanger shell and end cover/s** shall be calculated as per the following procedure

$$\text{Corrosion Rate} = \frac{\text{T (previous)} - \text{T (present)}}{\text{Time between present and previous inspections}}$$

T (previous) – Thickness reading taken during inspection

T (present) -- Thickness reading taken at present

$$\text{Remaining life (Years)} = \frac{\text{T (actual)} - \text{T (minimum)}}{\text{Corrosion Rate}}$$

Where:

T (actual) = Actual minimum thickness

T (minimum) = Minimum required thickness as per applicable design code

- (II) For new heat exchangers and heat exchangers where service conditions are being changed, the probable corrosion rate for determination of remaining life shall be determined using following method;
- i) Corrosion rate may be calculated from data collected on similar material and service
 - ii) If data on similar material or service is not available, then it can be estimated from published data
 - iii) If corrosion rate can not be established from above, the thickness determination shall be made immediately after 3 months of service by thickness measurement. Subsequent measurements shall be made after appropriate intervals until corrosion rate is established.

B. TUBE SHEET

The life of the tube sheet shall depend upon the following factors;

- a) Available effective thickness shall not be less than the minimum design thickness
- b) Tube sheet hole clearance shall not exceed limits allowed for tube thinning upon rolling beyond the specified thinning limits of particular tube material.

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Annexure-III**Pressure Testing of Heat Exchangers****A. PROCEDURE OF TESTING OF SHELL AND TUBE TYPE EXCHANGERS**

Except for differential pressure designs, an independent hydrostatic test of the shell-side and tube-side shall be performed. Testing of shell and tube exchanger shall be done in three stages using water. In services where water ingress is not desirable, testing may be done with a compatible fluid.

B. SHELL TEST:

Heat exchanger shell will be hydrostatically tested to ensure the structural integrity of the shell and also to identify the leaky tubes. The floating head bundles shall be tested using appropriate test rings.

All the choked tubes will be cleaned internally prior to test. If de-choking is not possible, then the choked tubes shall be plugged after puncturing. All the welds and joints shall be checked thoroughly for any visible leaks.

Tube sheets will be visually checked for any possible tube leaks and/ or tube to tube sheet joint leaks. In case of tube leak, both the tube ends are plugged with tapered or any suitably designed plugs. The plug material shall be same as that of tube.

In the event of rolled tube to tube sheet joint leak, re-rolling of the tube shall be carried out up to the allowable permissible limit. In case of welded tube to tube joints, necessary repair of seal weld shall be carried out as per standard engineering practice.

Pressure testing is repeated till satisfactory results are observed and no tube or tube to tube sheet joint leak is observed.

It is desirable to remove the testing fluid from the shell by air before doing the floating head test. Plug positions shall be marked in the tube sheet layout for future reference.

C. TUBE TEST

During the tube testing, the tubes will be internally pressurised along with end covers. The tube side test is carried out after ensuring the removal of shell side fluid by blowing air.

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The tube test enables the detection of any tube failure under internal pressure. It also enables detection of leaks from end cover joints & tube sheet to shell joints.

If tube is found leaking, shell test is to be repeated to identify the leaky tube. The tube test is to be repeated till satisfactory results are obtained.

D. COMBINED SHELL-COVER TEST

This test is carried out after fixing shell covers and applying pressure through shell side. The test pressure shall be minimum 80% of the shell test pressure.

