International Hydrographic Review, Monaco, LXV(1), January 1988

THE PRESENT AND FUTURE OF THE CHINESE SURVEYING AND CHARTING

by LIU CHANG GUI (*)

The ocean covers more than seventy per cent of the total area of the earth, so its political, economical and military values have attracted great human attention since early time. Along with the development of ocean related activities in the recent twenty to thirty years, oceanic economics have become an important factor for countries concerned with the sea. Many countries in the world specify ocean study as one of the important scientific research areas and at the same time pay more and more attention to ocean surveying and charting. As a result, the science and technology of ocean surveying and charting developed rapidly in these countries. That is true for China, where science and technology in this respect developed continuously. Here is a brief description of China's main status on ocean surveying and charting and also some ideas about future development in these areas.

1. THE MAIN STATUS OF OUR OCEAN SURVEYING AND CHARTING

China is situated at the west coast of the Pacific Ocean and is a country with a long coastline bordering a vast sea area as well as the possessor of numerous islands. Therefore, ocean surveying and charting plays an important role not only in China's ocean exploitation and the use of ocean resources, but also in improving our socialist economy and defence constructions.

After the year 1949, surveying and charting activities developed extensively. Hydrographic ranks expanded from small to large, and surveying and charting equipment was updated continuously. Technological effort included the development and manufacture of high precision electronic positioning systems, 10,000-meter echosounder, side scan sonar, sea gravimeter, etc., and the utilization of the technology of microwave, laser, computer and artificial earth satellite positioning. As for charts, the variety and quantity has increased year by

(*) Director, Mapping Agency of the Navigation Guarantee Department, Chinese Navy Headquarters, 4 Kaifeng Road, Tianjin, China.

year together with a continuously improved quality. As a result, offshore nautical charts have been completely updated several times; to date more than 1300 sheets of nautical charts of China's waters and more than 1200 sheets for external waters have been published for domestic use, and more than 100 sheets are supplied for foreign use. The following is a brief account of the status of our country's surveying and charting works:

(1) Survey

(a) Control survey and topographic survey

Control survey is the foundation of ocean surveying and charting. In the early days, just after the founding of the People's Republic of China, surveying works were conducted along the coast. Plane control for a region was an independent system, while calculations were made directly on the surface of the 1880 Clarke spheroid applying summarized small area figure adjustment. In 1952, the spheroid used was replaced by Bessel's. In 1954, according to China's unified requirements, the spheroid used was changed again to Krasofsky and calculations were made on the Gauss-Krüger projection surface. In the 1970s, photoelectric, laser and microwave ranging, etc., were introduced into surveying work, thus further ensuring the accuracy of the control survey. The height datum used in ocean surveying and charting is 'Huanghai Height Mean Sea-Level', the local sea-level is adopted for the islands far away from the mainland.

Topographic and coastal survey is mainly used to provide topographic and coastal data of regions close to the sea for the compilation of charts. The plotting scale used should be the same as the bathymetric survey scale and the land area proximate to the sea survey area from a charting standpoint. Sheets are freely subdivided and in line with local conditions by following the principle that the whole survey district should be covered by a minimum number of sheets. Starting from 1958 normal topographic and coastal surveys were carried out extensively according to the 'Specification of plane-table survey' promulgated by our country. From 1958 to the end of 1986 China had completed a total of more than 1500 sheets of topographic and coastal plots on various scales, covering an area of more than 2,300 square kilometers and a coastline of more than 22,000 kilometers. This fulfilled the requirements for compiling and publishing charts, and also provided the necessary information for the improvement of the national economy.

(b) Bathymetric survey

Bathymetric survey is a main component of ocean surveying and charting; such survey consists of the measurement of water depths of different bottom points from the depth datum and, also, the measurements to be able to position the data.

