Technical specifications for green design evaluation of water heater products

Jianfang Zong, Xin Zhang, Haihong Chen, Jianwei Tian, Dongfeng Gao, Han Yuan, Jinxin Guan
China National Institute of Standardization (No.4 Zhichun Road, Haidian District, Beijing)
zongjf@cnis.ac.cn

Abstract. This paper presents the principles of green design of water heaters, analyzes the general principles of green design of water heater products, the process and key points of green design, evaluation requirements, life cycle assessment report preparation methods and evaluation methods. The technical specification of green design evaluation of water heater products has a practical supporting effect on the systematic support of the establishment of eco-design evaluation mechanism in China. The research and formulation of standards will be conducive to improving and promoting the green design ability of enterprises, enhancing the level of integrated management and cleaner production levels, thereby fostering a group of green design demonstration enterprises with green development awareness and brand influence. Meanwhile, it has positive guiding significance in leading green production and promoting green consumption.

1. Introduction

In 2016, the Ministry of Industry and Information Technology issued the “Industrial Green Development Plan (2016-2020)” (Ministry of Industry and Information Technology Regulations (2016) No. 225), proposed to actively promote the evaluation of green products and other key works, and strive to achieve the goals of creating 100 green design demonstration enterprises, 100 green design centers, and developing and promoting ten thousand green products by 2020. In order to implement this important task, we will firmly promote cleaner production, reduce the use of toxic and harmful raw materials, and actively promote the evaluation of green products. The Ministry of Industry and Information Technology organizes relevant key industries to actively develop green product design standards.

With the enhancement of domestic living standards, the application of water heater in the industrial and civil buildings has become increasingly popular, and the water heater has already become one of the major household energy-consuming equipment. The domestic water heater mainly includes four main classes, namely, the electric water heater, gas water heater, solar water heater and heat pump water heater developed in recent years, while its domestic sales were quickly increased from less than 8 million sets 10 years ago to the present 40 million plus sets. By developing eco-design of water heaters, meeting the need of consumption upgrades, and increasing the supply of green products, consumers are willing to choose and use green products, thereby it will alleviate the pressure on resources and energy, and reduce the adverse impact upon the environment and human beings [1].

The technical specifications for green design evaluation of water heater products are also developed to implement the requirements and key tasks of China’s “Guidelines for the Construction of Green Manufacturing Standard System”. The research content is in line with the “National Standardization
System Construction and Development Plan (2016-2020)” related to the standardization focus of “environmental protection” and “energy conservation and low carbon” in key areas of “strengthening the standardization of ecological civilization, serving green development”. It is also related to the solid promotion of cleaner production in our "Industrial Green Development Plan (2016-2020)” to reduce the use of toxic and hazardous raw materials, and actively promote the key works of green product evaluation.

The technical specification of green design evaluation of water heater products has a practical supporting effect on the systematic support of the establishment of ecological design evaluation mechanism in China. The research and formulation of standards will be conducive to improving and promoting the green design ability of enterprises, enhancing the level of integrated management and cleaner production levels, thereby fostering a group of green design demonstration enterprises with green development awareness and brand influence. Meanwhile, it has positive guiding significance in leading green production and promoting green consumption.

2. Basic principles of green design

The purpose of the green design of water heater products is to reduce environmental pollution and improve the renewable utilization rate of water heater products in order to reduce the adverse environmental impact of water heater products within their life cycle, and to develop more ecological, economical and sustainable water heater product systems. The basic principles of green design of water heater products include requirements-oriented, process-oriented and risk-oriented.

2.1 Requirements-oriented

The green design is required to conforms to the design principles of GB/T24256 [2], and is guided by comprehensive requirements: a) Integrated consideration of the resource attributes and comprehensive utilization needs of water heater products and their systems; b) Taking full account of the environmental attributes and environmental requirements at all stages of the water heater product life cycle, especially the environmental requirements in use and disposal; c) Adopting a customized design to avoid functional waste, so that the function of the water heater product properly reflects the energy attributes and system requirement.

