

PETRONAS TECHNICAL STANDARDS

DESIGN AND ENGINEERING PRACTICE

MANUAL

FIELD INSPECTION PRIOR TO COMMISSIONING OF MECHANICAL EQUIPMENT

PTS 61.10.08.11

SEPTEMBER 2009



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This revision of PTS **61.10.08.11** - FIELD INSPECTION PRIOR TO COMMISSIONING OF MECHANICAL EQUIPMENT (**September 2009, Revision 1**) has been updated to incorporate PETRONAS Lessons Learnt, Best Practice and new information issued by relevant industry code and standards. All updates in the document are highlighted in *italic* font.

The previous version of this PTS **61.10.08.11 (July 1999)** will be removed from PTS binder / e-repository from herein onwards.

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PREFACE

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They are based on the experience acquired during the involvement with the design, construction, operation and maintenance of processing units and facilities. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

The objective is to set the recommended standard for good technical practice to be applied by PETRONAS' OPU in oil and gas production facilities, refineries, gas processing plants, chemical plants, marketing facilities or any other such facility, and thereby to achieve maximum technical and economic benefit from standardisation.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where PTS may not cover every requirement or diversity of condition at each locality. The system of PTS is expected to be sufficiently flexible to allow individual operating units to adapt the information set forth in PTS to their own environment and requirements.

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TABLE OF CONTENTS

1.	INTRODUCTION	5
1.1	SCOPE	5
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS	5
1.3	DEFINITIONS	5
1.4	CROSS REFERENCES	6
1.5	SUMMARY OF CHANGES SINCE LAST REVISION	6
2.	INSPECTION.....	7
2.1	GENERAL	7
2.2	ROGUE MATERIALS	7
2.3	DESIGN MODIFICATIONS.....	8
3.	PRESSURE TEST PROCEDURES	9
3.1	GENERAL	9
3.2	HYDROSTATIC TESTING	9
3.3	PNEUMATIC TESTING	11
4.	MECHANICAL EQUIPMENT, GENERAL	12
5.	VESSELS, COLUMNS, REACTORS AND THEIR INTERNALS.....	13
6.	FURNACES.....	14
7.	BOILERS	16
8.	DESUPERHEATERS - STEAM TEMPERATURE CONTROL EQUIPMENT	17
9.	SHELL-AND-TUBE HEAT EXCHANGERS	18
10.	AIR-COOLED HEAT EXCHANGERS	19
11.	GRAPHITE EQUIPMENT	20
12.	ATMOSPHERIC STORAGE TANKS	21
13.	ATMOSPHERIC TANKS FOR SOLIDS AND SILOS	22
14.	PIPING	23
15.	VALVES	25
16.	SAFETY/RELIEF VALVES.....	26
17.	RUBBER AND GRE/GRP-LINED EQUIPMENT	28
18.	ROTATING EQUIPMENT.....	29
19.	CENTRIFUGAL COMPRESSORS	31
20.	RECIPROCATING COMPRESSORS/VACUUM PUMPS	35
21.	ROTARY TYPE COMPRESSORS	38
22.	BLOWERS/FANS	40
23.	CENTRIFUGAL PUMPS	41
24.	RECIPROCATING PUMPS	43
25.	ROTARY POSITIVE-DISPLACEMENT PUMPS	45
26.	MIXERS.....	46
27.	ROTARY FILTERS.....	49
28.	ROTATING DISC CONTACTORS	51
29.	STEAM TURBINES.....	52
30.	GAS TURBINES	54

31.	DIESEL ENGINES.....	56
32.	ROTARY STOP VALVES	57
33.	EXTRUDERS	58
34.	REFERENCES	59

APPENDICES

APPENDIX 1	PNEUMATIC PRESSURE TESTING.....	60
APPENDIX 2	RULES FOR EXPANDING FURNACE TUBES INTO RETURN FITTINGS...	67

1. INTRODUCTION

1.1 SCOPE

This PTS specifies requirements and gives recommendations for field inspection prior to the commissioning of mechanical equipment (e.g. during new construction projects and minor projects, and existing equipment following maintenance or plant modifications).

