सत्यमेव जयते

Ministry of Power
Government of India

ENERGY CONSERVATION GUIDELINES
FOR MSME SECTOR

Bureau of Energy Efficiency
Ministry of Power, Government of India

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नितिन गडकरी

NITIN GADKARI

मंत्री
सड़क परिवहन एवं राजमार्ग और
सूक्ष्म, लघु और मध्यम उद्यम
भारत सरकार
Minister
Road, Transport & Highways and
Micro, Small & Medium Enterprises
Government of India

सत्यमेव जयते

150 YEARS OF CELEBRATING THE MAHATMA

स्वच्छ भारत
एक कदम स्वच्छता की ओर

Message

Cost optimization on account of energy usage is important as energy cost constitutes a major component of the overall production cost in case of MSMEs especially in the energy intensive MSMEs.

The Ministry of MSME has taken a number of initiatives to support the MSME units to increase their competitiveness and become global players. It is important to increase the awareness among MSME units on various options to improve energy efficiency so as to improve their cost competitiveness.

I am happy to note that the Bureau of Energy Efficiency (BEE), Ministry of Power, has taken the initiative of preparing the Energy Conservation (EC) Guidelines for MSMEs to standardize the energy performance values of various energy consuming equipment and systems deployed for their manufacturing process. I am sure that these Guidelines will go a long way in helping the country to save its energy resources and improve energy security.

(NITIN GADKARI)

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आर. के. सिंह
R. K. SINGH

विद्युत एवं नवीन और नवीकरणीय ऊर्जा
राज्य मंत्री (स्वतंत्र प्रभार) एवं
कौशल विकास और उद्यमशीलता राज्य मंत्री
भारत सरकार
Minister of State (Independent Charge)
for Power and New & Renewable Energy and
Minister of State in the Ministry of Skill Development
and Entrepreneurship
Government of India

MESSAGE

Energy efficiency is an integral part of our national energy strategy since it enhances our global competitiveness, contributes to energy security and reduces environmental pollution. The country's development agenda focuses on the need for rapid economic growth while placing a high value on the environment and protecting ecological balance.

To address this concern, the Ministry of Power, Government of India through Bureau of Energy Efficiency (BEE) has undertaken several initiatives for conserving and efficient use of energy in different sectors of the economy. Some of these programs were aimed at enhancing energy efficiency in MSME sector.

I am happy to note that Bureau of Energy Efficiency (BEE), have developed the Energy Conservation (EC) Guidelines for MSME sector. These guidelines will help the MSME sector to achieve high operational efficiency of energy consuming utilities and will result in energy saving. I firmly believe that the EC Guidelines will be a useful document for the industries and will help them to operate their installations more efficiently to achieve the best performance.

I congratulate BEE for preparing the EC Guidelines and strongly urge the MSME units to encourages their implementation in the country.

(R. K. Singh)

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PREFACE

India is among the fastest growing large economies. The country needs to grow continuously at a high growth rate to ensure availability of basic human needs to all its citizens. The Government of India has put in place policy mechanisms to ensure that country follows a sustainable development path in its growth journey. The growing economy results in increase in energy demand. Among various sectors of economy, the industry sector in the country is largest consumers of energy.

The Micro, Small and Medium Enterprises (MSME) sub- sector occupies a prominent position in the Indian Industry sector due to its significant contribution to Gross Domestic Product (GDP); type, variety and range of products it manufacture; employment opportunities that it generate at a local level, its geographical spread and presence in almost all parts of the country. The share of MSME sector in India's total industrial energy consumption is also very high.

To help MSME sector in the country become energy efficient and adopt best available technologies and operating practices, the Bureau has undertaken various initiatives since 11th Five Year Plan period. The 'BEE-SME program' was among the flagship programmes of BEE that has focused exclusively on improving the energy efficiency of MSME sector in the country. BEE is also implementing a few GEF projects in partnership with UNIDO and World Bank in various MSME clusters in the country.

The Energy Conservation Guidelines for MSME sector is one more initiative by the BEE to support the high energy consuming MSME sub-sectors improve their energy efficiency. The Energy Conservation (EC) Guideline has standardized the energy performance values of various energy consuming equipment and systems deployed for the manufacturing process. I am sure that the EC Guidelines for the MSME sector will enable the industrial units operate in an efficient manner.

On behalf of BEE team, I appreciate the efforts of TERI who have assisted BEE in developing this document. I also acknowledge the support and cooperation extended by respective association of MSME entrepreneurs representing various sub-sectors. I am sure that the MSME sector will make full use of this document and will contribute to the Government of India's efforts in improving energy intensity of industry sector.

Director General

Bureau of Energy Efficiency

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LIST OF ABBREVIATIONS

AAS	Actual Air Supply
AC	Alternating Current
APFC	Automatic Power Factor Controller
AHU	Air Handling Unit
APH	Air Preheater
AVR	Automatic Voltage Regulator
BEE	Bureau of Energy Efficiency
BOPs	Best Operating Practices
BTK	Bull's Trench Kiln
$CaCO_3$	Calcium Carbonate
CaO	Calcium Oxide
$Ca(OH)_2$	Calcium Hydroxide
CFL	Compact Fluorescent Lamp
CFM	Cubic Feet per Minute
CNC	Computer Numerical Control
CO	Carbon Monoxide
COC	Cycle of Concentration
CPH	Charge Preheater
CTC	Cut, Twist and Curl
DBC	Divided Blast Cupola
DC	Designated Consumer
DD	Down Draft
DG	Diesel Generator
DOL	Direct Online
DPR	Detailed Project Report
DRI	Direct Reduced Iron
EAF	Electric Arc Furnace
EC	Energy Conservation
ECBC	Energy Conservation Building Code
ECP	Endless Chain Pressure

EE	Energy Efficient
EPDM	Ethylene Propylene Diene Monomer
FAD	Free Air Discharge
FBD	Fluidised Bed Dryer
FRP	Fibre Reinforced Plastic
GCV	Gross Calorific Value
HAG	Hot Air Generator
HBI	Hot Briquetted Iron
hp	Horse Power
HTST	High Temperature Short Time
IBR	Indian Boiler Regulations
ID	Internal Diameter
IE2	High Efficiency
IE3	Premium Efficiency
IF	Induction Furnace
IGBT	Insulated Gate Bipolar Transistor
IQF	Individual Quick Freezing
kVA	Kilo Volt-Ampere
kW	Kilo Watt
LED	Light Emitting Diode
LPD	Lighting Power Density
mm	Milli Metre
MS	Mild Steel
MSME	Micro, Small and Medium Enterprises
NaCl	Sodium Chloride
NG	Natural Gas
NPSH	Net Positive Suction Head
O_2	Oxygen
OD	Outer Diameter

OEM	Original Equipment Manufacturer
OLTC	On-load Tap Changer
PAT	Perform, Achieve and Trade
PCC	Points of Common Coupling
PLC	Programmable Logical Controller
POP	Plaster of Paris
PVC	Poly Vinyl Chloride
PWM	Pulse Width Modulation
RCC	Reinforced Cement Concrete
RPM	Rotations per Minute
RTC	Ready to Cook
RTE	Ready to Eat
SEC	Specific Energy Consumption
SEGR	Specific Electricity Generation Ratio

SME	Small and Medium Enterprise
SPC	Specific Power Consumption
SPV	Solar Photo Voltaic
STP	Standard Temperature and Pressure
T&D	Transmission and Distribution
TDD	Total Demand Distortion
TDS	Total Dissolved Solids
TFH	Thermic Fluid Heater
THD	Total Harmonic Distortion
tpd	Tonne per day
VFD	Variable Frequency Drive
WC	Water Column
WHR	Waste Heat Recovery
VFD	Variable Frequency Drive

LIST OF DEFINITIONS

In the Energy Conservation Guidelines as herein defined where the context so admits, the following words and expression will have the meaning as specified:

Designated consumer

The Designated Consumer means any consumer specified under clause (e) of Section 14 of the Energy Conservation (EC) Act (2001) with a threshold limit for energy consumption as specified by the EC Act, from time to time.

Energy Conservation Act

The Energy Conservation (EC) Act provides regulatory impetus to energy efficiency related activities in the country. The EC Act was enacted in 2001 and became effective from 2002. It was amended in 2010 to increase regulatory impetus to the existing Act.

MSME sector

Under the Micro, Small and Medium Enterprises (MSME) sector, the manufacturing industries are defined by the Government of India as follows:

Enterprises	Investment in plant & machinery
Micro enterprises	Does not exceed twenty five lakh rupees
Small enterprises	More than twenty five lakh rupees but does not exceed five crore rupees
Medium enterprises	More than five crore rupees but does not exceed ten crore rupees

Source: Ministry of Micro, Small and Medium Enterprises, https://msme.gov.in/know-about-msme

Standards

Standards are optimum performance values achieved by an energy consuming equipment in daily operation.

STP conditions

STP is defined as a temperature of 273.15 K (0 °C, 32 °F) and an absolute pressure of 105 Pa (100 kPa, 1 bar).

Targets

Targets are equal to the best achievable values of an energy consuming equipment in daily operation.

USER GUIDE ON ENERGY CONSERVATION GUIDELINES FOR MSME SECTOR

The Energy Conservation (EC) Guidelines document for MSME sector has been prepared by the Bureau of Energy Efficiency (BEE) in a manner to ensure that it is user-friendly for all stakeholders in the MSME sector. The stakeholders are encouraged to familiarize themselves with the EC Guidelines by reading the user guide thoroughly.

The EC Guidelines is structured into 6 different sections covering a wide range of energy/resource intensive MSME sectors operating in the country. Sections 1 to section 4 provide introductory details about the background towards preparation of the document and the definitions used.

Section 5 and section 6 focuses on best operating practices (BOP); type of common monitorable parameters and intervals of measurements; and inspection and frequency of maintenance requirements. Section 5 has 9 sub-sections and each section covers different types of common equipment/ areas used across different MSMEs (Table I). The industry shall refer to all relevant sub-sections towards application of BOP and to achieve maximum energy saving. The industry shall evaluate the performance of the equipment using the formula provided in the respective sections.

Table I: Common equipment covered under section 5

Sub-section	Equipment covered
5.1	Air compressors
5.2	Pumps and pumping system
5.3	Fans and blowers
5.4	Cooling towers
5.5	Electric motors
5.6	Transformer
5.7	Lighting
5.8	Power generation set
5.9	Harmonic distortion

The optimum performance bench marks of the equipment are defined as 'standard value' and the best performance bench marks are defined as 'target value'. Standard values and target values for the equipment and processes have been derived after statistical analysis of real time operational data. These values were also validated by industrial bodies as well as sectoral experts.

Section 6 includes 25 different sub-sections of energy intensive/ energy consuming/ resource intensive MSME sectors (Table II). The industry shall refer to the relevant sub-section towards application of BOP and resource utilization practices to achieve optimum energy saving. The industry shall evaluate the performance of the equipment using the formula provided in the respective sections.

Table II: MSME sectors covered under section 6

Sub-section	MSME sector
6.1	Foundry industry
6.2	Forging industry
6.3	Sponge iron industry
6.4	Aluminium industry
6.5	Brass industry
6.6	Machine tools industry
6.7	Galvanizing and wire drawing industry
6.8	Refractory industry
6.9	Ceramic industry
6.10	Brick industry
6.11	Clay tile industry
6.12	Glass industry
6.13	Chemicals and dyes industry
6.14	Textile industry
6.15	Paper industry
6.16	Limestone industry
6.17	Coir industry
6.18	Jaggery industry
6.19	Oil mill
6.20	Tea industry
6.21	Rice mill
6.22	Ice making industry
6.23	Seafood industry
6.24	Dairy industry
6.25	Food processing industry

1. BACKGROUND

The Energy Conservation (EC) Act, 2001, provides for efficient use of energy and its conservation in India. The Government of India set up the Bureau of Energy Efficiency (BEE) under the provisions of the EC Act. The mission of BEE is to assist in developing policies and strategies with a thrust on self-regulation and market principles, within the overall framework of the EC Act with the primary objective of reducing energy intensity of the Indian economy. The Bureau coordinates with industries, government departments, and other organizations and recognizes, identifies and utilizes the existing resources and infrastructure, in performing the functions assigned to it under the EC Act.

The industry sector is one of the largest end-users of energy in India. It is one of the focus sectors of the BEE to enhance energy efficiency. The BEE had launched Perform, Achieve and Trade (PAT) scheme during the year 2012 to address energy efficiency in large industries in the country. Energy efficiency targets are being provided to a set of large industries categorized as Designated Consumers (DCs) to reduce their specific energy consumption levels on a periodical basis.

Apart from large industries, the micro, small and medium enterprise (MSME) is an important sector of the Indian economy comprising several energy-intensive industries, such as foundry, forging, ceramics, refractory, glass, dairy, textile, etc. The industries in the MSME sector generally exist as clusters across different geographical locations of the country. The MSME sector exhibits a number of commonalities, such as technology use, production capacities, operating practices, etc. With the use of obsolete technologies and poor operating practices, it offers a significant potential for energy saving through technology upgradation and adoption of best operating practices (BOPs) in the production processes.

In its endeavour to accelerate uptake of energy efficiency in the MSME sector, BEE had initiated an SME programme during the year 2009 with an objective to improve the energy performance of MSME sector. The BEE-SME programme aims to accelerate the adoption of energy efficient technologies and practices in different energy intensive SME sub-sectors through various activities. The activities undertaken under the SME programme include preparation of cluster manuals, awareness creation through workshops, knowledge sharing, and technical support by making available Detailed Project Reports (DPRs) on energy efficient (EE) technologies. The Bureau has envisaged that the energy performance of MSMEs can be further improved by adopting best operating practices in their premises by making available suitable Energy Conservation (EC) Guidelines for the targeted MSME sectors. The EC Guidelines were prepared covering a wide range of MSMEs, wherein the enegy costs are predominant in some sectors (Category-C and Group-D) and raw material costs are maximum in a few sectors (Group-E) like micro industries as specified in Table 1.1.

Table 1.1: Different categories of industries covered under EC guidelines

Category	Details
Category–A	DCs covered under PAT scheme but limited to the following industries: (1) aluminium, (2) cement, (3) chlor-alkali, (4) fertilizers, (5) iron and steel, (6) petrochemicals covering only cracker units, (7) petroleum refineries, (8) pulp and paper, (9) textile, and (10) thermal power stations.
Category–B	Large industries with energy consumption of less than the existing minimum threshold limits for DCs.
Category–C	Small scale enterprises with energy costs accounting for more than 30% of the total production cost.
Group–D	Medium enterprises with energy costs accounting for 10% to 30% of the total production costs.
Group –E	Micro industries with material costs more significant than energy costs.

2. OBJECTIVES

The overall objective of the Energy Conservation (EC) Guidelines is to guide the management and operators in large industries and MSMEs to manage energy consumption by standardizing energy performance values of various energy consuming equipment and systems deployed for the manufacturing process.

One of the important components under the overarching framework of the EC Guidelines is benchmarking of standard energy performance values and a procedure for establishing best energy performance for major energy consuming equipment, such as boiler, furnace, thermic fluid heater, waste heat recovery equipment, motor, etc. The objective of this document is to provide EC Guidelines for MSME sector that would help them in adopting best operating practices (BOPs) in their processes and equipment to improve the energy performance.

3. ENERGY CONSERVATION GUIDELINES

The Energy Conservation (EC) Guidelines is a comprehensive, hand-holding document related to major energy consuming equipment and system in different industries in the MSME sector to guide them to manage energy efficiently.

3.1 Standards and targets

The EC Guidelines consists of two distinct components, namely, (1) Standard component and (2) Target component for both process specific and common energy consuming equipment employed across industries in the MSME sector. For an industry to operate efficiently, it is essential to operate various energy consuming equipment efficiently and ensure proper monitoring and recording of all key operating parameters pertaining to each equipment/system. An industry shall maintain optimum operating parameters of the different equipment based on feedback received from the relevant sections, thereby achieving optimum operation of the equipment, which shall be termed as standard values of operation. Thus, the standard values of an equipment shall be defined as follows:

Standards are optimum performance values achieved by an energy consuming equipment in daily operation

The industry shall further improve the performance of the equipment by operating them at the best possible operating parameters, which shall be termed as target values of operation. The target values as mentioned in the guidelines are better than the standard values, which the industry shall strive to achieve for the best possible performance of the equipment. Thus, the target values of an equipment shall be defined as follows:

Targets are equal to the best achievable values of an energy consuming equipment in daily operation

3.2 Components of standards

The standard component comprises four distinct sections that focus on the relevant instructions concerning routine operations of the respective equipment. These include: (1) management and control, (2) measurement and recording, (3) maintenance and inspection, and (4) installation of new facility. The primary focus of the standard components is provided in Table 3.1. The instructions are intended to guide the industries to achieve optimum performance of the equipment.

Table 3.1: Components of standards

Component	Primary focus
1. Management and control	A. This section provides guidelines for managing and controlling key operating parameters in different energy consuming equipment in an industry, for example, air ratio, flue gas temperature, surface temperature, waste heat recovery, efficiency of motors, efficiency of fans, corrected power factor of electrical equipment, lighting power density, etc. B. The section further covers load sharing during part load conditions in a multi-equipment, for example, part load operations of equipment, such as boiler, pump, fan, blower, air compressor, refrigeration and air-conditioning system, etc.

Component	Primary focus
2. Measurement and recording	A. This section provides frequency of measurements and recording of operating parameters, for example, fuel consumption, temperature of steam, temperature of flue gases, analysis of flue gases, inlet and outlet temperatures of heating and cooling media, supply and return temperature of cooling water, etc.
3. Maintenance and inspection	A. This section highlights preventive maintenance and the overhauling schedule for various equipment. B. It further provides schedule for regular calibration of instruments to maintain accuracy in data measurements.
4. Necessary measures when installing new facilities	A. This section suggests directions for the installation of energy efficient equipment for retrofitting in the existing equipment and system upgradation.

3.3 Components of targets

The target components provide a set of instructions for the efficient use of energy consuming equipment and energy management practices that shall be followed to achieve the best performance of the equipment. The instructions under target components shall relate to the existing practices as well as include guidance for selecting new equipment with advanced features.

3.4 Revision of Energy Conservation Guidelines

The EC Guidelines applicable for different industries under the MSME sector shall be revised from time to time on a periodical basis based on inputs from various stakeholders and as per recommendations of the technical committee constituted by the Bureau of Energy Efficiency.

4. METHODOLOGY

4.1 Activities followed for preparation of EC Guidelines

A review of the Energy Conservation (EC) Guidelines pertaining to industries in Japan was carried out to draw a blueprint of the EC Guidelines applicable for Indian industries. The secondary data was collated from BEE-SME programme, GEF-World Bank programme, GEF-UNIDO programme, SAMEEEKSHA platform, etc., for the analysis. Relevant secondary data from different industries was collected and discussed by undertaking field visits. The type of secondary information included energy audit reports, performance analysis reports of equipment and systems, sectoral study reports, detailed project reports, cluster manuals, cluster reports, etc. Other sources of secondary data include original equipment manufacturers, sectoral experts, stakeholder consultations with industries and industry associations, secondary sources, such as websites, etc.

Extensive interactions with industry personnel and industry associations were carried out to finalize key operating parameters in different process equipment as well as common equipment. Relevant secondary data from different industries was collated and sanitized to exclude extremely high or low values. These data were validated through field visits to industries and discussions with stakeholders. The key operating parameters include air ratio, flue gas temperature, surface temperature, level of waste heat recovery (WHR), type of electric motors used and motor driven equipment, lighting, etc.

The draft EC Guidelines for micro, small and medium enterprise (MSME) sector was presented in stakeholder consultation workshops to obtain inputs from all key stakeholders. The stakeholders included relevant government bodies, progressive industries, industry associations, and technical consultants, etc., and with their inputs, the EC Guidelines for the MSME sector were finalized.

4.2 Major energy consuming equipment

The analysis of cluster data collated through field visits and secondary sources in 25 MSME sub-sectors showed that they are energy intensive and/or account for significant energy consumption. The review of information pertaining to the target MSME sectors revealed that the equipment used by most of the MSMEs could be grouped in two sets (1) process equipment and (2) common equipment.

Process equipment are directly involved in the production process and generally account for a major share of energy consumption in the industry. The energy performance of process equipment largely influences the performance of the total industry.

The common equipment are auxiliary equipment used commonly across a number of MSME sub-sectors, the types and capacities would depend on their associated processes and scale of operation. Some of the common equipment include motor, pump, air compressor, fans and blowers, cooling tower, power generation equipment, transformer, lighting, etc.

Common equipment provide support for the production process and account for only a low share of total energy consumption in the industry.

4.3 Evaluation of standard and target values

4.3.1 Standard values

The standard values are arrived at by using the following equation:

Standard value = Average value of the data samples

A nominal tolerance of +2.5% to –2.5% of the standard value is considered to accommodate variations in performance of the equipment within the range of standard values.

Upper limit = Standard value +2.5% of the standard value

Lower limit = Standard value –2.5% of the standard value

4.3.2 Target values

The target values are arrived at by using the following equation:

Target value = Average value of the data samples – the standard deviation of the data series

A nominal tolerance of +2.5% to –2.5% of the target value is considered to accommodate variations in performance of the equipment within the range of the target values.

Upper limit = Target value + 2.5% of the target value

Lower limit = Target value –2.5% of the target value

4.4 Structure of EC Guidelines

The EC Guidelines covering different MSME sub-sectors is divided into two sections. Section 5 provides Energy Conservation Guidelines for Common Equipment used in the MSME sub-sectors. Section 6 provides Energy Conservation Guidelines for major process equipment used in individual MSME sub-sectors covering best operating practices, performance assessment along with typical performance indicators, and efficient resource utilization.

5. ENERGY CONSERVATION GUIDELINES FOR COMMON EQUIPMENT

This section provides Energy Conservation (EC) Guidelines for the equipment used commonly across different types of industries in the MSME sector. These common equipment include air compressor, pump, fans and blowers, cooling tower, electric motor, transformer, lighting, power generator set, etc.

5.1 Air compressors and compressed air network

Air compressors are used in industries for a variety of applications to meet process requirements, operate pneumatic tools, and meet instrumentation needs. These are mechanical equipment used to compress and pressurize air. The centralized compressor air network` consists of compressor(s), filter, after cooler, dryer, intelligent electronic control system, receiver tank(s), distribution piping, air cylinder, nozzle, ejector, etc. The pressurized air is transferred to various points of usage either directly or through receiver tanks. This section provides EC Guidelines for air compressors and compressed air network in a rational way. A typical schematic of air compressor network is shown in Figure 5.1.

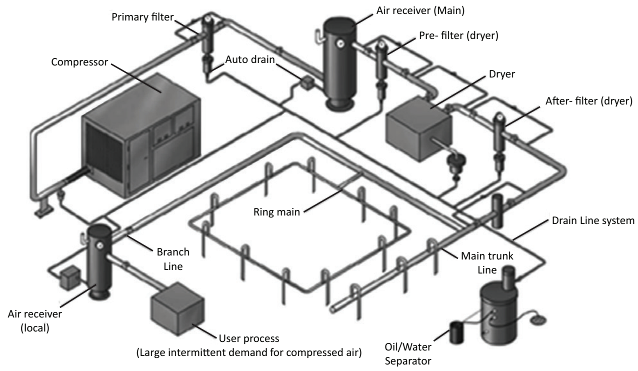

Figure 5.1 Air compressor network

Standards components	
1. Management and control	The industry shall undertake the following: A. Manage and control operations as per the instructions provided by the Original Equipment Manufacturer (OEM). It shall maintain specific power consumption (SPC) of air compressor as specified in Table 5.1. B. Ensure that the quality of suction air to the compressor is clean, cool, and dry air for optimum performance. C. Pre-set a minimum generation pressure of compressed air based on plant requirements to optimize the performance. Maintain optimum pressure setting of slightly more than maximum requirement for the plant to compensate envisaged pressure losses in distribution line. D. Install receiver tanks of sufficient capacities for compressed air storage so as to cater to load demands and process fluctuations without any trouble irrespective of compressor operational status. E. Use suitable size of air compressor to meet compressed air demands. The industry shall use dedicated air compressors to meet exclusive high or low pressure demands.

	F. Install intelligent flow controller for effective compressed air demand management involving multiple compressor operation. G. Use the most energy efficient compressors to meet base load in case of multi compressor operation. H. Isolate compressed air distribution lines wherein compressed air is not required for a prolonged time period. I. Install suitable pressure gauges on discharge side of air compressor pipe line, air receivers, and end-use points to monitor the pressure of the compressed air for estimating pressure losses in distribution lines. J. Use air blowers or air gun, wherever feasible, to reduce compressed air usage and leakage levels.
2. Measurement and recording	The industry shall measure and record the following: A. Electricity consumption on daily basis using dedicated energy meter. B. Discharge pressure and temperature of compressed air and inlet temperature of air on daily basis to evaluate free air discharge (FAD) of individual air compressors to assess the specific power consumption (SPC). C. Pressure across inlet air filter and record pressure drop. Higher pressure drop will increase electricity consumption (refer Table 5.2). Measure load time and unloading time of the individual compressor on daily basis. D. Leakage on monthly basis to estimate air leakages and undertake remedial actions to plug off leakages. Some of the common points of leakage in a compressed air system include joints, valves, bends, etc.
3. Maintenance and inspection	The industry shall: A. Inspect and clean air filters on weekly basis. Replace air filters based on suction air conditions. B. Avoid moisture carryover in compressed air by draining the accumulated moisture on a daily basis. C. Check oil level and oil leakage for oil-based compressor system on daily basis. D. Inspect and remove fouling of inter-cooler and after-cooler to ensure optimum performance air compressors on quarterly basis. E. Inspect the compressor for vibration and noise level on quarterly basis. F. Undertake overhauling of air compressors on a periodical basis, as recommended by OEMs. G. Calibrate instruments and gauges as per the recommendations of the suppliers to ensure reliability and maintain accuracy of data.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Undertake demand assessment of compressed air to select a suitable compressed air system based on the existing requirements as well as considering the immediate expansion plans. This includes energy efficient systems, such as in-built VFD, motor with permanent magnet, inverter type air compressor, etc. B. Select and install air compressors with the lowest SPC while meeting the compressed air demands. C. Avoid installing oversized air compressors, which may lead to inefficiencies in operation. D. Install air compressor closer to point of use. E. Consider the following while designing and installing a compressed air network:

	a. Installing ring main loop header for minimizing pressure losses in compressed air distribution network. b. Use seamless metallic pipes or fibre reinforced plastic (FRP) pipe for compressed air lines. Install optimum size piping and increase diameter of pipes whenever a new compressor is added to the system. c. Provide a minimum slope of 1 inch for every 10 ft in main header to facilitate moisture drainage. The distance between two drain points shall not exceed 30 metres. Provide adequate auto drain traps and strainers in receiver, main, and branch lines. d. Avoid unnecessary bends and turns in distribution network to minimize pressure losses. Take tapings from branches from top of the main pipeline. e. Install separate high pressure and low pressure lines. f. Use moisture separators to remove moisture before entering pneumatic equipment. The separator is not required if the industry has installed air dryer. g. Install dedicated air receiver close to the location wherein intermittent high volume compressed air is required. h. Install pressure reduction valves for low pressure applications and boosters for high pressure applications. G. Meet fluctuations in compressed air demands using VFD-enabled screw air compressors. While using multiple air compressors system, the industry shall use one-inverter type air compressor with a suitable pressure setting to meet the variable load conditions while the other air compressors shall be used in continuous operation to cater to the base load. Use reciprocating compressor for part-load applications. H. Use centrifugal compressors for meeting high volume air with low pressure applications, wherever feasible. I. Install air dryers in the distribution line which supplies to dry air usage points only, for example, instrumentation air. J. Ensure the proper location of air compressors and the quality of suction air as per the recommendation of OEM. K. Avoid exposure of compressor to direct sunlight or other heat-producing units, while ensuring adequate ventilation of air compressor room.
Target components	
	The industry shall: A. Ensure compressed air leakage within 3% to 10%. B. Maintain operating SPC within the design range as provided by the OEMs.

The typical specific power consumption levels of different types of air compressors used in the industry are provided in Table 5.1.

Table 5.1: Specific energy consumption of air compressor

Type	FAD range (cfm)	Pressure range (bar)	SPC range (kW/cfm)
Reciprocating	20–7000	0.8–12	0.20–0.35
Screw (Single stage)	50–1500	0.8–13	0.14–0.25
Screw (Multi stage)	50–1500	0.8–24	0.18–0.35

Source: Collation of data from original equipment manufacturers

Table 5.2: Effect of pressure drop across air inlet filter on power consumption

Pressure drop across air filter (mm WC)	Increase in power consumption (%)
0	0
200	1.6
400	3.2
600	4.7
800	7.0

Source: Energy efficiency in electrical utilities, Guide book for national certification examination for energy managers and energy auditors, chapter 3.3, BEE.

5.1.1 Common monitorable parameters and performance assessment

The industry shall monitor the following common monitorable parameters to assess the performance of air compressor (Table 5.3).

Table 5.3: Common monitorable parameters in air compressor

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Air pressure	kg/cm^2	Pressure gauge	Daily
Inlet temperature	^{0}C	Thermocouple	Daily
Loading time	sec	Electronic timer	Daily
Unloading time	sec	Electronic timer	Daily
Electricity consumption	kWh	Energy meter	Daily

The industry shall assess the specific power consumption using the following formula:

$$\text{Specific power consumption (kW/cfm)} = \frac{\text{Electricity Consumption (kW)}}{\text{Free air discharge (cfm)}}$$

Free Air Discharge (FAD) of an air compressor is estimated using the following formula:

$$FAD = \frac{V}{t} \times \frac{P_d}{P_s} \times \frac{T_i}{T_o}$$

where,

FAD = Free Air Discharge (ft^3/min)

V = Volume of air receiver including interconnecting pipes (ft^3)

t = Time taken to fill receiver (min)

P_d = Cut-off or final air pressure (kg/cm^2)

P_s = Atmospheric air pressure (kg/cm^2)

T_o = Compressed air exit temperature (°K)

T_i = Inlet air temperature (°K)

Leakage test is carried out to quantify the level of air leakage from compressed air network, and is computed as follows:

$$\text{Leakage rate (\%)} = \frac{\text{Onload time (sec)}}{\text{Onload time (sec)} + \text{off load time (sec)}} \times 100$$

Annual energy wastage (kWh) = FAD (cfm) × Leakage rate (%) × SPC (kW/cfm) × Annual operating hours (hour)

5.2 Pump and pumping system

Pumps are used for a wide range of applications to transfer fluids through mechanical action. According to the basic operating principle, pumps can be classified as either dynamic pumps or positive displacement pumps. Dynamic pumps are further classified into centrifugal pumps and special-effect pumps. Positive displacement pumps are further classified into rotary pumps and reciprocating pumps. Centrifugal pumps account for the major share of electricity consumption in the industrial sector. Some of the centrifugal pumps used by the industry include: (1) mono-block pumps, (2) end-suction pumps, (3) split-case pumps, and (4) multi-stage pumps. This section provides EC Guidelines for pumps and pumping system in a rational way.

Standards components	
1. Management and control	The industry shall undertake the following: A. Operate pumps close to the best operating point as specified by the OEMs. It shall ensure optimum loading of the pumps. B. Use pumps with highest efficiency to meet the base load when multiple pumps are in operation. C. Install variable frequency drive (VFD) for fluctuating loads instead of throttling. D. Use on-line monitoring for centralized large system and periodical measurement for decentralized smaller pumps. E. Use a number of smaller pumps in parallel operation in place of single pump of higher capacity. F. Manage and control the loading of pumps near the best operating point of respective characteristic curve in case of multiple pumps in operation. G. Manage the piping network of the pumping system and the control operating parameters, such as flow rate, pressure, and temperature to meet process requirements. H. Replace worn-out pumps with energy efficient pumps. I. Maintain a minimum Net Positive Suction Head (NPSH) of pumps as prescribed by the manufacturer.
2. Measurement and recording	The industry shall measure and record the following: A. Key operating parameters such as the total differential head, flow rate, and electricity consumption to evaluate efficiency of pumps on monthly basis.
3. Maintenance and inspection	The industry shall undertake the following: A. Check the condition of gland sealing on daily basis and undertake maintenance to avoid leakages. B. Inspect the pump for vibration and noise level on quarterly basis. C. Inspect and ensure proper tension of belts for belt driven pumps. D. Undertake periodical maintenance including overhauling of the pumps according to the instructions provided by the OEM. E. Ensure dynamic balancing of pump assembly after each overhauling. F. Calibrate instruments and gauges as per the recommendations of the suppliers to ensure reliability and maintain accuracy of data.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Install pumping network using seamless/ FRP pipes for minimum system resistance. B. Use a booster for small loads requiring higher pressures. C. Select correct capacity of pump with energy efficient systems, such as IE3 motor or permanent magnet synchronous motor, variable frequency drives (VFDs), etc., to avoid energy wastage. D. Install suction valve of proper size as recommended by OEM.
Target components	
	The industry shall: A. Ensure pump efficiency close to the design values provided by the OEMs. B. Replace rewound motors in pumps with IE3 motors.

5.2.1 Common monitorable parameters and performance assessment

The industry shall monitor the following common monitorable parameters as shown in Table 5.4 to assess the performance of pumps.

Table 5.4: Common monitorable parameters in pump

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Electricity consumption	kWh	Energy meter	Daily
Suction head	metre	Pressure gauge	Daily
Delivery head	metre	Pressure gauge	Daily
Flow rate	m^3/sec	Flow meter	Daily
Fluid temperature	ºC	Thermocouple	Daily

The industry shall estimate pump efficiency using the the following formula:

$$\text{Pump Efficiency (\%)} = \frac{\text{Hydraulic power} \times 100}{\text{Shaft power}}$$

$$\text{Hydraulic power } (P_d) = \frac{Q \text{ X } (h_d - h_s) \times \rho \times g}{1000}$$

Pump shaft power (P_s) = Electricity consumption × Motor efficiency

where,

g Acceleration due to gravity (m/s^2)

h_d Discharge head (metre)

h_s Suction head (metre)

Q Flow rate (m^3/s)

P Density of fluid (kg/m^3)

5.3 Fans and blowers

Fans and blowers are used to deliver air at a desired high velocity (and accordingly at a high mass flow rate) but at a relatively low static pressure. Such systems are used for different applications to transfer air through mechanical action. Based on operating principle, fans are grouped in two categories, namely (1) centrifugal fans and (2) axial flow fans. The industrial blowers are grouped into (1) centrifugal blowers and (2) positive displacement blowers. The selection of a fan or blower depends on various process requirements, such as air volume, system resistance, output pressure, and working environment. This section provides EC Guidelines for fans and blowers in a rational way.

Standards components	
1. Management and control	The industry shall undertake the following: A. Ensure that the quality of suction air to fan or blower is clean for optimum performance. B. Ensure no blockage or restrictions at inlet or suction of fan or blower. C. Manage and operate fans and blowers close to best operating point of the characteristic curve, as provided by the manufacturer. D. Use blowers in series for high resistance, and in parallel connection for low resistance system in case of multiple blower operation. E. Use multiple blowers in parallel to generate higher volume in place of a single, large pumping system. F. Undertake pressure holding test to detect and plug-off for leakages in distribution system. G. Replace over-sized fans/ blowers with optimum size system to meet the process requirements for high-load conditions. H. Retrofit existing fan or blower with a VFD in case of fluctuating load conditions in place of damper control. I. Use on-line monitoring for centralized large system and periodical measurement for decentralized smaller blowers.
2. Measurement and recording	The industry shall measure and record the following: A. Key operating parameters on daily basis to assess specific energy consumption (SEC) of fan or blower. The parameters include pressure head, temperature, and electricity consumption.

3. Maintenance and inspection	The industry shall undertake the following: A. Ensure allowable impeller inlet seal clearances a per design. These clearances include axial overlap, radial clearance, back plate clearance, labyrinth seal clearance, etc., as per instructions provided by OEM. B. Undertake corrective maintenance in case of a significant drop in pressure head observed in the system. C. Undertake overhauling of fans and blowers according to the instructions provided by the manufacturers. D. Inspect the blower and fan for vibration and noise levels on quarterly basis. E. Ensure dynamic balancing of fans/ blowers assembly after each overhauling. F. Calibrate instruments and gauges as per the recommendations of the suppliers to ensure reliability and maintain accuracy of data.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Undertake demand assessment of air to select suitable fan or blower as applicable, while considering the dust type, its concentration, etc., while handling dust-laden gases. B. Select and install correct capacity of fan/ blower with highest efficiency as provided in Table 5.6, considering existing requirements, immediate expansion plans, plant layout, and routing of pipes. C. Avoid unnecessary bends and turns while installing air ducts. D. Install direct coupled motor drives wherever possible. E. Provide sufficient straight length of duct (at least 3 times the duct diameter) and shall avoid bends close to fan inlet to avoid uneven air flow and vibrations.
Target components	
	The industry shall consider the following: A. Ensure operating efficiency of fan/ blower close to the design values provided by the OEMs. B. Replace rewound motors with IE3 motors.

5.3.1 Common monitorable parameters and performance assessment

The industry shall monitor the following common monitorable parameters as shown in Table 5.5 to assess the performance of fans and blowers.

Table 5.5: Common monitorable parameters in fans and blowers

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Electricity consumption	kWh	Energy meter	Monthly
Suction head	mm WC	Pitot tube	Monthly
Delivery head	mm WC	Pitot tube	Monthly
Fluid temperature	°C	Thermocouple	Monthly

$$\text{Velocity (m/s)} = Cp \times \sqrt{\frac{2 \times 9.81 \times \Delta p}{\gamma}}$$

Cp – Pitot tube coefficient (use manufacturer's value or assume 0.85)

Δp - Average velocity pressure measured using pitot tube and inclined manometer over the cross-section of duct, mm Water Column

γ - Gas density at flow conditions, kg/m^3

$$\text{Volumetric flow(Q), (m}^3\text{/sec)} = \text{Velocity, V(m/sec)} \times \text{Area (m}^2\text{)}$$

$$\text{Fan Mechanical Efficiency } (\eta_{mechanical}), (\%) = \frac{\text{Volume in m}^3\text{/sec} \times \Delta p \text{ (total pressure) in mm WC}}{102 \times \text{power input to fanshaft in kW}}$$

Air density at 0 °C – 1.293 kg/m^3

$$\text{Fan Static Efficiency } (\eta_{static}), (\%) = \frac{\text{Volume in m}^3\text{/sec} \times \Delta p \text{ (static pressure) in mm WC}}{102 \times \text{power input to fanshaft in kW}} \times 100$$

Power input to shaft (kW) = Electricity consumption (kW) × Motor efficiency (%)

The static efficiency equation is the same as mechanical efficiency except that the outlet dynamic pressure is not added to the fan static pressure.

The industry shall refer to the typical performance indicators of centrifugal fans as provided in Table 5.6.

Table 5.6: Efficiency of centrifugal fans

Fan category	Peak efficiency range (%)
Airfoil backward curved/ inclined	79 – 83
Modified radial	72 – 79
Radial	69 – 75
Pressure blower	58 – 68
Forward curved	60 – 65

Source : Energy efficiency in electrical utilities, guide book for national certification examination for energy managers and energy auditors, chapter 3.5, BEE.

5.4 Cooling towers

Cooling tower is used to reduce the temperature of water close to wet bulb temperature of air through evaporation of water. Different types of cooling towers used include (i) natural draft system and (ii) mechanical draft system. Cooling tower is an essential auxiliary equipment in process refrigeration and air-conditioning system used in different industries. This section provides EC Guidelines for cooling towers in a rational way.

Standards components	
1. Management and control	The industry shall undertake the following: A. Install automatic/ thermostatic controller in cooling tower to switch off cooling tower fans automatically when the temperatures of return water and supply water are almost same.. B. Install variable frequency drive (VFD) for varying cooling demands in the process. C. Use cellular PVC (poly vinyl chloride) drift eliminators in place of wooden blade drift eliminators. D. Use PVC fills in place of wooden bars. E. Ensure proper functioning of drift eliminators to control drift losses within limits as provided in Table 5.8. F. Maintain cycle of concentration (COC) within the limit as provided in Table 5.8 to minimize make-up water consumption in cooling water. G. Use on-line monitoring for centralized large system and periodical measurement for decentralized smaller cooling tower.
2. Measurement and recording	The industry shall measure and record the following: A. Quantity of make-up water addition used towards compensation of water losses, such as evaporation loss, drift loss, blowdown loss, etc., on daily basis. B. Electricity consumption of the cooling tower (includes associated fans and pumps) with dedicated energy meter in place. C. Inlet and outlet temperatures of water, water flow rate and its pressure on daily basis. D. Ambient conditions that include dry bulb temperature, wet bulb temperature, and relative humidity.
3. Maintenance and inspection	The industry shall undertake the following: A. Undertake visual inspection of fills in the cooling tower once in three months to ensure proper distribution of water. B. Carry out chemical disinfection of cooling water sump to avoid micro-organism growth.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Undertake load assessment for selection of suitable cooling tower system. B. Install cooling tower with moulded FRP fans of aerofoil design. C. Install multiple cooling tower systems in parallel in place of a single large system to meet higher volume requirements of cooling water.

Target components	
	The industry shall: A. Maintain cycle of concentration (COC) of 8 to 10 for optimum performance. B. Maintain an approach of 4 °C – 5 °C. C. Control the drift loss 0.001% – 0.005% of circulating flow rate.

5.4.1 Common monitorable parameters and performance assessment

The industry shall monitor the following common monitorable parameters as shown in Table 5.7 to assess the performance of cooling tower.

Table 5.7: Common monitorable parameters in cooling tower

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Ambient dry bulb temperature	°C	Thermometer	Daily
Ambient wet bulb temperature	°C	Thermometer	Daily
Cooling water inlet temperature	°C	Thermometer	Daily
Cooling water outlet temperature	°C	Thermometer	Daily
Cooling duty water flow rate	m^3/hr	Flow meter	Daily
Makeup water	m^3/day	Flow meter	Daily

The performance of cooling tower can be assessed using following formula.

$$\text{Effectiveness} = \frac{\text{Range}}{(\text{Range} + \text{Approach})} \times 100$$

Range = Entering cooling water temperature (return from process)–Leaving water temperature (supply to process)

Approach = Cooling water temperature (supply to process)–Ambient wet bulb temperature

The industry shall refer to the typical performance indicators of cooling towers as provided in Table 5.8.

Table 5.8: Performance parameters of cooling tower

Parameter	Control value
Cycle of concentration (COC)	8–10
Approach	4 °C–5 °C
Drift loss	0.001%–0.005% of circulating flow rate

Source: Energy efficiency in electrical utilities, guide book for national certification examination for energy managers and energy auditors, chapter 3.5, BEE.

5.5 Electric motors

Electric motors are connected with various rotating equipment, such as air compressor, pump, fan, blower, conveyor, etc. This section provides EC Guidelines for electric motors in a rational way.

Standards components	
1. Management and control	The industry shall undertake the following: A. Operate motors in the range of 75%–80% load for maximum efficiency. Avoid under-loading of the motors. B. Stop motor driven equipment when not in use or during idle operation. C. Ensure balancing of voltage in all three phases of motors for optimum performance. D. Ensure operating power factor close to unity. E. Ensure adequate ventilation of motors to avoid overheating. F. Use direct online (DOL) starters for motors upto 5 hp, star-delta type starters for 5–20 hp motors, and soft starter for motor with more than 20 hp capacity. G. Avoid rewinding of motors more than two times. Replace rewound and standard motors with energy-efficient motors (IE2 motors) as specified in Table 5.10.

2. Measurement and recording	The industry shall measure and record the following: A. Electricity consumption, voltage, current and power factor on daily basis. B. Motor body temperature, vibration, rpm, etc., on monthly basis.
3. Maintenance and inspection	The industry shall undertake the following: A. Inspect for wear and tear of foundation bolts, shaft, and bearings on quarterly basis. B. Check proper tightness of electrical cables connecting motor terminals to avoid any arcing and short circuit on quarterly basis. C. Inspect and maintain motor-driven equipment on quarterly basis to reduce mechanical losses occurring in electric motors, power transmission units, and machines that apply loads to the motors, for example, the industry shall ensure proper tension of belts to minimize transmission losses. D. Calibrate instruments as per the recommendations of the suppliers to ensure reliability and maintain accuracy of data. E. Monitor and maintain lubricant oil level on daily basis.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Install energy saving measures, such as VFD, motor with permanent magnet slip power recovery system, fluid couplings, etc., for variable load applications to minimize energy consumption. B. Use cogged v-belts instead of flat v-belts for belt driven motor applications.
Target components	
	The industry shall consider the following: A. Install IE3 motors for various applications as provided in Table 5.11. B. Maintain unbalanced voltage within 1%–3%.

5.5.1 Common monitorable parameters and performance assessment

The industry shall monitor the following common monitorable parameters as shown in Table 5.9 to assess the performance of motors.

Table 5.9: Common monitorable parameters in motors

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Voltage	Volt	Power analyzer	Daily
Current	Ampere	Power analyzer	Daily
Power factor	-	Power analyzer	Daily
Electricity consumption	kWh	Energy Meter	Daily

The industry shall refer to the efficiencies of IE2 motors as provided in Table 5.10.

Table 5.10: Energy efficiencies of IE2 motors

Rating (kW)	Efficiency (%)		
	2-Pole	4-Pole	6-Pole
0.37	72.2	70.1	69.0
0.55	74.8	75.1	72.9
0.75	77.4	79.6	75.9
1.1	79.6	81.4	78.1
1.5	81.3	82.8	79.8
2.2	83.2	84.3	81.8
3.7	85.5	86.3	84.3
5.5	87.0	87.7	86.0
7.5	88.1	88.7	87.2
11	89.4	89.8	88.7
15	90.3	90.6	89.7
18.5	90.9	91.2	90.4
22	91.3	91.6	90.9
30	92.0	92.3	91.7

Source: IS 12615:2011 (Three-phase, 50Hz, single speed and squirrel cage induction motors)

Note: IE2 motors stand for High Efficiency

The industry shall refer to the efficiencies of IE3 motors as provided in Table 5.11.

Table 5.11: Energy efficiencies of IE3 motors

Rating (kW)	Efficiency (%)		
	2-Pole	4-Pole	6-Pole
0.37	75.5	73.0	71.9
0.55	78.1	78.0	75.9
0.75	80.7	82.5	78.9
1.1	82.7	84.1	81.0
1.5	84.2	85.3	82.5
2.2	85.9	86.7	84.3
3.7	87.8	88.4	86.5
5.5	89.2	89.6	88.0
7.5	90.1	90.4	89.1
11	91.2	91.4	90.3
15	91.9	92.1	91.2
18.5	92.4	92.6	91.7
22	92.7	93.0	92.2
30	93.3	93.6	92.9

Source: IS 12615:2011 (Three-phase, 50Hz, single speed and squirrel cage induction motors)

Note: IE3 motors stand for Premium Efficiency

5.6 Transformer

A transformer is static electrical equipment which transforms alternating current (AC) electrical power from one circuit to another at constant frequency by step-up or step-down according to the end-use requirement. The transformer can be of core type or shell type based on placement of primary coil and secondary coil around steel core. Based on application, transformer can be step-up or step-down, power transformer, distribution transformer, etc. This section provides EC Guidelines for transformers in a rational way.

