EXECUTIVE SUMMARY

0.1 INTRODUCTION

Waste heat is defined as the sensible heat in non-combustible gases leaving furnaces used for processing metals and ores, chemical processes and combustion engines. Flue gases available in adequate quantities and at elevated temperatures generally of values 300°C or more from the exhaust of any equipment in a process, offer potential schemes for heat recovery.

The principal uses of steam generated in heat recovery systems are :

- For process heating
- For power generation
- For use as a stripping medium in a process application

0.2 CLASSIFICATION OF WASTE HEAT BOILERS

Waste heat boilers (WHBs) may be broadly classified into three categories according to their applications. They are :

- Process / Industrial WHBs
- Electric power station WHBs
- Marine WHBs

WHBs can also be classified into following three categories according to the ways the water/steam mixture is made to circulate through the evaporators in the WHBs :

- Natural circulation type
- Assisted/forced circulation type
- Once through type

WHBs may also be classified according to the relative position of flue gas path. They are :

- Fire tube type
- Water tube type

0.3 APPLICATIONS

Some of the major applications of Waste Heat Boilers (WHBs) are as :

- Reformed gas WHB
- Petrochemical furnace flue gas WHB
- Nitrous gas WHB
- Sulphurous gas WHB
- Coke dry quenching system WHB
- Incinerator flue gas WHB
- WHB for steel industry including sponge iron industry
- WHB for combustion engine exhaust (i.e., gas turbines and diesel engine exhaust)
  WHB for cement and lime kilns
- WHB for copper and zinc furnace
- Hydrogen gas fired WHB
- WHB for dichromate roasting kilns
- WHB for glass melting furnace

0.4 MAJOR INDIAN MANUFACTURERS

The major Indian manufacturers of WHBs in the country are:

- ACC-Babcock Ltd. (ABL)
- Bharat Heavy Electricals Ltd. (BHEL)
- Bharat Heavy Plates & Vessels Ltd. (BHPV)
- Buckau Wolf India Ltd. (BWI)
- Cethar Vessels Ltd. (CVL)
- ISGEC John Thompson (IJT)
- Laxmi Boilers (South) Private Ltd. (LBSPL)
- Larsen and Toubro Ltd. (L&T)
- Punj-Lloyd Ltd. (PLL)
- Texmaco Ltd. (Texmaco)
- Thermax Ltd. (Thermax)

An engineering company Balcke-Durr Kaveri Private Ltd. (Balcke Durr Kaveri) also supply WHBs on a turnkey basis (manufacture of their WHBs, is however by others).

0.5 FOREIGN COLLABORATIONS/ASSOCIATIONS

The large WHB manufacturers in the country have technical collaborations/technical associations with reputed foreign WHB manufactur-

ers. Smaller WHB manufacturers do not have any technical collaborations.

ABL and Balcke Durr Kaveri have equity participation of their foreign collaborators. BHEL have a collabora-tion with Henry Vogt of USA for WHBs for combined cycle/cogeneration applications. BWI would augment their collaboration with Deutsche Babcock Energie Und Umwelttechnik AG, Germany to include WHBs in the event of an order. L&T have a collaboration with Cockerill Mechanical Industries, Belgium for gas turbine exhaust based WHBs and with Babcock Enterprises, France for chemical process plant based WHBs. Upto 1973 L&T had supplied sulphuric acid and oleum plants, WHBs, based on designs from Chemibau Germany. PLL have a collaboration agreement with Backer en Rueb Breda BV, Netherlands, for gas turbine exhaust based WHBs.

HPV has a technical association with Hollandse Constructie Groupe, Holland for the manufacture of combined cycle plant WHBs. They also have a technical association with Deutsche Babcock Borsig, Germany for reformed gas WHBs, syn-loop WHBs and convertor gas WHBs. Thermax has supplied WHBs for a variety of applications in technical association with foreign WHB manufacturers like Oschatz GmbH, Germany; Lentjas AG, Germany; Deltak Corporation, USA; Lurgi, Germany; and Heurtey Petrochem Engineering, France.