The information given in this PTS has been arranged according to the type of equipment, such as columns, furnaces, compressors, pumps etc., and a separate section is dedicated to pressure testing procedures.

Excluded from the scope of this PTS is the inspection of the instrumentation associated with the mechanical equipment (*for which PTS 62.10.08.11 shall apply*)

Inspection of equipment can be divided into three main stages, only the **second** of which is within the scope of this PTS:

- 1) Manufacturing, which should be covered by the appropriate specifications, standards and codes laid down in the equipment purchase order.
- 2) Erection and pre-commissioning
- 3) Operational maintenance, which should be covered by local procedures at the operating site.

This PTS is a revision of the PTS with the same number dated July 1999. Other than editorial changes, this revision has not been extensive; a summary of the main non-editorial changes is given in (1.5).

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by PETRONAS, the distribution of this PTS is confined to companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them.

This PTS is intended for use in oil refineries, chemical plants, gas plants, supply/marketing installations and, where applicable, in exploration and production.

When PTSs are applied, a Management of Change (MOC) process should be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this PTS, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this PTS which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this PTS as closely as possible.

1.3 DEFINITIONS

For the purposes of this PTS the following definitions shall apply:

1.3.1 General definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, installation, and commissioning or management of a project or operation of a facility. The Principal may sometimes undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant, authorised to act for the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.4 CROSS REFERENCES

Where cross-references to other parts of this PTS are made, the referenced section number is shown in brackets. Other documents referenced by this PTS are listed in (34).

1.5 SUMMARY OF CHANGES SINCE LAST REVISION

Other than editorial changes, the following are the main changes since the last revision:

Section	Change
1.1	Added reference to PTS 62.10.08.11. for inspection of instruments.
3.1	Added details regarding removal or isolation of appurtenances during pressure test
3.2	Replace low-carbon with carbon steel
3.2	Added note regarding opening of vents and drains when drying by blowing.
14.3	Added reminder that bolts shall extend completely through nuts.
14.4	Added PTS reference for maximum deviation of flange
14.11	Added 'belly-down' orientation of reducers in suction piping to pumps.
15	Inserted step 8 regarding check for valve accessibility.
16.7	Added requirement regarding on orientation of relief valve outlets.
16.16	Added reminder for inspection of pilot operated valves used in wet gas
18	Inserted step 14, 20, 21, 22, 23 and 24
18.4	Added dessicants and dummy parts in packing materials and protective devices.
18.15	Added visual inspection method
18.17	Added detail on checking process and utility lines.
19	Added inspection detail on lube oil/seal oil or seal gas system, process piping, and fuction testing of compressor.
20	Inserted step 2, 3, 4, 8, 14, 28 and 29.
21	Inserted step 8, 24 and 25.
22	Inserted step 4, 7, 8 and 10
Appendix 1 section 4	Incorporated a table of dimensions for various zones as a function of pressure and volume.

2. INSPECTION

2.1 GENERAL

Handover procedures shall be agreed between the Principal and the Contractor before precommissioning commences, and shall include the respective responsibilities of the Contractor, the Manufacturer and the Principal.

Early inspection of individual items will allow any non-compliances to be identified at an early stage, thus avoiding subsequent delays in construction progress. Furthermore, special attention to precommissioning inspection will contribute to equipment reliability when the equipment is brought on stream.

As it will not normally be possible to complete all checks on any one item at the same time, checklists should be used to ensure that essential points are not overlooked. Systematic performance of the handover inspections will facilitate the collection of accurate 'as-built' information and baseline measurements essential for completion of the Equipment Record Cards, see PTS 70.10.01.10.

The objective of inspection during construction or maintenance is to ensure that:

1. the equipment has been supplied in accordance with the purchase order;
2. the equipment has been installed correctly;
3. all required documentation has been completed.

A piece of equipment or part of an installation which is meant to operate with other equipment shall be inspected and tested in conjunction with the latter to ensure proper operation of the complete assembly, for example, a compressor together with its drive, auxiliary gear and piping system.