Standards components	
1. Management and control	The industry shall undertake the following: A. Operate transformer close to best efficiency loading point to minimize no-load losses and load losses. B. Maintain the power factor close to unity at transformer level to reduce the load losses. C. Ensure proper electrical compatibilities while operating two or more transformers in parallel. These include voltage ratio, impedance, polarity, etc. D. Maintain the operating temperature of the transformer within the prescribed limits as provided by the manufacturer to achieve full life span services and reduce energy losses. E. Switch off under-loaded transformer put in parallel operation to reduce part-load energy losses. F. Make necessary tap adjustment in transformer to compensate output voltage drop due to long cable runs.
2. Measurement and recording	The industry shall measure and record the following: A. Key operating parameters such as voltage, power factor, loading and harmonics on daily basis. B. Temperature of oil and windings of the transformer. C. Room temperature and moisture level wherein the transformer is installed on daily basis.
3. Maintenance and inspection	The industry shall undertake the following: A. Undertake scheduled preventive maintenance as per manufacturer's instructions to ensure the following: oil and winding temperature, oil level and leakage, oil level in OLTC (on-line tap changer) mechanism, earth resistance, condition of relief diaphragm, sealing arrangement, etc. B. Check and replace silica gel when the colour turns to pink.

4. Necessary measures when installing new facilities	The industry shall consider the following: A. Undertake load assessment of the plant to select suitable size and number of transformers, considering best efficiency points for loading and routine/ seasonal operations. B. Select transformers with the minimum eddy losses for non-linear load applications. C. Select the transformer with relatively low no-load losses (for example amorphous core type) to maintain the best efficiency at low loads. D. Install oil-filled transformer which is more efficient and have long life than a dry-type transformer. E. Install OLTC-enabled transformers for new installations to maintain end-use voltage close to the design level.
Target components	
	The industry shall consider the following: A. Maintain winding temperature within 100 °C –120 °C. B. Maintain oil temperature within 90 °C. C. The industry shall maintain unity power factor at the transformer.

5.6.1 Common monitorable parameters and performance assessment

The industry shall monitor the following common monitorable parameters as shown in Table 5.12 to assess the performance of transformers.

$$\text{Transformer loading (\%)} = \frac{\text{Measured power (kVA)}}{\text{Rated power (kVA)}} \times 100$$

Table 5.12: Common monitorable parameters in transformer

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Voltage	Volt	Voltmeter	Daily
Current	Ampere	Ammeter	Daily
Power	kVA	Power analyzer	Weekly
Oil temperature	^{0}C	Temperature gauage	Daily
Winding temperature	^{0}C	Tempeature gauge	Daily
Tap position	-	-	Daily
Harmonics	%	Power analyzer	Monthly

5.7 Lighting system

Lighting is used for illumination of different areas of the industry. Based on the specific requirements, different illumination levels are required in different areas of the plant. This section provides EC Guidelines for lighting system in a rational way.

Standards components	
1. Management and control	The industry shall undertake the following: A. Maintain lighting systems in different areas based on standard illumination levels as provided in Table 5.14. B. Install suitable control systems to auto switch off or dimming of lighting system. The control systems include motion sensors, timers, interlocking with security systems to avoid lighting when not required, etc. C. Manage dimming or turning-off the light in a way that eliminates excessive or unnecessary lighting. D. Eliminate unwanted lighting within the industrial premises. E. Use natural lighting wherever feasible.

2. Measurement and recording	The industry shall measure and record the following: A. Illumination level of lighting systems installed in various sections on quarterly basis.
3. Maintenance and inspection	The industry shall undertake the following: A. Undertake cleaning of window panes to ensure maximum utilization of daylight and lighting systems on quarterly basis. B. Clean and replace lighting fixtures and lamps as per requirements.
4. Necessary measures when installing new facilities	While installing a new lighting system, the industry shall optimize energy use in lighting, based on the information concerning lighting systems in the Energy Conservation Building Code (ECBC). The industry shall consider the following: A. Replace inefficient lighting with energy-efficient lighting facilities, such as LEDs, induction lamps, etc. B. Maintain standard illumination with minimum lighting power density (LPD). The LPD range for a few application areas in industries is shown in Table 5.13. C. Install sodium vapour lamps for area lighting in place of mercury vapour lamps. D. Use electronic ballasts in place of conventional chokes. E. Select suitable lighting fixtures that can be easily maintained and allow easy cleaning and replacement of light source. F. Provide due consideration to factors affecting the total lighting efficiency while selecting lighting fixtures. The factors include illuminance efficiency of the light sources, efficiency of lighting circuits and lighting fixtures, etc. G. Ensure maximum use of natural day light and reduce electric lighting load, for example, use of translucent roof, large fibre glass skylight, high opening in the wall, etc. H. Use solar tubes and solar photo voltaic (SPV)-based lighting system wherever feasible.
Target components	
	The industry shall consider the following: A. Ensure lighting power density (LPD)* as specified in Table 5.15.

* Lighting power density (LPD) is defined as the ration of installed lighting power, in wattages, in a building space to the space area in square meters or square feet (watt/ft2 or watt/m2). The lighting power density (LPD) is evaluated using the following formula.

$$\text{LPD}\left(\frac{\text{W}}{\text{m}^2}\right) = \frac{\text{Lux}}{\text{Efficacy}}$$

$$\text{Lux} = \frac{\text{Lumen}}{\text{m}^2}$$

$$\text{Efficacy} = \frac{\text{Lumen}}{\text{watt}}$$

5.7.1 Common monitorable parameters and performance assessment

The industry shall monitor the following common monitorable parameters as shown in Table 5.13 to assess the performance of lighting system.

The industry shall refer to the standard illumination for lighting as provided in Table 5.14.

Table 5.13: Common monitorable parameters in lighting system

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Illumination	lux	Lux meter	Quarterly
Electricity consumption	kWh	Energy meter	Daily

Table 5.14: Standard illumination for lighting

Lighting area	Average illumination (Lux)	Limiting glare index
Furnace rooms, bending, annealing lehrs	100	28
Mixing rooms, forming (blowing, drawing, pressing, rolling)	150	28
Cutting to size, grinding, polishing, toughening	200	25
Finishing (bevelling, decorating, etching, silvering)	300	22
Brilliant cutting	700	19
General inspection	200	19
Fine inspection	700	19
Storage areas	150	25
Maintenance workshop	150	28
Entrance, corridor, stairs	100	28
Outdoor areas	20	25

Source: IS: 6665.1972: Code of practice for industrial lighting

The industry shall refer to the lighting power density as provided in Table 5.15.

Table 5.15: Lighting power density for industries

Lighting area	Average illumination (Lux)	Lighting power density (w/m^2)
Administrative building	50–400	5.0–9.5
Administrative corridor	100	2.3–7.1
Shop floor lighting (process)	150–300	6.0–12.0
Workshop	150–300	7.1–14.1
Warehouse - storage area	100–150	3.5–7.08

Source: Energy Conservation Building Code, Government of India

5.8 Power generator set

This section provides EC Guidelines on BOP in diesel or gas-based backup power generator set in a rational way.

5.8.1 Common monitorable parameters and performance assessment

The industry shall monitor the following common monitorable parameters as shown in Table 5.16 to assess the performance of power generator set.

The industry shall refer to the typical specific electricity generation ratio (SEGR) values of diesel-based power generators as provided in Table 5.17.

Standards components	
1. Management and control	The industry shall undertake the following: A. Ensure efficient operation of captive power generation system to maintain optimum specific energy generation ratio (SEGR).@ B. Manage operations in such a way to ensure proper load distribution while maintaining SEGR close to design level, in case of multiple power generation system operation. C. Install waste heat recovery (WHR) system in case of continuously operated power generation system.
2. Measurement and recording	The industry shall measure and record the following: A. Electricity generation and fuel consumption on daily basis by installing dedicated energy meter and flow monitoring system.

3. Maintenance and inspection	The industry shall undertake the following: A. Maintain proper functioning of injection pump and faulty nozzles to optimize fuel consumption. B. Clean and maintain carbon brushes to ensure proper contacts. C. Replenish lubricating oil as per the recommended schedule to maintain the quality of the lubricant. D. Clean the filters once in a month to avoid blockage. E. Inspect for vibration and noise level on quarterly basis. F. Inspect for wear and tear of foundation bolts, and bearings on quarterly basis. G. Undertake periodical maintenance including overhauling according to the instructions provided by the OEM. H. Ensure dynamic balancing after each overhauling. I. Calibrate instruments and gauges as per the recommendations of the suppliers to ensure reliability and maintain accuracy of data.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Assess critical backup load for installing backup power generation system.
Target components	
	The industry shall ensure the following: A. Maintain SEGR of backup power generation system referring to Table 5.17.

@ Specific Energy Generation Ratio (SEGR) is the ratio of electricity generation to the corresponding fuel consumption.

Table 5.16: Common monitorable parameters in diesel-based power generator set

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Electricity generation	kWh	Energy meter	Daily
Diesel consumption	litre	Flow meter	Daily

$$\text{SEGR (kWh/lit)} = \frac{\text{Electricity generation (kWh)}}{\text{Fuel consumption (litre)}}$$

Table 5.17: SEGR for diesel-based power generator set

Rating (kVA)	Recommended SEGR (kWh/litre)
1450	3.84
1100	3.88
625	3.73
608	3.50
550	3.50
500	3.84
400	3.69
310	3.30
250	3.20
180	3.07
175	3.00
166	3.00
160	3.00
120	3.00

kVA—kilovolt-ampere; kWh—kilowatt-hour

Source: Petroleum Conservation Research Association

5.9 Harmonics distortion

Harmonic distortion is the alteration of the voltage pattern of sinusoidal wave due to non-linear loads like VFDs, fluorescent ballasts, computer power supplies, battery chargers, etc., which draw electricity differently than non-electronic equipment. The non-linear loads lead to harmonics distortions in the overall electrical system. Limiting the harmonics is important to avoid harmonic injections to the grid and consequent voltage distortion at grid level. This section provides EC Guidelines for limit the harmonics in a rational way.

Standards components	
1. Management and control	The industry shall undertake the following: A. Determine the magnitude of harmonic distortion at points of common coupling (PCCs*) in the electrical system. B. Identify source(s) of harmonics in the electrical distribution network for their operational status. The harmonics may be induced due to either partial malfunctioning or total failure of the equipment. C. Use the following measures to minimize harmonic distortions: a. Pulse width modulation (PWM) in AC drives. b. Drive with effective choke filtering. c. Tuned LC (inductive and capacitance) filters d. Standard cabling and earthing practices. e. Shunt filters or harmonic traps. f. External active filters.
2. Measurement and recording	The industry shall measure and record the following: A. Total voltage distortions and total current distortions at PCCs on monthly basis.
3. Maintenance and inspection	The industry shall undertake the following: A. Inspect operational status of different harmonic filtration systems installed in electrical distribution network on monthly basis. B. Carry out scheduled preventive maintenance of harmonics filters as per OEMs instructions.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Select transformer with built-in passive harmonic filtration for low voltage distribution network. B. Undertake the assessment of the non-linear devices and select suitable size of filtration/tuned LC filters in electrical distribution network.
Target components	
	The industry shall ensure the following: A. Total harmonic voltage distortion in the range as specified in Table 5.18. B. Total harmonic current distortion in the range as specified in Table 5.19.

* In the industry, PCC exists between (1) plant and electricity supply network, and (2) non-linear load and other loads

Table 5.18: Harmonic voltage distortion limits

Bus voltage at point of common coupling	Individual voltage distortion (%)	Total voltage distortion THD* (%)
V≤ 1.0 kV	5.0	8.0
1 kV <V≤ 69 kV	3.0	5.0

Source: IEEE standard 519-1992

* Total harmonic distortion (THD) is the ratio of the root mean square of the harmonic content, considering harmonic components up to the 50th order and specifically excluding inter harmonics, expressed as a percentage of the fundamental. Harmonic components of order greater than 50 may be included when necessary.

Table 5.19: Harmonic current distortion limits for general distribution system

	Individual harmonic order (odd harmonics)					
Isc/IL	3 ≤ h< 11	11≤h<17	14≤h<23	23≤ h<35	35 ≤ h ≤ 50	TDD
<20	4.0	2.0	1.5	0.6	0.3	5.0
20<50	7.0	3.5	2.5	1.0	0.5	8.0

Source: IEEE standard 519-1992

I_{sc}: Maximum short-circuit current at PCC

I_L: Maximum demand load current (fundamental frequency component) at PCC

h: Integral multiples of fundamental frequency (f), for example 3 ≤h< 11 means distorted frequency in the distribution network lies between 3f and 11f.

TDD: Total demand distortion, harmonic current distortion in % of maximum demand load current (15 or 30 minutes demand)

5.9.1 Common monitorable parameters and performance assessment

The industry shall monitor the following common monitorable parameters as shown in Table 5.20 to assess the magnitude of harmonic distortion at PCCs.

Table 5.20: Common monitorable parameters for harmonics at PCC level

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Total harmonic distortion (V_{THD} and I_{THD})	%	Power analyzer	Monthly

6. ENERGY CONSERVATION GUIDELINES FOR PROCESS EQUIPMENT

This section provides Energy Conservation (EC) Guidelines for different industries in MSME sector (Table 6.1). It focuses on best operating practices, operational aspects, common monitorable parameters, performance assessment with typical performance indicators of major energy consuming equipment and efficient resource utilization.

Table 6.1: Industries covered under MSME sector

S No.	Industry
1	Foundry industry
2	Forging industry
3	Sponge iron industry
4	Aluminium industry
5	Brass industry
6	Machine tools industry
7	Galvanizing and wire drawing
8	Refractory industry
9	Ceramic industry
10	Brick industry
11	Clay tile industry
12	Glass industry
13	Chemicals and dyes industry
14	Textile industry
15	Paper industry
16	Limestone industry
17	Coir industry
18	Jaggery industry
19	Oil mill
20	Tea industry
21	Rice mill
22	Ice making industry
23	Seafood industry
24	Dairy industry
25	Food processing industry

FOUNDRY

6.1 Foundry Industry

6.1.1 Background

The foundry industry is one of the energy intensive industries in the micro, small and medium enterprise (MSME) sector. Foundry industry produces different types of castings that include malleable castings, steel castings, ductile iron castings, and gray iron castings. It manufactures a variety of metal cast components for different applications, such as automobiles, tractors, railways, machine tools, sanitary, pipe fittings, defence, aerospace, earth moving equipment, textile, cement, electrical, power machinery, pumps/valves, wind turbine generators, etc.

6.1.2 Production process

The foundry industry mainly follows the manual process. The primary process steps in a foundry industry include mould preparation, melting, pouring, knockout and finishing operations. The melting process accounts for a major energy consumption in the foundry industry mostly in the form of thermal energy, which is met either from coke in cupolas or electricity in induction furnaces.

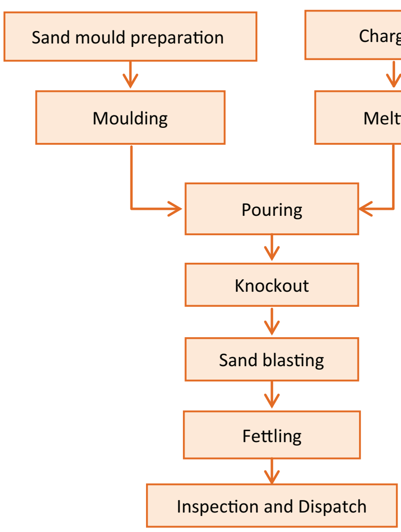

Figure 6.1 Process flow in foundry

Sand preparation

Green sand is prepared by mixing fresh sand and binders, such as bentonite, coal dust, water, and other additives in mixers.

Mould preparation

The mould flask comprises two halves, that is, cope (upper half) and drag (bottom half). The mould cavity is formed by packing sand around the pattern, which is a replica of the external shape of the desired casting. Moulds are prepared either manually or using moulding machines.

Melting

The charged material is melted either in cupola furnace or induction furnace. Depending upon product chemistry, charge batch is prepared comprising pig iron, metal scrap and foundry return, etc., which is charged using manual or mechanical system. The typical temperature of molten metal for grey iron is about 1400 °C and for steel grade is 1650 °C. The typical capacities of melting furnaces used in foundries is provided in Table 6.2. The molten metal is poured into sand moulds either manually or using semi/automatic pouring system.

Table 6.2: Furnace capacities in foundries

Type	Capacity
Cupola furnace	1.5-10.0 tonne/hr
Induction furnace	0.1-2 tonne/batch

Casting

The poured molten metal takes the shape of the mould. The cast product is sand blasted after demoulding and other downstream finishing processes.

6.1.3 Process equipment

The melting furnace, that is, cupola or induction furnace is the major energy consuming equipment in a foundry. The primary energy use in the furnace is thermal energy which is met through combustion of coke in cupola or use of electricity in induction furnace.

The industry shall improve the energy performance, that is, reduce specific energy consumption (SEC) level of the melting furnace by optimizing various operating parameters. These include reduction of various energy losses occurring in the furnace through routine inspection and maintenance and keeping key operating parameters within specified limits as prescribed by the original equipment manufacturers (OEMs). This section provides EC Guidelines covering best operating practices, operational aspects and performance assessment for furnaces used in foundry industries in a rational way.

Standards components	
1. Management and control	A. General The applicable common EC Guidelines for producing molten metal either using cupola furnace or induction furnace are provided below. a. Maintain correct temperature of molten metal as per requirements of the products. Avoid super-heating of metal to prevent energy loss. b. Keep the moulds ready before undertaking melting campaign. c. Use dry and clean raw materials for melting in furnaces. Construct a shed for raw material storage to avoid accumulation of moisture due to rains. d. Use preheated ladle to avoid metal chilling. e. Minimize the pouring distance between the furnace and pouring points. f. Use appropriate lining material and thickness. g. Avoid charging large size of raw material. The size shall be restricted to below 1/3rd of the internal diameter of cupola furnace to avoid bridging. h. Ensure optimum loading of the furnace. The low capacity utilization of the furnace shall lead to higher SEC level of the furnace. Ensure synchronization between raw material charging and pouring operation while matching with the melting capacity. Some of the practices that the industry shall follow will include charge material preparation, quantity of material, and availability of operational equipment/ system in downstream processes. B. The industry using cupola furnace shall ensure the following: a. Prepare bed with only natural draft and add coke in multiple installments which shall not be less than four equal installments. Add fresh coke only when previous material is ignited and flame is visible. On completion of bed preparation, consolidate the bed to achieve proper bed height with addition of coke, if required. b. Blowdown ash from the bed before bed consolidation. Restrict the use of blower to a minimum time (45 seconds). c. Maintain correct height of bed coke, which is about 900 mm (3 ft) above the centre line of top tuyeres. d. Use booster coke evenly, preferably on every 5th charge using additional 50% of charge coke. e. Switch on the blast immediately after the stack is filled after bed preparation to ensure trouble-free starting of melting operation. Such practices shall result in loss of melt initially due to chilling. f. Maintain full stack height filled with raw material by charging regularly to ensure their optimum preheating. g. Use coke of 3-6 inch size for bed preparation to avoid formation of initial chill metal and provide stability to bed. h. Maintain a charge coke height of about 200 mm (8 inch) in the cupola to maintain suitable temperature and obtain optimum melt rate. i. Use limestone of 1-2 inch size thick for effective de-slagging and reduced lining corrosion. Use limestone of calcium oxide (CaO) content of more than 45%. j. Maintain optimum air blast rate in cupola operation. Higher blast rate would lead to increased coke consumption apart from oxidation of metals. Low blast would result in lower metal temperature, slower melting, and higher coke consumption. k. Maintain appropriate blast pressure for penetration of blast air into coke bed. Incorrect air penetration affects melt temperature, carbon pick-up, and melting rate apart from burning of refractory lining. l. Install pressure gauge in a suitable location in the blastline of the cupola furnace for measurement of air pressure. m. Distribute blast air flow in a manner to feed 55% of blast to bottom tuyeres and 45% to top tuyeres using pre-set position of control valves.

	n. Provide sufficient number of vent holes of suitable size in bottom door for venting steam/ gas from sand bed. Such practices shall help to avoid failure of sand bed. o. Use either two number of 2 inch solid mild steel (MS) bar or 3 number of 1.5 inch bar for supporting bottom door. p. Ensure atleast 72 hours of ageing of patching mass to ensure adequate quality and plasticity. q. Use oxygen lancing as the safety option to open blocked metal tap hole. The oxygen lancing arrangement shall consist of an oxygen cylinder fitted with a regulator and lancing tube of mild steel (MS) pipe with 6 mm OD (outer diameter) and 2 mm ID (internal diameter) r. Ensure light green colour of slag with higher fluidity. s. Install proper slag dam for collecting hot slag generated during melting. C. The industry using induction furnace shall follow operating practices: a. Avoid charging of rusty raw material which would lead to increased time for melting and reduced metal content per charge. b. Use baled steel scrap and loose borings to a limited extent. c. Avoid over-filling and shall not charge the furnace beyond coil level. d. Maintain short and optimum charging time for raw materials and holding time for molten metal. e. Remove sand from foundry return (that is, runner and risers) using tum blast or shot blast operation. f. Follow proper sequence for charging of raw material in the furnace. For example, fill bigger size metal first followed by smaller size; fill the gaps with turnings and boring. g. Run the furnace at maximum power since beginning of the operation to minimize cycle time. h. Install dedicated energy meter for measuring electricity consumption in every batch. i. Ensure no voltage drop at source and maintain unity power factor during furnace operation. j. Use hydraulic lid mechanism during superheating of melt to reduce radiation heat losses. k. Deslag regularly using proper tools with flat head instead of rod or bar to eliminate building up of slag on furnace walls. l. Use suitable ladle size to minimize the return of liquid metal to the furnace. m. Ensure optimum loading of furnaces in case of multi-furnace operating simultaneously. n. Optimize the performance of the induction furnace by maintaining a well-laid production schedule.
2. Measurement and records	The industry shall measure and record the following: A. Common monitorable parameters for assessing the performance of furnace on daily basis. These parameters include energy consumption (charge coke, bed coke, booster coke, etc., for cupola furnace and electricity for induction furnace) and total metallic charge on a batch basis. B. Voltage, current and power factor for induction furnace on batch basis. C. Use appropriate system for measuring temperature of molten metal at regular intervals for cupola furnace and every batch for induction furnace. D. Temperature of cooling water for coil and panel cooling in induction furnance to assess the condition of the furnace refractory lining and the coil losses. The return temperature shall be maintained less than the design value of the respective models of the OEMs. E. Use suitable logsheet(s) for measurement and recording of common monitorable parameters. The frequency of measurement and recording shall be hourly, shift basis, daily, weekly or monthly, based on the type of data.

<table>
<tr><td>3. Maintenance and inspection</td><td>A. The industry using cupola furnace shall ensure the following:
a. Undertake proper lining or repair work of cupola as necessary after each melt operation while maintaining correct internal diameter of the cupola furnace.
b. Inspect burn-back or erosion of lining using a standard sliding stick gauge. Use patching material to repair erosion of less than 75 mm and high alumina refractory bricks for repairing more erosions.
c. Undertake periodical inspection of wind box to avoid air leakages. Ensure proper sealing of air tuyeres to avoid air leakages.
d. Undertake calibration and maintaintenance of instruments as per recommendations of suppliers to record reliable and accurate data. It shall maintain proper record of calibration and plans of next calibration for all key instruments.
B. The industry using induction furnace shall ensure the following:
a. Check and clean the panel as per the instructions provided by OEMs.
b. Carry out regular inspection of crucible lining and repair as required.
c. Check for hotspots in the melting system (furnace assembly, power supply, interconnecting bus bar, water-cooled leads, etc.) and take remedial action.
d. Undertake proper maintenance of water-cooled leads to avoid electrical losses.</td></tr>
<tr><td>4. Necessary measures when installing new facilities</td><td>The industry having cupola furnace shall do the following:
A. Install a mechanical charging system to eliminate error in manual charging and reduce drudgery of workers.
B. Provide a sand packing of 20–25 mm thick between shell and refractory brick lining for expansion clearance.
C. The industry using coke route shall install divided blast cupola (DBC) furnace of suitable design and capacity to achieve energy efficiency.
D. Explore duplexing using cupola for melting and induction furnace for superheating and alloying for metal chemistry.
E. Install blower having suitable capacity and correct air pressure. It shall avoid over-sized or under-sized blower.
F. Install blower close to the furnace to avoid transmission loss.
G. Optimize the shell height of cupola (about 16-22 ft) to reduce heat losses through exhaust flue gases.
H. Install necessary locking system fitted in fettling door which is used for initial ignition of bed coke. The locking system shall include two-tier mechanical wedge facility.

The industry having induction furnace shall do the following:
A. Install melt processor to control process parameters and reduce interruptions. Locate the spectro-testing lab near the melt shop for faster chemical analysis.
B. Use appropriate lining material, thickness and its sintering in the furnace. Thick lining reduces molten metal output and thin lining leads to more heat losses.
C. The industry using electricity route shall install energy efficient Insulated Gate Bipolar Transistor (IGBT)-type induction furnace of suitable capacity to achieve energy efficiency.</td></tr>
<tr><td colspan="2">Target components</td></tr>
<tr><td></td><td>The industry shall:
A. Maintain SEC level of induction furnace in the range of 550–650 kWh per tonne.
B. Maintain coke consumption in cupola furnace in the range 8%-10% of metal.</td></tr>
</table>

Notes:

1. Air blast rate

The air blast pressure for a cupola is provided below:

$P = 0.005\ D^2 - 0.0134\ D + 39.45$

where,

P = Blast pressure (inch of water column)

D = Internal diameter at the melting zone (inch)

2. Weight of coke bed

The weight of coke bed shall be calculated from the bulk density of coke. The industry shall build a dummy well having internal diameter equal to the cupola and height of 2 feet for this purpose. The coke shall be weighed and filled in the dummy well.

The bulk density of coke is calculated using the following formula:

$$\text{Bulk density} \left(\frac{kg}{m^3}\right) = \frac{\text{Weight of coke (kg)}}{\text{Volume of coke}(m^3)}$$

$$\text{Volume of coke } (m^3) = \frac{\pi \times D^2 \times H}{4}$$

where,

Pi (π) = 3.14

D = Diameter of dummy well (in metre)

H = Height of dummy well (in metre) (at least 0.61 metre)

6.1.4 Common monitorable parameters and performance assessment

The industry shall monitor, measure, and control all key operating parameters specific to the industry. It shall further undertake routine inspection and maintenance of furnace and associated equipment to ensure optimum performance. This section provides performance assessment of process furnace, that is, cupola furnace and induction furnace.

(1) Performance assessment of cupola furnaces

The industry shall measure common monitorable parameters as shown in Table 6.3 to assess the performance of cupola furnace.

The industry shall estimate the following indicators to evaluate the performance of cupola furnaces.

i) Charge coke to metal ratio

The charge coke to metal ratio shall be calculated using the following formula.

$$\text{Charge coke to metal ratio} = \frac{\text{Total coke charged including booster coke (kg)}}{\text{Total metal charged (kg)}}$$

ii) Total coke percentage

The total coke percentage shall be calculated using the following formula.

$$\text{Total coke percentage} = \frac{\text{(Total coke charged + Bed coke- Equivalent return coke) (kg)}}{\text{Total metal charged (kg)}}$$

iii) Melting rate

The melting rate shall be calculated using the following formula.

$$\text{Melting rate} = \frac{\text{Total metallics charged (tonne)}}{\text{Duration of melting campaign (hr)}}$$

where,

Melting campaign is equal to the duration of melting campaign (air blast-on to air blast-off period)

The industry shall refer to the typical performance indicators of cupola furnaces as provided in Table 6.4.

Table 6.4: Typical performance indicators for cupola furnaces

Performance indicator	Typical range
Ratio of total charge coke to metal in percentage	6.75%-8.00 %
Total coke consumption in percentage of metal	8%-10 %

Source: Based on data from different industries

(2) Performance assessment of induction furnace

The operating performance efficiency of the induction furnace can be established in direct method by comparing the operating SEC with rated or design values as provided by the manufacturer. The industry shall monitor common performance indicators as shown in Table 6.5 to assess the performance of induction furnace.

Table 6.3: Common monitorable parameters in cupola furnace

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Campaign duration*	hour	Clock	Batch-wise
Temperature of melt	°C	Pyrometer	Batch-wise
Quantity of total metallic charge	tonne	Electronic balance	Batch-wise
Quantity of total charge coke@	tonne	Electronic balance	Batch-wise
Quantity of bed coke	tonne	Electronic balance	Batch-wise
Quantity of return coke	tonne	Electronic balance	Batch-wise

* includes blast-on to blast-off

@ includes booster coke

Table 6.5: Common monitorable parameters in induction furnace

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Number of batches	-	-	Daily
Temperature of melt	^{0}C	Thermocouple	Batch-wise
Quantity of total metallic charge	tonne	Electronic balance	Batch-wise
Electricity consumption	kWh	Energy meter	Batch-wise

$$\text{Specific energy consumption}\left(\frac{\text{kWh}}{\text{tonne}}\right) = \frac{\text{Total power consumption (kWh)}}{\text{Total metal charged(tonne)}}$$

The industry shall refer to the typical performance indicators of induction furnaces as provided in Table 6.6.

Table 6.6: Typical performance indicators for induction furnaces

Performance indicator	Typical range
Specific energy consumption	550 – 650 kWh per tonne

Source: Based on data from different industries

6.1.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall use consistent quality of raw materials for producing melt. The output of the furnace, that is, useful melt available is directly proportional to the purity of raw materials. The quantity of fluxing agent is dependent on the level of impurities present in raw materials and coke. Higher level of slag formation indicates more impurities present in raw materials and more fluxing agents are required.
2. The industry shall remove sand and other impurities from plant returns to minimize slag formation.
3. The industry shall reduce spillage while pouring melt into moulds. Spillage reduces productivity of the industry.
4. The industry shall make efforts to maximize sand reclamation while removing castings from sand moulds.
5. The industry shall recover and reuse runner and risers from castings at the maximum possible temperature to reduce energy consumption.
6. The industry shall undertake periodical repair insulation of ladles used for pouring of melt.
7. The industry using induction furnace shall ensure proper temperatures of cooling water and optimum heat transfer for coil cooling.
8. The industry shall use appropriate tools in finishing operations to improve product quality and reduce rejections.

FORGING

6.2 Forging industry

6.2.1 Background

The forging industry is one of the energy intensive industries in the micro, small and medium enterprise (MSME) sector. It uses mostly manual processes. Forging is usually followed by heat treatment and machining, which are done either in-house or outsourced. Automobile sector is one of the the major end-users of forging industry. Other end-users include industrial machinery, power, construction & mining equipment, railways and general engineering. The major raw materials used in forging industry are mild steel, carbon steel, alloy steel, stainless steel, aluminium, super alloy and special steel, etc. depending on the type of application.

6.2.2 Production process

Forging is a metal deformation process at forging temperature. It is performed either in presses or hammers. The primary shaping of the product is done in dies using one of the following process namely, open die, closed die or impression, and ring forging. The major process steps involved in forging process include die-making and setting, raw material preparation, heating, forging, trimming and finishing (Figure 6.2).

Die making and setting

Based on the shape and specifications of final product, impressions are created in a steel tool die either in in-house tool room or outsourced. Corresponding die is installed in the hammer or press for shaping.

Raw material preparation

The raw material received in the shape of rod, bar, billet, etc., undergoes physical inspection and chemical testing before routed for shearing operation.

Heating

The sized material is heated to about 1150°C-1250°C using fossil-fuel fired or induction furnace. The

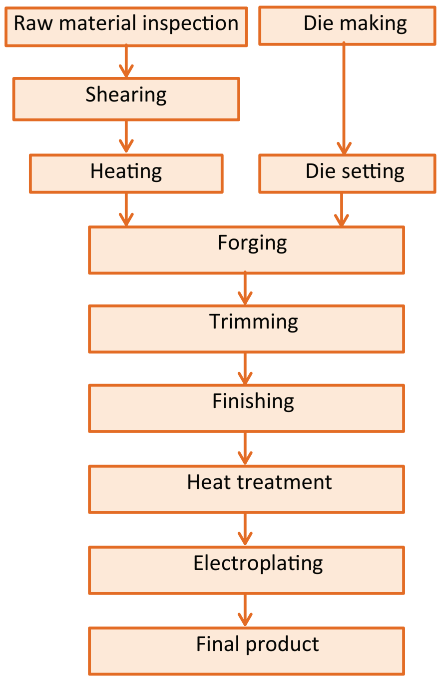

Figure 6.2 Process flow in forging industry

capacities of these furnaces depends on production capacities of individual industry (Table 6.7).

Table 6.7: Capacities of process furnaces

Type	Fuel used	Capacity
Forging furnace	Oil, natural gas	50-400 kg/hr
Induction furnace	Electricity	100-500 kg/hr

Forging

The shaping of heated material is done in a single or multiple stroke using a press or hammer. Impression die forging is used for simple shape and uses a single press stroke. Most of the forging processes require multiple dies of different impressions for sequential forging operation. In sequential forging using hammers, first stroke is edging which increases the cross-section of the work piece. The second stroke is blocking to refine the shape for finish forging. The final stroke to finish-forging to complete the shape. In finish-forging, bulk of metal is forced into the impression while a thin layer called flash, flowing out between the dies at the parting plane.

Trimming. The unwanted material in the forged product is removed either manually or with trimming dies.

Finishing. It includes fettling, shot blasting, cleaning, and machining of the forged product. Based on requirements, the forged products are subjected to heat treatment and electroplating.

6.2.3 Process equipment

In forging industry, thermal energy accounts for a major share of total energy consumption, which takes place either in fuel-fired furnace or electrical heating induction furnace.

1) Fuel-fired furnaces

The industry shall improve the energy performance of the furnace, that is, reduce specific energy consumption (SEC) level by optimizing various operating parameters. These include reduction of various heat losses, such as flue gas loss, structural heat loss, etc., occurring in the furnace through routine inspection and maintenance and keeping key operating parameters within specified limits as prescribed by the original equipment manufacturers (OEMs). This section provides EC Guidelines covering best operating practices, operational aspects and performance assessment for fuel-fired furnaces used in forging industries in a rational way.

Standards components	
1. Management and control	The industry shall undertake the following: A. Process temperature a. Maintain temperature of furnace as per process requirements. Do not overheat or underheat the products to ensure optimum energy performance. b. Use sufficient number of temperature indicators, for example, walls and roof to ascertain temperature gradient across the furnace. B. Air ratio a. Maintain correct air ratio based on type of fuel(s) used to minimize heat losses. Adjust and control air ratio based on variations in fuel consumption rate to maintain required furnace temperatures. Set the air ratio in such a way to ensure complete combustion without high excess air. b. Use suitable oxygen (O_2) analyser (on-line or portable type) to monitor and maintain air ratio within prescribed limits as provided in Table 6.8 as standard values. c. Integrate combustion air supply with combustion equipment for automatic regulation of air flow while considering real-time plant load and operating conditions. d. Install blower having suitable capacity and correct air pressure. Avoid use of over-sized or under-sized blower. Install the blower close to the furnace to avoid transmission loss. e. Minimize heat losses through air ingression by adopting suitable measures, such as minimizing size of opening, proper sealing of furnace, etc. f. Maintain slight positive pressure in the furnace. C. Flue gas temperature a. Reduce exhaust flue gas temperature by installing suitable waste heat recovery (WHR) system and maintain flue gas temperature as specified in Table 6.9 as standard value. Use suitable design of WHR system(s) based on waste heat available and type of application. b. Monitor temperature of exhaust gases and WHR media using online or portable instruments.

	D. Surface temperature a. Maintain external surface temperature within the range as provided in Table 6.10 as standard value. b. Provide suitable thermal insulation of the furnace based on operating temperature. These measures include use of appropriate thickness of insulation, low thermal conductivity of insulating materials, veneering of internal surfaces, etc. E. Ensure proper pre-heating of furnace oil about 100 °C to reduce the viscosity level. F. In case of batch type furnace, close all the furnace openings after the operation to retain residual heat in the furnace and reduce cold start duration. Undertake precautionary measures, such as removal of burners and place them outside to ensure safety. G. Placement of burner a. Place burners in a manner to ensure even distribution of heat across the furnace. b. In small furnaces, ensure that the axis of the burner is not parallel to the hearth, but always at an upward angle. H. Monitor the flame length and control regularly to ensure the following: a. The flame does not touch any solid object under heating to avoid scaling of product surfaces. b. The flame does not impinge on the refractory roof which shall lead to increased maintenance and reduced life of furnace. c. The flame length is restricted to avoid direct entry into the chimney or exit through the furnace openings, which would otherwise increase energy loss. I. Ensure proper damper setting to maintain positive draft and avoid cold air ingress to the furnace. J. Use online measurement and recording equipment to monitor and control key operating parameters. K. Use instruments with better resolution to ensure accurate measurements. L. Ensure adequate loading for optimum capacity utilization of the furnace. The low capacity utilization of the furnace will result in increased SEC level. M. Ensure synchronization between raw material heating and forging operation. Some of the practices include raw material preparation, correct quantity of raw material, correct residence time and availability of press/ hammer in downstream processes.
2. Measurement and recording	The industry shall measure and record the following: A. All common monitorable parameters on daily basis for evaluating the performance of the furnace. These parameters include fuel(s) consumption, production, furnace temperature, temperature of exhaust gases, preheat temperature, residual oxygen (O_2) and carbon monoxide (CO) in flue gases, furnace pressure, etc. B. Temperatures of skin surfaces on quarterly basis to undertake remedial action. C. Use suitable logsheet(s) for measurement and recording of key operating paramaters. The logsheets would help the industry in: (1) assessing energy performance of the furnace and (2) identifying deviations in operating parameters to undertake corrective measures.
3. Maintenance and inspection	The industry shall undertake the following: A. Clean and maintain the WHR systems on or before 20% reduction in pre-heat temperature to ensure optimum performance. B. Check the condition of furnace surface insulation on half-yearly basis and undertake required maintenance. C. Calibrate instruments as per recommendations of suppliers to record reliable and accurate data. Maintain proper record of calibration and plans for all key instruments.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Select furnace with specifications compatible to application, fuel type, load fluctuations, etc. B. Select appropriate combustion equipment and accessories, for example, burner with high turndown ratio to suit part load in intermittent furnace, built-in furnace automation system, WHR, etc.

Target components	
	The industry shall consider the following: A. Maintain air ratio as specified in Table 6.8 as target value. B. Ensure exhaust flue gas temperatures in the range provided in Table 6.9 as target value. C. Maintain skin temperature of the furnace as specified in Table 6.10 as target value.

* *Note:*

1. The waste heat recovery rate is the ratio of heat recovered to the sensible heat available in exhaust gases under rated load operation.
2. An air-preater (APH) is a device used to preheat the combustion air at ambient temperatures to higher levels by extracting waste heat from flue gases.

Table 6.8: Air ratio for furnaces in forging industry[&]

Parameter	Furnace type	Air ratio[@]	
		Liquid fuel	Gas fuel[#]
Standard	Forging furnace	1.18-1.23	1.14-1.17
	Heat treatment furnace[*]	1.18-1.23	1.14-1.17
Target	Forging furnace	1.15-1.20	1.12-1.15
	Heat treatment furnace[*]	1.15-1.20	1.12-1.15

Source: Performance data from different industries

& Except box furnace

* Include normalizing, annealing, hardening, tempering and carburizing furnaces

\# Refers to natural gas (NG) only

@ Air Ratio is defined as the ratio of actual air supplied (AAS) to the theoretical air requirement. The air ratio is considered based on steady-state operations at constant load conditions. It can be measured and verified at specific measurement points while maintaining maximum permissible limit for carbon monoxide (CO) level to 200 ppm. The air ratio shall be estimated using the following formula.

$$\text{Air ratio} = \frac{21}{21 - \%\text{ oxygen in flue gases}}$$

Table 6.10: Surface temperatures of fuel-fired furnaces

Parameter	Furnace type	Surface temperature (°C)[#]	
		Ceiling	Side wall
Standard	Forging furnace	120	100
	Heat treatment furnace	100	90
Target	Forging furnace	110	85
	Heat treatment furnace	90	75

Source: Based on data from different industries

\# Average skin temperature under steady state operation

Table 6.11: Surface temperatures of induction heating furnaces

Furnace type	Skin temperature (°C)[#]	
	Standard	Target
Electric furnance	90	70

Source: Based on data from different industries

\# Average skin temperature under steady state operation

Table 6.9: Exit flue gas temperature in forging furnaces

Furnace type	Exhaust gas temperature (°C)	Waste heat recovery rate (%)		Flue gas temperature[*] (°C)
		Standard[α]	Target[β]	
Forging furnace	600-1000	30	49	250-300
Heat treatment furnace	Upto 600	30	38	250-300

Source: Based on data from different industries

α Estimated heat drop based on the upper limit of gas temperatures and net heat transfer with 60% efficiency for heat exchanger

β Estimated heat drop based on the lower limit of gas temperatures and net heat transfer with 65% efficiency for heat exchanger

* Considering natural draft systems for higher flue gas temperature and induced draft system for lower temperatures

The industry shall compute waste heat recovery (WHR) rate using the following formula.

$$\text{Waste heat recovery rate (\%)} = \frac{\text{Recovered heat (kcal)}}{\text{Sensible heat in exhaust gases (kcal)}} \times 100$$

2) Induction heating furnace

The industry shall improve the energy performance of the furnace, that is, reduce specific energy consumption (SEC) level by optimizing various operating parameters. These include reduction of various energy losses occurring in the furnace through routine inspection and maintenance and keeping key operating parameters within specified limits as prescribed by the OEMs. This section provides EC Guidelines covering best operating practices, operational aspects and performance assessment for induction furnaces used in forging industries in a rational way.

Standards components	
1. Management and control	The industry shall ensure the following: A. Reduce distribution losses in electrical wiring in induction heating furnace. The measures include shorter cable lengths, proper current carrying capacity of conductors, and minimum voltage imbalance. B. Install suitable phase-protection relay/ single phasing preventer to avoid burn outs of distribution lines. C. Manage and control current flow to induction furnace to minimize electrical losses. D. Install dedicated energy meter for measuring electricity consumption in every batch. E. Reduce heat losses from the furnace surfaces to maintain external surface temperature based on the standard value as provided in Table 6.11. The measures include higher thickness of insulation, selecting low thermal conductivity insulating materials, veneering as applicable on internal surfaces, etc. F. Reduce heat losses through radiation and air ingression by adopting suitable measures, such as minimum openings, proper sealing, etc. G. Use automatic control systems to ensure effective use of electricity. H. Ensure optimum loading of induction furnace.
2. Measurement and recording	The industry shall measure and record the following: A. Key parameters such as electricity consumption, production and furnace temperature on daily basis using online or portable instruments for evaluating the performance of the furnace. B. Electricity consumption, voltage, current, and power factor for induction furnace on batch basis. C. Skin temperatures of the furnace on monthly basis to take remedial measures for reducing heat losses.
3. Maintenance and inspection	The industry shall undertake the following: A. Check proper tightness of electrical cables connecting the furnace to avoid any arcing and short circuit on quarterly basis. B. Inspect insulation of the furnace on quarterly basis and provide suitable insulation to reduce heat losses according to the instructions concerning maintenance and inspection provided by OEM. C. Undertake preventive maintenance and routine inspection of electrical induction furnace, including repair of internal surface erosion.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Select induction furnaces with built-in automation to control furnace temperature.
Target components	
	The industry shall ensure the following: A. Specific energy consumption of 70–100 litre per tonne in fuel-fired forging furnaces. B. Specific energy consumption of 400–600 kWh per tonne in induction type forging furnaces. C. Maintain external surface temperature based on the target value as provided in Table 6.11.

6.2.4 Common monitorable parameters and performance assessment

The industry shall monitor common performance indicators as shown in Table 6.12 to assess the performance of fuel-fired furnaces.

The specific energy consumption (SEC) of fuel-fired forging furnace shall be evaluated using the following formula to assess its performance.

$$\text{Specific energy consumption (kcal/tonne)} = \frac{\text{Total energy consumption (kcal/day)}}{\text{Quantity of material processed (tpd)}}$$

Total energy consumption (kcal/day)

= Fuel consumption (kg/day) × Calorific value (kcal/kg)

2) Performance assessment of induction heating furnaces

The industry shall monitor common performance indicators as shown in Table 6.13 to assess the performance of induction heating furnaces.

Specific energy consumption

The industry shall evaluate the SEC of the induction heating furnace using the following formula to assess the performance.

$$\text{Specific energy consumption (kWh/tonne)} = \frac{\text{Total energy consumption (kWh/day)}}{\text{Quantity of material processed (tpd)}}$$

The industry shall refer to the typical performance indicators of forging furnaces as provided in Table 6.14.

Table 6.14: Typical performance indicators for forging furnaces

Performance indicator	Specific energy consumption
Fuel-fired furnace	70-100 litre per tonne
Induction furnace	400-600 kWh per tonne

Source: http://www.indiasavesenergy.in/Uploads/Documents/635955349367237369.pdf

6.2.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall use consistent quality of raw materials to reduce rejections from the process.
2. The industry shall use appropriate temperatures in heat treatment processes to reduce rejections.
3. The industry shall use appropriate tools in finishing operations to improve product quality and reduce rejections.
4. The industry shall use suitable material handling and transport system for easy handling of materials to reduce processing time and fatigue.
5. The industry shall arrest leakages from compressed air lines to reduce power consumption.
6. The industry shall use compressed air only at required pressure to optimize energy consumption. Use of compressed air at high pressures would increase energy consumption.
7. The industry shall use air guns in place of compressed air for requirements of air at low pressures.

Table 6.12: Common monitorable parameters in fuel-fired furnaces

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Furnace temperature	°C	Thermocouple	Daily
Air ratio	kg/kg fuel	Flue gas analyzer	Daily
Flue gas temperature	°C	Thermocouple	Daily
Surface temperature	°C	Infrared thermometer	Quarterly
Fuel consumption	litre	Flowmeter	Daily
Quantity of raw material processed	tonne	Electronic balance	Daily

Table 6.13: Common monitorable parameters in induction heating furnace

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Furnace temperature	°C	Thermocouple	Daily
Quantity of material processed	tpd	Electronic balance	Daily
Surface temperature	°C	Thermocouple	Quarterly
Electricity consumption	kWh	Energy meter	Daily

SPONGE IRON

6.3 Sponge iron industry

6.3.1 Background

The sponge iron industry is one of the energy intensive industries in the micro, small and medium enterprise (MSME) sector. Sponge iron or direct reduced iron (DRI) is used as the main raw material in secondary steel-making processes, such as electric arc furnace (EAF) and induction furnace (IF). It is used as a substitute to scrap in secondary steel making. Sponge iron production predominantly involves thermal energy.