2.2 Process-oriented

Green design is guided by the appropriate process design to meet the requirements of advanced technology and methodological science: a) Pursuing the improvement of the environmental indicators of water heater products without reducing the technical performance indicators of water heater products; b) Product reduction and lightweight design; c) Choosing optimal integration scheme for selection of raw materials, processes and product inspection methods; d) According to more appropriate manufacturing techniques.

2.3 Risk-oriented

Green design is guided by risk avoidance, takes environmental protection as the target, and ensures economy appropriate as premise: a) In the green design of water heater products, priority is given to environmentally friendly advanced design technology; b) Ensure the safety of water heater products in process of manufacture, operation, maintenance, and final disposal; c) While realizing the function of water heater products, to pursuit of reduction, reuse and recycling, to improve the environmental impact of the equipment life cycle, especially the environmental impact of the use and disposal; d) Pay attention to the improvement of the comprehensive utilization performance of water heater products to reduce secondary pollution; e) Comprehensively consider the environmental interests of water heater products, including environmental benefits and costs; f) It should also give consideration to the environmental interests of enterprises, customers and society.
3. Green design process and key points

3.1. Overview
The design phase of water heater product includes requirements analysis, concept design, structure design and detailed design. The key points of green design at each design phase are shown in Figure 1.

3.2. Key points of Green Design in Requirement Analysis
It is required to increase product greening requirement analysis and develop product green design goals. Product greening requirement analysis includes, but is not limited to the following: green-related laws, regulations, policies, standards and patents, advanced industry-related green design and/or manufacturing technology; product demanders’ comments on green-related needs and requirements; take full account of the environmental pollutions of water heater product at all stages of life cycle and product system boundaries.

3.3. Key points of Green Design in Concept Design
It is required to predict and analyze the green design indicators of the product's entire life cycle, conduct a comprehensive review of product technical indicators, economic indicators and green design indicators, and determine the key points of green design. The key points of green design considered at each stage of the product life cycle include but are not limited to selection and use of raw materials, structure design, manufacturing, packaging process, product transportation, product use, recycling, and other design requirements.

3.4. Key points of Green Design in Structure Design
The main points of green design in structure design include, but are not limited to: fully consider of green design indicators such as energy efficiency improvement, light weight, packaging and transportation convenience, and recycling convenience; improve product energy efficiency grade, reduce product weight and enhance ease of use by optimizing product structure; make products easy to process and produce, improve production efficiency and pass rate by simplifying the product structure; improve the convenience of product installation, use, disassembly and recycling.

3.5. Key points of green design in detailed design

3.5.1. Selection and use of raw materials. When selecting raw materials, it is advisable to consider: not use prohibited substances, and use fewer restricted substances; give preference to localized raw materials; give priority to standardized, series-based raw materials; give priority to the selection of raw materials with abundant and renewable sources and using rare materials as little as possible; preferred metal materials should withstand the expected mechanical, chemical and thermal effects without polluting the water; plastic materials that are preferred should meet the effects of mechanical, physical and chemical properties, be resistant to the effects of ultraviolet rays, aging and corrosion, and do not pollute water quality; Reduce the use of thermosetting plastics; corrosion-resistant materials; preferentially use materials that are easily decomposed, and recycled; preferentially select suppliers that have environmental management system capabilities or meet the requirements of the green supply chain; carefully select artificial chemicals that are not yet known about their toxicity and side effects, and when necessary, the supplier is required to provide a chemical safety data sheet (SDS).
Figure 1. Brief design process and key points of green design
When using raw materials, it is advisable to consider: reduce the types of materials used in similar products; reduce the amount of materials use; improve the utilization rate of materials, and reduce waste generation and emissions; use recyclable raw materials, and the material utilization rate should reaching over 85%; improve the utilization rate of raw materials and reduce waste of scraps through customizing the size of raw material; avoid the use of electroplating parts; select compatible materials when mixing materials must be used; encourage the use of pollution-free green new materials.

3.5.2. Product structure design. Light weight design includes, but is not limited to the following: structural optimization and reduction of product weight; reducing the number of product parts, and the internal structure of the same type of product should be as modularized and standardized as possible, model parts can be shared to achieve weight reduction; using new materials to reduce product weight.