A record of all manufacturing data books, shop inspection reports, and the Manufacturer's inspection and test reports should be kept in the equipment file. This information shall be recorded on the appropriate Equipment Record Card, which shall be completed before commissioning. All pressure testing, when performed by a Contractor, shall be witnessed by the Principal and shall be recorded on the appropriate Equipment Record Card.

2.2 ROGUE MATERIALS

A 'rogue material' is a material of incorrect type or grade.

Many materials are similar in appearance and so the installation of rogue materials can easily occur.

In order to eliminate rogue materials from equipment or an installation, explicit procedural checks shall be established for critical circuits.

Critical circuits are selected according to process flow schemes, inspection data and inspection experience. The criteria for selection shall be:

- service conditions (high temperature, low temperature, high pressure);
- nature of products (corrosive, flammable, lethal);
- type of material (alloys and alloy steels, carbon steel with special requirements).

For these critical circuits the minimum special inspection requirements shall apply:

1. Full traceability of all materials used, i.e transfer and recording of heat numbers or other unique identifiers.
2. Random alloy verification prior to installation (only for alloys and alloy steels such as 5 Cr- $\frac{1}{2}$ Mo steel).
3. A 100 % alloy verification check, including all weldments, after completion of erection of these systems (only for alloys and alloy steels such as 5 Cr- $\frac{1}{2}$ Mo steel).

2.3 DESIGN MODIFICATIONS

Design modifications during the manufacturing period may not be incorporated in the plant equipment after the final inspection in the shop. An up to date record shall be kept of all design modifications and associated specifications and drawings. The plant equipment shall be examined on arrival at site for compliance with purchase order requirements and any non-conformity reported and recorded. If the plant equipment requires modification on site it is essential that full and explicit information shall be made available, together with the certified materials required to perform the modifications. The modifications shall be performed in such a manner that the Manufacturer's guarantees are not invalidated.

Plant equipment which has been modified on site shall be subject to the same inspection requirements as for the original equipment.

3. PRESSURE TEST PROCEDURES

3.1 GENERAL

Equipment design codes and local regulations, which may vary from country to country, often lead to differences of opinion as to the correct test pressure to be applied to pressure-containing equipment.

Local regulations shall be strictly adhered to unless exemption has been obtained. If these regulations are less stringent than the design code, the latter shall prevail.

Equipment which has been pressure tested at the Manufacturer's works shall not be re-tested after installation, unless required by local regulations or if there is any reason to suspect the integrity of the equipment, e.g. due to damage during transport. In such circumstances a retest shall be carried out in accordance with the governing code or specification.

After major repairs such as replacement of a nozzle, renewal of a shell plate or changes in piping, the affected equipment shall be re-tested to the original test pressure. If the equipment is to be pressure-tested in the installed position, it shall be ensured that all parts of the assembly, including the supporting structure, can withstand the loading resulting from the pressure test. Where necessary, temporary supports shall be erected prior to hydrotesting.

All non-destructive testing and stress relieving shall be completed with acceptable results before pressure testing.

The equipment to be pressure tested shall be properly vented during filling to avoid air pockets.

Only a hand or air operated small-capacity test pump shall be used. Where bellows are installed in the test circuit, special precautions shall be taken to prevent overpressurizing. A pressure relief valve and pressure gauge shall be installed at the highest point of the equipment and on the test pump. The gauges shall have accuracy as specified in the applicable code and shall have a scale range suitable for the test pressure.

Before pressure is applied, appurtenances that should not be subjected to the test pressure shall be disconnected or isolated.

Following the application of the hydrostatic test pressure, examination for leakage shall be made of the joints and connections and of all regions of high stress, such as head knuckles, regions around openings, and thickness transition sections. Any leaks that are present shall be corrected and retested in accordance with the applicable specifications.

For pressure testing of new pipelines, see PTS 31.40.40.38.

3.2 HYDROSTATIC TESTING

3.2.1 General

Wherever reference is made to pressure testing in this PTS, the medium used shall be water.

NOTE If this is impractical the use of other non-flammable liquids may be considered if agreed by the Principal.