6.3.2 Production process

The sponge iron manufacturing involves reducing of iron ore using coal or natural gas in a rotary kiln. The DRI produced from gas based process requires immediate conversion into blocks of Hot Briquetted Iron (HBI) for longer shelf life. The major processes involved in the production of sponge iron are as follows.

Reduction of iron ore to sponge iron: The raw materials comprising iron ore and coal/ gas, fed from one end of the inclined rotary kiln move along the length.

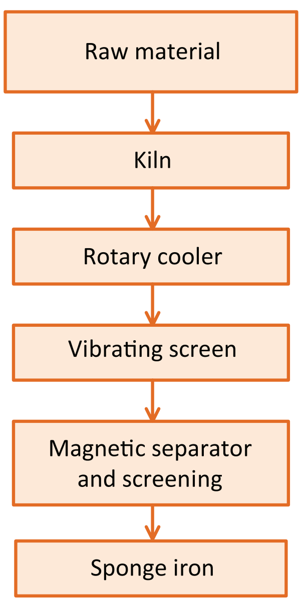

Figure 6.3 Sponge iron production process

Initially the moisture is removed from the material, which is gradually heated up by the hot gases flowing in the counter direction. In the reduction zone of the kiln, the oxygen in iron ore is removed, forming carbon monoxide (CO) leaving the metallic iron. A temperature of about 950 °C-1050 °C is maintained in the kiln. Higher the temperature, faster would be the oxygen removal. The critical factor in the reduction of iron is formation of carbon monoxide through controlled combustion of fuel. The optimum batch cycle for the process is 10-12 hours. The level of metalization depends on density of sponge iron and the metallic luster.

Cooling of sponge iron. After metallic formation, the sponge iron and residual charge are transferred to a rotary cooler through a belt conveyor at about 250 °C, above which the sponge iron would tend to re-oxidise combining with oxygen in ambient air. The sponge iron is cooled down to about 100 °C through indirect cooling in rotary cooler.

Electro magnetic separation and screening. The discharge from the rotary cooler is passed through an electro magnetic separator, wherein sponge iron is separated from char and other impurities. It is screened in size fraction to separate lumps and fines for storage and dispatch.

6.3.3 Process equipment

The rotary kiln is the major energy-consuming equipment in a sponge iron industry. The industry shall improve the energy performance of the kiln by optimizing various operating parameters. These include reduction of various heat losses occurring in the furnace through routine inspection and maintenance and keeping key operating parameters within specified limits as prescribed by the OEMs. This section provides EC Guidelines covering best operating practices, operational aspects, performance assessment and typical performance indicators for rotary kiln used in sponge iron industry in a rational way.

Standards components	
1. Management and control	The industry shall undertake the following: A. Maintain following raw material size for feeding in the kiln-iron ore of 5 to 18 mm; dolomite of 4 to 8 mm and coal maximum upto 18 mm. B. Maintain a temperature of first preheating zone in the range of 900 °C-1000 °C and the metallization zone in the range of 1000 °C-1050 °C. C. Maintain appropriate air supply with adequate pressure as recommended by the OEM in submerged air system of the kiln. D. Monitor temperature of exhaust gases and waste heat recovery (WHR) media using online or portable instrument. E. Reduce the exhaust flue gas temperature based on WHR recovery rate* as specified in Table 6.15 as standard value. Install suitable WHR system(s) such as charge preheater (CPH)* for iron ore based on the waste heat available. F. Manage the damper position as per kiln requirements. G. Maintain optimum carbon monoxide level to produce optimum level of sponge iron. H. Maintain external temperature of the kiln within the range as specified in Table 6.16 as standard value. Undertake thermal insulation work other than product cooling section of the kiln. These include use of suitable thickness of insulation, low thermal conductivity insulating materials, heat resistant paints, etc. I. Use dry and clean raw materials and provide shed for raw material storage to avoid accumulation of moisture due to rains. J. Ensure adequate loading of the kiln for optimum capacity utilization.
2. Measurement and records	The industry shall measure and record the following: A. Key operating parameters such as quantity of raw materials charged, sponge iron yield, fuel consumption and temperature of preheating zone and metallization zone on daily basis. B. Size of iron ore, dolomite, and coal on daily basis. C. Ensure better resolution of measuring instruments for accurate measurements. D. Use suitable logsheet(s) for measurement and recording of common monitorable parameters as applicable.
3. Maintenance and inspection	The industry shall undertake the following: A. Clean and maintain the WHR systems on or before 20% reduction in pre heat temperature to ensure optimum performance. B. Check the condition of furnace lining on half-yearly basis and undertake required maintenance. C. Calibrate instruments as per recommendations of suppliers to record reliable and accurate data. Maintain proper record of calibration and plans for all key instrumentation.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Use fluidized bed gasification system to utilize reject coal dust and char for either generating hot air for moisture removal in raw materials or power generation through micro turbine. B. Use high temperature flue gases from the kiln for generating steam through waste heat recovery boiler for power generation.
Target components	
	The industry shall ensure the following: A. Specific energy consumption of sponge iron production in the range of 0.64–0.82 toe per tonne. B. Maintain dolomite size of 4-8 mm. C. Ensure exhaust flue gas temperatures in the range of 100 °C-150 °C. D. Maintain skin temperature of the furnace in the range of 70 °C-90 °C.

* Note:

1. Waste heat recovery rate is the ratio of heat recovered to the sensible heat available in exhaust gases under rated load operation.
2. Charge preheater shall be used to preheat raw material such as iron ore.

Table 6.15: Waste heat recovery from rotary kiln in sponge industry

Furnace type	Exhaust gas temperature (°C)	Waste heat recovery rate (%)		Flue gas temperature* (°C)
		Standard[α]	Target[β]	
Rotary kiln	850-900	49	58	100-150

Source: Based on data from different industries

α Estimated heat drop based on the upper limit of gas temperatures and net heat transfer with 60% efficiency for heat exchanger

β Estimated heat drop based on the lower limit of gas temperatures and net heat transfer with 65% efficiency for heat exchanger

* Considering natural draft systems for higher flue gas temperature and induced draft system for lower temperatures

The industry shall compute waste heat recovery rate using the following formula.

$$\text{Waste heat recovery rate (\%)} = \frac{\text{Recovered heat (kcal)}}{\text{Sensible heat in exhaust gases (kcal)}} \times 100$$

Table 6.16: Surface temperatures of kiln

Furnace type	Skin temperature (°C)#	
	Standard	Target
Electric furnace	90	70

Source: Based on data from different industries

Average skin temperature under steady state operation

6.3.4 Common monitorable parameters and performance assessment

The industry shall monitor, measure, and control all key operating parameters specific to the industry. It shall further undertake routine inspection and maintenance of the furnace and associated equipment to ensure optimum performance. This sections provides performance assessment of the rotary kiln. The operating performance efficiency of the kiln shall be established by comparing the operating SEC with rated or design values as provided by the manufacturer. The industry shall monitor common performance indicators as shown in Table 6.17 to assess the performance of the kilns.

Table 6.17: Common monitorable parameters in rotary kiln

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Quantity of iron ore	tonne	Electronic balance	Daily
Fuel consumption	unit*	Electronic balance/Flow meter	Daily
Furnace temperature	°C	Thermocouple	Hourly
Flue gas temperature	°C	Thermocouple	Daily
Temperarature of preheated charge	°C	Thermocouple	Daily
Surface temperature	°C	Infrared thermometer	Quarterly

* coal measured in tonne; natural gas measured in Sm^3

$$\text{Specific energy consumption (kcal/kg)} = \frac{\text{Energy consumption (kcal)}}{\text{Sponge iron formed(kg)}}$$

Energy consumption (kcal) = Fuel consumption (tonne) × Gross calorific value (kcal/tonne)

Where,

Fuel consumption in tonne for coal and Sm^3 for natural gas,

Gross calorific value in kcal per tonne for coal and kcal per Sm^3 for natural gas

The industry shall refer to the typical performance indicators of sponge iron production as provided in Table 6.18.

Table 6.18: Typical performance indicators for sponge iron production

Performance indicator	Typical range
Specific energy consumption	0.64-0.82 toe per tonne

Source: Based on data from different industries

6.3.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall use consistent quality of raw materials to improve yield.
2. The industry shall minimize time delay in converting DRI produced from gas-based kiln to HBI blocks for longer shelf life.
3. The industry shall use coal of appropriate quality.
4. The industry shall use covered coal storage to minimize moisture pickup and improve injectability.
5. The industry shall recover and recycle dolo-char and coal ash upto ± 3 mm size.
6. The industry shall use appropriate tools in finishing operations to improve product quality and reduce rejections.

ALUMINIUM

6.4 Aluminium industry

6.4.1 Background

The aluminium industry is one of the energy intensive industries covered under micro, small and medium enterprise (MSME) sector. The aluminium industry produces a variety of products, such as utensil, pressure-die casts, extruded products, etc. The raw materials used by aluminium industry in the MSME sector include used aluminium and assorted scraps. The products manufactured vary greatly in terms of size, weight, and thickness. Some of the products manufactured in aluminium industry are provided in Table 6.19.

Table 6.19: Products from aluminium industries

Type	Products
Building hardware	Door & window hinges, stoppers, knobs, studs, handles
Sanitary & bathroom fittings	Venetian blinds, hangers, taps, curtain, fittings
Industry	Industrial control valves, & cycle tube valves in automobile engine cylinder, piston, crank shaft, valves, etc.
Decorative and artisan products	Plate, cups, lamp, bells
Others	Precision machine components

6.4.2 Production process

The major process steps in aluminium industry include melting, forming/shaping, annealing, and finishing. The finishing operation includes turning, milling, grinding, drawing, boring, threading, etc. Extrusion, pressure die-casting and pressmode of shaping are commonly used in the shaping process.

1) **Aluminium extrusion**

Aluminium scraps are melted at about 660 °C in oil fired bulk melting furnace.The melt is poured for billet casting. The hot billets are sized on saw table to smaller sizes to desired length for further processing. Cut billets are heated prior to forming of the slab in the extruder. The temperature of the slab is critical for shaping the slab through extrusion die. It is done through heavy press forming machines. The extrusion process is performed in either of two methods, namely, (1) direct extrusion, in which the moving ram forces the billet through a stationary die, and (2) indirect extrusion, in which the die assembly pushes against the stationary slab. The extruded products are annealed, inspected, and packaged as final products for onward marketing (Figure 6.4.).

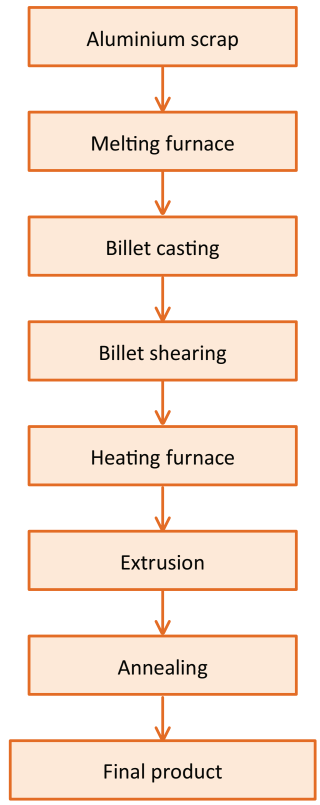

Figure 6.4 Extrusion process

2) **Aluminium pressure die-casting**

In pressure die-casting units (Figure 6.5), electric resistance furnaces are used for melting and holding of aluminium melt. In large capacity industries, oil-fired bulk melting furnace are used for melting while holding is done in resistance-type

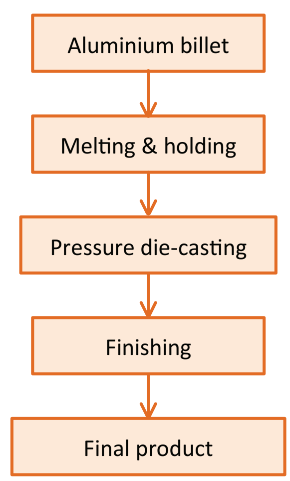

Figure 6.5 Pressure die casting

furnaces. The melt is taken out in transfer ladle and shifted to holding furnace, which is either manually or automatically poured in pressure die-casting machines. The size of scooping ladle varies with the type of castings. The runners and risers are removed from castings. The castings are sent to various finishing operations.

3) **Aluminium utensil manufacturing**

The utensil manufacturing comprises melting of aluminium ingots and scrap in a furnace (electrical/fuel fired) followed by slab casting (Figure 6.6). The hot slabs are sized to smaller sizes on a saw table. The sized slabs are converted to flat sheets through hot rolling process. The sheets are cold rolled to further reduce the thickness to the desired level. After dressing the rough edges, the sheets are made into circular shape after which annealing is done to relieve the stresses. This is followed by press forming in heavy press machines to provide desired shape of utensils. In the forming process, spinning operation is critical in utensils such as buckets, tubs, etc., which requires high degree of skill. The uneven edges are removed in turning wheel. The extra edge is cut to size and the buffing operation removes outer and inner layers on the surface. The utensil is dipped in water and chemicals in three stages to remove minor particles and provide natural shining.

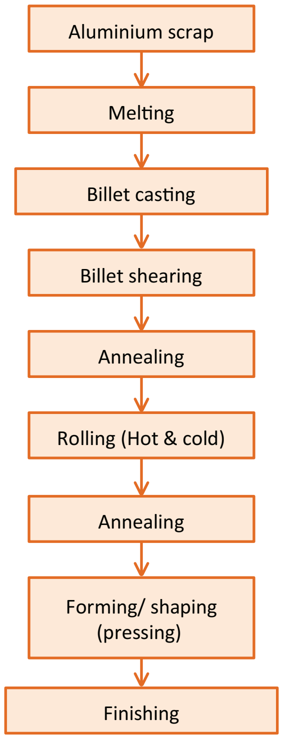

Figure 6.6 Utensil manufacturing

The capacity of furnaces used in aluminium industries are provided with Table 6.20.

Table 6.20: Capacities of aluminium melting furnaces

Type	Capacity
Bulk melting furnace (oil-fired)	Above 500 kg
Electric furnace (induction/ resistive)	80-1500 kg per batch
Pit furnace	600-900 kg per batch

6.4.3 Process equipment

The melting furnace in the aluminium industry is the major energy consuming equipment. The primary energy use in the furnace is thermal energy which is met through electricity or combustion of fuels (coal, coke, furnace oil, diesel, etc.). The industry shall improve the energy performance, that is, reduce specific energy consumption (SEC) level of the melting furnace by optimizing various operating parameters. These include reduction of various heat losses occurring in the furnace through routine inspection and maintenance and keeping key operating parameters within specified limits. This section provides EC Guidelines covering best operating practices, operational aspects, and performance assessment for furnaces used in aluminium industry in a rational way.

Standards components	
1. Management and control	General A. The industry shall undertake the following common EC Guidelines for producing aluminium melt either using fuel-fired furnace or electrical furnace: a. Install suitable weighing system for monitoring and controlling of raw materials. b. Maintain furnace temperature as required to produce liquid metal which is about 660 °C. Avoid super-heating of metal to prevent energy and dross losses. Use suitable temperature indicators to monitor the temperature of melt. c. Maintain dross losses in the range of 2%-4%. d. Maintain external temperature of furnace surfaces within the range as specified in Table 6.21 as standard value. Thick lining reduces melting capacity and thin lining leads to increased heat losses. e. Use preheated ladles for transfer of liquid metal. f. Minimize ladle transportation distance to avoid temperature loss of molten metal. g. Ensure that the quantity of liquid metal returned with transfer ladle is as low as possible. h. Provide adequate insulation of transfer ladle. i. Use dry and clean charge material. j. Ensure adequate loading of furnace for optimum capacity utilization. The low capacity utilization of the furnace shall lead to higher SEC or poor energy performance of the furnace. The loading of a furnace is dependant on quantity of charge material, residence time, and availability of operational equipment/ system in downstream processes. B. Fuel-fired furnaces (bulk melting and pit furnaces) a. The industry shall undertake the following practices in fuel-fired furnaces: b. Install a stack of suitable height for routing the exhaust flue gases instead of venting at workplace. c. Maintain correct air ratio in the furnace as specified as standard value in Table 6.22. Use suitable oxygen (O_2) analyser (online or portable type) to monitor the air ratio. Adjust and control air ratio based on variations in fuel consumption rate to maintain required furnace temperature. Set the air flow in such a manner to avoid high excess air but ensure complete combustion of fuel. d. Install blower having suitable capacity and correct air pressure. Avoid over-sized or under-sized blower. Further, to install blower close to the furnace to avoid transmission loss. e. Reduce the exhaust flue gas temperature based on WHR recovery rate* specified in Table 6.23 as standard value. Install suitable WHR system(s), such as air preheater*, charge preheater*, etc., based on waste heat available and the type of application. C. Electrical furnace (Induction and resistive furnaces) The industry shall undertake the following practices in electrical furnaces: a. Maintain short and optimum holding time for molten metal. b. Use dedicated energy meter for measuring electricity consumption. c. Avoid charging of contaminated raw material which would lead to increased time for melting and reduced liquid metal yield. d. Avoid using large size scarp for more than 1/3rd the diameter of furnace crucible to avoid bridging slag formed.

	e. Avoid over-filling and restrict filling to the coil level in the induction furnace. f. Follow proper sequence for charging of raw material in induction furnace. For example, first fill bigger size metal followed by smaller size; fill the gaps with turnings and boring. g. Operate the furnace at maximum power rating since beginning of the operation to minimize cycle time. h. Ensure no voltage drop at source and maintain power factor close to unity during furnace operation. i. Cover resistive furnace crucible with charge material to reduce surface losses and preheat the charge material. j. Add suitable type and quantity of flux material to remove the slag formed. k. Continue furnace heating at the minimum power rating at the end of shift/ batch to avoid thermal shock to coils and refractories which will increase maintenance and reduce furnace life. This will also ensure quick start up after shutdown. l. Use suitable lid mechanism during superheating of melt to reduce radiation heat losses. m. Install melt processor in induction furnaces to control process parameters and reduce interruptions. n. Deslag regularly using proper tools with flat head instead of rod or bar to eliminate building up of slag on furnace walls. Use of flat head would eliminate damage to refractory lining. o. Monitor temperature of cooling water used for coil cooling and panel cooling to assess the condition of the furnace refractory lining and the coil losses. p. Ensure optimum loading of furnaces in case of multi-furnace operation.
2. Measurement and records	The industry shall measure and record the following: A. Common monitorable parameters, such as temperature of liquid metal, quantity of charge material, final products, in-house returns and dross losses on daily basis. B. Fuel/ electricity consumption as applicable on daily basis. C. Use dedicated energy meter for electrical furnaces for measuring electricity consumption. D. Temperature of exhaust gases, preheat temperatures, residual oxygen (O_2) and carbon monoxide (CO) in flue gases, etc., for fuel-fired furnaces. E. Use suitable online or portable temperature indicators to indicate real time liquid metal temperature. F. Use suitable logsheet(s) for measurement and recording of common monitorable parameters as applicable. G. Ensure better resolution of measuring instruments for accurate measurements.
3. Maintenance and inspection	The industry shall undertake the following: A. Undertake proper lining or repair work of the furnace as required. B. For bulk melting furnaces, repair, renovate and maintain the WHR systems on a periodical basis to avoid scale formation and ensure optimum performance. C. Undertake infrared/ thermal scans of induction furnace assembly, power supply, interconnecting bus bar, water-cooled leads, etc., once in six months towards identification of hot spots and undertake remedial actions. D. In batch operation of electric furnace, clean the crucible surface before start up. E. Undertake calibration and maintenance of instruments as per recommendations of suppliers to record reliable and accurate data. Maintain proper record of calibration and calibration plans for all key instruments.

4. Necessary measures when installing new facilities	The industry shall consider the following: A. Install mechanical charging system for continuous melting furnace to ensure smooth and continuous charging operation. B. Optimize ladle size to avoid return of liquid metal back to the furnace. C. Install energy-efficient furnace (for example, insulated gate bipolar transistor (IGBT) furnace in case of electrical route) along with built-in automation. In case of fuel-fired furnace, install WHR system for maximum heat recovery.
Target components	
	The industry shall ensure the following: A. Restrict dross losses below 2%. B. Specific energy consumption of 120-200 litre per tonne in fuel-fired furnaces. C. Specific energy consumption of 400-600 kWh per tonne in electrical furnaces. D. Maintain external surface temperature based on the target value as provided in Table 6.21. E. Maintain air ratio of fuel fired furnaces based on the target value as provided in Table 6.22. F. Ensure exit flue gas temperature in the range as provided in Table 6.23 as target value.

* Note:

1. Waste heat recovery rate is the ratio of heat recovered to the sensible heat available in exhaust gases under rated load operation.
2. Air-preater (APH) is a device used to preheat the combustion air at ambient temperatures to higher levels by extracting waste heat from flue gases.
3. Charge preheater (CPH) may be used to preheat the charge material e.g. aluminium billet or scrap,mainly in bulk melting furnaces.

Table 6.21: Surface temperatures of aluminium melting furnace

Parameter	Furnace type	Surface temperature (°C)#	
		Ceiling	Side wall
Standard	Bulk melting furnace	100	90
	Electric furnace	-	90
Target	Bulk melting furnace	90	75
	Electric furnace	-	75

Source: Based on data from different industries

\# Average skin temperature under steady state operation

Table 6.22: Air ratio for aluminium melting furnace

	Furnace type	Air ratio@	
		Coal	Furnace oil
Standard	Pit furnace	1.35-1.40	1.18-1.23
	Bulk melting furnace	-	1.18-1.23
Target	Pit furnace	1.32-1.38	1.15-1.20
	Bulk melting furnace	-	1.15-1.20

Source: Based on data from different industries

@Air Ratio is defined as the ratio of 'actual air supplied' (AAS) to the theoretical air requirement. The air ratio is considered based on steady state operations at constant load conditions. It can be measured and verified at specific measurement points while maintaining maximum permissible limit for carbon monoxide (CO) level to 200 ppm. The air ratio shall be estimated using the following formula.

$$\text{Air ratio} = \frac{21}{21 - \%\text{ oxygen in flue gases}}$$

Table 6.23: Waste heat recovery for aluminium melting furnaces

Furnace type	Exhaust gas temperature (°C)	Waste heat recovery rate (%)		Flue gas temperature* (°C)
		Standard$^{\alpha}$	Target$^{\beta}$	
Bulk melting furnace	500-600	30	49	150-250

Source: Based on data from different industries

α Estimated heat drop based on the upper limit of gas temperatures and net heat transfer with 60% efficiency for heat exchanger

β Estimated heat drop based on the lower limit of gas temperatures and net heat transfer with 65% efficiency for heat exchanger

* Considering natural draft systems for higher flue gas temperature and induced draft system for lower temperatures

The industry shall compute waste heat recovery (WHR) rate using the following formula.

$$\text{Waste heat recovery rate (\%)} = \frac{\text{Recovered heat (kcal)}}{\text{Sensible heat in exhaust gases (kcal)}} \times 100$$

6.4.4 Common monitorable parameters and performance assessment

The industry shall monitor, measure, and control all key operating parameters of melting furnaces specific to the industry. It shall further undertake routine inspection and maintenance of furnaces and associated equipment to ensure optimum performance. This section provides performance assessment of process furnaces, such as fuel-fired furnace and electrical furnace. The industry shall use the relevant sections for undertaking performance assessment of furnace systems.

1) Performance assessment of fuel-fired furnace

The industry shall monitor common performance indicators as shown in Table 6.24 to assess the performance of the kilns.

The industry shall assess the performance of the fuel-fired melting furnace using the following formula.

$$\text{Specific enerrgy consumption (kcal/kg)} = \frac{\text{Total energy consumption (kcal)}}{\text{Quantity of charge material (kg)}} \times 100$$

Total energy consumption (kcal) = Fuel consumption (kg) X Gross calorific value (kcal/kg)

Table 6.24: Common monitorable parameters in fuel fired furnaces

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Furnace temperature	°C	Thermocouple	Hourly
Air ratio	kg/kg fuel	Flue gas analyser	Daily
Flue gas temperature	°C	Thermocouple	Daily
Fuel consumption	kg/day	Flow meter	Daily
Quantity of charge material	kg/day	Electronic balance	Daily
Quantity of final product	kg/day	Electronic balance	Daily
Surface temperature	°C	Infrared thermometer	Quarterly

(2) Performance assessment of electrical resistance furnace

The industry shall monitor common performance indicators as shown in Table 6.25 to assess the performance of the electrical resistance furnaces.

Table 6.25: Common monitorable parameters in electric resistance furnaces

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Furnace temperature	°C	Thermocouple	Hourly
Electricity consumption	kWh	Energy meter	Daily
Quantity of charge material	kg	Electronic balance	Daily
Quantity of final product	kg	Electronic balance	Daily
Surface temperature	°C	Infrared thermometer	Quarterly

The industry shall refer to the typical performance indicators of aluminium industry as provided in Table 6.26. It shall assess the performance of the electrical melting furnance using the following formula:

$$\text{Specific energy consumption (kWh/kg)} = \frac{\text{Electricity consumption (kWh)}}{\text{Quantity of charge material (kg)}} \times 100$$

Table 6.26: Typical performance indicators for aluminium furnace

Performance indicator	SEC
Oil-fired furnace	120-200 litre per tonne
Electrical furnace	400-600 kWh per tonne

Source: Based on data from different industries

6.4.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall use consistent quality of raw materials for producing melt. The output of the furnace, that is, useful melt available is directly proportional to the purity of raw materials used for melting. The quantity of fluxing agent used in melting is dependent on the level of impurities present in raw materials. Higher level of slag formation indicates more impurities present in raw materials and more fluxing agents are required.
2. The industry shall collect metal returns and rejections from the process for reuse in melting at the maximum possible temperature to reduce energy consumption.
3. The industry shall cover the melt surface with aluminium billets to increase the temperature and reduce energy consumption.
4. The industry using induction furnace shall ensure proper temperatures of cooling water and optimum heat transfer for coil cooling.
5. The industry shall undertake periodical repair of ladles for pouring of melt.
6. The industry shall reduce spillage while pouring melt into moulds. Spillage reduces productivity of the industry.
7. The industry shall undertake periodical inspection and maintenance of crucible to ensure maximum heat transfer.
8. The industry shall use appropriate tools in finishing operations to improve product quality and reduce rejections.
9. The industry shall arrest leakages from compressed air lines to reduce power consumption.
10. The industry shall use compressed air only at required pressure to optimize energy consumption. Use of compressed air at high pressures would increase energy consumption.
11. The industry shall use airguns in place of compressed air for requirements of air at low pressures.

BRASS

6.5 Brass industry

6.5.1 Background

The brass industry is one of the energy intensive industries covered under the micro, small and medium enterprise (MSME) sector. The raw materials used by the brass industry in MSME sector include used brass and assorted scraps. It produces a variety of products such as handicrafts, decorative items, and industrial products. Some of the brass products manufactured in brass industry are provided in Table 6.27.

Table 6.27: Products from brass industries

Type	Products
Building hardware	Door and window hinges, stoppers, knobs, studs, handles
Sanitary & bathroom fittings	Venetian blinds, hangers, taps, curtain, fittings
Electronic & electrical accessories	Socket pin, battery terminal, switches, tester, computer sockets
Agricultural implements	Tractor accessories
Brass jewellery and buttons	Necklace, ear rings, bracelet, rings, bangles
Industry accessories	Industrial control valves, automobile & cycle tube valves
Decorative and artisan products	Plate, cups, lamp, bells

6.5.2 Production process

The major process steps in brass industry include melting, forming/shaping, annealing, and finishing. In the manufacturing process, thermal energy accounts for a major share of the total energy consumption, mainly for melting. The major process steps used in brass industry include casting/ shaping and finishing operations. The finishing operation includes turning, milling, grinding, drawing, boring, threading, electro plating,etc. The production process followed in a brass industry is shown in Figure 6.7.

Raw material preparation. Any foreign material present in brass scrap is removed. It is fed into a crucible in the furnace. The industry uses either manual or semi-mechanized system in the production process.

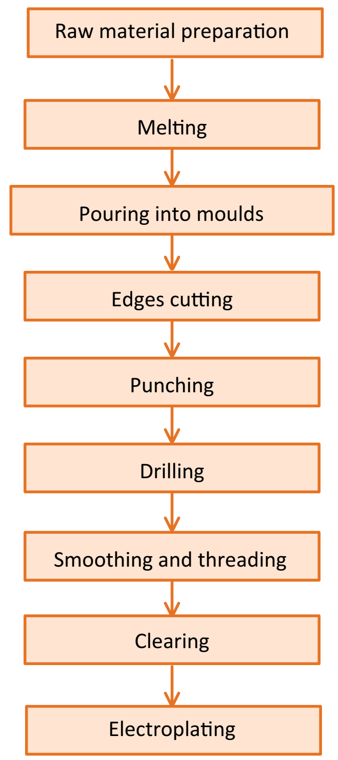

Figure 6.7: Production process in brass industry

Brass melting. Different capacities of crucibles are used based on requirements. The types of furnaces used for melting operation include electrical induction furnace and coal fired pit furnace. The temperature of melt maintained in the furnace varies from 950 °C–1100 °C. Fluxing agent is added for removal of slag from the top. The details of brass melting furnaces are provided in Table 6.28.

Pouring and casting. Liquid brass is poured in moulds using ladles. The melt solidifies and takes the shape of the mould.

Finishing. Once the mould becomes cooler, casting is taken out for downstream finishing processes such as trimming, punching, drilling, smoothing, threading, clearing, etc. Some of the castings are preheated at about 750 °C for artisan and decorative activities.

Table 6.28: Capacities of brass melting furnaces

Type	Capacity
Induction furnace	Upto 1500 kg
Coal-fired pit furnace	25-300 kg per batch

6.5.3 Process equipment

The melting furnace, that is, pit furnace or induction furnace is the major energy-consuming equipment in a brass industry. The main energy use in the furnace is thermal energy which is met through combustion of coal or use of electricity. The industry shall improve the energy performance, that is, reduce specific energy consumption (SEC) level of the melting furnace by optimizing various operating parameters. These include reduction of various heat losses occurring in the furnace through routine inspection and maintenance and keeping key operating parameters within specified limits as prescribed by the original equipment manufacturers (OEMs). This section provides EC Guidelines covering best operating practices, operational aspects, and performance assessment for melting furnaces used in brass industry in a rational way.

Standards components	
1. Management and control	The industry shall undertake the following: A. General The industry shall undertake the following common EC Guidelines for producing liquid metal either using pit furnace or electrical furnace: a. Install suitable weighing system for measurement of raw materials. b. Maintain furnace temperature as required to produce liquid metal. Avoid super-heating of metal to prevent energy and scale losses. Use suitable temperature indicators to monitor the temperature of melt. c. Maintain external temperature of furnace surfaces within the range as specified in Table 6.29 as standard value. Thick lining reduces molten melting capacity and thin lining leads to increased heat losses. d. Keep the moulds ready before undertaking melting campaign. e. Pre-heat moulds to avoid metal chilling. f. Use dry and clean raw materials for melting in furnaces. Provide shed for raw material storage to avoid accumulation of moisture due to rains. g. Ensure adequate loading of furnaces for optimum capacity utilization. The low capacity utilization of the furnace shall lead to higher SEC or poor energy performanceof the furnace. The loading of a furnace is dependant on charge material preparation, quantity of raw material, residence time inside the furnace, etc. B. Pit furnace a. Install a stack of suitable height for routing the exhaust flue gases instead of venting at workplace. b. Maintain correct air ratio based on type of fuel and its composition as specified as standard value in Table 6.30. Use portable oxygen (O_2) analyser to calculate air ratio. Adjust and control air ratio based on variations in fuel consumption rate to maintain required furnace temperatures. Set the air flow in such a manner to avoid high excess air but ensure complete combustion of fuel. c. Install blower having suitable capacity and correct air pressure. Avoid over-sized or under-sized blower. Further, install the blower close to the furnace to avoid transmission loss. d. Reduce exhaust flue gas temperatures based on WHR recovery rate* specified in Table 6.31 as standard value. Install suitable waste heat recovery (WHR) system(s), such as air preheater*, charge preheater*, etc., based on waste heat available and type of application. C. Electrical furnaces (Induction/ resistive) a. Maintain short and optimum holding time for molten metal. b. Use dedicated energy meter for measuring electricity consumption. c. Avoid charging of contaminated raw material which would lead to increased time for metling and reduced liquid meltal yield. d. Avoid using large size scarp for more than 1/3rd the diameter of furnace crucible to avoid bridging. e. Avoid over-filling and restrict filling to the coil level in the induction furnace.

	f. Follow proper sequence for charging of raw material in the furnace. For example, bigger size metal shall be filled first followed by smaller size. The gaps shall be filled with turnings and boring. g. Operate the furnace at maximum power rating since beginning of the operation to minimize cycle time. h. Ensure no voltage drop at source and maintain unity power factor during furnace operation. i. Use suitable lid mechanism during superheating of melt to reduce radiation heat losses. j. Continue furnace heating at the minimum power rating at the end of shift/ batch to avoid thermal shock to coils and refractories which will increase maintenance and reduce furnace life. This will also ensure quick start up after shutdown. k. Add suitable flux material of required quantity to remove the slag formed. l. Carry out de-slagging once the furnace is full and the molten metal has attained the operating temperature. Avoid building up of slag on furnace walls. Use proper tools for de-slagging. m. Provide adequate insulation of pouring ladle. n. Monitor temperature of cooling water used for coil cooling and panel cooling to assess the condition of the furnace refractory lining and the coil losses. o. Ensure optimum loading of furnaces in case of multi-furnace operation.
2. Measurement and records	The industry shall monitor and record the following: A. Key operating paratmeters such as temperature of liquid metal, quantity of charge material, final products, and in-house returns on daily basis. B. Fuel and electricity consumption as applicable on daily basis. C. Use dedicated energy meter for electrical furnaces for measuring electricity consumption. D. Temperature of exhaust gases, pre-heat temperatures, residual oxygen (O_2) and carbon monoxide (CO) in flue gases, etc., for fuel-fired furnaces. E. Use suitable temperature indicators (online or portable) to indicate real-time liquid metal temperature. F. Use suitable logsheet(s) for measurement and recording of common monitorable parameters. The logsheets would help the industry in: (1) assessing energy performance of the furnace and (2) identifying deviations in operating parameters to undertake corrective measures. G. Ensure better resolution of measuring instruments for accurate measurements.
3. Maintenance and inspection	The industry shall undertake the following: A. Undertake proper lining or repair work of the furnace on a regular basis and based on requirements. B. For bulk melting furnace, repair, renovate, and maintain the WHR systems once in six months to avoid scale formation and ensure optimum performance. C. Undertake infrared/ thermal scans of induction furnace assembly, power supply, interconnecting bus bar, water-cooled leads, etc., once in six months towards identification of hotspots and undertake remedial actions. D. Undertake proper maintenance of water-cooled leads in induction furnace to avoid electrical losses. E. Undertake calibration and maintaintenance of instruments as per recommendations of suppliers to record reliable and accurate data. Maintain proper record of calibration and calibration plans for all key instruments.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Install mechanical charging system for continuous melting furnace to ensure smooth and continuous charging operation. B. Optimize ladle size to avoid return of liquid metal back to the furnace. C. Install energy efficient furnace (for example, insulated gate bipolar transistor (IGBT) furnace in case of electrical route) along with built-in automation. In case of fuel-fired furnace, install WHR system for maximum heat recovery.

Target components	
	The industry shall ensure the following: A. Specific energy consumption of brass melting as specified in Table 6.34. B. Maintain external surface temperature in the range of 75 °C-90 °C. C. Maintain flue gas temperature in the range of 150 °C-250 °C. D. Maintain air ratio of fuel fired furnaces based on the target value as provided in Table 6.30.

* Note:

1. Waste heat recovery rate is the ratio of heat recovered to the sensible heat available in exhaust gases under rated load operation.
2. Air-preater (APH) is a device used to preheat the combustion air at ambient temperatures to higher levels by extracting waste heat from flue gases.
3. Charge preheater (CPH) may be used to preheat the charge material

Table 6.29: Surface temperatures of brass melting furnace

Parameter	Furnace type	Skin temperature (°C)#
Standard	Electric furnace	90
Target	Electric furnace	75

Source: Based on data from different industries

\# Average skin temperature under steady state operation

Table 6.30: Air ratio for furnaces

Parameter	Kiln type	Air ratio@		
		Coal	Biomass	Furnace oil
Standard	Pit furnace	1.35-1.40	1.49-1.56	1.18-1.23
Target	Pit furnace	1.32-1.38	1.32-1.39	1.15-1.20

Source: Based on data from different industries

@Air Ratio is defined as the ratio of actual air supplied (AAS) to the theoretical air requirement. The air ratio is considered baed on steady-state operations at constant load conditions. It can be measured and verified at specific measurement points while maintaining maximum permissible limit for carbon monoxide (CO) level to 200 ppm. The air ratio shall be estimated using the following formula.

$$\text{Air ratio} = \frac{21}{21 - \%\text{ oxygen in flue gases}}$$

Table 6.31: Waste heat recovery for industrial furnaces

Furnace type	Exhaust gas temperature (°C)	Waste heat recovery rate (%)		Flue gas temperature* (°C)
		Standard$^{\alpha}$	Target$^{\beta}$	
Pit furnace	600-700	35	51	150-250

Source: Based on data from different industries

α Estimated heat drop based on the upper limit of gas temperatures and net heat transfer with 60% efficiency for heat exchanger

β Estimated heat drop based on the lower limit of gas temperatures and net heat transfer with 65% efficiency for heat exchanger

* Considering natural draft systems for higher flue gas temperature and induced draft system for lower temperatures

The industry shall compute waste heat recovery (WHR) rate using the following formula.

$$\text{Waste heat recovery rate (\%)} = \frac{\text{Recovered heat (kcal)}}{\text{Sensible heat in exhaust gases (kcal)}} \times 100$$

6.5.4 Common monitorable parameters and performance assessment

The industry shall monitor, measure, and control all key operating parameters specific to the industry. It shall further undertake routine inspection and maintenance of furnaces and associated equipment to ensure optimum performance. This section provides performance assessment of process furnaces, that is, induction furnace and pit furnace. The industry shall use the relevant sections for undertaking assessment of furnace system.

1) Pit furnace

The industry shall monitor common performance indicators as shown in Table 6.32 to assess the performance of the pit furnaces.

The industry shall assess the performance of the furnace using the following formula.

$$\text{Specific enerrgy consumption (kcal/kg)} = \frac{\text{Total energy consumption (kcal)}}{\text{Quantity of raw material (kg)}}$$

Total energy consumption (kcal) = Fuel consumption (kg) × Gross calorific value (kcal/kg)

2) Induction furnace

The industry shall monitor common performance indicators as shown in Table 6.33 to assess the performance of the induction furnaces.

Table 6.32: Common monitorable parameters in pit furnace

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Temperature of liquid metal	°C	Thermocouple	Hourly
Quantity of metallic charge	kg	Electronic balance	Daily
Quantity of final product	kg	Electronic balance	Daily
Air ratio	kg/kg fuel	Flue gas analyzer	Daily
Flue gas temperature	°C	Thermocouple	Daily
Fuel consumption	kg	Electronic balance	Daily
Surface temperature	°C	Infrared thermometer	Quarterly

Table 6.33: Common monitorable parameters in induction furnace

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Temperature of melt	°C	Thermocouple	Hourly
Quantity of metallic charge	kg	Electronic balance	Daily
Quantity of final product	kg	Electronic balance	Daily
Surface temperature	°C	Infrared thermometer	Quarterly
Electrcity consumption	kWh	Energy meter	Daily

$$\text{Specific enerrgy consumption (kWh/kg)} = \frac{\text{Total power consumption (kWh)}}{\text{Total metal charged (kg)}}$$

The industry shall refer to the typical performance indicators of brass industry as provided in Table 6.34.

Table 6.34: Typical performance indicators for brass industry

Specific energy consumption	Typical range (toe/ tonne)
Extrusion	0.08-0.19
Foundry	0.06-0.11
Electroplating	0.03-0.14
Machining	0.01-0.19

Source: Based on data from different industries

6.5.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall use consistent quality of raw materials for producing melt. The output of the furnace, that is, useful melt available is directly proportional to the purity of raw materials used for melting. The quantity of fluxing agent used in melting is dependent on the level of impurities present in raw materials. Higher level of slag formation indicates more impurities present in raw materials and more fluxing agents are required.
2. The industry shall collect metal returns and rejections from the process for reuse in melting at the maximum possible temperature to reduce energy consumption.
3. The industry shall recover the waste heat from furnace openings by placing the raw material close to the openings to increase the input temperature and reduce energy consumption.
4. The industry shall keep optimum distance between melting furnace and casting section to avoid chilling of melt or requirement for super heating.
5. The industry using coal-fired furnace shall use covered coal storage to minimize moisture pickup, which otherwise would lead to increased energy consumption in melting.
6. The industry shall use an optimum coal of size ¾ to 1 inch in the furnace to ensure complete combustion and reduce coal consumption.
7. The industry using induction furnace shall ensure proper temperatures of cooling water and optimum heat transfer for coil cooling.
8. The industry shall undertake periodical repair of ladles for pouring of melt.
9. The industry shall reduce spillage while pouring melt into moulds. Spillage reduces productivity of the industry.
10. The industry shall maximize the recovery of wax used for moulding to reduce operating costs.
11. The industry shall use appropriate tools in finishing operations to improve product quality and reduce rejections.
12. The industry shall arrest leakages from compressed air lines to reduce power consumption.
13. The industry shall use compressed air only at required pressure to optimize energy consumption. Use of compressed air at high pressures would increase energy consumption.
14. The industry shall use airguns in place of compressed air for requirements of air at low pressures.

MACHINE TOOLS

6.6 Machine tools industry

6.6.1 Background

The machine tools industry is one of the energy consuming industries in the micro, small and medium enterprise (MSME) sector. Different products manufactured in machine tools industry include spindles, centre grinding machines, self-centering steady rests, bar feeding attachments, rotary tables, index tables, special purpose machines, coordinate measuring machines, aerospace fixtures, CNC (computer numerical control), machine enclosures, sound proofs, armature rewinding machines, etc. The industry may be categorized based on the type of products: (i) manufacturing components (used in aerospace, automobile, electrical and electronic and other machineries), (ii) accessories (used in conventional and CNC machine tools), (iii) CNC machines and special purpose machines, and (iv) heat treatment units. The products requiring heat treatment are generally outsourced. Most of the machine tools industries use steel as the raw material with the limited use of cast iron and pig iron.

6.6.2 Production process

The major processes followed in machine tools industry are milling, grinding, drilling, turning, and machining. The process sequence depends on the product type (Figure 6.8).

Milling process. Milling is the contour shaping process that removes excess material from the pre-shaped work piece. In this process, holes, slots, pockets, three-dimensional surface contours, etc. are made on axially non-symmetric work piece. Milling process uses manual milling or CNC milling.

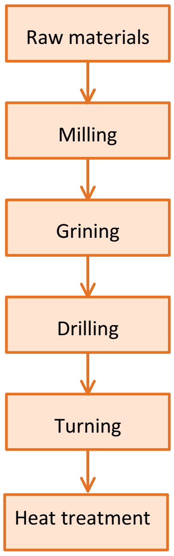

Figure 6.8: Process flow in machine tools industry

Grinding process. It removes the material from flat and cylindrical rough surfaces produced in milling process, impart close tolerance, and improve surface finish. Different types of grinding process include surface grinding, centred grinding, centreless grinding, and contour grinding.

Drilling process. The drilling process includes spot drilling, centre drilling, deep drilling, gun drilling, trepanning, or micro-drilling to produce through-hole or blind-hole on metallic and non-metallic materials.

Turning process. Turning creates holes, grooves, threads, tapers, various diameter steps, and contoured surfaces through hard turning, facing, parting, grooving, boring, knurling, etc.

Heat treatment furnaces. This step is used to release stresses induced in the work piece during various machining operations in a heat treatment furnace.

6.6.3 Process equipment

Various machining equipment and heat treatment furnaces form the major energy consuming equipment in a machine tool industry. The main energy use in machine tools industry is electricity. The industry shall improve the energy performance, that is, reduce specific energy consumption (SEC) level, by reducing various energy losses occurring in machining equipment and heat treatment furnace through routine inspection and maintenance and keeping key operating parameters within specified limits as prescribed by the original equipment manufacturers (OEMs). This section provides performance assessment for melting furnaces used in machine tools industry in a rational way.

Standards components	
1. Management and control	The industry shall undertake the following: A. Maintain power factor at the receiving end by installing measures such as automatic power factor controller (APFC) and capacitor banks in the distribution system as specified in Table 6.36 as the target value. B. Use direct online (DOL) starters for motors upto 5 hp, star-delta type starters for 5–20 hp motors, and soft starter for motor with more than 20 hp capacity. C. Install energy saver device in welding machines to minimize energy consumption during the non-operating period. D. Undertake actions to reduce distribution losses in power receiving and transforming equipment. These measures include use of shorter distribution lines, proper current-carrying capacity of conductors, appropriate distribution voltage, etc. E. Distibute single-phase loads in such a way that there is no current imbalance in the three-phase distribution system. F. Install phase-protection relay/single phasing preventer to avoid burnouts of distribution line. G. Induction heating furnace a. Ensure optimum loading for better capacity utilization. b. Manage and control current flow to induction furnace to minimize electrical losses. c. Maintain external temperature of the furnace within the range as specified in Table 6.35 as standard value. Undertake hot face thermal insulation work, including suitable thickness of insulation, low thermal conductivity insulating materials, heat resistant paints, etc.
2. Measurement and recording	The industry shall measure and record the following: A. Common monitorable parameters such as production quantity, electricity consumption, voltage, current, and power factor on daily basis. B. Use suitable logsheet(s) for measurement and recording of key operating parameters. The logsheets would help the industry in (1) assessing energy performance of the furnace and (2) identifying deviations in operating parameters to undertake corrective measures. C. Skin temperatures of the furnace on monthly basis to take remedial measures for reducing heat losses.
3. Maintenance and inspection	The industry shall: A. Undertake preventive maintenance and routine inspection of electrical induction furnace and distribution system. B. Check the condition of furnace surface insulation on quarterly basis and undertake required maintenance.
4. Necessary measures when installing new facilities	The industry shall: A. Install CNC machine for machining process. B. Select equipment with energy efficient motors in machining process. C. Adopt inverter type welding machine to reduce energy consumption.