0.6 STRUCTURE OF INDIAN INDUSTRY

The Indian industry for WHBs can be classified into the following two major categories :

- WHBs for combined cycle/cogeneration applications
- WHBs for process applications

0.6.1 The manufacturers who have already supplied WHBs for combined cycle/cogeneration plant applications are BHEL, BHPV, L&T and Thermax. Other potential manufacturers in this category are ABL, BWI and PLL. Balcke Durr Kaveri, an engineering company, can also supply WHBs on a turnkey basis in association with their sub-suppliers/ fabricators in this category.

0.6.2 The manufacturers in the category of WHBs for process applications, generally manufacture WHBs for a variety of applications. The major manufacturers in this category who supplied a large number of WHBs

for many applications are L&T and Thermax. L&T manufacture WHBs for process applications like reformed gas WHBs for ammonia, methanol and hydrogen plants; cracker-off gas WHBs for petrochemical industry; synthesis loop WHBs for fertiliser plants and sulphurous gas WHBs. Thermax manufacture WHBs for diesel engine exhaust, WHBs for dichromate roasting kilns and glass furnaces, WHBs for sulphurous gas, WHBs for nitric acid/caprolactum plants, reformed gas WHBs, WHBs for sponge iron plants, WHBs for pyrite roasters and copper smelters; carbon monoxide fired type WHBs for carbon black industry and hydrogen gas WHBs for chlor-alkali industry. IJT is another WHB manufacturer who has supplied WHBs for sulphurous gas, WHBs for nitrous gas, carbon monoxide fired WHBs, WHBs for caprolactum plant and WHBs for reformed gas. Texmaco has supplied WHBs mainly as replacements to the existing units or based on drawings supplied by consultants/end-users; and have supplied WHBs for sulphurous gas, nitrous gas, reformed gas and cracker off gas applications. BHPV has supplied WHBs for process applications to fertiliser and petrochemical plants. ABL has supplied WHBs for synthesis gas heat recovery and zinc roasters. CVL has supplied WHBs for diesel engine exhaust. Balcke Durr Kaveri has supplied WHBs on a turnkey basis for diesel engine exhaust, incinerator gas, nitrous gas, reformed gas and blast furnace gas. BHEL has supplied WHBs for gas turbine combined cycle and cogeneration plants, and is presently supplying a WHB for a sponge iron plant. They are also in a position to offer WHBs for sulphurous gas and diesel engine exhaust. LBSPL supply WHBs for blast furnace gas applications. They can also supply small WHBs for gas turbine and diesel engine exhaust applications.

0.7 MAJOR COMPONENTS OF WASTE HEAT BOILERS

The major components generally provided for a WHB are indicated below. However, the components specifically provided for a WHB depends on its type and application.

- Economiser
- Evaporator
- Boiler drum
- Boiler circulation pumps
- Superheater
- Safety valves
- Structural frame work
- WHB casing
- Inlet duct

- Auxiliary burners
- Flue gas bypass duct
- Weather protection damper
- Expansion joints
- Soot blowers
- Instrumentation

0.8 MANUFACTURING PROCESS

The WHB comprises several sub-systems, assemblies, equipment and components. While some of the equipment and components would be manufactured and assembled in the shop, the other equipment and components are bought out items. Small WHBs are generally manufactured and fully assembled in the shop. In case of large WHBs the various sub-systems, assemblies and components would have to be assembled at site.

The fabrication of pressure and non-pressure parts and auxiliary equipment for WHBs involves a variety of skills, unique manufacturing methods and requires facilities for almost every metal working and forming process. Welding is also extensively employed in the manufacture of WHB components and WHB itself.

0.9 MAJOR BOUGHT OUT ITEMS

The major bought out items in the manufacture of WHBs are :

- Carbon steel and alloy steel tubes and plates for the pressure and non-pressure parts
- Structural steel
- Dampers and their drives
- Auxiliary equipment like fans, electrostatic precipitator, regenerative air preheater and fuel oil pumps and strainers etc.
- Piping, valves and fittings
- Safety valves with silencers
- Boiler circulation pumps
- Electric motors and associated accessories
- Thermal insulation and cladding
- Electric heat tracing system
- Supports and hangers
- Sample coolers
- Intermittent and continuous blowdown tanks
- Boiler integral instruments and controls

- Monorails and hoists for maintenance
- Asbestos sheets

0.10 TOTAL CAPACITY, PRODUCTION AND UTILISATION

All the WHB manufacturers indicated under para 0.4 above, are already the manufacturers of boilers/heat exchangers, and for most of them, WHBs are only an addition to their production range. Thus, there was no specific need for them to import capital equipment.