The water quality to be used for hydrostatic testing depends on the material(s) from which the equipment to be tested is manufactured (see below). Whatever the source of the hydrotest water, it shall be filtered through a 10 µm filter when filling the system.

Special precautions shall be taken if weather conditions can cause freezing or heating up of the test water.

The perimeter of the hydrostatic testing should be barricaded and signs set up to inform others that a hydrostatic test is in progress.

After testing, the equipment shall be drained and dried to prevent corrosion. Do not leave systems filled with water. During draining a vent valve shall be open at the highest point of the equipment to prevent vacuum.

- NOTES:
1. Leaving systems filled with water requires the consent of the Principal.
 2. Check for thermal expansion and freezing conditions when leaving systems filled with water.
 3. In the context of this PTS, the term "potable water" means water having a chloride content of no more than 250 mg/kg. In some areas, drinking water may have a slightly higher chloride content and may be considered "potable" for this PTS if approved by the Principal.
 4. In the context of this PTS, the terms "condensate", "boiler feed water" and "demineralised water" mean water having a chloride content of no more than 2 mg/kg.
 5. *If equipment is dried by blowing, drains or vents shall be opened in order to avoid pressurising the equipment.*

3.2.2 Carbon steel and low-alloy steel

Equipment manufactured from carbon steel or low-alloy steel may be hydrostatically tested with potable, brackish or salt water as available. If potable water is not used, the test water shall be completely drained and the equipment flushed with potable water immediately after testing and thoroughly dried with hot air or steam.

3.2.3 Austenitic stainless steel

The water used for hydrostatic testing shall not contain a concentration of chlorides, either present originally or resulting from evaporation, that may precipitate stress corrosion cracking or pitting. If biological components are left in systems or introduced with the testing water, there is also the possibility of Microbiologically Induced Corrosion (MIC).

The stainless steel shall be clean prior to final assembly and hydrostatic testing.

The equipment and/or piping shall be tested with condensate (water), boiler feed water or demineralized water.

Alternatively, it may be tested with potable water **provided** that it is either drained and mechanically dried immediately after the testing, or flushed with condensate, boiler feed water or demineralized water immediately after the testing.

- NOTES:
1. Equipment such as shell-and-tube heat exchangers may have crevices which prevent proper draining and mechanical drying.
 2. When flushing with condensate, boiler feed water or demineralized water it is essential that all surfaces previously wetted during the test are flushed. The quantity and velocity of the flushing water depends on the equipment volume and shall be determined in consultation with the Principal.
 3. Removing water or drying by blowing with hot air or gas shall not be performed unless the testing or flushing has been done with condensate, boiler feed water or demineralized water.
 4. In locations where water of the required quality is not available (initially or permanently), temporary facilities shall be used (e.g. mobile packaged demineralization units) to prepare the test water.
 5. The risk of pitting corrosion is considerably reduced if the time between hydrostatic testing and start-up is short.
 6. Clean systems, and the use of boiler feed water or condensate as test water, minimise the risk of Microbiologically Induced Corrosion.
 7. Consider the use of biocide to minimise the risk of Microbiologically Induced Corrosion.
 8. If equipment or piping is to be left idle longer than one month, it shall be preserved in accordance with PTS 70.10.70.11.

Steam-traced or electrically traced systems should be tested or at least properly flushed with condensate or demineralized water prior to the functional testing of the tracing. Stainless steel bellows should preferably be isolated from the system during hydrostatic testing. If this is not possible, the hydrostatic testing shall be done with condensate, boiler feed water or demineralized water.

3.2.4 Ferritic stainless steels and medium/high nickel alloys

Due to the possibility of pitting corrosion, (3.2.3) shall also apply to ferritic stainless steels and medium/high-nickel alloys.

3.2.5 Duplex stainless steel

Duplex stainless steel is highly susceptible to crevice corrosion when in contact with oxygen-containing water.

The preferred hydrostatic testing method is to use potable water and to carefully rinse the equipment immediately after the pressure test with condensate, boiler feed water or demineralized water, followed by thorough drying or dewatering of the equipment and filling with nitrogen in such a way that all oxygen is removed from the system.

