10. Rudder

The rudder is the most important part of the ship. If the rudder becomes defective, the ship can no longer operate, even though the condition of the hull and machinery is satisfactory. Similar to the propeller, the rudder is normally immersed under water, therefore, details of its condition can be observed only during a bottom inspection when the ship is docked. Inspection of the rudder also includes inspection of deformation, checking for cracks and the condition of rudder bearing wear down.

10-1 Type of rudder

There are many types in rudder. The followings are the typical examples.

Fig. 10-1 hanging rudder

Fig. 10-2 Symplex rudder

Fig. 10-3 Rudder with one pintle

Fig. 10-4 Mariner rudder
Fig. 10-5 T-Type rudder with 2 pintles
Fig. 10-6 Mariner rudder with 2 pintles,

Colt nozzle rudder
Active rudder
Fig. 10-5 Old type Rudder with many pintles (Single plate rudder)

Santa Maria

Cutty Sark (1)

Cutty Sark (2)

Nelson's Flag  Ship  VICTORY

Flap rudder, Fig. missing
10.2 Lifting and Removing Rudder
At first the rudder bearing clearance (Between inner diameter of bush and rudder stock or pintle) should be measured when inspecting the condition of the bearing. If an abnormality is found, the rudder should be lifted or removed, depending on its construction. In conventional rudders with upper and lower pintles or lower pintle only, the rudder has to be lifted. However, for a hanging rudder or a Mariner type rudder, the rudder should be lowered; for a Simplex rudder, the rudder post should be removed. In any case, the tiller of the steering gear should be overhauled and removed, in such a way that the rudder and steering gear should be disconnected, and the jumping stopper removed. An example of the sequence for lifting the rudder is shown in Fig. 10-6; If the rudder is lifted by a jack, the jack should be positioned under the vertical frame of the rudder, otherwise it might dent the bottom plate of the rudder. If the sequence is not followed correctly, the rudder might drop and break the shoe piece; therefore, work should be carried out with much care.

10.3 Lost of Rudder
Instances where the rudder did not respond when the ship was underway because the rudder had dropped into the sea bottom are extremely rare, case although not impossible. Generally, in this case, the rudder stock and the upper rudder plate remain. The rudder stock and the pintle are made of forged steel, the rudder body made by welding steel plates, and pintle bearings are castings. In general, rudder loss occurs because of welding defects in the part connecting a casting in the rudder and the rudder plate. cf. Fig. 10-7
If the cracks is found in the horizontal direction at the upper part of the rudder, carefully check the cracks after the stagings are erected.

**10.4 Rudder Stock Failure**

Rudder stock failure is very rare, but in the past, there was an incident when a whale in a dying condition hit the rudder of a whale catcher boat operating in the Antarctic Ocean, the rudder broke and dropped into the sea. Unfortunately the rudder was a hanging rudder without shoe piece.

![Diagram of rudder stock failure](image)

**Fig.10-8 Hanging rudder will drop when rudder stock is broken**
Genellary no such incidents have happened. But in 1960, a tanker of 30,000 gross tons, just built and handed over to the owner, was underway heading for the Persian Gulf. The captain reported that when an impact was felt at the stern and the ship suddenly turned to portside. The main engine was stopped immediately. After inspection, it was discovered that the rudder stock of diameter 450 mm was cut completely at the position shown in Fig.10-7 and had swung to port. As a contingency measure, the rudder was lashed by wire rope; the rudder was swung using the mooring winch until the ship reached Karachi Port. At this port, rudder stock was joined by welding after edge preparation to a depth of 50 mm all around and a doubler was provided. Thereafter, the ship sailed under its own power to Japan. After investigation of the history when the rudder stock was manufactured, it was found that the rudder stock had a slight bend at the location where the damage happened. Then rectified by locally heating in the furnace and faired using a press. The fairing by a press had caused large residual stress, and the material strength had degraded when it was heated. Sometimes these processes will cause the breaking of rudder stock.

Photo.10- Broken surface
Fig.10- Temporaly repair

10-5 Crack in rudder plate
(1) At the slot weld
The rudder plate and rudder frame can be welded directly on one side of the rudder, but the cover plate on the other side can not weld directly. So these members are joined by slot welding. If assembly accuracy is poor, slot welding is incomplete and cracks occur. Consequently, cracks appear in the rudder plate only on one side.

Photo. 10-1 Crack in the rudder plate at the slot weld

(2) Both ends
Sometimes cracks are found at the front edge and/or aft end.