Target components	
	The industry shall ensure the following: A. Specific energy consumption for components and accessory production is 5100–6900 kWh/tonne. B. Specific energy consumption for machining is 550–650 kWh/tonne. C. Maintain external temperature of the furnace in the range of 70 °C–90 °C.

Table 6.35: Surface temperatures of induction furnace for heat treatment

Furnace type	Skin temperature (°C)#	
	Standard	Target
Electric furnace	90	70

Source: Based on data from different industries

#Average skin temperature under steady-state operation

Table 6.36: Target power factor for equipment

Load type	Target power factor
Induction motor#	0.95
Distribution system	0.99
Induction furnace*	0.95
Welding machine	0.90 and above
DC drives	0.90 and above
Fluorescent lamp	0.95 and above

Source: Improving Motor and Drive System Performance – A Sourcebook for Industry

Power factor is measured after the correction system.

* Capacitors are usually included with induction furnaces.

6.6.4 Common monitorable parameters and performance assessment

The industry shall monitor common performance indicators as shown in Table 6.37 to assess the performance of the induction heating furnace.

Table 6.37: Common monitorable parameters in induction heating furnace

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Furnace temperature	°C	Thermocouple	Daily
Quantity of material processed	tpd	Electronic balance	Daily
Surface temperature	°C	Thermocouple	Quarterly
Voltage	Volt	Power analyser	Daily
Current	Ampere	Power analyser	Daily
Power factor	–	Power analyser	Daily
Electricity consumption	kWh	Energy meter	Daily

(1) Specific energy consumption

The industry shall evaluate the SEC of the machine tools industry using the following formula to assess the performance:

$$\text{Specific energy consumption (kWh/kg)} = \frac{\text{Total energy consumption (kWh/day)}}{\text{Quantity of material processed (kg/day)}}$$

The industry shall refer to the typical performance indicators of machine tool industry as given in Table 6.38.

Table 6.38: Typical performance indicators for machine tool industry

Parameter	Specific energy consumption
Components and accessories	5100–6900 kWh/tonne
Machining	550–650 kWh/tonne

Source: Based on data from different industries

6.6.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall select and use correct size and shape of raw materials to optimize the use of raw materials and reduce metal wastes during various finishing operations.
2. The industry shall use appropriate tools in finishing operations to improve product quality and reduce rejections.

C. Adopt suitable production planning to enhance productivity and minimize wastage.

4. The industry shall use correct quantity of liquid lubricant to minimize losses. It shall consider using solid lubricant in place of liquid lubricant, especially in end milling and turning operations.
5. The industry shall minimize wear at the cutting edge of the tools using ultrasonically assisted machining, hot machining, or lubricant/hard coatings of tools.
6. The industry shall arrest leakages from compressed air lines to reduce power consumption.
7. The industry shall use compressed air only at required pressure to optimize energy consumption. Use of compressed air at high pressures would increase energy consumption.
8. The industry shall use airguns in place of compressed air for requirements of air at low pressures.

GALVANIZING AND WIRE DRAWING

6.7 Galvanizing and wire drawing industry

6.7.1 Background

The galvanizing industry is one of the energy consuming industries in micro, small and medium enterprise (MSME) sector. Galvanizing provides protective coating to avoid rusting of materials such as mild steel (MS) wires, nails, nuts and bolts, components of telephone/mobile tower and power transmission tower, etc. in various sizes and shapes. Also the wire drawing industry is one of the electricity intensive industries under MSME sector producing wire gauge items of various materials, such as mild steel, aluminium, copper, etc. The products are used in telecommunication industries, switchgear manufacturers, electrical panel manufacturers, steel plants, electric motor manufacturers, etc.

6.7.2 Production process

(1) Galvanizing industry

Galvanizing is the process of applying anti-corrosive zinc coating on iron/steel items. It includes material preparation, caustic cleaning, acid pickling, fluxing, dipping in molten zinc bath, and quenching (Figure 6.9).

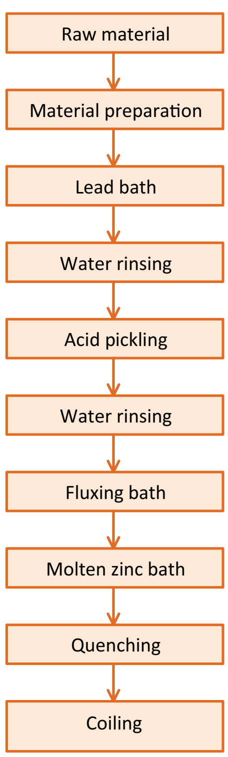

Figure 6.9: Galvanizing process

Material preparation.This involves cropping/shearing, hole punching, grinding, filling, etc.

Lead bath.The raw material is passed through a lead bath that helps to produce coatings with spangles and lower the surface tension in zinc bath to obtain a smooth surface of the coating. It is then subjected to rinsing in hot water.

Acid pickling.The material is subjected to acid pickling to remove iron oxides, scales, etc. from the material surface. Hydrochloric acid at room temperature or sulphuric acid at about 60 ^{o}C–80 ^{o}C is used for this purpose. The material is rinsed in water to remove the acid.

Fluxing. This is carried out using active chloride salt to make the steel surface active and free of oxides through pre-fluxing or in-situ fluxing. Pre-fluxing uses zinc chloride-ammonium chloride solution and in-situ fluxing uses solid mixture on the top of molten zinc bath.

Galvanizing. The material is dipped in molten zinc bath maintained at about 445 ^{o}C–455 ^{o}C. For continuous galvanizing, the rate of immersion and withdrawal is dependent on thickness of the material. The galvanized material is withdrawn through a bath of clear zinc to avoid contamination by flux.

Water quenching. The galvanized material is quenched in water to clear the surface of corrosive salts.

(2) Wire drawing industry

Wire drawing is a metal working process to reduce the cross section of a wire to smaller sizes by pulling through a single or a series of drawing dies. The rolled coil is cleaned and descaled and subjected to annealing before being drawn through the dies. The pay-off spool feeds the wire into the drawing die with lubricant in dry or liquid form. A tensiometer installed in the system measures the tensile load of wire emerging after size reduction. The pick-up spool assembly mounted directly on the shaft of a step or induction motor provides the required force to pull the wire drawn after size reduction. A jockey mechanism is used to maintain tension of the wire drawn from one coil to the other. The drawn wire is dipped in a chromate protective solution from weathering action before coiling of the drawn wire. A typical wire drawing process is shown in Figure 6.10.

6.7.3 Process equipment

The molten zinc bath furnace accounts for a major share of thermal energy consumption in a galvanizing industry. Wire drawing industry mostly uses electricity. Both these industries shall improve the energy performance of the process equipment by optimizing various operating parameters through routine inspection and maintenance and keeping key operating parameters within specified limits as prescribed by the OEMs. This section provides EC Guidelines covering best operating practices, operational aspects and performance assessment for galvanizing and wire drawing industry in a rational way.

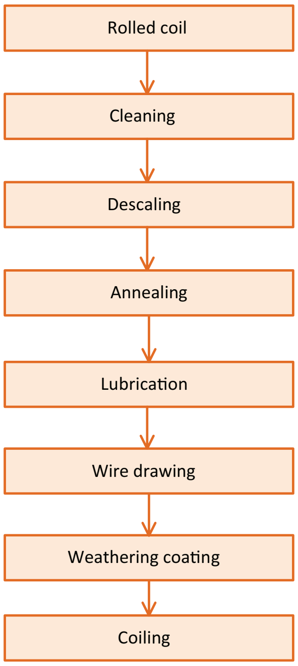

Figure 6.10: Wire drawing process

Standards components	
1. Management and control	A. General The applicable common EC Guidelines for galvanizing and wire drawing industries are provided below. a. Maintain correct temperature of furnace as per requirements. b. Use a sufficient number of temperature indicators to monitor temperature. c. Maintain correct air ratio based on type of fuel(s) within prescribed limits as provided in Table 6.39 as standard value. Use on-line or portable type oxygen (O_2) analyser to calculate air ratio. Set the air flow in such a manner as to avoid high excess air but ensure complete combustion of the fuel. d. Install blower having suitable capacity and correct air pressure. Avoid over-sized or under-sized blower. e. Minimize heat losses in furnace through air ingression by adopting suitable measures. These include minimizing size of opening, proper sealing of furnace, etc. f. Reduce the exhaust flue gas temperatures based on waste heat recovery (WHR) rate shown in Table 6.40. Install suitable WHR system(s) such as air preheater based on waste heat available in exhaust gases. g. Monitor temperature of exhaust gases and waste heat recovery media using on-line or portable instrumentation. h. Maintain external temperature of furnace surfaces within the range as specified in Table 6.41 as standard value.

	i. Ensure that the flame does not impinge the refractory surfaces of the furnace, which otherwise would result in reduced life of furnace. Restrict the flame length in such a way that it does not exit through furnace opening or enter chimney. j. In case of using furnace oil in furnaces, ensure proper preheating to reduce the viscosity level. k. Place burners properly for equal distribution of heat throughout the furnace for the proper operation of the furnace. l. Maintain a minimum positive draft inside the furnace through proper damper setting in flue gas path. Avoid negative pressure inside the furnace to prevent cold air ingress from furnace openings. m. Use dedicated energy meter for measuring energy consumption in induction furnace. n. Monitor the temperature of cooling water used for coil cooling and panel cooling to assess the condition of the furnace refractory lining and the coil losses in electrical furnaces. o. Ensure better resolution of temperature indicators for accurate measurement of temperatures inside the furnace. B. Galvanizing a. Maintain the temperature of galvanizing bath with a variation of ±2 °C. Large variations in the bath temperature would lead to more dross. b. Adjust correct feed rate of materials inside molten bath. High feed rate bath will lead to formation of thick coating of zinc layer. c. Undertake measures to reduce vapour losses from caustic bath and acid bath. d. Ensure that the galvanized product is cooled below 200 °C–250 °C before water quenching. C. Wire drawing industry a. Ensure proper cleaning and descaling of the wire before transferring to annealing furnace. b. Maintain correct temperature in annealing furnace depending on the input material. c. Monitor the temperature of lubricant in case of using liquid lubricant system.

2. Measurement and recording	The industry shall measure and record the following: A. Common monitorable parameters such as fuel consumption, production quantity, temperature of furnace, temperature of exhaust gases, preheat temperatures, residual oxygen (O_2) and carbon monoxide (CO) in flue gases, furnace pressure, etc. for fuel fired furnace on daily basis. B. Common monitorable parameters such as production quantity, electricity consumption, voltage, current, and power factor on daily basis for induction furnaces. C. Skin temperatures of the furnace on quarterly basis to take remedial measures for reducing heat losses. D. In wire drawing industry, record the temperature of oil lubricant. E. Use suitable logsheet(s) for measurement and recording of key operating parameters. The logsheets would help the industry in (1) assessing energy performance of the furnace and (2) identifying deviations in operating parameters to undertake corrective measures.
3. Maintenance and inspection	The industry shall: A. Undertake preventive maintenance and routine inspection of electrical induction furnace and distribution system as recommended by the manufacturer. B. Check the condition of furnace surface insulation on half-yearly basis and undertake required maintenance. C. Repair, renovate, and maintain the WHR systems in galvanizing furnace as recommended by the manufacturer to avoid scale formation and ensure optimum performance. D. Undertake drossing in galvanizing furnaces once in two weeks. E. Inspect and calibrate tensiometer in wire drawing industry on yearly basis. F. Calibrate instruments as per recommendations of suppliers to record reliable and accurate data. Maintain proper record of calibration and plans for all key instruments.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Select appropriate combustion equipment and accessories, for example, burner, built-in furnace automation system, etc., for galvanizing furnace. B. Install systems with automatic temperature controller in galvanizing furnace and induction heating furnace. C. Use energy efficient motors for various motive loads in galvanizing and wire drawing industries. D. Install solar water heating system to cater to full or partial hot water requirements.

Target components	
	The industry shall ensure the following: A. Specific energy consumption in the range 0.03–0.17 toe per tonne for galvanizing process. B. Specific energy consumption in the range 0.01–0.07 toe per tonne for wire drawing process. C. Air ratio of fuel fired furnaces based on the target value as given in Table 6.39. D. Exit flue gas temperature in the range of 250 °C–300 °C. E. External surface temperature in the range 70 °C–80 °C.

Table 6.39: Air ratio of furnaces in galvanizing industry

Parameter	Kiln type	Air ratio[@]
		Liquid fuel
Standard	Galvanizing furnace	1.26–1.33
	Lead bath furnace	1.26–1.33
Target	Galvanizing furnace	1.18–1.24
	Lead bath furnace	1.18–1.24

Source: Based on data from different industries

@ *Air ratio is defined as the ratio of actual air supplied (AAS) to the theoretical air requirement. The air ratio is considered based on steady-state operations at constant load conditions. It can be measured and verified at specific measurement points, while maintaining the maximum permissible limit for carbon monoxide (CO) level at 200 ppm. The air ratio shall be estimated using the following formula:*

$$\text{Air ratio} = \frac{21}{21 - \%\ \text{oxygen in flue gases}}$$

Table 6.40: Waste heat recovery in galvanizing industry

Exhaust gas temperature (°C)	Standard[α] waste heat recovery rate (%)	Target[β] waste heat recovery rate (%)	Flue gas temperature[#] (°C)
Up to 600	30	38	250–300

Source: Based on data from different industries

[α] Estimated heat drop based on the upper limit of gas temperatures and the net heat transfer with 60% efficiency for heat exchanger

[β] Estimated heat drop based on the lower limit of gas temperatures and the net heat transfer with 65% efficiency for heat exchanger

[#] Considering the natural draft systems for higher flue gas temperature and induced draft system for lower temperatures

The waste heat recovery rate is the ratio of the heat recovered to the sensible heat available in flue gases under rated load operation.

The following formula shall be used for calculating the waste heat recovery (WHR) rate.

$$\text{Waste heat recovery rate (\%)} = \frac{\text{Recovered heat (kcal)}}{\text{Sensible heat in exhaust gases (kcal)}} \times 100$$

Table 6.41: Surface temperatures of furnaces in galvanizing industry

Parameter	Kiln type	Side wall temperature (°C)[#]
Standard	Galvanizing furnace	80
	Lead bath furnace	100
Target	Galvanizing furnace	70
	Lead bath furnace	80

Source: Secondary data from industries

Average skin temperature under steady-state operation

6.7.4 Common monitorable parameters and performance assessment

The industry shall monitor, measure, and control all key operating parameters of melting furnaces specific to the industry. It shall further undertake routine inspection and maintenance of furnaces and associated equipment to ensure optimum performance. This section deals with the performance assessment of process furnaces such as fuel fired furnace and electrical furnace. The industry shall use the relevant sections for undertaking performance assessment of furnace systems.

1) Performance assessment of fuel fired furnace

The industry shall monitor common performance indicators as given in Table 6.42 to assess the performance of the fuel fired furnaces.

The industry shall assess the performance of the melting furnace using the following formula:

$$\text{Specific energy consumption (kcal/kg)} = \frac{\text{Total energy consumption (kcal)}}{\text{Quantity of material processed (kg)}}$$

Total energy consumption (kcal) = Fuel consumption (kg) × Gross calorific value (kcal/kg)

2) Performance assessment of electrical furnace

The industry shall monitor common performance indicators as given in Table 6.43 to assess the performance of electrical furnaces.

$$\text{Specific energy consumption (kWh/kg)} = \frac{\text{Electricity consumption (kWh)}}{\text{Quantity of material processed (kg)}}$$

Table 6.42: Common monitorable parameters in fuel fired furnace

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Furnace temperature	°C	Thermocouple	Hourly
Air ratio		Flue gas analyser	Hourly
Flue gas temperature	°C	Thermocouple	Daily
Surface temperature	°C	Infrared thermometer	Quarterly
Fuel consumption	litre	Flow meter	Daily
Quantity of material processed	kg	Electronic balance	Daily

Table 6.43: Common monitorable parameters in electrical furnace

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Furnace temperature	°C	Thermocouple	Daily
Quantity of material processed	tpd	Electronic balance	Daily
Surface temperature	°C	Thermocouple	Quarterly
Voltage	Volt	Power analyser	Daily
Current	Ampere	Power analyser	Daily
Power factor	–	Power analyser	Daily
Electricity consumption	kWh	Energy meter	Daily

The industry shall refer to the typical performance indicators of galvanizing and wire drawing industry as provided in Table 6.44.

Table 6.44: Typical performance indicators for galvanizing and wire drawing industry

Performance indicator	Specific energy consumption
Galvanizing industry	0.03–0.17 toe per tonne
Wire drawing industry	0.01–0.07 toe per tonne

Source: Based on data from different industries

6.7.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimization of the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall use correct quantity of bleaching agent to reduce costs.
2. The industry shall use correct quantity of acid for the pickling process.
3. The industry shall consider installation of regeneration system or reclamation of spent acid for reuse in pickling section.
4. The industry shall cover the hot surfaces of baths using floating balls to reduce evaporation losses.
5. The industry shall clean and reuse drawing lubricant in wire drawing. It shall undertake treatment of spent lubricant to reduce oil content in the discharge and to reduce waste volume using chemical breaking, electrolytic emulsion splitting, or ultrafiltration.
6. The industry shall avoid spillage of fuels to reduce wastage.
7. The industry shall use the required quantity of water for washing purposes and shall consider recycling of contaminated water after suitable water treatment.
8. The industry shall undertake periodical cleaning of water tanks.

REFRACTORY

6.8 Refractory industry

6.8.1 Background

The refractory industry is one of the energy intensive industries under micro, small and medium enterprise (MSME) sector. The products manufactured in the industry include both shaped and unshaped products such as high alumina refractory bricks, abrasive products, assorted tiles, refractory filters and bottom pouring set for steel industries, bed material for boiler, etc. The refractory products are produced mainly through batch processes; continuous process is also adopted in some industries. While batch production process limits the capacity of the furnaces, continuous process based industries have large production capacities and use machinery for (semi) automation processes.

6.8.2 Production process

Based on the type of the requirement, unshaped and different shapes and sizes of refractory products are produced in refractory industry. The process requires both electrical and thermal energy at different stages of production. The major process steps in the production of refractory products include mould preparation, body material preparation, shaping, drying, and firing (Figure 6.11).

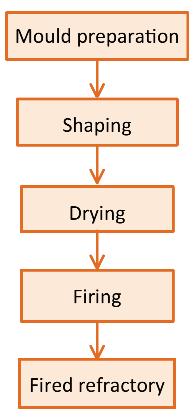

Figure 6.11: Refractory production process

Mould preparation. Most of the refractory products are shaped using metallic dies. Mould is used in manual casting during forming process. The moulds are made of Plaster of Paris (POP). Pre-shaped pattern is used to prepare green moulds which are strengthened through sun drying and, in some cases, controlled heating in kiln.

Body material preparation

Body material preparation is the first step in shaping of any refractory product. Batches of coarser size raw materials are reduced to desired mixture of target size through a series of operations such as crushing, grinding, sieving, and magnetic separation.

Shaping

Based on the type of products, shaping is done either through pressing or manual moulding. Pressing is done using hydraulic press or friction press.

Drying

The green products are stacked on trays and dried either in open sun or at room temperature before sintering. In continuous type kiln, the green products are either dried naturally or stacked on the kiln car and dried using hot waste gases from the kiln.

Firing

Firing is the process by which refractory products are thermally consolidated into a dense, cohesive body composed of fine, uniform grains. This process is also referred to as sintering or densification. Firing is done either in intermittent kiln (e.g. downdraft kiln) or continuous kiln (e.g. tunnel kiln). A temperature of about 1050 °C–1350 °C is maintained in the kiln depending on the type of the product. The types of kilns used in refractory industry and their production capacity are given in Table 6.45.

Table 6.45: Capacities of kilns in refractory industry

Type	Capacity
Downdraft kiln	100–150 tonnes per batch
Tunnel kiln	4–20 tonnes per day

6.8.3 Process equipment

The process equipment in a refractory industry comprise raw material processing and firing kiln. Crusher, pulveriser, ball mill, muller mixer, and press are the commonly used equipment in the raw material processing. The processing of raw material uses only electrical energy. The kiln is the major thermal energy consuming system in a refractory industry. The thermal energy requirement in the kiln is met through combustion of fuel (mainly coal). The industry shall improve the energy performance, that is, reduce specific energy consumption (SEC) level of the kiln by optimizing various operating parameters. These include reduction in various losses through routine inspection and maintenance and keeping key operating parameters within specified limits. This section provides EC Guidelines covering best operating practices, operational aspects and performance assessment for kilns used in refractory industries in a rational way.

Standards components	
1. Management and control	The applicable common EC Guidelines for raw material processing and the firing kiln are provided below. A. Operate ball mill at critical loading point to minimize specific energy consumption. B. Use grinding media of mixed sizes for efficient grinding. C. Use the correct and consistent quality of raw materials. D. Switch off conveyor used to carry the raw material when not in use. E. Use timer switches for switching off automatically on completion of grinding process. F. Maintain consistent batch time for similar batches. G. Maintain suitable pressure settings in press machine based on type of products. H. Maintain temperature of kiln as per product requirements. Avoid overheating or underheating of products to minimize rejections. I. Use a sufficient number of temperature indicators both at wall and at roof of kiln to monitor temperature profile across the kiln. J. Maintain correct air ratio in tunnel kiln based on type of fuel(s) used, as provided in Table 6.46 as standard value. Use oxygen analyser of on-line or portable type analyser for monitoring O_2 level. K. Maintain a slight positive pressure inside the kiln when forced draft is used (tunnel kiln) and slight negative pressure in case of natural draft combustion (downdraft kiln). L. Use sensible heat of flue gases for drying or preheating of the green product. M. Maintain the external temperature of furnace surfaces within the range as specified in Table 6.47 as standard value. Adopt various measures to improve thermal insulation of the furnace. These include suitable thickness of insulation, low thermal conductivity insulating materials, etc. N. Minimize furniture dead mass to product ratio with low thermal mass material. O. Use on-line or portable instruments to monitor temperature of kiln. P. Ensure better resolution of measuring instruments for accurate measurements.

	Q. Downdraft kiln (coal fired) a. Use coal of size from 3/4 to 1 inch for firing in the kiln. Avoid using lumps to avoid incomplete combustion. b. Feed fuel in small quantities at regular intervals in place of feeding lumps with large time gap. c. Keep the interval of fuel feeding between 1.5 and 2 hours to ensure complete combustion of the fuel and avoid formation of black smoke. d. Keep the feeding hole closed after fuel feeding is completed so as to ensure the entry of combustion air through the grate only. e. Use a suitable damper system along with built-in maneuvering wheel for adjusting damper position to control kiln draft. f. Use on-line temperature measurement system for controlling fuel feed. R. Tunnel kiln a. Ensure proper layout of burners for even distribution of heat in the firing zone. b. Arrange the products inside the kiln to ensure uniform heat gain by products. c. Avoid direct impingement of flame on products and furnace lining.
2. Measurement and recording	The industry shall measure and record the following: A. Fuel(s) consumption, production, temperature of kiln in different zones, temperature of exhaust gases, temperature of kiln surfaces, preheat temperatures, residual oxygen (O_2) and carbon monoxide (CO) in flue gases, etc., on daily basis. B. Develop and use suitable logsheet(s) for measurement and recording of key operating parameters. The logsheets would help the industry in (1) assessing energy performance of the furnace and (2) identifying deviations in operating parameters to undertake corrective measures.
3. Maintenance and inspection	The industry shall: A. Undertake repair and maintain required dimensions of coal combustion chamber/grate of downdraft kiln before beginning the new batch. B. Undertake maintenance of burner assembly in tunnel kiln as per recommendations of the supplier. C. Maintain regularly the kiln surfaces to repair deteriorated surfaces due to wear and tear with good quality insulation to avoid heat losses on half yearly basis. D. Inspect and clean chimney base, main flue path, and side flue path for any obstructions or blockage on half-yearly basis. E. Undertake calibration and maintenance of instruments as per recommendations of suppliers to record reliable and accurate data. Maintain proper record of calibration and calibration plans for all key instruments.

4. Necessary measures when installing new facilities	The industry shall consider the following: A. Provide proper length for preheating and cooling zones in tunnel kilns to minimize heat losses and gradual cooling of products. B. Minimize dead mass in cars of tunnel kilns using low thermal mass system. C. Select built-in automation system for new tunnel kilns. D. Use fluidized bed gasification system to utilize rejected coal dust for either generating hot air for moisture removal from green refractory or power generation through micro turbine. E. Adopt measures to recover and reuse sensible heat from flue gases in downdraft kilns. F. Use high alumina balls and internal lining to achieve consistent quality of the material in ball milling. G. Use solar photovoltaic system to meet part or full connected electrical load.
Target components	
	The industry shall ensure the following: A. Specific energy consumption of about 0.74 toe per tonne of refractory production. B. Target air ratio as specified in Table 6.46. C. Ensure external surface temperature in the range 70 °C–120 °C. D. Exit flue gas temperature in the range of 200 °C–250 °C.

Table 6.46: Air ratio for refractory kilns

Parameter	Kiln type	Air ratio of Coal[@]
Standard	Downdraft kiln	1.50–1.65
	Tunnel kiln	1.35–1.40
Target	Downdraft kiln	1.40–1.55
	Tunnel kiln	1.32–1.38

Source: Based on data from different industries

@ *Air ratio is defined as the ratio of actual air supplied (AAS) to the theoretical air requirement. The air ratio is considered based on steady-state operations at constant load conditions. It can be measured and verified at specific measurement points while maintaining the maximum permissible limit for carbon monoxide (CO) level at 200 ppm. The air ratio shall be estimated using the following formula:*

$$\text{Air ratio} = \frac{21}{21 - \%\text{ oxygen in flue gases}}$$

Table 6.47: Surface temperatures of kilns

Parameter	Kiln type	Surface temperature (°C)[#]	
		Ceiling	Side wall
Standard	Downdraft kiln	150	100
	Tunnel kiln	120	80
Target	Downdraft kiln	120	80
	Tunnel kiln	100	70

Source: Based on data from different industries

Average skin temperature under steady-state operation

6.8.4 Common monitorable parameters and performance assessment

The industry shall monitor common performance indicators as given in Table 6.48 to assess the performance of kilns.

Specific energy consumption

The industry shall evaluate the SEC of the kiln using the following formula to assess the performance:

$$\text{Specific energy consumption (kcal/kg)} = \frac{\text{Total energy consumption (kcal)}}{\text{Quantity of material processed (kg)}}$$

Total energy consumption (kcal) = Fuel consumption (kg) × Gross calorific value (kcal/kg)

Table 6.48: Common monitorable parameters in the kiln

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Furnace temperature	°C	Thermocouple	Hourly
Air ratio	kg/kg fuel	Flue gas analyser	Hourly
Flue gas temperature	°C	Thermocouple	Hourly
Surface temperature	°C	Thermocouple	Daily
Production in downdraft kiln	kg	Electronic balance	Batch-wise
Production in tunnel kiln	kg	Electronic balance	Daily
Fuel consumption	kg	Electronic balance	Daily

The industry shall refer to the typical performance indicators of refractory industry as given in Table 6.49.

Table 6.49: Typical performance indicators for refractory industry

Parameter	Specific energy consumption
Refractory brick	0.74–1.76 toe per tonne

Source: Based on data from different industries

6.8.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimization of the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall ensure good and consistent quality of refractory for firing in the kiln to improve yield.
2. The industry shall periodically check and ensure correct dimensions of moulds to avoid rejections.
3. The industry shall adopt an appropriate drying process for the green refractory to avoid breakage during drying.
4. The industry shall install eco natural ventilators to enhance drying process.
5. The industry shall maximize the collection of wastes from moulding areas for potential reuse.
6. The industry shall not overheat or underheat to enhance productivity.
7. The industry shall avoid spillage of fuels to reduce wastage.

CERAMIC INDUSTRY

6.9 Ceramic industry

6.9.1 Background

The ceramic industry is one of the energy intensive industries under micro, small and medium enterprise (MSME) sector. Ceramic products are characterized by high physical strength, chemical and wear resistance, and resistance to heat, fire and electricity. The main products manufactured in the industry include tile, sanitary-ware, pottery-ware, and technical ceramics (Table 6.50).

Table 6.50: Main products in ceramic industry

Category	Primary products
Tile	Wall tile, floor tile, vitrified tile
Sanitary-ware	Lavatory bowl, bidet, wash basin, cistern
Pottery	Tableware, crockery, earthenware, fine stoneware
Technical ceramic	Components for aerospace and automotive industries, electronics industry, biomedical, electrical insulator

The ceramic products are produced through both continuous and batch processes. While batch production process limits the capacity of the kilns, continuous process based industries have large production capacities and use machinery for (semi) automation processes.

6.9.2 Production process

The process requires both electrical and thermal energy at different stages of production. The major process steps in the production of ceramic products include body mould preparation, body mass preparation, shaping, drying, glazing, and firing (Figure 6.12).

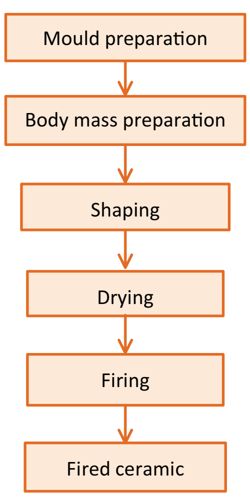

Figure 6.12: Ceramic production process

Mould preparation

Most of the ceramic products are shaped using dies, which are normally outsourced and kept ready in stock for use. Mould is used in slip casting during forming process for sanitary-ware and jigger machine for smaller ceramic products such as kitchen-ware. These are either made of Plaster of Paris (POP) or polymer. Pre-shaped pattern is used to make green moulds, which are strengthened through controlled heating and drying in a kiln.

Body mass preparation

Batches of coarser size raw materials are reduced to desired mixture of target size through crushing, grinding, sieving, and magnetic separation by following wet or dry body preparation methods to produce final body mix or slip. The body mass preparation is dry or wet process. In the dry process, the batch material is dry milled in a hammer mill or a pendular type mill. In wet process, the batch material is wet milled in a ball mill by mixing with water. The final slip of the desired particle size is screened to remove unwanted particulate matters and kept in agitating tank in which de-flocculants are added to avoid sedimentation of slurry. The material is passed through filter press to get rid of soluble salts and excess water to make a plastic body mix. Based on requirements, the moisture content of the body mix is reduced before pugging or directly fed into a pan or pug mill for de-aeration. The de-aerated body mass is transferred to casting areas.

Shaping

The products are shaped using pressing, extrusion, moulding, slip casting, tape casting, or fusion casting. Hydraulic press is common among ceramic industry. It is suitable for a wider product range (e.g. glazed/unglazed, single/double fired, and small/large size). In wet shaping, slip casting is done wherein clay mixture/body mass is poured into the mould under manual supervision. For kitchen-ware, shaping is done either through pressing or manual moulding. Pressing is done using jigger machine.

Drying

The green products are stacked on the kiln cars and dried using hot waste gases directed from the kiln. The green products are dried and allowed to cool down to room temperature naturally. The ceramic products are screened through on-line sorting followed by hammer test, brushing and water spraying before glazing.

Firing

The dried ceramic products are fired in a kiln to obtain thermally consolidated dense cohesive body at a temperature of 1150 °C–1250 °C. The ceramic industry uses either continuous kiln (tunnel kiln) or intermittent type kiln (shuttle kiln) for firing of ceramic products. The types of kilns used in ceramic industry and their production capacity are given in Table 6.51.

Table 6.51: Capacities of kilns in ceramic industry

Type	Capacity
Tunnel kiln	4–20 tonnes per day
Shuttle kiln	0.5–6.0 tonnes per batch

6.9.3 Process equipment

The process equipment in a ceramic industry comprises raw material processing and firing kiln. Crusher, pulveriser, ball mill, muller mixer, press, etc. are the commonly used equipment in raw material processing. In the processing of the raw material, only electrical energy is used. The kiln is the major thermal energy consuming system in a ceramic industry. The thermal energy requirement in the kiln is met through combustion of fuels such as coal, oil and natural gas. The industry shall improve the energy performance, that is, reduce specific energy consumption (SEC) level of the kiln by optimizing various operating parameters. These include reduction in various losses through routine inspection and maintenance and keeping key operating parameters within specified limits. This section provides EC Guidelines covering best operating practices, operational aspects and performance assessment for kilns used in ceramic industries in a rational way.

Standards components	
1. Management and control	The applicable common EC Guidelines for raw material processing and the kiln are provided below. A. Use correct and consistent quality of raw materials. B. Operate ball mill at the optimum loading point to minimize specific energy consumption. C. Use grinding media of mixed sizes for efficient grinding. D. Switch off conveyor used to carry the raw material when not in use. E. Use timer switches for switching off automatically on completion of grinding process. F. Ensure automatic switching off of ball mill, plunger, etc. upon achieving the required grain size of the slurry to avoid unnecessary running. G. Maintain required moisture content in the powdered raw material to ensure proper processing in plastic shaping. H. Maintain suitable pressure settings in press machine based on the type of products. I. Install variable frequency drive (VFD) on hydraulic motor of press and induced draft fan of spray dryer to minimize electricity consumption. J. Maintain temperature of kiln as per product requirements. Avoid overheating or underheating of products to minimize rejections. K. Use sufficient number of temperature indicators both at wall and at roof of kiln to ascertain temperature profile across the kiln. L. Ensure better resolution of measuring instruments for accurate measurements.

	M. Maintain correct air ratio in tunnel kiln/shuttle kiln based on the type of fuel(s) used as provided in Table 6.52 as standard value. It shall use a suitable oxygen analyser of on-line or portable type analyser for monitoring O_2 level. Adjust and control air ratio to ensure complete combustion of the fuel. N. Retrofit kilns with automatic air fuel ratio control system and integrate with control loop system. Install appropriate combustion equipment capable of regulating and controlling fuel supply automatically in line with load changes. Modify suitably the air train to regulate combustion air flow and kiln draft automatically. O. Maintain a slight positive pressure inside the kiln. P. Adopt measures to use high temperature of flue gases for drying or preheating of green product. Q. Maintain external temperature of kiln surfaces within the range as specified in Table 6.53 as standard value. Adopt various measures to improve thermal insulation of the kiln. These include suitable thickness of insulation, low thermal conductivity insulating materials, etc. R. Minimize the dead mass of kiln car that is used for carrying ceramic products inside the kiln. S. Ensure proper layout of burners for even distribution of heat in the firing zone. T. Avoid direct impingement of flame on products to avoid overheating. U. Arrange the products inside the kiln to ensure uniform heat gain by the products. V. Avoid direct impingement of flame on the refractory surface (both roof and side walls), which will otherwise lead to increased maintenance and reduced life of kiln. W. Install vacuum dust collector to avoid wastage of the raw material.
2. Measurement and recording	The industry shall measure and record the following: A. Fuel(s) consumption, production, temperature of kiln in different zones, temperature of exhaust gases, preheat temperatures, residual oxygen (O_2) and carbon monoxide (CO) in flue gases, kiln draft, etc. on daily basis. B. Temperatures of different kiln surfaces on daily basis to undertake remedial actions. C. Use suitable logsheet(s) for measurement and recording of key operating parameters. The logsheets would help the industry in (1) assessing energy performance of the kiln and (2) identifying deviations in operating parameters to undertake corrective measures.

3. Maintenance and inspection	The industry shall: A. Check and clean the burner nozzles when temperature variations are observed within the firing zone of the kiln. B. Maintain regularly the kiln surfaces to repair deteriorated surfaces due to wear and tear with good quality insulation to avoid heat losses. C. Undertake regular maintenance of blower impeller based on the recommendations of the OEM to ensure adequate delivery of combustion/cooling air in the kiln. D. Undertake calibration and maintenance of instruments as per recommendations of suppliers to record reliable and accurate data. Maintain proper record of calibration and calibration plans for all key instruments.
4. Necessary measures when installing new facilities	A. Provide proper length for preheating and cooling zones in tunnel kilns to minimize heat losses and gradual cooling of products. B. Select appropriate combustion equipment and accessories, for example, burner with high turndown ratio, built-in kiln automation system, etc. C. Adopt suitable preheating, firing, soaking, and cooling cycles in shuttle kiln to minimize energy consumption. D. Use high alumina balls and internal lining with alumina material to achieve consistent quality of material in ball milling. E. Switch over to piped natural gas if available for achieving energy efficiency and maintaining better uniformity of temperature during firing cycle resulting in quality yield.
Target components	
	The industry shall ensure the following: A. Achieve product to kiln furniture ratio of 1:2 or less. B. Hot face insulation using ceramic fibre of 1.0–1.3 gm per cm^3 density. C. Target air ratio maintained as specified in Table 6.52. D. External surface temperature in the range 70 °C–120 °C. E. Exit flue gas temperature in the range of 200 °C–250 °C.

Table 6.52: Air ratio for ceramic kilns

Parameter	Kiln type	Air ratio@	
		Liquid fuel	Gas fuel#
Standard	Tunnel kiln	1.26–1.33	1.15–1.18
	Shuttle kiln	1.26–1.33	–
Target	Tunnel kiln	1.18–1.24	1.12–1.15
	Shuttle kiln	1.18–1.24	–

Source: Based on data from different industries

\# *Refers to natural gas (NG) only*

@ *Air Ratio is defined as the ratio of actual air supplied (AAS) to the theoretical air requirement. The air ratio is considered based on steady-state operations at constant load conditions. It can be measured and verified at specific measurement points while maintaining the maximum permissible limit for carbon monoxide (CO) level at 200 ppm. The air ratio shall be estimated using the following formula:*

$$\text{Air ratio} = \frac{21}{21 - \%\ \text{oxygen in flue gases}}$$

Table 6.53: Surface temperatures of kilns

Parameter	Kiln type	Surface temperature (°C)#	
		Ceiling	Side wall
Standard	Tunnel kiln	120	80
	Shuttle kiln	120	100
Target	Tunnel kiln	100	70
	Shuttle kiln	100	80

***Source**: Based on data from different industries*

#Average skin temperature under steady-state operation

6.9.4 Common monitorable parameters and performance assessment

The industry shall monitor common performance indicators as given in Table 6.54 to assess the performance of kilns.

Specific energy consumption

The industry shall evaluate the SEC of the kiln using the following formula to assess the performance:

$$\text{Specific energy consumption (kcal/kg)} = \frac{\text{Total energy consumption (kcal)}}{\text{Quantity of material processed (kg)}}$$

Total energy consumption (kcal) = Fuel consumption (kg) × Gross calorific value (kcal/kg)

6.9.5 Efficient resource utilization

Efficient resource utilization includes an optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for the efficient utilization of resources:

1. The industry shall ensure good and consistent quality of castings for firing in the kiln to improve yield.
2. The industry shall periodically check and ensure correct dimensions of the moulds to avoid rejections.
3. The industry shall adopt an appropriate drying process for the castings to avoid breakage during drying.
4. The industry shall install natural ventilators to enhance drying process.
5. The industry shall maximize the collection of wastes from casting areas for potential reuse.
6. The industry shall inspect and stack only good quality castings for firing in the kiln.
7. The industry shall use correct quantity of colouring chemicals in the process. It shall further recover and reuse colouring chemicals used in the process.
8. The industry shall not overheat or underheat to enhance productivity.
9. The industry shall avoid spillage of fuels to reduce wastage.
10. The industry shall avoid idle running of machines to reduce energy consumption. It shall adopt suitable planning for the production.
11. The industry shall maximize the use of daylighting.

Table 6.54: Common monitorable parameters in the kiln

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Kiln temperature	°C	Thermocouple	Hourly
Air ratio	kg/kg fuel	Flue gas analyser	Hourly
Flue gas temperature	°C	Thermocouple	Hourly
Surface temperature	°C	Thermocouple	Daily
Production	kg	Electronic balance	Daily
Fuel consumption*	kg	Electronic balance	Daily

**Flow meter for natural gas measured in Sm^3*

BRICK

6.10 Brick industry

6.10.1 Background

The clay brick industry is one of the energy intensive industries in micro, small and medium enterprise (MSME) sector. Solid clay brick is the most predominant product from brick industry. The production of clay fired products such as hollow blocks, perforated bricks, etc. is insignificant at present. Brick industry is labour intensive, with only a few industries using semi-automatic or automatic brick processes for brick production.

6.10.2 Production process

The major process steps involved in brick manufacturing include clay winning, clay preparation, green brick moulding, drying, firing, cooling, and unloading (Figure 6.13).

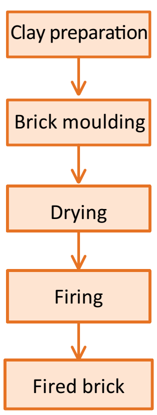

Figure 6.13: Brick production process

Clay winning

The raw material for green brick preparation is clay sourced from agricultural land, de-silted sand from lakes and ponds, etc. Manual excavation of soil is mostly practised, and mechanization is limited in the industry.

Clay preparation

This process ensures homogeneous and workable clay for the shaping process. Clay is separated from gravel, lime, and organic matter. It is puddled, watered, and left over for weathering and subsequent processing. It is followed by kneading of homogenised clay with spade or other manual or mechanical equipment into a plastic mass.

Green brick moulding

Brick is moulded manually using metal, wooden, or plastic moulds. Mechanized clay preparation and moulding processes are used by a few brick industries. The mechanized moulding process uses soft mud moulding, extrusion, or dry press process.

Drying

The green moulded brick contain 7–30% moisture, depending upon the type of moulding. During the drying process, much of the moisture contained in green brick is evaporated either through natural drying or drying in ventilated drying sheds. Natural drying method is the most common method of brick drying.

Firing

Firing is the most energy intensive process in the brick manufacturing. It converts a fairly loosely compacted blend of different minerals into a strong, hard, and stable product. Depending on the nature of clay, bricks are fired in the range 700 °C–1100 °C. Large-scale brick production uses continuous kiln, for example, Bull's trench kiln (BTK) and zig-zag kiln; small-scale brick production uses batch type clamp kiln.

Table 6.55: Typical production capacities of brick kilns

Kiln type	Capacity
Bull's trench kiln/ zig-zag kiln	0.2–0.6 lakh brick per day
Clamp kiln	Up to 1.5 lakh brick per batch

6.10.3 Process equipent

The kiln is the major energy consuming system in a brick industry. The primary energy used in the kiln is thermal energy through combustion of fuels such as coal, biomass, etc. The industry shall improve the energy performance, that is, reduce specific energy consumption (SEC) level of the kiln by optimizing various operating parameters. These include reduction in various heat losses such as flue gas loss, structural heat loss, etc. occurring in the kiln through routine inspection and maintenance and keeping key operating parameters within specified limits. This section provides EC Guidelines covering best operating practices, operational aspects and performance assessment for kiln used in brick industry in a rational way.

Standards components	
1. Management and control	The industry using BTK and zig-zag kiln shalll ensure the following: A. Ensure sufficient supply of combustion air in the kiln for complete combustion of the fuel. Monitor the colour of smoke at the exit of stack to ascertain the condition of combustion. Black smoke indicates incomplete combustion and unburnt formation. Combustion of fuel depends on factors such as air flow, brick stacking pattern, fuel size and fuel feeding frequency, length of preheating, firing and cooling zones. B. Fuel feeding practices Complete combustion of fuel is dependent on sizing and feeding practices along with supply of a sufficient quantity of combustion air. The industry shall adopt the following measures to improve fuel feeding practices: a. Use coal of size from 3/4th to 1 inch for firing in the kiln. Use coal crusher to reduce coal to the required size. b. Adopt fuel feeding in small quantities at regular intervals in place of feeding lumps with large time gap between successive feedings. Use feeding spoons of capacity not more than 750 gm in BTKs and 250–300 gm in zig-zag kiln to ensure complete combustion of fuel. c. Maintain the interval of fuel feeding at 30 minutes to ensure complete combustion of fuel and avoid formation of black smoke. d. Maintain the length of the combustion zone of the kiln as large as possible. i. In case of BTKs, feed the fuel in minimum of 3 lines as against the normal practice of 1 or 2 firing lines at a time. ii. In case of zig-zag kiln, keep longer combustion zone; that is, fuel feeding shall be done in 6 or 7 chambers simultaneously. iii. Use insulated feed-hole covers to reduce heat loss. iv. Use coal or mix-fuel (low-grade carbonaceous materials, wooden chips, saw dust, etc.) of proper ratio to maintain the desired temperature in the combustion zone. Take into account the calorific value, ash content and volatile materials in fuels while using mix-fuel. C. Monitor temperature at preheating, firing, and cooling zones. D. Ensure sufficient length of firing zone for complete burning of volatile materials present in the fuel. E. Ensure sufficient length of preheating zone to utilize the waste heat available in flue gases before entering side flue ducts. F. Ensure a sufficient cross-sectional area of side flue ducts for smooth flow of flue gases. G. Avoid cracks or openings on the side walls of kiln to avoid air ingression and dilution of flue gases. Construct the wicket with a double wall and fill the gap with ash. Air ingression would lead to slow fire travel rate and higher energy consumption. H. Use properly dried green bricks for firing in the kiln. High moisture would lead to higher energy consumption and defective product. I. Monitor fire travel rate on a daily basis to undertake corrective measures to achieve optimum production. J. Maintain the temperature of kiln top surface within the range as provided in Table 6.56 as standard value. K. Maintain a minimum thickness of 10 inch ash layer insulation at the top of stacked bricks to reduce heat losses and leakages from kiln top. L. Use energy efficient fans in case of induced draft zig-zag firing system.

	The industry using clamp kiln shall: A. Consider adding internal fuel (i.e. fuel mixed along with clay during clay preparation process) for complete firing of bricks using a less amount of fuel. Use locally available fuels as internal fuels. B. Plaster external surface of the kiln with clay and cow-dung to reduce heat losses.
2. Measurement and recording	The industry shall measure and record the following: A. Brick production* and fuel consumption (fuel consumption for BTK and fuel and electricity consumption for zig-zag kiln) on daily basis. B. Measure the temperature of firing zone on shift basis. C. Use a suitable logsheet for recording key operating parameters on hourly, daily, and monthly basis as applicable.
3. Maintenance and inspection	The industry shall: A. Undertake regular maintenance of external surfaces, flue ducts, chimney base, etc. B. Inspect and clean chimney base, main flue path, and side flue path for any obstructions or blocking on a regular basis. C. Undertake corrective maintenance in case of a significant drop in pressure head observed in the system. D. Undertake overhauling of fans and blowers according to the instructions provided by the manufacturers. E. Inspect the blower and fan for vibration and noise levels on quarterly basis. F. Ensure dynamic balancing of fans/blowers assembly after each overhauling. G. Calibrate instruments and gauges as per the recommendations of the suppliers to ensure reliability and maintain accuracy of data.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Switch over to energy efficient zig-zag firing. B. Select energy efficient induced draft fan with IE3 motor. C. Switch over to mechanization in material preparation and brick moulding.
Target components	
	The industry shall ensure the following: A. Specific energy consumption of 15–22 tonnes coal per lakh brick#. B. External surface temperature in the range of 50 °C–60 °C.

