Evaluation Method and Research of Special Equipment Inspection Institutions Based on Comprehensive Ability Level

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Abstract. The evaluation of special equipment inspection institutions is currently a highly valued issue in both domestic and international academic circles. This article combines the existing evaluation situation of special equipment inspection institutions in China, studies the evaluation method of special equipment inspection institutions based on comprehensive ability level assessment, and analyzes and discusses some issues that should be paid attention to in the evaluation of special equipment inspection institutions in China.

Keywords: mechanical engineering; special equipment; comprehensive evaluation; comprehensive ability level

1 Introduction

Special equipment refers to boilers, pressure vessels (including gas cylinders), pressure pipelines, elevators, lifting machinery, passenger ropeways, large amusement facilities, specialized motor vehicles in the field, and other special equipment stipulated by laws and administrative regulations that pose a significant risk to human life and property safety. According to the Notice on the Safety Status of Special Equipment in China in 2018 issued by the State Administration for Market Regulation in April 2019, the number of special equipment used in China had reached 13.9435 million units by the end of 2018, an increase of 7.5% from 2017 [1]. Among them, there are 403900 boilers, 6.2783 million elevators, 3.946 million pressure vessels, 2.3479 million lifting machinery, 1036 passenger ropeways, 25100 large amusement facilities, and 941200 motor vehicles in the factory [2].

With the continuous increase in the number and widespread use of special equipment, the importance of special equipment has also been increasingly concerned by the people. Special equipment is different from other production equipment, and a slight mistake during use can cause accidents [3]. According to the notice issued by the State Administration for Market Regulation, as of the end of 2018, there were 219 special equipment accidents in China, with 68 injuries and 224 deaths, resulting in a mortality rate of 0.22 per 10000 special equipment units. Compared with 2017, they

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are gradually decreasing, with decreases of 7.98%, 53.10%, 10.76%, and 26.67% respectively, which is still a significant gap compared to developed countries [4].

With the reform of China's social and economic system and the continuous development of regional economy, special equipment has become an indispensable means of production for people in production and life. In recent years, with the continuous increase in the number of special equipment, the role of special equipment in urbanization construction has also become increasingly important [5]. However, the safety issues of special equipment have always plagued special equipment inspection agencies, and various unexpected incidents of special equipment all indicate that there are deficiencies in China's special equipment inspection. In order to further enhance the government's ability in the supervision of special equipment safety, China has successively issued relevant laws, regulations and policies to implement unified and comprehensive supervision of the production (including design, manufacturing, installation, renovation, maintenance and other projects), use, inspection and testing of special equipment. At the same time, performance evaluation of special equipment inspection agencies has gradually become an important way to implement the special equipment safety supervision system. In this situation, in order to ensure the safety of special equipment, further improve the effectiveness of safety supervision work, ensure the normal development of the social economy and maintain social stability, it is very important to establish a scientific and reasonable evaluation system for special equipment inspection institutions.

2 Principles for Establishing Comprehensive Ability Level Assessment

The evaluation level should comprehensively reflect the representative information of things in various aspects, consisting of information that can describe the characteristics of things in all aspects. The establishment of a comprehensive capability level assessment system for special equipment inspection institutions aims to evaluate the current special equipment inspection institutions and quantify their quality. The following principles should be followed.

2.1 Principle of Comprehensiveness

The principle of comprehensiveness refers to the ability to comprehensively reveal the overall condition of the evaluation object and reflect the relevant influencing factors and their connections when constructing the evaluation index system for special equipment inspection institutions [4]. When determining the evaluation index system, it is necessary to not only focus on evaluation indicators with strong correlation, but also avoid duplicate design of indicators of the same type, so as to coordinate and assist each evaluation indicator, and ensure that the evaluation system can comprehensively reflect the overall characteristics of special equipment inspection institutions.

2.2 Principle of Operability

The principle of operability is one of the important criteria for testing the rationality of the design of the comprehensive ability level assessment system [6]. When selecting indicators, attention should be paid to whether the data is easy to obtain and whether the acquisition channels are real and reliable. When designing an evaluation index system, subjective and objective evaluation indicators are usually taken into account [7]. When determining subjective evaluation indicators, some indicators related to policy evaluation and social evaluation satisfaction will be included. These indicators usually do not have a unified evaluation standard, and their impact on the evaluation object is difficult to measure. Therefore, when selecting evaluation indicators, objective evaluation indicators should be chosen as much as possible to reduce the proportion of subjective evaluation indicators and make the evaluation results more authentic and accurate.