3.2.6 9 % Nickel alloy steel

When hydrostatically testing equipment manufactured from or containing 9 % Ni steel, the water used shall be of a neutral pH value, clear and free from sulphides which may otherwise precipitate stress cracking of the equipment. Complete and thorough draining and drying of the equipment is required after the removal of the test water.

3.2.7 Aluminium and aluminium alloys

The test water shall be of a neutral pH value and free from ions of heavy metals, e.g. copper, nickel and iron. These metals are readily deposited on the aluminium surface and cause severe pitting.

The equipment shall be thoroughly cleaned and dried after removal of the test water.

3.3 PNEUMATIC TESTING

Pneumatic testing is potentially a more dangerous operation than hydrostatic testing and should only be considered if hydrostatic testing is impossible or impractical. In such cases pneumatic testing (with air or inert gas) may be considered for:

- testing the tightness of linings, nozzle welds or flanged connections, with a pressure of 0.5 bar (ga) to 1.0 bar (ga);
- strength/integrity testing. For this, a procedure shall be agreed upon between the Principal and the Contractor, which may include additional non-destructive testing. If required, approval by local authorities shall be obtained.

Appendix 1 specifies requirements and gives recommendations for on-site pneumatic pressure testing of equipment and piping.

4. MECHANICAL EQUIPMENT, GENERAL

The following points are generally applicable to mechanical equipment. Points specific to particular types of equipment are included in the subsequent sections.

1. Check that all packing materials and protective devices used during transport and handling have been removed from the equipment, such as shock-absorbent materials from machined faces, blanking plates from orifices, blocking of shafts or rolling bearings and restraining devices from instruments, safety devices and protective equipment.
2. Check whether special (maintenance) tools and instruction manuals have been supplied.
3. Check that the nameplate is properly attached to the equipment in accordance with the specification. Compare the nameplate rating with the Equipment Record Card and note any variations.
4. Check the foundation bolts to make sure that they are straight and vertical and securely tightened. Shims should be located on either side of each foundation bolt and made in one piece. Layers of thin plates shall not be used.
5. Check whether the specified grouting is used and properly applied to baseplate and support.
6. Check that the insulation and fireproofing have been applied in accordance with the specification and that precautions have been taken to prevent the ingress of water.
7. Check and inspect any alterations made during plant construction and erection for compliance with the design specification, and record any deviations.
8. Check that specified materials have been used, see (2.2), and that welding, heat treatment, stress relieving and non-destructive testing have been carried out properly and fully documented.
9. Check wall thickness of shells, heat exchanger and furnace tubes, and nozzles and compare them with those stated on the Equipment Record Cards. Correct and complete these cards as necessary.
10. Check that the nozzle facings, flanges, flange finish, gaskets and stud bolts are in accordance with specified requirements and the alignment of flanges on process connections is correct.
11. Check the equipment for internal cleanliness before final sealing.
12. Check that the applied surface protection system complies with specified requirements.
13. Check that earth bosses are connected and in electrical contact with the shell.
14. Check that ladders, stairways, platforms and walkways are correctly installed, with handrails and flooring properly secured. Check operating platforms for alternative escape routes, which shall be freely accessible and clearly indicated.
15. Especially with vacuum equipment, if out-of-roundness, bulges or dents are suspected as a result of transport, handling, field welding or other cause, check the equipment and report any such defects. Procedures for rectification of any damage shall be agreed between the Principal and the Contractor.
16. Field welds shall be non-destructively tested where so specified, and the results recorded.
17. If a hydrostatic test is required in accordance with the design code and has not been carried out at the Manufacturer's works, such a test shall be performed locally. Field-erected equipment shall be hydrostatically tested according to Section (3). Particular attention shall be paid to those parts of equipment which have been modified during construction and erection.
18. A general inspection is required to check personnel hazards (e.g. tripping and headroom) associated with the accessibility of operating equipment. Hazards shall be removed or permanently marked and additional access provided as needed.