Vertical crack at front end
Suddenly ship’s speed dropped.
10.5.1 Detecting ingress of water into rudder
If we find some wet area in the rudder plate, it is likely that cracks have occurred in the rudder plate and sea water has ingressed. Even if water has entered into the rudder, only the buoyancy of the rudder is lost and no major casualty will occur. However, internal parts of the rudder might corrode, therefore, the plug in the bottom plate of the rudder should be opened and water should be drained out. If we strike the rudder plate with a test hammer, we can detect the ingress of water from the sound. In large ships, the rudder is high above the dock floor; if we cannot strike it with a test hammer, pick up a stone or something in the dry dock and throw it against the rudder. We can find the ingress of water from the sound made by the stone hitting the rudder.

Fig.10-8 Examination of Ingress of sea water throwing stone or something in the dry dock

10.5.2 Measures when cracks are detected
(1) Open the plug at the bottom of rudder plate and drain the sea water from the rudder.
(2) After close the plug fill the rudder with air to perform the air test and check the cracks.
(3) Re-weld the crack.
(4) After welding, carry out the air test again to confirm that the repair has been completed correctly.

10.6 Loss of Portable Box
The portable box is installed above or below the gudgeon so that it can be removed when raising or lowering the rudder for measurement of the clearance between pintle bush and sleeve. The portable box is fitted with only one side welding for easy take off. If the welding is poor or if the rudder hits a floating object, the box is easily broken and drop into the sea. Loss of the box is not a major problem; however, the area of the rudder decreases and the rudder response becomes a little poor, therefore, when no portable box is found, new box should be made and fitted. If the clearance above or below the gudgeon is large, we may conclude that the portable box has been lost.

![Image of Portable Box](image.png)

Ordinarily Portable box

Fig. 10-9 Portable box

10-7 Pintle
If we consider the rudder as a hinged door, the pintle is analogous to the vertical pin in the door hinge. Consequently, if the pin is damaged, the door cannot be opened or closed. Similarly, when the pintle damaged, the rudder loses its freedom of movement and the ship is unable to sail under its own power. Although the pintle is a small component, it plays a very important role. Depending on rudder type there are one or two pintles in the rudder.

10-7-1 Pintle construction
The bearing surface of pintle is covered with a copper alloy sleeve. After a tapered part as shown in Fig. 10-10, the end of the pintle has threads cut into it. The pintle is secured with a nut. If the nut loosens and comes off, the pintle will drop; therefore, the nut is kept with nut stopper. The shrink-fitted sleeve is only cylinder or with bottom. In small ships, a removable heel disk is often fitted to the bottom of the pintle; this heel disk support the weight of the rudder.
10-7-2 Damage to pintle
Because the pintle is short, it does not bend. The damages to the pintle are as follows.
1. Fracture
2. Sleeve drops off
3. Corrosion
4. Wear to sleeve and bush (excessive bearing clearance)
5. Sleeve slack
6. Loss of nut
7. Wear to nut stopper and bush stopper

10-7-3 Breakage of pintle and pintle lost
After Columbus sailed from the port of Cadiz, on "Santa Maria", the ship's rudder sustained damage. "Cutty Sark," a tea clipper, lost its rudder off the east coast of Africa while competing with "Thermopylae." The causes of damage in the above cases were attributed to a fracture of the pintle. Today, however, the pintles have adequate strength and there are no instances of fracture or lost.

When the nut is loose or lost and at the same time portable box is lost, pintle will fall down into the sea and also, if the nut securing device is out of order, pintle drops off. But this case is very rare. Because in almost case, the nut is fitted on the top of the pintle. The nut securing device is provided with means to prevent it from working loose. During inspection, the securing device should be carefully checked. To prevent the nut from rotating, steel pieces are welded as shown in the Fig.10-12. This welded nut stopper is not thick about 5mm. When the nut stopper is excessively corroded, the stopper should be renewed. Some ship has a split pin through the nut and pintle head. But pin is very thin and easily corroded. The split pin is not preferable. In most case, the nut does not become loose but it should be checked by tapping it with a test hammer.
Fig.10-12 Nut below (Mariner rudder)
Even if the nut is heavily corroded or disappeared, the pintle does not drop off.

Fig.10-13 Nut stopper (1)

Fig.10-14 Nut stopper (2)
For prevention from corrosion generally the nut is covered with cement. If the cement is defective, it should be renewed.

**Fig.10-16 Pintle lost**  
When the nut is lost, pintle will fall down into the sea.

### 10.7.4 Measurement and allowable values of bearing clearance

Measurement of clearances of all bearings are to be carried out during rudder inspection. Therefore, clearances of the sleeve and the bush in the longitudinal direction (F ≈ A) and the transverse direction (P ≈ S) of the rudder should be measured. The two methods described below may be used for measurement.

