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Ministry of Power
Government of India

ENERGY CONSERVATION GUIDELINES
FOR INDUSTRIES

Bureau of Energy Efficiency
Ministry of Power, Government of India

ENERGY CONSERVATION GUIDELINES

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MINISTER OF POWER

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DIRECTOR GENERAL,
BUREAU OF ENERGY EFFICIENCY

DIRECTOR, BUREAU OF ENERGY EFFICIENCY

CONTENTS

LIST OF TABLES

LIST OF ABBREVIATIONS

AAS	Actual Air Supplied
AC	Alternating Current
BOP	Best Operating Point
BFP	Boiler Feedwater Pump
CO	Carbon Monoxide
DC	Designated Consumer
DG	Diesel Generator
EC	Energy Conservation
ECBC	Energy Conservation Building Code
EM	Energy Management
ESCOs	Energy Service Companies
FRP	Fibre Reinforced Plastic
GCV	Gross Calorific Value
HVAC	Heating, Ventilation and Air Conditioning
IBR	Indian Boiler Regulation
IEMS	Industry Energy Management Systems
ISO	International Organization for Standardization
kCal	Kilo Calorie
kWh	Kilo Watt-hour
LED	Light Emitting Diode
LPD	Lighting Power Density

LPG	Liquefied Petroleum Gas
M&V	Monitoring and Verification
NAPCC	National Action Plan on Climate Change
NG	Natural Gas
NMEEE	National Mission for Enhanced Energy Efficiency
NPSH	Net Positive Suction Head
OEM	Original Equipment Manufacturer
OLTC	On-line tap changer
PF	Power Factor
PAT	Perform, Achieve and Trade
PVC	Poly Vinyl Chloride
SCADA	Supervisory Control And Data Acquisition
SCM	Standard Cubic Metre
SEC	Specific Energy Consumption
SME	Small and Medium Enterprise
SPC	Specific Power Consumption
SPV	Solar Photo Voltaic
STP	Standard Temperature and Pressure
TFH	Thermic Fluid Heater
VFD	Variable Frequency Drive
WHR	Waste Heat Recovery

LIST OF DEFINITIONS

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

Accredited Energy Auditing Firm

The accredited energy auditing firm refers to the firm that has been empanelled by the Bureau of Energy Efficiency (BEE) to undertake activities in Designated Consumers (DCs) as prescribed under the EC Act.

Certified Energy Manager

Energy manager means any individual possessing the qualifications prescribed under clause (m) of Section 14 of the Energy Conservation Act (2001). Any reference to the certified energy manager refers to a person who has qualified at the national certification examination for the role of certified energy manager and energy auditor conducted by the BEE. A candidate qualifying as a certified energy auditor automatically qualifies for the role of certified energy manager as well. Such persons can be considered by DCs for appointment or designated as energy manager under the EC Act.

Designated Consumer

The DC means any consumer specified under clause (e) of Section 14 of the Energy Conservation Act (2001). For the purpose of the EC Guidelines, the following industries are covered (1) aluminium, (2) fertilizers, (3) iron and steel, (4) cement, (5) pulp and paper, (6) chlor-alkali, (7) textile, (8) petrochemicals, (9) petroleum refineries, and (10) thermal power stations with a threshold limit for energy consumption as specified by the EC Act (2001), from time to time.

Energy Service Companies

Energy Service Companies (ESCOs) are the firms that offer energy services, usually design, retrofitting, and the implementation of energy-efficiency projects, after identifying energy-saving opportunities through energy audits of the existing facilities, energy infrastructure outsourcing, power generation and energy supply, and financing or assisting host entities in arranging finances for energy-efficiency projects by providing a savings guarantee, risk management in the implementation of the energy-efficiency projects, and also performing Measurement and Verification (M&V) activities to quantify actual energy savings post the implementation of energy-efficiency projects.

Standards

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

State Designated Agency

The state designated agencies (SDAs) are organizations identified by state Governments, in consultation with the BEE, under the provisions of the EC Act, 2001, to coordinate, regulate, and enforce the efficient use of energy and its conservation at the state level.

STP Conditions

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

Targets

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

1. BACKGROUND

The Energy Conservation (EC) Act, 2001, provides for the efficient use of energy and its conservation in India. The Government of India set up a Bureau of Energy Efficiency (BEE) under the provisions of the EC Act. The mission of the 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 the energy intensity of the Indian economy. The BEE coordinates with designated consumers (DCs), designated agencies, and other organizations and recognizes, identifies, and utilizes the existing resources and infrastructure, in performing the functions assigned to it under the EC Act. In addition to providing regulatory and promotional functions of the Bureau, the act also provides a list of energy-intensive industries and other establishments specified as DCs.

One of the flagship programmes of Bureau of Energy Efficiency is Perform, Achieve and Trade (PAT) scheme aimed towards enhancing energy efficiency in Indian industrial sector in general and Designated Consumers (DCs) in particular. The PAT scheme was formed under the National Mission for Enhanced Energy Efficiency (NMEEE). The NMEEE is one of the eight national missions under the National Action Plan on Climate Change (NAPCC) launched by the Government of India in the year 2008.

The Bureau has envisaged that the smooth implementation of PAT scheme can be enhanced and strengthened by formulating and making available a suitable 'Energy Conservation Guidelines' (EC Guidelines) for the targeted industry sub-sectors.

Japan is one of the pioneers in implementing energy efficiency at the global level. As part of their energy efficiency efforts, the Government of Japan had introduced EC guidelines to support industries to improve energy performance. Looking at their success, the Government of India, on similar lines, has also prepared EC Guidelines for different categories of industries operating in India (Table 1.1).

Table 1.1 Different categories of industries covered under the 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, (7) petroleum refineries covering only cracker units, (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 but limited to the following SME sectors: (1) glass, (2) foundry, (3) forging, (4) ceramics, (5) dairy, and (6) textile industries.
Group–D	Medium enterprises with energy costs accounting for 10% to 30% of the total production costs but limited to the following sectors: (1) brick, (2) hand tools, (3) food, and (4) limestone industries.
Group–E	Micro industries with material costs more significant than energy costs

2. OBJECTIVES

The overall objective of the EC Guidelines for large industries and SMEs is to guide the management and operators in large industries and SMEs to manage energy consumption by standardizing the 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 the benchmarking of standard energy performance values and a procedure for establishing target energy performance values for major energy-consuming equipment, such as boiler, furnace, thermic fluid heater, waste heat recovery (WHR) equipment, motor, etc.

The objective of this document is to provide EC guidelines to large industries that are covered as DCs under PAT mechanism of the EC Act, 2001, but limited to the list as provided in Section 1, hereafter termed as Category-A industries.

3. METHODOLOGY

3.1 Activities followed for preparation of EC Guidelines

A review of the EC Guidelines pertaining to industries in Japan was carried out to draw a blueprint of the EC Guidelines applicable for Indian industries. Relevant secondary data from different industries were collated through a questionnaire survey and field visits. Other sources of secondary data include (i) performance audits and sectoral study reports, (ii) original equipment manufacturers, (iii) industries, (iv) sectoral experts, (v) stakeholder consultations with industries and industry associations, and (vi) secondary sources such as relevant websites. Interactions with industry personnel and industry associations were carried out to understand key operating parameters in different utilities. Further discussions were held with OEMs and sectoral experts in India and Japan to ascertain the relevance of data collated for the different utilities.

A detailed data analysis of the relevant parameters of the various utilities in industries were carried out using statistical tools to benchmark key operating parameters as 'standard value' and 'target value'. These parameters include air ratio, flue gas temperature, surface temperature, level of WHR, efficiency of motors, efficiency of fans, corrected target power factor of electrical equipment, lighting power density, etc. The average values and standard deviations of the data samples of similar groupings were arrived at through data analysis. The collated data were sanitized to exclude extremely high or low values for the purpose of analysis.

In preparing the EC Guidelines, the existing technology standards and practices of various industry sub-sectors in India were considered. The draft EC Guidelines were presented in a stakeholder workshop in which representatives from industries, industry associations, original equipment suppliers, sectoral experts, etc., participated and provided their inputs.

The revised EC Guidelines were again presented in a second stakeholder workshop to ensure synergy with the industry. With these inputs, the EC Guidelines were finalized for Category-A industries.

The 'standard values' of an energy-consuming utility include optimum performance values, which are achieved by the industry under daily routine operations; the 'target values' of the utility represent better performance values than the standard values. These values focus essentially on those benchmarks which shall guide the industry to improve the performance of the existing facilities, new installations, and retrofits in the existing facilities. An empirical equation was considered to arrive at standard values and target values using the average and standard deviation of the data samples, which are discussed below.

3.2 Evaluation of Standard and Target Values

3.2.1 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

3.2.2 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 utilities 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

3.3 Revision of Energy Conservation Guidelines

The EC Guidelines applicable for Category-A industries will 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 BEE.

4. ENERGY CONSERVATION GUIDELINES

The EC guidelines is a comprehensive, hand-holding document related to major energy-consuming utilities in Category-A industries to guide top management as well as operators in industries to manage energy efficiently. The guidelines shall provide guidance to prepare its own 'Energy Management Manual' (EM Manual) for the efficient operation of various energy-consuming utilities in individual industries under Category-A.

4.1 Standards and Targets

The guidelines consist of two distinct components, namely, (1) the standard component and (2) target component for various common energy-consuming utilities employed across industries covered under Category A. For an industry to operate efficiently, it is essential to run various energy-consuming utilities efficiently and ensure a proper monitoring and recording of all key operating parameters pertaining to each utility.