Not long after the establishment of the People's Republic of China, the hydrographic surveying team was organized and bathymetric surveys for some major areas carried out. In 1958, normal bathymetric surveys for the whole country commenced. Along with the development of scientific technology, the

ocean surveying and charting have achieved considerable progress and improvement. The fleet of surveying vessels expanded from only general purpose low tonnage ships to 90 to 3000 ton specialized surveying vessels. Facilities were updated from lead-line and ordinary survey instruments to high precision shallow water echo sounder, 10,000-meter echo sounder and side scan sonar, while the surveyed areas were extended from coastal and offshore to medium and pelagic areas. By the end of 1986, the basic survey for the Chinese waters had been completed with a scope of more than 1300 sheets of bathymetric survey plots and more than two million kilometers of sounding lines. The completion of such basic survey is necessary for the development of the economy as well as resource exploration and scientific research, and China has gained tremendous economic and social benefits.

(c) Determination of the datum for sounding reduction

China's waters are extensive and tidal changes rather complicated. To analyze the tidal phenomena in different sea areas and to obtain information about changes, a large number of tidal stations were established. After the commencement of the basic survey of the Chinese waters in 1958, several temporary tidal stations were established additionally. In order to meet the accuracy requirements of bathymetric survey, the water level is corrected by the method of cotidal zones under the condition that the survey is within the effective control range of the tidal station and only small tidal range and time difference changes exist.

The datum used for sounding reduction is different for different countries. Since 1949, based on the actual conditions of tidal changes all over the Chinese waters, and under the principle of both ensuring navigation safety of vessels and making full use of navigable channels, our hydrographic authority decided to use the theoretically lowest water as the datum for sounding reduction in Chinese waters. Actually, it has been used since 1958. In 1975, after making a thorough investigation and study, the reference datum was unified and from that time the confused situation was removed.

(d) Surveys of harbours and inland waterways

As hydrographic conditions at the river mouths are complicated and change frequently, bathymetric surveying must be carried out often in order to give assistance to channel dredging and to raise transportation benefits. Thus we organized survey and charting teams for harbours and inland waterways in 1955, specialized in surveying and charting of inland waters, navigable channels and harbours. Up to now, more than thirty harbours, from Dandong Harbour in the north to Sanya Harbour in the south, have been surveyed and their basic charts produced on scales larger than 1:10,000. In addition, repetition surveys and depth examinations are carried out periodically. During the last thirty years, more than 1.2 million sounding line kilometers have been surveyed and various atlases for river navigation have been completed and published.

(e) Marine gravity measurement

Marine gravity in our country was not measured before 1966. At the beginning, bottom gravity measurements on the continental shelf were carried out by using the subsea gravimeter. Sea surface gravity measurements were started in 1969. The comprehensive marine survey was started after the year 1976. Since 1980 the production of marine gravimeters in China developed rapidly; our home-made gravimeters Model ZY and DZY-2 have a high precision, and very good stability and reliability. The anti-interfering ability of these instruments reaches 200 gals, with an average daily drift of 0.1 mgal. The main feature of another type of gravimeter, Model DZV, matches the standards of similar advanced equipment on an international level.

(f) Positioning

For ocean surveying, positioning and sounding are the two major tasks. At present, four kinds of positioning methods are used for bathymetric surveying in China, i.e. microwave ranging system, radio navigational positioning system, satellite navigational positioning system and optical instruments such as theodolite, sextant, etc. Along with the development of modern science and technology, China's positioning facilities used for surveying also developed very rapidly. We began to use "Coordinator C" for basic surveying works at sea in 1958. Since 1966 "Hangce 1" navigator, "Jindao-4" radio positioning system, "691-A" navigational satellite receiver, a marine microwave ranger and an infrared ranger have been manufactured domestically and used in offshore bathymetric surveying. In the last twelve years, radio navigation technique improved to the level of integrated navigation systems with a central computer; thus the positioning system used in ocean surveying becomes an automatic system. Furthermore, some foreign positioning systems such as ARGO, Pulse-8, shallow water doppler sonar and integrated systems, etc., were imported to meet the various requirements of ocean surveying in China.