For all the manufacturers, the production of their WHBs is merged with the production of their other types of boilers. Hence, the production capacity, capacity utilisation and financial turnover of WHB segment alone are not available. The manufacturers have furnished the data on production, capacity utilisation and financial turnover for the division in which WHB is one of the products being manufactured. The total annual installed capacity and turnover for last three years of the divisions of various manufacturers in which WHBs are manufactured, are indicated in Table 0.1 below :

TABLE 0.1

ANNUAL INSTALLED CAPACITY AND TURNOVER OF MANUFACTURING DIVISIONS OF MAJOR WHB MANUFACTURERS

Sl. No.	Year	Annual Installed Capacity, (Metric Tonnes)	Financial Turnover, (Rs. Crores)
1.	1989-90	1,96,674	987.59
2.	1990-91	1,92,567*	1,040.90
3.	1991-92	1,87,272*	1,078.29

* reductions in subsequent years due to reductions in capacity by BHEL

0.11 GROWTH OF INDUSTRY

The growth of WHB industry is directly linked to the demand, which however, has been sluggish. Some of the reasons for the above are the relative cheap availability of electrical energy from the grid, high cost of heat recovery equipment, lack of energy audits, resource

crunch and non-availability of adequate incentives to user industry. The total number of WHBs supplied/under supply to-date by the various manufacturers for different applications is summarised in Table 0.2.

0.12 PERFORMANCE OF INDUSTRY

In the WHB industry, the technology itself is imported. This is true for both the major categories of the WHB industry in the country viz. gas turbine exhaust WHB and process industry WHB. The major indigenous manufacturers have technical collaboration agreements/ technical associations with foreign manufacturers as indicated earlier. Over the years, the major manufacturers have been able to acquire the complete knowhow for the design and manufacture of WHBs. Further, through the on-going collaborations, the major manufacturers are also constantly updating their technical knowhow. The indigenous manufacturers have been able to manufacture and supply the WHBs as required by the different Indian industries.

The international scene is dominated by the foreign world renowned manufacturers. Though spare capacity has been available with the indigenous manufacturers, export performance of the WHBs has been poor. Only four waste heat boilers have so far been exported from the country. Manufacturers will have to put in more efforts to improve export performance. The potential export markets for WHBs by the Indian manufacturers are the Middle East countries and South-East Asia.

TABLE 0.2

TOTAL NUMBER OF DIFFERENT TYPES OF WHBs SUPPLIED FOR DIFFERENT APPLICATIONS BY INDIAN MANUFACTURERS

Sl. No.	Type of WHB	No. of WHBs Supplied	Remarks
1.	Gas turbine exhaust gas WHB	60	
2.	Blast furnace gas WHB	1	
3.	Carbon monoxide fired WHB	10	
4.	Cracker off gas WHB	15	
5.	Diesel generator exhaust gas WHB	32	
6.	Dichromate industry WHB	2	
7.	Glass industry WHB	5	
8.	Hydrogen gas fired WHB	3	For chloralkali industry

Table - 0.2 (Contd.)

Sl. No.	Type of WHB	No. of WHBs Supplied	Remarks
9.	Incinerator off gas fired WHB	4	
10.	Nitrous gas WHB	10	
11.	Pthalic anhydride industry WHB	1	
12.	Reformed gas WHB	20	
13.	Sponge iron industry WHB	1	
14.	Sulphurous gas WHB	87	
15.	Synthesis gas WHB	8	
16.	Zinc/copper industry WHB	5	

0.13 DEMAND FOR ENERGY RECOVERY SYSTEMS

The major energy consumer in the country is the industries. The potential for energy savings in the industrial sector by way of heat recovery is very high. Table 0.3 presents the potential for energy recovery industry wise.