An industry shall maintain optimum operating parameters of the different utilities based on feedback received from the relevant process sections, thereby achieving optimum operation of the utility, which shall be termed as 'standard values' of operation. Thus the standard values of a utility shall be defined as:

> **Standards are optimum performance values achieved by an energy consuming utility 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 terms as "target values" of operation. The target values as mentioned in guidelines are better than the standard values, which the industry shall strive to achieve best possible performance of the equipment. Thus, the target values of a utility shall be defined as:

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

4.2 Components of Standards

The standard component comprises four distinct sections that focus on the relevant instructions concerning routine operations of the respective utilities. 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 4.1. The instructions are intended to guide the industries to achieve optimum performance of the utilities. The concrete activities in the standard components (1), (2), (3), and (4) shall be described in the EM Manual.

Table 4.1 Components of standards

Component	Primary focus
(1) Management and control	This section provides guidelines for managing and controlling key operating parameters in different energy consuming equipment in an industry e.g. air ratio, flue gas temperature, surface temperature, WHR, efficiency of motors, efficiency of fans, corrected power factor of electrical equipment, lighting power density etc. It further covers load sharing during part load conditions in a multi-equipment e.g. part load operations of equipment such as boiler, pump, fan, blower, air compressor, air-conditioning system etc.
(2) Measurement and recording	This section provides frequency of measurements and recording of operating parameters e.g. 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	This section highlights preventive maintenance and the overhauling schedule for various equipment. It further provides schedule for regular calibration of instruments to maintain accuracy in data measurements.
(4) Installation of new facility	This section suggests directions for the installation of energy efficient equipment for retrofitting in the existing utility and system upgradation.

4.3 Components of Targets

The target components provide a set of instructions for the efficient use of energy consuming equipment or 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.

4.4 Scope of Energy Conservation Guidelines

The DC generally follows energy management (EM) policies to reduce energy consumption in different energy-consuming processes and utilities. The general guidelines for EM policy are provided in section 5. The primary equipment/utilities considered under DCs shall be grouped (Table 4.2).

Table 4.2 Details of equipment under Category-A industries

S. No.	Name of section	Equipment covered
1.0	Combustion of fuel	Boiler, industrial furnace, thermic fluid heater
2.0	Heating, cooling, and heat transfer 2.1 Heating equipment 2.2 Air-conditioning and hot water supply equipment	Boiler, steam system, condensate recovery system, industrial furnace, thermic fluid heater. Heat transport equipment, air-conditioning equipment, hot water equipment, thermic fluid heater
3.0	Waste heat recovery and usage	Boiler, condensate recovery system, industrial furnace, gas turbine, gas engine, diesel engine, thermic fluid heater
4.0	Conversion of heat to electricity 4.1 Power generation facilities 4.2 Cogeneration facilities	Boiler, steam turbine, gas turbine, gas engine, diesel engine
5.0	Prevention of energy loss due to heat radiation and electric resistance 5.1 Prevention of heat loss due to radiation and conduction 5.2 Prevention of electricity loss due to electric resistance	Boiler, steam system, condensate recovery system, industrial furnace, thermic fluid heater, electrical distribution system

S. No.	Name of section	Equipment covered
6.0	Conversion of electricity to motive power, heat, and light 6.1 Facilities using motors and heaters 6.2 Industrial pump and pumping system 6.3 Industrial air compressor and compressed air network system 6.4 Industrial fans and blowers 6.5 Industrial lighting system 6.6 Cooling tower 6.7 Transformer	Motor, industrial heater, pumping system, air compressor and compressed air system, fan and blower, industrial lighting, cooling tower, transformer
7.0	Industry Energy Management System	Overall plant energy management

5. ENERGY MANAGEMENT POLICY

The designated consumer shall manage energy appropriately, depending on the input energy characteristics within the plant or in a utility in line with the existing EM policies. The DCs shall modify EM policies as needed, and in line with points from A to K (mentioned below). The DC shall suitably and effectively conserve energy through complying with various standards, as prescribed in the EC Guidelines, concerning the various energy-consuming utilities associated with different processes used.

Standard Components	
	A. The DC shall develop and adopt EM policies, including the installation of new utilities or the upgradation of the existing ones. B. The DC shall prepare a suitable Energy Policy Statement within the EM policy. It shall revisit the Energy Policy Statement on a periodical basis, and shall modify as required. C. The DC shall develop a management structure for an effective planning and implementation of EC measures. D. The DC shall involve the necessary resources (human and finance) to achieve energy conservation. E. The DC shall designate a Certified Energy Manager to ensure the implementation of EC measures. F. The DC shall prepare a document covering instructions on energy conservation at the plant level (hereafter termed as the 'EM Manual'), including EC targets by retrofitting/ replacing the existing inefficient equipment or installing new facilities as required. G. The DC shall ensure compliance of Energy Management at the plant level. It shall review the implementation status of the target EC measures and provide directions for future improvements. H. The DC shall review the EM manual and its compliance periodically, and modify based on the feedback from the plant personnel. I. The DC shall discuss EM with the employees and provide training to capacitate them. J. The DC shall ensure proper monitoring and maintain the recording in suitable documentation for each utility that would enable generation of status report of individual utility. K. The DC shall undertake calibration of all instruments used in monitoring and measurement on a regular basis to ensure data reliability.

Target Components

A. The DC shall manage gate-to-gate energy consumption and implement EC measures that are technically and economically viable to improve the energy performance of the plant.

B. The DC shall identify EC measures with appropriate implementation strategies.

C. The DC shall consider the existing standards for EM systems such as ISO 50001 to ensure synergy.

D. The DC shall ensure an efficient utilization of thermal energy generated from primary energy sources.

E. The DC shall optimize the recovery of heat available in either flue gases or surplus steam for use in suitable energy-consuming utilities within the plant.

F. The DC shall target to recover and re-use the energy generated while burning or processing combustible waste to the maximum extent.

G. The DC shall identify and implement EC measures to improve the performance of electrical equipment and reduce the overall electricity consumption.

H. The DC shall utilize services of accredited energy-auditing firms, Energy Service Companies (ESCOs), etc., to identify and implement potential EC measures and achieve energy efficiency.

I. The DC shall put in place suitable instrumentation and software tools for monitoring energy consumption and verifying energy savings.

J. The DC shall manage the specific energy consumption (SEC) as per targets set under PAT mechanism by complying with various standards of energy-consuming utilities as mentioned in the EC Guidelines and implementing appropriate EC measures.

K. The DC if being a lessee shall cooperate with the lessor to promote energy-efficiency activities jointly under the cost-sharing mechanism, so that appropriate and effective EC measures can be implemented as per the clause in the lessee agreement.

L. The DC shall put in efforts to facilitate other industries to implement EC measures through information sharing and advisory support to promote a national initiative on energy conservation.

6. COMBUSTION OF FUEL

The energy sources used in industries include both thermal and electrical energy. Thermal energy is generated from the combustion of different types of fuels, such as coal, petcoke and biomass (solid fuels), furnace oil, diesel, naphtha and internally generated liquid fuels (liquid fuels) and natural gas (NG), LPG, off-gases, fuel gas and internally generated gaseous fuels (gaseous fuels). The thermal energy is either directly used in processes for heating, melting, etc., or used for power generation. This section provides the EC guidelines covering combustion of fuels in boilers, industrial furnaces, and thermic fluid heaters (TFH) in a rational way.

Standards Components	
(1) Management and control	A. The industry shall maintain optimum and correct air ratio while burning fuel(s) in boilers, furnaces, and TFHs (hereafter termed as 'combustion facilities'). The fuel combustion process shall be managed and maintained in accordance with the instructions provided on air ratios, which shall be provided in the EM Manual. B. The industry shall maintain air ratio for the boiler, as specified in Table 6.1 as the standard value and use Table 6.2 for industrial furnaces/TFH as the standard value. C. In cases where more than one combustion (of fuel) utilities are used, the combustion load for each utility of the industry shall be manged and controlled to achieve the highest-possible efficiency. The efficiency herein refers to the ratio of heat gained by the material to the total heat input to the combustion utility. D. The combustion utilities shall be suitably operated to achieve a high level of combustion efficiency under specific operating conditions, which shall be described in the EM Manual. The specific operatating conditions shall be finalized based on various factors of fuels, such as the particle size of solid fuels, moisture content, viscosity of liquid fuels, calorific value, pressure of gaseous fuels. E. The combustion utilities shall be managed according to the instructions provided in the operation manual related to draft, operating temperature, and loading conditions for optimum performance, which shall be described in the EM Manual.
(2) Measurement and recording	A. All the key parameters of combustion utility shall be maintained and recorded regularly. The frequency of measurements shall be adhered to, which shall be explained in the the EM Manual. The industry shall use the measured data for evaluating the performance of combustion utility. Some of the parameters that shall be measured and recorded include the quantity of fuel fired, temperature of exhaust gases, residual oxygen (O2), and carbon monoxide (CO) in flue gases and unburnt carbon for solid fuels in bottom ash and fly ash. B. The industry shall measure useful heat gain either through steam generation in boilers or through the quantity of material processed in furnaces for assessing the performance.
(3) Maintenance and inspection	A. The DC shall undertake periodical inspection and maintenance of combustion facilities to maintain good operating conditions which shall be described in the EM Manual.
(4) Necessary measures when installing new facilities	A. The DC shall decide the compatible size and system specifications of the combustion utility based on application, fuel type, temperature of combustion air and heat load fluctuations. B. The DC shall select suitable and appropriate combustion equipment along with accessories (e.g. burner, associated auxiliaries including built-in automation) for new utility. C. The DC shall select appropriate accessories for combustion air supply and integrate with combustion equipment for the automatic regulation of air flow considering real-time plant load and other operating conditions.

