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**Energy efficiency evaluation methods for process
automation**

过程自动化能效评估方法

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Energy efficiency evaluation methods for process automation

1 Scope

This Standard specifies the energy efficiency evaluation indicator system, the general model of energy efficiency evaluation, and the general procedure of energy efficiency evaluation for the process industry.

This Standard applies to energy efficiency evaluation and energy efficiency diagnosis, etc. in the process industry.

2 Terms and definitions

The following terms and definitions apply to this document.

2.1

Energy

Electricity, fuel, steam, heat, compressed air and other similar media.

Note 1: Energy in various forms, including renewable energy, can be purchased, stored, disposed of, used in devices or processes, and recycled.

Note 2: Energy can be defined as the power of a system to generate external activities or work.

[GB/T 23331-2012, definition 3.5]

2.2

Energy conversion

The transformation of the physical or chemical form of energy.

[CEN/CLC/TR 16103:2010, definition 4.1.7]

2.3

Primary energy

Energy which has not undergone any conversion process.

[CEN/CLC/TR 16103:2010, definition 4.3.8]

2.9

Specific energy consumption

Energy consumption per physical unit output.

[CEN/CLC/TR 16103:2010, definition 4.3.10]

2.10

Energy management

Coordinating activities to direct and control the energy use of an entity.

[CEN/CLC/TR 16103:2010, definition 4.5.1]

2.11

Input

The flow of products, substances, or energy which enter a unit process.

[GB/T 24040-2008, definition 3.21]

2.12

Output

The flow of products, substances, or energy leaving a unit process.

[GB/T 24040-2008, definition 3.25]

2.13

Device

An entity which implements control, execution, and/or sensing functions, and connects with other such entities in the automation system.

[GB/T 19659.1-2005, definition 3.11]

2.14

Process

A set of interrelated or interacting activities which transform inputs into outputs.

[GB/T 24040-2008, definition 3.11]

3.3 Material consumption

The consumption of various materials, auxiliary materials, etc. by devices, production units, production processes, and the entire production process of other products during the process industry production.

Example: The materials consumed in the ethylene production process include mixed naphtha, hydrogenated tail oil, etc.; the auxiliary materials consumed include various catalysts, additives, etc. The materials consumed in the steel production process include iron ore; the auxiliary materials include coolants and recarburizers, etc.

3.4 Pollution releases

The releases of various types of pollution generated by devices, production units, production process sections, and the entire production process of other products during the process industry production.

Example: Wastes such as water pollutants, atmospheric pollutants and solid waste discharged from the steel production process. Atmospheric pollutants mainly contain fluorine, sulfur dioxide, various particulate matter, etc. Water pollutants mainly include heavy metals and suspended solids such as fluoride, cyanide, lead, etc. Solid waste mainly includes blast furnace slag and steel slag, etc.

3.5 Production management

During the process industry production, on-site operation of devices, production units, production process sections; process parameter setting and adjustment, etc.; as well as the quality testing and guarantee of raw materials, intermediate products and final products; and the factors such as balance of supply and demand of materials and energy.

Example: Outlet temperature, excess air coefficient, exhaust gas temperature setting, etc. of blast furnace and cracking furnace, etc.

3.6 Output factors

The definition of energy efficiency is the ratio of output energy, product, service or performance to input energy or other quantitative relationship. Therefore, output factors, including the number of products and the amount of energy output, will affect energy efficiency.

Example: Production capacity, device energy utilization efficiency, product output of specific energy consumption, etc. during the production process.

- B** Lost resource R_{l1}
- C** Recycled resource R_{c2}
- D** Lost resource R_{l2}
- E** Recycled resource R_{cq}
- F** Lost resource R_{lq}

Figure 3 -- Energy efficiency indicator analysis of process production

According to the energy efficiency evaluation method in this clause, refer to Appendix A for evaluation examples in practical applications.

6 Energy efficiency benchmark

The energy efficiency benchmark is to compare the basic quantitative value provided by the energy efficiency level. The methods for establishing energy efficiency benchmark include:

- a) Mechanism modeling method: According to the objective laws of thermodynamics, chemical reaction, physical change, etc., derive the energy efficiency function relationship formula. The energy efficiency benchmark established by the mechanism modeling method is an ideal value;
- b) Mathematical analysis method: Based on historical data, through data fitting or statistical analysis methods, determine the energy efficiency baseline;
- c) Empirical method: Use industry-defined standards, or the best energy efficiency results in the production process of excellent enterprises or this enterprise as energy efficiency benchmarks.

The energy efficiency benchmark preferentially selects the design value calculated by the mechanism modeling method. When there is no design value, it is possible to consider using mathematical statistics to select the data of past historical period or the best historical data. When the above two situations are not feasible, empirical method can also be used to determine the energy efficiency benchmark.

7 General procedure of energy efficiency evaluation for process industry

The general evaluation procedure of production energy efficiency for process industry is shown in Figure 4.

processes and systems;

- d) For each component of the evaluation object, based on the established energy efficiency indicator system, calculate the applicable indicators;
- e) Compare the calculation results of each indicator of the evaluation object with the established energy efficiency benchmark; analyze the comparison results;
- f) Form energy efficiency diagnostic output, for production energy efficiency optimization;
- g) Adopt various energy efficiency optimization methods, to improve the energy efficiency level. At the same time, modify the corresponding energy efficiency benchmark.