E. PRECAUTIONS

- a. Ensuring that equipment foundations & supporting structure, connected ancillary equipment (instrument, valves etc) are capable of withstanding the test pressure, including static head in the specified test pressure etc.
- b. The test pressure should be gradually applied – initially to a value of 50% of the specified test pressure; thereafter the pressure shall be increased in stages of approximately 10% of the specified test pressure until this is reached.
- c. The specified test pressure includes the amount due to static head acting at any point under consideration. Particular care should be taken when applying a hydraulic test to vertical exchangers, which may have been tested initially horizontally.
- d. If a crack-propagation mechanism exists e.g. Amine, Caustic service etc, repeated pressure testing can cause the crack to grow. Therefore the pressure shall be applied gradually.
- e. On completion of hydraulic test, gradual depressurisation to atmospheric pressure from the vent connection shall be ensured before draining.
- f. Care should be taken when hydraulically testing the shell side of the heat exchanger with previously/currently plugged tubes. The air in such tubes can become compressed causing the plug to shoot out.
- g. Under no circumstances, the test pressure shall exceed the design differential pressure of the tube sheet.
- h. The chloride level in testing water shall be limited to 50 PPM for austenitic stainless steel and 100 PPM for Aluminium. Alternatively, use demineralised water for hydrostatic testing.
- i. During the hydrostatic testing, the pressure gauge shall be installed at the highest point. When dial indicating pressure gauges are used, the range of such gauges shall be so selected that the test pressure lies between one-third and two-third range of the calibrated gauge.

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Annexure-IV**A TYPICAL LIST OF TOOLS FOR INSPECTION**

The common tools used for inspection of heat exchangers are given below:

- i) Ultrasonic flaw detector and thickness gauge.
- ii) Radiographic equipment
- iii) Magnetic particle inspection equipment
- iv) Fibroscope/ Boroscope
- v) Dye penetrant inspection equipment
- vi) Inspector's hammer
- vii) Inside and outside callipers
- viii) Flash light
- ix) Small magnet
- x) Small mirror
- xi) Pit gauge
- xii) Steel foot rule
- xiii) Plumb line and levels
- xiv) Scraper
- xv) Wire brush
- xvi) Magnifying glass
- xvii) Portable eddy current tester

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Annexure-V

A TYPICAL CHECK LIST FOR INSPECTION PRIOR TO ERECTION & COMMISSIONING

The checklist format shall include the following information.

1. Equipment No.
2. Service
 - a) Shell
 - b) Tube
3. Purchase order no. and date
4. Serial No. and type
5. Manufacturer
6. Main Dimensions
 - a) Shell
 - b) Tube
7. Material of construction
 - a) Shell
 - b) Shell cover
 - c) Channel Head
 - d) Channel Head Cover
 - e) Floating Head Cover
 - f) Tubes
 - g) Tube Sheets
 - h) Baffles
 - i) Fasteners
8. Maximum Allowable Working Pressure
9. Maximum Allowable Working Temperature
10. Stress-relieved
11. Radiography
12. Hydrostatic Test Pressure

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CHECK LIST

- i) Check for proper alignment of supports.
- ii) Check name plate attachment.
- iii) Check foundation/saddle support bolts and shims for any mechanical damage.
- iv) Inspect shell/channel/shell cover for any bulges or dents.
- v) Inspect visually weld joints for any damage during handling.
- vi) Check any alteration made during fabrication.
- vii) Check and record wall thickness of all the components of exchangers and also of their nozzles.
- viii) Check that the test holes in reinforcement plates are not plugged.
- ix) Check nozzle flanges facing, gaskets and bolts for mechanical damage.
- x) Check free end of slotted holes in saddles are free.
- xi) Check insulation and fire proofing.
- xii) Check painting quality.
- xiii) Check and witness hydrostatic tests of shell and tube side.
- xiv) Check that connected piping do not strain the exchanger nozzles.
- xv) Check the Earthing connection.

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Annexure-VI**INSPECTION METHODOLOGY FOR PACKINOX HEAT EXCHANGER**

Following gives Inspection requirements of Packinox exchangers installed at Refineries in Catalytic Reforming units. However, original manufacturer guidelines shall be considered for the finalization of inspection methodology for specific plate type exchanger's installation in Refineries and other installations :-

A. Preparation for Internal inspection

1. Purge operating gases and fill the heat exchanger with nitrogen gas.
2. Depressurize down to atmospheric pressure
3. When the temperature inside the shell is less than 150⁰ C (thermometer on top of shell), open the top manhole and remove the recycle gas inlet elbow on the bottom of the exchanger.
4. Ventilate the shell side of the heat exchanger with dry air (dew point less than – 30⁰ C).
5. When the temperature inside the shell is acceptable, check explosivity and oxygen content before entering.

