# IV. MAINTENANCE OF INLAND WATERWAY AND AIDS TO NAVIGATION IN CHINA*

## 1. Foreword

This paper introduces the maintenance situation of inland waterway and aids to navigation in the People's Republic of China. It is divided into three parts, the first part describes briefly China's inland water system, inland waterway and inland waterborne transportation. The second and third parts introduces respectively the maintenance of inland waterway and maintenance of aids to navigation in China. Since the founding of new China, the inland waterway work has made great progress and significant contributions to the inland waterborne transportation industry and even to the whole construction and development of the national economy. However, as China's territorial area is so large, her history of inland waterborne transportation is so long and the inland waterway works is so complicated, I could only give a brief introduction to China's maintenance of inland waterway and aids to navigation with the emphasis on China's longest river -- the Yangtze (Changjiang) River.

## 2. Brief Introduction to China's Inland Water System, Waterway And Inland Waterborne Transportation

In the vast territory of China, there are a large number of rivers and lakes which make up an extensive network of inland waterborne transportation. Rivers with a drainage area of 1000 square kilometers amount to over 5800 and lakes with a water area of one square kilometer amount of over 2600. The total length of those rivers is 430000 km. Most of these rivers are abundant in water and rich in water resources and beneficial to the development of inland navigation industry in China. In the southern part of the country, rivers have large and stable discharges and are ice-free all the year round, thus navigation is flourishing; in the northern part, rivers have small and unstable discharges and are frozen in winter, so, the development of waterborne transportation is constrained.

The total mileage of navigable rivers is 110000 km. The total length of waterways with a water depth over one meter is 64000 km., 58% of the total mileage of the navigable rivers, in which, 5800 km is navigable for 1000 ton class vessels, 16900 km for 300 ton class vessels and 54800 km for 50 ton class vessels.

The Yangtze River is the largest inland water system in China, and it has 700 odd tributaries and 70000 km is navigable. The catchment area of the river is 1.8 million square kilometer. Within the river basin there are abundant resources and the economy is well developed. This river also interconnects with many lakes, railways, trunk highways and seaborne traffic, so, they form the largest communications and transportation network and have a very important economic position in China.

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The Yangtze River takes its source at the southwest slope of the Mountain Gelatantong in the Qinghai--Tibet Plateau of southwest China, and it runs through nine provinces (including one autonomous region) and Shanghai municipality. The length of the trunk is 6300 km, the longest in China and third longest in the world.

The total length of the section above Yibin is 3498 km, where the flow of the river is considerably small. In this section, the river runs through precipitous mountain valleys with swift rapids and numerous hazardous rocky shoals. Only the stretches approaching to Yibin in the lower part of the said section with a local name "Jinshajiang River" are navigable for junks and small motorboats. So, the shipping at present is underdeveloped. Below Yibin, in the low water season the minimum flow of the river is some 2000 cu.m per second, and it increases gradually on its way down the river to a minimum flow of about 6000 cu.m per second at Datong Gauge Station (the flow gauge station closest to the estuary). Here, the water flow is abundant, and the river is wide and deep. Thanks to the favorable condition for water transportation and the rich industrial and agricultural resources along both sides of the river, this section of the Yangtze River makes itself an important transport line running through six provinces and one municipality, and the shipping there is flourishing.

The Pearl River is one of the four biggest rivers in China, and it is next to the Yangtze River with regard to the navigational condition. The length of its trunk is 2167 km., the river discharge is abundant and sand content is small, and the river course is stable and has a favorable condition of navigation. There are 988 rivers in the Pearl River basin, the total length is 36000 km, of which 13000 km is navigable, the natural resources are plentiful and the industry and agriculture are well developed.

The Heilongjiang River water system is composed of the Heilongjiang River, the Songhuajiang River, the Nenjiang River, the Usuri River and some small tributaries. Among them, the Heilongjiang River and the Usuri River are boundary rivers between China and Russia. The total length of waterway in this water system is 4800 km the river flow is abundant, but is frozen in winter, so, the navigation period is only about 200 days.

The Yellow River is the second longest river in China with a total length of 5464 km. In the upstream of the river, there are rapids and valleys; the middle reaches run through the loess plateau and the channels vary frequently; in the lower reaches silts deposit seriously, the river is wide and shallow, and some obstructions are brought about to navigation, so, only a few separate sections are open to navigation, the total navigable length being 1644 km.

In the Huaihe River system, the waterways are densely distributed. The total length of the trunk and tributaries is about 20000 km. This is one of the flourishing inland transportation regions.

China is a country with long water transportation tradition. As early as 219 B.C., some 2200 years ago, our ancestors built the Xiang--Gui Canal. It was the first summit canal in the world. The construction of the Grand Canal began in 485 B.C., about 2500 years ago. Its total length is about 1700 km. It was the first and longest in the world. The Grand Canal links up five major river systems, so an extensive network of waterway is formed. After the completion of the Grand Canal, it played a very important role in the political, economic and cultural development of ancient China. Currently, the water traffic volume from Jining to Hangzhou on the Grand Canal is only next to the volume on the Yangtze River.

The barge fleet and integrated barge fleet are the principal form of freight movement on China's inland rivers. The main classes of barges operating on the rivers of China are: 50 tons, 100 tons, 300 tons, 500 tons, 1000 tons, 2000 tons, 3000 tons, and 5000 tons barges. Most of the barges operating on the main tributaries are of 300 to 500 tons class, and those operating on the Yangtze River are of 1000 and over 1000 tons class. The major commodities of freight movement are coal, petroleum, ores, iron and steel, building materials, lumber, grains, cotton, fertilizers, insecticides and general cargoes. Passenger traffic is decreased in recent years because of the booming development of highway transportation and civil aviation.

In 1994, the cargoes transported by water transportation departments amounted to 700 million tons, and the freight turnover is 170 billion ton--kilometers.

Besides the flourishing development of inland waterborne transportation on the trunk of the Yangtze River, the Pearl River, the Huaihe River, the Songhuajiang River and the Grand Canal, in the well-developed areas of the Yangtze River delta and the Pearl River delta, inland navigation is also an important transportation mode. Take Jiangsu province for example. The navigable mileage within the boundary of this province is 23787 km. In 1994, cargoes moved by water transportation amounted to 190 million tons, and the freight turnover was 32.6 billion ton--kilometers. In this province, inland water transportation makes up 39.3% of the total of highway and water transportation; in the aspect of freight turnover, inland water transportation accounts for 48%.

Among the various modes of transportation, inland water transportation is a mode that has special advantages. For the transport of bulk cargo, barges and river boats have the advantages of large capacity, high productivity and low fuel consumption. The physical size and weight of large and heavy cargo units transported by water is virtually unlimited. The throughput capacity of navigable waterway is tremendous. The investment in the construction of navigation channels is also lower than that in highway and railway, in addition, the construction of waterway does not occupy any farmland, and also has the effect of comprehensive utilization of water resources. So, in the transport of bulk cargo, such as coal, fuel and so on, inland water transportation still has a stronger competition ability as well as a tremendous potential in further development.

However, the development of inland navigation can't do without the support of the waterway department as a vanguard. The maintenance work of inland waterway and aids to navigation is the foundation of the development of inland water transportation, just as the cargo transport by trains and trucks can't do without railway and highway. At the same time, the waterway department is also a service department which has to serve shipping vessels. To guarantee the smooth passage for sailing vessels in the navigable rivers, the waterway department should first of all guarantee a sufficient dimension of waterway, including:

The depth of waterway: the vertical distance from water surface to the bottom at the shallowest spot in the waterway.

The width of waterway; the horizontal distance from one band to the other at the narrowest spot along the waterway.

The radius of curvature: the smallest arc radius on a middle line of the waterway.

Secondly, the waterway department should guarantee every mark is set in its accurate position, every light is bright and every signal is correct and exhibited timely.

