Comparative study of domestic and foreign hydrographic surveying specifications

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Abstract. In view of the problems such as GB 1212327-2022, which has just been released and implemented but still has not been interpreted and analyzed in a timely and comprehensive manner, the main contents and changes of the latest version of the international hydrographic standard are comparatively studied by sorting out the existing data and drawing on the opinions and suggestions of scholars engaged in hydrographic survey industry. Secondly, it compares the main contents and changes of GB 1212327-2022 and GB 1212327-1998, and summarizes the background of the changes and the significance of the revision. Finally, the author analyzes the main contents of the international hydrometric standards and the national standard hydrometric standards, compares the differences between the two, dialectically views the advantages and disadvantages of the two, which aims at promoting the conformity with the international standards, promoting the continuous improvement of Chinese hydrometric standards, and serving the army, national defense and other industries.

Keywords: Comparative study; Hydrographic survey; International standard; National standard

1 Introduction

The birth of hydrographic measurement standards can be traced back to Europe in the late 18th and early 19th centuries [1]. The wave of navigation stimulated more and more countries to explore the oceans around the world, while also driving the growth of ocean trade. In order to ensure the safety of navigation and trade, it was necessary to develop a sufficiently economical and safe route [2]. Therefore, more and more people were engaged in hydrographic surveying work, and developing a unified set of hydrographic surveying standards became an urgent need for those engaged in hydrographic surveying at that time. In modern times, with the development of high-precision and cutting-edge technologies such as GPS, countries have begun to attach importance to the once overlooked ocean, invested more and more efforts in the development and utilization of marine resources, and formulated and updated their own standards, aiming to fully ensure their legitimate rights and interests.

Z. Wang et al. (eds.), *Proceedings of the 2023 2nd International Conference on Public Service, Economic Management and Sustainable Development (PESD 2023)*, Advances in Economics, Business and Management Research 273,
https://doi.org/10.2991/978-94-6463-344-3_73

In 1957, the Seventh International Hydrographic Congress (IHC) was held, and participating countries officially began discussing the establishment of hydrographic standards [3]. The first edition of S-44, titled "Recommended Accuracy Standards for Hydrographic Surveying," was published in January 1968. Since then, IHO has made efforts to regularly update this standard to keep up with existing technologies and methods, and it has now been updated to the latest S-44 6th edition in 2020[4].

In order to keep up with the development trend of international hydrographic surveying and further standardize the various works of China's hydrographic surveying industry, a series of measurement specifications and technical regulations have been successively issued and implemented in China [5]. Until today, in the context of the update of the International Hydrographic Survey Standard to the 6th edition of S-44, China's hydrographic survey specifications have followed closely and have also been updated to the 2022 edition [6]. Prior to this, many scholars had conducted their own analysis and comparative research on the previously published international standards and domestic norms, but due to the limitations of publication time, they were unable to interpret and analyze GB 12327-2022 in a timely manner [7].

This article conducts relevant research in the context of the recent update of the National Hydrographic Survey Standards. By summarizing and sorting out the respective contents and developments of the International Hydrographic Survey Standards and the National Hydrographic Survey Standards, a comparative study is conducted between the National Hydrographic Survey Standards and the International Hydrographic Survey Standards, in order to further analyze the latest version of the National Hydrographic Survey Standards and promote the development and gradual improvement of China's Hydrographic Survey Standards.

2 Comparative Study on International Hydrographic Standards

2.1 Classification of measurement levels

In recent years, with the vigorous development of the shipping industry, the technological level of the global shipping industry has been rapidly improved [8]. Among them, the application of satellite positioning technology has also been widely applied. The improvement of satellite positioning technology has helped hydrographic surveying personnel obtain more precise, real-time, and accurate positioning data and results, and also provided more opportunities and higher requirements for the development of hydrographic surveying, resulting in the emergence of superior surveying [9]. In the sixth edition of S-44, a new and more stringent super measurement was proposed, which is an extension of super measurement and has the strictest uncertainty, data coverage requirements, and data coverage requirements [10]. In the sixth edition of S-44, it is explicitly stipulated that super measurement is only limited to key areas such as port areas, berthing areas, waterways, straits, and shallow water areas. This is because super measurements often require more rigorous and accurate measurements of the terrain and water depth of the seabed, typically using tools such