** Brick production (kg/day)= Number of lines fired per day x Number of bricks per line x Average weight of fired bricks (kg)*

 # Considering GCV of coal as 4500 kcal/kg

Table 6.56: Top surface temperatures of BTK and zig-zag kiln

Parameter	Kiln type	Top surface temperature (°C)#
Standard	Bull's trench kiln	60–80
	Zig-zag kiln	60–80
Target	Bull's trench kiln	50–60
	Zig-zag kiln	50–60

Source: Based on data from different brick kiln units

 # Average skin temperature under steady-state operation

6.10.4 Common monitorable parameters and performance assessment

The industry shall monitor common performance indicators as given in Table 6.57 to assess the performance of the kilns.

The industry shall assess the performance of the kiln using the following formula:

$$\text{Specific energy consumption (tonne coal/lakh brick)} = \frac{\text{Total coal consumption (tonne)}}{\text{Brick production (lakh)}}$$

The industry shall refer to the typical performance indicators of brick industry as provided in Table 6.58.

6.10.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimization of the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall periodically check and ensure correct dimensions of the moulds to avoid rejections. It shall use good quality plastic moulds for hand moulding operation.
2. The industry shall adopt an appropriate drying process for the green bricks to avoid breakage during drying.
3. The industry shall inspect and stack only good quality dried bricks for firing in the kiln.
4. The industry shall maximize the collection of wastes from moulding areas for potential reuse.
5. The industry shall not overheat or underheat to enhance productivity.
6. The industry shall improve firing practices to enhance the production of good quality bricks.
7. The industry shall avoid spillage of fuels to reduce wastage.
8. The industry shall recover and reuse unburnt fuel from bottom ash.
9. The industry using Bull's trench kiln shall use ash collected after firing to improve kiln insulation.
10. The industry shall optimize plant layout so as to ensure location of various processes such as moulding, drying, and firing in such a way that the overall movement of the product is properly synchronized.
11. The industry shall consider using conveyor or motor-driven carts for shifting of bricks inside the plant to reduce manual handling.
12. The industry shall consider using semi-mechanization for production of bricks to ensure good and consistent product quality as well as potential for product diversification.

Table 6.57: Common monitorable parameters in brick kiln

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Kiln temperature in firing zone	°C	Thermocouple	Daily
Flue gas temperature at chimney base	°C	Thermocouple	Daily
Top surface temperature	°C	Infrared thermometer	Daily
Production of fired brick	Number	–	Daily
Weight of fired brick	kg	Electronic balance	Daily
Fuel consumption	kg	Electronic balance	Daily

Table 6.58: Typical performance indicators for brick industry

Performance indicator	Typical range
Specific energy consumption	15–22 tonnes coal per lakh brick

Source: Based on data from different industries

CLAY TILE

6.11 Clay tile industry

6.11.1 Background

The clay tile manufacturing is one of the energy intensive indutries in the micro, small and medium enterprise (MSME) sector. The clay tile industry produces a variety of products such as decorative roof tiles, floor tiles, floral facade tiles, hand rails, wear resistant pavement materials, industrial flooring, etc. Top soil is used as the raw material in clay tile industry.

6.11.2 Production process

Different soils are mixed to obtain required clay quality for moulding.The major process steps involved in clay tile manufacturing include clay winning, clay preparation, green tile shaping/forming (manual/machine moulding), drying, and firing.

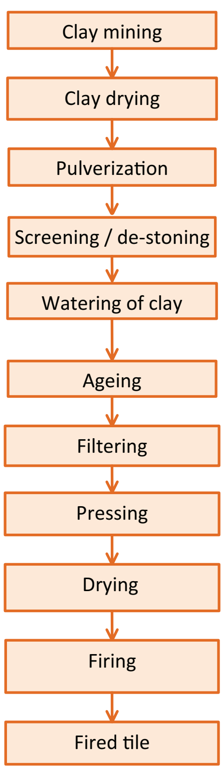

Figure 6.14: Tile manufacturing process

Clay winning

The raw material for green tile preparation is clay sourced from agricultural land, de-silted sand from lakes and ponds, etc. While manual excavation of soil is mostly practised, mechanization is limited in the industry. Mined clays are transported to clay yard in the factory and stored for future use in tile making.

Clay preparation

This process ensures homogeneous and workable clay for the shaping process. The mined clay undergoes crushing, grinding, mixing and screening.Clay is separated from gravel, lime, and organic matter. It is puddled, watered and left over for weathering and subsequent processing. It is followed by kneading of homogenized clay with spade or other manual or mechanical equipment into a plastic mass.

Forming or shaping

The clay is shaped using hand moulding, extrusion, pressing, etc. In hand moulding, tile is moulded manually using metal or wooden moulds. Mechanized moulding process is commonly used in tile industry. The mechanized shaping uses extrusion or dry press process.

Drying

The moisture in manually moulded green tile is removed using natural drying either in open sun or racks. Ventilated drying shed is used for machine moulded products.

Firing

Firing is the process of vitrification and strengthening at about 700 °C–1100 °C depending on type of clay. Tiles are fired in Hoffmann kiln. The typical production capacity of Hoffmann kiln is provided in Table 6.59.

Table 6.59: Production capacities in clay tile industry

Type	Capacity
Hoffmann kiln	15,000 tiles per day

6.11.3 Process equipment

The kiln is the major energy consuming system in a clay tile industry. The main fuels used are coal, biomass, petcoke, diesel, furnace oil, etc. The industry shall improve the energy performance, that is, reduce specific energy consumption (SEC) level of the kiln by optimizing various operating parameters. These include reduction of various heat losses such as flue gas loss, structural heat loss, etc., occurring in the kiln through routine inspection and maintenance and keeping key operating parameters within specified limits. This section provides EC Guidelines covering best operating practices, operational aspects, and performance assessment for kiln used in clay tile industry in a rational way.

Standards components	
(1) Management and control	The industry shall consider the following: A. Ensure sufficient supply of combustion air in the kiln for complete combustion of fuel. Monitor the colour of smoke at the exit of stack to ascertain the condition of combustion. Black smoke indicates incomplete combustion and unburnt formation. B. Feed fuel continuously in small quantities at regular intervals in place of feeding lumps with large time gap. C. Keep the interval of fuel feeding between 1½–2 hours to ensure complete combustion of fuel and avoid formation of black smoke. D. Keep the feeding hole closed after fuel feeding is completed so as to ensure the entry of combustion air through the grate only. E. Use suitable damper system along with built-in manoeuvering wheel for adjusting damper position to control kiln draft. F. Use on-line temperature measurement system for controlling fuel feed. G. Ensure no crack or opening on the side walls to avoid air ingression and dilution of flue gases. Air ingression would lead to slow fire travel rate and higher energy consumption. H. Stack dried tiles for firing in the kiln. High moisture would lead to higher energy consumption and defective product. I. Monitor the temperature of firing chamber and avoid over-heating. J. Maintain external temperature of kiln top surface within the range as provided in Table 6.60 as standard value. Undertake thermal insulation work of the kiln by providing suitable insulation bricks. K. Ensure better resolution of measuring instruments for accurate measurements.
2. Measurement and recording	The industry shall measure and record the following: A. Fuel consumption and number of chambers fired on daily basis. B. Measure the temperature of firing chamber on shift basis. C. Temperatures of kiln surfaces once in a week to undertake remedial action. D. Use a suitable logsheet for recording key operating parameters on hourly, daily, and monthly basis as applicable.
3. Maintenance and inspection	The industry shall: A. Undertake regular maintenance of external surfaces, flue ducts, chimney base, etc. B. Inspect and clean chimney base, main flue path, and side flue path for any obstructions or blocking on a regular basis. C. Calibrate instruments and gauges as per the recommendations of the suppliers to ensure reliability and maintain accuracy of data. D. Maintain the kiln surfaces and undertake repair of deteriorated surfaces on a regular basis due to wear and tear with good quality insulation to avoid heat losses.

Standards components	
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Switch over to continuous type kilns such as tunnel kiln. B. Replace standard motors with energy efficient IE3 motors for a variety motive applications in raw material handling and moulding.
Target components	
	The industry shall ensure the following: A. Specific energy consumption 1.25–2.0 tonne wood per chamber with standard capacity of 6,000 tiles. B. Ensure external surface temperature in the range 50 °C–60 °C.

Table 6.60: Surface temperatures of kilns in clay tile industry

Kiln	Parameter	Top surface temperature (°C)#
Hoffmann	Standard	60–80
	Target	50–60

Source: Based on data from different industries

#Average skin temperature under steady state operation

6.11.4 Common monitorable parameters and performance assessment

The industry shall monitor common performance indicators as shown in Table 6.61 to assess the performance of the kilns.

The industry shall assess the performance of the kiln using the following formula:

$$\text{Specific energy consumption (tonne wood/chamber)} = \frac{\text{Total wood consumption (tonne)}}{\text{Number of chambers fired}}$$

Wood consumption (tonne) = Wood consumption per chamber × Number of chambers fired

Table 6.61: Common monitorable parameters in clay tile kiln

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Kiln temperature in firing zone	°C	Thermocouple	Daily
Flue gas temperature at chimney base	°C	Thermocouple	Daily
Top surface temperature	°C	Infrared thermometer	Daily
Production of clay tiles	Number	-	Daily
Weight of fired tile	kg	Electronic balance	Daily
Fuel consumption	kg	Electronic balance	Daily

Table 6.62: Typical performance indicators for clay tile industry

Performance indicator	Typical range
Specific energy consumption	1.25–2.0 tonne wood per chamber*

Source: Based on data from different industries

*Capacity of chamber = 6000 standard clay tiles

The industry shall refer to the typical performance indicators of clay tile industry as provided in Table 6.62.

6.11.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall periodically check and ensure correct dimensions of the moulds to avoid rejections.
2. The industry shall adopt appropriate drying process for the green tiles to avoid breakage during drying.
3. The industry shall inspect and stack only good quality dried tiles for firing in the kiln.
4. The industry shall use suitable shed with natural ventilators to enhance drying process.
5. The industry shall maximize the collection of wastes from moulding section for potential reuse.
6. The industry shall not overheat or under-heat to enhance productivity.
7. The industry shall improve firing practices to enhance the production of good quality tiles.
8. The industry shall avoid spillage of fuels to reduce wastage.
9. The industry shall recover and reuse unburnt fuel from bottom ash.

GLASS

6.12 Glass industry

6.12.1 Background

The glass industry is one of the energy intensive industry sectors covered under micro, small, and medium enterprises (MSME) sector. The glass products produced by the industry include container glass, float glass, sheet glass, fibre glass, domestic glass, and speciality glass.The major indusrial end-user of glass products include automobile industries and construction sector.

6.12.2 Production process

The glass industry uses both continuous and batch processes. Thermal energy accounts for about a major share of energy consumption. The main steps in glass manufacturing process include batch preparation, melting and refining, conditioning, shaping and forming, heat treatment (annealing), and finishing operations (Figure 6.15).

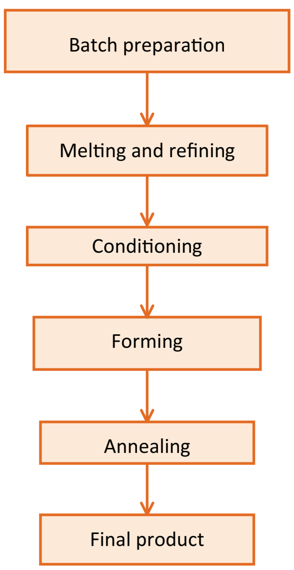

Figure 6.15: Process flow in glass industry

Batch preparation

The commonly used raw materials in glass production include silica sand, soda ash, calcium carbonate, and cullets (recycled glass).

Glass melting

Glass melting involves an end-fired furnace (tank furnace) for large capacities continuous melting. The molten glass is distributed to the shaping end through refiner zone after removing air bubbles. The smaller capacity industries use pot furnaces. The temperature of the glass melt is maintained at about 1400 °C–1450 °C. The capacities of furnaces used in glass industries are provided in Table 6.63.

Table 6.63:Capacities of glass melting furnaces

Type	Capacity (tonne per day)
Tank furnace	25–200
Pot furnace	4–7

Shaping and forming.

Depending on product line, melt glass is shaped in automatic press, blowing machine, mouth blowing or manual process. The smaller glass bangle manufacturing units use reheating furnaces to increase handling temperature before shaping process. The details of reheating furnaces is shown in Table 6.64.

Table 6.64:Details of reheating furnaces in glass bangle units

Parameter	Value
Furnace temperature	1200 °C
Flue temperature	500 °C
Fuel used	Natural gas

Decoration

The glass products are subjected to various decorative operations like cutting, painting, embossing, etc., as per the requirements. The products are further heat treated before finishing.

Heat treatment

The annealing lehr is used for removal of stresses in glass products through gradual heating, soaking, and cooling. The details of annealing lehr are provided in Table 6.65.

Table 6.65: Details of annealing lehr

Parameter	Annealing lehr	Muffle furnace
Temperature	500 °C–1000 °C	About 900 °C
Exhaust	Less than 50 °C	400 °C–500 °C
Fuel used	Natural gas	Coal, Natural gas

6.12.3 Proces equipment

The furnace is the major energy consuming centre in a glass industry. The primary energy use in the furnace is thermal energy through combustion of fuels, such as oil or gas. The industry shall improve the energy performance, that is, reduce specific energy consumption (SEC) level of the furnace by optimizing various operating parameters. These include reduction of various heat losses such as flue gas loss, structural heat loss, etc., occurring in the furnace through routine inspection and maintenance and keeping key operating parameters within specified limits. This section provides EC Guidelines covering best operating practices, operational aspects, and performance assessment for furnaces used in glass industries in a rational way.

Standards components	
1. Management and control	The industry shall: A. Process temperature a. Maintain furnace temperature as per the requirements. Avoid overheating of melt to prevent energy losses. b. Use sufficient number of temperature indicators to monitor the temperature profile across the furnace. B. Air ratio a. Maintain suitable air ratio based on type of fuel and its composition as specified as standard value in Table 6.66. Ensure complete combustion of fuel and avoid formation of unburnts. Use online or portable oxygen (O_2) analyser for monitoring. b. Minimize air ingression using suitable measures such as minimizing openings, proper sealing, etc. c. Maintain slight positive draft in the furnace. d. Retrofit suitable automatic air fuel ratio control system in each combustion equipment, and integrate with control loop system, if not already installed. e. Install on-line measurement and recording equipment to monitor and control key operating parameters. C. Flue gas temperature a. Minimize exhaust flue gas temperatures based on WHR recovery rate* shown in Table 6.67. Install suitable waste heat recovery (WHR) system(s) such as air preheater, charge preheater, etc., based on waste heat available and type of application. b. Monitor temperature of exhaust gases and WHR media using on-line or portable instrumentation.

	D. Surface temperature a. Maintain external temperature of furnace surfaces within the range as provided in Table 6.68. b. Undertake hot face thermal insulation using insulating material having low thermal conductivity. E. Ensure better resolution of measuring instruments for accurate measurements. F. Use either automatic or portable system for temperature monitoring.
2. Measurement and recording	The industry shall measure and record the following: A. Fuel consumption, quantity of charge material, temperature of furnace, exhaust gases, preheated air/charge material, surfaces, residual oxygen (O_2) and carbon monoxide (CO) in flue gases. B. The frequency of recording shall be hourly, shift basis, daily, weekly or monthly based on type of data. C. Develop and use suitable logsheet(s) for measurement and recording of key operating paramaters. The logsheets would help the industry in: (1) assessing energy performance of the furnace and (2) identifying deviations in operating parameters to undertake corrective measures.
3. Maintenance and inspection	The industry shall: A. Undertake calibration and maintenance of instruments as per recommendations of suppliers to record reliable and accurate data. B. Undertake proper lining or repair work of the furnace on a periodical basis or during shutdown. C. Repair, renovate, and maintain the WHR systems and ensure optimum performance. D. Undertake calibration and maintenance of instruments as per recommendations of suppliers to record reliable and accurate data. Maintain proper record of calibration and calibration plans for all key instruments.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Select appropriate combustion equipment and accessories for efficient operation. B. Use apporiate heat recovery system for reheating furnace. C. Use high quality regenerative checker for optimimum heat recovery.
Target components	
	The industry shall ensure the following: A. Specific energy consumption in tank furnace is 120–170 of NG Sm^3 per tonne of melt. B. Specific energy consumption in pot furnace is 300–350 of NG Sm^3 per tonne of melt. C. Target air ratio of furnaces as specified in Table 6.66. D. External surface temperature in the range of 80 °C–120 °C. E. Exit flue gas temperature in the range of 150 °C –250 °C for induced draft system and 250 °C–300 °C for natural draft system.

** Note:*

1. *Waste heat recovery rate is the ratio of heat recovered to the sensible heat available in exhaust gases under rated load operation.*
2. *Air-preheater (APH) is a device used to preheat the combustion air at ambient temperatures to higher levels by extracting waste heat from flue gases.*
3. *Charge preheater (CPH) may be used to preheat the charge material, for example, cullets (recycled broken or waste glass used in glass making).*

Table 6.66: Air ratio for furnaces in glass industry

	Furnace type	Air ratio@	
		Liquid fuel	Gas fuel#
Standard	Tank furnace	1.18–1.23	1.14–1.17
	Melting furnace	1.18–1.23	1.14–1.17
	Annealing lehr	1.18–1.23	1.14–1.17
	Reheating furnace	1.18–1.23	1.14–1.17
Target	Tank furnace	1.15–1.20	1.12–1.15
	Melting furnace	1.15–1.20	1.12–1.15
	Annealing lehr	1.15–1.20	1.12–1.15
	Reheating furnace	1.15–1.20	1.12–1.15

Source: Performance data from different industries

Refers to natural gas (NG) only

@ *Air ratio is defined as the ratio of actual air supplied (AAS) to the theoretical air requirement. The air ratio is considered based on steady-state operations at constant load conditions. It can be measured and verified at specific measurement points while maintaining maximum permissible limit for carbon monoxide (CO) level to 200 ppm. The air ratio shall be estimated using the following formula:*

$$\text{Air ratio} = \frac{21}{21 - \%\text{ oxygen in flue gases}}$$

Table 6.67:Waste heat recovery in glass industry

Furnace type	Exhaust gas temperature (°C)	Waste heat recovery rate (%)		Flue gas temperature* (°C)
		Standard$^{\alpha}$	Target$^{\beta}$	
Tank furnace	1200–1300	47	57	150–250
Pot furnace	800–1000	37	49	250–300
Reheating furnace	600–800	30	45	250–300

Source: Based on data from different industries

α *Estimated heat drop based on the upper limit of gas temperatures and net heat transfer with 60% efficiency for heat exchanger*

β *Estimated heat drop based on the lower limit of gas temperatures and net heat transfer with 65% efficiency for heat exchanger*

* *Considering natural draft systems for higher flue gas temperature and induced draft system for lower temperatures*

The industry shall compute waste heat recovery (WHR) rate using the following formula:

$$\text{Waste heat recovery rate (\%)} = \frac{\text{Recovered heat (kcal)}}{\text{Sensible heat in exhaust gases (kcal)}} \times 100$$

Table 6.68:Surface temperatures of industrial furnaces

	Furnace type	Furnace temperature (°C)	Surface temperature (°C)#	
			Ceiling	Side wall
Standard	Tank furnace	1450	150	100
	Pot furnace	Upto1400	150	100
	Reheating furnace	Upto 1000	150	120
Target	Tank furnace	1450	120	80
	Pot furnace	Upto1400	120	80
	Reheating furnace	Upto 1000	120	80

Source: Based on data from different industries

Average skin temperature under steady state operation

6.12.4 Common monitorable parameters and performance assessment

The industry shall monitor common performance indicators as shown in Table 6.69 to assess the performance of the glass melting furnaces.

The industry shall assess the performance of the furnace using the following formula:

$$\text{Specific energy consumption (Sm}^3\text{/tonne)} = \frac{\text{Total fuel consumption (Sm}^3\text{/day)}}{\text{Quantity of raw material (tonne/day)}}$$

The industry shall refer to the typical performance indicators of glass production as provided in Table 6.70.

6.12.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall use consistent quality of raw materials for producing glass melt.
2. It shall minimize the use of fluxing agent by using good quality raw materials.
3. The industry shall collect and reuse glass wastes or cullets to minimize energy consumption for glass production.
4. The industry shall maximize use of cullets of consistent quality either in-house or outsourced for melting.
5. The industry shall collect cullets formed during various processes to reuse in melting at the maximum possible temperature for reducing energy consumption.
6. The industry shall keep optimum distance between melting furnace and other process sections to avoid chilling of melt.
7. The industry shall use appropriate tools in finishing operations to improve product quality and reduce rejections.
8. The industry shall arrest leakages from compressed air lines to reduce power consumption.
9. The industry shall use compressed air only at required pressure to optimize energy consumption. Use of compressed air at high pressures would increase energy consumption.
10. The industry shall use airguns in place of compressed air for requirements of air at low pressures.

Table 6.69: Common monitorable parameters in glass melting furnaces

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Furnace temperature	°C	Thermocouple	Hourly
Air ratio	kg/kg fuel	Flue gas analyser	Hourly
Flue gas temperature	°C	Thermocouple	Daily
Surface temperature	°C	Thermocouple	Daily
Fuel consumption	Unit*	Flow meter	Daily
Raw material processed	kg	Electronic balance	Daily

* *litre for liquid fuel and Sm³ for natural gas.*

Table 6.70: Typical performance indicators for glass production

Furnace type	Specific energy consumption
Tank furnace	120–170 Sm^3 NG per tonne melt
Pot furnace	300–350 Sm^3 NG per tonne melt

Source: Based on data from different industries

CHEMICALS AND DYES

6.13 Chemicals and dyes industry

6.13.1Background

The chemicals and dyes industry is one of the energy intensive industries under micro, small, and medium enterprises (MSME) sector. In the chemicals and dyes industry, two broad colouring products are dyes and pigments. The dyes are used as colour substrates to textiles, paper, and other substances. Pigments are used for colouring paints, inks, cosmetics, and plastics. The industry uses both thermal energy and electrical energy for the production processes.

6.13.2 Production process

The generic process steps for manufacturing dyes and pigments include batch preparation, slurry formation through chemical reaction, filtration, drying, pulverization, classification, and ball milling/ blending (Figure 6.16). The slurry of batch material is prepred either in reaction vessel or through coupling reaction. It is transferred to spray dryer or filter press to produce granule or wet cake, respectively. Wet cake is dried in tray dryer. The dried products are pulverized, classified, and grinded or blended as per requirement of the final product.

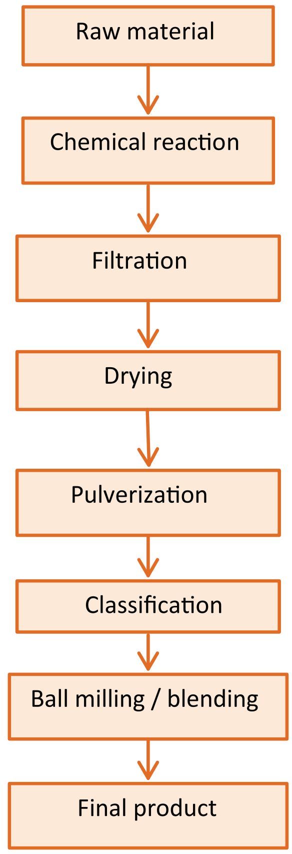

Figure 6.16: Production process in dyes and chemicals industry

6.13.3 Process equipment

The major form of energy use is thermal and electricity. Thermal energy is used in boiler, thermic fluid heater (TFH), hot air generator (HAG), etc., which is met through combustion of fuels such as coal, oil, natural gas, biomass, etc. The industry shall improve the energy performance, that is, reduce specific energy consumption (SEC) level of boiler, TFH, HAG, etc. by optimizing various operating parameters. These include reduction of various heat losses in boiler, TFH, and HAG through routine inspection and maintenance as prescribed by the OEMs.This section provides EC Guidelines covering best operating practices, operational aspects and performance assessment for fuel fired process utility such as boiler, TFH, HAG, etc., used in dyes and chemicals industries in a rational way.

Standards components	
1. Management and control	The industry shall: A. Maintain correct air ratio in boiler, thermic fluid heater (TFH), and hot air generator (HAG) as specified as standard value in Table 6.71. Use suitable oxygen (O_2) analyser (on-line or portable type) to monitor the air ratio. Adjust and control air ratio to avoid high excess air while ensuring complete combustion of fuel. B. Use automatic air-fuel ratio control system in the combustion system and integrate with control loop. C. Install blower having suitable capacity and correct air pressure. Avoid over-sized or under-sized blower. D. Install blower close to the combustion equipment to avoid transmission loss. E. Monitor material to liquor ratio to optimize water and energy consumption levels in reaction vessel. F. Monitor the temperature of reaction vessel and the system shall be switched off on completion of the reaction using control system. G. Minimize heat losses through air ingression by adopting suitable measures such as minimizing size of opening, proper sealing of furnace, etc. H. Use on-line or portable instrumentation for monitoring temperature of exhaust gases and preheated air temperature. I. Reduce exhaust flue gas temperature using suitable WHR system and maintain flue gas temperature as specified in Table 6.72 as standard value. Install suitable WHR system based on waste heat available and type of application. J. Carry out blowdown to maintain the level of total dissolved solids (TDS) in boiler water as recommended by OEM. K. Manage recovery and reuse of waste heat in condensate return according to the instructions concerning parameters, such as the quality and quantity of condensate, temperature, etc., in case of using boiler. Reuse of condensate helps in reducing water treatment and blowdown requirements. An effective condensate recovery system improves boiler efficiency. L. Maintain external skin temperatures of boiler, TFH, HAG, etc. within the range as specified in Table 6.73 as standard value. M. Undertake thermal insulation work on different systems such as steam and condensate pipes, ducts, equipment (TFH and HAG), etc., which are used for transporting heat media either through steam or hot fluid according to the industrial standard practices for thermal insulation works and equivalent standards. N. Maintain appropriate quality of feedwater in boiler according to Indian Boiler Regulations (IBR), 1950 or an equivalent standard as suggested by the manufacturers. O. Use dry steam from boiler in heating processes to enhance heat transfer. Close steam flow to the process when it is not in operation. Use appropriate steam separator or steam trap to maintain the required dryness fraction of steam. P. Maintain proper draft in combustion equipment using proper damper setting in flue gas path. Q. Ensure proper pre-heating of furnace oil to reduce the viscosity level in case of using furnace oil based combustion system. R. Ensure synchronization of switching off of both fuel supply and air supply (blower) upon reaching set temperature in boiler and TFH. S. Use either automatic system or portable temperature indicators to monitor temperatures. T. Ensure better resolution of measuring instruments for accurate measurements.

2. Measurement and recording	The industry shall measure and record the following: A. Fuel consumption, residual oxygen (O_2), and carbon monoxide (CO) in flue gases, and unburnt carbon in bottom ash and fly ash for solid fuels, preheat air temperature, exhaust gas temperature, etc., on daily basis. Monitor the following parameters on periodical basis: a. Boiler- steam generation, pressure, feedwater temperature and total dissolved solids (TDS), temperature and quantity of condensate, surface temperature. b. TFH- thermic fluid circulation rate, pressure, supply and return temperature of fluid, surface temperature. c. HAG- Hot air volume, supply temperature, surface temperature. B. Use suitable logsheet(s) for measurement and recording of key operating paramaters. The frequency of recording shall be hourly, shift basis, daily, weekly or monthly based on requirements. The logsheets would help the industry in: (1) assessing energy performance and (2) identifying deviations in operating parameters to undertake corrective measures.
3. Maintenance and inspection	The industry shall: A. Maintain components related to the heat transfer of equipment, such as heat-transfer surfaces, heat exchangers, etc., according to the instructions as specified by the suppliers. Clean the equipment periodically as per the instructions to get rid of soot, scale or dirt to avoid deterioration of heat transfer surfaces and performance. B. Repair, renovate, and maintain the WHR systems in flue path once in six months to avoid scale formation and ensure optimum performance. C. Inspect and maintain steam traps on steam lines periodically as per the instructions of the manufactuters to prevent steam leaks and clogging caused by the malfunctioning of traps. D. Calibration and maintenance of instruments as per recommendations of suppliers. Maintain proper record of calibration and the plans for all key instruments.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Select compatible capacity and specifications of boiler, TFH, HAG, etc., based on application, fuel type, load fluctuations, etc. B. Install boiler, TFH, HAG, etc., with the highest efficiency that meets the process requirements. C. Use rotary dryer in place of tray dryer wherever feasible. D. Select appropriate combustion equipment and accessories, for example, burner, built-in automation system, etc. E. Use improved streamlined pipe route (avoiding unnecessary bends and joints) for transporting heat media (water, thermic fluid, hot air, etc.) to minimize heat radiations.
Target components	
	The industry shall ensure the following: A. Target air ratio as specified in Table 6.71. B. Target exit flue gas temperature in the range as specified in Table 6.72. C. Target external surface temperature as specified in Table 6.73. D. Preheat temperature of furnace oil close to 100 °C.

Table 6.71:Air ratios for boiler, thermic fluid heater, and hot air generator+

Parameter	Load factor (%)	Air ratio@			
		Coal ^	Biomass#	Liquid fuel	Gas fuel$
Standard	50–100	1.35–1.40	1.49–1.56	1.26–1.33	1.15–1.18
Target	50–100	1.32–1.38	1.32–1.39	1.18–1.24	1.12–1.15

Source: Based on data from different industries

\+ *Combustion of fuels under Standard Temperature and Pressure (STP) conditions is assumed and the effect of parameters, such as variation in fuel compositions, is ignored.*

@ *Air ratio is defined as the ratio of actual air supplied (AAS) to theoretical air requirement. The following formula shall be used for calculating air ratio (value rounded to two digits).The air ratio is considered based on a steady state operation at constant load conditions and can be measured and verified at specific measurement points, while maintaining maximum permissible limit for carbon monoxide (CO) level to 200 ppm.*

$$\text{Air ratio} = \frac{21}{21 - \%\ \text{oxygen in flue gases}}$$

^ *Includes fixed bed and fluidized bed type boiler*

\# *includes wood, bagasse, rice husk, etc.*

$ *Refers to natural gas (NG) only*

Note: *Gross calorific value (GCV) of fuels*

The GCV of different fuels, considering the standard composition of fuels are given below.

- *Indian coal- up to 5,000 kcal per kg; liquid fuels (light diesel oil, high speed diesel, and furnace oil) - 10,500 to 10,800 kcal per kg; biomass fuels – 3,100 to 4,500 kcal per kg (Source: https:// beeindia.gov.in/sites/ default/files/2Ch1.pdf)*
- *Bagasse - 2250 kcal per kg*
- *(Source: http://biomasspower.gov.in/document/ regulatory-order/TN)*
- *Natural gas- 8,500 to 9,000 kcal per SCM (Standard cubic meter) (Source: GAIL India Limited)*

Table 6.72:Waste heat recovery from boiler in chemicals and dyes industry

Exhaust gas temperature (°C)	Waste heat recovery rate (%)		Flue gas temperature* (°C)
	Standard^α	Target^β	
400–600#	22	43	200–250

Source: Based on data from different industries

α *Estimated heat drop based on the upper limit of gas temperatures and net heat transfer with 60% efficiency for heat exchanger.*

β *Estimated heat drop based on the lower limit of gas temperatures and net heat transfer with 65% efficiency for heat exchanger.*

* *Considering natural draft systems for higher flue gas temperature and induced draft system for lower temperatures.*

\# *Only boiler is considered for WHR system as the operating temperatures of TFH and HAG are lower.*

The industry shall compute waste heat recovery (WHR) rate using the following formula:

$$\text{Waste heat recovery rate (\%)} = \frac{\text{Recovered heat (kcal)}}{\text{Sensible heat in exhaust gases (kcal)}} \times 100$$

6.13.4 Common monitorable parameters and performance assessment

1) Performance assessment of boiler

The industry shall monitor common performance indicators as shown in Table 6.74 to assess the performance of boiler.

Table 6.73:Surface temperatures of boiler, TFH, and HAG

Parameter	Surface temperature (°C)#
Standard	Ambient temperature + 30
Target	Ambient temperature + 20

Source: Based on data from different industries

#Average skin temperature under steady state operation

Table 6.74: Common monitorable parameters in boiler

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Steam pressure	bar	Pressure gauge	Hourly
Steam generation	kg/hr	Flow meter	Daily
Fuel consumption	Unit*	Electronic balance/ Flow meter	Daily
Air ratio	kg/kg fuel	Flue gas analyser	Daily
Flue gas temperature	°C	Thermocouple	Daily
Feedwater temperature	°C	Thermocouple	Daily
Surface temperature	°C	Thermocouple	Quarterly

** Fuel consumption measured in kg for solid fuels, litre for liquid fuels, and Sm^3 for gaseous fuels.*

The performance of boiler is expressed in terms of thermal efficiency. The thermal efficiency of boilers shall be estimated using the following methods:

a) Thermal efficiency of boiler by direct method

The thermal efficiency of boiler by direct method is the ratio of heat output to heat input.

$$\text{Thermal efficiency (\%)} = \frac{\text{(Quantity of steam (kg/hr)} \times \text{(Enthalpy of steam–Enthalpy of feedwater) (kcal/kg)}}{\text{Fuel firing rate (kg/hr)} \times \text{Gross calorific value (kcal/kg)}} \times 100$$

b) Thermal efficiency by indirect method

The thermal efficiency of boiler by indirect method involves evaluating various heat loss fractions occurring in boiler under steady state conditions. The thermal efficiency of boiler by indirect method can be expressed as follows:

Thermal efficiency = 100 – (L1 + L2 + L3 + L4 + L5 + L6 + L7 + L8)

where

L1 = Loss due to dry flue gas (%)

$$L1 = \frac{m \times C_p \times (T_f - T_a)}{GCV\ of\ fuel} \times 100$$

where

m = mass of dry flue gas (kg/kg fuel)
C_p = Specific heat of flue gas (kcal/kg °C)
T_f = Flue gas temperature (°C)
T_a = Ambient temperature (°C)

L2 = Loss due to hydrogen in fuel (H_2)

$$L2 = \frac{9 \times H_2 \times \{584 + C_p(T_f - T_a)\}}{GCV\ of\ fuel} \times 100$$

where

H_2 = kg of hydrogen present in fuel on 1 kg basis

Cp = Specific heat of superheated steam (kcal/kg°C)

Tf = Flue gas temperature (°C)

Ta = Ambient temperature (°C)

584 = Latent heat corresponding to partial pressure of water vapour

L3 = Loss due to moisture in fuel

$$L3 = \frac{M \times \{584 + C_p(T_f - T_a)\}}{GCV\ of\ fuel} \times 100$$

where

M = kg moisture in fuel on 1 kg basis

Cp = Specific heat of superheated steam in kcal/kg°C

Tf = Flue gas temperature (°C)

Ta = Ambient temperature (°C)

584 = Latent heat corresponding to partial pressure of water vapour

L4 = Loss due to moisture in air

$$L4 = \frac{AAS \times humidity\ factor \times C_p \times (T_f - T_a) \times 100}{GCV\ of\ fuel}$$

where

AAS = Actual mass of air supplied per kg of fuel

Humidity factor = kg of water/kg of dry air

Cp = Specific heat of superheated steam in kcal/kg°C

Tf = Flue gas temperature in °C

Ta = Ambient temperature in °C (dry bulb)

L5 = Loss due to carbon monoxide

$$L5 = \frac{\%CO \times C}{\%CO + \%CO_2} \times \frac{5744}{GCV\ of\ Fuel} \times 100$$

where

CO = Volume of CO in flue gas (%)

CO_2 = Volume of CO_2 in flue gas (%)

C = Carbon content kg / kg of fuel or when CO is obtained in ppm,

CO formation (Mco) = CO (in ppm) x 10^6 x Mf x 28

Mf = Fuel consumption in kg/hr

L5 = Mco x 5744#

Heat loss due to partial combustion of carbon

L6 = Loss due to surface radiation, convection and unaccounted

Generally, this loss is insignificant and difficult to measure. The surface heat loss and unaccounted losses are assumed based on the type and size of boiler as given below:

Industrial fire tube / packaged boiler : 1.5% to 2.5%

Industrial water tube boiler : 2% to 3%

This loss can be calculated if the surface area of boiler and its surface temperature are known:

$L6 = 0.548 \times [T_s/55.55)^4 - (T_a/55.55)^4] + 1.957 \times (T_s - T_a)^{1.25} \times$ sq.rt of $[(196.85\ V_m + 68.9)/68.9]$

where

L6 = Radiation loss in W/m^2

Vm = Wind velocity in m/s

Ts = Surface temperature (°K)

Ta = Ambient temperature (°K)

L7 = Unburnt losses in fly ash (for solid fuel firing)

$$L7 = \frac{\text{Total ash collected/kg of fuel burnt} \times \text{G.C.V of fly ash} \times 100}{GCV\ of\ fuel}$$

L8 = Unburnt losses in bottom ash (for solid fuel firing)

$$L8 = \frac{\text{Total ash collected/kg of fuel burnt} \times \text{G.C.V of bottom ash} \times 100}{GCV\ of\ fuel}$$

ii) Performance assessment of TFH

The industry shall monitor common performance indicators as shown in Table 6.75 to assess the performance of TFH.

a) Thermal efficiency of TFH

The thermal efficiency of TFH by direct method is the ratio of heat output to heat input.

$$\text{Thermal efficiency (\%)} = \frac{\text{Quantity of thermic fluid} \times \text{Specific heat} \times \text{(Inlet temperature-Outlet temperature)}}{\text{Fuel firing rate} \times \text{Gross calorific value}}$$

where

Quantity of thermic fluid (kg per hr) = volume X density at operating temperature

Specific heat of thermic fluid in kcal/kg °C

Inlet temperature in °C

Outlet temperature in °C

Fuel firing rate in kg per hr

Gross calorific value in kcal/kg

Table 6.75: Common monitorable parameters in thermic fluid heater

Common monitorable parameters	Unit	Instrument	Frequency of measurement
Flow rate of thermic fluid	kg/hr	Flow meter	Daily
Supply temperature	°C	Thermocouple	Daily
Return temperature	°C	Thermocouple	Daily
Air ratio	kg/kg fuel	Flue gas analyser	Daily
Flue gas temperature	°C	Thermocouple	Daily
Surface temperature	°C	Thermocouple	Quarterly
Fuel consumption	Unit*	Electronic balance/ Flow meter	Daily

*Fuel consumption measured in kg for solid fuels, litre for liquid fuels and Sm^3 for gaseous fuels.

For fuel-fired thermic fluid heater, the thermal efficiency shall also be evaluated using indirect method similar to the procedure provided under the performance assessment of boiler.

2) Performance assessment of HAG

The industry shall monitor common performance indicators as shown in Table 6.76 to assess the performance of HAG.

a) Thermal efficiency of HAG

The thermal efficiency of HAG by direct method is the ratio of heat output to heat input.

$$\text{Thermal efficiency (\%)} = \frac{\text{Quantity of air} \times \text{Specific heat} \times \text{(Inlet temperature- Outlet temperature)}}{\text{Fuel firing rate} \times \text{Gross calorific value}} \times 100$$

where

Quantity of air (kg per hr) = suction volume of air ×density of air at operating temperature

Specific heat of air in kcal/kg °C
Inlet temperature in °C
Outlet temperature in °C
Fuel firing rate in kg per hr
Gross calorific value in kcal/kg

For fuel-fired hot air generator, the thermal efficiency shall also be evaluated using indirect method similar to the procedure provided under the performance assessment of boiler.

6.13.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall recover, treat, and re-use water used in various process sections.
2. The industry using boiler shall recover and reuse condensate at maximum possible temperature to reduce energy consumption and make-up water consumption.
3. The industry shall avoid spillage of fuels to reduce wastage.
4. The industry shall avoid idle running of motors to reduce energy consumption.
5. The industry shall arrest leakages from compressed air lines to reduce power consumption.
6. The industry shall use compressed air only at required pressure to optimize energy consumption. Use of compressed air at high pressures would increase energy consumption.
7. The industry shall use airguns in place of compressed air for requirements of air at low pressures.
8. The industry shall install natural ventilators.
9. The industry shall maximize the use of day lighting.

Table 6.76: Common monitorable parameters in HAG

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Flow rate of air	kg/hr	Flow meter	Daily
Inlet air temperature	°C	Thermocouple	Daily
Outlet air temperature	°C	Thermocouple	Daily
Air ratio	kg/kg fuel	Flue gas analyser	Daily
Exhaust flue gas temperature	°C	Thermocouple	Daily
Surface temperature	°C	Thermocouple	Quarterly
Fuel consumption	Unit*	Electronic balance/ Flow meter	Daily

* Fuel consumption measured in kg for solid fuels, litre for liquid fuels and Sm^3 for gaseous fuels

TEXTILE

6.14 Textile industry

6.14.1 Background

The textile industry is one of the energy intensive industries under micro, small, and medium enterprises (MSME) sector. The textile process includes starting from hand-spun and hand-woven to sophisticated and automate systems. The fabric and garment production consists of cotton, blended and 100% non-cotton. The raw materials used in fabric production include cotton, wool, silk, jute, synthetic fibre, etc. The synthetic fibre includes filament yarn and spun yarn from polyester, viscose, nylon, and acrylic.The industry uses thermal energy and electricity. The thermal energy is met from combustion of fuels like coal, biomass, petcoke, oil, natural gas, etc.

6.14.2 Production process

The manufacturing of textile fabric and garment starts from cotton refining, yarn making, and spinning of yarn which is subsequently used in looming section for weaving of fabrics. The fabrics are dyed and printed to produce the desired cloth. The textile industry may be either centralized or decentralized to undertake part or complete production process. This section focuses on weaving, dyeing, and printing, which are energy intensive processes/steps in textile industry.

i) Weaving

Weaving of grey fabric is carried out either in handloom or powerloom. Fabric production consists of doubling, winding, and weaving (Figure 6.17).

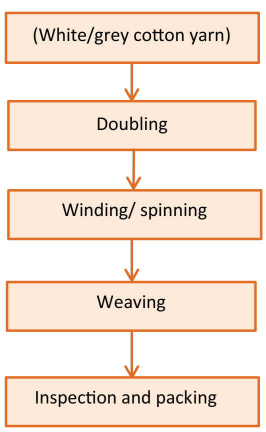

Figure 6.17: Process flow in spinning mills

Doubling

Raw threads are doubled to improve yarn uniformity, abrasion resistance, tenacity, and flexural endurance as per product requirements.

Winding

Winding is the process of transferring yarn or thread from one type of package to another to facilitate subsequent processing. The fibres are drawn across the wheel, and as it spins, the fibres are collected in bobbin.

Weaving

In weaving, the bobbins are transferred to loom machine, wherein the yarn is converted into fabric.

ii) Dyeing and printing

The grey fabric is coloured and design is imparted through dyeing and printing process. Fabric dyeing and printing process is given below (Figure 6.18).

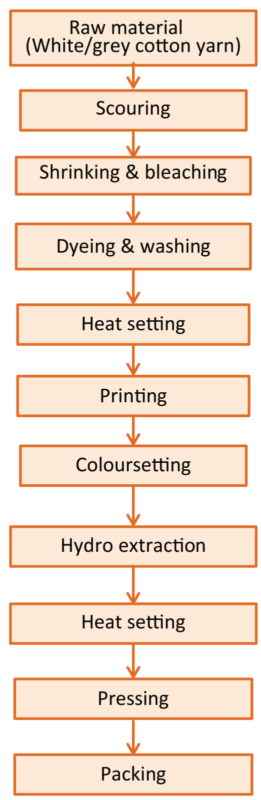

Figure 6.18: Dyeing and printing process

Pre-treatment of fabric

The pre-treatment of grey fabric comprises scouring, bleaching, and shrinking. In scouring, fabric is treated with hot alkaline liquors and other chemicals like wetting agent, defoamer, detergent, and stabilizer for cleaning. Scouring is followed by bleaching, a chemical treatment process for discoloration and removal of natural coloured impurities like minerals, proteins, colouring matter, etc., which may be present in the fabric. Bleached fabric becomes white in colour. It is followed by shrinking process in drum washer machine at high temperature and pressure in the presence of bleaching agents.

Dyeing

The dyeing process is done to impart colours to the fabric using a dye in jet dyeing machine or jigger machine. The temperature of the water is initially raised to about 50 °C. Concentrated dyestuff solution is added to the water. The temperature of the solution is raised to about 130 °C and maintained for about 60 minutes. After dyeing, the fabric is unloaded from the machine and taken to the folding and rolling machines for improving the width of cloth, which gets shrunk during the washing and dyeing processes.

Printing

Printing of cloth is done using flat bed printing, rotary printing or hand printing. The colour print paste is fed onto the screens from where it is transferred to the fabric. After colour printing, the fabric is passed through a drying chamber maintained at about 145 °C.

Colour fixing, heat setting and finishing

Printed fabric is dried in loop machine at 110 °C–120 °C for colour fixing. It is washed in a series of normal water and hot water baths in the presence of chemicals for colour setting. The heat setting of the fabric is done in stenter machines at about 150 °C–220 °C. After heat setting, the cloth is sent for pressing and finishing.

6.14.3 Process equipment

The industry shall improve the energy performance by optimizing various operating parameters in fuel fired equipment such as boiler, thermic fluid heater (TFH), etc., through routine inspection and maintenance and keeping key operating parameters within specified limits as prescribed by the OEMs. This section provides EC Guidelines covering best operating practices, operational aspect, and performance assessment of fuel fired equipment in textile industry in a rational way.

Standards components	
1. Management and control	The industry shall: A. Maintain correct air ratio in boiler and thermic fluid heater (TFH) as specified as standard value in Table 6.77. Use suitable oxygen (O_2) analyser (on-line or portable type) to monitor the air ratio. Adjust and control air ratio to avoid high excess air while ensuring complete combustion of fuel. B. Use automatic air-fuel ratio control system in the combustion system and integrate with control loop. C. Install blower having suitable capacity and correct air pressure. Avoid over-sized or under-sized blower. D. Install blower close to the combustion equipment to avoid transmission loss. E. Minimize heat losses through air ingression by adopting suitable measures such as minimizing size of opening, proper sealing of furnace, etc. F. Use on-line or portable instrumentation for monitoring temperature of exhaust gases and preheated air temperature. G. Reduce exhaust flue gas temperature using suitable WHR system and maintain flue gas temperature as specified in Table 6.78 as standard value. Install suitable WHR system based on waste heat available and type of application. H. Carry out blowdown to maintain the level of total dissolved solids (TDS) in boiler water as recommended by OEM. I. Manage recovery and reuse of waste heat in condensate return according to the instructions concerning parameters, such as the quality and quantity of condensate, temperature, etc., in case of using boiler. Reuse of condensate helps in reducing water treatment and blowdown requirements. An effective condensate recovery system improves boiler efficiency. J. Maintain external skin temperatures of boiler and TFH within the range as specified in Table 6.79 as standard value.