TABLE 0.3

ENERGY CONSERVATION POTENTIAL IN INDIAN INDUSTRIES

Sl. No.	Particulars	Share of Energy Cost, (%)	Conservation Potential,(%)
1	Iron & steel	15.8	8-10
2	Fertilizers & pesticides	18.3	10-15
3	Textile	10.9	20-25
4	Cement	34.9	10-15
5	Chlor-alkali	15.0	10-15
6	Pulp & paper	22.8	20-25
7	Aluminium	34.2	8-10
8	Ferrous foundry	10.5	15-20
9	Petrochemical	12.7	10-15
10	Ceramics	33.7	15-20
11	Glass	32.5	15-20
12	Refineries	1.0	8-10
13	Sugar	3.4	70-80
14	Ferro-alloys	36.5	8-10

Source : Survey

The demand for WHBs in the Indian market is expected to increase, as the industries are making efforts towards energy conservation.

0.14 RAW MATERIALS

Presently, most of the pressure parts and other raw materials required for the manufacture of WHBs are available indigenously. Certain types of boiler quality plates, special alloy steels and fin tubes are not available indigenously and, therefor, are being imported from countries like Germany, Japan, United Kingdom and USA. However, from now on, fin tubes will be available indigenously with the installation of a high frequency spiral fin welding machine at BHEL works at Tiruchirapalli.

0.15 LATEST TECHNOLOGICAL DEVELOPMENTS

Particularly in the combined cycle, the WHB is a key element although it perhaps has not received as much attention as the more visible gas and steam turbines. One of the major reasons is that WHBs are not normally subjected to as severe operational demands as advanced gas turbines with their steady rise in firing temperatures, pressure ratios and outputs. Over the last ten years, the WHBs for combined cycle have undergone certain radical changes, especially for utility-matched units where the maximum emphasis is on electric power generation combined cycle efficiency. Today's WHB designs for combined cycle plants are maturing in that the arrangements are becoming standardised. But the new challenges are posed by higher limits of pressure and temperature on the steam sides and higher capacities on the gas side. The next ten years, the WHBs should see most (if not all) of the major design improvements and innovations maximising waste heat recovery efficiencies contributing to improvements in overall thermal efficiency of modern combined cycle power plants.

The latest technological developments in the field of WHBs have been in the areas listed below :

- technological developments in welding fins to tubes
- thin tubesheet design for reformed gas WHBs
- hydraulic tube expansion process for tube to tubesheet joints
- material technology advances for tubes and tube sheet of synthesis loop WHBs

- once-through WHBs behind gas turbines

- selective catalytic reduction systems in WHBs

- dampers and expansion joints on gas turbine exhaust to WHBs

- high temperature supplementary fired water cooled gas turbine exhaust duct in high temperature WHBs for process industry

- WHBs for integrated coal gasification combined cycle (IGCC) plants

- WHBs in chemically recuperated gas turbine with intercooler and reheat system

- Kalina cycle based on water-ammonia mixture in WHB and steam turbine

- WHBs in solid waste to energy systems.

BHEL have installed a high frequency spiral fin welding machine with a production capacity of 2000 tons of fin tubes per annum. With this, the latest fin welding technology would now be available in India.

With regard to the other technological developments in the field like thin tube sheet design, material technology advances, etc., the same are already available with the reputed Indian manufacturers by virtue of their collaboration with the reputed foreign WHB manufacturers. Indian manufacturers have already supplied such WHBs in India.

For the refinery and chemical process plants, steam supply should be very reliable to prevent costly process losses. In many cases standby boilers are generally provided only for this purpose. However, process plants having multiple gas turbines installation with cogeneration facilities using supplementary fired water cooled gas turbine ducts together with WHBs, could eliminate the need for standby boilers. Presently there are no such installations in India. The foreign WHB manufacturers of these type of WHBs have on-going collaborations with Indian manufacturers. The collaborations could be extended to cover the above type of WHBs also, if the demand for such WHBs arises.

It is widely regarded that coal gasification combined cycle is the leading clean coal technology for future plants. The overall efficiencies of the

types of plants are reported to be in the range of 43 to 46% range corresponding to turbine inlet temperature range of 1100°C to 1300°C. The efficiency gains are determined by the degree of integration between coal gasifier and the combined cycle. The worlds largest IGCC demonstration facility of 253 MW is scheduled to be commissioned this year in Buggenum, Netherlands. A number of other large demonstration units are being installed in USA and Japan. Although BHEL have installed a 6 MW demonstration unit, efforts must be made to develop and further scale-up this technology for commercial units. This is especially required since India's new major thermal power plants are planned to be coal based.