5. VESSELS, COLUMNS, REACTORS AND THEIR INTERNALS

1. Check and inspect equipment internals for correct tray levels, weir heights, downcomer clearances, seal pans, draw-off trays, position of spiders, demisters and correct fastening, packing and bolts.
2. Check beam fastening and ensure one end is free to move.
3. Check the presence of drain holes where required and the hole configuration of liquid inlet devices in relation to the trays below.
4. Check and inspect the welds of stiffening rings, especially for vacuum equipment.
5. Check and inspect the strip lining, if applicable, especially at nozzle locations.
6. Check and inspect the lining of the cylindrical parts of manholes and nozzles, and the flange surface lining, if fitted.
7. Check that test holes in reinforcement plates are open.
8. Check that dewatering holes are located in appropriate positions.
9. Check the adjacent (steel) structure for interference with nozzles due to expansion/contraction.
10. Check the verticality of tall equipment and the correct slope, if any, of horizontal equipment.
11. Test for leaks from the draw-off trays. An allowable leakage rate may be stated in the specification.
12. Before final boxing-up, a check on proper installation of internals, correct flange finishes and cleanliness shall be carried out jointly by operational and technical staff.

6. FURNACES

1. Check the proper position and support of radiant and convection bank tubes. Remove any temporary bracing installed for transportation.
2. Check that the furnace tubes are straight and that there is proper clearance between the tubes; if not, adjust the roof tube supports by installing or removing shims.
3. Check whether tubes have been correctly expanded into fittings, see Appendix 2. Take readings of original expansion and enter these into the records.
4. Check that the return fitting plugs are properly bolted.
5. Check the fuel supply system, both oil and gas for leakage.
6. Check expansion joints for free movement (when hot)
7. Check the furnace structure and plating for correct bolting/welding, construction and painting of plates and beams; check roof for rain water draining facilities.
8. Check the dampers for correct operation. Ensure that the position marker on the outside coincides with the real position of the damper inside. Ensure that dampers will not close under the effect of gravity.
9. Check expansion pieces in ducting for tightness and adequate support near the expansion pieces.
10. Check provisions for installation and removal of spade-type blinds in flue gas ducting.
11. Check the burner installation, the correct position and shape of burner throats, the correct position of fuel guns in the throats, adjustability of air registers, fuel guns, the correct position and size of peepholes and observation windows. Record the result of the burner position measurement and issue a 'burner protocol' to be filled in by the inspection department.
12. Ensure that burner throats and ignition burner are visible from observation windows. Ensure that observation windows are not obstructed by furnace tubes.
13. Inspect the heater access doors. They should move freely and at the angle specified and should not be obstructed.
14. Inspect and test the steam to the furnace, i.e. snuffing steam to fire box and header boxes and steam for soot blowing and burners.
15. Inspect and test the soot blower equipment for correct working within the full range of operation.
16. Check sootblower system and in particular:
 - expansion;
 - purge facilities;
 - self-draining of steam supply piping system;
 - tightness of valves.
17. Test the concrete lining of the ducting for voids by tapping with a very light hammer. Inspect the lining for cracks wider than 1.5 mm. These cracks shall be cut out in such a way that a dovetail is obtained for repairs. For further checks on refractory, anchors, etc., see PTS 64.24.32.30.
18. Carry out a tightness test on air preheaters. Cleaning devices of fixed-type preheaters should be carefully checked. Packing between flanges shall be checked for tightness.
19. Apply a smoke-bomb test as a final check on the tightness of the firebox, ducting, dampers, air preheater etc. During this test the flue gas side shall be kept under pressure with the forced-draught fan.

20. Hydrostatically test the furnace coils in accordance with the design data sheets. The test pressure shall be maintained for approximately half an hour plus the time required for checking on leaks (see Section 3).
21. After a furnace with horse-shoe type fittings has been closed following a routine cleaning or inspection shutdown, a tightness test shall be carried out to check that the horse shoe fittings do not leak. This test may be conducted with medium pressure steam, provided that the pressure and temperature do not exceed the furnace design conditions.

If tubes or fittings have been repaired, a hydraulic test is required. The set pressure for this strength test shall be established by the plant inspector in accordance with local rules.

Normally, the test pressure amounts to 1.5 times the design pressure multiplied by a factor S/S' where S and S' represent the allowable material stress values at ambient temperature and design temperature respectively.