	K. Undertake thermal insulation work on different systems such as steam and condensate pipes, ducts, TFH, etc., which are used for transporting heat media either through steam or hot fluid according to the industrial standard practices for thermal insulation works and equivalent standards. L. Maintain appropriate quality of feedwater in boiler according to Indian Boiler Regulations (IBR), 1950 or an equivalent standard as suggested by the manufacturers. M. Use dry steam from boiler in heating processes to enhance heat transfer. Close steam flow to the process when it is not in operation. Use appropriate steam separator or steam trap to maintain the required dryness fraction of steam. N. Maintain proper draft in combustion equipment using proper damper setting in flue gas path. O. Ensure proper pre-heating of furnace oil to reduce the viscosity level in case of using furnace oil based combustion system. P. Ensure synchronization of switching off of both fuel supply and air supply (blower) upon reaching set temperature in boiler and TFH. Q. Ensure better resolution of measuring instruments for accurate measurements.
2. Measurement and recording	The industry shall measure and record the following: A. Fuel consumption, residual oxygen (O_2), and carbon monoxide (CO) in flue gases, and unburnt carbon in bottom ash and fly ash for solid fuels, preheat air temperature, exhaust gas temperature, etc., on daily basis. Monitor the following parameters on periodical basis: a. Boiler – steam generation, pressure, feedwater temperature and total dissolved solids (TDS), temperature and quantity of condensate, surface temperature. b. TFH- thermic fluid circulation rate, pressure, supply and return temperature of fluid, surface temperature. B. Use suitable logsheet(s) for measurement and recording of key operating parameters. The frequency of recording shall be hourly, shift basis, daily, weekly or monthly based on requirements. The logsheets would help the industry in: (1) assessing energy performance and (2) identifying deviations in operating parameters to undertake corrective measures.
3. Maintenance and inspection	The industry shall: A. Maintain components related to the heat transfer of equipment, such as heat-transfer surfaces, heat exchangers, etc., according to the instructions as specified by the suppliers. Clean the equipment periodically as per the instructions to get rid of soot, scale or dirt to avoid deterioration of heat transfer surfaces and performance. B. Repair, renovate, and maintain the WHR systems in flue path once in six months to avoid scale formation and ensure optimum performance. C. Inspect and maintain steam traps on steam lines periodically as per the instructions of the manufacturers to prevent steam leaks and clogging caused by the malfunctioning of traps. D. Calibration and maintenance of instruments as per recommendations of suppliers. Maintain proper record of calibration and the plans for all key instruments.

4. Necessary measures when installing new facilities	The industry shall consider the following: A. Select compatible capacity and specifications of boiler and TFH based on application, fuel type, load fluctuations, etc. B. Install boiler and TFH with the highest efficiency that meets the process requirements. C. Install WHR boiler to generate power using micro turbine. D. Select appropriate combustion equipment and accessories, for example, burner, built-in automation system, etc. E. Use improved streamlined pipe route (avoiding unnecessary bends and joints) for transporting heat media (water, thermic fluid, etc.) to minimize heat radiations.
Target components	
	The industry shall ensure the following: A. Maintain air ratio based on the target value as provided in Table 6.77. B. Ensure exit flue gas temperature in the range as provided in Table 6.78 as target value. C. Maintain external surface temperature based on the target value as provided in Table 6.79. D. Ensure preheat temprature of furnace oil close to 100 °C.

Table 6.77: Air ratios for boiler and thermic fluid heater in textile industry +

Parameter$	Load factor (%)	Air ratio@			
		Coal ^	Biomass#	Liquid fuel	Gas fuel&
Standard	50–100	1.35–1.40	1.49–1.56	1.26–1.33	1.15–1.18
Target	50–100	1.32–1.38	1.32–1.39	1.18–1.24	1.12–1.15

Source: Based on data from different industries

\+ *Combustion of fuels under Standard Temperature and Pressure (STP) conditions is assumed and the effect of parameters, such as variation in fuel compositions, is ignored.*

$ *includes boiler and TFH*

@ *Air ratio is defined as the ratio of actual air supplied (AAS) to theoretical air requirement. The following formula shall be used for calculating air ratio (value rounded to two digits).The air ratio is considered based on a steady state operation at constant load conditions and can be measured and verified at specific measurement points, while maintaining maximum permissible limit for carbon monoxide (CO) level to 200 ppm.*

$$\text{Air ratio} = \frac{21}{21 - \%\text{ oxygen in flue gases}}$$

^ *Includes fixed bed and fluidized bed type boiler*

\# *includes wood, bagasse, rice husk, etc.*

& *Refers to natural gas (NG) only*

Note: Gross calorific value (GCV) of fuels

The GCV of different fuels, considering the standard composition of fuels are given below.

- Indian coal- up to 5,000 kcal per kg; liquid fuels (light diesel oil, high speed diesel and furnace oil) - 10,500 to 10,800 kcal per kg; biomass fuels – 3,100 to 4,500 kcal per kg (Source: https:// beeindia.gov.in/sites/ default/files/2Ch1.pdf)
- Bagasse - 2250 kcal per kg
- (Source: http://biomasspower.gov.in/document/ regulatory-order/TN)
- Natural gas- 8,500 to 9,000 kcal per SCM (Standard cubic metre) (Source: GAIL India Limited)

Table 6.78:Waste heat recovery from boiler in textile industry

Exhaust gas temperature (°C)	Waste heat recovery rate (%)		Flue gas temperature* (°C)
	Standard[α]	Target[β]	
400-600#	22	43	200−250

Source: Based on data from different industries

α *Estimated heat drop based on the upper limit of gas temperatures and net heat transfer with 60% efficiency for heat exchanger.*

β *Estimated heat drop based on the lower limit of gas temperatures and net heat transfer with 65% efficiency for heat exchanger.*

* *Considering natural draft systems for higher flue gas temperature and induced draft system for lower temperatures.*

\# *Only boiler is considered for WHR system as the operating temperatures of TFH are lower.*

Table 6.79:Surface temperatures of boiler and TFH in textile industry

Parameter	Surface temperature (°C)#
Standard	Ambient temperature + 30
Target	Ambient temperature + 20

Source: Based on data from different industries

 # Average skin temperature under steady state operation

The industry shall compute waste heat recovery (WHR) rate using the following formula:

$$\text{Waste heat recovery rate (\%)} = \frac{\text{Recovered heat}}{\text{Sensible heat in exhaust gase}} \times 100$$

6.14.4 Common monitorable parameters and performance assessment

i) Performance assessment of boiler

The industry shall monitor common performance indicators as shown in Table 6.80 to assess the performance of boiler.

The performance of boiler is expressed in terms of thermal efficiency. The thermal efficiency of boilers shall be estimated using the following methods:

a) Thermal efficiency of boiler by direct method

The thermal efficiency of boiler by direct method is the ratio of heat output to heat input.

$$\text{Thermal efficiency (\%)} = \frac{\text{Quantity of thermic fluid} \times \text{Specific heat} \times \text{(Inlet temperature-Outlet temperature)}}{\text{Fuel firing rate} \times \text{Gross calorific value}} \times 100$$

b) Thermal efficiency by indirect method

The thermal efficiency of boiler by indirect method involves evaluating various heat loss fractions occurring in boiler under steady state conditions. The thermal efficiency of boiler by indirect method can be expressed as follows:

Thermal efficiency = 100 – (L1 + L2 + L3 + L4 + L5 + L6 + L7 + L8)

where

L1 = Loss due to dry flue gas (%)

$$L1 = \frac{m \times C_p \times (T_f - T_a)}{GCV\ of\ fuel} \times 100$$

where

m = mass of dry flue gas (kg/kg fuel)

C_p = Specific heat of flue gas (kcal/kg °C)

Table 6.80: Common monitorable parameters in boiler

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Steam pressure	bar	Pressure gauge	Hourly
Steam generation	kg/hr	Electronic balance/Flow meter	Daily
Fuel consumption	Unit*	Electronic balance	Daily
Air ratio	kg/kg fuel	Flue gas analyser	Daily
Flue gas temperature	°C	Thermocouple	Daily
Feedwater temperature	°C	Thermocouple	Daily
Surface temperature	°C	Thermocouple	Quarterly

* *Fuel consumption measured in kg for solid fuels, litre for liquid fuels and Sm^3 for gaseous fuels.*

T_f = Flue gas temperature (°C)

T_a = Ambient temperature (°C)

L2 = Loss due to hydrogen in fuel (H_2)

$$L2 = \frac{9 \times H_2 \times \{584 + C_p(T_f - T_a)\}}{GCV\ of\ fuel} \times 100$$

where

H_2 = kg of hydrogen present in fuel on 1 kg basis

C_p = Specific heat of superheated steam (kcal/kg°C)

T_f = Flue gas temperature (°C)

T_a = Ambient temperature (°C)

584 = Latent heat corresponding to partial pressure of water vapour

L3 = Loss due to moisture in fuel

$$L3 = \frac{M \times \{584 + C_p(T_f - T_a)\}}{GCV\ of\ fuel} \times 100$$

where

M = kg moisture in fuel on 1 kg basis

C_p = Specific heat of superheated steam in kcal/kg°C

T_f = Flue gas temperature (°C)

T_a = Ambient temperature (°C)

584 = Latent heat corresponding to partial pressure of water vapour

L4 = Loss due to moisture in air

$$L4 = \frac{AAS \times humidity\ factor \times C_p \times (T_f - T_a) \times 100}{GCV\ of\ fuel}$$

where

AAS = Actual mass of air supplied per kg of fuel

Humidity factor = kg of water/kg of dry air

Cp = Specific heat of superheated steam in kcal/kg°C

Tf = Flue gas temperature in °C

Ta = Ambient temperature in °C (dry bulb)

L5 = Loss due to carbon monoxide

$$L5 = \frac{\%CO \times C}{\%CO + \%CO_2} \times \frac{5744}{GCV\ of\ Fuel} \times 100$$

where

CO = Volume of CO in flue gas (%)

CO_2 = Volume of CO_2 in flue gas (%)

C = Carbon content kg/kg of fuel, or

When CO is obtained in ppm,

CO formation (Mco) = CO (in ppm) x 10^6 x Mf x 28

M_f = Fuel consumption in kg/hr

L5 = M_{co} x 5744#

Heat loss due to partial combustion of carbon

L6 = Loss due to surface radiation, convection and unaccounted
Generally, this loss is insignificant and difficult to measure. The surface heat loss and unaccounted losses are assumed based on the type and size of boiler as given below:

Industrial fire tube/packaged boiler : 1.5 to 2.5%

Industrial watertube boiler : 2% to 3%

This loss can be calculated if the surface area of boiler and its surface temperature are known:

$L6 = 0.548 \times [T_s/55.55)^4 - (T_a/55.55)^4] + 1.957 \times (T_s - T_a)^{1.25} \times$ sq.rt of $[(196.85\ V_m + 68.9)/68.9]$

where

L6 = Radiation loss in W/m^2

Vm = Wind velocity in m/s

T_s = Surface temperature (°K)

T_a = Ambient temperature (°K)

L7 = Unburnt losses in fly ash (for solid fuel firing)

$$L7 = \frac{\text{Total ash collected/kg of fuel burnt} \times \text{G.C.V of fly ash} \times 100}{GCV\ of\ fuel}$$

L8 = Unburnt losses in bottom ash (for solid fuel firing)

$$L8 = \frac{\text{Total ash collected/kg of fuel burnt} \times \text{G.C.V of bottom ash} \times 100}{GCV\ of\ fuel}$$

ii) Performance assessment of TFH

The industry shall monitor common performance indicators as shown in Table 6.81 to assess the performance of thermic fluid heater.

a) Thermal efficiency of TFH

The thermal efficiency of TFH by direct method is the ratio of heat output to heat input.

$$\text{Thermal efficiency (\%)} = \frac{\text{Quantity of thermic fluid} \times \text{Specific heat} \times (\text{Inlet temperature-Outlet temperature})}{\text{Fuel firing rate} \times \text{Gross calorific value}} \times 100$$

where

Quantity of thermic fluid (kg per hr) = volume × density at operating temperature

Specific heat of thermic fluid in kcal/kg °C

Inlet temperature in °C

Outlet temperature in °C

Fuel firing rate in kg per hr

Gross calorific value in kcal/kg

For fuel-fired thermic fluid heater, the thermal efficiency shall also be evaluated using indirect method similar to the procedure provided under the performance assessment of boiler.

6.14.5 Efficient resource utilization

Efficient resource utilisation includes optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall recover, treat, and re-use water used in various process sections to attain zero discharge and minimize the make-up water consumption.
2. The industry using boiler shall recover and reuse condensate at maximum possible temperature to reduce energy consumption and make-up water consumption.
3. The industry shall ensure maximum recovery of dyes and colours for reuse in the process.
4. The industry shall avoid spillage of fuels to reduce wastage.
5. The industry shall arrest leakages from compressed air lines to reduce power consumption.
6. The industry shall use compressed air only at required pressure to optimize energy consumption. Use of compressed air at high pressures would increase energy consumption.
7. The industry shall use airguns in place of compressed air for requirements of air at low pressures.
8. The industry shall install eco natural ventilators.
9. The industry shall maximize the use of day lighting wherever feasible.

Table 6.81:Common monitorable parameters in thermic fluid heater

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Flow rate of thermic fluid	lit/hr	Flow meter	Daily
Supply temperature	°C	Thermocouple	Daily
Return temperature	°C	Thermocouple	Daily
Air ratio	kg/kg fuel	Flue gas analyser	Daily
Flue gas temperature	°C	Thermocouple	Daily
Surface temperature	°C	Thermocouple	Quarterly
Fuel consumption	Unit*	Electronic balance/ Flow meter	Daily

* *Fuel consumption measured in kg for solid fuels, litre for liquid fuels and* Sm^3 *for gaseous fuels.*

PULP AND PAPER

6.15 Pulp and paper industry

6.15.1 Background

The pulp and paper industry is one of the energy intensive industries under micro, small, and medium enterprises (MSME) sector. The major products produced by paper mills are kraft paper and duplex board. The industry also produces writing paper, printing paper, filter paper, gray board, poster paper, hard tissue paper, etc. The raw material used by the industry is either agro residue or waste paper.

6.15.2 Production process

The production process of paper involves pulp making, paper making, and paper finishing (Figure 6.19).

i) Pulp making

In chemical pulping using agro residue, the raw materials (bagasse/wood chips) and chemicals are cooked in a digester to remove lignin and result in break up of the wood into fibres. The process results in a slurry, where fibres are loose but intact and have maintained their strength. Most chemical pulp is made by the alkaline kraft or sulphate process, which is based on acid cooking liquor process suited for specialty pulp. In the unbleached stage, a dark brown pulp is obtained. The cooking chemicals are recovered back to the process through evaporation. Cooked pulp is washed and screened to achieve more uniform quality.

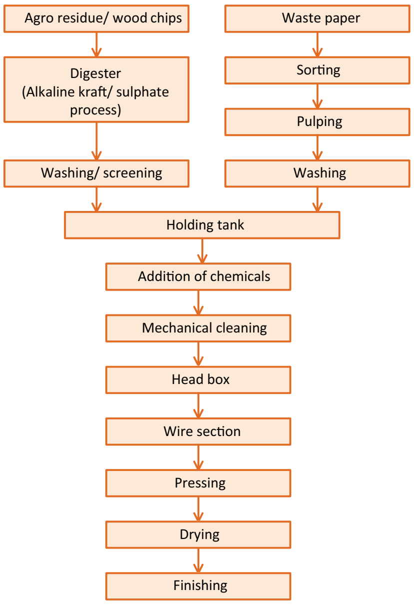

Figure 6.19: Paper manufacturing process

In recycle based pulp making, the recycled paper completely or partially consists of recycled fibres. As the origins of papers will be different, the collected paper is sorted into different categories. In most cases, bales or loose paper waste is transported to the pulper using conveyor belt. Before processing, de-inking of waste paper is carried out using washing and floatation process. Adhesive particles are removed using fine screening.

The slurry is transferred to holding tanks. Chemicals are added which are sizing agents to reduce penetration of ink and water. Additives such as clay, chalk, titanium oxide, etc., are added to improve optical properties of the paper and board. The pulp is sent through various types of mechanical cleaning equipment before it is sent for paper making.

ii) Paper making

The cleaned or processed pulp is pumped to the head box wherein it is passed through a thin, horizontal slit and fed evenly across the full machine width on to a moving, endless wire mesh. In the mesh, water is removed with gravity and suction resulting in sheet formation where the fibres start to spread and consolidate into a thin mat. By the time the thin mat reaches the end of the wire section, it attains the form of sheet, which has high moisture and low strength. The moist paper sheet is passed through the press section comprising heavy cylinders in which most of the moisture is squeezed out and drawn away by suction. The low-moist paper is passed through a dryer section comprising drying cylinders steam-heated to about 100 °C. At the end of drying, the paper is smoothened using hot polished iron rollers mounted in pairs one above the other (calenders). This further helps to consolidate, polish, and glaze the surface of the paper. Large reels of paper are produced at the end of the process.

iii) Paper finishing

Finishing process is done to improve the characteristics, appearance, and properties of paper. The large reels of papers are cut into sheets and coating is applied and additives are added to improve the quality. The paper acquires high lustre surface through a combination of heat, pressure, and friction.

6.15.3 Process equipment

The industry shall improve the energy performance by optimizing various operating parameters in fuel fired equipment such as boiler through routine inspection and maintenance and keeping key operating parameters within specified limits as prescribed by the OEMs. This section provides EC Guidelines covering best operating practices, operational aspects, and performance assessment of boiler in pulp and paper industry in a rational way.

Standards components	
1. Management and control	The industry shall ensure the following: A. Maintain correct air ratio in boiler as specified as standard value in Table 6.82. Use suitable oxygen (O_2) analyser (on-line or portable type) to monitor the air ratio. Adjust and control air ratio to avoid high excess air while ensuring complete combustion of fuel. B. Use automatic air-fuel ratio control system in the combustion system and integrate with control loop. C. Install blower having suitable capacity and correct air pressure. Avoid over-sized or under-sized blower. D. Install blower close to the combustion equipment to avoid transmission loss. E. Minimize heat losses through air ingression by adopting suitable measures such as minimizing size of opening, proper sealing of furnace, etc. F. Use on-line or portable instrumentation for monitoring temperature of exhaust gases and preheated air temperature. G. Reduce exhaust flue gas temperature using suitable WHR system and maintain flue gas temperature as specified in Table 6.83 as standard value. Install suitable WHR system based on waste heat available and type of application. H. Carry out blowdown to maintain the level of total dissolved solids (TDS) in boiler water as recommended by OEM. I. Manage recovery and reuse of waste heat in condensate return according to the instructions concerning parameters, such as the quality and quantity of condensate, temperature, etc., in case of using boiler. Reuse of condensate helps in reducing water treatment and blowdown requirements. An effective condensate recovery system improves boiler efficiency. J. Maintain external skin temperatures of boiler within the range as specified in Table 6.84 as standard value. K. Undertake thermal insulation work on different systems such as steam and condensate pipes, ducts, etc., which are used for transporting heat media either through steam according to the industrial standard practices for thermal insulation works and equivalent standards. L. Maintain appropriate quality of feedwater in boiler according to Indian Boiler Regulations (IBR), 1950 or an equivalent standard as suggested by the manufacturers. M. Use dry steam from boiler in heating processes to enhance heat transfer. Close steam flow to the process when it is not in operation. Use appropriate steam separator or steam trap to maintain the required dryness fraction of steam.

	N. Maintain proper draft in combustion equipment using proper damper setting in flue gas path. O. Ensure proper pre-heating of furnace oil to reduce the viscosity level in case of using furnace oil based combustion system. P. Ensure synchronization of switching off of both fuel supply and air supply (blower) upon reaching set temperature in boiler. Q. Ensure better resolution of measuring instruments for accurate measurements.
2. Measurement and recording	The industry shall measure and record the following: A. Fuel consumption, residual oxygen (O_2), and carbon monoxide (CO) in flue gases, and unburnt carbon in bottom ash and fly ash for solid fuels, preheat air temperature, exhaust gas temperature, etc., on daily basis. B. Monitor steam generation, pressure, feedwater temperature and total dissolved solids (TDS), temperature and quantity of condensate of boiler on daily basis. C. Boiler surface temperature on quarterly basis. D. Monitor total water consumption of process on daily basis. E. Use suitable logsheet(s) for measurement and recording of key operating paramaters. The frequency of recording shall be hourly, shift basis, daily, weekly or monthly based on requirements. The logsheets would help the industry in: (1) assessing energy performance and (2) identifying deviations in operating parameters to undertake corrective measures.
3. Maintenance and inspection	The industry shall: A. Maintain components related to the heat transfer of equipment, such as heat-transfer surfaces, heat exchangers, etc., according to the instructions as specified by the suppliers. Clean the equipment periodically as per the instructions to get rid of soot, scale or dirt to avoid deterioration of heat transfer surfaces and performance. B. Repair, renovate, and maintain the WHR systems in flue path once in six months to avoid scale formation and ensure optimum performance. C. Inspect and maintain steam traps on steam lines periodically as per the instructions of the manufactuters to prevent steam leaks and clogging caused by the malfunctioning of traps. D. Calibration and maintaintenance of instruments as per recommendations of suppliers. Maintain proper record of calibration and the plans for all key instruments.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Install boiler with the highest efficiency that meets the process requirements. B. Install WHR boiler to generate power using micro turbine. C. Select appropriate combustion equipment and accessories, e.g., burner, built-in automation system, etc. D. Use improved streamlined pipe route (avoiding unnecessary bends and joints) for transporting heat media, that is, water to minimize heat radiations.
Target components	
	The industry shall ensure the following: A. Maintain air ratio based on the target value as provided in Table 6.82. B. Ensure exit flue gas temperature in the range as provided in Table 6.83 as target value. C. Maintain external surface temperature based on the target value as provided in Table 6.84. D. Ensure preheat furnace oil close to 100 °C. E. Maintain water consumption as 55–60 m^3 per tonne of paper.

Table 6.82: Air ratios for boiler used in pulp and paper industry⁺

Parameter	Load factor (%)	Air ratio@			
		Coal ^	Biomass#	Liquid fuel	Gas fuel&
Standard	50–100	1.35–1.40	1.49–1.56	1.26–1.33	1.15–1.18
Target	50–100	1.32–1.38	1.32–1.39	1.18–1.24	1.12–1.15

Source: Based on data from different industries

\+ *Combustion of fuels under Standard Temperature and Pressure (STP) conditions is assumed and the effect of parameters, such as variation in fuel compositions, is ignored.*

@ *Air ratio is defined as the ratio of actual air supplied (AAS) to theoretical air requirement. The following formula shall be used for calculating air ratio (value rounded to two digits). The air ratio is considered based on a steady state operation at constant load conditions and can be measured and verified at specific measurement points, while maintaining maximum permissible limit for carbon monoxide (CO) level to 200 ppm.*

$$\text{Air ratio} = \frac{21}{21 - \%\ \text{oxygen in flue gases}}$$

^ *Includes fixed bed and fluidized bed type boiler*

\# *includes wood, bagasse, rice husk, etc.*

& *Refers to natural gas (NG) only*

Note: Gross calorific value (GCV) of fuels

The GCV of different fuels, considering the standard composition of fuels are given below.

- Indian coal- up to 5,000 kcal per kg; liquid fuels (light diesel oil, high speed diesel, and furnace oil) - 10,500 to 10,800 kcal per kg; biomass fuels – 3,100 to 4,500 kcal per kg (Source: https:// beeindia.gov.in/sites/ default/files/2Ch1.pdf)
- Bagasse - 2250 kcal per kg
- (Source: http://biomasspower.gov.in/document/ regulatory-order/TN)
- Natural gas- 8,500 to 9,000 kcal per SCM (Standard cubic metre) (Source: GAIL India Limited)

Table 6.83: Waste heat recovery from boiler in pulp and paper industry

Exhaust gas temperature (°C)	Waste heat recovery rate (%)		Flue gas temperature* (°C)
	Standard$^{\alpha}$	Target$^{\beta}$	
400−600	22	43	200−250

Source: Based on data from different industries

α *Estimated heat drop based on the upper limit of gas temperatures and net heat transfer with 60% efficiency for heat exchanger*

β *Estimated heat drop based on the lower limit of gas temperatures and net heat transfer with 65% efficiency for heat exchanger*

* *Considering natural draft systems for higher flue gas temperature and induced draft system for lower temperatures*

The industry shall compute waste heat recovery (WHR) rate using the following formula:

$$\text{Waste heat recovery rate (\%)} = \frac{\text{Recovered heat (kcal)}}{\text{Sensible heat in exhaust gases (kcal)}} \times 100$$

6.15.4 Common monitorable parameters and performance assessment

The industry shall monitor common performance indicators as shown in Table 6.85 to assess the performance of the boiler.

The performance of boiler is expressed in terms of thermal efficiency. The thermal efficiency of boilers shall be estimated using the following methods:

a) Thermal efficiency of boiler by direct method

The thermal efficiency of boiler by direct method is the ratio of heat output to heat input.

$$\text{Thermal efficiency (\%)} = \frac{\text{(Quantity of steam (kg/hr)} \times \text{(Enthalpy of steam-Enthalpy of feedwater (kcal/kg))}}{\text{Fuel firing rate (kg/hr)} \times \text{Gross calorific value (kcal/kg))}} \times 100$$

Table 6.84: Surface temperatures of boiler in pulp and paper industry

Parameter	Surface temperature (°C)#
Standard	Ambient temperature + 30
Target	Ambient temperature + 20

Source: Based on data from different industries

 # Average skin temperature under steady state operation

Table 6.85: Common monitorable parameters in boiler

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Steam pressure	bar	Pressure gauge	Hourly
Steam generation	kg/hr	Flow meter	Daily
Fuel consumption	Unit*	Electronic balance/ Flow meter	Daily
Air ratio	kg/kg fuel	Flue gas analyser	Daily
Flue gas temperature	°C	Thermocouple	Daily
Feedwater temperature	°C	Thermocouple	Daily
Surface temperature	°C	Thermocouple	Quarterly

* *Fuel consumption measured in kg for solid fuels, litre for liquid fuels, and Sm³ for gaseous fuels.*

b) Thermal efficiency by indirect method

The thermal efficiency of boiler by indirect method involves evaluating various heat loss fractions occurring in boiler under steady state conditions. The thermal efficiency of boiler by indirect method can be expressed as follows:

Thermal efficiency = 100 – (L1 + L2 + L3 + L4 + L5 + L6 + L7 + L8)

where

L1 = Loss due to dry flue gas (%)

$$L1 = \frac{m \times C_p \times (T_f - T_a)}{GCV\ of\ fuel} \times 100$$

where

m = mass of dry flue gas (kg/kg fuel)

C_p = Specific heat of flue gas (kcal/kg °C)

T_f = Flue gas temperature (°C)

T_a = Ambient temperature (°C)

L2 = Loss due to hydrogen in fuel (H_2)

$$L2 = \frac{9 \times H_2 \times \{584 + C_p(T_f - T_a)\}}{GCV\ of\ fuel} \times 100$$

where

H_2 = kg of hydrogen present in fuel on 1 kg basis

Cp = Specific heat of superheated steam (kcal/kg°C)

T_f = Flue gas temperature (°C)

T_a = Ambient temperature (°C)

584 = Latent heat corresponding to partial pressure of water vapour

L3 = Loss due to moisture in fuel

$$L3 = \frac{M \times \{584 + C_p(T_f - T_a)\}}{GCV\ of\ fuel} \times 100$$

where

M = kg moisture in fuel on 1 kg basis

C_p = Specific heat of superheated steam in kcal/kg°C

T_f = Flue gas temperature (°C)

T_a = Ambient temperature (°C)

584 = Latent heat corresponding to partial pressure of water vapour

L4 = Loss due to moisture in air

$$L4 = \frac{AAS \times humidity\ factor \times C_p \times (T_f - T_a) \times 100}{GCV\ of\ fuel}$$

where

AAS = Actual mass of air supplied per kg of fuel

Humidity factor = kg of water/kg of dry air

C_p = Specific heat of superheated steam in kcal/kg°C

T_f = Flue gas temperature in °C

T_a = Ambient temperature in °C (dry bulb)

L5 = Loss due to carbon monoxide

$$L5 = \frac{\%CO \times C}{\%CO + \%CO_2} \times \frac{5744}{GCV\ of\ Fuel} \times 100$$

where

CO = Volume of CO in flue gas (%)

CO_2 = Volume of CO_2 in flue gas (%)

C = Carbon content kg/kg of fuel, or

When CO is obtained in ppm,

CO formation (Mco) = CO (in ppm) x 10^6 x Mf x 28

Mf = Fuel consumption in kg/hr

L5 = Mco x 5744#

Heat loss due to partial combustion of carbon

L6= Loss due to surface radiation, convection and unaccounted
Generally, this loss is insignificant and difficult to measure. The surface heat loss and unaccounted losses are assumed based on the type and size of boiler as given below:

Industrial fire tube/packaged boiler : 1.5 to 2.5%

Industrial water tube boiler : 2 to 3%

This loss can be calculated if the surface area of boiler and its surface temperature are known:

$$L6 = 0.548 \times [(T_s/55.55)^4 - (T_a/55.55)^4] + 1.957 \times (T_s - T_a)^{1.25} \times \text{sq.rt of } [(196.85\, V_m + 68.9)/68.9]$$

where

L6 = Radiation loss in W/m^2

Vm = Wind velocity in m/s

Ts = Surface temperature (°K)

Ta = Ambient temperature (°K)

L7= Unburnt losses in fly ash (for solid fuel firing)

$$L7 = \frac{\text{Total ash collected/kg of fuel burnt} \times \text{G.C.V of fly ash} \times 100}{GCV\ of\ fuel}$$

L8 =Unburnt losses in bottom ash (for solid fuel firing)

$$L8 = \frac{\text{Total ash collected/kg of fuel burnt} \times \text{G.C.V of bottom ash} \times 100}{GCV\ of\ fuel}$$

The industry shall monitor water consumption in the process to assess specific water consumption as shown in Table 6.86.

The industry shall calculate specific water consumption using the following formula:

$$\text{Specific water consumption } (m^3/(\text{tonne paper}) = \frac{\text{Total water consumption } (m^3/\text{day})}{\text{Total paper production (tonne/day)}}$$

The industry shall refer to the typical performance indicators of paper industry (kraft paper) as provided in Table 6.87.

6.15.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall recover, treat and re-use water used in various process sections.
2. The industry using boiler shall recover and reuse condensate at maximum possible temperature to reduce energy consumption and make-up water consumption.
3. The industry shall ensure maximum recovery of dyes and colours for reuse in the process.

Table 6.86: Specific water consumption

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Paper production	tonne	Electronic balance	Daily
Water consumption	m^3	Flow meter	Daily

Table 6.87: Typical performance indicators for paper industry

Type	Specific energy consumption
Agro based paper	0.32 toe per tonne
Waste based paper	0.10 toe per tonne

Source: Based on data from different industries

4. The industry shall avoid spillage of fuels to reduce wastage.
5. The industry shall arrest leakages from compressed air lines to reduce power consumption.
6. The industry shall use compressed air only at required pressure to optimize energy consumption. Use of compressed air at high pressures would increase energy consumption.
7. The industry shall use airguns in place of compressed air for requirements of air at low pressures.
8. The industry shall install natural ventilators.
9. The industry shall maximize the use of day lighting.

LIMESTONE

6.16 Limestone industry

6.16.1 Background

The limestone industry is one of the energy-consuming industries under the micro, small, and medium enterprises (MSME) sector. The main products are hydrated/slaked lime and quicklime. Lime has applications in different sectors, for example building and construction sector, tanneries, sugar industries, chemical industries, metallurgic industries.

6.16.2 Production process

Limestone manufacturing involves quarrying raw limestone, crushing and sizing, calcination, and processing lime further through hydration.

Raw material crushing and screening

Large lumps of raw limestone are crushed to a size of 2–4 inches and screened to separate large lumps. The screened limestone powder is further pulverized to finer size.

Calcination

The prepared limestone is calcined at about 950 °C–1000 °C in the kiln. The process produces calcium oxide or quicklime (CaO) and carbon dioxide (CO_2). The quicklime is crushed, pulverised into fine powder, and sorted into different fractions by screening.

Hydration

The quicklime is converted to slaked lime by water addition which produces calcium hydroxide ($Ca(OH)_2$) or slaked lime. The slaked or hydrated lime is screened and pulverized before packing.

6.16.3 Process equipment

The industry shall improve the energy performance by optimizing various operating parameters in lime kiln through routine inspection and maintenance, and keeping key operating parameters within specified limits. This section provides EC Guidelines covering best operating practices, operational aspects, and performance assessment of fuel fired equipment in the limestone industry in a rational way.

Standards components	
1. Management and control	The industry shall undertake the following: A. Maintain furnace temperature as per process requirements. Avoid overheating or under-heating of the products to optimize the yield and specific energy consumption (SEC). Use sufficient number of temperature indicators to maintain uniform temperature gradient across the furnace. B. Ensure consistent quality and size of raw material before charging in the kiln. C. Minimize air ingression using suitable measures. These include minimizing unnecessary openings, proper sealing of furnace, etc. D. Ensure appropriate mixture of charge by maintaining limestone to coal ratio using appropriate coal fineness. E. Ensure suitable thermal insulation of the kiln. These include suitable thickness of insulation, low thermal conductivity insulating materials, etc. F. Ensure better resolution of temperature indicators for accurate measurement of temperatures inside the kiln.
2. Measurement and recording	The industry shall measure and record the following: A. Fuel consumption, raw material charge, yield, temperature of kiln, unburnt coal, uncalcined limestone, etc., on a daily basis. B. Temperture of kiln surfaces on a quarterly basis. C. Develop and use suitable log sheet(s) for measurement and recording of key operating parameters. The frequency of recording shall be on hourly basis during the entire batch cycle. The log sheets would help the industry in assessing the kiln performance.

3.	Maintenance and inspection	The industry shall do the following: A. Repair worn-out lining high alumina refractory tile and mortar. B. Undertake scheduled maintenance in pulverizer and blower impeller for wear and tear, bearing condition, vibration level, etc. C. Calibrate and maintain instruments as per the recommendations of the suppliers to record reliable and accurate data.
4.	Necessary measures when installing new facilities	The industry shall consider the following: A. Replace standard motors with energy efficient IE3 motors for motive loads. B. Install suitable sytem to recover and reuse heat from process (exothermic hydration).
Target components		
		The industry shall ensure the following: A. External skin temperatures of kiln less than 60 °C.

6.16.4 Common monitorable parameters and performance assessment

The industry shall monitor common performance indicators as shown in Table 6.88 to assess the performance of the kilns.

Specific energy consumption

The industry shall evaluate the specific energy consumption (SEC) of the kiln using the following formula to assess the performance:

$$\text{Specific energy consumption (kcal/kg)} = \frac{\text{Total energy consumption (kcal)}}{\text{Quantity of material processed (kg)}}$$

Total energy consumption (kcal) = Fuel consumption (kg) × Gross calorific value (kcal/kg)

6.16.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall ensure maximum capacity utilization of the kiln to reduce energy losses.
2. The industry shall avoid spillage of fuels to reduce wastage of fuels.
3. The industry shall recover and reuse unburnt coal from bottom ash.
4. The industry shall recover and reuse partially calcined limestone from the process.

Table 6.88: Common monitorable parameters in kiln

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Furnace temperature	ºC	Thermocouple	Daily
Surface temperature	ºC	Infrared thermometer	Quarterly
Limestone quantity	tonne	Electronic balance	Daily
Lime production	tonne	Electronic balance	Daily
Fuel consumption	kg	Electronic balance	Daily

COIR

6.17 Coir industry

6.17.1 Background

The coir industry is one of the resource intensive industries under the micro, small, and medium enterprises (MSME) sector. Coir products are made of fibre from the husks of coconuts. Though, traditionally the industry is labour intensive, diversification in product range led to increased mechanization in the coir industry, especially in fibre extraction and weaving. Various types of products manufactured in the coir industry include mats (rod/brush mats, fibre mat, creel mat, bit mat, cord, cable or ribbed mats), matting, matting rugs, carpets, rubberized coir products, and others, such as ropes, screens, acoustic ceiling, rubberized coir mattresses, acoustical back panels, etc.

6.17.2 Production process

The production process involves extraction of fibres from the husk through retting, a curing process, that partially decomposes the husk allowing the separation of coir fibre along with pith which is the residue. The fibres are separated through beating either manually or mechanical process. The coir fibre is spun into yarn. Two types of coir fibres are produced, namely brown coir and white coir. The industry mainly uses manual process with limited use of mechanization. The yarn and fibres are bleached or dyed, and woven with hand-operated loom or powerloom to make mats and matting.

i) Handloom weaving

The raw coir fibre is disintegrated to remove dust and other foreign materials. The clean fibre is woven in hand-operated loom to produce mats. After weaving, the coir mats are cut manually into the required size. The semi-finished product is sent to stencilling units for designing and finishing (Figure 6.20).

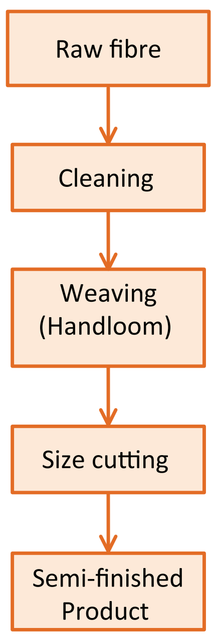

Figure 6.20: Handloom weaving

ii) Dyeing

The coir yarn is bleached by soaking in hot water and bleaching agents. It is followed by dyeing in which colours are added to the yarn as per design requirements. The water from the dyed yarn is removed using centrifuge. The balance moisture is dried in natural sunlight. It is wound on bobbins in spooling machine and taken to warping machine. The coir yarn is finally processed in power loom to produce coir mattings (Figure 6.21).

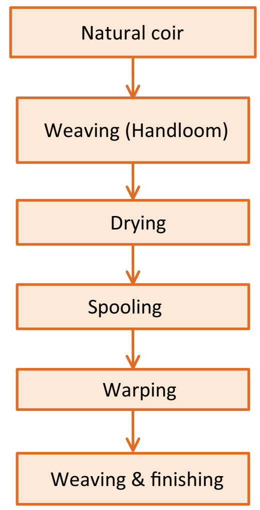

Figure 6.21: Dyeing

iii) Stenciling

The raw material for stenciling is semi-finished coir mats. The mats are processed in shearing machines to smoothen the surface. The design pattern is placed over the mat, colours are sprayed on the pattern, and the design is embossed on the surface. Compressed air is used for colour spraying. After stenciling, the mats are dried in natural sunlight. The unwanted material is removed manually in the finising process (Figure 6.22).

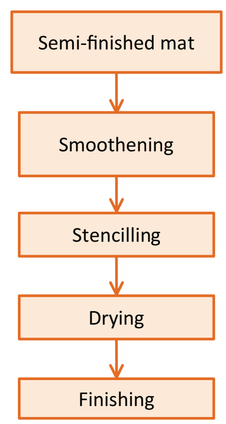

Figure 6.22: Stencilling

iv) Rubber coir mats

The input material is coir mat from upstream coir industries. The mats are cut manually to the required sizes of 2–3 feet. A rubber-based mixture comprising rubber, clay, sulphur, and oil is prepared in the mixing mill. The mixture is processed in the calendaring machine to produce rubber sheet. The rubber sheet is cut to required sizes and bonded with coir mats at the bottom side, which are kept over plates. The plates are pressed in hot press, where a temperature of about 80 °C is maintained using electrical heater to produce rubber coir mats(Figure 6.23).

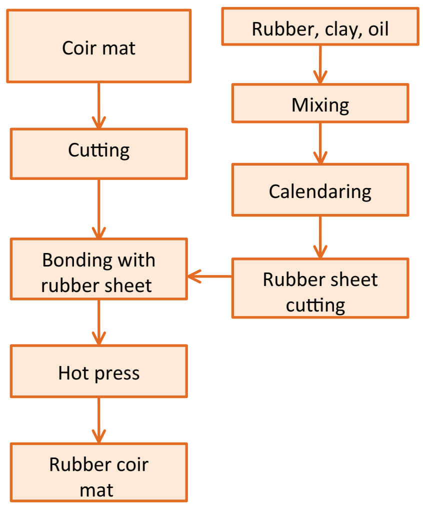

Figure 6.23: Rubber coir mat

v) PVC tufted products

Poly Vinyl Chloride (PVC) and other raw materials are mixed and stirred in a mixing machine till it is converted to liquid form. It is pumped to tufting machine, wherein the PVC liquid is spread over a bed of required size. Pieces of coir yarn are tufted on the PVC liquid. The PVC mats are heated using electric heating panels to ensure bonding between coir pieces and PVC. The PVC mat is passed through shearing machine to remove unwanted sections and cut to required sizes in the cutting machines. The PVC mats are sent to the printing section to emboss designs (Figure 6.24).

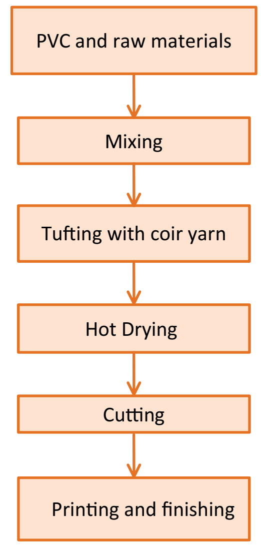

Figure 6.24: PVC tufted products

6.17.3 Process equipment

This section provides EC Guidelines covering best operating practices and operational aspects for the coir industry in a rational way.

Standards components	
1. Management and control	The industry shall undertake the following: A. Procure suitable quality of coir fibre to undertake weaving. B. Implement suitable measures to reduce wastage during manual cutting of woven products. These measures include cutting different sizes of the products in a manner that maximum yarn is utilized in making the product. C. Utilize maxiumum heat from the combustion of fuel while generating hot water. Adopt measures such as reduction of openings, proper size of vessels made of high heat transfer of material. Use lids during heating of water. D. Use only the required quantity of water for dyeing process. E. Allow steady heating of water with controlled fuel feeding without formation of smoke and unburnts. F. Use clean vessels free from scaling for optimum heat transfer in hot water generation. G. Generate and use compressed air at required pressure in the case of using air compressor. H. Switch off compressor during idle period. I. Use correct size of air compressor suitable to their process. J. Avoid using motors that are rewound more than two times as it would reduce motor efficiency and increase energy consumption. Use energy efficient motors for its applications.

	K. Ensure proper loading of mixer in rubber coil mat production. Low level of loading mixer would lead to increased energy consumption. L. Switch off the mixer when not in use. M. Install automatic system to cut off electrical heating on achieving set temperature in press system. N. Follow proper work schedule for different category of products to optimize resource utilization. O. Install energy efficient LED lighting to reduce electricity energy consumption. P. Use suitable log sheets to record quantity of raw material procurement, production, wastage, and energy consumption.
2. Measurement and recording	The industry shall measure and record the following: A. Raw material quantity, production, fuel consumption, electricity consumption, water consumption, etc., on a daily basis. B. Develop and use suitable logsheet(s) for recording of key production parameters. The frequency of recording shall be on a daily and monthly basis. The logsheets would help the industry in assessing the yield and wastages to undertake corrective measures.
3. Maintenance and inspection	The industry shall undertake the following: A. Check for leakages of compressed air from joints in pipelines and plug them in the stencil process. B. Clean the heating vessels on a monthly basis to get rid of soot, scale, or dirt to avoid deterioration of heat transfer surfaces and performance. C. Clean suction filters of air compressor in stenciling unit on a monthly basis.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Select equipment of correct specifications to ensure optimum capacity utilization. B. Undertake proper treatment of rejection from dyeing process to recovery and reuse dye and water. C. Use power looms in place of handloom to improve productivity and quality. D. Use solar energy for hot water generaion and solar photovoltaic to meet electricity requirements. E. The industry shall use power looms in place of handloom to improve productivity and quality. F. The industry shall select equipment of correct specifications to ensure optimum capacity utilization. G. The industry shall undertake proper treatment of rejection from dyeing process to recovery and reuse dye and water.

6.17.4 Common monitorable parameters and performance assessment

The industry shall monitor common performance indicators as shown in Table 6.89 to assess the performance of the coir industry.

Table 6.89: Common monitorable parameters in coir industry

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Production	kg	Electronic balance	Daily
Electricity consumption	kWh	Energy meter	Daily
Fuel consumption	kg	Electronic balance	Daily

The industry shall estimate SEC using the following formula:

$$\text{Specific energy consumption (kcal/kg)} = \frac{\text{Electrical energy} + \text{Thermal energy}}{\text{Total production}}$$

where

SEC is expressed as kcal/kg

Electrical energy (kcal/day) = Electricity consumption (kWh/day) × 860 (kcal/kWh)

Thermal energy (kcal/day)= Fuel consumption (kg/day) × Gross calorific value (kcal/kg)

Total production is in kg/day

6.17.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall use the raw material in an optimal way to minimize rejections from the processes.
2. The industry shall measure the fuel used for hot water generation.
3. The industry shall recover and reuse colouring chemicals to reduce operating costs.
4. The industry shall consider using the rejections from the process for producing value added products, if any.
5. The industry shall install natural ventillators.
6. The industry shall maximize the use of day lighting.

JAGGERY

6.18 Jaggery industry

6.18.1 Background

The Jaggery industry is one of the energy consuming industries under the micro, small, and medium enterprises (MSME) sector. Jaggery is a honey brown coloured raw lump of sugar. It is a natural sweetener produced from sugarcane. Jaggery is made where sugarcane is grown extensively.

6.18.2 Production process

Jaggery making is a batch process. The raw material for jaggery making is sugarcane. The jaggery production involves sugarcane crushing, juice filtration, clarification, boiling, and crystallization (Figure 6.25).

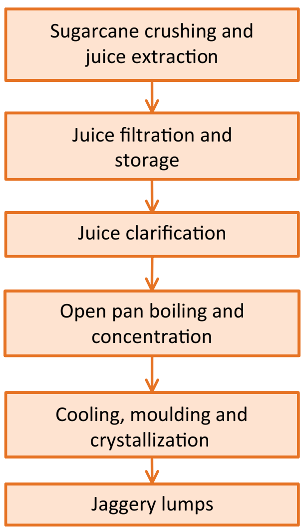

Figure 6.25: Jaggery production

Sugarcane crushing

The sugarcane is crushed to extract juice. The industry uses multiple roller arrangement to extract maximum juice from sugarcane.

Juice filtration

The suspended solids such as bagasse, trashes, and other suspended particulate matters from the juice are removed in a strainer. The filtered juice is sent for clarification.