In chemically recuperated gas turbine with intercooler and reheat, the heat recovery system is crucial as it contains the elements of a methane steam reformer section. This concept can convert more than 60% of LHV of pipeline natural gas to shaft work. This is projected to provide a stack gas which is sulphur and particulate free while also avoiding the need for selective catalytic reduction system (if NOx levels are above pollution control requirement). The concept is promising.

A pilot Kalina cycle plant in USA has demonstrated a combined cycle efficiency of more than 55%. Larger capacity designs are being worked out.

The solid waste to energy system combines the principles of a combined cycle/cogeneration plant with those of solid waste to energy system. The approach is sufficiently novel that co-inventors from three x@3 Oklahoma firms (USA) - Waste Systems Inc., CH Guernsey & Co. and Applied Thermal Systems were allowed 21 claims in process patent by the US Department of Commerce Patent and Trademark office. The uniqueness of the new system relates to the method of configuring the technologies and components in a way as to maximise steam and electrical production efficiency from incineration of municipal waste.

0.16 TECHNOLOGY STATUS OF INDIAN MANUFACTURERS

Most indigenous manufacturers have adopted the WHB technology on the following basis or a part there-of :

- technical collaboration with reputed foreign manufacturers
- adopted standard technology available from existing boiler manu-

facturing technology and in-house development and visits to other manufacturing units/user industries

- procured a part of the technology through purchase of plant and equipment

- training of personnel at foreign manufacturer's works and training in India by personnel of foreign manufacturers

- personal experience in existing boiler manufacturing units in India and abroad

It is considered that the Indian manufacturers have the adequate technical knowhow for the design and manufacture of the WHBs required by the various industries. Feedback obtained from reputed Indian academic institutes and research laboratories also indicate that there is no major technological gap between Indian and foreign WHB manufacturers. This would imply that in case of Indian WHB manufacturers with foreign collaboration, or with equity participation by the foreign WHB manufacturers, have been able to absorb the technology and also indigenise the same. Feedback obtained from Indian manufacturers also indicate that there is no technological gap between themselves and the foreign manufacturers.

0.17 FEEDBACK FROM USER INDUSTRIES

Feedback obtained from various user industries indicate that performance of the indigenously made WHBs is generally satisfactory. Users of WHBs in process industry, especially process integrated type are critical of the need for statutory annual inspection of the WHBs which hampers their production. They were of the opinion that waiving the above requirement would save huge production losses incurred due to outage of WHB for this inspection period.

0.18 MANPOWER

The required technical and skilled manpower for the manufacture of WHBs is considered available in the country and the major manufacturers of WHBs have not expressed any requirement of specially skilled technical personnel in this regard.

0.19 RESEARCH AND DEVELOPMENT

WHB technology has basically been developed from the fired boiler experience. In view of this certain selected applicable research and developments in the field of boilers are equally applicable to WHBs. Based on discussions with reputed WHB manufacturers, it was noted that at present there was no specific R&D efforts undertaken by them in the field of WHB. Not all the manufacturers have R&D activities; only the major manufacturers have R&D centres. The major objectives of the R&D centres of the reputed manufacturers of boilers are oriented in the following directions:

- Absorption and adaptation of imported technology
- Development of new and improved products
- Import substitution
- Cost reduction in manufacture

The important developments from the R & D centres could also be adopted for the WHBs, if applicable.

0.20 MODERNISATION PROGRAMS

Though WHB manufacturers have not indicated details of their modernisation programs, it was generally felt that there is scope for modernisation of their workshops through introduction of sophisticated machines and increased computerisation, etc. These are to be taken up by the major Indian WHB manufacturers in phases after evaluating their feasibility vis-a-vis market needs and the financial position. However the industry feels that with the recessionary trends still persisting in the Indian Industry and a general slump in demand of engineering goods, these modernisation programs are not expected to be initiated in the immediate future.