Besides the above mentioned, it is also necessary to guarantee the normal operation of ship locks and navigation facilities. On some particular reaches, some specific necessities for sailing vessels should be provided so as to guarantee smooth passage and safety of vessels.

For example, on the mountainous river with torrential rapids, it is necessary to set up some heaving stations to help the upbound vessels ascend the rapids. In the foggy area, it is necessary to observe the fog condition and exhibit fog signals. In additions, a sufficient cross-section coefficient should be guaranteed for an artificial canal or restricted channel with rocky bottom.

To further realize the standardization and modernization of inland navigation so as to bring the potential of inland water transportation into full play, and to raise the capability of communications and transportation, the State promulgated "Inland Navigation Standard of People's Republic of China" after an extensive investigation and study.

| Class of waterway | Tonnage category | Dimension of barge L*B*D (m) | Dimension of barge fleet L*B*D (m) | Dimension of waterway (m) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Depth | Width | | Radius of curvature |
| | | | | | Single lane | double lane | |
| I | 3000 | 75*16.2*3.5 | (1)350*64.8*3.5<br>(2)271*48.6*3.5<br>(3)267*32.4*3.5<br>(4)192*32.4*3.5 | 3.5~4.0 | 120<br>100<br>75<br>70 | 245<br>190<br>145<br>130 | 1050<br>810<br>800<br>580 |
| II | 2000 | 67.5*10.8*3.4<br>75*14*2.6 | (1) 316*32.4*3.4<br>(2) 245*32.4*3.4<br>(3) 180*14*2.6 | 3.4~3.8<br><br>2.6~3.0 | 80<br>75<br>35 | 150<br>145<br>70 | 950<br>740<br>540 |
| III | 1000 | 67.5*10.8*2.0 | (1)243*32.4*2.0<br>(2)238*21.6*2.0<br>(3)167*21.6*2.0<br>(4)160*10.8*2.0 | 2.0~2.4 | 80<br>55<br>45<br>30 | 150<br>110<br>90<br>60 | 730<br>720<br>500<br>480 |
| IV | 500 | 45*10.8*1.6 | (1)160*21.6*1.6<br>(2)112*21.6*1.6<br>(3)109*10.8*1.6 | 1.6~1.9 | 45<br>40<br>30 | 90<br>80<br>50 | 480<br>340<br>330 |
| V | 300 | 35*9.2*1.3 | (1)125*18.4*1.3<br>(2)89*18.4*1.3<br>(3)87*9.2*1.3 | 1.3~1.6 | 40<br>35<br>22 | 75<br>70<br>40 | 380<br>270<br>260 |
| VI | 100 | 26*5.2*1.8<br>32*7*1.0<br>32*6.2*1.0<br>30*6.4*1.0 | (1)361*5.5*2.0<br>(2)154*14.6*1.0<br>(3)65*6.5*1.0<br>(4)74*6.4(7.5)*10 | 1.0~1.2 | 25<br>15<br>15 | 45<br>30<br>30 | 105<br>130<br>200<br>220 |
| VII | 50 | 21*4.5*1.75<br>23*5.4*0.8<br>30*6.2*0.7 | (1)273*4.8*1.75<br>(2)200*5.4*0.8<br>(3)60*6.5*0.7 | 0.7~1.0 | 10<br>13 | 20<br>25 | 85<br>90<br>100 |

L --- Length B --- Breadth D --- Draft

The purpose of the formulation of Inland Navigation Standard is to form gradually an interconnected water network in a water system, even in the whole country, through the standardization of inland waterway, so as to bring the inland transportation's economic and social function into full play.

The range of application and technical requirement of the above standard should be carried out with concerned regulations.

Currently, according to the arrangement made by the Ministry of Communications, various waterway departments are carrying out the classification work of inland waterway. After the rivers are rationally classified through synthetic technical and economic study, not only some rules will be provided for the waterway department, but also related factors, such as the types of sailing vessels, dimensions of ship locks and crossing river bridges and cables, etc. will be coordinated and matched with the standards, so a series of classes will be formed to promote standardization, serialization and generalization of inland navigation. Thereby the waterway work will bring about a strong motive force upon the further promotion of inland water transportation, and make great contributions to the development of the national economy.

Navigation Clearance Dimension for On-water River-crossing Structure

| | Natural and canalized river (m) | | | | Restricted waterway (m) | | | |
|---|---|---|---|---|---|---|---|---|
| | $H_m$ | $B_m$ | b | h | $H_m$ | $B_m$ | b | h |
| I-(1) | 24 | 160 | 120 | 7.0 | | | | |
| I-(2) | 18 | 125 | 95 | 7.0 | | | | |
| I-(3) | 18 | 95 | 70 | 7.0 | | | | |
| I-(4) | 18 | 85 | 65 | 8.0 | 18 | 130 | 100 | 7.0 |
| II-(1) | 18 | 105 | 80 | 6.0 | | | | |
| II-(2) | 18 | 90 | 70 | 6.0 | | | | |
| II-(3) | 10 | 50 | 40 | 6.0 | 10 | 6.5 | 50 | 6.0 |
| III-(1) | | | | | | | | |
| III-(2) | 10 | 70 | 55 | 6.0 | | | | |
| III-(3) | 10 | 60 | 45 | 6.0 | 10 | 85 | 65 | 6.0 |
| III-(4) | 10 | 40 | 30 | 6.0 | 10 | 50 | 40 | 6.0 |
| IV-(1) | 8 | 60 | 50 | 4.0 | | | | |
| IV-(2) | 8 | 50 | 41 | 4.0 | 8 | 80 | 66 | 3.5 |
| IV-(3) | 8 | 35 | 29 | 5.0 | 8 | 45 | 37 | 4.0 |
| V-(1) | 8 | 46 | 38 | 4.0 | | | | |
| V-(2) | 8 | 38 | 31 | 4.5 | 8 | 75~77 | 62 | 3.5 |
| V-(3) | 8.5 | 28~30 | 25 | 5.5, 3.5 | 8, 5 | 38 | 32 | 5.0, 3.5 |
| VI-(1) | | | | | 4.5 | 18~22 | 14~17 | 3.4 |
| VI-(2) | 4.5 | 22 | 17 | 3.4 | | | | |
| VI-(3) | 6 | 18 | 14 | 4.4 | 6 | 25~30 | 19 | 3.6 |
| VI-(4) | 6 | 18 | 14 | 4.4 | 6 | 28~30 | 21 | 3.4 |
| VII-(1) | | | | | 3.5 | 18 | 14 | 2.8 |
| VII-(2) | 3.5 | 14 | 11 | 2.8 | 3.5 | 18 | 14 | 2.8 |
| VII-(3) | 4.5 | 18 | 14 | 2.8 | 4.5 | 25-30 | 19 | 2.8 |

$H_m$ --- Clear height $B_m$ --- Clear width
b --- Upper bottom width h --- Side height

Effective Dimension of Shiplock (m)

| Class of waterway | $L_k$ | $B_k$ | $H_k$ | Class of waterway | $L_k$ | $B_k$ | $H_k$ |
|---|---|---|---|---|---|---|---|
| I-(1) | | | | IV-(2) | 120 | 23 | 2.5~3.0 |
| I-(2) | | | | IV-(3) | 120 | 12 | 2.5~3.0 |
| I-(3) | 280 | 34 | 5.5 | V-(1) | 140 | 23 | 2.0~2.5 |
| I-(4) | | | | V-(2) | 100 | 23 | 2.0~5.0 |
| II-(1) | | | | V-(3) | 100 | 12 | 2.5~3.0<br>2.0~2.5 |
| II-(2) | 280 | 34 | 5.5 | VI-(1) | 190 | 12 | 2.5~3.0 |
| II-(3) | 195 | 16 | 4.0 | VI-(2) | 160 | 16 | 1.5 |
| III-(1) | | | | VI-(3) | 80 | 8 | 1.5 |
| III-(2) | 260 | 23 | 3.0~3.5 | VI-(4) | 80 | 8 | 1.5 |
| III-(3) | 180 | 23 | 3.0~3.5 | VII-(1) | 140 | 12 | 2.5 |
| III-(4) | 180 | 12 | 3.0~3.5 | VII-(2) | 110 | 12 | 1.2 |
| IV-(1) | 180 | 23 | 2.5~3.0 | VII-(3) | 70 | 8 | 1.2 |