Target Components

A. The industry shall make consistent and regular efforts to reduce the air ratio of combustion facilities towards the reference air ratio (table 6.1) for boilers (table 6.2) and for industrial furnaces as target values.

B. The DC shall retrofit suitable automatic air-fuel ratio control systems in each combustion equipment, and integrate with control loop system, if not already installed, which shall be described in the EM Manual.

C. The DC shall select and use appropriate combustion equipment (e.g. burners and auxiliaries), based on the type of combustion equipment and the type of fuel used. The combustion system shall be capable of regulating fuel supply automatically in line with load fluctuations.

D. The DC shall suitably modify air train to regulate combustion air flow and furnace pressure automatically.

E. The DC shall consider regenerative burner while installing a new burner or replacing an existing one to recover and re-use heat from waste hot gases.

F. The DC shall consider computer-aided automatic combustion management system / tool for a finer control of combustion equipment.

G. The management shall install suitable on-line measurement and recording equipment to monitor and control key operating parameters in the combustion utility. The measurements shall include fuel supply, temperature of exhaust gases, residual oxygen, and carbon monoxide levels in flue gases.

H. The DC shall periodically collect and analyse unburnt carbon in fly ash and bottom ash for solid fuels.

Table 6.1 Air ratios for boilers+

Parameter	Boiler capacity (tph)	Load factor (%)	Air ratio@					
			Coal^			Biomass fuel#	Liquid fuel	Gas fuel&
			Pulverised fuel	Fluidized bed*	Others$			
Standard[α]	> 100	50 – 100	1.16-1.20	1.15-1.18	-	-	-	-
	51 - 100	50 – 100	-	1.15-1.18	1.20-1.25	-	-	-
	11 - 50	50 – 100	-	1.18-1.24	1.24-1.30	1.47-1.55	1.18-1.25	1.12-1.15
	Upto 10	50 – 100	-	1.20-1.25	1.35-1.40	1.49-1.56	1.26-1.33	1.15-1.18
Target[β]	> 100	50 – 100	1.12-1.17	1.10-1.16	-	-	-	-
	51 - 100	50 – 100	-	1.12-1.17	1.17-1.20	-	-	-
	11 - 50	50 – 100	-	1.14-1.18	1.22-1.26	1.32-1.39	1.13-1.18	1.10-1.14
	Upto 10	50 – 100	-	1.15-1.20	1.32-1.38	1.32-1.39	1.18-1.24	1.12-1.15

Source: Boiler operational data

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

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

\+ 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.

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

^ Air ratio for petcoke is excluded in the EC Guidelines

* Includes (1) Atmospheric Fluidized Bed, (2) Pressurized Fluidized Bed and (3) Circulating Fluidized Bed

$ Except pulverized fuel and fluidized bed

\# Includes use of wood up to 10 tph capacities; bagasse or rice husk firing for other capacities.

& Gaseous fuel covers natural gas (NG) only. Fuels such as by-product gases as produced and used in steel industries are not considered.

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

- Load factor of the boiler used for power generation shall be considered the same as that of connected turbine load factor

Table 6.2 Air ratio for industrial furnaces+

Parameter	Kiln type	Air ratio@		
		Liquid fuel	Gas fuel&	Fuel gas#
Standard	Oil heating (TFH)	1.20-1.27	1.15-1.18	-
	Reheating furnace	1.18-1.23	1.14-1.17	-
	Process fired heater (Refinery)	-	-	1.14-1.31
Target	Oil heating (TFH)	1.18-1.22	1.12-1.15	-
	Reheating furnace	1.15-1.20	1.12-1.15	-
	Process fired heater (Refinery)	-	-	1.11-1.24

Source: Performance data from different industries

\+ Combustion of fuels under the 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 the air ratio (value rounded to two digits). The air ratio is considered based on 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.

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

& Gaseous fuel covers NG only. Fuels such as by-product gases as produced and used in steel industries are not considered.

Mix of fuel gases or off-gases with furnace oil or NG per requirements; data provided by Centre for High Technology.

Note 1: GCV of fuels

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

- Liquid fuels (light diesel oil, high speed diesel and furnace oil) - 10,500 to 10,800 kcal per kg; biomass fuels - 3100 to 4500 kcal per kg (source: https:// beeindia.gov.in/sites/ default/files/2Ch1.pdf)
- Natural gas : 8,500 to 9,000 kcal per scm (Source: GAIL India Limited)

7. HEATING, COOLING AND HEAT TRANSFER

The industry may need heating and/or cooling based on the process requirements. The heat load is met either through direct heat transfer or, indirectly, through heat exchange media. The type of heat source would include steam/hot water from a boiler, combustion products/flue gas in a furnace, hot fluid from TFH, etc. The cooling demand in the industry is achieved with the chiller (refrigeration) system and space comfort through heating, ventilation, and air-conditioning (HVAC) system.

7.1 Heating equipment

Standards Components	
(1) Management and control	A. The equipment (boiler, furnace and thermic fluid heater) shall have capacities appropriate for the desired performance. The facilities that use different sources of heat media such as steam, hot water, hot air, etc. (e.g. heating facilities, cooling facilities, dryers, heat exchangers, etc.) shall follow the instructions, which shall be described in the EM Manual. The instructions are related to temperature, pressure, volume, etc. to automatically control and optimize the supply of heat quantity. B. Industrial furnaces used for heating, melting and heat treatment shall be operated to improve the heat pattern in a way that increases thermal efficiency of the equipment which shall be elaborated in the EM Manual. C. The DC shall ensure optimum loading for better utilization of the capacity without over-loading or under-loading. D. In case of the multiple heating equipment operating in parallel, the load sharing for each equipment shall be regulated/ adjusted in such a way that highest level of thermal efficiency may be achieved as a whole, which shall be described in the EM Manual. E. The DC shall optimise the sequencing of material flow to reduce delays and avoid repeated heating of materials. F. Equipment for intermittent or batch operations shall be scheduled in a way that streamlines the entire chain of operation, which shall be described in the EM Manual. G. The DC shall maintain an appropriate quality of feedwater according to Indian Boilers Regulation (IBR), 1950 or an equivalent standard as suggested by the manufacturers which shall be provided in the EM Manual. H. The DC shall close steam flow to the process that is not in operation. I. The DC shall use dry steam in heating processes to enhance heat transfer.
(2) Measurement and recording	A. The DC shall measure and record operating parameters either on-line or periodically to enhance heat transfer which shall be described in the EM Manual. The operating parameters include the temperature of heated or cooled objects, pressure, and flow rates.

(3) Maintenance and inspection	A. Components related to the heat transfer of equipment, such as heat-transfer surfaces of boilers, industrial furnaces, heat exchangers, etc. shall be maintained according to the instructions concerning their maintenance and inspection, which shall be described in the EM Manual. The equipment shall be periodically cleaned to get rid of soot, scale or dirt to avoid deterioration of heat transfer surfaces and heat transfer performance.
(4) Necessary measures when installing new facilities	A. While installing new equipment for heating, the following points shall be considered. a. Use materials with the highest possible thermal conductivity b. Adopt the best possible layout of heat exchangers to improve total efficiency.
Target Components	
	A. The DC shall use higher dryness fraction of steam for better heat transfer. It shall also install an appropriate steam separator or steam trap to maintain the required dryness fraction of steam. B. The DC shall consider using improved properties and shapes of wall surfaces of industrial furnaces to enhance radiation heat transfer. C. The DC shall consider using improved properties and shapes of heat transfer surfaces to enhance the heat transfer coefficient of such surfaces. D. The DC shall use higher thermal conductivity materials for heat exchanging components employed. E. The DC, wherever feasible, shall use direct heating of objects. F. The DC shall consider increasing the number of stages of evaporators in multiple-effect evaporators based on the potential for enhancing the overall thermal efficiency. G. The DC shall consider improving the efficiency of distillation towers by optimizing parameters such as pressure, reflux ratio, vapour recompression, etc. H. The DC shall optimise the number of stages of heat exchangers and their layout for enhancing the thermal efficiency. I. The DC shall explore possibilities of integrating industrial furnaces operated at high temperatures and low temperatures to promote multi-step use of heat for improving the overall efficiency of furnace systems. J. The DC shall use automatic control systems to ensure an effective use of heat energy. K. The DC shall streamline processes that would require repeated heating. L. The DC shall consider including preliminary treatment methods that would help in energy saving. For example, preparatory steps such as removal of moisture content, preheating, and pre-grinding. M. The DC shall install a boiler or an industrial furnace with the highest efficiency that meets the process requirements. N. Heating with vacuum steam media shall be considered as an alternative to hot water media used in heating facilities.

