An Evaluation on the Implementation Effect of the National Standard - Norm of Water Intake-Part 1: Fossil Fired Power Production (GB/T18916.1-2012)

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Abstract: The evaluation on the implementation effect of the standard not only constitutes an important basis for promoting the implementation and the quality of the standard, but also provides an important technical basis for implementing national water conservation actions and achieving the dual control targets for water consumption and intensity. This article analyzes and evaluates the implementation effect of the National Standard GB/T18916.1-2012 *Norm of Water Intake-Part 1: Fossil Fired Power Production* from three aspects including the Standard's technical indexes, implementation effect and implementation benefits, and provides a foundation and reference to study and conduct evaluations on the implementation effect of the national standard for the norm of water intake.

1 Introduction

With the rapidly development of society and economic, the shortage of water resources is increasingly serious ^[1], which become the bottleneck of the sustainable development of economic in China ^[2]. The norm of water intake for industrial products is one of the main indicators for the assessment of water efficiency and water conservation level of each industry and enterprise ^[3]. It is also a vital control indicator of water supply for the enterprises and the basic of water management and distribution by enterprises ^[4]. In order to promote the development of a feedback mechanism for the implementation status and effect of standards, which could respond to requirement of the State Council in the *Plan for Deepening the Reform of Standardization Work* ^[5] to “conduct evaluations on the implementation effect of a standard and establish a mandatory statistical analysis and reporting mechanism for the implementation of national standards”, and improve the alignment between standard formulation and the implementation effect, it is necessary to carry out evaluations on the implementation effect of the national standard for the norm of water intake in the fossil fired power production industry as a typical

water-intensive industry, since it is significant for continuously promoting the formulation and revision of the standard for the norm of water intake in this industry and for a more effective implementation and application of the standard.

2 Analysis of current situation

2.1 The current situation of fossil fired power production

Fossil fired power plants play an important role in development of China ^[6]. At present, more than 80% of the country's power plants are fossil fired power plants, and most of these enterprises are water-intensive ^[7]. However, the circulating water system still could be improved ^[8]. According to the research of current situation, it is obvious that the quantity of fossil fired power generation has shown a continuous upward trend. However, the total water consumption of fossil fired power generation in China was 4.54×10^9 tons in 2000, and reached a peak of 9.13×10^9 tons in 2011. In 2017, the fossil fired power generation decreased by 37.7% to 5.69×10^9 tons (See Figure 1).

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Fig 1. Changes of fossil fired power generation and water consumption in China (2000-2017)

Analysis the data of 2000 and 2017, the trend showed that the fossil fired power generation increased by 3.1 times, at the same time, the water consumption of the industry just increased by 25%. The result pointed out that the water consumption for unit power generation quantity

is 1.25 kg/kW·h, which decreased by 69.5% with the water consumption in 2000 (See Figure 2). Consequently, the effect of water conservation of fossil fired power generation was remarkable.

Fig 2. The water consumption for unit power generation (2000-2017)

2.2 Introduction of the standard GB/T18916.1-2012

As the first part of the national standard for the norm of water intake, National Standard GB/T18916.1-2012 *Norm of Water Intake-Part 1: Fossil Fired Power Production* [9] was published on June 29, 2012 and took effect as of January 1, 2013, replacing GB/T18916.1-2002. The standard specifies the terms and definitions, calculation method, and the norm of water intake for fossil fired power production, and is applicable to the management of water intake during the production and design process of fossil fired power production enterprises in electric power industry. The standard has improved the national standard system for the norm of water intake, and effectively supported the implementation of several policies in China,

such as the access policy for water consumption and water conservation in water-intensive industries, the most stringent water management mechanism, the National Water Conservation Action, the Water Consumption and Intensity dual-control, which greatly promoted the improvement of water conservation management and technologies in industries and enterprises [10].

3 Evaluation on the implementation effect of the standard

There are a large number studies on the evaluation of the implementation of standards abroad. In 1997, the study on the economic benefits of standardization in Germany, Austria and Switzerland organized by the German Ministry of economy and technology and the German Society for Standardization (DIN), which shows the result

that standards contributed substantially to the economic growth in the second half of the last century^[11]. BSI and CBI have organized studies about the contribution of standardization to long-term productivity growth in British, which pointed out there is a positive correlation between standard stock and labor productivity^[12, 13]. Besides, the other studies also identified the implementation of standards has a positive role in promoting the economy^[14, 15].