B. Inspection of the Upper Portion (Hot End) of the Heat Exchanger

1. Access through the top manhole.
2. Inspect the header exterior, connecting pipes, bellows, bundle suspension & pressure vessel top head interior.

The exchangers that do not have a top manhole, the upper portion of the bundle may be inspected with a remote camera via the inspection nozzle & vent nozzle. To view areas not visible it is necessary to use a video camera suspended on a rope.

C. Inspection of the Lower Portion (Cold End) of the Heat Exchanger

1. Access through the recycle gas inlet nozzle.
2. Remove the protection sheet of the expansion bellows, taking care not to damage the waves.
3. Visually inspect :
 - a) The interior of the bottom of the pressure vessel
 - b) Lower bellow (s)
 - c) Connecting pipe (s).

D. Inspection of the Bundle Welded Walls

1. Access the pressure vessel interior between the bundle welded wall and the pressure vessel

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2. Between the bundle welded wall and the pressure vessel, install a ladder, safety belt and lighting. Where access is not possible due to limited space between bundle and pressure vessel, use a video camera suspended on a rope
3. For health and safety reasons, inspector must wears a dust mask and safety glasses to protect against dust.
4. Check visually the welded walls especially the welds at the corners of reinforcing thick plates and areas near the bundle suspension brackets (pay particular attention to these areas on Packinox H/E made before August 91).

E. External Inspection

After removal of insulation (top head & first top shell), the following points may be visually inspected:

1. The pressure vessel head.
2. The nozzle to head welds
3. Ladders, platforms and insulation supports.

F. Spray Bars

1. Spray bars may be inspected after removal from the bundle. For removal refer OEM guidelines

G. Visual Examination of the Effluent Outlet

1. If during the production cycle, the effluent side P is higher than 30% of the normal P, it is possible that salt deposits occurred on channel ends (iron chloride, ammonia chloride). If salt deposits are detected, take samples for analysis by the Refinery laboratory. In general, these products are water soluble; it is possible to clean the heat exchanger with a sodium carbonate solution as per OEM guidelines.
2. Visual examination of effluent outlet channels shall be carried out by remote field camera.

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Annexure-VII

COMMONLY USED MATERIALS OF CONSTRUCTION
AND LIKELY AREAS OF DETERIORATION

Deterioration may be expected on all the surfaces of heat exchanger in contact with hydrocarbon, chemical, sea water, fresh water, steam and condensate. The form of attack may be electrochemical, mechanical or combination of both. The attack may be further influenced by certain accelerating factors such as temperature, stress, fatigue, high velocity of flow and impingement.

1.0 MATERIAL OF CONSTRUCTION

The material used for construction of various parts of exchangers are selected to resist, most economically, the type of corrosion expected. Most commonly used material of construction of exchanger parts are given below:


Shell	Carbon steel, Alloy steel, corrosion resistant clad steel (Monel or stainless steel cladding).
Channel	Carbon steel, Alloy steel, corrosion resistant clad steel (Monel or stainless steel cladding).
Shell cover	Carbon steel, Alloy steel, corrosion resistant clad steel (Monel or stainless steel cladding).
Tubes	Carbon steel, alloy steel (5% Cr. 1/2% Mo. etc) stainless steel, non ferrous material such as Admiralty/Aluminium Brass, Cupro Nickel, Titanium etc. Bimetallic types having inner and outer layer of different materials are used in exchangers where unusual corrosion problem exists. (An example of its use will be where it is desirable to use. Cupro Nickel tube in sea water cooled unit in which shell side fluid is corrosive to Cupro Nickel) Various combinations of metals can be used for fabrication of duplex tubes
Baffles	Carbon steel, Naval Brass etc.
Tube Sheets	Carbon steel, Naval Brass, Aluminium Bronze, Cupro Nickel, clad carbon steel, stainless steel etc.
Floating Head	Carbon steel, Alloy Steel, clad steel, Cast Iron, Cast Cupro Nickel (90 Cu 10Ni) etc.

