Technical specification for green design evaluation of commercial refrigerating appliances

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Abstract. This paper sets out the principle of green design of commercial refrigerating appliances, and analyzes the general provisions on green design of commercial refrigerating appliances, the green design process and key points, evaluation requirements, preparation methods for a life-cycle evaluation report, and evaluation methods. The Technical Specification for Green Design Evaluation of Commercial Refrigerating Appliances plays a practical supporting role in systematically supporting the establishment of China’s eco-design evaluation mechanism. The research on and formulation of standards will help improve and promote the green design capabilities of enterprises, improve comprehensive management and cleaner production, and thereby cultivate a batch of green design demonstration enterprises with green development awareness and brand influence. Meanwhile, it has positive guiding significance to guiding green production and promoting green consumption.

1. Introduction

In 2016, the Industrial Green Development Plan (2016-2020) (GXBG [2016] No. 225) issued by the Ministry of Industry and Information Technology proposes to actively promote the evaluation of green products and other key tasks, striving to promote the realization of the goals of creating one hundred green design demonstration enterprises and one hundred green design centers and developing and promoting ten thousand green products by 2020. In order to implement this important task, efforts should be made to solidly promote cleaner production, reduce the use of toxic and hazardous raw materials, and actively promote the evaluation of green products and other key tasks. Related key industries are actively developing green product design standards under the arrangement of the Ministry of Industry and Information Technology.

Commercial refrigerating appliances are a branch of refrigerating products. It has been more than a century since the advent of the first refrigerator. Established foreign manufacturers of commercial refrigerating products, such as True Manufacturing, Turbo air, and Japanese Hoshizaki Group, have a production history of many years, and have entered China in recent years to establish production bases or sales networks. China's commercial refrigerating appliance industry started late. As a new industry developed after the reform and opening up, jointly driven by domestic and foreign market demands, China's commercial refrigerating appliance industry has maintained rapid development in recent years. After development over the years, China has formed a complete industrial chain for commercial refrigerating appliances with mature technology and market. At present, China has become a major producer and consumer of commercial refrigerating appliances. Enterprises carry out eco-design of commercial refrigerating appliances to meet the upgraded consumption demand, increase the supply of...
green products so that consumers may choose and use green products, reduce the impact of refrigerants, foaming agents and toxic and harmful materials used in commercial refrigerating appliances, and thereby alleviate the resource and energy pressure and reduce the adverse impact on the environment and humans [1].

In addition, the Technical Specification for Green Design Evaluation of Commercial Refrigerating Appliances is to implement the requirements and key tasks of China's Guidelines for the Construction of the Green Manufacturing Standard System. The research content of such specification complies with the standardization focuses on "environmental protection" and "energy conservation and low carbon" in the key areas of "strengthening ecological civilization standardization and serving green development" under the Plan for the Construction and Development of the National Standardization System (2016-2020). Meanwhile, such specification is also the key task on solidly promoting cleaner production, reducing the use of toxic and hazardous raw materials, and actively promoting the evaluation of green products under the Industrial Green Development Plan (2016-2020).

The Technical Specification for Green Design Evaluation of Commercial Refrigerating Appliances plays a practical supporting role in systematically supporting the establishment of China's eco-design evaluation mechanism. The research on and formulation of standards will help improve and promote the green design capabilities of enterprises, improve comprehensive management and cleaner production, and thereby cultivate a batch of green design demonstration enterprises with green development awareness and brand influence. Meanwhile, it has positive guiding significance to guiding green production and promoting green consumption.

2. Basic principles of green design
The green design of commercial refrigerating appliances aims at reducing environmental pollution and improving the recyclability rate of commercial refrigerating appliances, to reduce the adverse environmental impact generated during the entire life cycle of commercial refrigerating appliances, and develop a commercial refrigerating appliance system that is more ecological, economical, and sustainable. The basic principles of green design of commercial refrigerating appliances include: demand orientation, process orientation, and risk orientation.