The evaluation and study on the implementation effect of the standard for water conservation could help standardization personnel understand the benefits of the standardization work^[16], and at the same time identify weaknesses and promote the improvement of water conservation technologies and management^[17]. The evaluation on the implementation effect of the standard

often involves multiple factors and indicators, which is a comprehensive analysis with the interaction of multiple factors^[18]. The shortcomings and gaps of the evaluated object may be identified through the comprehensive evaluation, so that improvement measures may be adopted timely or future work may be carried out accordingly.

For the evaluation on the implementation effect of the National Standard *Norm of Water Intake-Part 1: Fossil Fired Power Production*, this paper mainly uses questionnaires to collect data from two aspects, the implementation of the Standard (GB/T18916.1-2012), water intake and consumption in the industry, which covers 268 fossil fired power plants in 28 provinces and cities. The main contents of the survey are shown in Table 1.

Table1. Main Contents of the Survey

Category	Main content
Basic information	Scale, cooling method of generating sets, unit rated capacity
Water intake and consumption	Annual water intake, proportion of unconventional water resources, quantity of water intake for unit power generation quantity, quantity of water intake for unit rated capacity, reuse rate of sewage water from recirculating cooling water, waste water reuse rate
Implementation of standard	Understanding of the standard, adoption of the standard in water conservation management, benefits from implementing the Standard

3.1 Evaluation of the technical indexes

3.1.1 Evaluation of the applicability

The evaluation of the applicability of the standard mainly analyzes the current industry status and the industry status at the time of standard formulation to decide whether the goal of improving backward production capacity has been

achieved, and to determine the degree of consistency between the norm indexes and the market development needs^[19, 20]. Through an analysis of the survey results, it is obvious that the water intake of the three types of cooling mode which including recirculating cooling, once-through cooling, and air cooling, with the unit rated capacity respectively under 300 MW, at 300 MW, and at or above 600 MW, and compare them with the norm indexes of water intake in GB/T18916.1-2012 (see Table 2).

Table2. A Comparison between the Current Water Intake in the Fossil Fired Power Production Industry and the Norm Indexes of Water Intake in GB/T18916.1-2012

Type		unit rated capacity < 300 MW		unit rated capacity at 300 MW		unit rated capacity at or above 600 MW	
		Quantity of water intake for per unit of power generation	Quantity of water intake for per unit of rated capacity	Quantity of water intake for per unit of power generation	Quantity of water intake for per unit of rated capacity	Quantity of water intake for per unit of power generation	Quantity of water intake for per unit of rated capacity
Status quo in the fossil fired power production industry	Recirculating cooling	1.76	0.74	1.79	0.65	1.97	0.65
	Once-through cooling	-	-	0.50	0.10	0.41	0.09
	Air cooling	0.85	0.28	0.40	0.20	0.51	0.11
	Recirculating cooling	3.20	0.88	2.75	0.77	2.40	0.77
GB/T18916.1-2012	Once-through cooling	0.79	0.19	0.54	0.13	0.46	0.11
	Air cooling	0.95	0.23	0.63	0.15	0.53	0.13

Note*: the unit of quantity of water intake for per unit of power generation is $\text{m}^3/\text{MW}\cdot\text{h}$, the unit of quantity of water intake for per unit rated capacity is $\text{m}^3/(\text{GW}\cdot\text{S})$.

(1) Whether the goal of improving backward production capacity has been achieved

In the formulation of the standard, the principle for determining the norm indexes was to ensure that more

than 60% of the generating sets at that time could achieve such indexes^[21]. Based on the unit rated capacity of fossil fired power production sets at that time, about 300 million kilowatts of generating sets could not meet the requirements of the norm indexes. According to an analysis of the current water intake in the fossil fired power production industry, 92% of the generating sets with recirculating cooling, 75% of the sets with once-through cooling, and 76% of the sets with air cooling can meet the requirements of the norm indexes in the standard, that is, on average, 81% of the sets can meet the requirements. Based on the current unit rated capacity of fossil fired power production sets, after the implementation of the standard, about 186 million kilowatts of generating sets could not meet the requirements. Therefore, the implementation of the standard has at least promoted the index reaching of 114 million kilowatts of backward production capacity, with an index reaching proportion of 15%.