22. Check proper installation of skin thermocouples (if applicable); see Standard drawing S 24.615.
23. Check operation of observation windows and the functioning of the air purge to the windows on the radiant cell.
24. Check that the locking pin of any spring hanger support is removed and the pointer within the operation range. Note the position in the cold, and later in the hot, condition.

7. BOILERS

1. Check the boiler structure and plating for correct bolting/welding, construction/conservation plates, beams and painting.
2. Check that the air and flue gas ducts are adequately supported and that sufficient allowance has been made for expansion.
3. Check the fuel oil and gas supply system for leakage.
4. Check that the internals of the steam drum are in the correct position, properly fastened and free of debris. Check the downcomer and riser tubes, if possible.
5. Check the air preheater, if any.
6. Check that the intermittent blowdown lines are adequately supported and clamped. Make sure that the line size is not smaller than the blow-down connection.
7. Check that the blowdown valves fail to close and check that continuous blowdown lines have position indicators (from 0 – 100 % with intervals of 10 %).
8. Check whether cleaning and boiling-out procedures have been carried out in accordance with the method described in PTS 70.10.80.11.
9. Check that statutory requirements have been satisfied.
10. Check the proper position of observation doors. Ensure that the burner throats, burner tips, side wall tubes, rear end tubes and superheater tubes are clearly visible.
11. Inspect the burner installation, the correct position and shape of burner throats, the correct position of the fuel guns in the throat, the adjustability of air registers, fuel guns, if applicable and the cleanliness of the fuel gun nozzles. Record the results of the burner position measurements.
12. Inspect and test the soot blower equipment for correct working within the full range of operations. Pay attention to purge facilities and steam shut-off valves.
13. Pressure test the boiler in accordance with the code or regulation under which it is designed. Boiler feed water shall be used as a testing medium (see Section 3).
14. Apply a smoke-bomb test as a final check on the tightness of the firebox, ducting, dampers, etc. During this test the flue gas side is kept under pressure with the forced-draught fan.
15. After starting up the boiler, the set pressure, maximum relief and the reseating pressure of the safety valves shall be checked at working temperature and adjusted if necessary.

8. DESUPERHEATERS - STEAM TEMPERATURE CONTROL EQUIPMENT

1. Check that the direction of injection is correct.
2. Check the size of the injection nozzle and venturi.
3. Check that the bolts are in accordance with specified requirements.
4. Check that the forces and movements on flange connections are within acceptable limits and the equipment is adequately supported.
5. Check whether associated valves, instrumentation, and straight lengths of piping upstream and downstream of the injector are in accordance with the specification.
6. Check for proper installation of the low-alloy carbon steel inner tube, if fitted.

9. SHELL-AND-TUBE HEAT EXCHANGERS

1. Check that the correct material has been used for drain/vent plugs.
2. Check whether anodes/sacrificial plates have been installed where specified.
3. Check that test holes in reinforcement plates are open and that dewatering holes are located in appropriate positions.
4. Check that threaded holes for pulling eyes in contact with the fluid are plugged off with dummy bolts.
5. Check that impingement protection, if provided, is properly installed.
6. Check that the extended bolt ends for bolt tensioning (external as well as internal) are properly protected.
7. Check that the test flange or test ring is present and properly stored.
8. Check the verticality of vertical heat exchangers and correct slope, if any, of horizontal heat exchangers.
9. New heat exchangers which have been tested at the Manufacturer's works in accordance with the design test pressures need not be retested after installation, unless required by local regulations. It is good practice, however, to test the tightness of the floating head and channel flanges. Pneumatic testing at a pressure of 1 bar (ga) is normally sufficient.
10. Whenever a shell cover, channel or floating head cover has been removed for cleaning or repair purposes, the heat exchanger shall be subject to a hydrostatic pressure test not exceeding 110 % of the design pressure.
11. Re-tubed replacement bundles shall be subjected to a full pressure test in situ to prove the tightness of the tube-to-tubesheet connections.
12. In cases where the heat exchanger design is based on differential pressure, care should be taken not to overload the tubesheets. Special care shall be taken if bellows are installed.
13. Heat exchangers provided with sheet gaskets which have been idle for more than three months after the date of hydrostatic testing at the Manufacturer's works may be opened on a spot-check basis to check for deterioration of the gaskets.