$L_k$ --- Length $B_k$ --- Width $H_k$ --- Water depth over gate sill

## 3. Maintenance of Inland Waterway

The Chinese Government attaches great importance to the maintenance of inland waterway. Early in 1964, the State Council issued "The instructions concerning the strengthening of administration and maintenance of waterway". It emphasizes that to guarantee the smooth passage and safe navigation, improve the navigation condition, raise the throughput of waterway, and bring the function of water transportation into full play in the national economy, the department concerned must strengthen seriously the administration and maintenance of waterway. In 1987, the State Council promulgated again "Administrative regulations of waterway of the People's Republic of China". The above mentioned instructions and regulations emphasize that the planning of the development of waterway should accord with the principle of comprehensive utilization of water resources, the waterway and its facilities are protected by the State, no body and no department can encroach upon or destroy them, etc. At the same time, the regulations also stipulated the main obligations of waterway departments at various levels and pointed out that the administrative organ of waterway should strengthen administration and maintenance, maintain the stipulated channel dimension and keep the waterway and its facilities in a good state so as to ensure unobstructed and safe navigation.

The regulations stipulate that the Ministry of Communications is in charge of the administration and maintenance of waterway and aids to navigation all over China. The ministry is also authorized to stipulate and promulgate technical standards and administrative rules as well as regulations for inland waterway and aids to navigation, and to take all necessary measures for the

development and improvement of inland waterway to cope with the problems which may arise in waterborne transportation.

Directly under the Ministry of Communications or provincial governments, inland waterway bureaus are set up on the Yangtze River, the Heilongjiang River and provincial waterways. They are responsible for administrative work on the maintenance of waterway and aids to navigation of the river sections under their jurisdiction. Here, let us take the Changjiang Waterway Bureau for an example.

The Changjiang Waterway Bureau is in charge of the management of waterway and aids to navigation along the trunk channel from Yibin to Liuhekou (2688.8 km) of the Yangtze River. The main function of the waterway bureau is, on the basis of the policy prescribed by the Ministry of Communications and according to the shipping requirements, to draw up the work plans and regulations for effective maintenance of waterway and aids to navigation on the Yangtze River and to supervise and check frequently the performance of its branch offices.

Under the waterway bureau, there are five branch offices, namely Louzhou, Chongqing, Yichang, Hankow and Nanjing Branch Offices. The length of the river assigned to each branch office ranges from 300 to 850 km., and each office is equipped with some dredgers, working boats, a certain number of aids and other waterway facilities. The main duty of the branch office is to assist the district office to fulfill the task of maintaining waterway and aids as assigned by the waterway Bureau and to ensure that the aids are in accurate position and good technical condition, so as to provide a safe channel for navigation.

Under the Branch Office, the river is further divided into three to five parts with one district office for each part, assigned with a river length of 150 to 200 km. the main task for the district office is to provide guidance to the waterway stations in daily maintenance of waterway and aids to navigation. Each district office is equipped with a light-tender. The district office itself has to ensure that the dimension of the channels and their related aids are properly maintained. it is responsible for overhaul of workboats and facilities as well as for supply of materials.

Under the district office, there are a number of grass-root units called waterway stations. These units are directly responsible for the daily maintenance of waterway and aids. Due to the rise and fall of the water level and the shifting of the navigable channels, the waterway stations have to take soundings of the waterway section assigned to them regularly, particularly in the low water season. They may have to take soundings several times a day. Based upon the results of the soundings, floating and land based marks are installed and maintained to indicate the direction and borders of the safe and economical navigable channels. The length of waterway section assigned to the station depends upon the special features of the section. For example, on the upper reaches of the Yangtze river where there are torrents and swift rapids hazardous for navigation, the length assigned to a station is usually about 10 km, whereas on the lower reaches of the river, where the water is deep and the channel is wide, the maximum length can be 100 km or more.

The concrete tasks of maintenance of waterway are as follows:

To set up aids to navigation according the layout principle and keep them in well-maintained state.

To strengthen observation and analysis of rapids and shoals in the river section, study the trend of evolution of channel shifting and adopt suitable measures in time to guarantee sufficient channel dimensions.

To examine periodically the training structures and ship-passing structures, and always keep them in good technical state.

To strengthen the protection of water, and prevent the deterioration of waterway condition.

The maintenance work of waterway may be divided into three categories, and any river section that can meet one of the following conditions should be classified as the first category:

Class I to IV waterway: navigable day and night;

Class V to VII mountainous waterway: navigable day and night, and the annual cargo throughput exceeds one million tons;

Class V to VII plain waterway: navigable day and night, and the annual throughput of cargo exceeds three million tons;

Class V to VII canal and water-net waterway: navigable day and night, and the annual cargo throughput exceeds five million tons; Tidal estuary waterway: navigable for five hundred ton class seagoing vessel; Waterway used mainly for tourism: the number of tourists exceeds one million person-time;

Class VII and some substandard waterways: which are navigable seasonally only are classified as the third category.

The waterway whose condition is between the first category and the third category is classified as the second category.

The waterway department should provide dependable, safe and good navigation conditions for all the vessels that navigate on the inland waterway. Once an insufficient channel dimension appears or a doubtful obstruction is discovered, the waterway department should actively adopt effective measures. The usually adopted measures include:

*Surveying*

There are various kinds of surveying long-distance to meet the requirements of sailing vessels, surveying for the need of various waterway work, such as adjustment of aids, dredging, jetting, snagging etc., and shoal surveying to accumulate information for waterway regulation in the future.

A pilot chart is a successive chart of the whole waterway of a river; it should reflect the topography, objects, water depths and so on, especially the underwater obstructions within the area inundated at the maximum water level. The objects related to navigation and the variation of channels as well as the facilities of a harbour both in water and on the bank should also be shown in this chart.

The pilot chart should provide the mariners necessary information for sailing, and also provide the waterway department with information for maintenance, planning, construction, layout of aids and administration of navigation.

On the Yangtze River, the scope of surveying for the pilot chart is stipulated to the extent that the land should be surveyed 1.5 kilometer outward from both banksides. If some conspicuous objects like pagoda, big trees, etc. outside of the 1.5 kilometer limit which are useful to navigation and surveying, they should be entered in this chart.

The depth of water and elevation of land are expressed by contour line.

The surveying and publication of a pilot chart are undertaken by the waterway bureau and its branch offices in accordance with "The specifications of surveying for transport engineering" stipulated by the Ministry of Communications.

A pilot chart is to be supplemented and re-surveyed periodically. When a variation occurs in a local area, in addition to the notice to mariners given by the waterway department, a corrected map should be supplemented or the finished chart of a training works or dredging works provided. When the channel varies enormously or the pilot chart can not meet the need of the developed waterborne transportation, a repeated overall surveying and a new chart may be necessary.

Maintenance surveying at the shoal section is to meet the practical needs of waterway maintenance. The range to be surveyed generally includes the shoal area and a part of upstream and downstream stable deep pool. the scale of surveying varies according to different natural conditions of the river section, generally, 1/1000 to 1/10000.

The content of surveying should include the whole underwater relief, surface velocity and direction of current. The interval between two surveying for the first category maintenance waterway, i.e. frequently varying shoal section, should be less than four months, and in a stable shallow shoal area, less than one year. The appropriate time for surveying is the post-freshet period and low water season. When there is a special need, for instance, need of dredging, or surface blasting, the surveying time may be added, and the surveying scope may be reduced properly or just at the shoal area only.

