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भारतीय मानक ब्यूरो

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भारतीय मानक मसौदा

धात्विक पुनरापक का डिज़ाइन, निर्माण और परीक्षण — रीति संहिता

(*आईएस 12392 का पहला पुनरीक्षण*)

Draft Indian Standard

Design, Manufacture and Testing of Metallic Recuperator — Code of Practice

(*First Revision of IS 12392)*

ICS 25.180.01

Industrial Fuel-Fired Furnaces Sectional Committee, MTD 26

Last date of comment: **31st August 2024**

FOREWORD

(*Formal clauses will be added later*)

Recuperators, in general, and metallic recuperators, in particular are being increasingly used in industrial furnaces in India. At present, the manufacture and testing of metallic recuperators is being done according to the standard of the manufacturers in the country, in order to provide some guidelines for metallic recuperators, this code has been prepared.

The aim of the standard is to draw up specification for recuperators which would help, both, the purchaser and the manufacturer in ordering and manufacturing of a metallic recuperators, and the requirements to be met by the manufacturer. It also covers the provisions of the guarantee that the manufacturer is expected to give for the recuperators.

This standard was first published in 1988. While reviewing this standard, in the light of experience gained during these years, the Committee decided to revise the standard to keep pace with the latest technological developments.

In this revision, the following changes have been made:

a) References clause has been added;
b) Terminology clause has been added;

c) Reference graph which depicts the relationship between flue gas exit temperature & the percentage of available heat has been added;
d) Types of recuperators clause has been updated by adding the typical recuperator designs in clause 4.1 and a new classification has been added based on the heating medium;
e) Format for recuperator specification sheet has been added as annexure in clause 5.2.2;
f) Clarification note has been added in clause 5.2.2; and
g) Format for recuperator test report has been added as annexure in clause 11.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2: 2022 'Rules for rounding off numerical-values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Draft Indian Standard

FOR DESIGN, MANUFACTURE AND TESTING OF METALLIC RECUPERATOR — CODE OF PRACTICE

(*First Revision*)

1 SCOPE

This draft standard covers guidelines for design, manufacture, inspection and testing of metallic recuperators, to be used with industrial furnaces/kilns/other heating systems.

2 REFERENCES

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

IS No.	*Title*
IS 8849 : 2024/ ISO 13574 : 2015	Industrial Furnaces and Associated Processing Equipment — Vocabulary (*second revision*)

3 TERMINOLOGY

For the purpose of this standard, the following definitions in addition to those given in IS 8849 shall apply.

3.1 Recuperator

A recuperator is an equipment used to recover heat from hot flue gases of a furnace/kiln by preheating the air/gas, which will be fed to the furnace heating system. The flue gases and air/gas flow in adjacent passageways usually in opposite directions transferring heat from high temperature (flue gases) to the low temperature (air/gas) through a metallic wall thus reducing the energy required to attain a specific energy liberation required in the furnace/kilns with an objective of improving overall efficiency of the heating system. This is explained by the typical heat balance diagram, as illustrated in Figure 1.

3.2 Flue gas (Exhaust gas)

Gas that is generated by fuels after completion of combustion process, including uncombusted gas.

3.3 Exit temperature

The temperature of flue gases as they leave a heating system.

3.4 Overall combustion efficiency

The ratio of the useful heat in the heating system to the gross heat in the fuel supplied. This can also be illustrated in percentage available heat curve. The available heat gives an idea of overall thermal efficiency of the system, as illustrated in Figure 2.

3.5 Available heat

The gross quantity of heat released within a combustion chamber minus both the dry flue gas loss and the moisture loss. It represents the quantity of heat remaining for useful purposes.

3.6 Excess air

The air remaining after a fuel has been completely burned, or that air supplied in addition to the quantity required for combustion.