7.2 Air-conditioning Facilities and Hot Water Supply Facilities

Standards Components	
(1) Management and control	A. The DC shall 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. Details of these instrutions shall be described in the EM Manual and shall include the necessary parameters, such as operational time, set temperature range (lower limit and upper limit), ventillation air per hour, and humidity. B. The DC shall manage the air-conditioning of office buildings to essential zones, reducing loads with potential options such as window shades, wall with low thermal mass, etc., and operate according to the instructions, which shall be described in the EM Manual. The operating instructions shall include operational time, room temperatures, air ventillation per hour, humidity, and the effective use of outdoor air. The utility shall adhere to air cooling and/or heating temperatures as recommeded in the Energy Conservation Building Code (ECBC). C. The air-conditioning system that includes heat source utilities, heat transport utilities, and air-conditioner utilities shall be controlled in a synchroized manner to improve the overall energy efficiency, which shall be described in the EM Manual. The DC shall attempt to improve by modifying operational parameters without compromising the system performance. Some of the key operational parameters, such as cooling water temperatures, chilled/hot water temperatures, and seasonal variations in outdoor air conditions shall be considered. D. Air-conditioning utilities with one or more heat sources using either similar or different energy sources shall be operated in a manner to achieve improvement in overall energy efficiency of the air conditioning system. The EM Manual shall elaborate on better operating practices for such arrangements. The overall improvement shall be established by opting the optimum number of heat source utilities in service, considering the variations in outdoor air conditions and heat load fluctuations. E. If the heat transport equipment includes more than one pump, the utility shall be managed to achieve improvement in energy efficiency and shall be described in the EM Manual. The DC shall use options such as auto controls to switch off pumps or change (increase or decrease) the speed according to the load variations by integrating with variable frequency drives (VFDs). F. In an air conditioner equipment, having more than one air conditioning equipment of the same model or more than one air conditioner of different types, the utility shall be managed in such a way that it achieves improvement in the overall energy efficiency of the air-conditioner equipment, which shall be described in the EM Manual. G. Efficiency of hot water supply equipment shall be enhanced by reducing supply points with seasonal changes and load requirement in processes as described in the EM Manual. The instructions in the EM Manual shall focus on output parameters such as temperature and pressure. H. Heat source equipment and the associated auxiliary equipment (e.g. burner and water pump) shall be operated, monitored and automatically controlled in response to load fluctuations, which shall be described in the EM Manual. I. If multipe heat-source equipment are provided in heat-source utility for hot-water-supply system, the utility shall be managed in such a way that it improves the overall energy efficiency of the heat-source utilities, which shall be described in the EM Manual. The improvement shall be achieved through adjusting (increasing or decreasing) the numbers of units in operation based on the process load conditions.

(2) Measurement and recording	A. The DC shall monitor and record parameters (e.g. temperature, and humidity) to keep track of air-conditioning in different sections of the industry. The DC shall use online monitors or hand-hold instruments for this purpose, which shall be described in the EM Manual. B. Parameters necessary to improve the efficiency of the overall HVAC system (that include heat source equipment, heat transportation equipment and air conditioner equipment) shall be periodically measured and/or recorded which shall be described in the EM Manual. C. Parameters necessary to improve the efficiency of hot water supply shall be measured and recorded periodically (e.g. quantity, feed water temperature and hot water supply temperature), which shall be described in the EM Manual.
(3) Maintenance and inspection	A. The DC shall undertake periodical inspection and maintenance of air-conditioning equipment to maintain good operating conditions which shall be described in the EM Manual. The improvement shall include both the equipment level and HVAC system level to achieve the overall energy efficiency. B. The DC shall maintain and inspect periodically hot-water supply equipment to keep them in good conditions according to the instructions provided on maintenance and inspection, which shall be described in the EM Manual. C. Automatic control systems or devices used in air conditioning and hot water supply equipment shall be maintained and inspected periodically in order to keep them in a good condition, which shall be described in the EM Manual.
(4) Necessary measures when installing new facilities	A. Air-conditioning equipment While installing a new air conditioning utility, the DC shall ensure the following: a. Select a suitable utility that is capable of responding to changes in heat demands. The DC shall consider installing a dedicated control system for each section of air conditioning to ensure better control. b. The DC shall install a high efficiency system within heat source utility (e.g. heat pumps) as well as heat transport utility of integrated air-conditioning system to accommodate fluctuating load demands. It shall be equipped with split control, flow control, storage system, etc. The heat transport system shall use variable pump head control for efficient operation. c. The DC shall use variable air-volume and flow-rate systems with speed control to respond to load variations. d. The DC shall introduce suitable heat exchanger for reducing air cooling/ heating loads. For example, the DC shall consider options such as outdoor air cooling during winter season and water humidification to reduce air cooling loads. e. The DC shall avoid direct discharge of exhaust heat from production systems close to air-conditioning section to avoid increase in air-conditioning loads. f. The DC shall minimize air-conditioning loads by installing a local air-conditioning system around workers or radiant heating in case the air conditioning of the entire workplace is not essential. g. The DC shall avoid ingression of hot air or exgression of conditioned air by closing gaps and openings as much as possible to reduce the air-conditioning load. h. The location and process of installing an outdoor unit of an air-conditioner should be determined based on both solar radiation and ventilation condition of the installation location, in case the units are installed closely together, which shall be described in EM Manual. i. The air conditioning utility shall be equipped with suitable control and measurement devices to manage operations on its own. The controlling parameters include temperature and humidity of the different sections of air-conditioning. B. Hot water supply equipment The DC shall evaluate load assessment of hot water requirements to select suitable hot water supply utility to achieve overall energy efficiency. It shall consider following before undertaking installation of a new utility. a. Select compatible technology that responds efficiently to load variations. b. Install a dedicated hot water supply system to cater to sections with lower loads. c. Explore use of 'heat pump system' and/or a latent heat recovery system for heat source equipment.

Target Components	
	A. Air conditioning equipment The DC shall focus on the following aspects to ensure efficient use of energy in air-conditioning utility. a. For only air conditioning, the DC shall use heat source equipment with high energy efficiency, such as heat pump and storage system and gas cooling or heating system. For simultaneous air cooling and heating loads within the plant, the DC shall consider using a heat recovery system. Further, in case of the availability of a potential exhaust heat, the use of a heat recovery system, e.g. heat pump and exhaust-heat-driven heat source equipment shall also be considered. b. The DC shall improve thermal insulation of walls and roofs for the air-conditioned areas. It shall include higher thickness of walls and roofs, low thermal conductivity materials, and double-layer thermal insulation. It shall further consider reducing external heat sources through shielding solar radiation through windows using window shades, heat reflecting glasses, heat shield window films and thermal buffer zone with double insulation structure. c. The air-conditioning utility shall be equipped with a carbon dioxide sensor or a similar type of device to minimize the outdoor air-handling load. It shall consider the cooling of air with water from cooling towers during the winter season. d. The air-conditioning utility shall minimize air flow volume and circulation water volume by setting a large temperature difference in the utility. e. The DC shall insulate pipes and ducts to reduce heat losses. B. Hot water supply equipment The DC shall examine the following to enhance the energy efficiency in hot water-supply systems. a. Use of a heat pump or latent heat-recovery system to enhance the efficiency of hot water-supply utilities. b. Use of alternate systems to reduce power consumption in the ventilation system in the workplace, machine rooms, and electric rooms. For example, the air volume controller with suitable sensors.

8. WASTE HEAT RECOVERY AND USAGE

The WHR system is employed to recover and reuse sensible heat available in hot streams, such as exhaust gases from boilers, furnaces, gas turbines, diesel generator (DG) sets, etc. WHRs are used in various applications depending on the quantum of recoverable heat available for extraction. Some of the applications include a WHR boiler, air pre-heater, charge/scrap pre-heating, economiser, etc.

Standards Components	
(1) Management and control	A. Recovery and reuse of waste heat from flue gases for different types of utilities (gas turbine, gas engine, diesel engine, boiler, industrial furnace, TFH, etc.) shall be managed according to the instructions concerning waste gas temperatures or the WHR rates as described in the EM Manual. B. Recovery and reuse of waste heat in condensate return shall be managed according to the instructions concerning parameters, such as the quantity of condensate, temperature, etc., as described in the EM Manual. C. Recovery of sensible heat, latent heat, etc., as available from various sources (gas turbine, gas engine, diesel engine, boiler, industrial furnace, TFH, etc.) shall be managed according to the instructions concerning the rate of recovery as described in the EM Manual. D. Waste heat from exhaust gases shall be utilized suitably according to temperature conditions (e.g. preheating temperature) and operating conditions of equipment.
(2) Measurement and recording	A. The parameters concerning waste heat and its utilization in each utility shall be measured and recorded. These include temperature of waste heat, quantity of waste heat medium and composition, etc. which shall be monitored periodically and the data shall be recorded according to the instructions described in the EM Manual.
(3) Maintenance and inspection	A. Systems such as heat exchangers and waste heat boilers (hereafter, "WHR equipment") shall be periodically maintained and regularly inspected according to the instructions mentioned in the EM Manual.
(4) Necessary measures when installing new facilities	A. The DC shall employ adequate measures while installing a new pipe or system towards the transportation of waste heat with a minimum temperature drop. These measures include preventing air intrusion, enhancing thermal insulation, etc. B. The exhaust gas temperature of boiler shall be reduced by recovering sensible heat by installing waste heat recovery equipment or retrofitting the existing waste heat recovery system considering the reference values as specified in table 8.1. C. The exhaust gas temperature of the industrial furnace shall be reduced by recovering sensible heat by installing a WHR or retrofitting existing waste heat recovery system considering the reference values as specified in table 8.2. D. The DC shall undertake appropriate actions to maximize waste heat recovery while installing a new WHR utility. The actions shall include selection and use of materials with improved properties, shapes and areas of heat transfer (e.g. finned surfaces). E. The DC shall install on-line instrumentation to monitor the temperature of exhaust gases and the waste heat recovery media. F. The DC shall include suitable cleaning systems for the WHR facilities/ heat exchangers to avoid scale formation and to ensure optimum heat transfer as per instructions provided in the EM Manual.