(g) The automatic system for offshore bathymetric survey

Along with the development of computer techniques many countries in the world have developed their own automatic survey system. During field operations all acquisition and logging of data, navigation and positioning are accomplished completely by computer. It improves the accuracy and method of surveying and reduces the labour intensity. Our research on bathymetric survey automation started rather late, actually at the beginning of the 1980s. Although the time is so short, only a few years, gigantic progress has been achieved. Recently, after the production of an automated surveying system for channel dredging, we also completed similar work on an automatic offshore bathymetric survey system.

In the automatic offshore bathymetric survey system microprocessor technique is used for the offshore bathymetric survey. Utilizing the real time control and calculation ability of the microprocessor, the automatic offshore bathymetric survey and automatic plotting of depths are realized. In addition, tape recorded data are supplied for post processing and automatic charting. The applied

software is programmed according to the requirements of offshore navigation and bathymetric surveying.

(2) Cartography

(a) Compilation of nautical charts

As nautical charts are used directly for positioning during navigation, and are vital to navigation safety, they are a major chart product and are most advanced in development in our country. According to their scale and usage, nautical charts are divided into three classes, i.e. general charts of the sea area, sailing charts and harbour charts.

General charts are usually drawn on scales of 1:2,000,000 and smaller. They are usually supplied for the use of organizations at all levels and for naval as well as commercial vessels to study the sea area and draft a navigational plan.

Sailing charts are usually drawn on scales of 1:100,000 to 1:200,000. The scales of coastal charts are 1:100,000 to 1:190,000 and those of offshore sailing charts are 1:200,000 to 1:490,000. Scales of 1:500,000 to 1:990,000 are also used for offshore sailing charts and 1:1,000,000 to 1:2,000,000 are for pelagic sailing charts. They are supplied mainly to naval and commercial vessels for sailing along the coast or in coastal, offshore and pelagic areas.

Harbour charts are usually drawn on scales larger than 1:100,000, depending upon the area of the harbour covered. They are supplied mainly for naval and commercial vessels entering into or departing from harbours, anchorages or passing through narrow channels, and also for harbour construction and administration.

Projection of nautical charts: for charts on scales of 1:20,000 or larger, the Gauss-Krüger projection is used; on scales smaller than 1:20,000, Mercator projection is generally used. Those sets of nautical charts having a common scale of 1:1,000,000 or smaller for the whole set utilize the unified standard parallel; all other charts utilize the middle parallel of the chart itself as the standard parallel.

The contents shown on nautical charts fully embody the special needs for navigation, stressing depiction of appropriate elements of the sea area, correctly reflecting geographical features therein and their changes, and indicating navigational obstructions correctly, distinctly in as much detail as possible. As for the land portion, stress is on showing navigation objects and surface and land features along the coast.

Since 1949, quantities of our nautical charts covering the coastal area for the use of domestic vessels have been fully revised three times. At each revision, improvements were made, not only in contents but also in method of presentation. The compilation and publication of the third generation charts marked the entry into a new stage in the development of our nautical charts. We have laid down a complete cartographic specification as well as symbol and abbreviation standards for nautical charts, thus achieving normalization, standardization and serialization of cartography. As the nautical chart originated from navigation, along with the development of navigation technology the variety of nautical charts increased

continuously. After the 1970s, we compiled and published, in addition to ordinary nautical charts, a variety of special nautical charts, such as Loran-A hyperbolic navigation charts, Loran-C hyperbolic navigation charts, etc. Circular lattice charts, radar navigation charts and great circle sailing charts are also compiled and published.

(b) Compilation of nautical charts for the use of foreign vessels

In order to ensure navigation safety for foreign vessels, nautical charts for the use of foreign vessels have been compiled and published since 1976.