Improving the air tightness of the gas system includes, but is not limited to, the following: the installation position of the detachable parts on the gas path should be marked; the gas pipe (including the ignition burner gas pipe) should be located in a heatless and non-corrosive position, otherwise protective measures shall be taken; the air tightness of the gas pipe shall comply with the relevant standards and shall not be detrimental to the air tightness of the gas pipe when it is normally transported, installed and used, and the gas contightness of the gas pipe should be guaranteed by mechanical means except using threaded sealing materials (liquid, sealing adhesive, sealing tape, etc.) when certain parts of the path are disassembled during normal maintenance, such as metal-to-metal squeezing seal or rubber sealing ring, etc., its air tightness after removal and re-installation still need to be guaranteed. If the gas pipe is not sealed by thread or mechanical means, its air tightness shall not be achieved by soft brazing or adhesive; reduce the number of gas connections, and under the premise of ensuring the gas flow, the gas external connection adopts G1/2 external threads connection method; the sealing ring of the gas connection port adopts economical, suitable and durable materials; pipeline gas should be connected by hard hose (or metal hose); curved supply pipe should be smooth to avoid reducing the ventilation capacity; use the thread connection in accordance with GB/T 7306.1 [3], GB/T 7306.2 [4] and GB/T 7307 [5]; the interface of gas appliance with screw connection can be constructed with ordinary piping tools, and there should be no looseness or deformation that damages the air tightness during connection.

Improving the tightness of the water flow system includes, but is not limited to, the following: The connection with the water supply pipeline should adopt a threaded connection that meets the specification of GB/T 7306.1, GB/T 7306.2 or GB/T 7307 and the NPT thread standard GB/T 12716 [6]; water inlet and outlet design should adopt pipe thread connection, whose strength can withstand the effect of water heater pressure test and hot water temperature; reduce the number of connection parts of the water flow system, and the connection should be equipped with a sealing ring; for combustion appliances with water flow system , the water does not penetrate into the gas path; gas instantaneous water heater and gas fired heating and hot water combi-boilers system should be equipped with flow stabilization or flow adjustment devices; gas fired water heaters are equipped with safety valves and pressure gauges or pressure sensors, and the heating system does not damage the skin of the expansion tank; closed appliance heating system is equipped with automatic exhaust device; when gas instantaneous water heaters and gas fired heating and hot water combi-boilers use drain valves (pressure relief valves) as freezing resistance unit, they can be easily drained by hand or common tools; The heating system of the closed appliance with water heating is equipped with safety valve and pressure gauge, and the heating water does not damage the skin of the expansion tank; the hot water flow system is equipped with a pressure relief safety device, and the relief pressure is greater than the maximum applicable water pressure and less than the pressure resistance value of the water system (not suitable for heating and dual-purpose water heaters); the connecting water pipe of the storage water heater has sufficient high temperature resistance.

It is required to carry out the design to improve the heating efficiency of the water heater in accordance with GB20665 [7], so that the heating efficiency of the water heater is above level two.
It is required to carry out the design to increase the inherent energy consumption of the water heater in accordance with GB 21519 [8], so that the 24h inherent energy consumption coefficient of the water heater is not higher than 0.6, and the energy consumption index at all levels is shown in Table 1.

**Table 1. 24h energy consumption coefficient grade of water heater**

| Energy level | 24h energy consumption coefficient $\varepsilon$ |
|--------------|-----------------------------------------------|
| A            | $\varepsilon \leq 0.6$                       |
| B            | $0.6 < \varepsilon \leq 0.7$                 |

The design of packaging and transportation convenience includes, but is not limited to:

a) Compact structure, reduce packaging and transport volume;

b) Large products adopt split structure, and the center of gravity is stable, which is convenient for packaging, loading and unloading and transportation.

The recycling convenience design asks for full consideration of the difficulty of the product scrapping process, and optimizing the product structure, making it easy to install and disassemble, and reusing the product after discarding.