2.3 Principle of Operabilit Principle of Combining Quantitative and Qualitative Analysis

When determining the comprehensive ability rating system, due to the selection of different indicator units, it is not possible to analyze them based on a unified evaluation standard [8]. Therefore, it is necessary to standardize the raw data of the obtained indicators. Therefore, the selection of indicators should follow the principle of quantification, and it is necessary to evaluate the results of the model calculation, identify the problems existing in the evaluation object, and propose solutions [9]. While ensuring operability, the coordination between qualitative and quantitative analysis is used to minimize the subjectivity of evaluation indicators, in order to facilitate analysis, comparison, and prediction.

3 Comprehensive Ability Level Assessment

After determining the ability score for each evaluation item of the inspection agency, the comprehensive ability level is determined according to the following method:

- Assuming the ability score value corresponding to the evaluation item, where is the total number of items evaluated.
- Calculate the comprehensive ability score according to formula (1):

$$D = \sum_{i=1}^{n} v_i / 5n \times 100 \quad \text{if } \forall v_i \neq 0 \text{ and } \sum_{i=1}^{n} v_i > 0 \tag{1}$$

- Based on the score, determine the comprehensive ability level of the inspection agency according to Table 1.

Table 1. Capability level of inspection agency

D	**D≥80**	**60≤D<80**	**40≤D<60**	**20≤D<60**	**D<20**
Comprehensive capability level of inspection institutions	Level 1	Level 2	Level 3	Level 4	Level 5

The comprehensive common evaluation items are shown in Table 2, and the inspection capability score of special equipment is calculated according to formula (1). Then, based on the score, determine the special equipment capability level of the inspection agency according to Table 1.

Table 2. Comprehensive common evaluation items

Category	**Subcategory**	**Score**
Basic Information of the Institution	Years of experience in inspection work	1~8: 1 8~12: 2 ≥12: 5
	Original value of total fixed assets	1~100: 1 100~300: 2 300~3000:3 3000~30000:4 ≥30000: 5
	The original value of the inspection equipment	<150: 1 150~1000: 2 1000~10000:3 ≥10000: 5
	Office space area	<100: 1 100~300: 2 300~2000:3 2000~10000:4 ≥10000: 5
	Validity period of certification (accreditation)	term of validity ≤current date: 5 term of validity >current date: 0
Approved categories and projects	Approved project code	Calculate the number of projects and scores for various types of special equipment separately
	Validity period of approved project	term of validity ≤current date: 5 term of validity >current date: 0
Research ability	Number of national standards related to special equipment participation	≥10 : 5
	Average annual research and development expenses related to special equipment (10000 yuan)	≥ 1000 : 5
	Percentage of average annual research and	≥ 3% : 5

	development expenses related to special equipment to average annual business revenue	
	The number of researchers with the titles of researcher and senior engineer	< 2 : 1 2~10 : 2 ≥ 10 : 5
	Whether to undertake the work of the International Organization for Standardization Professional Technical Committee in the field of special equipment related specialties	Yes : 5 No : 0
	Whether to undertake the work of the National Professional Standards and Technical Committee (including sub technical committees) or the Secretariat of the Provincial Standardization and Technical Committee	Yes : 5 No : 0
Personnel situation	Number of inspection and testing personnel	<30 : 1 30~120 : 2 120~300 : 4 ≥ 300 : 5
	Number of inspectors	<96 : 1 96~240 : 2 ≥ 240 : 5
	Number of Senior Inspectors	<3 : 1 3~10 : 2 ≥ 10 : 5
	Number of inspection and testing personnel with senior engineer or above qualifications	<30 : 1 30~80 : 2 ≥ 80 : 5
	Number of researchers with the titles of researcher and senior engineer	<2 : 1 2~10 : 2 ≥ 10 : 5
	Number of Senior Pressure Equipment Inspectors (G-CY)	<2 : 1 2~4 : 2 ≥ 4 : 5
	Number of Supervisors and Inspectors for Pressure Equipment (S-JJ)	<8 : 1 8~12 : 2 12~30 : 4 ≥ 30 : 5
	Number of Supervisors and Inspectors for Pressure Equipment (Y-JJ)	<18 : 1 18~20 : 2 20~40 : 4 ≥ 40 : 5