2.1 Requirements-oriented
Green design follows the design principles under GB/T24256[2] and is guided by comprehensive demands: considering the resource attributes and comprehensive resource utilization requirements of commercial refrigerating appliances and their system in an integrated manner; fully considering the environmental attributes and requirements of commercial refrigerating appliances at each stage of the life cycle, especially the environmental requirements in the use and scrapping of such appliances; adopting customized design to avoid functional waste, so that the functions of commercial refrigerating appliances can properly reflect energy attributes and system requirements.

2.2 Process-oriented
Guided by appropriate process design, green design meets the requirements for advanced technology and scientific methods: improve environmental indicators of commercial refrigerating appliances without reducing their technical performance indicators; product reducing and lightweight design; for selection of raw materials, process flow, and product testing methods, the optimal integration scheme should be selected; based on more suitable manufacturing technology.

2.3 Risk-oriented
Green design is guided by risk avoidance, aims at environmental protection, and is subject to economic suitability: in the green design of commercial refrigerating appliances, priority is given to environmentally friendly advanced design technologies; ensure the safety of commercial refrigerating appliances during processing and manufacturing, use and maintenance, and final disposal; while realizing the functions of commercial refrigerating appliances, pursue reduction in quantity and reuse and recycling, and improve
the environmental impact of equipment during the life cycle, especially the environmental impact during the use and scrapping; place emphasis on the processing methods of refrigerants during the scrapping of commercial refrigerating appliances, to avoid and reduce their pollution to the environment; attach importance to the improvement in the comprehensive utilization of resources for commercial refrigerating appliances, to reduce secondary pollution; comprehensively consider the environmental benefits of commercial refrigerating appliances, including environmental effects and costs; take into account the environmental benefits of enterprises, customers, and society.

3. Green design process and key points

3.1 Overview
The design stage of commercial refrigerating appliances includes demand analysis, conceptual design, structural design, and detailed design. The key points of green design at each design phase are shown in Figure 1.

3.2 Essentials of green design in demand analysis
Increase green demand analysis for products and formulate product green design goals. Green demand analysis for products includes but is not limited to: greening-related laws, regulations, policies, standards, and patents; industry-related advanced green design and/or manufacturing technology; product demander's demand and requirements in greening-related aspects; fully considering the environmental pollution at each stage of the life cycle of commercial refrigerating appliances and the system boundaries of commercial refrigerating appliances.

3.3 Essentials of green design in conceptual analysis
Predict and analyze the green design indicators in the full life cycle of products, comprehensively evaluate technical, economic, and green design indicators of products, and determine essentials of green design. The essentials of green design considered at each stage of the life cycle of products include but are not limited to: selection and use of raw materials; structural design; manufacturing; packaging process; product transportation; product use; recycling; other design requirements.

3.4 Essentials of green design in structural design
The essentials of green design in structural design include but are not limited to: fully considering green design indicators, such as improving energy efficiency, condensation and drainage, anti-wear and corrosion protection of materials, thermal efficiency, refrigerating system, packaging and transportation convenience, and recycling convenience; improving the energy efficiency rating, increasing the total displayed area and effective volume, and facilitating the use by optimizing the product structure; simplifying the product structure to make it easy to process and produce products, and improve production efficiency and qualified rate; improving the convenience in product installation, use, recycling, and disassembly.

3.5 Essentials of green design in detailed design

3.5.1 Selection and use of raw materials. When raw materials are selected, the followings are considered: not use banned substances and use less restricted substances; give priority to standard and serialized raw materials; give priority to renewable raw materials from abundant sources, and try not to use or use less rare materials as much as possible; use durable materials, and materials that do not produce mildew or peculiar smell; give priority to GWP environmentally friendly refrigerants; the inner and outer surfaces of materials are wear-resistant and easy to clean; the metal parts are wear-resistant; reduce the use of thermosetting plastics; give priority to materials that are easy to decompose, recyclable, and recyclable; give priority to suppliers who have environmental management system capabilities or meet the requirements of the green supply chain; in principle, no artificial chemical substances with unclear toxic
and side effects are used; when necessary, suppliers are required to provide a material safety data sheet (SDS).