*Adjustment of aids*

The middle and lower reaches of the Yangtze River belong to the alluvial plain river, and there are about thirty famous shallow shoals scattering over thousand-kilometer long waterways. Generally, these shoals are located at branched sections, banded sections and the confluence of tributaries. In every low water season, because the water level falls and the depth at the shoal

area is not large enough, obstruction to navigation is formed. Owing to the variation of the boundary condition of the river bed and incoming sand and water, the configuration and elevation of these shoals vary accordingly, especially in the low water season. The swinging of the main current subjected to the variation of the river bed and discharge makes the maintenance of waterway even more difficult. In the severely varying shoal reach, the channel is often shifted within two or three days. Sometimes, even in one day, one channel is scoured, and another is silted up. The waterway station has to move more than ten buoys at one night in order to open up a newly-scoured channel for the sailing vessels. In doing so, frequent sounding is needed to hunt for a new channel, the labour intensity is large and workers must have rich experiences and master the evolution law of the waterway, but that is still one of the most economical and convenient measures to guarantee the channel dimension of a navigable waterway, and enjoys priority in the measures adopted by the waterway department.

*Hydraulic jetting*

In the middle and lower reaches of the Yangtze River and some medium or small rivers, shallow sand dune or sand barriers occur frequently and form obstruction to navigation. These kinds of obstructions, which are often small in dimension are not easy to be found and fixed. It is neither economical nor easy to excavate them with big dredgers. Recently, the newly-developed hydraulic jetting method is an effective means of dredging shallow sand spot on the river bed. The hydraulic jetting dredger has the advantages of low building cost, low operation cost, easy maneuvering, no direct contact with the river bed and good dredging effect.

The Changjiang Waterway Bureau began the experiment of hydraulic jetting in the middle reaches of the river in 1960s. In 1970s and 1980s, they built two jetting dredgers and accumulated some experiences in the desilting of sand by hydraulic jetting dredgers.

Currently, they have completed the design of the third hydraulic jetting dredger on the basis of the past experience, and will begin to build it soon.

The dimensions and parameters of the newly-developed hydraulic dredger are as follows:

| | |
|---|---|
| Length of dredger | 33.23 m |
| Width of dredger | 8.2 m |
| Draft | 1.5 m |
| Power of main engine | 2 x 268 kw |
| Power of pump | 2 x 175 kw |
| Number of nozzles | 8 |

After the pilot test the dredging capacity of this dredger is determined to be 300 $m^3$/hour.

Another prominent feature of this dredger is that it can be used where the bigger dredger is not accessible (such as the bankside of a pontoon) or the safety of execution is not assured in dredging (such as ship's spillway), and this function can not be substituted.

*Snagging*

Snagging is to clear away some isolated obstructions (for example reefs) in mountainous and rocky bottom rivers, and sand dunes in sandy bottom rivers or remove some sunken objects obstructing navigation, for example, snags.

In the middle and lower reaches of the river, the surface blasting method is often adopted, that is to place the explosive charges onto the surface of the sand dunes in shallow water and then detonate the charge. the energy of the explosives is absorbed in loosening the bed sediment which turns into suspension and is carried away by the flow. Generally, in surface blasting, a large part of the energy will penetrate through the water and dissipate in the air, thus, only a small part of energy acts on the bed sediment. So, the underwater drilling and blasting methods should be discussed. The drilling rigs are rather expensive, what is more, navigation must be forbidden during operation, so it is not so advantageous as surface blasting. So far, it is still adopted on the middle and lower reaches. In some waterway districts which have more shoaly reaches, a snagging team is set up, one head and three firemen are allocated and working boats are provided.

Generally, electric detonation is used for underwater firing, and the explosives used for the charge can be TNT, nitramine and emulsify explosives; currently, the latter is usually adopted, for it is relatively safe. In general, the quantity of explosive used is about 25 to 100 kilograms.

When underwater blasting is needed, the explosives are packed in plastic bags by weight of 20 or 25 kilograms, and then filled with clay to weight the explosive cartridge, making it easier to sink swiftly and accurately to the river bed. Single charge, double charge or multi-shotfiring may be used.

There are two execution methods of underwater surface blasting. One is to use a position boat and anchor it at a safe place, at least 100 metres upstream from the engineering site. The position boat is equipped with a winch and some exploding instruments, and small rowboat is attached. The explosive cartridge is placed on the rowboat. After a towing line is loosened, the row boat is lowered to the shallowest area above the sand dune, and then the cartridge is put into the river bed. Finally, a motorboat is used to tow away the rowboat to a safe place, after that, the position boat detonates the explosive cartridge. Another method is to use a motorboat for a speedy and single shot-firing, that is to put the processed explosive cartridge on the bow of the motorboat and steer the motorboat to the shoal area. After the shallowest water depth is measured, the explosive cartridge is put on to the river bed, at the same time, the motorboat moves downstream with the flow to a safe place and detonates the cartridge.

Snagging and surface blasting on sandy shoals is an effective measures to deepen the water depth, but special attention must be paid to safety in operation.

*Bed sweeping*

When a new channel is opened, when a doubtful obstruction is discovered in the existing channel, or when a wreckage or a landslide along the river occurs, bed sweeping is needed to determine the accurate position of obstruction and the degree of obstruction to navigation.

Bed sweeping is divided into three kinds, i.e. flexible sweeping, rigid sweeping and compound sweeping. Flexible sweeping is done by two sweeping boats. Each boat takes one end of a long sweeping rope just like a pair of trawlers, one left, one right, sets out from the upstream of the sweeping area and drifts currentwise to the lower reach. to keep the sweeping rope's moving and contacting with the river bed in the whole procedure of sweeping, it is necessary to fasten some plumbs on the sweeping rope at a certain interval, in addition, some small buoys are attached to the sweeping rope by strings, thus, the moving locus of the sweeping rope is recognized from the position of those buoys. If there is no obstruction, the sweeping boats will continue to flow downstream, if the sweeping rope is hooked by the obstruction, the two sweeping boats will naturally approach each other, then the position of obstruction is determined. This method is applicable for the finding and detection of wrecks, unknown underwater reefs and other obstructions.

In rigid bed sweeping, one vertical, depth-adjustable and scaled stick is installed at each side of the sweeping boat's bow. At the lower ends of two vertical sticks, a horizontal sweeping rod is installed, forming the shape of "**11**". The sweeping boat sets out from the upstream of the area to be swept heading the current, and drifts currentwise. When the sweeping rod touches the obstruction, it may be felt from both the vibration of the sweeping rod and noise, the water depth above the obstruction may be read out directly from the scaled vertical sticks. This method is applicable for the determination of accurate depth of obstructions.

In 1960s, a successful endeavor of rigid bed sweeping was completed at the swift rapids named Qingtan. Qintan was the first famous swift rapids caused by landslide four hundred years ago. Before the training of the rapids, the navigable width was only 33 metres. After surface blasting, both the depth and width need to be determined by rigid sweeping. But, under the condition of a current velocity 7 m/s, gradient 10‰, it is obvious that the above mentioned method was not applicable. After a comprehensive study, the following method was adopted ,i.e., two big position vessels were fixed at the slack water area above the rapids, each had a big capstan at stern, two steel wire ropes formed a splayed shape, and by means of loosening one wire and winding another or vice versa, the sweeping boat was let to move transversely. The sweeping showed that the width of the navigable channel was increased to 100 metres, thus, the sailing fleet with only one barge could be increased to two barges, greatly raising the traffic capability.

The compound sweeping is combination of flexible sweeping and rigid sweeping, with the sweeping rod for rigid sweeping replaced by the sweeping rope, but, so far it has been seldom used.

The above mentioned measures were all developed by technicians and workers in the waterway department and proved to be very effective. In practice, some other measures were tested, but could not be popularized due to too much limitation, such as: rake dredging, bandaling and diversion by scraped vessels, etc.