3.5.3. **Manufacturing.** To give sufficient consideration to difficulty and economy of product manufacturing, as well as factors such as pollutant emissions, resource use, human health and safety in the manufacturing process: analyzing, confirming the rationality of design requirements such as performance of components, accuracy and surface structure, and reducing processing and processing volume; marking and classifying toxic and hazardous materials, and giving safety protection requirements for the production process; giving priority to the use of clean energy; giving priority to the use of advanced producing technology and equipment; using advanced green manufacturing technology to reduce energy consumption and pollutant emissions in the production process; Reducing energy consumption and dust pollution, and using advanced green materials to reduce the use of toxic and hazardous substances.

3.5.4. **Packaging Process.** In regard of packaging materials, it is required to consider: first use non-toxic, harmless, easily decomposable or biodegradable packaging materials; preferentially use recyclable packaging materials; use the same kind of packaging material for the same type of products; make packaging waste treated in a harmless manner.

In regard of packaging design, it is required to consider: reduce the use of packaging materials under the premise of meeting the packaging requirements; avoid excessive packaging, and reduce the volume of packaging; give priority to the use of reusable packaging designs; ensure the convenience and safety of lifting, handling and disassembling.

3.5.5. **Product Transportation.** In regard of product transportation, it is required to consider: select the most economical, green transporting mode through integrating transport distance, cargo weight and volume; optimize the process of loading and unloading to increase the handling rate.

3.5.6. **Use.** In regard of using products, it is required to consider: prolong the service life of the product, such as analyzing the failure modes of parts and the product life, and adopt the corresponding improvement measures; for products with frequent technological updates and rapid market changes, spare room for product upgrades or transformations should be reserved through partial replacement to achieve functional expansion or functional enhancement.

3.5.7. **Recycle and Re-use.** In regard of product recycle and re-use, it is required to consider: analyze the state of the product at the end of its life and the impact on the environment during recycling, and propose a treatment plan when the product is discarded; improve the recycling rate and reuse rate of the product; make the non-recyclable as harmless as possible, and avoid the production of hazardous waste.
after the product is scrapped; avoid doing harm to the operators during their recycling and disassembling the product.

4. Technical Requirements

4.1 Basic Requirements

The pollutant discharge of production enterprises shall meet the requirements of the national or local pollutant discharge standards, and aggregate discharge control should meet the national and local aggregate 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 shall not have been major quality, safety and environmental accidents in the past three years.

Production enterprises shall establish, implement, maintain and continuously improve the quality management and environmental management systems in accordance with GB / T 19001 [9] and GB / 24001 T [10], respectively. Production enterprises should carry out product green design work in accordance with the relevant requirements of GB/T 24256. While considering environmental requirements, the design work should also give due consideration to product durability, reliability, serviceability, reusability, remendability, modularity, intelligence, easy disassembly (separation) and easy recyclability of components that have adverse effects on the environment, etc., which should be formed a green design plan of product.

Production enterprises shall adopt advanced technologies and techniques encouraged by the state, and shall not use eliminated or prohibited technologies, techniques, equipment or related substances issued by the state or relevant departments; requirements shall be formulated based on the principles of saving materials during design and production. Production enterprises should carry out green supply chain management and establish green supply chain management performance evaluation mechanism and procedures and determine evaluation indicators and evaluation methods. Production enterprises should put forward management requirements related to quality, environment, energy, and safety for major raw material suppliers, production partners, and related service parties.

The main energy-consuming equipment of the production enterprise shall meet the relevant national energy efficiency standards of level 2 and above. The product quality should meet the corresponding product quality standards and meet the compulsory product certification requirements. The product description should include the relevant description requirements for the use of hazardous substances, materials that require special treatment (such as fluorine-containing foam materials) and the recycling after the product disposal. Production enterprises should publish technical guidance information on product disassembly in an appropriate manner, and the information should be easily obtained by the relevant organizations. Product packaging should comply with the requirements of GB/T 191 [11], GB/T 1019 [12] and GB/T 31268 [13].