When raw materials are used, the followings are considered: reduce the types of materials used in similar products; reduce the amount of materials used under the premise of ensuring functions; use environmentally friendly foaming agents for the foaming layer of refrigerating appliances; ensure safety when flammable refrigerants are used; conduct reducing design through CAE simulation; while heat dissipation is maintained, use high-efficiency heat exchangers to reduce the use of materials; improve the utilization rate of materials and reduce waste generation and emissions; when mixed materials must be used, select materials with good compatibility; encourage the use of pollution-free green new materials.

3.5.2. Structural design of products. The structural design of products includes boxes, doors, the refrigerating system, the control system, accessories and packaging. The essentials of green design in the design process include but are not limited to the following:

Improve the strength and rigidity of commercial refrigerating appliances and their components so that they are durable during installation, transportation, and use. Attention should be paid to the following upon design: the strength of internal parts of appliances, such as shelves, baskets, and handrails and their supports, reaches a high level, to ensure their functions; for sliding shelves, baskets, pallets, or drawers, maintain their shapes and flexibility under full load; prevent all parts with cease devices from accidentally falling when they are pulled out to the limits under full load; remain stable.

The design for easy drainage and cleaning includes but is not limited to the following: the places requiring drainage, the drip trays, or evaporating dishes have sufficient drainage capacity, leaving enough space for the installation to facilitate disassembly and cleaning; avoid the deposition of dirt and make it easy to remove dirt at all interfaces and joints within the net volume (effective volume).

To enhance the design with the thermal insulation effect, the following should be considered: the thermal insulation layer is effective and permanently fixed, and under normal conditions of use, the thermal insulation materials do not shrink or condense; the vapor barriers prevent the thermal insulation materials from absorbing moisture and avoid the deterioration of thermal insulation performance; ensure that particles of insulation materials do not enter the food displaying space at positions where there are insulation materials inside.

The design of commercial refrigerating appliances to improve the refrigerating effect includes but is not limited to the following: for all parts and components of the refrigerating system that bear internal pressure, the design and structure consider the maximum pressure that the appliances can withstand when they are running or at rest; take effective measures to prevent the adverse effect of condensate of commercial refrigerating appliances and their components on the operation or control of the refrigerating system; when selecting refrigerants, consider the possible hazards of the refrigerants and the heat transfer medium or second refrigerants, such as toxicity and flammability; perform the matching optimization of the refrigerating system, improve the work efficiency of the refrigerating system from the aspects of refrigerating mode, selection of refrigerants, and selection of components of the refrigerating system; prioritize the use of the refrigerating system to enhance the heat exchange technology and improve heat exchange efficiency; optimize the air circulation and heat exchange structure of the refrigerating system to enhance the heat transfer efficiency in air circulation.

The design of commercial refrigerating appliances to improve the defrosting and waterproof and vapor condensation effects includes but is not limited to the following: try to avoid accumulating ice, frost, or snow and water melted from frost on the inner surface of the refrigerating space (excluding the surface of the test bag) to improve the defrosting capacity of the appliances; under the premise of ensuring defrosting effect and normal use, adopt the most optimized defrosting method and defrosting control method to optimize the defrosting time for products; optimize product insulation design to reduce the frosting and water vapor condensation amount of products; prioritize the use of non-electric heating method, anti-condensation method, and anti-condensation automatic control method; reduce water vapor condensation or not affect the performance of commercial refrigerating appliances, and improve the water vapor condensation effect of appliances.
Figure 1. Brief design process and key points of green design
The design to reduce energy consumption and improve energy efficiency is in line with GB 26920 [3], so that the energy efficiency index of commercial refrigerating appliances is not higher than 65%. See Table 1 for the grading indicators by energy efficiency grade.

| Energy efficiency index | Energy efficiency rating |
|-------------------------|-------------------------|
| η≤55%                   | 1                       |
| 55%<η≤65%               | 2                       |
| 65%<η≤80%               | 3                       |
| 80%<η≤90%               | 4                       |
| 90%<η≤100%              | 5                       |