Target Components	
	A. The DC shall put in efforts towards efficient heat recovery from various feasible waste heat sources (gas turbine, gas engine, diesel engine, TFH, etc.), taking into account the type of fluid (e.g. contaminated fluid, corrosive fluid, etc.) so that the waste streams are exhausted at minimum possible temperatures. B. The flue gas temperature of the boiler shall be reduced by recovering sensible heat in the exhaust gases by appropriate measures and methods either on the existing system or installing a new system considering the reference values as specified in table 8.1. C. The flue gas temperature of an industrial furnace shall be reduced by recovering sensible heat in exhaust gases using appropriate WHR either on the existing system or by installing a new system considering the reference values as specified in table 8.2. D. The DC shall also consider other measures for improving overall waste heat recovery. These include an appropriate sizing of duct or pipe, suitable layout, avoidance of leakage, use of efficient insulation materials, regular maintenance, and use of temperature recording systems both at source and usage points. E. The DC shall enhance the WHR system by considering use of materials with better properties, shapes (e.g. fins), and areas of heat transfer. The utility shall also install heat storage facilities. It shall further enhance the recovery of waste heat through by considering new technology options, such as Organic-Rankine Cycle (ORC), vapour absorption systems, etc.

Table 8.1 Flue gas temperature of boilers

Parameter	Boiler capacity (tph)	Flue gas temperature@					
		Coal			Biomass fuel#	Liquid fuel+	Gas fuel&
		Pulverised fuel	Fluidized bed*	Others$			
Standard	> 100	140	140	-	-	-	-
	51 - 100	-	140	140	-	-	-
	11 - 50	-	140	140	180	190	140
	Upto 10	-	220	220	220	220	220
Target	> 100	130	130	-	-	-	-
	51 - 100	-	130	130	-	-	-
	11 - 50	-	130	130	160	180	130
	Upto 10	-	200	200	200	200	220

Source: Boiler performance data from different plants

@ Average temperature at the outlet of the final stage of heat recovery from flue gas or chimney base

* (1) Atmospheric fluidised bed, (2) pressurised fluidised bed and (3) circulating fluidised bed

$ Except pulverized fuel and fluidized bed

Includes wood, briquette, rice husk, bagasse, etc.

\+ Liquid fuels includes light diesel oil, high speed diesel and furnace oil

& Gaseous fuel covers natural gas (NG) only

Table 8.2 Waste heat recovery for industrial furnaces

Exhaust gas temperature (°C)	Standard$^{\alpha}$ waste heat recovery rate (%)	Target$^{\beta}$ waste heat recovery rate (%)	Flue gas temperature# (°C)
Upto 600	30	38	250-300
600-1000	42	52	200-300
More than 1000	47	56	200-300

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 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 rate

$$\text{Waste heat recovery rate (\%)} = \frac{\text{(Exhaust gas temperature-Flue gas temperatue)}}{\text{(Exhaust gas temperature)}} \times 100$$

Where, temperatures are measured in °C

9. CONVERSION OF HEAT TO ELECTRICITY

The thermal power plants use solid, liquid, and gaseous fuels for generating electricity. The generated electricity is either supplied to the grid or used as captive power. The power generation may be based on steam turbine, gas turbine, diesel engine, gas engine, etc.

9.1 Power-generation Utilities

Standards Components	
(1) Management and control	A. A thermal power plant, which is used either for public distribution or dedicated captive power generation utility, shall be operated efficiently, which shall be described in the EM Manual. Further, multiple power-generation facilities operating in parallel shall be managed to ensure a proper load distribution within the utilities and improve thr overall efficiency which shall be described in the EM Manual. B. The power generation plant shall take into consideration typical characteristics of each generation utility for determining load distribution while ensuring an overall efficient operation.
(2) Measurement and recording	A. The DC shall periodically measure the overall performance of power generation utility and shall record the results according to the instructions, which shall be described in the EM Manual.
(3) Maintenance and inspection	A. The DC shall be periodically inspected and maintained to ensure a trouble-free and smooth operation and achieve the highest possible energy efficiency. Details of maintenance and inspection shall be described in the EM Manual.
(4) Necessary measures when installing new facilities	A. The DC shall select and install a new power-generation utility of optimum capacity taking into account the existing power requirements and considering the future trends of power demands for captive power generation. B. The design net heat rate of the newly installed power-generating utility at the receiving end shall not be significantly higher than the average level of the existing thermal power generation utilities.
Target Components	
	A. The DC shall install state-of-the-art on-line measurements and recording equipment to measure and control key operating parameters.

9.2 Cogeneration Utilities

Standards Components		
(1) Management and control	A.	The DC shall manage and operate equipment used in cogenertaion facilities (e.g. boilers, gas turbines, steam turbines, gas engines, and diesel engines) to achieve optimum energy efficiency under variable load conditions, which shall be described in the EM Manual.
	B.	The DC shall take into account characteritics of different facilities to determine an optimum load distribution to respond to load variations for achieving the highest energy efficiency.
	C.	For cogeneration utilities with back pressure or extraction-type turbines, the industry shall control minimum allowable values of back pressure or bleeder pressure according to the instructions concerning the values, which shall be described in the EM Manual.
(2) Measurement and recording	A.	The key parameters that influence the overall efficiency of equipment (e.g. boilers, gas turbines, steam turbines, gas engines, and diesel engines) shall be periodically measured and recorded according to the instructions concerning measurements and records of such parameters, which shall be described in the EM Manual.
	B.	In case of cogeneration utilities operated under low pressure, which is close to the minimum allowable limit for back pressure or extraction turbine, the facilities shall periodically measure and record the operating parameters, which shall be described in the EM Manual. These key parameters, which shall be measured and recorded, include operational time, inlet/outlet pressure, back or extraction pressure, and quantity of steam used, etc.
(3) Maintenance and inspection	A.	Cogeneration utilities shall be periodically maintained and inspected in a way that maintains the highest level of overall efficiency, which shall be described in the EM Manual.
(4) Necessary measures when installing new facilities	A.	The DC shall thoroughly analyse the actual use and future trends of heat and power demands and the availability of exhaust heat while selecting and installing a new cogeneration utility of optimum capacity. Historical data recorded for a period of one year or more shall be used for this purpose.
Target Components		
	A.	The DC shall consider installing new cogeneration utility in case of large quantity of steam/ hot water demand and the continuous availability of exhaust heat throughout the year.
	B.	The DC shall explore modifying the existing operating conditions of extraction/ back pressure turbine if it helps in improving the overall performance of the utility while ensuring the services.

10. PREVENTION OF ENERGY LOSS DUE TO HEAT RADIATION AND ELECTRIC RESISTANCE

Thermal energy and electrical energy are commonly used in various industrial processes. Radiation loss takes place in high temperature zones, which is controlled by better insulation on the surface and reducing openings. Electrical losses occur in various distribution lines connecting electrical utilities, such as resistance heating systems, cables, transformers, motors, etc.

10.1 Prevention of Heat Loss Due To Radiation and Conduction

Standards Components	
(1) Management and control	A. The DC shall undertake thermal insulation work on different systems such as steam and condensate pipes, ducts, equipment, etc., which are used for transporting heat media, process fluid for heating, etc. (hereafter, "heat-using equipment") according to the industrial standard practices for thermal insulation works and equivalent standards. B. The existing industrial furnaces shall be thermally insulated to improve the insulation performance to maintain external surface temperature based on the standard value as listed in table 10.1. The external surface temperature for the boiler shall be maintained as per Note (2) provided in table 10.1.
(2) Measurement and recording	A. The DC shall periodically measure all key parameters of surfaces to keep track and reduce heat losses. These parameters include the temperature of external surfaces of furnace, heated object temperature, mass of the object and waste gas temperature, etc. The results shall be analysed, heat losses shall be quantified, and the heat balance shall be prepared, which shall be described in the EM Manual.
(3) Maintenance and inspection	A. Heat-using equipment shall be periodically inspected to maintain proper insulation to reduce heat losses according to the instructions concerning maintenance and inspection of the measures (e.g. insulation work), which shall be described in the EM Manual. B. Steam traps shall be periodically maintained and inspected to prevent steam leaks and clogging caused by the malfunctioning of traps. The maintenance and inspection of the steam traps shall be detailed in the EM Manual.
(4) Necessary measures when installing new facilities	A. While installing a new heat-using utility, actions to improve thermal insulation shall be undertaken. These include employing optimum thickness of insulation, selecting low thermal conductivity material, multi-layer insulation, etc. B. The DC shall minimize heat losses through radiation and air ingression by adopting suitable measures. These include minimum openings, proper sealing, double doors, air curtains, etc. C. The DC shall reduce the heat radiation area by transporting heat media through a streamlined pipe route. D. For a batch operated furnace with an operating temperature more than 1000°C, the utility shall apply veneering on interior surfaces.

Target Components	
	A. The DC shall examine the potential measures such as low thermal mass furniture and better insulation for bodies, bases, fixtures, and equipment used in handling hot materials to minimize heat losses. It includes boilers, furnaces, steam system, condensate recovery system, etc. B. The industrial furnace shall be provided with optimum insulation using compatible material to reduce heat losses from the surfaces. The surface temperature of an industrial furnace shall be maintained as specified in table 10.1 as the target value. C. For batch type furnaces operating with an internal temperature of more than 600°C, the utility shall consider insulation based on the temperatures listed in table 10.1 as the target value. D. The DC shall examine various measures to improve thermal insulation of heat-using facilities. These shall include higher thickness of insulation, selecting low thermal conductivity insulating materials, veneering on internal surfaces, etc. E. The DC shall minimize heat losses through dissipation and air leakage by adopting appropriate measures. These measures include reduced openings, improved sealing, double doors, air curtains, etc. F. The DC shall examine the existing thermal sealing and undertake measures in heat-using facilities to prevent leakage of heat media from locations like rotating parts, joints, etc. G. The DC shall also examine use of improved streamlined pipe route for transporting heat media to reduce heat radiations. H. The DC shall examine methods such as covering of open-type facilities, steam-using facilities and transport facilities which use high-temperature materials to reduce heat losses, except in cases wherein it is required to cool the facilities while transportation.