as scanning sonar. In deep water areas, the accuracy of side scanning sonar is affected by water depth and is prone to data bias. Therefore, in order to improve measurement accuracy, the implementation of superelevation measurement is usually chosen in shallow water areas. In addition, in shallow water areas, there are often more navigational activities and more dense offshore facilities, which also puts new requirements on the measurement of navigation channels. By using super measurements, surveyors can obtain more accurate data, help maintain the navigation safety of navigation channels, protect the marine environment, and other aspects. The main technical requirements for super measurement are shown in Table 1.

Table 1. Main technical requirements for ultra deep water depth measurement

grade	water depth THU	water depth TVU	feature detection	feature search	depth coverage rate
superior grade	1m	a=0.15m b=0.0075m	Cube side length＞0.5m	200%	200%

The significance of introducing the concept of superior measurement and related indicator requirements is as follows:

1.Improving the accuracy of hydrographic measurement: Superelevation measurement can provide high-precision basic data, and incorporating it into hydrographic measurement standards can improve the accuracy and credibility of hydrographic measurement, helping to better meet the application needs of the marine field.

2.Standardizing the application of super measurements: Incorporating super measurements into hydrographic standards helps to standardize the application of super measurements, improve the comparability and credibility of super measurements, and promote the development and application of super measurement related technologies.

3.Promoting the development of ocean surveying and mapping: Incorporating super surveying into hydrographic standards can promote the development of ocean surveying and better support the marine economy and national security undertakings. As an emerging measurement level standard, superior measurement will also play an important role in the future development trend. With the continuous progress of measurement technology, the accuracy and reliability of ultra precision measurement will also be further improved. In addition, with the support of future big data and artificial intelligence, it is possible to conduct more in-depth analysis and application of superior measurement data, further improving its application value and significance.

Therefore, incorporating super measurements into hydrographic standards is a necessary and significant measure, which can improve the accuracy and credibility of hydrographic surveys, standardize the application of super measurements, and promote the development of marine surveying.

2.2 Measurement error and uncertainty

The measurement standard in S-44 version 5 defines the total vertical uncertainty, which refers to the degree of inaccuracy in water depth measurement caused by various errors when measuring water depth in the vertical direction [11]. It can also be understood as the uncertainty of corrected depth, but this version of the standard only spec-

ifies specific requirements for water depth measurement. The 6th edition also comprehensively stipulates the total vertical uncertainty requirements for measurement elements above the vertical reference plane, such as fixed targets with important navigation significance, elements of general navigation significance, and clearance height. This reflects the continuous progress and improvement of the standard, as well as the flourishing development of modern hydrographic measurement technology, especially the emerging high-precision measurement technologies such as satellite positioning technology, satellite altimetry technology, and multi beam bathymetry. More measurement elements are needed to ensure measurement accuracy, thus putting forward new requirements for elements with important navigation significance above the vertical reference plane and elements of high clearance measurement. This means that these elements must meet certain vertical uncertainty requirements in order to be considered accurate and reliable, and to better carry out subsequent data processing and result display work to serve various industries. The specific comparative changes are shown in Table 2.

Table 2. S-44, 6th Edition, Total Vertical Uncertainty Requirements for Other Elements

Measurement element	uncertainty type	2 class/m	1b class/m	1a class/m	1a class/m	super class/m
Fixed objects with significant navigation significance above the vertical reference plane	THU	5	2	2	2	1
	TVU	2	2	1	0.5	0.25
Elements with general navigation significance above the vertical reference plane	THU	20	20	20	10	5
	TVU	3	2	1	0.5	0.3
Clearance height/range line/sector light height	THU	10	10	50	20	1
	TVU	3	2	1	0.5	0.3

From this, it can be seen that the significance of the improvement in this aspect of S-44 version 6 is as follows:

1. Improve measurement accuracy: When conducting vertical measurements, calculating the total vertical uncertainty can evaluate the accuracy and reliability of measurement results, thereby improving measurement accuracy.