The design of sheet coverage of charts for foreign vessels fully considers the requirements of these vessels. The method of expression is to facilitate use by foreign mariners; for example, these charts are additionally annotated with necessary English descriptions, geographic names are given with Chinese phonetic alphabets, etc. These nautical charts show bottom topography, aids to navigation, navigational obstructions, hydrographic elements, etc.

To improve their quality, we are commencing to plan an overall revision of them, including new specifications for chart compilation, cartographic symbols, etc.

(c) Compilation of special charts

Nautical charts are primarily used for navigation; generally, they cannot meet the requirements of the other usage. Along with the development of navigation technology China has compiled and published a number of special charts.

Special charts are also called thematic charts, which are charts showing some kind of special content. At present, special charts develop very rapidly, the varieties increase continuously; objects shown on charts are quite widely spread, involving different fields of oceanography. Special charts we have compiled and published include those for fishing, marine gravity and magnetic anomaly depiction, bottom geological structure, tidal current prediction, island charts, etc.

To meet the requirements of marine engineering for design and exploration, China started to print large scale marine topographic charts in 1983 and has progressed well. Marine topographic charts reflect the overall geographical status of a sea area, showing especially more detail in bottom and coastal features than ordinary nautical charts.

(d) Compilation of situation charts

Situation charts are usually put together from several sheets which reflect the natural geographical features and political and economic situations. As for their content, equal stress is laid on both sea and land. Land and marine topography are expressed by hypsometric method in addition to isolines, thus land features may have more stereoscopy. More than thirty sets of situation charts for various sea areas have been published in succession, for example: North-West Pacific Ocean Situation Chart (1:3,000,000, 16 sheets), Situation Chart of the

World (1:10,000,000, 12 sheets), etc. All of them have rich content, harmonious colours, distinct level divisions, and have been well received by the users. These situation charts may be used as either a wall chart for a bird's eye view of the overall situation or a reference chart to be placed on table.

(e) Compilation of river sailing atlases

A river sailing atlas reflects the land and hydrographic features of rivers, serving as a necessary reference document for shipping administration, transport organization and navigation safety assurance. We have compiled and published successively the Changjiang River Sailing Atlas, Zhujiang River Delta Sailing Atlas, Xijiang River Sailing Atlas, etc. A river sailing atlas usually consists of an introductory map including an index chart, distance table, situation chart, plot showing depth datum and corrected levelling curves, hydrographic and meteorological charts, etc. To ensure its accuracy, the Gauss-Krüger projection is utilized. These atlases are rich in contents and fairly reflect overall geographical features and sailing peculiarities of the river. They are of a high pragmatic value and have been well received by shipping organizations.

(f) Compilation of chart atlases

The chart atlas is the chart work of a fairly high scientific nature. It summarily reflects the research achievements in ocean surveying and charting as well as in many other aspects in connection with ocean and sea. In order to make the atlas meet the required completeness in contents and tally with the real situation, various scientific information must be collected.

The first big volume chart altas compiled was the Pacific Ocean Chart Atlas published in 1960, which is supplied to organizations at different levels to study the geographic features and sailing peculiarities of the Pacific Ocean. Atlas contents are the situation chart, nautical chart, time zone chart, tables of distances between important ports and other information and statistical tables in connection with the Pacific Ocean. The whole volume of the atlas has plentiful contents, stresses main points, is rich in practical nature. It does not only possess the characteristics of an atlas but also gives consideration to the traditional practice of nautical charts.

After 1963, we compiled and published, one after another, Huanghai Sea and Bohai Sea, Donghai Sea, and Nanhai Sea Harbour and Anchorage Chart Atlases. These are our small size coastal nautical chart atlases comprising a general chart, division charts, harbour and anchorage charts, written description, etc. The text describes generally the geographic situation, anchorage and wharf conditions, etc., of the sea area. The atlas is easy to read because it presents a contrast between charts and written description. Since the contents of the atlases are systematic and comprehensive, they may be used either for analysis and study of geographic features of sea areas or as a reference document during sailing. They are well received by mariners.