Table 10.1 Surface temperatures of industrial furnace

Parameter	Furnace design temperature (°C)	Surface temperature (°C)#		
		Ceiling	Side wall	Bottom*
Standard	Up to 600	80	70	75
	600-1,000	100	90	100
	More than 1,000	120	100	120
Target	Up to 600	60	60	60
	600-1,000	90	75	85
	More than 1,000	110	85	100

Source: Based on data from different industries

\# Indicates average skin temperature under steady state operation

* Indicates bottom surfaces not in contact with ground but with open air

Note 1: The surface temperatures of rotary kilns in cement industries are generally observed to be higher than the range provided in the table, which are not included separately in the guidelines.

Note 2: The surface temperatures of a boiler shall be maintained at about 15 to 20 oC above ambient temperature.

10.2 Prevention of Electricity Loss Due To Electric Resistance

Standards Components	
(1) Management and control	A. The DC shall manage and operate electrical systems such as transformers and uninterruptible power supply systems to achieve the highest efficiency and minimise energy losses, which shall be described in the EM Manual. It shall ensure efficient operation even during part-load conditions. The DC shall further adjust the number of units (transformers or uninterruptible power supply systems) in operation for optimum load allocation as per power requirements of various sections. B. The DC shall undertake actions to reduce distribution losses in power-receiving and transforming utilities. These actions shall include shorter distribution lines, proper current-carrying capacity of conductors, and an appropriate distribution voltage, etc., which shall be described in the EM Manual. C. Operating practices to control starting or stopping of capacitors in line with the operation of the equipment in which they are installed shall be described in the EM Manual. D. The DC shall distribute single-phase loads in such a way that there is no current imbalance in the three-phase distribution system, which shall be described in EM Manual. E. The utility shall be equipped with phase-protection relay/ single phasing preventer to avoid motor burn outs. F. The equipment that use electricity (hereafter, electricity-using utility') shall be managed and controlled according to the instructions concerning standard operating practices of the utility, which shall be described in the EM Manual. G. The DC shall manage and control current flow to electricity-using facilities to minimise electrical losses which shall be described in the EM Manual.
(2) Measurement and recording	A. The DC shall periodically measure and record parameters that are required to reduce electricity losses, which shall be described in the EM Manual. Some of the parameters shall include electricity consumption and voltage, current and power factor in power-receiving and transforming equipment etc.
(3) Maintenance and inspection	A. The DC shall undertake preventive maintenance and routine inspection of electrical equipment (power-receiving and transforming equipment, and power distribution equipment), which shall be described in the EM Manual.
(4) Necessary measures when installing new facilities	A. While installing new equipment for power-receiving and distribution equipment, the DC shall select suitable capacity and high efficient equipment to achieve the overall energy efficiency.
Target Components	
	A. The DC shall examine the improvements of the power factor at the receiving end by installing measures, such as automatic power factor controller, capacitor banks, etc., in the distribution facilities as shown as the target value in Table 10.2. B. The DC shall install advanced management systems such as Supervisory Control and Data Acquisition (SCADA), which shall be integrated with each of the electricity-using utility towards automatic monitoring and recording of all key operating parameters.

Table 10.2 Target power factor

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

11. CONVERSION OF ELECTRICITY TO MOTIVE POWER, HEAT AND LIGHT

Electric motors are widely used in industries for various loads, such as fans, blowers, pumps, compressors, conveyors, etc. A wide range of capacities of motors are used for these applications. Further, electricity is used for heating and melting applications in furnaces and various types of industrial lighting.

11.1 Facilities Using Motors and Heaters

Standards Components	
(1) Management and control	A. The DC shall stop motor driven equipment when not in use or during idle operation, which shall be described in the EM Manual. It shall take into account the energy losses during idle run period versus energy consumption during intitial start-up. B. Parallel operation of multiple motors shall be managed in a way to achieve high efficiency of the motors as a whole, which shall be described in the EM Manual. Suitable load allocation during parallel operation of multiple motors shall be implemented during partial load conditions to maintain higher efficiency under varying load conditions. C. The DC shall review the current use, end pressure and discharge rate of fluid machines (e.g. pumps, fans, blowers, compressors, etc.), and manage to reduce the load of the connected electric motors according to the instructions which shall be described in the EM Manual. The instructions may include the number of operating units, speed reduction, pipe layout and dimensions, impeller size, etc., to cater to the variable load conditions. D. The DC shall adopt measures in electric heating utilities (e.g. induction furnaces, arc furnaces, and resistance furnaces) to enhance the efficiency, which shall be provided in the EM Manual. The measures include loading pattern, reducing idle operation, better insulation, installation of the WHR system, etc., as applicable. E. The electrolytic facilities shall use electrodes of a suitable size, shape, and characteristics, and shall be managed to attain high efficiency, which shall be described in the EM Manual. The instructions include distance between electrodes, concentration of electrolytes, and contact resistance of conductors. F. The DC shall manage use of electricity in different types of electricity-using utilities (e.g. motor driven utilities, electric heating utilities, etc.) with a view to reduce electrical losses (e.g. voltage or current losses), which shall be described in the EM Manual.
(2) Measurement and recording	A. The DC shall measure such parameters of electricity-using equipment and record the results which will be necessary to reduce electrical losses, which shall be described in the EM Manual.
(3) Maintenance and inspection	A. The motor-driven equipment shall be periodically inspected and maintained to reduce mechanical losses occurring in electric motors, power transmission units, and machines that apply loads to the motors, which shall be described in the EM Manual. B. The motor-driven utility shall be periodically inspected and maintained for different fluid machines (e.g. pumps, fans, blowers, and compressors) to prevent leakages and reduce resistance of pipes and ducts, which shall be described in the EM Manual. C. The DC shall reduce electric resistance losses in electric-heating equipment and electrolytic equipment through periodic maintenance and inspection of wire connections, contacts of switch, etc. which shall be described in the EM Manual.

(4) Necessary measures when installing new facilities	A. The DC shall install and use efficient motors of suitable sizes as provided in table 11.1. B. The DC shall install motors with compatible configurations to meet applications with large fluctuations of loads.
Target Components	
	A. The DC shall install and use high-energy, efficient motors as provided in Table 11.1. B. The industry shall install energy-saving measures such as VFD in a motor-applied utility with large load fluctuations. C. The DC shall examine different heating methods (combustion of fuel, steam, hot air, thermic fluids, electric heating, etc.) for the selection of electric heating. It shall consider parameters, such as heat load, temperature range and energy costs for comparison.

Table 11.1 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
37	93.7	93.9	93.3
45	94.0	94.2	93.7
55	94.3	94.6	94.1
75	94.7	95.0	94.6
90	95.0	95.2	94.9
110	95.2	95.4	95.1
125	95.3	95.5	95.2
132	95.4	95.6	95.4
160	95.6	95.8	95.6
200	95.8	96.0	95.8
250	95.8	96.0	95.8
315	95.8	96.0	95.8

Source: Is 12615:2011 (three-phase, 50Hz, single-speed and squirrel-cage induction motors)
Note: IE3 motors stand for premium efficiency level; however, high tension and direct current motors are excluded in the table.

11.2 Pumps 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 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) multistage pumps. The guideline covers centrifugal pumps, boiler feed water pumps (BFP), and vertical turbine pumps.

Standard Components	
(1) Management and control	A. The DC shall use 'characteristic curves' provided by the manufacturer for the monitoring and control of pump operation. The pump(s) shall be operated close to 'Best Operating Point' (BOP) as specified by the pump manufacturer. B. The DC shall use pumps with highest efficiency to meet the base load when multiple pumps are in operation. C. In case of the DC using multi-pumps, it shall manage and control the loading of pump in such a way that it achieves the highest possible loading near the BOP in respective characteristic curve. D. The DC shall ensure optimum loading of pumps during the entire range of operation both during full load or part load while operating multiple pumps in parallel, which shall be provided in the EM Manual. E. The DC shall manage the piping network of the pumping system and the control operating parameters, such as flow rate, pressure, and temperature, which shall be provided in the EM Manual. F. The DC shall maintain a minimum Net Positive Suction Head (NPSH) of pumps as prescribed by the manufacturer.
(2) Measurement and recording	A. The DC shall measure and record key operating parameters such as the total differential head, flow rate and power consumption to evaluate efficiency of pumps which shall be described in EM Manual. It shall use on-line monitoring for centralized large system and periodical measurement for decentralised smaller pumps.
(3) Maintenance and inspection	A. The DC shall undertake routine/scheduled overhauling of pumps according to the instructions provided by the manufacturers, which shall be described in the EM Manual. B. The DC shall maintain and inspect parameters, such as speed of motor, body temperature in pump ends, and vibration on a periodical basis, which shall be described in the EM Manual. C. The DC shall undertake corrective maintenance in case of a significant drop in the total differential head observed in the pumping system. D. The DC shall ensure a dynamic balancing of pump assembly after each overhauling.
(4) Necessary measures when installing new facilities	A. The DC shall select correct capacity of pump with energy efficient systems such as IE3 motor or permanent magnet synchronous motor, variable frequency drives (VFD), cogged v-belts for belt driven systems, etc., while considering existing demand and immediate future expansion plans. B. The DC shall undertake water balance of the plant to assess the total pumping capacity. C. The DC shall undertake the dynamic balancing of pump assembly during installation. D. The DC shall optimize the number of stages available in a multi-stage pump (e.g. boiler feedwater pump) in case of availability of the head margins. E. The DC shall design and install a pumping network with minimum system resistance using seamless pipes, which shall be described in the EM Manual. F. The DC shall use a booster for small loads requiring higher pressures.
Target Components	
	A. The DC shall select and install most efficient pumps while matching the BOP with system parameters, considering both the existing requirements and the immediate expansion plans. B. The DC shall install a proper size of suction valve as recommended by the manufacturers. C. The DC shall further include measures, such as correct sizing, seamless or fibre-reinforced plastic (FRP) pipe, better layout, plugging off leakages, application of improved insulation (hot and cold media), and the regular maintenance and installation of the appropriate measurement systems for pressure and flow, both at the source and points of usage.