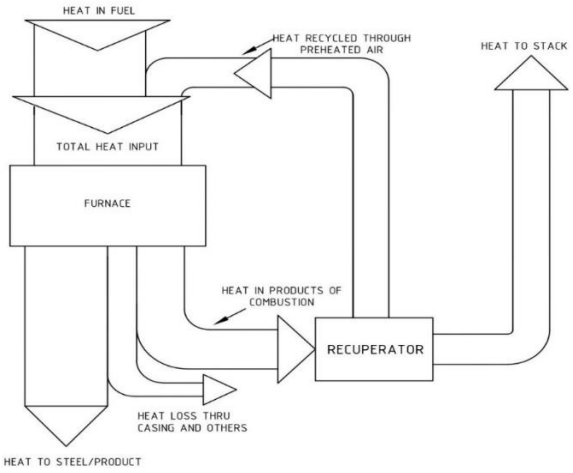

FIG 1 TYPICAL HEAT BALANCE DIAGRAM OF A FURNACE

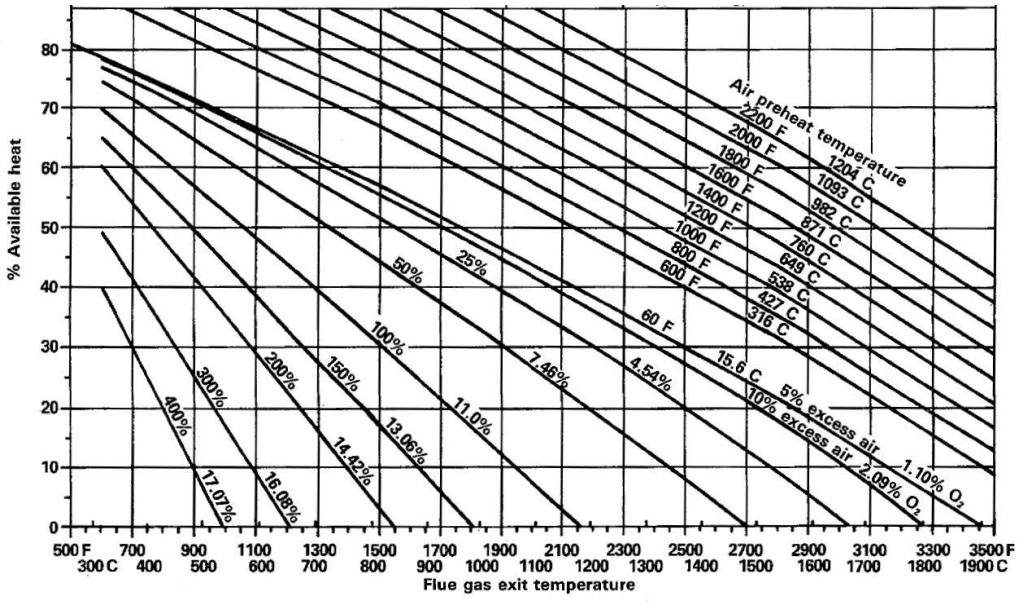

FIG 2 AVAILABLE HEAT OF PRODUCTS OF COMBUSTION AND RELATIONSHIP WITH AIR PREHEAT AND FURNACE TEMPERATURE
(*source: North American Combustion Handbook*)

4 TYPES OF RECUPERATORS AND THEIR SELECTION

4.1 Depending on the method of heat transfer taking place from the hot flue gases to the cold air/gas, the recuperator can be grouped into following three categories:

a) *Convection type* — The tubular heat transferring element may be made either from drawn tubes, ERW tubes, fin or fabricated or from cast tubes. Material of construction for the cast tubes could be either alloy cast iron or alloy steel, depending on the design requirement. A convection type tubular recuperator may be installed in the flue duct. A typical example is shown in Fig 3.

b) *Radiation type* — Radiation type recuperator has two concentric shells with the air/gas to be preheated passing through the annular space between the two shells and the hot waste gases passing in the centre. This is called a 'Double Shell Type' radiation recuperator. If tubes are arranged around the rising/descending hot waste gases, it is called a 'Tube Radiation Recuperator'. A typical example is shown in Fig 4.

c) *Combination recuperator* — As the name suggests, generally a part of it is a radiation recuperator (either double shell or tubular type) and the other part is a convection recuperator. There could be also combination of a double shell radiation recuperator and a tubular radiation recuperator. A typical example is shown in Fig 5.