2. Enhance the comparability of measurement results: By calculating the total vertical uncertainty, the differences between different measurement results can be evaluated, thereby comparing the accuracy and reliability of different measurement methods, ensuring the comparability of measurement results, and facilitating the analysis and comparison of different measurement results.

3. Increase the repeatability of measurement: By calculating the total vertical uncertainty, the error range of the measurement results can be determined and used as a reference. When conducting repeated measurements, the error can be reduced, thereby increasing the repeatability of the measurement.

4. Guiding Engineering Surveying and Scientific Research: The requirements of S-44 6th edition have important guiding significance for vertical engineering survey-

ing and scientific research, helping surveyors choose appropriate measurement methods and improving the accuracy and reliability of measurement.

3 Comparative Study on Domestic Hydrographic Survey Standards

3.1 Precision of water depth point plane position

The accuracy of the plane position of the water depth point is related to factors such as the accuracy of measuring equipment, the water environment where the water depth point is located, the method of measuring data processing, and the selection of benchmarks [12]. When conducting water depth measurements, it is necessary to fully consider these factors and take appropriate measures for accuracy control to ensure the accuracy and reliability of the water depth measurement results. The comparisons of plane position accuracy of water depth points between the 1998 and 2022 versions are shown in Table 3.

Table 3. Comparisons of Plane Position Accuracy of Water Depth Points

	1998 Edition				
range	Mapping on a scale greater than 1:5 000	(Including) 1:5 000 and greater than (including) 1:100 000 scale mapping	Mapping at a scale of less than 1:100 000		
index	The mean square error of the positioning point shall not exceed 1.5mm on the diagram	The mean square error of the positioning point shall not exceed 1.0mm on the diagram	The mean square error of the positioning point shall not exceed 100m on site		
	2022 Edition				
range	First class measurement or mapping at a scale greater than 1:2000	Second class measurement or mapping at a scale greater than 1:5000	Third class measurement or less than (including) 1:5 000 but greater than 1:25 000 scale	Fourth class measurement or less than (including) 1:25 000 and greater than (including) 1:50 000 scale	Fifth class measurement or less than 1:50 000 scale
index	Limit error of plane position (95% confidence) not greater than 1m	The limit error of plane position (95% confidence) shall not exceed 2m	The limit error of plane position (95% confidence) shall not exceed 5m	Limit error of plane position (95% confidence) not greater than 10m	Limit error of plane position (95% confidence) not greater than 20m

The following conclusion can be drawn from the above table:

1. GB 12327-2022 comprehensively considers the scale and measurement level compared to GB 12327-1998. The combination of scale and measurement level can not only more accurately reflect the complexity and accuracy requirements of hydrographic surveys, but also better ensure the accuracy and reliability of the produced

charts. Simultaneously considering scale and measurement level has also improved the adaptability of regulations, especially in narrow waterways, important sea areas, and other water areas.

2.At the same time, the limit error of the plane position is used to replace the mean square error of the positioning point on the graph. Although the mean square error of the positioning point can reflect the measurement accuracy, it is only a statistical feature and cannot well reflect the accuracy changes in the measurement data. The limit error of the plane position not only reflects the overall measurement accuracy, but also allows for a more comprehensive and accurate analysis of the data, and is more in line with international standards.