11.3 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 devices used to compress and pressurize air. The centralised 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. The compressors can be classified into (1) positive displacement compressor and (2) dynamic compressor.

Standard Components	
(1) Management and control	A. The DC shall ensure the drawing of clean, cool, and dry air by compressors for optimum performance. It shall manage and control operations as per the instructions provided in the EM Manual in the compressed air system. B. The DC shall use a suitable size of air compressors to meet the plant demands. C. The DC shall pre-set a minimum possible generation pressure to optimise system performance, which shall be explained in the EM Manual. D. The DC shall install receiver tanks with sufficient capacities for storing compressed air to cater to load demands and fluctuations. E. The DC shall use dedicated air compressors to meet exclusive high- or low-pressure demands. F. In case of operation of multiple air compressors, the DC shall use the most efficient compressors to meet the base load.
(2) Measurement and recording	A. The DC shall undertake an on-line monitoring of pressure and air flow at the downstream of compressor and the power consumption of individual compressors to assess the performance, i.e. Specific Power Consumption (SPC) which shall be described in the EM Manual.
(3) Maintenance and inspection	A. The DC shall inspect and clean air filters on a weekly basis. The replacement of air filters shall be based on suction air conditions. B. The DC shall undertake an overhauling of air compressors on a periodical basis, as is recommended by the manufacturer. C. The DC shall avoid moisture carryover by compressed air. It shall drain the moisture accumulated on a regular basis. D. The DC shall conduct leakage tests and plug off the compressed air leakages, which shall be described in the EM Manual.
(4) Necessary measures when installing new facilities	A. The DC shall undertake demand assessments 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 a inbuilt VFD, motor with permanent magnet, inverter type air compressor, etc. B. The DC shall select and install air compressors with the lowest SPC while meeting the compressed air demands. C. The DC shall install air compressor in a direction that a hermetically closed room or intake of contaminated air (oil, gas, etc.) is avoided. D. The DC shall design and install a compressed air network with a minimum pressure drop. It shall use seamless metallic pipes or 'fibre reinforced plastic' (FRP) pipe for compressed air lines, which shall be described in the EM Manual. E. The DC shall install intelligent electronic control systems to minimise energy consumption and reduce loss of compressed air. It shall also include an auto-drain system for moisture removal. F. The DC shall locate air compressors in such a way that it reduces the piping length and minimises line-pressure losses. G. The DC shall meet fluctuations in compressed air demands using VFD-enabled screw air compressors. In case of a multiple air compressors system, the DC 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. H. The DC shall use centrifugal compressors for meeting a high volume with low pressure applications, wherever feasible. I. The DC shall install air dryers in the distribution line which supplies to dry air usage points only, e.g. instrumentation air. J. The DC shall ensure the proper location of air compressors and the quality of suction air as per the recommendation of the manufacturers, which shall be described in the EM Manual.

Target Components	
	A. The DC shall undertake demand assessment of compressed air at plant level to select and install a suitable compressed air system. B. The DC shall avoid installing oversized air compressors, which may lead to inefficiencies. C. The DC shall undertake the necessary measures such that the overall leakage from the compressed air network shall remain less than 10% of the total compressed air generation. D. The DC shall optimise a compressed air system using a ring-frame network and avoiding unnecessary bends, redundant pipes, valves, etc.

$$\text{Specific power consumption (SPC)} = \frac{\text{Actual power consumption (kW)}}{\text{Free air discharge (Nm}^3\text{/minute)}}$$

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

11.4 Fans and Blowers

Industrial fan and blower systems are employed to generate low-pressure air volumes or gases for transferring against the system resistance caused due to ducts, dampers, or other components. Such systems are used for different applications to transfer air through mechanical action. Based on the operating principle, fans are grouped in two categories, namely, (1) centrifugal fans and (2) axial flow fans. Similarly, industrial blowers are grouped into (1) centrifugal blowers and (2) positive displacement blowers. The selection of a fan or blower depends on the various process requirements, such as air volume, system resistance, output pressure, and working environment.

Standard Components	
(1) Management and control	A. The DC shall use 'characteristic curves' provided by the manufacturer for managing and controlling operations of fans and blowers. It shall operate fans/blowers close to 'best operating point' (BOP) of the characteristic curve, which is the intersection of fan curve and system resistance curve. B. If a DC has multiple blowers, it shall use the blowers in series for high resistance, and in parallel connection for low resistance system. C. The DC shall operate more fans in parallel instead of a single large fan for higher volume requirements.
(2) Measurement and recording	A. The DC shall measure and record key operating parameters such as pressure, temperature, air velocity and power input to assess specific energy consumption (SEC), which shall be described in EM Manual. The DC shall use on-line monitoring for centralized large system and periodical measurement for decentralised smaller blowers.
(3) Maintenance and inspection	A. The DC shall undertake a routine overhauling of fans and blowers according to the instructions provided by the manufacturers, which shall be described in the EM Manual. It shall ensure a dynamic balancing of fans/ blowers assembly after each overhauling. B. The DC shall maintain and inspect parameters, such as the motor speed and vibration on a periodical basis, which shall be described in the EM Manual. C. The DC shall ensure an allowable impeller inlet seal clearances that include axial overlap, radial clearance, back plate clearance, and labyrinth seal clearance. It would further ensure a 'full-open' and 'full-close- conditions of inlet damper positioning for the efficient operation of fans/ blowers. D. The DC shall conduct a periodical inspection for leakages and plug off leakages in distribution lines, which shall be described in the EM Manual. E. The DC shall undertake corrective maintenance in case of a significant drop in pressure head observed in the system.

(4) Necessary measures when installing new facilities	A.	The DC shall select and install correct capacity of fan/blower with highest efficiency considering existing requirements, immediate expansion plans, plant layout and routing of pipes as provided in table 11.2.
	B.	The DC shall ensure dynamic balancing of fan/ blower assembly while installing a new system.
	C.	The DC shall use a booster for small loads requiring higher pressures.
	D.	The DC shall 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.
	E.	The DC shall select fan or blower with energy efficient systems such as IE3/ permanent magnet synchronous motor, VFD, etc., to maintain optimum performance.
	F.	The DC shall install fans and blower in a direction that a hermetically closed room or intake of contaminated air (oil, gas, etc.) is avoided.
	G.	The DC shall design and install fans and blowers network with a minimum system resistance using seamless pipes, which shall be described in the EM Manual.
	H.	The DC shall replace over-sized fans/ blowers with an optimum size system to meet the process requirements for high-load conditions.
	I.	The DC shall retrofit existing fan or blower with a VFD in case of fluctuating load conditions, which shall be described in EM Manual.
	J.	The DC shall install fans/ blowers in the proper location and ensure a suitable quality of suction air, as recommended by the manufacturers, which shall be described in the EM Manual.
	K.	The DC shall ensure a proper belt alignment to minimize side wear and evenly distribute stress on the entire belt for belt-driven system.
	L.	The DC shall replace/trim impeller blades as per the requirements of the process for optimum loading.
Target Components		
	A.	The DC shall assess air volume demand of the plant to identify the total system capacity.
	B.	The DC shall select and install the most efficient fans and blowers as shown in table 11.2, while matching the best efficiency point and considering both the existing requirements and immediate expansion plans.
	C.	The DC shall ensure proper sizing of inlet of blower as per design values.
	D.	The DC shall further include measures such as the correct sizing of pipe, appropriate layout, plugging off leakages, application of improved insulation (for hot stream), regular maintenance, recording system, etc.
	E.	The DC shall install multiple systems in parallel to generate a higher volume in place of a single, large system.