For the dredging of large quantities of soil, no doubt, excavation with various kinds of dredgers is the best choice. Because there is already a special subject concerning dredging, here the details are omitted.

In the mountainous upper reaches of the Yangtze River, because of some protruding bedrock from the banks, detrital fans formed by pebbles and debris from brooklets, or landslides, etc.. The water-carrying section was reduced and then some rapids with torrential current and steep gradient were formed. These rapids seriously menace the upbound vessels. The heaving station is an important navigation aid to overcome the rapids resistance to the upbound vessels.

The rapids resistance is composed of gradient resistance and current resistance. The gradient resistance is the downstream component of the vessels weight on the slope surface, the current resistance is the force of current energy acting upon the upbound vessel. According to the full-scale test, within the total resistance of rapids at the medium and low water level, the gradient resistance is nearly two times as large as the current resistance.

When the vessel ascends a rapids, if the effective thrust of the vessel is larger than the sum of the gradient resistance and current resistance, the vessel can ascend rapids by herself. But, in comparison with increasing the power of vessels main engine to overcome rapids resistance, the setting up of the heaving station has the advantages of less investment, fast construction and effectiveness.

According to the "Technical specifications of maintenance of waterways on inland rivers", whether it is necessary to set up a heaving station is determined by technical and economic demonstration in accordance with the category of maintenance of waterway, standard barge train and upbound loading capacity. On the upper reaches of the Yangtze River, the heaving station is set up when the current velocity is larger than 4 m/s, and the gradient is larger than 3‰.

The operating procedure of heaving is that a heaving barge is set up (i.e. a barge mounted with one or two windlasses) at a suitable place in the slack water area of the upstream of the rapids, the upbound vessel accepts and fastens one end of the wirerope passed from the warp-transmitting boat which is waiting for the upbound vessel at a certain place downstream of the rapids, then, the heaving barge begins to wind the wirerope from the other end until the upbound vessel ascends the rapids, finally lets go the wirerope.

The technical parameters are as follows:

| | Total length (m) | Width (m) | Draft (m) | Tonnage (t) | Power of main engine |
|---|---|---|---|---|---|
| Heaving barge | 38.1 | 8.51 | 1.0 | 280 | 2*88.26 |
| Wrap-trans-mitting boat | 25.3 | 5.0 | 1.05 | 58.6 | 2*110 |

In addition to the aforesaid maintenance work of waterway, to strengthen the administration of waterway is also one of the important links in the various sorts work. So, any construction activities by other departments, including the construction of river barrages, and river-crossing facilities, and the construction along the river, or the construction of some facilities concerning navigation, regulation works of waterway, and diversion and irrigation projects should tally with

concerned stipulations. Application for construction should be submitted higher authorities for approval before the implementation of construction.

## 4. Maintenance of Aids to Navigation

As stated above, in addition to the regulations promulgated in 1964 and 1987, the Chinese government again promulgated "Regulations of the People's Republic of China on aids to navigation" in 1995. This regulations stipulates that anybody and any department should not damage or endanger aids to navigation and their attached facilities, and any behavior affecting the effect of aids to navigation not be allowed. All of these fully illustrate that the Chinese Government attaches great importance to the aids to navigation. Of course, the stipulation also provides that "the administration organization and specialized units should be responsible for the maintenance of aids to navigation, and guarantee the good technical state of the aids".

The system of aids to navigation in use and specifications of aids to navigation in China are as follows:

In the past years, the installation of aids to navigation on rivers in China was in compliance with "The specifications of aids to navigation on inland waterway" issued by the Ministry of communications of China in 1955. In the past four decades, sciences and techniques have developed greatly and many experiences have been accumulated. Based on these, in order to facilitate marine navigation, to ensure safety, to obviate inconvenience arising from different maritime buoyage systems used in different countries and to avoid navigation accidents caused by misinterpretation of various sea marks, the Ministry of Communications of China has decided to adopt "A" system in the IALA Maritime System, which has been recommended by the International Association of Lighthouse Authority and hitherto adopted by the majority of maritime countries. The ministry also stipulated the "China Maritime Buoyage System" National Standard), in compliance with this standard, and the reform of the sea area buoyage system in China was completed in 1986.

According to the principle of " linking river with the sea", China's riverine and estuarine " Aids must comply with the maritime buoyage system and the practical condition of inland rivers. So, the Ministry of Communications of China stipulated and promulgated" aids to navigation on \inland waterways" and "The main dimension of aids to navigation on inland waterways" which were put into effect in 1986.

The standard stipulates the kinds, functions, color characters of lanterns, legends and layout principles of aids to navigation.

Inland waterway aids to navigation is important for sailing vessels guaranteeing safe navigation. Its principal function is to mark the direction and boundary of inland navigation channels and obstacles, to promulgate concerned information, and to indicate the safe and economical channel to sailing vessels.

According to the function of aids to navigation, they may be classified into three kinds, they are: aids for navigation use, signal aids and special purpose aids.

Aids used for navigation include crossing marks, bankwise marks, leading marks, transitional leading marks, double crossing leading marks, lateral marks, mid-ground marks, position indicating marks, flooding marks and bridge opening marks.

Signal marks are used to promulgate concerned navigational information to sailing vessels, including traffic control stations, sound horn marks, limit marks, water depth displaying signals, drift buoys and regulating lock signal lights.

Special purpose marks are used to mark various kinds of construction along or across a navigable channel, or to indicate a special area which is not for navigation use, such as cable marks and special purpose buoys.

In light of "Aids to navigation on inland waterways" and "The main dimension of aids to navigation on inland waterways". China's riverine and estuarine aids include the following:

*Crossing Mark:*

It marks the beginning and the ending of a crossing fairway and instructs ships to come from one bank to the other bank, and then continue their course along the bank, or to sail along the bank and alter their courses to the opposite bank. The crossing mark may be installed at the intersection of the upper and lower crossing channels to instruct ships sailing from the opposite bank to turn to the opposite bank again when they approach the mark.

*Bankwise Mark*:

It marks the direction of a bankwise channel and instructs ships keep their course along the bank.

*Leading mark or transit mark:*

They are composed of two beacons, one of which is in front of the other, forming a leading lien to point out the direction of a narrow or restricted channel and instruct ships to sail along the leading line.

*Transitional leading mark:*

It consists of a front beacon and a rear beacon, marking one side is a narrow channel indicated by leading marks and the other side is an open bankwise channel or crossing channel, thus it instructs ships to sail along the leading line, and then turn to the open bankwise channel or crossing channel.

*Double crossing leading mark:*

It consists of three beacons (one front two rear or one rear two front) forming a tripod double crossing leading mark, marking the directions of the upper and the lower narrow channels respectively and instructing ships to sail along a leading line, and then turn to another leading line.

*Lateral mark:*

Lateral marks are set on the channel side of shoals, reefs, wrecks or other obstructions to mark the lateral border of the channel; in a waterway network, these marks are placed on both sides of a stable channel to mark out the configuration of banks, protrusion or unnavigable branches so as to instruct ships to sail on the navigation channel.

*Mid-ground or bifurcation buoy:*

The mid-ground or bifurcation buoy marks an isolated danger in the mid-river or at the end of a bifurcated channel, indicating that both sides of the buoy are navigable.

*Position indicating mark:*

Placed on lakes, reservoirs, waterway networks or other open water area, this mark indicates the location of the river mouth, island, shallow shoals and reefs, instructing ships to follow the aids to enter the river mouth or warning ships to avoid dangerous areas.

*Flooding mark*:

Placed on the flooded bank or island to the channel side, this mark indicates the bank line or the configuration of the island.

*Bridge opening mark:*

Placed at the centre of the beam of the passable bridge opening on the side facing to the coming ships, this mark guides ships to navigate through the opening.

The functions of signal marks are described as follows.

*Traffic control station:*

At the upper and lower end of a narrow or sharp bend channel, a single passage of a bridge or a ship lock, vessels sailing ahead are invisible to each other, thus there may be the risk of collision. This signal is used to control upbound or downbound vessels in one way passage or to indicate that navigation is prohibited.