4.2 Evaluation Indicator Requirements

The evaluation indicators of water heater products can be selected from the perspectives of resource and energy consumption and impact on the environment and human health. They usually include resource attribute indicators, energy attribute indicators, environmental attribute indicators, and product attribute indicators. The requirements of the evaluation indicator name, reference value, judgment basis (pollutant monitoring method, product inspection method and calculation method of each indicator) of electric water heater are shown in Table 2.

| Indicator name                  | Unit | Indicator direction | Reference value                                                                 | Judgment basis                                                                 |
|--------------------------------|------|---------------------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| Product harmful substance content | -    | -                   | Products should comply with GB / 26572 T [14]                                | Provide a table of hazardous substance content in raw materials, test according to GB/T 26125 [15] and provide a test report |
| Recovery marking | - | - | The recovery marking of products and components comply with GB/T 23384 [16]. If the packaging material is carton (bag), it is recommended to use recycled paper mixed mode to meet the relevant requirements of GB/T 31268. Provide symbols instructions and related management documentation. |
|------------------|---|---|---|
| Packaging and packaging materials | - | - | Do not use HFCs as foaming agents. The total amount of heavy metals lead, cadmium, mercury and hexavalent chromium in packaging and packaging materials shall not exceed 100 mg/kg. It should be marked according to GB/T18455 [17]. Provide supporting materials. |
| Recycling rate | % ≥ | 80 | Calculate according to QB/T 4505 [18] and provide supporting materials. |
| The 24h inherent energy consumption | - | ≤ | 0.6 (GB 21519-2008 Energy Efficiency grade 1 Requirements). Provide supporting materials. |
| Hot water output rate | - | ≥ | 70% (GB 21519-2008 Energy Efficiency grade 1 Requirements). Detect according to Chapter 5 of GB 21519-2008 and provide test reports. |
| Rated capacity | L | - | The deviation between actual capacity and rated capacity is no more than 10%. Detect according to GB/T 20289 and provide test reports. |
| Container pulse pressure | - | ≥ | 160,000 times. Detect according to GB/T 20289 and provide test reports. |
| Hot water output volume from a single heating | /L | ≥ | Rated hot water capacity/L hot water volume/L C≤40 80 | Detect according to Appendix A and provide a test report. |
| Electrical safety | - | | Products should comply with GB 4706.1 [20], GB4706.12 [21]. Detect according to GB 4706.1, GB 4706.12 and provide inspection reports. |

5. Preparation Method of Product Life Cycle Assessment Report

5.1 Method
Prepare a product life cycle assessment report based on the life cycle assessment methodology framework and overall requirements given in GB/T 24040 [22] and GB/T 24044 [23].

5.2 Report Content Framework
The report shall provide basic information such as report information, applicant information, object information, adopted standard information. The report information includes report number, compiler, reviewer, release date, etc., and the applicant information includes the company name, organization code, address, contact person, and contact information, etc. In the report, the main technical parameters and functions of the product, including physical form, manufacturer, usage scale, etc. should be provided. Product weight, packaging size and material should also be stated in the life cycle assessment report.
The report shall provide the compliance status of the basic requirements and the evaluation indicator requirements. It shall also provide a description of improvement of all evaluation indicators in reporting period compared with those in base period, or the comparison of products with equivalent functions. The report shall describe in detail the evaluation objects, functional units and main functions of the product, provide the material composition and main technical parameter table of the product, draw and explain the system boundary of the product, and disclose the software tools used based on the Chinese life cycle database.

The report should provide the life cycle stages to be considered, indicating the inventory factors considered at each stage and the collected field data or background data, and explain the allocation methods and results when it involves data distribution. The report should provide characteristic values of the different impact types at each stage of the product life cycle and also provide a comparative analysis of the distribution of different impact types at various life cycle stages. Based on the analysis of the conformity evaluation results of the indicators and the life cycle assessment results, a specific plan for product green design improvement should be proposed. The conclusion of the product's conformity with the evaluation indicators, the results of the life cycle assessment, and the proposed improvement plan should be made according to the evaluation conclusion.

It should be provided in the report as an appendix: product original packaging drawing; the list of production materials; product technology sheet (schematic diagram of production process, etc.); data collection sheet for each unit process, and the others.