Table 11.2 Efficiency of fans

Fan categories		Peak efficiency range (%)
Centrifugal fan	Airfoil backward curved/ inclined	79 – 83
	Modified radial	72 – 79
	Radial	69 – 75
	Pressure blower	58 – 68
	Forward curved	60 – 65
Axial fan	Van-axial	78 – 85
	Tube-axial	67 – 72
	Propeller	45 – 50

Source: Secondary data from websites

$$\text{Specific power consumption (kW/m}^3\text{/min)} = \frac{\text{Actual power consumption (kW)}}{\text{Total air volume (m}^3\text{/minute)}}$$

$$\text{Fan mechanical efficiency (\%)} = \frac{\text{(Volume} \left(\frac{\text{(m}^3}{\text{hr)}}\right) \text{X Total pressure (mm WC)X 100)/}}{\text{(102 X Power input to fan shaft (kW))}}$$

$$\text{Fan static efficiency (\%)} = \frac{\text{(Volume} \left(\frac{\text{(m}^3}{\text{hr)}}\right) \text{X Static pressure (mm WC)X 100}}{\text{102 X Power input to fan shaft (kW)}}$$

11.5 Lighting System

Standards Components	
(1) Management and control	A. Lighting systems shall be managed according to the instructions based on Energy Conservation Building Code (ECBC), thus ensuring required lighting power density as mentioned in table 11.3 and IS Code of Practice for Industrial Lighting: 6665-1972, or their equivalent standards, which shall be described in the EM Manual. Dimming or turning-off the light shall be managed in a way that eliminates excessive or unnecessary lighting, which shall be described in the EM Manual.
(2) Measurement and recording	A. The DC shall periodically measure the illumination level of lighting systems installed in various sections, which shall be recorded according to the instructions concerning measurements and records of illuminance in different process sections or workplaces to be lit, which shall be described in the EM Manual.
(3) Maintenance and inspection	A. Lighting systems shall be periodically maintained and inspected according to the instructions concerning maintenance and inspection, which shall be described in the EM Manual. The instructions shall include cleaning and replacement of lighting fixtures and lamps.
(4) Necessary measures when installing new facilities	A. While installing a new lighting system, the DC shall optimise energy use in lighting, based on the information concerning lighting systems in the ECBC. These include the following: B. The DC shall replace inefficient lighting with energy-efficient lighting facilities, such as LEDs, induction lamps, etc., maintaining standard illumination with a minimum LPD. The LPD range for a few application areas in industries is shown in Table 11.3. C. The DC shall select suitable lighting fixtures that can be easily maintained and allow for an easy cleaning and replacement of the light source. D. The DC shall 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. E. The DC shall install systems that avail natural day light (e.g. use of translucent roofs) to maximize lighting and reduce the electric lighting load. F. The DC shall install appropriate control systems to auto switch off or the dimming of the lighting system. It shall include measures, such as motion sensors, timers, and interlocking with security systems to avoid lighting when not required.
Target Components	
	A. The DC shall use lighting fixture with a dimming function and automatic control devices, when natural lighting can be used. B. The DC shall consider using energy efficient lighting system such as LED and induction lighting along with suitable auto control systems to improve the energy efficiency. C. The DC shall install a natural lighting system e.g. translucent sheets, etc. to maximise the energy saving. D. The DC shall use solar photo voltaic (SPV) based lighting system to use renewable energy sources.

Table 11.3 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

The lighting power density (LPD) is arrived at by using the following formulae.

$$LPD\,(\frac{W}{m2}) = \frac{Lux}{Efficacy} \qquad LPD\left(\frac{W}{m2}\right) = \frac{Lux}{Efficacy} \qquad Efficacy = \frac{lumen}{watt}$$

11.6 Cooling Tower

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 essential auxiliary equipment in process refrigeration and air-conditioning system used in oil refinery, petrochemical industry, thermal power station, etc.

Standard Components	
(1) Management and control	A. The DC shall maintain cycle of concentration (COC) within the limit as provided in table 11.4 to minimize make-up water consumption in cooling water, which shall be described in EM Manual. B. The DC shall describe the minimum set point of cooling water temperature for each process. It shall stop fan operation using automation/controller when the cooling water temperature falls below minimum set temperature. C. The DC shall ensure proper functioning of drift eliminators to control drift losses within limits as provided in table 11.4.
(2) Measurement and recording	A. The DC shall measure and record ambient conditions (e.g. dry bulb temperature, wet bulb temperature, relative humidity) and operating parameters of cooling tower (e.g. inlet and outlet temperatures of water, flow rate of water, etc.) to evaluate effectiveness of cooling tower which shall be described in EM Manual. B. The DC shall measure and record quantity of make-up water addition used towards compensation of water losses such as evaporation loss, drift loss, blowdown loss, etc., which shall be described in EM Manual.
(3) Maintenance and inspection	A. The DC shall carry out visual inspection of fills on a periodical basis to ensure proper distribution of water over surface area. B. The DC shall adopt the suitable mechanism to treat the water used in cooling towers to keep levels of micro-organisms to a minimum, which shall be described in EM Manual.
(4) Necessary measures when installing new facilities	A. The DC shall undertake heat load assessment to select the suitable capacity of cooling tower considering existing requirements, immediate expansion plans, etc. It shall be installed with suitable control mechanism such as variable frequency drive (VFD, thermostatic controller, etc.) to maximise the performance of cooling tower. B. The DC shall install cooling tower having highest performance as provided in table 11.4, while matching plant load requirements. C. The DC shall design and install cooling tower network with minimum system resistance using seamless pipes. D. The DC shall select the cooling tower with moulded FRP fans of aerofoil design. E. The DC shall select and install cooling tower with drift eliminators to reduce drift losses. It shall also use PVC (poly vinyl chloride) fills in place of wooden bars.

Target Components	
	A. The facility shall select and install cooling tower matching load requirement and considering existing requirements as well as immediate expansion plans. B. The DC shall further include measures such as correct sizing and type of pipes, suitable layout, etc. for optimum performance of cooling tower. C. The DC shall install multiple cooling tower systems in parallel in place of a single large system to meet higher volume requirements of cooling water.

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

$$\text{Range} = \text{A} - \text{B}$$

A = Entering cooling water temperature (return from process)

B = Cold well water temperature (supply to process)

$$Approach = \text{B} - \text{C}$$

B = Cold well water temperature

C = Ambient wet bulb temperature

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

Table 11.4 Performance parameters of cooling tower

Parameter	Unit	Control value
Approach*	^{0}C	4.0-5.0
Cycle of concentration (COC)#	-	8-10
Drift loss	(%)	0.001–0.005% of circulating flow rate

Source: Secondary data

* A minimum approach of 3.8 shall be maintained to have better performance of cooling tower

\# COC of less than 5 would lead to poor performance of cooling tower

11.7 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 is used in various applications of electrical networks e.g. power transmissions and distribution in power generation units, industrial plants, commercial establishment, data centres, railway vehicles, wind turbines, etc. It could be core type or shell type based on placement of primary coil and secondary coil around steel core. Considering the application, transformer could be step-up or step-down, power transformer, distribution transformer, etc.

Standard Components	
(1) Management and control	A. The DC shall ensure proper electrical compatibilities while operating two or more transformers in parallel. These include voltage ratio, impedance, polarity, etc., which shall describe in EM Manual. B. The DC shall optimise the transformer losses by maintaining suitable loading which depends on "no-load losses" and "load losses" of the transformer. It shall operate the transformer close to the best efficiency loading point. C. The DC shall maintain the power factor close to unity at transformer level to reduce the load losses. D. The DC shall maintain the operating temperature of the transformer within the prescribed limits as specified by the manufacturer to achieve full life span services and reduce losses, which shall be described in EM Manual. E. The DC shall consider switching off the under-loaded transformer used in parallel operation to reduce part-load energy losses. F. The DC shall make necessary tap adjustment in transformer to compensate output voltage drop due to long cable runs.

(2) Measurement and recording	A.	The DC shall measure and record the key operating parameters such as voltage, power factor and harmonics on a periodical basis, which shall be described in **EM Manual**. It shall also record the room temperature and moisture level, wherein the transformer is installed.
(3) Maintenance and inspection	A.	The DC shall undertake the scheduled preventive maintenance as per manufacturer's instructions to ensure the following: (i) oil and winding temperature, (ii) oil level and leakage, (iii) oil level in OLTC (on-line tap changer) mechanism, (iv) earth resistance, (v) condition of relief diaphragm, (vi) sealing arrangement, etc.
(4) Necessary measures when installing new facilities	A.	The DC shall 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.	The DC shall select the transformers with the minimum eddy losses for non-linear load applications.
	C.	The DC shall select the transformer with relatively low no-load losses (e.g. amorphous core type) to maintain the best efficiency at low loads.
	D.	The DC shall consider installing a liquid-filled transformer, which is more efficient and have long life than a dry-type transformer.
	E.	The DC shall ensure installation of the OLTC enabled transformers for new installations to maintain end-use voltage close to the design level.
Target Components		
	A.	The DC shall install the best efficiency transformers for the given rating, while matching the plant load requirements.
	B.	The DC shall optimise the transformer loading with respect to the best efficiency point.
	C.	The DC shall maintain unity power factor at the transformer

$$\text{Loading of transformer (\%)} = \frac{\text{Actual Load} \quad \text{(kVA)}}{\text{Transformer rating } (kVA)} \times 100$$

$$\text{Transformer loss (kW)} = No\ Load\ Loss + ((\frac{Average\ \ Transformer\ Loading\ \ (\%)}{100})^2 \times Full\ load\ loss)$$

$$\text{Optimum loading / best efficiency point (\%)} = \sqrt{\frac{No\ Load\ Loss}{Full\ Load\ Loss}} \times 100$$

12. INDUSTRY ENERGY MANAGEMENT SYSTEM

Industry Energy Management Systems (IEMS) for a DC shall have standing instructions for the following actions to study the efficient use of energy.

Standard components	
	A. The dedicated certified energy manager will be responsible for monitoring and controlling energy use pattern within the industry. B. The energy manager shall ensure periodic monitoring activities for all major energy-consuming equipment or system. The schedule may be yearly, seasonal, monthly, weekly, daily, or hourly, based on the type of requirements of the system or equipment. The performance results of the systems shall be improved, if the performance is lower than the desired value. C. The DC shall review maintenance conditions and compare operating characteristics, performance deterioration, etc., to take remedial actions and improve the energy efficiency.
Target components	
	A. The DC shall undertake appropriate actions to achieve the energy efficiency in individual equipment as well as in the industry as a whole. B. The DC shall implement integrated and centralized automatic controls for various facilities (e.g. combustion, heat-using, WHR, cogeneration, electricity-using, air conditioning, ventilating, and lighting facilities) to improve the energy performance.

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