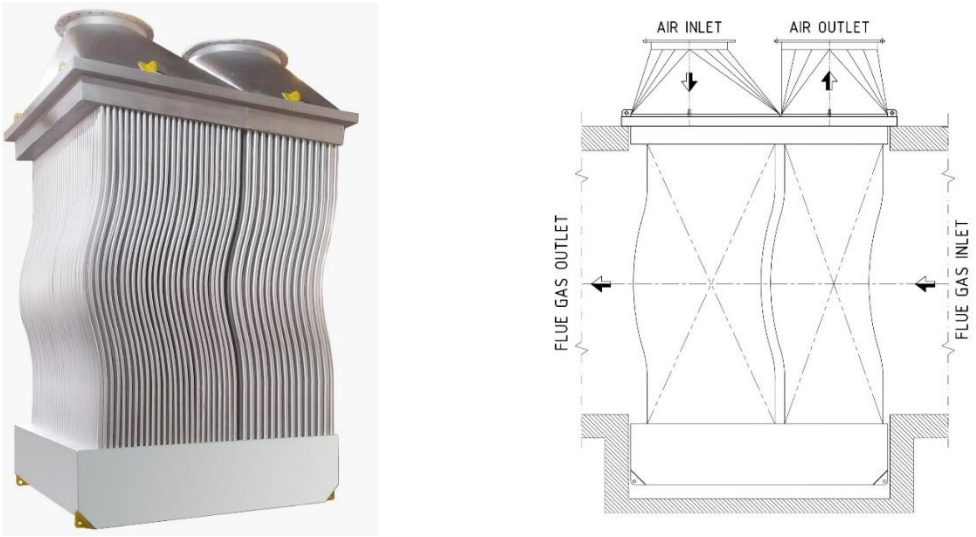

FIG 3 TYPICAL CONVECTION RECUPERATOR

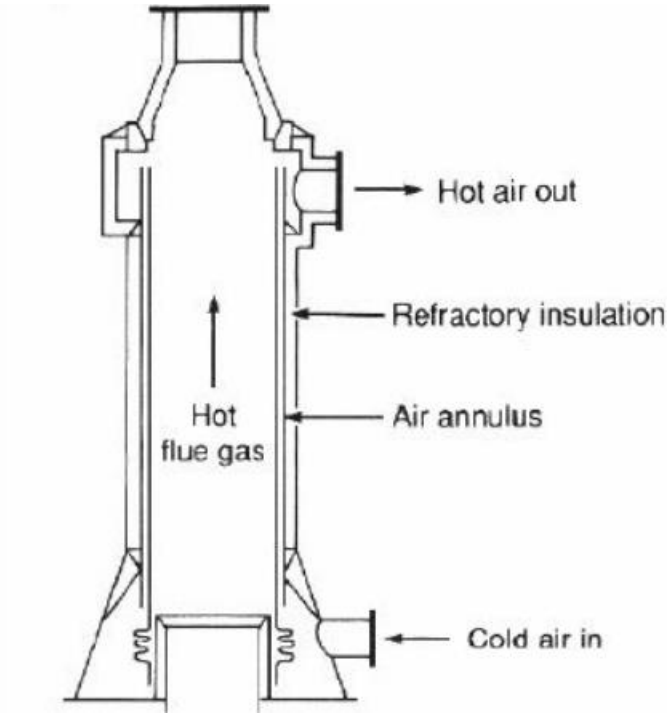

FIG 4 TYPICAL RADIATION RECUPERATOR

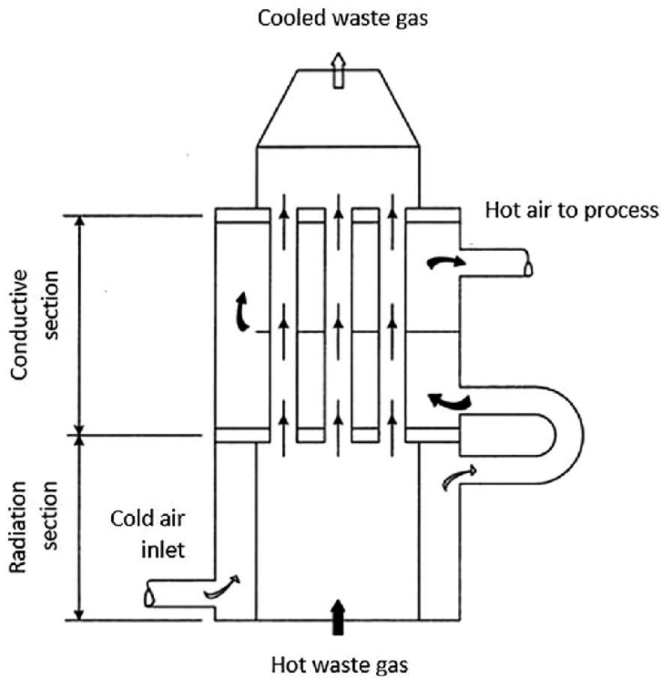

FIG 5 TYPICAL COMBINATION RECUPERATOR

4.2 Depending on the handled (heated) medium, Recuperators are grouped into the following categories:

a) Air Recuperators — The handled (heated) medium can be atmospheric air, furnace/process gasses, mixtures, with various combinations of gaseous elements like Hydrogen, Nitrogen, SOx, NOx, waste gasses from combustion, etc., and any such mixture which is not intended to be used as a fuel for processes.
b) Gas Recuperators — The handled (heated) medium is a fuel gas (combustible gas) like BFG, COG, Mixed Gas, LPG, Natural Gas, Bio Gas, Producer Gas, etc., which are to be used for combustion and as a fuel.

4.3 Selection of recuperators

The following guidelines are recommended for the selection of a suitable recuperator:

4.3.1 Convection type recuperators are generally used with flue gas temperatures below 1050 °C at recuperator. For higher flue gas temperature, radiation type recuperators are used. In special applications, recuperators achieving heat transfer, both by radiation and convection methods, are also used. Recuperators can be categorized depending on the constructional features and the method in which it is installed on the path of the waste gases.

4.3.2 Metallic recuperators can be installed with furnaces, using various types of fuels like coal, oil and gases either by themselves or in combination with other. The application of fuel that is intended to be used in the furnace shall be taken into consideration while selecting the type of recuperator. It is also important to consider the corrosion aspect of the fuel/flue gases while

selecting the material for construction of the heat exchanging surfaces. Only that fuel, for which the furnace equipped with a recuperator has been designed, shall be used. In case of any change in type or quality of fuel in such a furnace, a prior consultation with the furnace/recuperator manufacturer is necessary.

5 DESIGN PARAMETERS

5.1 *Operating Data of Equipment Where Metallic Recuperator is Used* – The purchaser shall furnish the following data/information to the manufacturer regarding the operating parameters of furnace/process equipment where a recuperator is intended to be installed for optimum design of the recuperator:

a) Type of furnace installation,
b) Capacity of furnace,
c) Type of fuel,
d) Calorific value (kcal/Nm^3 or kcal/kg)
e) Fuel quantity (to be specified whether with or without recuperator), (kg/hr or Nm^3/hr or lit/hr.)
f) Percentage of excess air for combustion, (% or Nm^3/h),
g) Flue gas volume (Nm^3/h),
h) Air volume to be preheated (Nm^3/h),
j) Fuel gas volume to be preheated (Nm^3/h),
k) Flue gas temperature at inlet to recuperator (K or °C),
m) Desired temperature of preheated air (K or °C),
n) Desired temperature of preheated fuel gas (K or °C),
p) Inlet temperature of handled air / fuel gas (K or °C),
q) Flue gas withdrawal by natural draft stack/forced draft stack/ID Fan.
r) Permissible pressure drop on flue gas side [mm of H_2O (gauge)],
s) Permissible pressure drop on air/fuel gas side (if fuel gas preheating desired) [mm of H_2O (gauge)],
t) Type of installation desired
    1) Underground flue duct,
    2) Overground flue duct,
    3) Any other type of installation, inside insulated casing.
u) Details of available space for recuperator installation (maximum flue duct width, depth and length, drawing showing proposed layout, wherever possible).

5.2 The manufacturer on receipt of the data from the purchaser would work out the design parameters of the recuperator and shall furnish the data for the operation of the recuperator. The manufacturer shall inform the purchaser of the following parameters (which result out of the design of the recuperator) :

a) Flue gas temperature at inlet to recuperator (°C),
b) Flue gas volume plus cooling air volume (Nm^3/h),
c) Air inlet/outlet temperature (°C),

d) Flue gas outlet temperature (°C),
e) Useful heat transfer / gain (kcal/hr.)
f) Pressure drop on flue gas side [mm of H_2O (gauge)],
g) Pressure drop on air side [mm of H_2O (gauge)],
h) Maximum permissible temperature of flue gas at inlet of recuperator (K or °C),
j) Maximum permissible air preheat temperature at outlet of recuperator (K or °C), and
k) Minimum air volume that should be passed through the recuperator at any period of time (m^3/h).

5.2.1 In order to be specific about the requirement of the Recuperator the useful data for design condition should be put in a tabulated form which should be the basis of design and operation. A typical form may be as in Annexure I.

5.2.2 *Performance guarantee by the manufacturer* — It should be understood that the salient performance data for the recuperator, such as air preheat temperature, overall thermal efficiency and the pressure drops on the waste gas and air/fuel gas side that would be attainable so far as the input data regarding the operation of the furnace/process equipment given by the purchaser are the same in actual operation and this would be guaranteed by the manufacturers as per the operating data sheet in Annexure I.

Clarification Note:

It should be understood that the recuperator is an equipment which is designed to recover the energy from the sensible heat available in the flue gas passing through the recuperator. Based on the quantity and available temperature of the flue gas as well as the quantity of the combustion air/fuel gas, the Air/Fuel Gas preheat will be determined. If the data of actual operating condition varies from the specified condition, the air preheat will also change. Under such condition the performance data need to be redefined or corrected. A good idea will be to see the flue gas actual temperature downstream of the recuperator vis-à-vis the operating data sheet which gives the indication of performance of the recuperator.

6 MATERIALS FOR RECUPERATOR

6.1 The manufacturer of recuperators normally designs the recuperator, and guarantee its performance and the suitability of materials used for construction to the purchaser. Therefore, it is the responsibility of the manufacturer to satisfy himself that the right quality of materials has been chosen and used in manufacturing the recuperator to achieve the guaranteed performance of the recuperator. The materials used should withstand the wall temperatures which is attainable in the heat transfer areas at the maximum operating conditions as agreed to between the manufacturer and the purchaser. Conditions as dictated by presence of undesirable impurities in fuel oil/gases should be considered by the recuperator manufacturer while choosing the material for construction. The most important part are the tubes of the Recuperator. Depending on the design, the tubes can be of various materials like ferritic stainless steel, Austenitic stainless steels, Duplex, Alloy Cast Iron, Alloy Steel, Carbon Steel, etc. in the hot areas and in the colder areas of the Recuperator, the tubes are normally made of carbon steel. The material selection is as per the design standards of

the Recuperator manufacturer and is guided by the operating condition, skin temperature of the tubes as well as of the flue gas, its dust content, corrosive nature or not, etc. The Tubes can be circular or elliptical, or polygonal and straight or bent as per design. The material and design of the tube is a matter of Recuperator manufacturer designer's experience.