Juice clarfication

The clarification of juice is carried out either using chemicals or locally available vegetable-base clarificants. On heating, scum is formed, which rises to the surface of the juice and is removed using wooden sieve. The juice becomes white in colour. In the clarification process, a precipitate of coagulated albumin, fats, waxes, gums, etc., settles down at the bottom of the clarifier. The clear juice is transferred for open pan heating. The precipitate is sent to rotary drum vacuum filters to separate juice from the mud.

Open pan heating

The clarified juice is boiled in an open pan using single or multiple pans in series. The juice is stirred continuously and the dirt particles are taken out manually. The internally generated bagasse in cane crushing is used as fuel. Upon reaching the correct temperature of about 100 °C–120 °C, heating is stopped.

Cooling, moulding, and crystallization.

The concentrated mass is transferred to cooling pan for crystallization. The mass is stirred slowly and intermittently to ensure formation of granular structure. The semi-solid mass is put in moulds of different sizes for solidification. On cooling, the jaggery is removed from the mould.

6.18.3 Process equipment

The industry shall improve the energy performance by optimizing various operating parameters in fuel-fired furnace used for open pan boiling through routine inspection and maintenance, and keeping key operating parameters within specified limits. This section provides EC Guidelines covering best operating practices, operational aspects, and performance assessment of open pan boiling furnace in the jaggery industry in a rational way.

Standards components	
1. Management and control	The industry shall adopt the following: A. Ensure continuous fuel feeding in small quantities and smaller sizes for complete combustion and prevent formation of black smoke. B. Ensure the time gap between successive fuel feeding will not cause flame out. C. Use properly dried solid fuels for firing. High moisture would lead higher fuel consumption. D. Ensure sufficient length of firing zone for complete burning of volatile materials present in the fuel. E. Ensure sufficient length of preheating zone of juice pan to utilize the sensible heat available in flue gases before exhausted to chimney. F. Maintain proper flame length to avoid flame exit through chimney. G. Maintain sufficient air passage without any obstruction to ensure smooth air flow to sustain combustion. H. Remove bottom ash at regular intervals to clear the passage for flue gas towards the chimney. I. Ensure sufficient height and cross-sectional area of chimney to maintain the required draft in the furnace. J. Plug off all leakages from the furnace to ensure hot gases move along the complete length and transfer maximum heat to the pans. K. Install energy efficient motors of appropriate size. L. Avoid use of motors that are rewound more than two times as it would reduce motor efficiency and increase energy consumption. M. Install automatic voltage regulator (AVR) for controlling variations in voltage from grid power. N. Install automatic power factor controller (APFC) for keeping power factor close to unity. O. Use suitable starter based on connected load to avoid high starting current, for example (1) soft starter for high load centre and operation requiring frequent switching off, (2) star-delta for medium motive load, and (3) direct online (DOL) for smaller load.
2. Measurement and recording	The industry shall measure and record the following: A. Fuel consumption, electricity consumption, production, etc. B. Process temperature and exit flue gas temperature on a daily basis. C. Surface temperature on a quartlery basis. D. Use a suitable logsheet for recording key operating parameters on a regular basis – hourly, shift, daily, etc.
3. Maintenance and inspection	The industry shall undertake the following: A. Clean the internal surfaces of pans on a monthly basis to remove scaling, dirt, etc., for better heat transfer. B. Undertake cleaning of external surfaces of the pans on a regular basis to remove soot and deposits for enhancing heat transfer. C. Inspect and clean chimney base and flue path on a daily basis. Remove the ash deposit to ensure sufficient cross-sectional area for flue gases.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Maximize juice extraction using hot imbibition water either in last roller or in one before. This practice shall help in reducing the loss of sugar in bagasse and in increasing the yield of jaggery. B. Use dosing of SO_2 gas and limewater for improving juice clarification. C. Adopt measures to avoid overheating or hot spot development when juice is being concentrated. The measures include on-line temperature monitoring, adequate agitation using wooden stirrer to avoid caramelization. D. Use galvanized iron pans or copper pans for better heat transfer in juice heating and boiling. E. Use mother seed for faster and better crystallization.
Target components	
	A. The industry shall maintain a maximum pan temperature at about 120 °C to optimize the yield.

6.18.4 Commpon monitorable parameters and performance assessment

The industry shall monitor common performance indicators as shown in Table 6.90 to assess the performance of jaggery industry.

The industry shall estimate SEC using the following formula.

$$\text{Specific energy consumption (kcal/kg)} = \frac{\text{Electrical energy + Thermal energy}}{\text{Total production}}$$

where

SEC is expressed as kcal/kg

Electrical energy (kcal/day) = Electricity consumption (kWh/day) × 860 (kcal/kWh)

Thermal energy (kcal/day) = Fuel consumption (kg/day) × Gross calorific value (kcal/kg)

Total production is in kg/day

6.18.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall dry the biomass generated during juice extraction for firing.
2. The industry shall avoid idle running of crusher to reduce energy consumption.
3. The industry shall use energy efficient LED lighting.
4. The industry shall maximize the use of day lighting.
5. The industry shall install natural ventilators.

Table 6.90:Common monitorable parameters in open pan furnace

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Fuel consumption	kg	Electronic balance	Daily
Electricity consumption	kWh	Energy meter	Daily
Process temperature	°C	Thermocouple	Daily
Exit flue gas temperature	°C	Thermocouple	Daily
Production	kg	Electronic balance	Daily

OIL MILL

6.19 Oil mill

6.19.1 Background

Oil mills extract and refine oil from different oil seeds using mechanized process. Oil milling is an electricity intensive process. The raw materials used in oil mills include oil seeds and additives to increase the shelf life.

6.19.2 Production process

The production process in an oil mill involves sourcing of seeds of required quality. After cleaning, the seeds are passed through an expeller (1st pass) wherein the seeds are crushed and oil is separated, and wet oil cake is formed. The oil cake is passed through expeller (2nd pass) wherein most of the remaing oil in the cake is extracted. The expellers are electrical motor driven systems. The oil is filtered using fine filter cloth to remove sediments. The filter oil is filled in bottles which are packed in cartons and dispatched.

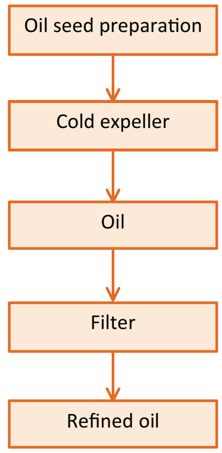

Figure 6.26: Process flow of oil milling

6.19.3 Process equipment

The oil expeller in the oil mill is the major energy-consuming equipment. The industry shall improve the energy performance, that is, reduce SEC level by reducing various energy losses occurring in oil extraction through routine inspection and maintenance as prescribed by the suppliers. This section provides EC Guidelines covering best operating practices, operational aspects, and performance assessment for oil milling industry in a rational way.

Standards components	
1. Management and control	The industry shall use the following: A. Use only matured oil seeds in the milling. B. Control feed rate of seeds and worm spinning rate to maintain the yield. C. Use seed cracker to reduce the load on expellers. D. Ensure adequate loading of process equipment for optimum capacity utilization of oil extraction. The low capacity utilization will lead to increased SEC level or poor energy performance. The loading of the mill is dependent on the quantity of seeds available for extraction, its quality, etc. E. Extract maximum oil from seeds to improve yield. F. Restrict motor rewinding to maximum two times. G. Ensure balancing of voltage in all three phases of motors for optimum performance. Maintain unbalanced voltage within 1%. Install automatic voltage regularor (AVR) for controlling voltage variations from grid power. H. Install automatic power factor controller (APFC) to keep the power factor close to unity. I. Use direct online (DOL) starters for motors upto 5 hp, star-delta type starters for 5–20 hp motors, and soft starter for motor with more than 20 hp capacity. J. Switch off motors during idle production periods. K. Operate motors in the range of 75%–80% load for maximum efficiency. Avoid under-loading of the motors. L. Ensure adequate ventilation for motors to avoid overheating of motors.

2.	Measurement and recording	The industry shall measure and record the following: A. Electricity consumption of the plant and oil production on a daily basis. B. Measure and record motor body temperature and vibration on a monthly basis. C. Supply voltage, power factor, and lubrication level on a daily basis. D. Develop and use suitable logsheet(s) for measurement and recording of key operating parameters. The frequency of recording shall be shift, daily, monthly, etc., based on the type of data. E. The logsheets would help the industry in assessing energy performance.
3.	Maintenance and inspection	A. The industry shall inspect oil filter on a daily basis so that consistent quality of oil is produced.
4.	Necessary measures when installing new facilities	The industry shall consider the following: A. Install energy efficient motors to reduce energy consumption. B. Use eco-ventillators in place of exhaust fans to reduce energy consumption.
Target components		
		The industry shall ensure the following: A. Specific energy consumption of 100–150 kWh per tonne of oil seeds. B. Use mature oil seeds with at least 40% oil content.

6.19.4 Common monitorable parameters and performance assessment

The industry shall monitor common performance indicators as shown in Table 6.91 to assess the performance of oil mill.

The industry shall assess the performance of the oil mill using the following formula:

$$\text{Specific energy consumption (kWh/tonne)} = \frac{\text{Total energy consumption (kWh)}}{\text{Production (tonne)}}$$

6.19.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall inspect and ensure required quality of seeds for oil extraction.
2. The industry shall maintain oil expeller to ensure the level of extraction of oil.
3. The industry shall inspect filter on a regular basis so that consistent quality of oil is produced.
4. The industry shall consider installing solvent extraction system to maximize the extraction of oil from the cake.
5. The industry shall avoid idle running of expeller to reduce energy consumption.
6. The industry shall use energy efficient LED lighting.
7. The industry shall maximize the use of day lighting.
8. The industry shall install natural ventilators.

Table 6.91: Common monitorable parameters in oil mill

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Electricity consumption	kWh	Energy meter	Daily
Production	tonne	Electronic balance	Daily

TEA INDUSTRY

6.20 Tea industry

6.20.1 Background

The tea industry is one of the energy consuming industries under the micro, small, and medium enterprises (MSME) sector. Green tea leaves are used as the raw material in the tea industry. The main products from the tea industry are CTC (Cut, Twist, and Curl) and Orthodox. The tea industry uses both thermal and electrical energy. Thermal energy is met from biomass.

6.20.2 Production process

The tea production process comprises withering, CTC/rolling, fermentation, drying, and grading/sorting (Figure 6.27).

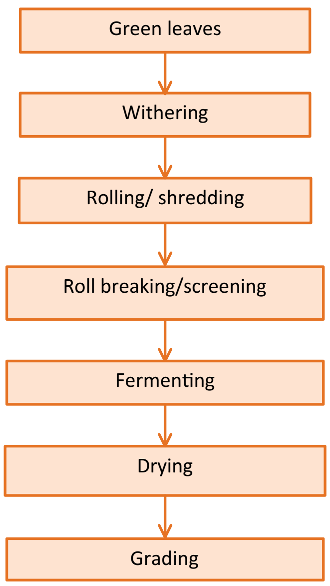

Figure 6.27: Process flow in tea industry

Withering

In withering, the surface moisture of the green leaves are removed apart from partial removal of embedded moisture to obtain proper physical conditions suitable for rolling. Two types of withering processes are used, namely (1) open or natural withering and (2) artificial withering. Artificial withering is done at about 20 °C–25 °C, wherein the moisture is reduced to about 55% in Orthodox tea production (hard withering) and about 70% in CTC tea production (light withering). Hard withering takes about 12–18 hours and light withering is accomplished in 6 hours. Air circulation is continued to avoid spoiling of withered leaves.

CTC and orthodox

In CTC, a rotor vane is used to shred withered leaves. A reconditioned powder (made of pulverized fly-off from dryer or fibre removed during grading) is added to compensate for any loss of juice from tea leaves during shredding. It is mixed well with withered leaves and crushed by double action rollers. During rolling, the heat generated through friction reduces moisture of the leaves to 55%. Depending on the grade of tea, 3–4 CTC machines are used. Apart from twist and curl, the enzymes released during rolling help in fermentation. In orthodox, only rolling is done which helps in twisting leaves continuously, breaking the leaf structure, and releasing juices for oxidation. Light rolling is done initially followed by heavy rolling.

Fermentation

The fermentation process is done naturally or in a rotating drum. Fermentation of rolled tea leaves turns the leaves into reddish brown colour. Short or light fermentation gives more flavoured and aroma rich tea, whereas long or deep fermentation forms colour in tea brewing.

Drying

The fermented tea leaves are transferred to a dryer to arrest fermentation and reduce the moisture level to about 3%. A temperature of about 90 °C–160 °C is maintained in the dryer. Drying is a critical process to control the quality of the final tea. The industry uses either endless chain pressure (ECP) dryer having multiple chain trays or fluidized bed dryer (FBD). A temperature of about 90 °C is maintained in the ECP dryer, and in the FBD dryer a temperature of 140 °C–160 °C is maintained.

Grading and packing

The dried black tea is graded based on quality and packed for dispatch.

6.20.3 Process equipment

The industry shall improve the thermal energy performance of hot air dryer used for drying of fermented tea leaves. It shall undertake routine inspection and maintenance, keeping key operating parameters such as temperature, speed in ECP dryer. and pressure in FBD, moisture, within the specified limits. This section provides EC Guidelines covering best operating practices, operational aspects, and performance assessment for hot air dryer in the tea industry in a rational way.

Standards components	
1. Management and control	The industry shall undertake the following: A. Use low pressure roller for under-withered leaves and high-pressure roller for over-withered leaves. B. Maintain a difference of about 4 °C between dry bulb temperature and wet bulb temperature for better withering conditions. C. Use optimum loading during rolling process. D. Use either programmable logical controller (PLC) or variable frequency control (VFD) to control withering fans instead of damper control. E. Use suitable measures to control hot air flow and the temperature in the dryer during fluctuating loads. The measures include control of blower speed using VFD, auto temperature controller, etc. F. Reduce initial air flow in artificial withering process to about 2/3rd of the volume after the completion of withering process to avoid spoiling of withered leaves. G. Maintain correct combustion air ratio as specified in Table 6.92 using suitable oxygen analyser. H. Use better insulation material for hot face insulation to avoid heat losses. I. Regulate and control the use of humidifiers used for floor fermentation. J. Use ball breaker after fermernation to avoid ball formation. K. Use temperature indicators to monitor temperatures in the dryer. L. Ensure better resolution of temperature indicators for accurate measurement of temperatures. M. Install automatic voltage regulator (AVR) for controlling variations in voltage from grid power. N. Ensure unity power factor using automatic power factor controller (APFC). O. Install blower having suitable capacity and correct air pressure. Avoid over-sized or under-sized blower. P. Install blower close to the combustion equipment to avoid transmission loss. Q. Limit motor rewinding up to two times. R. Minimize heat losses through air ingression by adopting suitable measures, such as minimizing the size of opening, proper sealing of dryer.
2. Measurement and recording	The industry shall measure and record the following: A. Quantity of tea leaves processed, production, fuel consumption, electricity consumption, temperature of hot air, exit flue gas temperature, residual oxygen (O_2), and carbon monoxide (CO) in flue gases on a daily basis. B. Suitable logsheet(s) for measurement and recording of key operating parameters. The frequency of recording shall be hourly, daily, weekly, or monthly based on the type of data. The logsheets would help the industry in: (1) assessing energy performance and (2) identifying deviations in operating parameters to undertake corrective measures. C. Surface temperature of dryer on a quarterly basis.
3. Maintenance and inspection	The industry shall undertake the following: A. Inspect and arrest hot air leakages from ducts, isolating dampers, joints, etc., as applicable. B. Undertake cleaning of, heat transfer surfaces, ducts, and pipes in hot air transfer lines on a monthly basis. C. Renovate, repair the insulation and lining in the dryer on a quarterly basis. D. Undertake calibration and maintenance of instruments such as temperature indicator as per recommendations of suppliers to record reliable and accurate data. Maintain proper record of calibration and the plans for all the key instruments.

4. Necessary measures when installing new facilities	The industry shall consider the following: A. Select compatible capacity and specifications of hot air dryer based on application, fuel type, load fluctuations, etc. B. Install PLC-based withering system. C. Install high efficient fluidized bed dryer to meet the process requirements. D. The industry using biomass as fuel shall install biomass gasifer to improve combustion efficiency. E. Install energy efficient fan in the process. F. Replace standard motors with energy efficient IE3 motors.
Target components	
	The industry shall ensure the following: A. Specific energy consumption in the range of 0.40–0.82 toe per tonne B. Target combustion air ratio in dryer as specified in Table 6.92.

Table 6.92: Air ratio for dryer

Parameter	Air ratio@	
	Wood#	Gas fuel&
Standard	1.49–1.56	1.15-1.18
Target	1.32–1.39	1.12-1.15

Source: Performance data from different industries

@ Air ratio is defined as the ratio of actual air supplied (AAS) to theoretical air requirement. The following formula shall be used for calculating air ratio (value rounded to two digits). The air ratio is considered based on a steady state operation at constant load conditions and can be measured and verified at specific measurement points, while maintaining maximum permissible limit for carbon monoxide (CO) level to 200 ppm.

$$\text{Air ratio} = \frac{21}{21 - \%\ \text{oxygen in flue gases}}$$

Includes use of wood up to 10 tph capacities; bagasse or rice husk firing for other capacities.

& Refers to natural gas (NG) only

Note: Gross calorific value (GCV) of fuels

- The GCV of different fuels, considering the standard composition of fuels are given below.
- Natural gas – 8500 to 9000 kcal per SCM (Standard cubic meter) (Source: GAIL India Limited)

6.20.4 Common monitorable parameters and performance assessment

The industry shall monitor common performance indicators as shown in Table 6.93 to assess the performance of tea industry.

The industry shall estimate SEC using the following formula:

$$\text{Specific energy consumption} = \frac{\text{Electrical energy} + \text{Thermal energy}}{\text{Total production}}$$

where

SEC is expressed as kcal/kg

Electrical energy (kcal/day) = Electricity consumption (kWh/day) × 860 (kcal/kWh)

Thermal energy (kcal/day) = Fuel consumption (kg/day) × Gross calorific value (kcal/kg)

Table 6.93 Common monitorable parameters of tea industry

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Production	kg	Electronic balance	Daily
Fuel consumption	kg	Electronic balance	Daily
Electricity consumption	kWh	Energy meter	Daily
Temperature of hot air	°C	Thermocouple	Daily
Air ratio	kg/kg fuel	Flue gas analyser	Daily

Total production is in kg/day

The industry shall refer to the typical performance indicators for tea production as provided in Table 6.94.

Table 6.94: Typical performance indicators for tea production

Performance indicator	Typical range
Specific energy consumption	0.40–0.82 toe per tonne

Source: Based on data from different industries

6.20.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall ensure suitable and consistent quality of tea leaves to maximize productivity.
2. The industry shall use suitable magnets to remove iron-contamination, if any, from the processed tea leaves.
3. The industry shall avoid idle running of roller to reduce energy consumption.
4. The industry shall use energy efficient LED lighting.
5. The industry shall install natural ventillators.
6. The industry shall maximize the use of day lighting.

RICE MILL

6.21 Rice mill

6.21.1 Background

The rice mill is one of the energy intensive industries in the micro, small, and medium enterprises (MSME) sector. The paddy is processed into rice in the mills. The rice mill generally produces two type of rice namely parboil rice and raw rice. A majority of rice mills are involved in producing parboiled rice. The rice mills are categorized based on the milling capacity, varying 3–6 tonne per hour (tph).

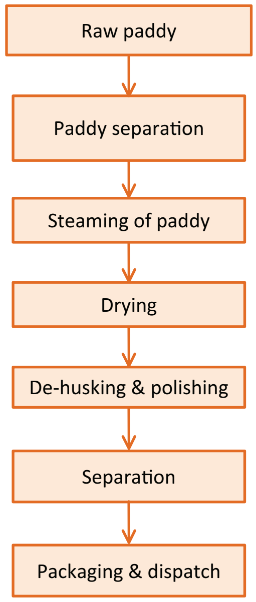

Figure 6.28: Production process of parboiled rice

6.21.2 Production process

The general process steps to produce parboiled rice include paddy preparation, steaming, drying, milling, polishing, etc. (Figure 6.28).

Paddy preparation

The foreign materials such as rice straw, dust, stone, sand, and seedless/premature paddy are removed.

Steaming

Paddy is heated using steam in two stages for full-parboiled rice or single stage for semi-parboiled rice. In case of raw rice, steaming operation is not done.

Drying

Cooked paddy is dried either on open floor in sun light or in dryer.

Milling

In this stage, the husk from the paddy is removed. Further grading and silky polishing of raw rice is carried out to produce premium quality rice.

6.21.3 Process equipment

The industry shall improve the energy performance by optimizing various operating parameters in fuel-fired equipment such as boiler, dryer, etc. through routine inspection and maintenance and keeping key operating parameters within specified limits as prescribed by the OEMs. This section provides EC Guidelines covering best operating practices, operational aspects, and performance assessment of fuel-fired equipment in rice mill industry in a rational way.

Standards components	
1. Management and control	The industry shall: A. Maintain correct air ratio in boiler, which is specified as standard value in Table 6.95. Use suitable oxygen (O_2) analyser (on-line or portable type) to monitor the air ratio. Adjust and control air ratio to avoid high excess air, while ensuring complete combustion of fuel. B. Use automatic air-fuel ratio control system in the combustion system and integrate with control loop. C. Use blower having suitable capacity and correct air pressure. Avoid over-sized or under-sized blower. D. Install blower close to the combustion equipment to avoid transmission loss. E. Integrate blower operation for combustion of air supply with rice husk feeding so that the blower is switched off automatically during non-feeding time. F. Minimize heat losses through air ingression by adopting suitable measures such as minimizing size of opening, proper sealing of furnace, etc. G. Restrict hot water temperature for soaking to about 60 °C. Higher temperatures would lead to overcooking of paddy. H. Use on-line or portable instrumentation for monitoring temperature of exhaust gases and preheated air temperature.

	I. Reduce exhaust flue gas temperature using suitable waste heat recovery (WHR) system and maintain flue gas temperature as specified in Table 6.96 as standard value. Install suitable WHR system based on waste heat available and type of application. J. Carry out blowdown to maintain the level of total dissolved solids (TDS) in boiler water as recommended by OEM. K. Enhance recycling of hot water drained from steaming bowl after treatment. L. Manage recovery and reuse of waste heat in condensate return according to the instructions concerning parameters such as the quality and quantity of condensate, temperature, etc. in case of using boiler. Reuse of condensate helps in reducing water treatment and blowdown requirements. An effective condensate recovery system improves boiler efficiency. M. Maintain external skin temperatures of boiler within the range as specified in Table 6.97 as standard value. N. Undertake thermal insulation work on different systems such as steam and condensate pipes, ducts, etc., which are used for transporting heat media either through steam according to the industrial standard practices for thermal insulation works and equivalent standards. O. Maintain appropriate quality of feedwater in boiler according to Indian Boiler Regulations (IBR), 1950 or an equivalent standard as suggested by the manufacturers. P. Use dry steam in heating processes to enhance heat transfer. Close the steam supply to the process when it is not in use. Use appropriate steam separator or steam trap to maintain the required dryness fraction of steam. Q. Maintain proper draft in combustion equipment using proper damper setting in flue gas path. R. Ensure proper pre-heating of furnace oil to reduce the viscosity level in case of using furnace oil based combustion system. S. Avoid using multiple belt-driven system from a common shaft. Use dedicated motors for individual load centres to shift from common drive to individual drive system. T. Ensure better resolution of measuring instruments for accurate measurements.
2. Measurement and recording	The industry shall measure and record the following: A. Paddy processed, rice production, fuel consumption, residual oxygen (O_2) and carbon monoxide (CO) in flue gases, and unburnt carbon in bottom ash and fly ash for solid fuels, preheat air temperature, exhaust gas temperature, etc. on daily basis. B. Monitor steam generation, pressure, feedwater temperature and total dissolved solids (TDS), temperature and quantity of condensate of boiler on daily basis. C. Boiler surface temperature on quarterly basis. D. Monitor total water consumption of process on daily basis. E. Use suitable logsheet (s) for measurement and recording of key operating parameters. The frequency of recording shall be hourly, shift basis, daily, weekly or monthly based on requirements. The logsheets would help the industry in: (1) assessing energy performance and (2) identifying deviations in operating parameters to undertake corrective measures.

3. Maintenance and inspection	The industry shall: A. Maintain components related to the heat transfer of equipment such as heat-transfer surfaces, heat exchangers, etc. according to the instructions as specified by the suppliers. Clean the equipment periodically as per the instructions to get rid of soot, scale or dirt to avoid deterioration of heat transfer surfaces and performance. B. Repair, renovate, and maintain the WHR systems in flue path, once in six months, to avoid scale formation and ensure optimum performance. C. Inspect and maintain steam traps on steam lines periodically as per the instructions of the manufacturers to prevent steam leaks and clogging caused by the malfunctioning of traps. D. Calibration and maintenance of instruments as per recommendations of suppliers. Maintain proper record of calibration and the plans for all key instruments.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Install boiler with the highest efficiency that meets the process requirements. B. Install waste heat recovery boiler to generate power using micro turbine. C. Select appropriate combustion equipment and accessories, for example. burner, built-in automation system, etc. D. Use improved streamlined pipe route (avoiding unnecessary bends and joints) for transporting heat media, that is, water to minimize heat radiations. E. Use lightweight plastic buckets in elevator system in place of mild steel buckets to reduce dead load in driving appliances. F. Use solar water heater to preheat water required for paddy soaking.
Target components	
	The industry shall ensure the following: A. Specific energy consumption of 25–50 kWh per tonne for raw rice production. B. Specific energy consumption of 0.93–1.60 Gcal per tonne for parboiled rice production C. Maintain air ratio based on the target value as provided in Table 6.95. D. Ensure exit flue gas temperature in the range as provided in Table 6.96 as target value. E. Maintain external surface temperature based on target value as provided in Table 6.97.

Table 6.95: Air ratios for boilers+

Parameter	Boiler capacity (tph)	Load factor (%)	Rice husk#
Standard	Up to 10	50–100	1.49–1.56
Target	Up to 10	50–100	1.32–1.39

Source: Performance data from different plants

\+ Combustion of fuels under Standard Temperature and Pressure (STP) conditions is assumed and the effect of parameters, such as variation in fuel compositions, is ignored.

Air ratio is defined as the ratio of actual air supplied AAS to theoretical air requirement. The following formula shall be used for calculating air ratio (value rounded to two digits). The air ratio is considered based on a steady state operation at constant load conditions and can be measured and verified at specific measurement points, while maintaining maximum permissible limit for carbon monoxide (CO) level to 200 ppm.

$$\text{Air ratio} = \frac{21}{21 - \%\ \text{oxygen in flue gases}}$$

\# Other than in-house rice-husk, industry may also use of other biomass and agro waste up to 10 tph capacities; bagasse along with rice husk firing for other capacities.

Table 6.96: Waste heat recovery from boiler in rice mill

Exhaust gas temperature (°C)	Waste heat recovery rate (%)		Flue gas temperature* (°C)
	Standard[α]	Target[β]	
400–600	22	43	200–250

Source: Based on data from different industries

α Estimated heat drop based on the upper limit of gas temperatures and net heat transfer with 60% efficiency for heat exchanger
β Estimated heat drop based on the lower limit of gas temperatures and net heat transfer with 65% efficiency for heat exchanger
* Considering natural draft systems for higher flue gas temperature and induced draft system for lower temperatures

The industry shall compute waste heat recovery (WHR) rate using the following formula.

$$\text{Waste heat recovery rate (\%)} = \frac{\text{Recovered heat (kcal)}}{\text{Sensible heat in exhaust gases (kcal)}} \times 100$$

Table 6.97: Surface temperatures of boiler

Parameter	Surface temperature (°C)#
Standard	Ambient temperature + 30
Target	Ambient temperature + 20

Source: Based on data from different industries

 # Average skin temperature under steady state operation

6.21.4 Common monitorable parameters and performance assessment

The industry shall monitor common performance indicators as shown in Table 6.98 to assess the performance of the boiler.

The performance of boiler is expressed in terms of thermal efficiency. The thermal efficiency of boilers shall be estimated using following methods:

a) Thermal efficiency by direct method

The thermal efficiency of boiler by direct method is the ratio of heat output to heat input.

$$\text{Thermal efficiency (\%)} = \frac{\text{(Quantity of steam (kg/hr)} \times \text{(Enthalpy of steam-Enthalpy of feedwater (kcal/kg))}}{\text{(Rice husk firing rate (kg/hr)} \times \text{Gross calorific value (kcal/kg))}} \times 100$$

b) Thermal efficiency by indirect method

The thermal efficiency of boiler by indirect method involves evaluating various heat loss fractions occurring in boiler under steady state conditions. The thermal efficiency of boiler by indirect method can be expressed as follows:

Thermal efficiency = 100 – (L1 + L2 + L3 + L4 + L5 + L6 + L7 + L8)

where

L1 = Loss due to dry flue gas (%)

$$L1 = \frac{m \times C_p \times (T_f - T_a)}{GCV\ of\ fuel} \times 100$$

where

m = mass of dry flue gas (kg/kg fuel)

C_p = Specific heat of flue gas (kcal/kg °C)

Table 6.98: Common monitorable parameters in boiler

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Steam pressure	bar	Pressure gauge	Hourly
Steam generation	kg/hr	Flow meter	Daily
Fuel consumption	kg	Electronic balance	Daily
Air ratio	kg/kg fuel	Flue gas analyser	Daily
Flue gas temperature	°C	Thermocouple	Daily
Feedwater temperature	°C	Thermocouple	Daily
Surface temperature	°C	Thermocouple	Quarterly

T_f = Flue gas temperature (°C)

T_a = Ambient temperature (°C)

L2= Loss due to hydrogen in fuel (H_2)

$$L2 = \frac{9 \times H_2 \times \{584 + C_p(T_f - T_a)\}}{GCV\ of\ fuel} \times 100$$

where

H_2 = kg of hydrogen present in fuel on 1 kg basis

Cp = Specific heat of superheated steam (kcal/kg°C)

Tf = Flue gas temperature (°C)

Ta = Ambient temperature (°C)

584 = Latent heat corresponding to partial pressure of water vapour

L3 = Loss due to moisture in fuel

$$L3 = \frac{M \times \{584 + C_p(T_f - T_a)\}}{GCV\ of\ fuel} \times 100$$

where

M = kg moisture in fuel on 1 kg basis

Cp = Specific heat of superheated steam in kcal/kg°C

Tf = Flue gas temperature (°C)

Ta = Ambient temperature (°C)

584 = Latent heat corresponding to partial pressure of water vapour

L4 = Loss due to moisture in air

$$L4 = \frac{AAS \times humidity\ factor \times C_p \times (T_f - T_a) \times 100}{GCV\ of\ fuel}$$

where

AAS = Actual mass of air supplied per kg of fuel

Humidity factor = kg of water/kg of dry air

Cp = Specific heat of superheated steam in kcal/kg°C

Tf = Flue gas temperature in °C

Ta = Ambient temperature in °C (dry bulb)

L5 = Loss due to carbon monoxide

$$L5 = \frac{\%CO \times C}{\%CO + \%CO_2} \times \frac{5744}{GCV\ of\ Fuel} \times 100$$

where

CO = Volume of CO in flue gas (%)

CO_2 = Volume of CO_2 in flue gas (%)

C = Carbon content kg/kg of fuel or when CO is obtained in ppm,

CO formation (Mco) = CO (in ppm) x 10^6 x Mf x 28

Mf = Fuel consumption in kg/hr

L5 = Mco x 5744#

Heat loss due to partial combustion of carbon

L6 = Loss due to surface radiation, convection and unaccounted

Generally this loss is insignificant and difficult to measure. The surface heat loss and unaccounted losses are assumed based on the type and size of boiler as given below:

Industrial fire tube/packaged boiler : 1.5–2.5%

Industrial watertube boiler : 2–3%

$L6 = 0.548 \times [(T_s/55.55)^4 - (T_a/55.55)^4] + 1.957 \times (T_s - T_a)^{1.25} \times$ sq. rt of $[(196.85\ V_m + 68.9)/68.9]$

This loss can be calculated if the surface area of boiler and its surface temperature are known:

where

L6 = Radiation loss in W/m^2

Vm = Wind velocity in m/s

Ts = Surface temperature (°K)

Ta = Ambient temperature (°K)

L7= Unburnt losses in fly ash (for solid fuel firing)

$$L7 = \frac{\text{Total ash collected/kg of fuel burnt} \times \text{G.C.V of fly ash} \times 100}{GCV\ of\ fuel}$$

L8 = Unburnt losses in bottom ash (for solid fuel firing)

$$L8 = \frac{\text{Total ash collected/kg of fuel burnt} \times \text{G.C.V of bottom ash} \times 100}{GCV\ of\ fuel}$$

The industry shall refer to the typical performance indicators of rice mill as provided in Table 6.99.

Table 6.99: Typical performance indicators for rice mill

Type	Specific energy consumption
Raw rice	25–50 kWh per tonne
Parboiled rice	0.93–1.60 Gcal per tonne

Source: Based on data from different industries

6.21.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall optimize the use of rice husk consumption in boiler.
2. The industry shall avoid spillage of fuel to reduce wastage.
3. The industry shall recover maximum condensate from the process at maximum possible temperature.
4. The industry shall maintain the temperature of soaking water close to about 60 °C.
5. The industry shall cut-off steam used for hot water generation in soaking of paddy upon reaching the required temperature.
6. The industry shall generate hot water required for soaking of paddy using solar water heater.
7. The industry shall auto cut-off steam required for steaming of paddy on completion of operation.
8. The industry shall recover and recycle water drained from soaking process after treatment.
9. The industry shall recover and recycle hot water drain from steaming bowl after treatment.
10. The industry shall avoid idle running of motors in paddy processing section.
11. The industry shall recover and use bran to produce value added products.
12. The industry shall use energy efficient LED lighting.
13. The industry shall maximize the use of day lighting.
14. The industry shall install natural ventilators.

ICE MAKING

6.22 Ice making industry

6.22.1 Background

Many of the food processing industries require storage of the processed food products for a longer duration. The ice making industries are the downstream industries that provide support to a large number of processing industries such as food, chemicals, etc.

6.22.2 Production process

The main type of ice produced by ice industry is block ice. The production process of ice making includes preparation of fresh water, preparation of brine/salt water, fresh water filling in moulds, freezing of water, and production of ice (Figure 6.29).

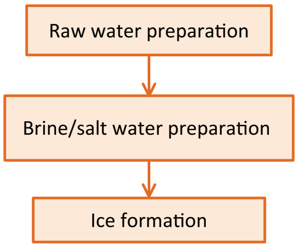

Figure 6.29: Ice making

Raw water preparation

Raw water is tested for salinity, TDS (total dissolved solids), PH value, hardness, odour, etc. and standardized for ice making.

Brine/salt water preparation

Brine water is a mixture of sodium chloride (NaCl) and water in the proportion of 1:3. It acts as a secondary refrigerant which converts water into ice block.

Ice formation

Raw water is filled in cans. Water is frozen to form ice block taking the shape of moulds Ice blocks in the cans get frozen with chilled brine solution in circulation. The brine solution is chilled using ammonia-based refrigeration system. The brine solution is kept in constant motion using agitators to increase heat transfer. The specific gravity of brine solution is maintained by adding compensating salt. The brine temperature is maintained at -10 °C to -11 °C. Ice formation is a batch process and ice cans with fully-formed ice blocks are removed from the freezing tank.

6.22.3 Process equipment

The ice making industry is electrical energy intensive industry with main energy consuming equipment is refrigeration system. The industry shall improve the refrigeration system energy performance, that is, reduce specific energy consumption (SEC) level by optimizing various operating parameters. These include reduction of various energy losses occurring in the refrigeration system through routine inspection and maintenance and keeping key operating parameters within specified limits as prescribed by the OEMs. This section provides EC Guidelines covering best operating practices, operational aspects, and performance assessment for refrigeration system used in ice making industry in a rational way.

6.22.4 Common monitorable parameters and performance assessment

The industry shall monitor common performance indicators as shown in Table 6.100 to assess the performance of the ice making.

Standards components	
1. Management and control	The industry shall undertake the following: A. Ensure matching of plant load with refrigeration system capacity, as part load operation will lead to higher specific energy consumption. B. Provide insulation of suitable type, size, and thickness to reduce energy loss from uninsulated valves, bare pipes, defective insulation of refrigeration system, etc. Inadequate insulation would result in corrosion of cold piping, ducts, chillers, etc. C. Optimize operational parameters such as temperatures of cooling water, chilled water and return water without affecting system performance considering seasonal weather conditions. D. Install stepped capacity control for low load conditions in case of using reciprocating type compressor in refrigeration system. E. Use automatic voltage regulator (AVR) for controlling variations in voltage from grid power. F. Use automatic power factor controller (APFC) for keeping power factor close to unity. G. Use direct online (DOL) starters for motors up to 5 hp, star-delta type starters for 5–20 hp motors and soft starter for motor with more than 20 hp capacity. H. Avoid rewinding of motors more than two times. Replace rewound and standard motors with energy efficient motors (IE2 motors). I. Use auto controls, variable frequency drives (VFDs), etc. for managing variable refrigeration load. J. Use on-line monitors or hand-hold instruments for measuring voltage, current, power consumption, power factor, etc.
2. Measurement and recording	The industry shall measure and record the following: A. Electricity consumption, supply voltage, current, power factor on daily basis. B. Temperatures of chilled water to process, return water, water inlet and outlet from cooling tower on daily basis. C. Motor body temperature, vibration and lubrication level on quarterly basis. D. Use suitable logsheet (s) for measurement and recording of key operating parameters. The frequency of recording shall be hourly, shift basis, daily, weekly or monthly based on requirements. The logsheets would help the industry in: (1) assessing energy performance and (2) identifying deviations in operating parameters to undertake corrective measures.
3. Maintenance and inspection	The industry shall undertake the following: A. Inspection and plug off leakages from pipes and other components in refrigeration system on daily basis. B. Check refrigerant charge and seals for correct charging and plug off leakages on monthly basis. C. Undertake periodical inspection and maintenance of refrigeration system as per the instruction of OEMs to ensure optimum performance. D. Calibrate and maintain the instruments as per recommendations of suppliers to record reliable and accurate data.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Replace reciprocating compressor with energy efficient screw or scroll compressor in refrigeration system. B. Use variable air-volume and flow-rate systems with speed control to respond to load variations. C. Install compact thermal storage system[@] in place of ice bank tank (IBT) for efficient operation and to overcome losses due to air ingrestion, poor insulation and agitator system in IBT.
Target components	
	The industry shall ensure the following: A. Specific energy consumption of 70–100 kWh per tonne of ice block.

@ Thermal storage system comprises an insulated tank having heat exchanger with phase change material to store thermal energy as latent heat

Table 6.100: Common monitorable parameters in ice making

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Production	tonne	Electronic balance	Daily
Electricity consumption	kWh	Energy meter	Daily
Inlet temperature of chilled water	°C	Thermocouple	Daily
Outlet temperature of chilled water	°C	Thermocouple	Daily
Temperature of sump	°C	Thermocouple	Daily

The industry shall assess the performance of ice making using the following formula.

$$\text{Specific energy consumption (kWh/tonne)} = \frac{\text{Electricity consumption (kWh/day)}}{\text{Ice production (tonne/day)}}$$

The industry shall refer to the typical performance indicators of ice making as provided in Table 6.101.

Table 6.101: Typical performance indicators for ice making

Performance indicator	Typical range
Specific energy consumption	70-100 kWh per tonne ice

Source: Based on data from different industries

6.22.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall ensure proper operation of agitators to maximize heat transfer from brine solution.
2. The industry shall treat the water used in cooling tower to keep the level of micro-organisms to a minimum.
3. The industry shall minimize water losses through drift and evaporation from cooling tower.
4. The industry shall use energy efficient LED lighting.

SEAFOOD

6.23 Seafood industry

6.23.1 Background

The seafood industry is one of the energy intensive industries under the micro, small, and medium enterprises (MSME) sector. A variety of seafood products are produced in the industry. These include fish, tiger shrimp, squid, cuttlefish, octopus, crab, clam, mussel either in ready-to-cook (RTC) or ready-to-eat (RTE) form of products.

6.23.2 Production process

The major steps involved in seafood processing include dressing (washing, gutting, skinning and trimming, etc.), grading, freezing, labelling and packing and cold storage (Figure 6.30).

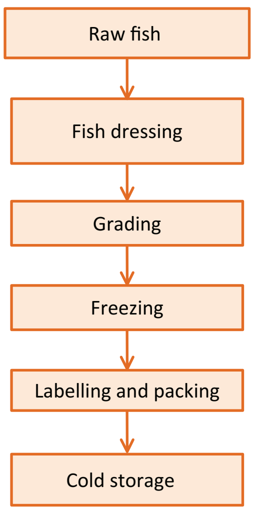

Figure 6.30: Seafood processing

Raw fish

Fresh or frozen fish/shrimp is received from cold storage transport at reception yard. Visual inspection is carried out for product specifications such as appearance, odour, texture, foreign matter, species homogeneity and physical characteristic such as size of fish as per procurement order. The fish is washed in a special washing table. After washing, it is stored in container with flake ice to maintain its temperature between 0 °C–4 °C.

Fish dressing

It includes beheading, gutting, skinning and trimming. During the entire process, the fish is covered with flake ice to maintain a temperature between 0 °C–4 °C. Prepared fish is washed with clean water from tap installed above working platform and it is temporarily stored in container with flake ice before downstream processes is undertaken.

Grading

The fishes are graded based on size.

Freezing.

Graded fish is either frozen in bulk in block form or individually quick frozen. The packages are stacked in plate freezer or blast freezer. The typical operating temperature of freezer is –40 °C with a cycle time of 2–4 hours per batch.

Labelling and packing

The output is glazed and sent for packing in cartons and labelled. To avoid excessive drying of fish in freezer, glazing is done. The product is sent through metal detector to inspect for metallic material.

Cold storage

The final product is packed in boxes and sent to cold storage for storing till dispatch. The cold storages are equipped to maintain products at or lower than –18 °C. The set temperature of cold storage facility is typically –23 °C. The products in cold storage follow first-in, first-out principal. The products in cold storage can have shelf life of about ten months without deterioration of quality. However, the products are generally dispatched within three months.

6.23.3 Process equipment

The seafood industry shall improve the refrigeration system energy performance, that is, reduce specific energy consumption (SEC) level by optimizing various operating parameters. These include reduction of various energy losses occurring in the refrigeration system through routine inspection and maintenance, and keeping key operating parameters within specified limits as prescribed by the OEMs. This section provides EC Guidelines covering best operating practices, operational aspects and performance assessment for refrigeration system used in seafood industry in a rational way.

Standards components	
1. Management and control	The industry shall undertake the following: A. Operate plate freezer with set temperature of not more than –40 °C for a cycle time of 2–4 hours per batch. B. Ensure uniform temperature of frozen fish storage space at about –23 °C to ensure a uniform temperature of frozen fish at –18 °C. C. Use auto control in freezer system to cut-off cold air supply upon reaching set temperature. D. Provide insulation of suitable type, size, and thickness to reduce energy loss from uninsulated valves, bare pipes, defective insulation of refrigeration system, etc. Ensure sufficient thickness of insulation to maintain surface temperature above dew point temperature of ambient air. It shall further limit corrosion on cold piping, ducts, chillers, etc. E. Avoid ingression of hot air or exgression of conditioned air by closing gaps and openings as much as possible to reduce the cooling load in processing floor area. F. Avoid entry of warm air from outside into cold room by having proper sealing arrangements, as provided below: a. Introduce good door management and keep the door of cold store closed whenever possible to keep away from warm air. b. Ensure obstruction free airflow from evaporators. c. Operate cold store at the highest possible temperature recommended for the product type, which shall reduce load in refrigeration system. d. Avoid warming of the product outside the cold room before loaded inside. e. Consider installing a low-power instant-on lighting system which can switch off automatically when the store is unoccupied. f. Use and maintain strip curtains to keep away from warm air and moisture. G. Adopt a section-wise air-conditioning system for operating parameters with signficant variations. For example, air conditioning requirement and load will be different for different sections of manufacturing, storage of products (finished or semi-finished), and workplace environment. The details of parameters shall include operational time, set temperature range (lower limit and upper limit), ventillation air per hour, and humidity. H. Manage the air-conditioning of process floors to only essential zones and reduce loads with potential options such as window shades, low thermal mass wall, etc. I. Consider modifications in the operational parameters without affecting system performance. These include cooling water temperatures, chilled/hot water temperatures, and seasonal variations in outdoor air conditions. J. For multi-pump requirement for transporting chilled water, operate pumps in such a way to achieve highest efficiency. Consider auto controls, variable frequency drives (VFDs), etc. for managing variable process cooling and refrigeration load. K. Ensure matching of plant load with refrigeration system capacity as part load operation will lead to higher specific energy consumption.
2. Measurement and recording	The industry shall measure and record the following: A. Temperatures of freezer (plate and IQF types), cold blast air, storage space and inlet and outlet temperatures of refrigerant on hourly basis. B. Quantity of fish processed, quantity of flake ice and water consumption. C. Electricity consumption on daily basis.
3. Maintenance and inspection	The industry shall consider the following: A. Clean and maintain the trays used in plate freezer for better heat transfer. B. Clean coils on monthly basis which become dirty on use. C. Use regularly watch-glass as inspection window to observe the level of refrigerant and recharge to maintain the required level whenever needed. D. Undertake periodical inspection and maintenance of refrigeration system (for example. heat exchanger) as per the instruction of OEMs to ensure optimum performance. E. Undertake inspection and plug off leakages from pipes and other components. F. Check refrigerant charge and seals regularly for correct charging and plug off leakages. G. Calibrate and maintain the instruments as per recommendations of suppliers to record reliable and accurate data.

4. Necessary measures when installing new facilities		The industry shall consider the following: A. Replace reciprocating compressor with energy efficient screw or scroll compressor in refrigeration system. B. Use variable air-volume and flow-rate systems with speed control to respond to load variations. C. Install desuperheater in ammonia based system to recover heat released during condensation of refrigerant for hot water generation. The hot water is used for shop floor use. D. Use evaporative condenser for higher heat transfer for low condensing application.
Target components		
		The industry shall ensure the following: A. 1100–1500 kWh per tonne of processed fish. B. Ratio of fish to flake ice consumption is 1:2. C. Ratio of fish to water consumption is 1:5.

6.23.4 Common monitorable parameters and performance assessment

The industry shall monitor common performance indicators as shown in Table 6.102 to assess the performance of the seafood industry.