6. Evaluation Methods
Self-evaluation or third-party evaluation may be carried out in accordance with the basic requirements of 3.1 and evaluation indicators of 3.2, while meeting the following conditions, the water heater products can be called green design products after publicity in www.green-label.org without objection based on the related procedure requirements, and then can be labeled according to GB/T32162 [24] requirements.

a) Meet the basic requirements (see 3.1) and evaluation indicators requirements (see 3.2)
b) Provide electric water heater life cycle assessment report according to 4.

When products labeled according to GB/T32162 requirements are making self-declaration of relevant information in various forms, the declaration shall include, but not be limited to, the requirements of 3.1 and 3.2, but certain verification instructions and materials need be provided in accordance with the relevant requirements.

7. Conclusion
The eco-design and evaluation of water heater products is the significant driving force to promote water heater product companies to reduce resources, energy consumption, pollutants, and greenhouse gas emissions from the source, enhance the technology to develop towards the energy saving, low carbon and green technology direction, and further promote the industrial transformation and upgrading. This paper analyzes the general principles of green design of water heater products, the green design process and key points, evaluation requirements, life cycle evaluation report preparation methods and evaluation methods. The ecological damage caused by the development and application of modern science and technology needs people to face directly. While through eco-products, the users can make more sensible and ecological decisions.

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).

References
[1] Jianfang Zong*, Dongfeng Gao, Jianwei Tian, Xin Zhang. Guideline for green design of water
heater products. E3S Web of Conferences 118, 02001 (2019).

[2] GB/T 24256, General Principle and Requirements of Eco-Design for Products.
[3] GB/T 7306.1, Pipe threads where pressure-tight joints are made on the threads--Part 1: cylindrical internal threads and taper external threads.
[4] GB/T 7306.2, Pipe threads where pressure-tight joints are made on the thread--Part 2: taper internal and external threads.
[5] GB/T 7307, Pipe threads where pressure-tight joints are not made on the threads.
[6] GB/T 12716, Pipe threads where pressure-tight joints are made on the threads.
[7] GB 20665, Minimum Allowable Values of Energy Efficiency and Energy Efficiency Grades for Domestic Gas Instantaneous Water Heater and Gas Fired Heating and Hot Water Combi-Boilers.
[8] GB 21519, Minimum Allowable Values of Energy Efficiency and Energy Efficiency Grades for Electrical Storage Water Heaters.
[9] GB/T 19001, Quality Management Systems-Requirements.
[10] GB/T 24001, Environmental Management Systems--Requirements with Guidance for Use (GB/T 24001-2004, ISO 14001: 2004, IDT).
[11] GB/T 191, Packaging-Pictorial Marking for Handling of Goods.
[12] GB/T 1019, General Requirements for the Package of Household and Similar Electrical Appliances.
[13] GB/T 31268, Restricting Excessive Packaging for Commodity-General Rule.
[14] GB/T 26572, Requirements of Concentration Limits for Certain Restricted Substances in Electrical and Electronic Products.
[15] GB/T 26125, Electrical and Electronic Products-Determination of Six Regulated Substances (Lead, Mercury, Cadmium, Hexavalent Chromium, Polybrominated Biphenyls, Polybrominated Diphenyl Ethers) (IEC 62321: 2008, IDT).
[16] GB/T 23384, The Recovery Marking of Products and Components.
[17] GB/T 18455, Package Recycling Marking.
[18] QB/T 4505, Requirements of Recycling for Household Water Heater.
[19] GB/T 20289, Electrical Storage Water Heaters.
[20] GB 4706.1, Household and Similar Electrical Appliances-Safety Part 1: General Requirements.
[21] GB 4706.12, Safety of Household and Similar Electrical Appliances-Particular Requirements for Storage Water Heaters.
[22] GB/T 24040, Environmental Management-Life Cycle Assessment-Principles and Frameworks.
[23] GB/T 24044, Environmental management - Life cycle assessment - Requirements and guidelines.
[24] GB/T 32162, Labeling for Eco-design Product.