Channels and floating head covers of coolers using sea water are sometimes strip-lined with suitable sea water corrosion resistant material.

Stainless Steel is also used as the material of construction for exchangers in special services.

2.0 SHELL

- i) Carbon steel shells are prone to internal corrosion and pitting when hydrocarbon streams contain compounds of sulphur such as hydrogen sulphide or mercaptans. At temperatures above 270 degree C, Sulphide compounds react with carbon steel and form Iron Sulphide scales. This usually results in a fairly uniform loss of metal. This type of corrosion is more predominant in preheat exchangers.

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- ii) Internal corrosion can also occur due to low temperature hydrochloric acid and or hydrogen sulphide corrosion in presence of moisture. Overhead condenser shells in crude, vacuum, vis-breaker and FCC distillation units are prone to this type of attack.
- iii) A combination of wet hydrogen sulphide and hydrochloric acid(that form due to hydrolysis of chlorides in crude during distillation) aggravates the internal corrosion of overhead condenser shells. It will be most pronounced in the bottom part of the shell and lower nozzles. This type of corrosion is fairly uniform or in the form of a groove following the line of flow of the condensate.
- iv) Re-boiler shells are prone to internal pitting or grooving due to steam condensate corrosion.
- v) Overhead condensers, coolers and exchangers in sour gas. MEA/DEA service are prone to shell side cracking due to stress corrosion cracking phenomenon at the weld joints if they are not properly stress relieved.
- vi) Erosion/ corrosion will take place around outlet nozzles of cooler shells due to solid particles like catalyst present in streams.
- vii) Grooving and thinning of shell may take place in coolers or condensers at the baffle resting locations due to galvanic corrosion.
- viii) Pitting type corrosion will take place in carbon steel heat exchangers shell in high temperature MEA/DEA or phenol service.
- ix) External corrosion of shells may result due to water seepage in the thermal insulation having high chloride concentration.

3.0 SHELL COVER

Shell cover of all the exchangers are prone to corrosion similar to that in shells.

4.0 TUBES

- i) Copper zinc alloy tubes like Admiralty Brass or Aluminium Brass tubes are susceptible to stress corrosion cracking in pipe-still overhead condensers service due to presence of Ammonia.
- ii) Cupro-Nickel alloy tubes in overhead condensers corrode when they are exposed to hydrocarbon vapours containing H₂S. Sulphide scales of nickel and copper are formed in Alkaline medium.
- iii) Erosion of tube ends are common in exchangers and is more pronounced where hydrocarbon streams contain solid particles such as catalyst. This phenomenon can be seen in exchangers in FCC unit.
- iv) Grooving around tubes may take place at baffle locations due to vibrations or crevice corrosion.
- v) Erosion corrosion occurs when the erosion affects of the coolant removes the protective film, thus exposing a fresh surface to corrosion. This type of attack occurs mainly at the tube ends. High velocity, abrupt change in flow direction, entrained air and solid particles will promote erosion corrosion of tubes in coolers and condensers.
- vi) Tubes in coolers and condensers are prone to localised pitting, dezincification or denickelification.

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- vii) Tubes in exchangers and coolers are susceptible to bulging or warping due to exposure to high temperatures above design range and may finally result in cracking.
- viii) Sustained vibrations caused due to high velocity or pulsating vapours striking the tubes may lead to fatigue cracks or corrosion fatigue in the form of circumferential fracture of the tubes.
- ix) When steam is used as a heating medium in tube side of exchangers and re-boilers, the condensate may cause grooving or pitting in the tubes.
- x) Outside surface of the tubes opposite to shell inlet nozzle may be subjected to erosion or impingement corrosion. In case of high temperature material flows into the tube inlet pass, the backside of the stationary tube sheet or tubes immediately adjacent to it, may suffer extensive corrosion.
- xi) Cooler tubes are susceptible to overheating and under deposits due to partial/ total blocking caused by;
 - a) Low velocity of water
 - b) Suspended solids in cooling water
 - c) High water outlet temperature resulting in the hard deposition of CaCO₃

5.0 TUBE SHEETS

- i) Non ferrous tube sheets like Naval Brass or Cupro Nickel are susceptible to Dezincification or denickelification in cooling water service.
- ii) Where tubes are prone to erosion corrosion, tube sheets also get damaged at the tube ligament areas by formation of rat holes.
- iii) Solid particles or marine growth that settles down on the tube-sheets due to inadequate screening of cooling water will cause localised attack on tube sheets. Galvanic corrosion of Tube sheets may take place at pass partition grooves when partition plates of channel or floating head cover made of noble metal like Monel or Stainless steel come in contact with tube-sheets of active metallurgy.