6.2 If agreed to between the purchaser and the manufacturer, any special material of construction can be utilized to suit specific requirements.

7 MANUFACTURER

7.1 The manufacturer shall ensure that the manufacturing practice used by them in their shop conforms to the standard practices specifically for bending, welding, etc, and manufacturer has to give due consideration to the operating condition to which the recuperator would be subjected to, when in use. It has to be understood, however, that a metallic recuperator for preheating combustion air/fuel gas is not a pressure vessel or a high-pressure heat exchanger, in the sense of the terms normally used while manufacturing and inspecting equipment for the chemical, fertilizer and similar process industries.

8 INSPECTION AND ACCEPTANCE OF RECUPERATOR PRIOR TO DESPATCH

8.1 Overall Dimensions

The overall dimensions for installation of the recuperator shall be checked to conform to the general arrangement drawing submitted by the manufacturer to the purchaser at the time of ordering. This would ensure that the recuperator can be installed in the duct or housing made by the purchaser in advance according to the information furnished by the recuperator manufacturer. Alternatively, a recuperator can also be supplied along with factory insulated housing, depending upon the size and transportability, as mutually agreed between the purchaser and manufacturer.

8.2 Pressure Test

Metallic recuperators, after completion of fabrication in a workshop and without the inlet and outlet ducting connections, shall be subjected to leakage test, either by flow pressure method or by static pressure method as agreed between the purchaser and the manufacturer. In the flow pressure method, air at a particular pressure is allowed to flow through the recuperator and the loss of volume of air due to leakage, if any, is measured. In a static pressure method, a pre-determined test pressure is applied to the recuperator which is closed with blind flanges, stop cock, etc, at its openings and the losses of pressure after a prescribed lapse of time is measured. The allowable losses in volume/pressure of air in the flow pressure test, as also in the static pressure test methods, are given below:

Method of Test	*Allowable Losses*	
	Air Recuperator (percent)	Gas Recuperator (percent)
Flow Pressure Method	0.2	0.002
Static Pressure Method	50 (in 6 minutes)	10 (in two hours)

Both the methods amount to the same level of leakage performance.

Note 1 — Tests are conducted at room temperature.
Note 2 — Applied air pressure in static pressure test method is recommended to be 1000 mm or 1.5 times the working air/gas pressure at recuperator inlet.

9 WORKMANSHIP AND FINISH

9.1 The workmanship so far as bending, welding of pressure parts, the tubes, etc. and the general appearance are concerned, should be checked to ensure that the recuperators are clean, sound and free from harmful defects.

10 REPAIR

10.1 In case a recuperator does not give satisfactory result when put to pressure test, rectification of the same is allowed twice by the same method as employed for the manufacture of the recuperator. Thereafter, the recuperator would be put to pressure test again.

11 CERTIFICATE

11.1 The manufacturer shall furnish certificates to the purchaser in respect of the following:

a) Result of pressure test as per the typical format as per Annexure II.
b) Warranty on workmanship and use of proper material.

11.2 In addition to the above, if specifically agreed between the purchaser and manufacturer, a certificate giving the specifications of the materials used and a copy of the original manufacturers' certificate for the same, may be furnished to the purchaser.

12 TESTING OF RECUPERATOR WHILE IN OPERATION

12.1 Running Tests

Testing of recuperators in operation would mean investigation during continuous operation along with the specific furnace when fully stabilized under specified operating conditions.

The period of test should be chosen in such a way that related furnace is in the same thermal state/steady operating temperature conditions at the start, throughout till the end of test. The running tests should consist of:

a) Preheat test for air/gas, and
b) Pressure drop test:

    1) Air side, and
    2) Gas side (flue gas).