The industry shall assess the performance of seafood industry using the following formula.

$$\text{Specific energy consumption (kWh/tonne)} = \frac{\text{Electricity consumption (kWh/day)}}{\text{Processed frozen fish (tonne/day)}}$$

$$\text{Specific flake ice consumption (tonne/tonne)} = \frac{\text{Flake ice consumption (tonne/day)}}{\text{Processed frozen fish (tonne/day)}}$$

Table 6.102: Common monitorable parameters in seafood industry

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Processed frozen fish	tonne	Electronic balance	Daily
Electricity consumption	kWh	Energy meter	Daily
Freezer temperature	°C	Thermocouple	Daily
Frozen fish storage temperature	°C	Thermocouple	Daily
Flake ice temperature	°C	Thermocouple	Daily
Flake ice consumption	kg	Electronic balance	Daily
Water consumption	kg	Flow meter	Daily
Inlet temperature of chilled water	°C	Thermocouple	Daily
Outlet temperature of chilled water	°C	Thermocouple	Daily
Temperature of sump	°C	Thermocouple	Daily

$$\text{Specific water consumption (tonne/tonne)} = \frac{\text{Water consumption (tonne/day)}}{\text{Processed frozen fish (tonne/day)}}$$

The industry shall refer to the typical performance indicators of seafood industry as provided in Table 6.103.

Table 6.103: Typical performance indicators for ice making

Performance indicator	Typical range
Specific energy consumption	1100–1500 kWh per tonne processed fish
Fish to flake ice consumption ratio	1:2
Fish to water consumption ratio	1:5

Source: Based on data from different industries

6.23.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall treat the water used in cooling tower to keep the level of microorganisms to a minimum.
2. The industry shall provide proper seal and plug off leakages in refrigeration system to maintain required refrigerant level.
3. The industry shall close the cold rooms immediately when not in use.
4. The industry shall use strip curtains in cold rooms to keep away from warm air and moisture.
5. The industry shall use energy efficient LED lighting.

DAIRY

6.24 Dairy industry

6.24.1 Background

The dairy industry is one of the energy intensive industries under the micro, small, and medium enterprises (MSME) sector. Dairy industries collect milk from both cooperative and private dairies. Milk is processed in dairy to different products such as packaged flavoured milk, ghee, butter, curd, khoa, milk powder, and paneer. The dairy industry uses two main types of processes: (i) heat treatment of milk to increase shelf life and packaging of liquid milk, and (ii) dehydration of milk to produce products such as butter, hard cheese and milk powder.

6.24.2 Production process

The general process steps in a dairy industry include raw milk collection, pasteurization, cream separation, standardization and homogenization, and final processing.

Raw milk collection

The raw milk is cooled to 4 °C at bulk milk coolers or in common milk chilling centre. The milk is rechilled at the processing facility to 4 °C and sent to silos for storage.

Pasteurization

High Temperature Short Time (HTST) is the most commonly used method for pasteurization. The milk is heated to about 72°C for about 15 seconds followed by rapid cooling.

Cream separation

Cream is separated from pasteurized milk in a centrifuge. The cream is cooled and the skimmed milk is pumped out.

Standardization and homogenization

Milk is standardized as per quality requirements and transferred to a homogenizer to spread out the fat evenly within the milk.

Final processing

The milk of different standards/fat contents is transferred to separate horizontal milk storage tank for either onward packaging as liquid milk or to be used in downstream process for desired products (package milk, paneer, cheese, curd, etc.).

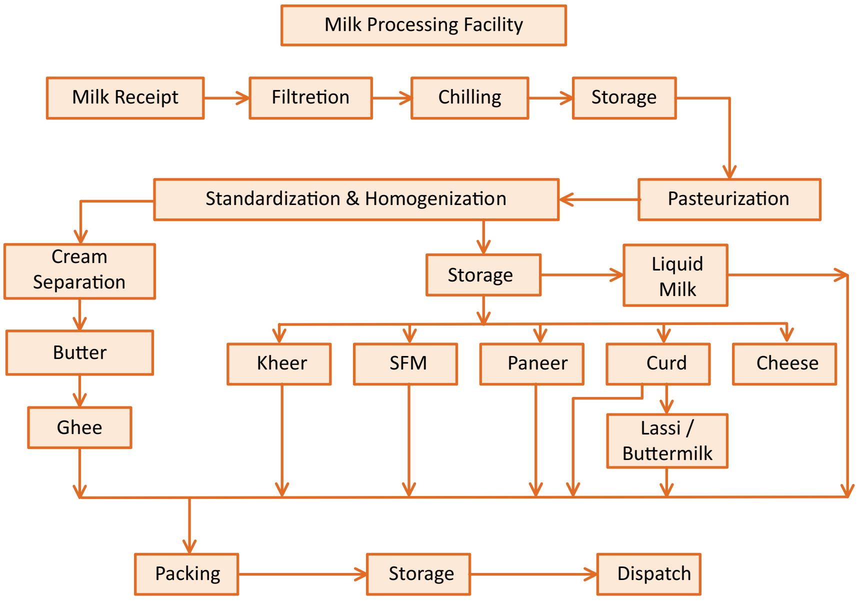

Figure 6.31: Process flowchart in dairy industry

6.24.3 Process equipment

The dairy industry uses thermal energy in the form of steam and hot water. Steam/hot water is generated in boilers of different capacities and fuels. Electricity is used in refrigeration compressor to produce chilled water for process and cold storage.

i) Boiler

The industry shall improve the thermal energy performance of boiler by optimizing various operating parameters. The operating parameters include reduction of air ratio, heat losses such as flue gas loss, structural heat loss, etc. occurring in the boiler through routine inspection and maintenance and keeping key operating parameters within specified limits as prescribed by the OEMs. This section provides EC Guidelines covering best operating practices, operational aspects and performance assessment for fuel fired process utility such as boilers used in dairy industries in a rational way.

Standards components	
1. Management and control	The industry shall: A. Maintain correct air ratio in boiler as specified as standard value in Table 6.104. Use suitable oxygen (O_2) analyser (on-line or portable type) to monitor the air ratio. Adjust and control air ratio to avoid high excess air while ensuring complete combustion of fuel. B. Use automatic air-fuel ratio control system in the combustion system and integrate with control loop. C. Install blower having suitable capacity and correct air pressure. Avoid over-sized or under-sized blower. D. Install blower close to the combustion equipment to avoid transmission loss. E. Minimize heat loss through air ingression by adopting suitable measures such as minimizing size of opening, proper sealing of furnace, etc. F. Use on-line or portable instrumentation for monitoring temperature of exhaust gases and preheated air temperature. G. Reduce exhaust flue gas temperature using suitable waste heat recovery (WHR) system and maintain flue gas temperature as specified in Table 6.105 as standard value. Install suitable WHR system based on waste heat available and type of application. H. Carry out blowdown to maintain the level of total dissolved solids (TDS) in boiler water as recommended by OEM. I. Manage recovery and reuse of waste heat in condensate return according to the instructions concerning parameters, such as the quality and quantity of condensate, temperature, etc. in case of using boiler. Reuse of condensate helps in reducing water treatment and blowdown requirements. An effective condensate recovery system improves boiler efficiency. J. Maintain external skin temperatures of boiler within the range as specified in Table 6.106 as standard value. K. Undertake thermal insulation work on different systems such as steam and condensate pipes, ducts, etc., which are used for transporting heat media either through steam according to the industrial standard practices for thermal insulation works and equivalent standards. L. Maintain appropriate quality of feedwater in boiler according to Indian Boiler Regulations (IBR), 1950 or an equivalent standard as suggested by the manufacturers. M. Use dry steam from boiler in heating processes to enhance heat transfer. Close steam flow to the process when it is not in operation. Use appropriate steam separator or steam trap to maintain the required dryness fraction of steam.

	N. Maintain proper draft in combustion equipment using proper damper setting in flue gas path. O. Ensure proper pre-heating of furnace oil to reduce the viscosity level in case of using furnace oil based combustion system. P. Ensure synchronization of switching off of both fuel supply and air supply (blower) upon reaching set temperature in boiler. Q. Ensure better resolution of measuring instruments for accurate measurements.
2. Measurement and recording	The industry shall measure and record the following: A. Milk processed, fuel consumption, residual oxygen (O_2) and carbon monoxide (CO) in flue gases, and unburnt carbon in bottom ash and fly ash for solid fuels, preheat air temperature, exhaust gas temperature, etc. on daily basis. B. Monitor steam generation, pressure, feedwater temperature and total dissolved solids (TDS), temperature and quantity of condensate of boiler on daily basis. C. Boiler surface temperature on quarterly basis. D. Monitor total water consumption of process on daily basis. E. Use suitable logsheet (s) for measurement and recording of key operating parameters. The frequency of recording shall be hourly, shift basis, daily, weekly or monthly based on requirements. The logsheets would help the industry in: (1) assessing energy performance and (2) identifying deviations in operating parameters to undertake corrective measures.
3. Maintenance and inspection	The industry shall: A. Maintain components related to the heat transfer of equipment, such as heat-transfer surfaces, heat exchangers, etc. according to the instructions as specified by the suppliers. Clean the equipment periodically as per the instructions to get rid of soot, scale or dirt to avoid deterioration of heat transfer surfaces and performance. B. Repair, renovate and maintain the WHR systems in flue path once in six months to avoid scale formation and ensure optimum performance. C. Inspect and maintain steam traps on steam lines periodically as per the instructions of the manufacturers to prevent steam leaks and clogging caused by the malfunctioning of traps. D. Calibrate and maintain of instruments as per recommendations of suppliers. Maintain proper record of calibration and the plans for all key instruments.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Install boiler with the highest efficiency that meets the process requirements. B. Install waste heat recovery boiler to generate power using micro turbine. C. Select appropriate combustion equipment and accessories, for example, burner, built-in automation system, etc. D. Use improved streamlined pipe route (avoiding unnecessary bends and joints) for transporting heat media , that is, water to minimize heat radiations.
Target components	
	The industry shall ensure the following: A. Maintain air ratio based on the target value as provided in Table 6.104. B. Ensure exit flue gas temperature in the range as provided in Table 6.105 as target value. C. Maintain external surface temperature based on the target value as provided in Table 6.106. D. Ensure preheat furnace oil close to 100 °C for furnace oil fired boiler.

Table 6.104: Air ratios for boilers+

Parameter	Boiler capacity (tph)	Load factor (%)	Air ratio@			
			Coal ^	Wood#	Liquid fuel	Gas fuel$
Standard	Up to 10	50 - 100	1.54-1.62	1.49-1.56	1.26-1.33	1.19-1.25
Target	Up to 10	50 -100	1.35 – 1.40	1.32-1.39	1.18 – 1.24	1.15 – 1.18

Source: Performance data from different plants

$ Refers to natural gas (NG) only

^ Air ratio for petcoke is excluded in the EC Guidelines

Includes use of wood up to 10 tph capacities; bagasse or rice husk firing for other capacities.

+ Combustion of fuels under Standard Temperature and Pressure (STP) conditions is assumed and the effect of parameters, such as variation in fuel compositions, is ignored.

@ Air ratio is defined as the ratio of actual air supplied AAS to theoretical air requirement. The following formula shall be used for calculating air ratio (value rounded to two digits).The air ratio is considered based on a steady state operation at constant load conditions and can be measured and verified at specific measurement points, while maintaining maximum permissible limit for carbon monoxide (CO) level to 200 ppm.

$$\text{Air ratio} = \frac{21}{21 - \%\ \text{oxygen in flue gases}}$$

Note 1: Gross calorific value (GCV) of fuels

- The GCV of different fuels, considering the standard composition of fuels are given below.
- Indian coal –up to 5,000 kcal per kg; Liquid fuels (light diesel oil, high speed diesel and furnace oil) - 10,500 to 10,800 kcal per kg; biomass fuels – 3,100 to 4,500 kcal per kg (source: https:// beeindia.gov.in/sites/ default/files/2Ch1.pdf)
- Bagasse - 2250 kcal per kg
- (source: http://biomasspower.gov.in/document/ regulatory-order/TN)
- Natural gas- 8,500 to 9,000 kcal per SCM (Standard cubic meter) (Source: GAIL India Limited)

Note 2: Load factor of boiler used for power generation shall be considered the same as that of connected turbine load factor

Table 6.105: Waste heat recovery from boiler in dairy industry

Exhaust gas temperature (°C)	Waste heat recovery rate (%)		Flue gas temperature* (°C)
	Standard$^{\alpha}$	Target$^{\beta}$	
400-600#	22	43	200-250

Source: Based on data from different industries

α Estimated heat drop based on the upper limit of gas temperatures and net heat transfer with 60% efficiency for heat exchanger
β Estimated heat drop based on the lower limit of gas temperatures and net heat transfer with 65% efficiency for heat exchanger
* Considering natural draft systems for higher flue gas temperature and induced draft system for lower temperatures
# Only boiler is considered for WHR system as the operating temperatures of TFH and HAG are lower.

The industry shall compute waste heat recovery (WHR) rate using the following formula.

$$\text{Waste heat recovery rate (\%)} = \frac{\text{Recovered heat (kcal)}}{\text{Sensible heat in exhaust gases (kcal)}} \times 100$$

Table 6.106: Surface temperatures of boiler

Parameter	Surface temperature (°C)#
Standard	Ambient temperature + 30
Target	Ambient temperature + 20

Source: Based on data from different industries

 # Average skin temperature under steady state operation

ii) Refrigeration systems

The dairy industry shall improve the refrigeration system energy performance, that is, reduce specific energy consumption (SEC) level by optimizing various operating parameters. These include reduction of various energy losses occurring in the refrigeration system through routine inspection and maintenance and keeping key operating parameters within specified limits as prescribed by the OEMs. This section provides EC Guidelines covering best operating practices, operational aspects and performance assessment for refrigeration system used in dairy industry in a rational way.

Standards components	
1. Management and control	The industry shall undertake the following: A. Pre-cool warm fresh milk using well/groundwater to reduce energy requirements of refrigeration system used in milk chilling centre. B. Avoid entry of warm air from outside into cold room by having proper sealing arrangements, as provided below: C. Introduce good door management and keep the door of cold store closed whenever possible to keep away from warm air. D. Ensure obstruction free air flow from evaporators. E. Operate cold store at the highest possible temperature recommended for the product type, which shall reduce load refrigeration system. F. Avoid warming of the product outside the cold room before loaded inside. G. Install low-power instant-on lighting system which can switch off automatically when the store is unoccupied. H. Use and maintain strip curtains to keep away from warm air and moisture. I. Avoid ingression of hot air or exgression of conditioned air by closing gaps and openings as much as possible to reduce the cooling load. J. Provide insulation of suitable type, size and thickness to reduce energy loss from uninsulated valves, bare pipes, defective insulation of refrigeration system, etc. Provide sufficient thickness of insulation to maintain surface temperature above the dew point temperature of ambient air. Further limit corrosion on cold piping, ducts, chillers, etc. K. Clean the coils on monthly basis which become dirty on use. L. Use regular watch glass as inspection window to observe the level of refrigerant and recharge to maintain the required level whenever needed. M. Adopt a section-wise air-conditioning system for operating parameters with signficant variations. For example, air conditioning requirement and load will be different for different sections of manufacturing, storage of products (finished or semi-finished), and workplace environment. The details of parameters shall include operational time, set temperature range (lower limit and upper limit), ventilation air per hour, and humidity. N. Manage the air-conditioning of process floors to only essential zones and reduce loads with potential options such as window shades, low thermal mass wall, etc. O. Optimize operational parameters such as temperatures of cooling water, chilled water and return water without affecting system performance considering seasonal weather conditions. P. Install stepped capacity control in reciprocating type comressor in refrigeration system for low load conditions. Q. Ensure matching of plant load with refrigeration system capacity, as part load operation will lead to higher specific energy consumption.

2. Measurement and recording	The industry shall measure and record the following: A. Electricity consumption, supply voltage, current, power factor on daily basis. B. Temperatures of chilled water to process, return water, water inlet and outlet from cooling tower on daily basis. C. Motor body temperature, vibration and lubrication level on quarterly basis. D. Use suitable logsheet (s) for measurement and recording of key operating parameters. The frequency of recording shall be hourly, shift basis, daily, weekly or monthly based on requirements. The logsheets would help the industry in: (1) assessing energy performance and (2) identifying deviations in operating parameters to undertake corrective measures.
3. Maintenance and inspection	The industry shall undertake the following: A. Inspection and plug off leakages from pipes and other components in refrigeration system on daily basis. B. Check refrigerant charge and seals for correct charging and plug off leakages on monthly basis. C. Undertake periodical inspection and maintenance of refrigeration system as per the instruction of OEMs to ensure optimum performance. D. Calibrate and maintain the instruments as per recommendations of suppliers to record reliable and accurate data.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Replace reciprocating compressor with energy efficient screw or scroll compressor in refrigeration system. B. Use variable air-volume and flow-rate systems with speed control to respond to load variations. C. Install desuperheater in ammonia based system to recover heat released during condensation of refrigerant for hot water generation. The hot water is used for shop floor use. D. Use evaporative condenser for higher heat transfer for low condensing application. E. Install compact thermal storage system[@] in place of ice bank tank (IBT) for efficient opeation and to overcome losses due to air ingestion, poor insulation and agitator system in IBT.
Target components	
	A. The industry shall maintain a specific energy consumption in the range of 90-120 kcal/kg processed milk

[@] Thermal storage system comprises an insulated tank having heat exchanger with phase change material to store thermal energy as latent heat

6.24.4 Common monitorable parameters and performance assessment

i) Boiler

The industry shall monitor common performance indicators as shown in Table 6.107 to assess the performance of the boiler.

The performance of boiler is expressed in terms of thermal efficiency. The thermal efficiency of boilers shall be estimated using following methods:

a) Thermal efficiency of boiler by direct method

The thermal efficiency of boiler by direct method is the ratio of heat output to heat input.

$$\text{Thermal efficiency (\%)} = \frac{\text{(Quantity of steam (kg/hr)} \times \text{(Enthalpy of steam-Enthalpy of feedwater (kcal/kg))}}{\text{Fuel firing rate (kg/hr)} \times \text{Gross calorific value (kcal/kg))}} \times 100$$

b) Thermal efficiency by indirect method

The thermal efficiency of boiler by indirect method involves evaluating various heat loss fractions occurring in boiler under steady state conditions. The thermal efficiency of boiler by indirect method can be expressed as follows:

Table 6.107 Common monitorable parameters in boiler

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Steam pressure	bar	Pressure gauge	Hourly
Steam generation	kg/hr	Flow meter	Daily
Fuel consumption	Unit*	Electronic balance/ Flow meter	Daily
Air ratio	kg/kg fuel	Flue gas analyser	Daily
Flue gas temperature	°C	Thermocouple	Daily
Feedwater temperature	°C	Thermocouple	Daily
Surface temperature	°C	Thermocouple	Quarterly

* Fuel consumption measured in kg for solid fuels, litre for liquid fuels and Sm^3 for gaseous fuels.

Thermal efficiency = 100 – (L1 + L2 + L3 + L4 + L5 + L6 + L7 + L8)

where

L1 = Loss due to dry flue gas (%)

$$L1 = \frac{m \times C_p \times (T_f - T_a)}{GCV\ of\ fuel} \times 100$$

where

m = mass of dry flue gas (kg/kg fuel)

C_p = Specific heat of flue gas (kcal/kg °C)

T_f = Flue gas temperature (°C)

T_a = Ambient temperature (°C)

L2 = Loss due to hydrogen in fuel (H_2)

$$L2 = \frac{9 \times H_2 \times \{584 + C_p(T_f - T_a)\}}{GCV\ of\ fuel} \times 100$$

where

H_2 = kg of hydrogen present in fuel on 1 kg basis

Cp = Specific heat of superheated steam (kcal/kg°C)

T_f = Flue gas temperature (°C)

T_a = Ambient temperature (°C)

584 = Latent heat corresponding to partial pressure of water vapour

L3 = Loss due to moisture in fuel

$$L3 = \frac{M \times \{584 + C_p(T_f - T_a)\}}{GCV\ of\ fuel} \times 100$$

where

M = kg moisture in fuel on 1 kg basis

C_p = Specific heat of superheated steam in kcal/kg°C

T_f = Flue gas temperature (°C)

T_a = Ambient temperature (°C)

584 = Latent heat corresponding to partial pressure of water vapour

L4 = Loss due to moisture in air

$$L4 = \frac{AAS \times humidity\ factor \times C_p \times (T_f - T_a) \times 100}{GCV\ of\ fuel}$$

where

AAS = Actual mass of air supplied per kg of fuel

Humidity factor = kg of water/kg of dry air

Cp = Specific heat of superheated steam in kcal/kg°C

Tf = Flue gas temperature in °C

Ta = Ambient temperature in °C (dry bulb)

L5 = Loss due to carbon monoxide

$$L5 = \frac{\%CO \times C}{\%CO + \%CO_2} \times \frac{5744}{GCV\ of\ Fuel} \times 100$$

where

CO = Volume of CO in flue gas (%)

CO_2 = Volume of CO_2 in flue gas (%)

C = Carbon content kg/kg of fuel, or

When CO is obtained in ppm,

CO formation (Mco) = CO (in ppm) × 10^6 × Mf × 28

Mf = Fuel consumption in kg/hr

L5 = Mco x 5744#

Heat loss due to partial combustion of carbon

L6= Loss due to surface radiation, convection and unaccounted

Generally, this loss is insignificant and difficult to measure. The surface heat loss and unaccounted losses are assumed based on the type and size of boiler as given below:

Industrial fire tube/packaged boiler : 1.5 to 2.5%

Industrial water tube boiler : 2 to 3%

This loss can be calculated if the surface area of boiler and its surface temperature are known:

$L6 = 0.548 \times [T_s/55.55)4-(T_a/55.55)4] + 1.957 \times (T_s - T_a)^{1.25} \times \text{sq.rt of } [(196.85\ V_m + 68.9)/68.9]$

where

L6 = Radiation loss in W/m^2

Vm = Wind velocity in m/s

Ts = Surface temperature (°K)

Ta = Ambient temperature (°K)

L7= Unburnt losses in fly ash (for solid fuel firing)

$$L7 = \frac{\text{Total ash collected/kg of fuel burnt} \times \text{G.C.V of fly ash} \times 100}{GCV\ of\ fuel}$$

L8 =Unburnt losses in bottom ash (for solid fuel firing)

$$L8 = \frac{\text{Total ash collected/kg of fuel burnt} \times \text{G.C.V of bottom ash} \times 100}{GCV\ of\ fuel}$$

ii) Refrigeration system

The industry shall monitor common performance indicators as shown in Table 6.108 to assess the performance of refrigeration system.

Table 6.108: Common monitorable parameters in refrigeration system

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Flow rate of coolant	kg/hr	Flow meter	Daily
Inlet temperature to evaporator	°C	Thermocouple	Daily
Outlet temperature from evaporator	°C	Thermocouple	Daily
Electricity consumption	kWh	Energy meter	Daily

The industry shall assess the performance of refrigeration system using the following formula.

$$\text{Specific energy consumption (kW/TR)} = \frac{\text{Electricity consumption (kW)}}{\text{Refrigeration load (TR)}}$$

In a centralized system, the total electricity consumption includes electricity consumption by compressor, chilled water pumps, condenser pumps and cooling tower fan. The industry shall estimate refrigeration load (TR) using the following formula.

$$TR = \frac{Q \times C_p \times (T_i - T_o)}{3024}$$

where

Q = Mass flow rate of coolant (kg/hr)

C_p = Specific heat of coolant (kcal/kg °C)

T_i = Inlet temperature to evaporator (°C)

T_o = Outlet temperature from evaporator (°C)

The industry shall assess the performance of refrigeration compressor using the following formula.

$$COP = \frac{\text{Cooling Effect (kW)}}{\text{Power input to compressor (kW)}}$$

The industry shall refer to the typical performance indicators of dairy industry as provided in Table 6.109.

Table 6.109: Typical performance indicators for dairy making

Performance indicator	Typical range
Specific energy consumption	90-120 kcal per kg processed milk

Source: Based on data from different industries

The industry shall assess the performance of dairy industry using the following formula.

$$\text{Specific energy consumption (kcal/kg)} = \frac{\text{Equivalent total enregy consumption (kcal/day)}}{\text{Milk processed (kg/day)}}$$

6.24.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall recover, treat and re-use of water used in various process sections.
2. The industry shall avoid spillage of fuels to reduce wastage.
3. The industry shall use timer to auto switch off fan in cooling tower to avoid idle operation upon reaching required temperature.
4. The industry shall treat the water used in cooling tower to keep the level of microorganisms to a minimum.
5. The industry shall avoid idle running of equipment to reduce energy consumption.
6. The industry shall close the cold rooms immediately when not in use.
7. The industry shall use strip curtains in cold rooms to keep away from warm air and moisture.
8. The industry shall use energy efficient LED lighting.
9. The industry shall maximize the use of day lighting.
10. The industry shall install natural ventilators.

FOOD PROCESSING

6.25 Food processing industry

6.25.1 Background

Food processing industry is one of the important energy consumer in micro, small, and medium enterprises (MSME) sector. A large and diversified type of food products are produced in the industries based on availability of raw materials and consumer requirements. These include sea food as well as fruit and vegetable processing. The fruit and vegetable processing industries cover products such as spices and pickles, fruit and vegetable powders, jams, sauces, ready to eat (RTE) and ready to cook (RTC) products. This section focuses mainly on fruits and vegetable processing industries.

6.25.2 Production process

Food processing involves primary processing, secondary processing, package and storage (Figure 6.32). The generic process steps followed by the food processing industry are provided below:

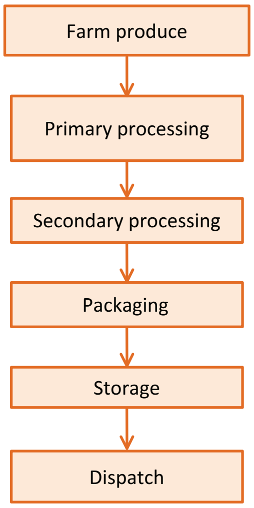

Figure 6.32: Food processing industry

Primary processing of farm produce

The farm produce are generally sourced from outside. The primary processing includes cleaning, sorting/grading, processing, grinding/homogenizing or temperature controlling.

Secondary processing

The secondary processing involves mixing of output from primary processing and additives followed by controlled heating. Heating includes sterilization and pasteurization to avoid bio-degradation and improve shelf life.

Packaging and storage

The products are packed and stored in normal/dry/cold storage facilities as per the product types and requirements.

6.25.3 Process equipment

The food processing industry would require both heating and cooling. Cooling may be done either naturally or using refrigeration system. The industry uses thermal energy as steam and hot water which is generated in boiler. Refrigeration load is used for chilling load.

i) Boiler, thermic fluid heater and electric ovens

The industry shall improve the thermal energy performance of boiler, thermic fluid heater (TFH) and electric ovens by optimizing various operating parameters and keeping them within specified limits as prescribed by the OEMs. This section provides EC Guidelines covering best operating practices, operational aspects and performance assessment for boilers, TFH, electric ovens, etc. used in food processing industries in a rational way.

Standards components	
1. Management and control	The industry shall undertake the following: A. Maintain correct air ratio in boiler and thermic fluid heater (TFH) as specified in Table 6.110 as standard value. Use on-line or portable oxygen (O_2) analyzer to monitor the air ratio. Adjust and control air ratio in such a manner to avoid high excess air but ensure complete combustion of fuel. B. Install blower having suitable capacity and correct air pressure. Avoid over-sized or under-sized blower. C. Install blower close to the combustion equipment to avoid transmission loss. D. Minimize heat loss through air ingression by adopting suitable measures such as minimizing size of opening, proper sealing, etc. E. Reduce exhaust flue gas temperature using suitable WHR system and maintain flue gas temperature as specified in Table 6.111 as standard value. F. Monitor temperature of exhaust gases and waste heat recovery media using on-line or portable instrumentation. G. Manage recovery and reuse of waste heat in condensate return in boiler according to the instructions concerning parameters, such as the quality and quantity of condensate, temperature, etc. Reuse of condensate helps in reducing water treatment and blowdown requirements. An effective condensate recovery system improves boiler efficiency. H. Maintain external skin temperatures of boiler, TFH, etc. within the range as specified in Table 6.112 as standard value. I. Undertake thermal insulation work on different systems such as steam and condensate pipes, ducts and TFH which are used for transporting heat media either through steam or hot fluid according to the industrial standard practices for thermal insulation works and equivalent standards. J. Maintain appropriate quality of feedwater in boiler according to Indian Boiler Regulations (IBR), 1950 or an equivalent standard as suggested by the manufacturers. K. Use dry steam from boiler to enhance heat transfer. Close steam flow to the process when it is not in operation. L. Maintain proper draft in combustion equipment using proper damper setting in flue gas path. M. Ensure proper pre-heating of furnace oil to reduce the viscosity level in furnace oil based combustion system. N. Electric ovens a. Ensure automatic control system to switch off heating cycle upon reaching set process temperature for the given product. Use sufficient number of temperature monitors to ensure uniform heating across the oven. b. Use dedicated energy meter for measuring energy consumption in ovens. c. Provide adequate insulation of ovens. d. Ensure optimum loading of ovens. e. Use automatic voltage regulator (AVR) for controlling variations in voltage from grid power. f. Use automatic power factor controller (APFC) for keeping power factor close to unity.

2. Measurement and recording	The industry shall measure and record the following: A. Fuel consumption, residual oxygen (O_2) and carbon monoxide (CO) in flue gases, and unburnt carbon in bottom ash and fly ash for solid fuels, preheat air temperature, exhaust gas temperature, etc. Monitor the following parameters as applicable: a. Boiler – steam generation, pressure, feedwater temperature, temperature and quantity of condensate b. TFH- thermic fluid circulation rate, pressure, supply and return temperature of fluid B. Temperatures of different surfaces of boiler, TFH, electric oven, etc. on monthly basis. C. Electricity consumption and quantity of materials processed in electric ovens. D. Use suitable logsheet (s) for recording of key operating parameters. The frequency of recording shall be hourly, shift basis, daily, weekly or monthly based on type of data. The logsheets would help the industry in: (1) assessing energy performance and (2) identifying deviations in operating parameters to undertake corrective measures.
3. Maintenance and inspection	The industry shall undertake the following: A. Clean heat transfer surfaces, heat exchangers to get rid of soot, scale and dirt on quarterly basis. B. Repair, renovate and maintain the WHR systems in flue path on yearly basis to avoid scale formation and ensure optimum performance. C. Undertake inspection of steam traps on steam lines to prevent steam leaks and clogging caused by the malfunctioning of traps. Maintain steam traps as per the instruction of OEMs. D. The industry shall undertake calibration and maintenance of instruments as per recommendations of suppliers. It shall maintain proper record of calibration and the plans for all key instruments. E. Undertake infrared/thermal scans of electric oven and power supply towards identification of hot spots.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Select appropriate combustion equipment and accessories for example. burner, built-in automation system, etc. B. Use renewable energy sources such as solar energy to meet part or full requirements of hot water requirements. C. Install automatic control system in electric ovens for close control of product quality.
Target components	
	The industry shall ensure the following: A. Maintain air ratio based on the target value as provided in Table 6.110. B. Ensure exit flue gas temperature in the range as provided in Table 6.111 as target value. C. Maintain external surface temperature based on the target value as provided in Table 6.112. D. Ensure preheat furnace oil close to 100 °C for furnace oil fired boiler.

Table 6.110: Air ratios for boiler and thermic fluid heater +

Parameter$	Load factor (%)	Air ratio@			
		Coal ^	Biomass#	Liquid fuel	Gas fuel&
Standard	50-100	1.35-1.40	1.49-1.56	1.26-1.33	1.15-1.18
Target	50-100	1.32-1.38	1.32-1.39	1.18-1.24	1.12-1.15

Source: Based on data from different industries

+ Combustion of fuels under Standard Temperature and Pressure (STP) conditions is assumed and the effect of parameters, such as variation in fuel compositions, is ignored.

$ Includes boiler and TFH

@ Air ratio is defined as the ratio of actual air supplied AAS to theoretical air requirement. The following formula shall be used for calculating air ratio (value rounded to two digits).The air ratio is considered based on a steady state operation at constant load conditions and can be measured and verified at specific measurement points, while maintaining maximum permissible limit for carbon monoxide (CO) level to 200 ppm.

$$\text{Air ratio} = \frac{21}{21 - \%\ \text{oxygen in flue gases}}$$

^ Includes fixed bed and fluidized bed type boiler

Includes wood, bagasse, rice husk, etc.

& Refers to natural gas (NG) only

Note: Gross calorific value (GCV) of fuels

The GCV of different fuels, considering the standard composition of fuels are given below:

- Indian coal –up to 5,000 kcal per kg; Liquid fuels (light diesel oil, high speed diesel and furnace oil) - 10,500 to 10,800 kcal per kg; biomass fuels – 3,100 to 4,500 kcal per kg (source: https:// beeindia.gov.in/sites/ default/files/2Ch1.pdf)
- Bagasse - 2250 kcal per kg
- (source: http://biomasspower.gov.in/document/ regulatory-order/TN)
- Natural gas- 8,500 to 9,000 kcal per SCM (Standard cubic meter) (Source: GAIL India Limited)

Table 6.111: Waste heat recovery from boiler in food processing industry

Exhaust gas temperature (°C)	Waste heat recovery rate (%)		Flue gas temperature* (°C)
	Standard$^\alpha$	Target$^\beta$	
400-600#	22	43	200–250

Source: Based on data from different industries

α Estimated heat drop based on the upper limit of gas temperatures and net heat transfer with 60% efficiency for heat exchanger

β Estimated heat drop based on the lower limit of gas temperatures and net heat transfer with 65% efficiency for heat exchanger

* Considering natural draft systems for higher flue gas temperature and induced draft system for lower temperatures

Only boiler is considered for WHR system as the operating temperatures of TFH are lower.

The industry shall compute waste heat recovery (WHR) rate using the following formula.

$$\text{Waste heat recovery rate (\%)} = \frac{\text{Recovered heat (kcal)}}{\text{Sensible heat in exhaust gases (kcal)}} \times 100$$

Table 6.112: Surface temperatures of boiler and TFH

Parameter	Surface temperature (°C)#
Standard	Ambient temperature + 30
Target	Ambient temperature + 20

Source: Based on data from different industries

 # Average skin temperature under steady state operation

ii) Refrigeration systems

The industry shall improve the refrigeration system energy performance, that is, reduce specific energy consumption (SEC) level by optimizing various operating parameters. These include reduction of various energy losses occurring in the refrigeration system through routine inspection and maintenance and keeping key operating parameters within specified limits as prescribed by the OEMs. This section provides EC Guidelines covering best operating practices, operational aspects and performance assessment for refrigeration system used in the food processing industry in a rational way.

Standard components	
1. Management and control	The industry shall undertake the following: A. Avoid entry of warm air from outside into cold room by having proper sealing arrangements, as provided below: a. Introduce good door management and keep the door of cold store closed whenever possible to keep away from warm air. b. Ensure obstruction free air flow from evaporators. c. Operate cold store at the highest possible temperature recommended for the product type, which shall reduce load refrigeration system. d. Avoid warming of the product outside the cold room before loaded inside. e. Install low-power instant-on lighting system which can switch off automatically when the store is unoccupied. f. Use and maintain strip curtains to keep away from warm air and moisture. g. Avoid ingression of hot air or exgression of conditioned air by closing gaps and openings as much as possible to reduce the cooling load. B. Provide insulation of suitable type, size and thickness to reduce energy loss from uninsulated valves, bare pipes, defective insulation of refrigeration system, etc. Provide sufficient thickness of insulation to maintain surface temperature above the dew point temperature of ambient air. Further limit corrosion on cold piping, ducts, chillers, etc. C. Clean the coils on monthly basis which become dirty on use. D. Use regular watch glass as inspection window to observe the level of refrigerant and recharge to maintain the required level whenever needed. E. Adopt a section-wise air-conditioning system for operating parameters with signficant variations. For example, air conditioning requirement and load will be different for different sections of manufacturing, storage of products (finished or semi-finished), and workplace environment. The details of parameters shall include operational time, set temperature range (lower limit and upper limit), ventillation air per hour, and humidity. F. Manage the air-conditioning of process floors to only essential zones and reduce loads with potential options such as window shades, low thermal mass wall, etc. G. Optimize operational parameters such as temperatures of cooling water, chilled water and return water without affecting system performance considering seasonal weather conditions.

	H. Install stepped capacity control in reciprocating type compressor in refrigeration system for low load conditions. I. Ensure matching of plant load with refrigeration system capacity, as part load operation will lead to higher specific energy consumption.
2. Measurement and recording	The industry shall measure and record the following: A. Electricity consumption, supply voltage, current, power factor on daily basis. B. Temperatures of chilled water to process, return water, water inlet and outlet from cooling tower on daily basis. C. Motor body temperature, vibration and lubrication level on quarterly basis. D. Use suitable logsheet(s) for measurement and recording of key operating parameters. The frequency of recording shall be hourly, shift basis, daily, weekly or monthly based on requirements. The logsheets would help the industry in: (1) assessing energy performance and (2) identifying deviations in operating parameters to undertake corrective measures.
3. Maintenance and inspection	The industry shall undertake the following: A. Inspection and plug off leakages from pipes and other components in refrigeration system on daily basis. B. Check refrigerant charge and seals for correct charging and plug off leakages on monthly basis. C. Undertake periodical inspection and maintenance of refrigeration system as per the instruction of OEMs to ensure optimum performance. D. Calibrate and maintain the instruments as per recommendations of suppliers to record reliable and accurate data.
4. Necessary measures when installing new facilities	The industry shall consider the following: A. Replace reciprocating compressor with energy efficient screw or scroll compressor in refrigeration system. B. Use variable air-volume and flow-rate systems with speed control to respond to load variations.

6.25.4 Common monitorable parameters and performance assessment

i) Performance assessment of boiler

The industry shall monitor common performance indicators as shown in Table 6.113 to assess the performance of boiler.

The performance of boiler is expressed in terms of thermal efficiency. The thermal efficiency of boilers shall be estimated using following methods:

a) Thermal efficiency of boiler by direct method

The thermal efficiency of boiler by direct method is the ratio of heat output to heat input.

Table 6.113: Common monitorable parameters in boiler

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Steam pressure	bar	Pressure gauge	Hourly
Steam generation	kg/hr	Flow meter	Daily
Fuel consumption	Unit*	Electronic balance	Daily
Air ratio	kg/kg fuel	Flue gas analyser	Daily
Flue gas temperature	°C	Thermocouple	Daily
Feedwater temperature	°C	Thermocouple	Daily
Surface temperature	°C	Thermocouple	Quarterly

* Fuel consumption measured in kg for solid fuels, litre for liquid fuels and Sm^3 for gaseous fuels.

$$\text{Thermal efficiency (\%)} = \frac{\text{Quantity of steam (kg/hr)} \times \text{(Enthalpy of steam-Enthalpy of feedwater (kcal/kg)}}{\text{Fuel firing rate (kg/hr)} \times \text{Gross calorific value (kcal/kg)}} \times 100$$

b) Thermal efficiency by indirect method

The thermal efficiency of boiler by indirect method involves evaluating various heat loss fractions occurring in boiler under steady state conditions. The thermal efficiency of boiler by indirect method can be expressed as follows:

Thermal efficiency = 100 – (L1 + L2 + L3 + L4 + L5 + L6 + L7 + L8)

where

L1 = Loss due to dry flue gas (%)

$$L1 = \frac{m \times C_p \times (T_f - T_a)}{GCV\ of\ fuel} \times 100$$

Where,

m = mass of dry flue gas (kg/kg fuel)

C_p = Specific heat of flue gas (kcal/kg °C)

T_f = Flue gas temperature (°C)

T_a = Ambient temperature (°C)

L2= Loss due to hydrogen in fuel (H_2)

$$L2 = \frac{9 \times H_2 \times \{584 + C_p(T_f - T_a)\}}{GCV\ of\ fuel} \times 100$$

where

H_2 = kg of hydrogen present in fuel on 1 kg basis

C_p = Specific heat of superheated steam (kcal/kg°C)

T_f = Flue gas temperature (°C)

T_a = Ambient temperature (°C)

584 = Latent heat corresponding to partial pressure of water vapour

L3= Loss due to moisture in fuel

$$L3 = \frac{M \times \{584 + C_p(T_f - T_a)\}}{GCV\ of\ fuel} \times 100$$

Where,

M = kg moisture in fuel on 1 kg basis

C_p = Specific heat of superheated steam in kcal/kg°C

T_f = Flue gas temperature (°C)

T_a = Ambient temperature (°C)

584 = Latent heat corresponding to partial pressure of water vapour

L4 = Loss due to moisture in air

$$L4 = \frac{AAS \times humidity\ factor \times C_p \times (T_f - T_a) \times 100}{GCV\ of\ fuel}$$

where

AAS = Actual mass of air supplied per kg of fuel

Humidity factor = kg of water/kg of dry air

Cp = Specific heat of superheated steam in kcal/kg°C

Tf = Flue gas temperature in °C

Ta = Ambient temperature in °C (dry bulb)

L5= Loss due to carbon monoxide

$$L5 = \frac{\%CO \times C}{\%CO + \%CO_2} \times \frac{5744}{GCV\ of\ Fuel} \times 100$$

where

CO = Volume of CO in flue gas (%)

CO_2 = Volume of CO_2 in flue gas (%)

C = Carbon content kg / kg of fuel or when CO is obtained in ppm,

CO formation (Mco) = CO (in ppm) × 10^6 × Mf × 28

Mf = Fuel consumption in kg/hr

L5 = Mco x 5744#

Heat loss due to partial combustion of carbon

L6 = Loss due to surface radiation, convection and unaccounted

Generally, this loss is insignificant and difficult to measure. The surface heat loss and unaccounted losses are assumed based on the type and size of boiler as given below:

Industrial fire tube / packaged boiler : 1.5 to 2.5%

Industrial watertube boiler : 2 to 3%

This loss can be calculated if the surface area of boiler and its surface temperature are known:

$L6 = 0.548 \times [T_s/55.55)4 - (T_a/55.55)4] + 1.957 \times (T_s - T_a)^{1.25} \times \text{sq.rt of } [(196.85\ V_m + 68.9)/68.9]$

where

L6 = Radiation loss in W/m²

Vm = Wind velocity in m/s

Ts = Surface temperature (°K)

Ta = Ambient temperature (°K)

L7 = Unburnt losses in fly ash (for solid fuel firing)

$$L7 = \frac{\text{Total ash collected/kg of fuel burnt} \times \text{G.C.V of fly ash} \times 100}{GCV\ of\ fuel}$$

L8= Unburnt losses in bottom ash (for solid fuel firing)

$$L8 = \frac{\text{Total ash collected/kg of fuel burnt} \times \text{G.C.V of bottom ash} \times 100}{GCV\ of\ fuel}$$

ii) Performance assessment of TFH

The industry shall monitor common performance indicators as shown in Table 6.114 to assess the performance of thermic fluid heater.

a) Thermal efficiency of TFH

The thermal efficiency of TFH by direct method is the ratio of heat output to heat input.

$$\text{Thermal efficiency (\%)} = \frac{\text{Quantity of thermic fluid} \times \text{Specific heat} \times \text{(Inlet temperature-Outlet temperatutre)}}{\text{Fuel firing rate} \times \text{Gross calorific value}} \times 100$$

where

Quantity of thermic fluid in kg per hr (= volume× density at operating temperature)

Specific heat of thermic fluid in kcal/kg °C

Inlet temperature in °C

Outlet temperature in °C

Fuel firing rate in kg per hr

Gross calorific value in kcal/kg

For fuel-fired thermic fluid heater, the thermal efficiency shall also be evaluated using indirect method similar to the procedure provided under the performance assessment of boiler.

iii) Refrigeration system

The industry shall monitor common performance indicators as shown in Table 6.115 to assess the performance of refrigeration system.

Table 6.114: Common monitorable parameters in thermic fluid heater

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Flow rate of thermic fluid	kg/hr	Flow meter	Daily
Supply temperature	°C	Thermocouple	Daily
Return temperature	°C	Thermocouple	Daily
Air ratio	kg/kg fuel	Flue gas analyser	Daily
Flue gas temperature	°C	Thermocouple	Daily
Surface temperature	°C	Thermocouple	Quarterly
Fuel consumption	Unit*	Electronic balance	Daily

* Fuel consumption measured in kg for solid fuels, litre for liquid fuels and Sm³ for gaseous fuels.

Table 6.115: Common monitorable parameters in refrigeration system

Common monitorable parameter	Unit	Instrument	Frequency of measurement
Flow rate of coolant	kg/hr	Flow meter	Daily
Inlet temperature to evaporator	°C	Thermocouple	Daily
Outlet temperature from evaporator	°C	Thermocouple	Daily
Electricity consumption	kWh	Energy meter	Daily

The industry shall assess the performance of refrigeration system using the following formula.

$$\text{Specific energy consumption (kW/TR)} = \frac{\text{Electricity consumption (kW)}}{\text{Refrigeration load (TR)}}$$

In a centralized system, the total electricity consumption includes electricity consumption by compressor, chilled water pumps, condenser pumps and cooling tower fan. The industry shall estimate refrigeration load (TR) using the following formula.

$$TR = \frac{Q \times C_p \times (T_i - T_o)}{3024}$$

where

Q = Mass flow rate of coolant (kg/hr)

C_p = Specific heat of coolant (kcal/ kg °C)

T_i = Inlet temperature to evaporator (°C)

T_o = Outlet temperature from evaporator (°C)

The industry shall assess the performance of refrigeration compressor using the following formula.

$$COP = \frac{\text{Cooling effect (kW)}}{\text{Power input to compressor (kW)}}$$

6.25.5 Efficient resource utilization

Efficient resource utilization includes optimum use of resources in production processes and minimizing the generation of wastes. The industry shall explore reuse and recycling of wastes generated to enhance resource utilization. It shall consider the following for efficient utilization of resources:

1. The industry shall procure and process consistent quality of farm produce.
2. The industry shall add measured quantity of additives and preservatives.
3. The industry shall maintain short and optimum holding time for the materials to ensure quality of the food products.
4. The industry shall recover, treat and re-use of water used in various process sections.
5. The industry using boiler shall recover and reuse condensate at maximum possible temperature to reduce energy consumption and make-up water consumption.
6. The industry shall avoid spillage of fuel to reduce wastage.
7. The industry shall regularly maintain and clean surfaces to optimize heat transfer.
8. The industry shall avoid idle running of equipment to reduce energy consumption.
9. The industry shall use suitable type of packing material to ensure life of food products.
10. The industry shall arrest leakages from compressed air lines to reduce power consumption.
11. The industry shall use compressed air only at required pressure to optimize energy consumption. Use of compressed air at high pressures would increase energy consumption.
12. The industry shall use airguns in place of compressed air for
13. requirements of air at low pressures.
14. The industry shall use solar water heater to meet hot water requirements.
15. The industry shall use energy efficient LED lighting.
16. The industry shall install natural ventilators.
17. The industry shall maximize the use of day lighting.

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