The design of commercial refrigerating appliances to reduce energy consumption and improve energy efficiency includes but is not limited to the following: reduce the energy consumption of appliances during operation by matching high-efficiency compressors, such as inverter compressors; improve the insulation performance of the foam layer by optimizing the foaming process; priority is given to energy-saving control methods (such as frequency conversion control and on-demand control); adopt forced heat exchange technology to increase product evaporation temperature; by adopting the vacuum insulation technology, such as vacuum glass and vacuum insulation panels (VIPs), improve the heat preservation performance of appliances; reduce the leakage of the internal cold energy of the appliances through the tightness design of the appliances, such as magnetic sealing strips; optimize the structure to increase the effective volume as much as possible; through the design of the direction, arrangement, and attachment of refrigerating pipelines, improve heat exchange efficiency; improve the circulation efficiency of the air duct, reduce the efficiency loss caused by wind resistance; improve the uniformity of the defrost temperature, reduce the power loss caused by the defrost time; reduce the heat transfer resistance of condensers, and improve the heat exchange efficiency.

Lightweight design includes but is not limited to the following: optimize the structure to reduce product weight, such as using micro-channel condensers, which can reduce the amount of refrigerants used and improve cooling efficiency, with the small parts occupying a small space; optimize the design of fixed supporting structures, and under the premise of ensuring the strength of the appliances, reduce the thickness of the shell and other materials; optimize the structure to reduce the production process, for example, the appliance shell adopts one-piece design to avoid multi-piece splicing; reduce the number of product parts and components and try to modularize and standardize the internal structure of the same type of products; under the premise of ensuring the refrigerating capacity, preferentially select refrigerating components such as compressors with small size and weight; select new structural materials with light weight and good performance for product upgrades; use new materials to reduce product weight, such as using vacuum insulation boards, which can reduce the thickness of the foam layer and reduce the use of foam materials and product weight.

Packaging and transportation convenience design includes but is not limited to the following: adopt a compact structure to reduce packaging and transportation volume; for exports, stretch film packaging can be used instead of carton and foam packaging; large products adopt a split structure with a stable center of gravity, which is convenient for packaging, loading and unloading, and transportation.

Detachable and recyclable design is adopted. Fully consider the difficulty in product scrapping, optimize the product structure, make products easy to install and disassemble, and reuse the products after being scrapped.

3.5.3. Manufacturing. Fully consider the difficulty and economy in product manufacturing, as well as factors such as pollutant emissions, resource use, human health and safety in the manufacturing process: analyze and confirm the rationality of design requirements such as the performance, accuracy and surface structure of parts, and reduce processing procedures and capacity; mark and classify toxic and hazardous materials, and give safety protection requirements for the production process; give priority to the use of advanced production technology and equipment; adopt advanced green manufacturing
techniques to reduce energy consumption and pollutant emissions in the production process; encourage refrigerating product manufacturers to create green plants and strictly control the leakage and discharge of refrigerants during the production process.

3.5.4. Packaging Process. The following should be considered for packaging materials: give priority to non-toxic, harmless, easy-to-decompose or biodegradable packaging materials; give priority to recyclable packaging materials; the same product should use the same packaging materials; packaging waste can be treated in a harmless manner.

The following should be considered for packaging design: on the premise of meeting packaging requirements, it is advisable to reduce the amount of packaging materials used; avoid excessive packaging and reduce the packaging volume; give priority to reusable packaging design; ensure the convenience and safety of lifting, handling and disassembly.

3.5.5. Product Transportation. The following should be considered for product transportation: choose the most economical, reasonable, and green transportation method after comprehensive consideration of transportation distance, cargo weight and volume; optimize the loading and unloading process to enhance the loading and unloading speed.

3.5.6. Use. The following should be considered when products are used: enhance the service life of the products, such as analyzing the failure mode of parts and components and the service life of products, and adopting corresponding improvement measures; explain to users in the relevant materials what should be noted for ensuring the realization of the green product design indicators in the use process, in order to reduce unnecessary energy waste and environmental pollution caused in the use, daily operation or maintenance process; for products with technological updates and rapid market changes, retain room for product upgrades or transformations, and achieve functional expansion or enhancement through partial replacement.