0.21 CONCLUSIONS

0.21.1 Basic technology for the manufacture of WHBs for a wide variety of applications in the industries already exists in the country. The level of this technology is also considered to be of a high standard.

0.21.2 The manufacture of WHBs is presently being carried out more or less, primarily by the three or four major manufacturers, which also serve as the repository of the latest technology acquired through foreign collaborations/associations.

0.21.3 It is considered that no major technological gap exists between the Indian WHB manufacturers and the foreign manufacturers. This has been possible due to the selective collaboration/association of a large number of Indian manufacturers with the foreign manufacturers. The Indian manufacturers have been able to adopt the technology to suit the Indian conditions.

0.21.4 All the WHB manufacturers are basically manufacturers of various other types of boilers. The WHB being an addition to their product range, and in many of the cases, no specific addition of capital equipment/enhancement of production capacity was required.

0.21.5 The required technical and skilled manpower for the manufacture of WHBs is considered to be already available in the country. Manufacturers have also not expressed any additional requirement in this regard.

0.21.6 Most of the materials required for the manufacture of WHBs are available indigenously except for some boiler quality plates, some special alloy steels and fin tubes which are presently imported.

0.21.7 Only the three or four major boiler manufacturers have at present separate research and development departments in their set up. However, there are no exclusive research and development activities presently being carried out in the field of WHBs. Some research and development activities in the field of high pressure boilers may have some spin-off benefits.

0.21.8 The growth of the Indian market for WHBs has been rather sluggish. The main reasons for the above are relatively low cost of electrical energy from the grid, deterrant high investment cost of WHBs, absence of energy auditing systems at user industries to show-up the importance of energy conservation etc.

0.21.9 Though state-of-the-art technology in regard to WHB and manufacturing capability are available in the country, exports of WHBs have been poor due to very stiff competition in the international market.

0.21.10 In view of the recent discoveries of large quantities of natural gas in the Bombay off-shore basin, Gandhar fields in Gujarat, Godavari basin and North-Eastern states, it is likely that gas based cogeneration and combined cycle plants will continue to play a dominant role in future power generation programmes of these regions. Even in the

process industries competitive market conditions and higher fuel costs are bound to increase the need for provision of some form of heat recovery systems to reduce the production costs. Considering the above, the demand for WHBs would pick up in the future.

0.22 RECOMMENDATIONS

0.22.1 Introduction of attractive incentives to user industries installing energy conservation schemes can be considered . This would encourage installation of more number of WHBs which would inturn give a fillip for higher production of WHBs.

0.22.2 Country's coal reserves is large when compared to natural gas reserves. The integrated coal gasification combined cycle plants (IGCC) could be commercially viable alternative in the near future. Hence it is necessary to develop the appropriate technology for WHBs to be used in the IGCC plants and necessary steps may be taken in this regard.

0.22.3 Materials for most of the components required for the WHBs are available in the country. However some boiler quality plates and special alloy steels are being presently imported. A dialogue should be initiated between the major WHB manufacturers and the Indian steel manufacturers to identify the other applications for these steels and to review whether these steels could be progressively manufactured in the country to reduce dependence on imports and help conserve foreign exchange.

0.22.4 A dialogue/study should be initiated between WHB user industries (of process integrated type) and the authorities concerned regarding increasing of statutory inspections of WHBs in these industries, in view of process production losses due to the outage of WHBs.

0.22.5 A dialogue/study can be initiated between the WHB manufacturers and manufacturers of other major power generation equipment for the formation of a consortium for quoting for large turnkey export jobs. This would assist the Indian manufacturers to succeed in bagging large orders in the international competitive market.

0.22.6 A major thrust in the field of exports is required by the WHB manufacturers. In order to improve the exports the following steps are recommended :

a) Periodic collection of market information on the potential

foreign customers by a central agency and accessibility of the same to the various Indian manufacturers on a regular basis.

b) Study whether non-availability of supplier's credit to user industries was a cause for loss of export orders.

c) Aggressive marketing including holding of exhibitions/seminars on Indian WHB industry in target countries.

d) The manufacturers should obtain an ISO 9000 series certification.

e) Provision of additional fiscal incentives for export of waste heat boilers in view of the extremely competitive global market. This would also indirectly help ancillary industries.