*Sound horn mark:*

Placed at the upper and lower extremities of the traffic controlling stretch or at a sharp bend, this mark indicates that ships are required to give sound signals.

*Limit mark:*

Erected at both the upstream and downstream ends of restricted channel (one way passage channel), this mark indicates the limit of this channel.

*Water depth displaying signal*:

Erected on the upper and lower banks of a shallow shoal channel, it displays the least navigable water depth.

*Drift buoy:*

It warns ships of the cross current in a channel.

*Regulation lock signal light:*

Placed at the upstream (or both upstream and downstream) close to a regulating lock, it prevents ships from entering into the lock at night.

The functions of special purpose marks are as follows.

*Cable mark:*

Cable marks are set on banks where pipelines or cables run across the river. Vessels are prohibited to anchor in the area of submerged lines, and they must adopted necessary measures when approaching overhead lines.

*Special purpose buoy:*

Special purpose buoys are used to mark out the specific water area of anchorage, fishing ground, recreation site, swimming pool, hydrographic surveying, underwater drilling, dredging and so on, or mark the intake, outlet, pump station and other hydrographic construction outside of the channel boundary.

Because of the time limit and also the complicacy of the specifications of aids to navigation, I could only give the following brief introduction.

For the crossing mark and leading mark, the top is one or two square boards facing the direction of the channel or the leading line. The bankwise mark has a spherical top.

The height of beacons of shore marks ranges from 5.5 to 10 metres varying with the characteristics of different rivers, reaches as well as the width of a river and the distance between two sequent marks.

The lateral marks, including light vessels, drum buoys, boat-shape buoys and catamarns, are installed with cone-shaped or spar-shaped tops.

The left side lateral mark has a cone-shaped top mark, and the right side mark has a can-shaped top mark. The colour of all shore marks and buoys is white in the day, white or green at night for those located on the left banks, and red both in the day and at night for those located on the right bank.

Now, the total number of aids to navigation installed on China's inland rivers is 36000.

There are various types of rapids and unstable shallow shoals in the waterway forming obstructions and impediments to navigation, so that vessels could only navigate within the marked water area. By means of a series of aids to navigation, the direction, boundary of the channel and obstructions are all marked, thus safe and economical waterways are pointed out to vessels.

The layout of aids to navigation is particularly a technical job. The general design of layout is to be performed based on the "Classes of layout of aids on inland waterways".

The class of the layout of aids on inland waterways should be based on the requirement of transportation and decided after economic study and demonstration.

In China, aids to navigation are divided into four classes.

First class: All marks are lighted. Vessels can be continuously guided from mark to mark ahead in day time and from light to light at night.

Second class: lighted marks and unlighted marks are placed in different stretches. Where vessels navigate day and night, lighted marks are installed and where vessels navigate in day time only, unlighted aids are placed. The density of marks is the same as for the first class.

Third class: All marks are unlighted. On bankwise channels with favorable navigation conditions, vessels can sail along the bank, and aids to navigation can be dispensed with.

Selectively placed aids to navigation: Marks are placed only on the sections where the navigation conditions are poor or at some particular places. On the sections with good navigational conditions, only obstructions are marked. Aids, whether lighted or unlighted, depend on different requirements and specific conditions.

The principle of a layout of navigation aids is that the layout of aids must be based upon the concrete navigation conditions of rivers, lakes and reservoirs, and it can point out a clear, safe, economical and convenient navigation channel. In doing this, attention should be paid to the effect of combination of shore mark and buoys, so as to ensure that every mark can play its maximum function. Since the shore mark is comparatively reliable, and its rate of failure or discrepancy caused by natural elements is mush smaller than that of the buoy, so, the functioning of the shore mark is of great importance.

When a shore mark is erected, a smallest safe navigation distance may be stipulated according to the concrete circumstances of the rivers. This distance is measured from the waterfront line where the shore mark is located.

When a buoy is set up, the water depth between two neighbouring buoys or, at the connecting line, from a buoy to the point where it has a safe distance from the bankline of a shore mark should be guaranteed, not less than the stipulated maintenance water depth. Under some

particular circumstances, the least safe navigation distance may be stipulated for a certain buoy or a beacon in water.

The depth of the lateral buoy may be varied uniformly according to different maintenance requirements of various water stages. When the water stage is rising, the buoyed channel may be widened suitable, and narrowed gradually when the stage is falling.

In general, the navigable water of a bankwise channel on a deep river stretch is about twice the standard channel width; if its width is two times less than the standard channel width, a lateral buoy must be set up to mark the channel boundary. On a wide river section, the navigable water may be widened suitable, but the maximum width must not exceed one third of the mean width of the river in the dry season.

In the flood season, the river width, water depth and current velocity all increase, so, the flooded bank, island and some obstructions must be marked and the economical channel must be opened timely.

In the dry season, the layout of aids to navigation must mark and point out the channel direction accurately, and attention should be paid to marking the configuration of navigation channel and displaying the least water depth of the navigation channel.

When the water level rises or falls abruptly, the layout of aids to navigation must be adjusted in time, and the position of shore mark should not be too far from the waterfront line, nor too high or be drowned by water.

On the tidal reach, the layout of aids to navigation must guarantee that the marked channel has enough water depth under the chart datum, and attention should be paid to buoy circuling due to the changing tidal current.

Where the fluctuation of water level and current speed are relatively small and the variation of channel is seldom, the channel is called a stable one. For example, in the waterway network area in China, the deep water is usually located in the middle of the channel. Vessels basically trace in mid-river, so, in the layout of aids, emphasis should be put on marking out the configuration of the river mouth, bankline, protruded bank and sharp bend. In addition, some lateral marks are also needed to prevent vessels from sailing into unavailable branches. In lakes and reservoirs, there is less restriction in water depth. So, the position indication marks are mainly set on the island, the protruded bank to make it easy for vessels to set their course.

On a relatively straight inland waterway, obstructive ought to be marked out by lateral marks mainly.

Generally, the shallow shoal channels are bent and narrow, and sand shoal channels vary in shape rapidly, especially in the low water season, so they are called unstable channels. In addition to buoying out the upper and lower deep water pools, it is also necessary to set some lateral buoys to mark the boundary of shoals and bent channels.

In mountain rivers, the fluctuation of water level is great, the flow is rapid, the current is turbulent, and the location of navigation channel changes greatly with changing water stages, so lateral marks must be set up to point out the protruding rock and be moved in time according to the variation of water level. Moreover, in the layout of aids, the slack water area ought also to be marked at the same time for the upbound vessels to use.

When sailing on the unstable channel, mariners may depend upon their own experiences, but, besides this, they have to strictly sail in the safe water area marked by aids to navigation, so the aids density should be higher than that for the stable channel.

In the general layout, the function of each aid on the inland waterway is not isolated. The aids are to be linked up harmoniously and integrally to point out the direction and boundary of all channels along a river, and provide vessels with a safe, continuous and most favourable fairway.

Compared with the highway and railway transportation, the inland waterborne transportation is more liable to be affected by the weather condition.

For inland waterborne transportation in China, the government advocates the policy of "safety first", so that, apart from ship's structure which should be solved by the design department and ship yard concerned and the navigation order such as the prevention of collisions which should be superintended by another department concerned, the most important aspect, which will be described here, is the effects of such element as meteorological and river conditions and the way to suit such circumstances.

As to meteorological conditions, there are wind, rain, snow, fog, frost, dew temperature, etc.

Wind, especially strong wind, together with its ensued waves exerts notable impact on waterborne transportation. But its result depends upon whether the river is big or small, wide or narrow, and upon the direction of the wind with relation to the channel. In addition, it also depends on the dimension of the ship. For instance, the lower reaches of the Yangtze River are open and wide, but wind has no effect on the passenger ship of a few thousand tonnage, even the strong wind of Beaufort force 7 or 8.