8 Energy efficiency diagnosis for process industry

The manufacturing process of process industry is continuous. The operation is required to be in a stable state. Large changes in the parameters reflecting the operation state shall be avoided as much as possible. When there is an abnormal energy efficiency in the production process, the calculation and analysis of multiple energy efficiency indicators at the equipment level, process level, and system level can be carried out; to diagnose the cause of abnormal energy efficiency and locate the abnormality; make corresponding adjustments to production and management; improve the energy efficiency level accordingly.

Δt - Temperature difference, in degrees Celsius ($^{\circ}\text{C}$);

w_{CO} - Carbon monoxide content in flue gas;

α - Air coefficient.

A.4.2.2 Indicator calculation

Take the relevant data of No. 1 cracking furnace in Fushun Ethylene Plant:

Flue gas temperature: $t_g=153$

Temperature of the hot air: $t_a=10$

Atomized steam consumption: $W=0$

Oxygen content of flue gas: $w_{\text{O}_2}=3.78\%$

Carbon monoxide content in flue gas: $w_{\text{CO}}=0$

Excess air coefficient: $\alpha=1.24$

Calculate according to the simplified formula: $\eta=92.29\%$.

A.5 Example of system energy efficiency evaluation - ethylene production system

A.5.1 Evaluation model and indicator

Take an ethylene production system in a petrochemical enterprise as an example. The technological process is mainly composed of units such as raw material preheating, cracking, quenching, compression, cold separation, thermal separation, refrigeration, waste alkali oxidation and gasoline hydrogenation. The energy efficiency evaluation model of the ethylene production system is shown in Figure A.4.

Where:

M_i - The mass of the input i -th fuel, steam, electricity, water or energy-consumed medium, in tons (t), kilowatt hours (kW · h) or cubic meters (m³);

R_i - The energy conversion factor, i.e. the conversion relationship between the input i -th fuel, steam, electricity, water or energy-consumed medium and kilogram of standard oil. GB 30250-2013 stipulates the energy conversion factor;

Q_j - The amount of the j -th energy input into the ethylene production system from the outside, in kilograms of standard oil (kgoe).

b) Energy consumption of ethylene cracking unit

The ethylene cracking system includes an ethylene cracking unit and a gasoline hydrogenation unit. The energy consumption sharing coefficient of the ethylene cracking unit is 0.7. The energy consumption sharing coefficient of the gasoline hydrogenation unit is 0.3. The types of energy consumed include fuel, water, electricity, steam, nitrogen, and wind. All energy is converted into standard oil:

1) Fuel: $E_{I1} = M_{\text{fuel oil}} \times R_{\text{fuel oil}} + M_{\text{fuel gas}} \times R_{\text{fuel gas}} + M_{\text{natural gas}} \times R_{\text{natural gas}} + M_{\text{liquid hydrocarbon}} \times R_{\text{liquid hydrocarbon}} + M_{\text{hydrogen}} \times R_{\text{hydrogen}}$

$$M_{\text{fuel gas}} = (M_{\text{LPG}} + M_{\text{naphtha}} + M_{\text{light hydrocarbon feed}} + M_{\text{hydrocracking tail oil}} + M_{\text{light vacuum cap oil}} + M_{\text{hydrogenated C5}} + M_{\text{externally-supplied propane}} + M_{\text{purge propane}} + M_{\text{tempered oil}}) \times 12\% - M_{\text{externally-supplied methane}} + M_{\text{externally-compensated LPG}} + M_{\text{hydrogen to fuel}};$$

2) Water: $E_{I2} = M_{\text{industrial water}} \times R_{\text{industrial water}} \times 0.7 + M_{\text{living water}} \times R_{\text{living water}} \times 0.7 + M_{\text{softened water}} \times R_{\text{softened water}} \times 0.7 + M_{\text{desalted water}} \times R_{\text{desalted water}} \times 0.7 + M_{\text{recycled water}} \times R_{\text{recycled water}} \times 0.7 + M_{\text{hot water}} \times R_{\text{hot water}} \times 0.7 - M_{\text{condensed water}} \times R_{\text{condensed water}} - M_{\text{deoxygenated water}} \times R_{\text{deoxygenated water}}$

3) Electricity: $E_{I3} = M_{\text{electricity}} \times R_{\text{electricity}} \times 0.7$

4) Steam: $E_{I4} = M_{\text{steam 3.5MPa}} \times R_{\text{steam 3.5MPa}} \times 0.7 + (M_{\text{steam consumption 1.0MPa}} - M_{\text{steam output 1.0MPa}}) \times R_{\text{steam 1.0MPa}} + (M_{\text{steam consumption 0.3MPa}} - M_{\text{steam output 0.3MPa}}) \times R_{\text{steam 0.3MPa}}$

5) Nitrogen and wind: $E_{I5} = M_{\text{nitrogen}} \times R_{\text{nitrogen}} \times 0.7 + M_{\text{compressed air}} \times R_{\text{compressed air}} \times 0.7 + M_{\text{decoking air}} \times R_{\text{decoking air}} \times 0.7$

c) Energy consumption of gasoline hydrogenation unit

The types of energy consumed by the gasoline hydrogenation unit include

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