(2) The consistency between the norm indexes and market development demand

According to a comparison of the degree of consistency between the norm indexes and the market development demand, the norm indexes are lower than the average level of the surveyed enterprises. However, 8% of the sets with recirculating cooling, 25% of the sets with once-through cooling, and 24% of the sets with air cooling in the surveyed enterprises could not reach the requirements for the quantity of water intake for per unit of power generation in the standard, and 15% of the sets with recirculating cooling, 25% of the sets with once-through cooling, and 33% of the sets with air cooling

could not reach the requirements for the quantity of water intake for unit rated capacity in the standard. It shows that the norm indexes are basically consistent with the current development and demand of the industry.

3.1.2 Evaluation of the advancement

Developed countries have carried out lots of work on the laws, regulations, technical standards, product quality, testing, and system management which related to water conservation evaluation^[22]. For example, countries such as the United States, Australia, and Japan have implemented national water resources standardization projects to test and manage water resources, established evaluation systems, and strengthened water management, which achieving significant water conservation and emission reduction benefits^[23]. However, there is no standard for the norm of water intake and consumption in in foreign countries.

With the average water consumption for power generation in 2008 as an example, the average quantity of water intake for unit power generation quantity by fossil fired power production sets in China was 1.11 times that of the average level of advanced countries, which was 1.57 times that of the United States, and 2.24 times that of South Africa (Table 3). Through decades of improvement in water conservation technologies, the current quantity of water intake for unit power generation quantity by fossil fired power production sets in China is $1.25 \text{ m}^3/(\text{MW} \cdot \text{h})$, which is about 55% lower than that in 2008 (Table 3)^[24-26].

Table3. A Comparison of the Average Water Intake between Domestic and Foreign Power Plants (2008)

Evaluated target	Water intake per unit of power generation/kg/kW·h	Water intake per unit of installed capacity/t/GM·S
Average value in China	2.80	0.58
Average value in advanced countries	2.52	0.700
Average value in the United States	1.78	0.490
Average value in South Africa	1.25 (0.2 for air cooling)	0.347(0.056 for air cooling)
Average value in power plants with recirculating cooling in Germany	1.8-2.4	
Reuther West Power Plant of Germany (1,000 MW)		0.500
Bay Power Plant of Canada	1.96	0.544

Based on the comparison of the data and consultancy of industry experts, the results shows that the technical indexes in GB/T18916.1-2012 are currently at the international leading level, basically equivalent to the average level of advanced countries. However, it could be seen from the comparison that the quantity of water intake for unit power generation quantity in the standard is still 1.35 times that of South Africa, especially the value of air cooling sets is 3.5 times. Besides, the quantity of water intake for unit rated capacity in the standard is 1.37 times that of South Africa, especially the value of air cooling sets is 3.04 times. Therefore, there still has the large gap and enormous potential for water conservation in China.

3.1.3 Evaluation of the reconciliation

The evaluation of the reconciliation of the standard mainly refers to the comparison with the domestic cleaner production evaluation index systems and standards, local standards for the norm of water consumption, and other documents which related to the norm indexes of water intake, with a purpose to determine the reconciliation of the technical indexes.

(1) Comparison of key technical indexes with relevant national, industry and local standards

Through a search of existing national, industry and

local standards, we have found one national standard to be related to GB/T18916.1-2012, that is, *Water Saving Enterprises-Fossil Fired Plant* ^[27], in which the norm index is broader than the quantity of water intake for unit rated capacity and stringent than the quantity of water intake for unit power generation quantity. Besides, the sub-paragraph 7.2.1 of the industry standard *Water Saving Guideline for Fossil fired power production Plant* ^[28] stipulates that “the water intake by fossil fired power production plants shall meet the requirements of GB/T18916.1”. In addition, a total of 30 provinces and cities across the country have formulated water

consumption norms for fossil fired power production, of which 4 local norm standards have a lower requirement on norm indexes, 16 local norm standards have consistent with GB/T18916. However, these has 10 local standards could not be compared due to the different classification scales.

(2) Degree of reconciliation with relevant national documents

In recently years, the government has published some policy to specifics the water intake and consumption in fossil fired power production (See Table 4).

Table4. Adoption of the Standard by the Administrative Sector

Department	Policy
Ministry of Water Resources of the People’s Republic of China	<i>Opinions on Conducting Water Resources Demonstrations for the Development and Planning of Large Coal Power Bases</i>
National Development and Reform Commission, Ministry of Ecology and Environment, and Ministry of Industry and Information Technology of the People’s Republic of China	<i>Evaluation Index System for Cleaner Production in the Power (Coal Fired Power Generation Enterprises) Industry</i>
National Development and Reform Commission, Ministry of Water Resources, and Ministry of Housing and Urban-Rural Development of the People’s Republic of China	<i>13th Five-Year Plan for Building a Water Conservation-Minded Society</i>

Through comparison, it is obvious that the indexes prescribed in the three national documents are all higher than the index requirements in the *Norm of Water Intake-Part 1: Fossil Fired Power Production* (GB/T18916.1-2012).