10. AIR-COOLED HEAT EXCHANGERS

If fans are installed well in advance of being commissioned, consideration should be given to the manual rotating of motors and fans at regular intervals to prevent Brinelling of bearings and pre-setting of V-belts.

1. Check the clearance between blade tips and fan ring and check for equal and proper pitch angle setting of all fan blades.
2. Check whether fins of the cooler tubes have been damaged during transport or handling. Damaged fins may be straightened if practicable, otherwise damaged tubes shall be replaced.
3. Check that the correct material has been used for drain/vent plugs.
4. Check the sliding supports of the header box for free and unobstructed moving.
5. Check the proper operation of the louvre adjustment mechanism, if fitted.
6. Bearings of fans and drives shall be inspected for cleanliness and proper lubrication.
7. Any lengths of grease tubing installed to facilitate re-greasing of out-of-reach overhead bearings shall be disconnected and pumped through with fresh grease to clean and prime the tubing before it is reconnected to bearings. After this the use of automatic lubricators shall be considered.
8. The correct fan rotation and blade setting shall be checked.
9. Sections of heat exchangers of the air-cooled type are normally tested at the Manufacturer's works. After assembly the sections shall be tested together with the associated piping in accordance with the relevant codes.
10. It is essential to remove the test water by air blowing and drying, see (3).
11. If the fan blade pitch is automatically adjustable, check:
 - That the motor capacity is sufficient over the full pitch range;
 - The correct positioning of fan blades in case of air failure.
12. A general check of the construction should include:
 - The sealing between cooler bundles;
 - The correct sloping of the horizontal parts of the air plenum and tube bundles;
 - Alignment of belt pulleys;
 - Rigidity of fan and belt guards;
 - Proper tension of belt drives;
 - Tube vibration check at maximum airflow;
 - Guards protecting personnel from hot surfaces;
 - Proper alignment of process piping to headers to ensure no excessive nozzle loading;
 - Full priming of grease lines between grease nipple and bearing house;
 - Tightness of fan blade securing bolts;
 - Vibration of fan and motor as a baseline for further degradation of bearings.
13. New heat exchangers which have been tested at the Manufacturer's works in accordance with the design test pressures need not be retested after installation, unless required by local regulations. It is good practice, however, to test the tightness of the bundle. Pneumatic testing at 1 bar (ga) is normally sufficient.

11. GRAPHITE EQUIPMENT

1. Graphite equipment is brittle and soft and can easily be damaged.
 - Carefully avoid mechanical impact and direct contact with metallic edges.
 - Graphite blocks, while they are outside the metallic shell, should be kept on a wooden base covered with corrugated cardboard, rubber mat, or other equally shock-absorbent material. Graphite blocks should be separated from each other by a sheet of corrugated cardboard.
 - A comparatively small dent in the region of the gasket recesses can render a graphite block useless.
2. Check that the graphite equipment has been installed in such way that it is accessible from all directions, thus allowing connecting pipes to be easily attached.
3. Check that the gaskets between the process fluid orifices of the equipment and the connecting piping are resistant to the fluids and process conditions and are in accordance with specified requirements.
4. Check that fastening torques and pressures are limited to those required for fluid tightness. If tightness is not achieved within the allowable torques or pressures specified by the Manufacturer, dismantle and replace the gaskets.
5. Check that the graphite equipment is not used as a support for piping.
6. Check that the connecting piping does not exert any strain, stress or bending moment on the graphite equipment. Ensure that bellows are correctly installed.
7. Check the diameter of the connecting pipework is not less than the corresponding orifices of the graphite equipment.
8. Check that tie rods, where provided, are tensioned.
9. After the piping is connected, check that the position of the tie rod bolts is within the limits as indicated by the Manufacturer to ensure proper spring loads.
10. Carbon tube exchangers should not be changed from vertical to horizontal position and vice versa.