6.0 FLOATING HEAD COVER

- i) Floating head cover which are generally made of carbon steel or lined with monel or lead get corroded in water service at bolts holes and the holes get enlarged.
- ii) Carbon steel pass partition plates which are in contact with non ferrous tube sheets undergo galvanic corrosion.
- iii) Floating head back up rings corrode due to retention of acidic condensate in overhead condensers.
- iv) Failure of gaskets sometimes causes crevice corrosion on gasket face of floating head cover flange.
- v) Low alloy strength steel stud bolts, for example ASTM-A-193 Gr. B7 crack due to sulphide stress cracking phenomenon in overhead condensers handling sour gases in presence of moisture.

7.0 CHANNEL AND CHANNEL COVER

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- i) Channel and channel covers are prone to water side corrosion in coolers and condensers.
- ii) Carbon steel pass partition plates corrode by galvanic action if they come in contact with noble metallurgy of tube sheets.
- iii) Unlined carbon steel channel covers are prone to pitting and tuberculation corrosion.
- iv) Monel lined or lead lined channels get corroded at defects in lining or its welds.

8.0 BAFFLES

- i) Baffles get thinned out due to general condensate corrosion in hydrocarbon streams.
- ii) Baffle holes get enlarged due to erosion corrosion and tube vibration.

9.0 AIR COOLED EXCHANGER

Improper bonding of fins with tubes or the damaged fins results in high differential temperature between passes causing tube bowing and warping. This finally results in tube roll joint leaks.

10.0 BOX COOLER

Problem encountered in box coolers are generally pitting type corrosion on external surface of coil.

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Annexure VIII**TUBE TO TUBESHEET JOINTS****A. Introduction**

The reliability of a shell-and-tube heat exchanger depends upon the integrity of many parallel tube-to-tube sheet joints, each of which must be virtually free of defects. The tube to tube sheet joint is highly stressed area and susceptible to failure

The tube to tube sheet joint perform following functions;

- Seal the tubes tightly to the tube sheets and create firm contact between the tube and tube sheet hole
- Transfer forces from the tube sheet to the tubes against pressure-induced loads.

B. Types of Tube-to-Tube Sheet Joints

Tube-to-tube sheet joints are made in the following ways:

1. Stuffing the space between the tube and hole with packing. The friction of the compressed packing against the tube and hole surfaces determines the strength and tightness of the joint.
2. Sealing the tube to the hole by means of an interference fit through rolling, with and without anchoring the tubes to annular grooves in the holes.
3. Welding or brazing the tubes to the tube sheets
4. Gluing the tubes to the tube sheets
5. Combination of the first four methods

Joints as described in 2, 3 and combination of the two are the joint configurations generally adopted in the hydrocarbon industry. In the selection of joint type, consideration shall be given to the effect of different coefficients of expansion of the tube and tube sheet material on joint integrity at service conditions.

C. Shear Load Test

Tubes used in the construction of heat exchangers may be considered to act as stays which support or contribute to the strength of the tube sheets in which they are engaged. Tube-to-tube sheet joints shall be capable of transferring the applied tube loads. Shear load test helps in establishing the allowable loads for tube-to-tube sheet joints. The test block simulating the tube sheet could be of any shape, but conformity with the tube pitch geometry is essential.

1. The test block shall extend a distance of at least one tube sheet ligament beyond the edge of the peripheral tubes in the assembly.
2. The finished thickness of the test block may be less but not greater than the tube sheet it represents.
3. For expanded joints, the expanded area of the tubes in the test block may be less but not greater than that for the production joint to be qualified.
4. There shall be no deviation in the procedure used to prepare the tube-to-tube sheet joints in the test specimen as compared to that used for production.