(g) Engraving is used in the production of all charts

Engraving is a new technique recently employed when producing a chart original. As compared to ordinary drafting, engraving possesses many advantages. For example, it reduces the time of chart production, improves the quality of chart production techniques and also promotes the development of chart production in the direction of automation. The utilization of engraving in our chart production was initiated in 1980, and at present this method is used for the production of all charts. The engraving method we generally use is mechanical engraving. The tools we use are mainly in two series: the first is a set of tools developed on the basis of a floating arm engraver, while the second set was developed on the basis of a ring engraver. Both kinds of tools can achieve ideal results for those familiar with their use. Symbols having definite shape and norm can generally be engraved by a symbol guide, numbers by a writing apparatus and text by use of transparent letters. When shading is required, we usually make a stripping plate and colour it in the printing process.

2. FUTURE DEVELOPMENT OF OCEAN SURVEYING AND CHARTING

In future, our ocean surveying and charting technology will undergo a still greater development in the following respects:

(1) Automation of surveying

Looking at the direction of development, a reasonable automation of bathymetry should provide multi-beam sounding equipment which will not only cover a wide swath of the sea floor but also possess the ability to detect the quality of a shallow bottom; sensing equipment for measuring pitch and roll, and settlement and squat of a vessel, to correct the depth of water and the plane position of the sounding points; tidal information telemetry, transmission and logging equipment to allow corrections to the water level automatically in real-time; and a small computer or microcomputer which suits the marine environment, to process the information obtained. The equipment also would have the function of real-time printing as well as tracking and depth plotting.

(2) Remote sensing bathymetric surveying system

Along with the development of space flight technology, space sensor technology and laser technology, water depth measurement by remote sensing is being developed progressively. In China, we are testing this application by using land satellite information to carry out depth measurements in shallow water areas. Water depth measurements in sea areas by remote sensing primarily requires development of an airborne remote sensing system, and China has launched research on that subject.

(3) Automation of charting

Utilization of computer techniques to achieve computer-assisted chart production is coming true. Automation of Chinese land map production has developed to the extent that some hardware, imported or domestic, has been acquired, trials for various cartographic methods initiated, and a partial cartographic software system established. All of these resources have been put initially into practical use in teaching cartography automation and map production. Some progress in this respect has also been achieved in operational charting. A computer controlled automatic plotter was manufactured and put into service in 1984. The plotter can make calculations of the basic mathematics of charts as well as the transformations between various projections; it can also draft automatically the hyperbolic lattice on radio navigation charts and any other curves or symbols which can be expressed by a mathematical model.

For complete automation of chart production, we will import a set of foreign automatic mapping systems, do a computerized study of the comprehensive theory for automation of charting and establish a data base. First of all, we will study and develop a high level data base management system, and then digitize the already existing graphical documents. In this system, the following shall be achieved successively: automatic compilation of charts; processing various documents of automated surveying and producing charts directly; establishment, renewal, maintenance and use of hydrographic and cartographic data bases; revision of and corrections to charts; development of new types of charts and automatic production of other special charts; synthetic use of various surveying documents, etc.

(4) Electronic chart

The electronic chart is a new kind of chart which has very good prospects. With the appearance of such a chart, many questions regarding cartography and administration of charts, etc., may be raised. According to the achieved progress of ocean survey automation, data storage, and redisplay techniques, we definitely have the conditions to study and produce electronic charts; we are striving to have our country's electronic chart appear in the near future.

At present, our country is faced with a challenge of modern technical revolution. Ocean related activities are rapidly developing. As ocean surveying and charting is considered a basic work, it must meet the present requirements and provide for the future development of ocean activities. Therefore, it is expected that Chinese ocean surveying and charting efforts will continue to improve.