3.2 Evaluation of implementation effect

3.2.1 Evaluation of the promotion

The evaluation of the promotion mainly evaluates the three aspects: the training of the standard, the citation of the standard in scientific papers, and the spread of the derivative materials of the standard ^[20]. From 2013 to 2017, the Ministry of Water Resources, the Ministry of Industry and Information Technology, the National Water Conservation Standardization Technical Committee (SAC/TC 442) and other organizations organized a total of 22 related training sessions for the publicity of the Standard, with a total of more than 2,000 people trained.

A total of 4 scientific articles cited the Standard, and downloads reached 154 times. In addition, the main derivative material of the Standard, *Water Intake Standardization Theories, Methods and Their Application*, was officially published in March 2015. This book provides a technical basis for improving the theoretical system for compiling China’s standard for the norm of water intake, and for China’s water consumption cap control and quota allocation mechanism. It was printed for the first time in April 2015, and its sales volume reached about 1,000 copies.

3.2.2 Evaluation of the implementation

Standard implementation is mainly evaluated from three aspects: administrative sector, enterprises, and third-party institutions. Since publication, the standard has been adopted by government departments in 6 documents, and by river basin agencies and local authorities in 3 documents, as shown in Table 5.

Table5. Adoption of the Standard by the Administrative Sector

Sector	Main content
Government departments	<i>12th Five-Year Plan for Building a Water Conservation-Minded Society</i> (Ministry of Water Resources, January 2012)
	<i>Notice of the State Council on Issuing the Action Plan for Prevention and Control of Water Pollution</i> (GF [2015] No. 17)
	<i>Action Plan for Water Conservation Nationwide</i> (FGHZ [2016] No. 2259)
	<i>Action Plan for the Dual Control of Total Water Consumption and Intensity during the 13th Five-Year Plan Period</i> (SZY [2016] No. 379)
	<i>13th Five-Year Plan for Building a Water Conservation-Minded Society</i> (FGHZ [2017] No. 128)
	<i>Guiding Opinions of the National Development and Reform Commission and the Ministry of Housing and Urban-Rural Development on Accelerating the Establishment and Improvement of a Progressive Pricing Mechanism for Over-Quota Non-Residential Water Consumption</i> (FGJG [2017] No. 1792)

River basin agencies and local authorities	<i>Plan for the Implementation of the Dual Control of Total Water Consumption and Intensity in Hebei Province (2016-2020)</i>
	<i>Implementation Plan for the Dual Control Action on Total Water Consumption and Intensity in Shanghai Municipality during the 13th Five-Year Plan Period</i>
	<i>Implementation Plan for the Dual Control Action on Total Water Consumption and Intensity in Haidong City during the 13th Five-Year Plan Period</i>

The evaluation on the standard implementation of enterprises, which is based on the 268 enterprises surveys. Among the surveyed enterprises, 259 of them were aware of the standard, accounting for 97%; 243 mastered the main content, accounting for 91%; 241 incorporated it in their water conservation management system, accounting for 90%. It is clear that this standard is well known around the China, has the great mastered and implemented by the enterprises.

The standard was used as a guide in the water-saving transformation and the production of fossil fired power production plants. A variety of water-saving activities were carried out and great water-saving and economic benefits were achieved^[29]. According to industry statistics, the average water intake per unit of power generation of the entire industry in 2017 was 1.25 m³/MW·h, which was about 41.9% lower than that in 2012.

Regarding the adoption of the standard, third-party institutions stipulated in the industry standard that “the water intake could be comprehensively evaluated based on GB/T18916.1 and the quantity of water intake for unit rated capacity of power plants”^[30]. At the same time, during a water balance test on a fossil fired power production plant which taken by Guangzhou Institute of Energy Testing, has pointed out the existing problems, water conservation potential, water saving measures and expected results based on the standard^[31].

3.2.3 Evaluation of the citation

Since the publication and implementation of the standard, it has been quoted in the *Regulations for the Administration of Water Intake Permits and Collection of Water Fees* (State Council Order, No. 460). There were mainly 5 national standards that cited the standard as a normative reference, involving design specifications, water saving enterprises evaluation, water consumption management guideline, water consumption audits, and water conservation assessment. A total of 4 industry standards quoted the standard. In addition, a total of 16 local standards cited the standard and adopted the requirement of norm indexes. However, the standard has not been cited in international standards.