	Number of Regular Boiler Inspectors (Y-GL)	<8 : 1 8~12 : 2 12~30 : 4 ≥ 30 : 5
	Number of Boiler Periodic Inspectors (S-GL)	<4 : 1 4~12 : 2 12~25 : 4 ≥ 25 : 5
	Number of Boiler Water Quality Inspectors (Y-SZ I, Y-SZ II)	<2 : 1 2~4 : 2 ≥ 4 : 5
	Quantity of Boiler Water Quality Inspection Inspectors (S-SZ)	<2 : 1 ≥ 2 : 5
	Number of Periodic Inspectors for Pressure Vessels (Y-RQ)	<6: 1 6~10 : 2 10~18 : 4 ≥18: 5
	Number of Pressure Vessel Inspectors (S-RQ)	<3 : 1 3~6 : 2 6~12 : 4 ≥ 12 : 5
	Number of Regular Gas Cylinder Inspectors (Y-QP)	<4 : 1 ≥ 4 : 5
	Number of pressure pipeline periodic inspectors (Y-GD)	<8 : 1 8~10 : 2 ≥ 10 : 5
	Number of Pressure Pipeline Inspectors (S-GD)	<6: 1 6~20 : 2 20~30 : 4 ≥30: 5
	Number of safety valve inspectors (F)	<2 : 1 ≥ 2 : 5
	Number of Senior Mechanical and Electrical Equipment Inspectors (G-JD)	<2 : 1 ≥ 2 : 5
	Number of Elevator Inspectors (Y-DT)	<8: 1 8~12 : 2 12~24 : 4 ≥24: 5
	Number of Elevator Inspectors (S-DT)	<8: 1 8~12 : 2 12~24 : 4 ≥24: 5
	Number of crane inspectors (Y-QZ)	<6: 1 6~8 : 2

		8~12 : 4 ≥12: 5
	Number of Crane Inspection Technicians (S-QZ)	<2: 1 2~4 : 2 4~6 : 4 ≥6: 5
	Number of inspectors for large amusement facilities (Y-YL)	<4 : 1 4~20 : 2 ≥ 20 : 5
	Number of inspectors for large amusement facilities (S-YL)	<2 : 1 2~15 : 2 ≥ 15 : 5
	Number of Passenger Cableway Inspectors (Y-SD)	<4 : 1 4~12 : 2 ≥ 12 : 5

4 Conclusions

With the reform of China's social and economic system and the continuous development of regional economy, special equipment has become an indispensable means of production for people in production and life. In recent years, with the continuous increase in the number of special equipment, the role of special equipment in urbanization construction has also become increasingly important. However, the safety issues of special equipment have always plagued us, and various unexpected incidents of special equipment all indicate that there are deficiencies in China's supervision of special equipment safety. In order to further enhance the government's ability in the supervision of special equipment safety, China has successively issued relevant laws, regulations and policies to implement unified and comprehensive supervision of the production (including design, manufacturing, installation, renovation, maintenance and other projects), use, inspection and testing of special equipment [10]. At the same time, the comprehensive capability level assessment of special equipment inspection agencies has gradually become an important means of evaluating the performance of special equipment safety supervision, and also an important way to implement the special equipment safety supervision system. This article summarizes and analyzes the research on safety assessment of special equipment inspection institutions at home and abroad, and constructs an evaluation index system for special equipment inspection institutions based on multiple inspection and evaluation items and indicators. The evaluation of special equipment inspection institutions is currently a highly valued issue in both domestic and international academic circles. This article combines the existing evaluation situation of special equipment inspection institutions in China, studies the evaluation method of special equipment inspection institutions based on comprehensive ability level assessment, and analyzes and discusses some issues that should be paid attention to in the evaluation of special equipment inspection institutions in China.

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