In China, the local television station and broadcasting station give predictions on wind several times each day, thus, the mariners can decide whether to take shelter or continue their voyage. Their decision depends on the river condition, wind scale, wind direction, wind speed and also the ship's ability against the wind.

The essential problem is the effect of rain, snow, and fog on visibility.

The safety department has stipulated that every big vessel must install a radar and some marks must be equipped with radar transponders. In addition, for a downbound fleet or flotilla sailing on the middle and lower reaches of the Yangtze River, the regulations stipulates that the visibility must exceeds 2000 metres for the downbound flotilla and 1000 metres for the upbound flotilla.

On the upper reaches, due to the specific geographic and meteorological conditions, the time of the beginning and dispersing of fog is relatively fixed; and in the fog haunted section the constant

route of fog movement is known: it originates from a deep valley and gradually moves into the river. So, after years of surveying and summing up the regular moving route of fog, the waterway department has set 66 fog signal stations to display light fog, medium fog and dense fog signal, in a accordance with the visibility of 1500, 1000, and 500 metres respectively to warn the mariners so that they can adopt suitable measures. Thus, with the help of fog signals the safety of vessels sailing in the foggy area is guaranteed.

*Night navigation*

Obviously, night navigation is a very important measures to raise the turnaround rate of vessels. Night navigation will almost double the efficiency in case that a ship only navigates by day.

However, night navigation requires the following conditions.

The requirement of the development of waterborne transportation. There is a great deal of cargoes to be transported.

The natural conditions of waterway suitable for night navigation, for example, the gradient, current speed, current direction, current state and enough water depth, width and radius of curvature.

A reliable aids system equipped with dependable lights, buoys or other buoyant apparatus.

Having enough capability, (including man power, techniques work and boat, etc) to guarantee the timely recovery when light failure or discrepancy of buoys occurs.

Now, over 10000 kilometers of waterway is open to night navigation.

The lantern, lens, chimney, light source, battery and accumulator adopted in China are as follows:

| Diameter of Lens (mm) | Bulb | | | Visibility (Nautical mile) | | |
|---|---|---|---|---|---|---|
| | Voltage(V) | Electric | Power (W) | White | Red | Green |
| 75 | 4.4 | 0.3 | 1.5 | 2.0 | 0.8 | 0.6 |
| 90 | 6.2 | 0.25 | 1.5 | 2.5 | 1.2 | 0.7 |
| 90 | 6.0 | 0.6 | 3.0 | 3.5 | 1.4 | 1.0 |
| 90 | 6.5 | 0.8 | 5.0 | 4.5 | 1.8 | 1.3 |
| 150 | 6.0 | 0.6 | 3.5 | 4.5 | 1.8 | 1.3 |
| 155 | 6.5 | 1.4 | 10.0 | 6.0 | 2.4 | 1.8 |
| 200 | 6.5 | 1.4 | 10.0 | 6.0 | 2.4 | 1.8 |
| 200 | 12.0 | 0.77 | 10.0 | 7.0 | 2.8 | 2.1 |

On the Yangtze River, due to the open and wide river surface and the busy transportation, the requirement for night navigation is relatively higher, so, 155 mm. and 200 mm. lenses are mounted on most of the lanterns.

The basic requirement of electric source is its better function and lower price. As to better function, it means that the voltage is stable when the battery is discharging continuously with a small electric current for a long time and self-discharging is small, besides, the battery should be small in volume and light in weight, shake proof and easy to move. Low price implies the small investment, long life-span, convenient repair and a small number of auxiliary facilities.

Now, the recommended electric sources are:

The first one is "B" series lead-acid accumulator for aids to navigation. Its advantages are small self discharging, long life-span, shackproof and low price per watt-hour. the Changjiang Waterway Bureau applies a large number of B-240 type lead-acid accumulators, generally, it can last over 45 days once charged and the life span is over four years. For the large drum buoys the B-500 type accumulator is adopted.

Another electric source is JQ series zinc aerate battery. It has a large capacity, small volume, light weight, and stable voltage after continuous discharging. The negative pole (zinc pole) is changeable, and the storage life is nearly three years. But the cost is a little higher than the lead-acid accumulator.

In addition, the solar energy battery and windmill generator are also adopted in a small number. These are adaptable where there is abundant sun light and wind resource, especially for fixed marks as well as the marks on the cliff; they are also used where it is difficult to tend them. The solar energy and windmill generator can be combined with the B-240 type lead-acid accumulator.

***Concerned rules and regulations***

In addition to the above mentioned "Aids to navigation on inland water" and "The main dimension of aids to navigation on inland waterway", other regulations are diversified by the class and layout of aids on different rivers. But as an obligation of the waterway bureau and other waterway departments, the general requirement is consistent, for example, the waterway bureau's obligation is to assign the task of maintenance of aids to the subordinate departments, to stipulate overall regulations on maintenance of aids, to ratify the layout of aids of branch offices and to superintend and examine the task implementation at the lower level.

The waterway station takes the responsibility of daily maintenance of aids within its jurisdiction, masters the water depth of the channel and the position of obstructions, installs or moves the marks timely, maintains the marks, lanterns, and energy and light source, keeps all aids in a good technical state, and guarantee a safe and smooth passage for vessels.

The following are some of the main regulations:

(1) Regulations on sounding and sweeping:

The waterway station has to sound the channel periodically; for a variable channel, sounding must be carried out daily, and the marks moved according to the variation of channel to ensure enough dimension of the channel.

When the position of an obstruction is unknown or a new channel is to be opened or the depth of a shallow shoal is to be ascertained, the waterway station has to carry out the sweeping of the channel. Through channel sweeping, the obstruction's accurate position and water depth can be obtained. If the present water depth is different from the original one, a new mark should be added and the results on channel sweeping should be submitted to the district office.

(2) Inspection of aids to navigation:

According to the technical specifications for inland waterway maintenance issued by the Ministry of Communications, waterway station's daily inspection should include the following contents:

Whether the water depth, width and radius of curvature are sufficient;
Whether the buoy's position is accurate, whether the mark is in good state, fastened and clean;
Whether there is anything tangled on the mooring rope;
Whether the lantern and electric source are normal and effective;

The contents of regular inspection, in addition to the above items, are:
Overall surveying of redouble and variable sections of the navigation channel as well as the potential section which is hopeful to become a fairway;
For night navigation, inspection of the characteristics and brightness of lights;
Whether the buoy and its mooring rope are intact or damaged.

The interval of inspection may be different according to natural conditions of the river reaches and the maintenance class, but, in general, the interval daily inspection should not exceed five days and that of regular inspection should not exceed fifteen days.

Moreover, the waterway bureau and its branch offices have to inspect the grass-root units regularly or irregularly.

(3) Regulations on maintenance of aids facilities:

The maintenance periods, contents and technical requirements of aids facilities are stipulated in compliance with the local characteristics of a river, the specialty of a navigation channel and the kind of marks and materials. Except for the rivers where the sand content is small, maintenance may be excited according to the following:

For the wooden shore marks, 2--3 times washing, 1--2 times painting are needed per year. the washing and painting for steel shore marks is the same as for wooden marks, but derusting is needed once every two years.

For bamboo and wooden buoys, 2--3 times washing per month, 1--2 times painting per half year, ashore repair per year.

For steel buoys, 1--2 times washing per month, once painting per half year, derusting, painting and repairing once every two years.

For steel drum buoys, 1--2 times washing per season, one painting per half year, derusting, painting and repairing once every three years.

For steel vessels, one painting per half year, overhauling once every five years.

The mooring chain and other mooring facilities must be examined periodically, the worn-out ones must be changed timely, and the mooring chain which has been used over one year must be thoroughly examined.

For the electric aids lantern, aids accumulator, solar accumulator, etc., a quality examination must be conducted once a year, and the unqualified ones must be repaired or replaced in time.