3.2 Positioning

In GB 12327-2022, the 5.4 GPS measurement in GB 12327-1998 has been modified to the GNSS control measurement in the new version [13]. According to the "5.1 level division" in the GB/T 18314 Global Positioning System Measurement Specification, "8.1 GNSS measurements of E level (including) and above shall be carried out in accordance with GB/T 18314" has been added. GNSS control measurement refers to a measurement method that uses global satellite positioning system (GNSS) observation data, relative position measurement of GNSS reference stations, and satellite orbit information to calculate three-dimensional coordinate control points and their accuracy levels in a large area, in order to support the design, construction, and maintenance of hydrographic engineering. In the hydrographic measurement specifications, the accuracy level of GNSS control measurement is usually determined based on the requirements for the use of control points and the actual measurement accuracy level [14]. The requirements for the use of control points can be determined based on factors such as their positioning accuracy requirements, measurement range, and complexity of terrain and geomorphology in the project; The measurement accuracy level needs to be quantitatively estimated and analyzed, taking into account the sources of GNSS measurement errors and their influencing factors. Changes have also been made to the indicators for sea control level GNSS measurements in the 2022 edition of the hydrographic survey specifications [15]. Sea level GNSS measurement refers to high-precision and highly reliable global positioning system (GNSS) measurements conducted in the marine field to achieve applications such as positioning, navigation, and measurement in the marine field. Compared with general GNSS measurements, this measurement is mainly applied in fields such as surveying and mapping, navigation channels, ports, submarine pipelines, and marine resource development in the marine field, with higher requirements for accuracy and reliability. The following Table 4 compares the indicators of sea control level GNSS measurements in the 1998 and 2022 versions of hydrographic surveys.

Table 4. Comparisons of GNSS measurement indicators at sea control level

project	grade					
	H_1		H_2		Hc	
	1998Edition	2022Edition	1998Edition	2022Edition	1998Edition	2022Edition
satellite elevation/(°)	≥15	≥15	≥15	≥15	≥15	≥15
Number of simultaneous observation satellites	≥4	≥6	≥4	≥6	≥4	≥6
Observation period length/min	60	40	45	40	30	30
Number of observation periods	≥2	≥2	≥1	≥1	≥1	≥1
sampling interval/s	15	15	15	15	15	15
GDOP	≤6	≤6	≤6	≤6	≤6	≤6
Ring edge limit	≤8	≤8	≤10	≤10	≤10	≤10
Satellite distribution quadrant	>2	>2	≥2	≥2	≥2	≥2

Note: For receivers with positioning software, while ensuring observation accuracy, the observation period length should not be less than 10 minutes and the sampling interval should not be less than 20 seconds.

From the above table, it can be seen that there has been a significant change in the length of observation satellites and observation periods in GB 12327-2022 compared to GB 12327-1998. At the same time, the number of observation satellites has increased and the observation duration has shortened, which also reflects the innovation of satellite technology in China. These changes also have significant implications:

1.Improved measurement accuracy. Observing multiple satellites simultaneously and obtaining data from multiple satellites for analysis and comparison can improve measurement accuracy, make measurement results more accurate, and thus ensure the accuracy and reliability of hydrographic measurement data.

2.Improved work efficiency. Observing multiple satellites simultaneously shortens the overall time of the entire observation process, enabling measurements to be completed more quickly and accurately.

3. More in line with international standards. The use of simultaneous observation of multiple satellites has become a widely adopted measurement method internationally, which is in line with international standards and can enhance China's international influence and competitiveness in the field of hydrography.

4 Summary

This article first starts with the classification of measurement levels, measurement errors, and uncertainty, and compares and analyzes the 5th and 6th editions of S-44. It highlights the continuous updating and improvement of S-44 publications, and further refines and strictly defines measurement levels and accuracy indicators. Secondly, a comparative study was conducted on water depth measurement and positioning between GB 12327-2022 and GB 12327-1998. Specific explanations were provided on the changes in measurement indicators of water depth point plane position accuracy and the emerging GNSS control measurement. It was clearly pointed out that the update of the national standard hydrographic measurement specifications is more in line with international standards and the actual situation in the implementation process of hy-

drographic measurement in China. In order to further benchmark international standards and address their gaps, the final chapter follows the example of Chapter 3 and compares and analyzes the applicable scope and accuracy indicators of water depth measurement and positioning, aiming to summarize the laws and shortcomings of the national standard for hydrographic measurement. While absorbing and drawing on international standards, it also understands advanced hydrographic measurement technology and management models. It should be clarified that the formulation of national norms and international standards adheres to a principle that is applicable to the actual situation of hydrographic surveys; Due to the varying levels of development and actual needs of hydrographic surveying in various countries, there are differences in their hydrographic surveying norms and international standards. Therefore, this difference should be viewed dialectically, and learned from and complemented by strengths and weaknesses.

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