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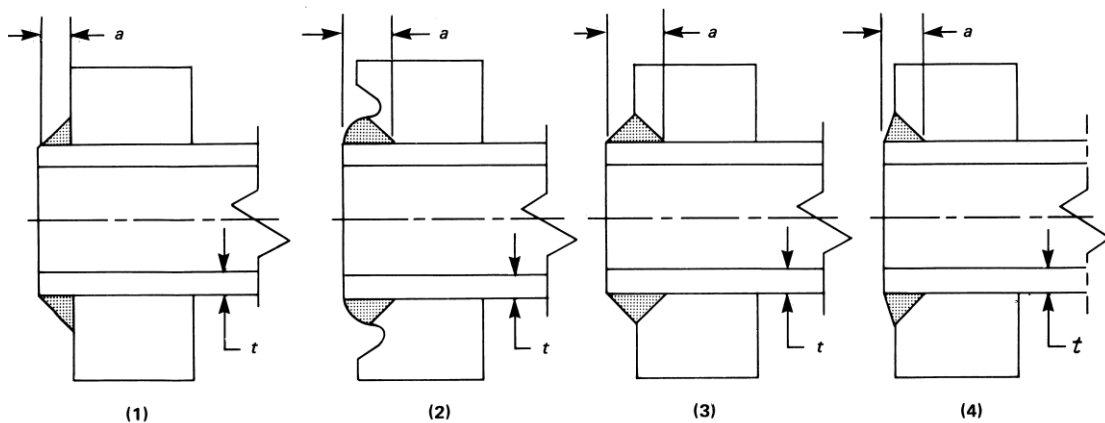


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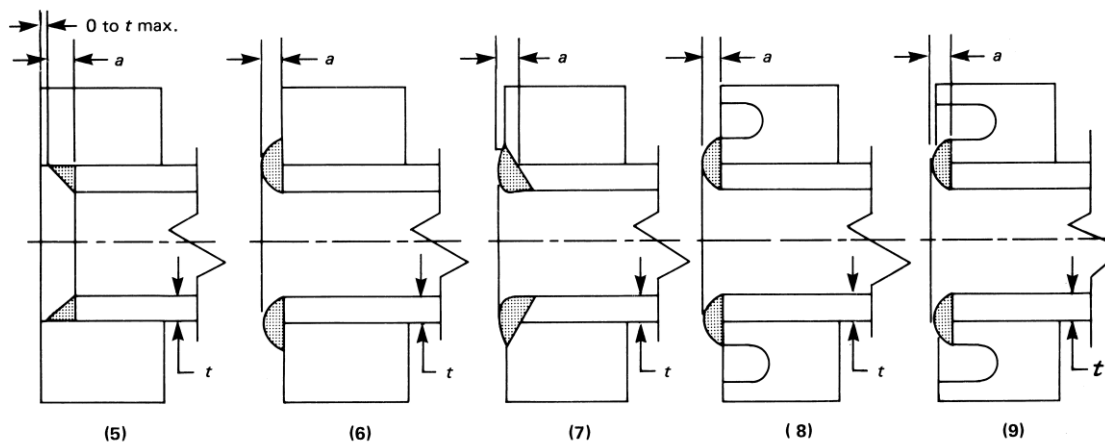
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5. All tubes in the test block array shall be from the same heat.
6. The tube-to-tube sheet joint specimen shall be loaded until mechanical failure of the joint or tube occurs. The load transmitted shall essentially remain axial. The factor for efficiency of joint shall be established to be greater than or equal to a predetermined efficiency based on the type of joint, material combinations, certain other qualifications of shear load test and acceptance standards for the factor for efficiency of joint determined by the test.

Some acceptable types of tube-to-tube sheet welds are illustrated in the figure below.



Some acceptable weld geometries where a is not less than $1.4t$.



Some acceptable weld geometries where a is less than $1.4t$.