(4) Report on channel dimension and broadcasting regulations:

In low water season, the waterway station should report everyday to the district office through VHF after sounding. The report contents should include: a. Time of sounding, b. Name of shoal. c. Least water depth of channel. d. Least width of channel. e. Local water mark. After receiving the report, the branch office of the waterway bureau should broadcast these information to sailing vessels to provide the sailing vessels with a basis for determining the draft limit.

(5) Publication of notice to mariners:

The notice to mariners is published by the branch office of waterway bureau, generally, once or twice every month and the contents include:

Monthly dimension maintained on main channel and economical channel.
The alteration of marks and signals.
The opening and closing of some channels
The alteration of lighted river section
In addition, the water marks on the main water gage along the river are broadcasted every day by the broadcasting station.

Others rules and regulations are "On watch rules for waterway stations" and "The regulations on examination quality of aids", and so on. Every waterway bureau has its own rules and regulations in compliance with specific river conditions and specific class navigation aids.

***Economic benefit evaluation of navigation aids***

The necessary investment in the installation of aids to navigation on an undeveloped river, from overall surveying, designing, purchasing of aids facilities and work boats to the establishment of administrative organs is quite different due to different natural conditions, requirements of navigation, and waterway dimensions and so on. So, here, I can only provide a unit maintenance price for the Yangtze River for reference.

| | |
|---|---|
| On the upper reaches | 36 yuan/set-day |
| On the middle reaches | 39 yuan/set-day |
| On the lower reaches | 45 yuan/set-day |

An illustration is needed here. The number of marks setting up on the upper reaches is much more than that on the lower reaches, but the unit expenditure for the lower reaches is much more expensive than that for the upper reaches. The reason is that the size of beacons and buoys on the lower reaches is different. On the lower reaches, usually, large drum buoys are attached with heavy chains and sinkers, thus, we have to employ a big light tender up to 1000 tons to maintain or move them. Moreover, the consumption of other materials and fuel increases accordingly, so the total expenditure of unit set-day is much higher than that for the upper reaches.

As to the evaluation of cost effectiveness of aids to navigation, it is well-known that the exploration of a river for navigation is different from any other industry, such as building an industry factory The river itself does not produce any concrete products; it only provides a possibility for vessels to ply on it. So, you can never expect to retrieve the investment from the installation and maintenance of aids to navigation.

But, we should realize that the work of the waterway departments including the installation and maintenance of aids to navigation is a kind of public welfare and closely related to people's livelihood, so that it is deemed to be a kind of public welfare facilities. By means of these, more and more vessels may sail to and fro linking up cities and the countryside, transporting more and more industrial and agricultural commodities, thus both industry and agriculture are developed and better economic results are achieved. Just because of this, many developed countries place special emphasis on the exploitation and development of inland waterways. At present, even in the countries where airborne and express highway transportation is well developed, the inland waterway transportation is still able to emulate other communications means in bulk cargo transportation, such as coal, cereal, ore, fuel, building materials, etc.

In addition, there is another difference in specialty between the setting up of aids to navigation and other industries. In a factory or a workshop, if you want to produce more commodities on the same technical basis, it is necessary to use more material, power or funds. But, on a river or a section of a river, once a number of aids to navigation are set up and well maintained, though, at the beginning, perhaps there are only a few vessels, later on, with the development of waterborne transportation, more and more vessels may sail on the river or section until its saturation is reached. You need not increase any material, fuel, fund and labor force that is to say, the more vessels navigate on it, the more benefit you will acquire.

Here is an example:

On the upper and middle reaches of the Yangtze River, before 1953, there were very few aids, and ships sailed on these reaches only in the day by day marks. In 1954, a preliminary reform was carried out in aids to navigation and lanterns were installed on beacons and buoys, thus night navigation started. The result is that the turnaround rate of vessels on the upper and middle reaches was raised by 40% and 30%--36% respectively.

Another example. On the lower reaches, at the beginning, the least water depth of the waterway was stipulated for river vessels later. Because of the development of the national economy, some seagoing vessels were required to sail up to Wuhan (1040 kilometers from Shanghai); in 1980s some foreign ocean-going vessels were promised to sail up to Nanjing (340 kilometers from Shanghai). Those vessels all have a deep draft. To cope with these vessels, after surveying and

investigating, we opened a new deep draft route for sea-going and ocean-going vessels by means of adding 274 buoys and publishing notice to mariners. In 1993 alone, there were 1815 ocean-going international liners which entered the Yangtze River.

From above, we can see that the value of the aids in promoting industrial and agricultural production as well as developing the national economy is uncountable.

Following the development of the national economy and the progress of science and technique, China's inland waterway aids to navigation, from aids facilities to maintenance measures, has made considerable progress. The following are few examples.

***Glass fiber reinforced plastic buoy and beacon.***

The lower reaches of the Yangtze river is wide and deep, and over 200 steel drum buoys (diameter 2400 mm) were adopted. Recently, due to the increment of sailing vessels, collision and losses of drum buoys often occurred. So, in 1991, the Changjiang Waterway Bureau began to develop a 2400 mm. glass fiber reinforced plastic drum buoy. After one year's pilot test, it has passed through the technical appraisement. The dimension, buoyant force, oscillation period and stability all met the designed requirements. It is simple, light, not prone to sinking and low in cost.

At the same time, glass fiber reinforced plastics has been gradually used for shore beacons. The body of a beacon is cylinder-shaped, and different top marks may be installed. The advantages are that the beacon has a most obvious objective, and its maintenance is simple. Some beacons also use enamel as their top marks, the advantage is that it needs no painting.

*New aids lantern*

In recent years, the new all plastic aids lantern and lenses, as well as the lantern case, have been broadly used on the marks. The size of lenses is 70--300 mm in diameter. Its characteristics is watertight, light in weight, with good transparency and ageing resistance. The red or green color may be put on lenses directly.

Following the development of electronic industry, the flasher of aids lantern has been improvement continuously. The flashers currently used are mainly assembled of integrated circuits. The characters of the lantern may be designed according to specific requirements; its performance is stable and dependable, and its self-discharging is small. In the past, to guarantee the quality of inland waterway aids lights, the mechanical bulb changer was adopted, once a bulb went out, the bulb changer rotated automatically until the second bulb reached the position of the focal point of the lens. But, now, these bulb changers are replaced by double filament incandescent bulbs. The life span of the double filament bulb is long. When the filament is worn-out, the second filament may light up automatically, and deliver a warning signal at the same time.

*New type of aids light source*

The solar battery is broadly adopted for the aids lantern, except the shore marks. it is also used in some buoys, combined with maintenance-free lead-acid battery. Its advantage is that it needs no periodical replacement, and it is easy in maintenance, low in cost and less in pollution to environment.

***Surveying and position fixing of aids to navigation***

previously, in the position fixing of sounding and buoy setting, technicians always used sextant and station pointer. But, due to the large width of the river, bad weather and poor sight line, the observation was often difficult, thus causing hidden danger to the safety of navigation. In 1994, the Changjiang Waterway Bureau introduced various kinds of advanced surveying instruments, such as microwave range finder, DGPS, etc., thus the automation of surveying and position fixing of aids to navigation has been accomplished.

All the above mentioned will play an important role in raising the maintenance quality of aids to navigation and cutting down the maintenance cost and labor intensity, besides, the safety of navigation of all the vessels sailing on the river is guaranteed.

The aforesaid is an introduction to the waterway and aids to navigation on inland water in China. But, it is for your reference only, because every country has her own natural conditions and characters, and the requirement of water transportation is different too. So, in implementation, one should consider the practical conditions and different requirements. However, one thing of great importance is common, that is, the general character is all the same; the maintenance of waterway and the setting up of aids to navigation is a very important measures to ensure the safety of vessels, and raise the turnaround rate of waterborne transportation, thus, promoting the development of industry and agriculture in the river basin and the development of the national economy.