3.3 Evaluation of the implementation benefits

3.3.1 Evaluation of the economic benefits

The norm of water intake for the fossil fired power production industry is an important basis for measuring the water conservation level, and also a key measure to improve water efficiency in industry^[32,33]. According to an analysis of the survey results, in 2017, the water intake

for unit power generation quantity in the entire industry was 1.25 m³/MW·h, which was about 41.9% lower than that in 2012. The quantity of water conservation accounted for about 10.07% of annual water intake.

3.3.2 Evaluation of the social benefits

The social benefits are mainly evaluated from the aspect of corporate social responsibility^[34], such as participating in the evaluation for *water efficiency leaders* and *water-saving enterprises*, which organized by the National Development and Reform Commission, the Ministry of Water Resources, and the Ministry of Industry and Information Technology. Besides, the enterprises of the fossil fired power production industry could also participate in the creation of water-saving entities and water conservation standard demonstrations and pilots organized by local authorities.

This standard is the important part of the norm of water intake standard system in China, which is the main basis for implementing planned water consumption and water permit mechanism, and take the significant support for conducting water resource demonstrations. It plays an essential role in the water conservation management and technological innovation of enterprises^[35]. In addition, it is an important support for the establishment and improvement of water conservation standard system in China, and other Chinese polices. However, during the implementation of the standard, there is no enterprise participated in the relevant selection programs.

3.3.3 Evaluation of the ecological benefits

The ecological benefits are mainly evaluated in terms of the reduction of waste water discharge by enterprises after the implementation of the norm standard.

The trend of discharge of waste water and the quantity of fossil fired power generation^[36] was shown in Figure 3. According to calculations, the discharge of waste water nationwide by the fossil fired power production industry decreased by 49% from 2012 to 2017, which from 5.49×10⁹ tons decreased to 2.80×10⁹ tons. It means that the annual average reduction rate is 9.8%.

Based on a statistical analysis, the discharge of waste water for unit power generation shown the obvious decrease trend from 2012 to 2017, which was shown in Figure 4. Take the survey result into consideration, there are 28% of the enterprises shows the significant decreases in waste water discharge, and 18.7% of the enterprises achieved zero discharge of waste water, after the implementation of the *Norm of Water Intake-Part 1: Fossil Fired Power Production* by fossil fired power production generation enterprises.

Fig 3. Changes of fossil fired power generation and the discharge of waste water in China (2012-2017)

Fig 4. Discharge of waste water for unit power generation (2012-2017)

4 Evaluation results

Based on the evaluation on the implementation effect of the National Standard *Norm of Water Intake-Part 1: Fossil Fired Power Production* (GB/T18916.1-2012), it is obvious that the implement of the standard has promote the development of the industry from the three aspects. In terms of the technical aspect, first of all, the implementation of standard promoted the index reaching of backward production capacity. Secondly, the norm indexes were well in line with market development demands. Besides, the key technical indexes were not only consistent with the foreign industry development, but also consistent with relevant national, industry, local standards, and the requirements in relevant national documents. In terms of implementation, the standard and its derivative materials were well spread. After the publication, the standard has been training by the relevant department, also cited in scientific papers, and used in publicity materials and related books as derivative materials. On the other side, the standard was excellent adopted by the

administrative sector, enterprises and the third-party institutions. Besides, the standard was quoted in many laws, regulations, national policy documents, and local standards. In terms of implementation benefits, after the implementation of the standard, the reduced quantity of water intake accounted for 10.07% of the annual water intake in the fossil fired power production, and the average discharge of waste water was reduced by 9.8%. However, in terms of social benefits, there is no enterprise has participated in the relevant selection programs for water efficiency leaders and water saving enterprises, or the demonstrations and pilots of related water conservation standards.

According to the evaluation and analysis of the implementation effect of the National Standard *Norm of Water Intake-Part 1: Fossil Fired Power Production* (GB/T18916.1-2012), the implementation has achieved initial results in regulating the water intake and consumption in the fossil fired power production industry. The norm indexes in the standard shall be further revised based on the current industry development so as to promote the development of water conservation technologies in this industry. In addition, supervision shall

be stepped up by establishing a real-time tracking mechanism for the implementation effect of the standard. Besides, the policy support, publicity efforts, and the self-regulation mechanisms of industry shall be strengthened in order to support the implementation of standard.

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