12.1.1 A test programme should be drawn jointly by the contracting parties (purchaser and supplier) mentioning the measurements to be taken, allowable tolerance, and measuring and regulating equipment, instruments to be used.

12.1.2 The time schedule for conducting performance tests should be mutually agreed upon. Tests should be conducted not later than 12 weeks after the date of commissioning.

12.1.3 Tests should be performed by the supplier in presence of client's representative. A record should be kept through the test recording all readings at short intervals of about 15 minutes on indicating/measuring instruments.

12.2 Preheat Test

Preheat temperature of fuel gas/combustion air should be measured by inserting a thermo-couple at a point in the Recuperator preheated gas/air outlet of the recuperator and connected to a calibrated temperature measuring equipment. Simultaneously, the measurement of the flue gas inlet and outlet temperatures and cross checking by way of calculating (based on the rate of fuel usage and oxygen content in the flue gas during test period) the volume of flue gases and gas/air being preheated are also necessary to co-relate with the preheat value.

12.3 Pressure Drop Test

The tolerance in the guarantee value under specified flow conditions shall be mutually agreed to between the purchaser and the manufacturer. This testing should be carried out with calibrated pressure gauge to simultaneously measure pressure across the recuperator both on flue gas side and on gas/air side. The locations of pressure taps must conform to norms prescribed by the Recuperator maker.

12.4 When the related furnace will often run on partial loads, performance test can be conducted also based on a partial load. The value of the partial load and corresponding guarantee values in recuperator performance should be mutually agreed to between the contracting parties and specified in the test programme. The results of the corresponding tests should be signed by the contracting parties.

Annexure I (Typical recuperator specification sheet)

OPERATING DATA				
SPECIFICATIONS		**UNITS**	**Max condition**	**Normal usage**
Connected heat load (approx.)		kW		
Excess Air		%		
WASTE GAS				
BEFORE DILUTION	Volume	Nm^3/h		
	Temperature	^oC		
	Quantum through Recuperator	%		
AFTER DILUTION	Dilution Air Volume	Nm^3/h		
	Inlet Temperature at air recuperator	^oC		
	Outlet Temperature (approx.)	^oC		
	Volume through recuperator	Nm^3/ h		
COMBUSTION AIR				
	Volume for Combustion	Nm^3/ h		
	Bleed Air Volume	Nm^3/ h		
	Bypass Air Volume	Nm^3/ h		
	Volume through Recuperator	Nm^3/ h		
	Inlet temperature	^oC		
	Air preheat at Recuperator	^oC		
PRESSURE DROP ACROSS RECUPERATOR				
	Flue gas side	mm WG		
	Air Side	mm WG		
MOMENTARY PERMISSIBLE OPERATING CONDITIONS (INDIVIDUALLY)				
Minimum Air flow		Nm^3/hr		
Maximum Flue gas inlet temperature		^oC		
Maximum Air preheat at Recuperator		^oC		
Minimum Flue gas outlet temperature		^oC		

Annexure II (Typical recuperator test report)

<table>
<tr><td colspan="3">LEAKAGE TEST REPORT</td><td>Equipment No.</td></tr>
<tr><td>Customer</td><td colspan="3"></td></tr>
<tr><td>Description</td><td colspan="2">Test Method</td><td>Remarks</td></tr>
<tr><td rowspan="2">Leakage Test of Recuperator.

No. of Units:

Static Air Pressure Method as per IS 12392 for Recuperators.</td><td colspan="2">Applied Static Air Pressure of ……. mm WC. Duration …… mins.</td><td rowspan="2">Pressure Drop Observed after ……. minutes.</td></tr>
<tr><td colspan="2"><u>Pressure Gauge: -</u>

Serial No. of equipment:</td></tr>
<tr><td>Date</td><td colspan="3">Signature</td></tr>
</table>