3.5.7. Recycle and Re-use. The following should be considered when products are recycled: analyze the state of products at the end of their service life and the impact of their recycling on the environment, and propose a treatment plan when the products are discarded; improve the recyclability rate and reuse rate of products; recycle plastic parts and scraps; achieve harmless disposal of non-recyclable materials as much as possible to avoid the generation of hazardous waste after the products are scrapped; avoid injury to operators during product recycling and disassembly.

4. Technical Requirements

4.1 Basic Requirements
The pollutant discharge of manufacturers should meet the requirements of national or local pollutant discharge standards, and the total pollutant control should meet the national and local total pollutant discharge control indicators; the relevant national standards for energy conservation and environmental protection should be strictly implemented and a standard list should be provided. There were no major quality, safety or environmental accidents in recent three years. Manufacturers should establish, implement, maintain and continuously improve the quality, environment, energy, and occupational health and safety management systems respectively in accordance with GB/T 19001[4], GB/T 24001[5], GB/T 23331[6] and GB/T 28001[7].

Manufacturers should carry out green design of products in accordance with the relevant requirements of GB/T 24256. In addition to environmental requirements, the design work should also give due consideration to the durability, reliability, maintainability, reusability, remanufacturing, modularization, and intelligence of products, and easy-to-disassemble (separate) and easy-to-recycle components that have a negative impact on the environment, and a product eco-design scheme should be formed.
Manufacturers should adopt advanced technologies and techniques encouraged by the State, and may not use eliminated or prohibited technologies, techniques, equipment and related substances issued by the State or relevant departments; requirements should be formulated based on the principle of saving materials during design and production. Manufacturers should carry out green supply chain management, establish green supply chain management performance evaluation mechanisms and procedures, and determine evaluation indicators and methods. Manufacturers should put forward management requirements related to quality, environment, energy, and safety for main raw material suppliers, production partners, and related service providers.

The main energy-consuming equipment of manufacturers should meet the relevant national energy efficiency standards of level 2 or above. The product quality should meet the corresponding product quality standards and the compulsory product certification requirements. The product manual should contain the relevant instructions on the use of hazardous substances, materials that require special treatment (such as fluorine-containing foam materials), and related recycling after the products are scrapped. Manufacturers should publish technical guidance information on product dismantling through appropriate methods, and the information should be easy for relevant organizations to obtain. Product packaging should meet the relevant requirements of GB/T 191[8], GB/T 1019[9] and GB/T 31268[10].

4.2 Evaluation Indicator Requirements

The evaluation indicators of commercial refrigerating appliances can be selected from the perspectives of resource and energy consumption and the impact on the environment and human health. They usually include resource, energy, environmental, and product attribute indicators. Requirements such as the names, reference value, and judgment basis (pollutant monitoring method, product inspection method, and calculation method of each indicator) of evaluation indicators of commercial refrigerating appliances are shown in Table 2.

| Indicator name | Unit | Indicator direction | Reference value | Judgment basis |
|----------------|------|---------------------|-----------------|----------------|
| Content of harmful substances in products | | | Products should meet the requirements of GB/T 26572[11] | Provide a content table of hazardous substances in raw materials, perform a test according to GB/T 26125[12], and provide a test report |
| Recyclable logo | | | Recyclable labels for products and parts meet the requirements of GB/T 23384[13] If the packaging materials are cartons (bags), it is recommended to use recycled paper mixed mode first to meet the relevant requirements of GB/T 31268[14] | Provide logo usage instructions and related management documents |
| Packaging and packaging materials | | | Do not use HFCs as blowing agents The total amount of heavy metals such as lead, cadmium, mercury and hexavalent chromium in packaging and packaging materials should not exceed 100mg/kg Should be marked in | Provide evidentiary materials, Provide evidentiary materials |

Table 2: Evaluation Indicator Requirements for Commercial Refrigerating Appliances
accordance with GB/T 18455 [15]

| Recyclability rate | % | ≥ | GB/T 32355[16] Assessment Values of Recyclability Rate for Electrical and Electronic Products |
|-------------------|---|---|----------------------------------------------------------------------------------|
| Energy efficiency indicator | | | Meet the national energy efficiency standards of level 2 |
| Types of refrigerants and foaming agents | | | Environmentally friendly refrigerants and foaming agents should be used: ODP=0, GWP≤150 |
| Recovery of refrigerants | | | Refrigerant recovery devices should be in place for the production process |
| Electromagnetic compatibility | | | Detect electromagnetic compatibility immunity, to meet limit requirements of national standards |
| Electrical safety | | | Perform a test and provide a test report in accordance with GB 4706.1 [18], GB 4706.13 [19] |
| Intelligent requirements (recommended indicators) | | | The products should meet the relevant intelligent requirements in GB/T 28219 [20] General Technology Requirements for Intelligent Household Appliances |

5. Preparation Method of Product Life Cycle Assessment Report

5.1 Methods
Prepare a life cycle evaluation report of commercial refrigerating appliances according to the life cycle evaluation methodology framework and general requirements given in GB/T24040[21], GB/T24044[22] and GB/T32161[23].

5.2 Content framework of the report
The report should provide basic information such as report information, applicant information, evaluation target information, and adopted standard information. Specifically, the report information includes report number, preparer, reviewer, and release date, and applicant information includes full company name, organization code, address, contact person, and contact information. The report should indicate main technical parameters and functions of products, including: physical state, manufacturer, and scope of use. Product weight, packaging size and materials should also be stated in the life cycle evaluation report.

The report should provide the compliance with the basic requirements and the evaluation indicator requirements, and provide an explanation of the improvement in all the evaluation indicator reporting periods compared with the base period, or an explanation of the comparison of products with equivalent functions. The reporting period when the current evaluation is carried out generally refers to the year immediately prior the year when products participate in the evaluation; the base period is a reference year, generally one year earlier than the reporting period.

The report should describe in detail the evaluation objects, functional units and main functions of the products, provide a table of material composition and main technical parameters of the products, draw
and explain the system boundaries of the products, and disclose the software tools used. The report should provide the life cycle stages to be considered, explain the inventory factors considered at each stage and the collected field data or background data, and explain the distribution methods and results when data distribution is involved. The report should provide the characteristic value of different impact types at each stage of the life cycle of the products, and make a comparative analysis of the distribution of different impact types at each life cycle stage. Based on the analysis of the conformity evaluation results of the indicators and the life cycle evaluation results, a specific plan for improvement in product eco-design is proposed.

The conclusion of products’ conformity with evaluation indicators, the life cycle evaluation results, and the proposed improvement plan should be explained, and whether the products are eco-design products shall be preliminary judged based on the evaluation conclusion. The report should be provided in the appendix: original packaging drawing of products; list of production materials of products; process sheet of products (schematic diagram of production process of products, etc.); data collection sheet for each unit process; others.

6. Evaluation Methods
Self-evaluation or third-party evaluation may be carried out in accordance with 3.1 basic requirements and 3.2 evaluation indicator requirements, provided that the following conditions should be met:

a) Meet the basic requirements (see 3.1) and evaluation indicator requirements (see 3.2);
b) Provide a life cycle evaluation report of commercial refrigerating appliances according to 4.

When a self-declaration is made on relevant information in various forms for the products labeled in accordance with the requirements of GB/T32162, the content of the declaration should include but be not limited to the requirements of 3.1 and 3.2, but certain verification materials proving compliance with relevant requirements must be provided.

7. Conclusion
The ecological design and evaluation of commercial refrigerating appliances are the important driving force to promote commercial refrigerating appliance enterprises to reduce resources, energy consumption, pollutants, and greenhouse gas emissions from the source, and to upgrade the development from process technology to energy conservation, low carbon, and green technology, thereby promoting industrial transformation and upgrading. This paper has analyzed the general principles of green design of commercial refrigerating appliances, the green design process and main points, evaluation requirements, preparation methods of life cycle evaluation reports and evaluation methods. People should directly face the ecological damage caused by the development and application of modern science and technology, and users may make more wise and ecological decisions through ecological products.

Acknowledgements
This paper is funded by National key research and development plan project “Research on key technology standards of eco-design for consumer electronics and other important products” (2017YFF0207901).

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[7] GB/T 28001 Occupational Health and Safety Management Systems – Requirements.
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