1) **By lifting the rudder**  
After lifting the rudder we can see the both pintle and the bush as shown in Fig.10-17. The outside diameter of pintle (outside diameter of pintle sleeve) using external calliper and the internal diameter of bush using internal calliper have to be measured in the three sections ie. top, middle and bottom. The difference of two values is the clearance and the mean value is the clearance between pintle and bush.  
An example of the results of clearance measurement is shown below.
2) Without lifting the rudder
Without lifting the rudder, we can measure the clearance using a feeler gauge inserting between the bush and the sleeve. The method of measuring clearances using a feeler gauge is shown in the Fig. 10-19.
The measurement is the same as above i.e. fore-aft and P and S side. But in this case we can not measure the clearance at the middle section.
The feeler gauge is a collection of thin metal plates of various thickness.

Clearances in the longitudinal (fore and aft) and transverse directions (P and S) should be measured in the similar way as before mentioned.

2-1) False clearance
When measuring the pintle clearance using a feeler gauge, the measurement of clearance at the end of the bush sometimes shows a smaller value while the actual value of the clearance is bigger. As shown in Fig. 10.20 and 21, the end of the bush should be chipped off and the clearance should be measured accurately.
2-3) Standard Clearance

i) Pintle
For a newly built ship, the standard clearance is 1.5 mm.
For a ship in service, **Maximum allowable clearances between pintle and bush is 6 mm.**
IF the actual clearance exceeds 6mm, the bush should be renewed.

3) Neck bearing
Clearance in the neck bearing can be measured after the rudder is overhauled. Unless other wise the measurement is carried out using a feeler gauge. The standard clearance is 4.0 mm, IF the clearance exceeds 5.0mm, the bush should be replaced. Actually the wear down of the neck bearing bush is smaller than the pintle.

4) Examination of the Survey Report in previous survey
If the clearance of the pintle is 5.5 mm, examine the past measurement results in the survey report. For instance, if the clearance at the previous inspection was 3.0 mm, the clearance increased by 2.5 mm. Then the clearance in the next survey will be increased up to 8.0mm. so the renewal of the bush should be strongly recommended.
If the clearance is 5.0 mm in the previous survey, in this case the wearing is only 0.5mm. renewal may be deferred until the next inspection. There are no clearly-defined standards for carrier-bearing clearances; however, examples of past measurements of various bearings are given below. The "△" mark indicates that bush renewal was recommended; The "A" mark indicates that renewal was deferred until the next inspection.
Fig.10-23  Clearance of neck bearing

Fig.10-24  Clearance of carrier bearing
The bearing cannot be oil lubricated because the pintle is always in the water. Consequently, very hard wood from tropical American trees, called lignumvitae, which is a suitable material for water lubricated bearings, was used in the past. Because this wood is a natural material and its quality varies; if lignumvitae of a soft quality is used, wear is faster. From 1960 onwards, synthetic resins such as Teflon rubber and phenol resins were used experimentally. Phenol resins were found to make excellent water lubricated bushes; there is no variation of quality as in lignumvitae and with a maximum allowable pressure of 350 kg/cm², twice that of lignumvitae and good wear characteristics, almost all bushes today are of phenol resin.

But in case of phenol resin, in some ships the wear to the bush is relatively fast. This is because of the misalignment of rudder center line. After the rudder is removed and the rudder center is re-aligned, further abnormal wear to the bush will be eliminated. However, it takes considerable time and money to align the rudder center, therefore, some shipowners prefer to economize by renewing the bush at every docking survey rather than aligning the rudder center.

Phenol resin or copper alloy is used in the bush of the neck bearing and copper alloy is used in the carrier bearing. The material used in the bush is always softer than the material used in the sleeve, so the bush wears out faster than the sleeve. The advantage is that the bush can be easily replaced when it wears out.
10.7.6 Slack of sleeve
The cylindrical sleeve is expanded by heating, and when the inner diameter becomes large, the pintle is inserted by shrinkage-fitting. The two members are only held against each other physically; therefore, the sleeve might become slack due to vibrations or ingress of sea water between the members. If the slack is excessive, the sleeve drops. When the rudder is lifted, strike the sleeve with a test hammer and check for slack. If we press the sleeve lightly with a finger while striking it with a test hammer, we might feel a slack of sleeve. If we find some slack, strike all around the sleeve with the hammer and record the slacked locations. If the slack is found over 2/3 rd of all surface, the sleeve should be replaced.

Fig.10-00 False clearance
Actual clearance (Left side) is much bigger than the value measured with filler gauge.

Fig.10-00 Examination of actual measurement
**10-7-7 Corrosion of bush retainer or support**

The bush retainer and support are a comparatively thinner welded rings made of steel plate. If some part of this ring is corroded, bush might work loose and fall off. When they become excessively thin, the bush retainer or support should be replaced. If the bush has been shrinkage-fitted into the shoe piece, it will not fall off; however, there are instances of the bush disappeared. The worn bush turned into a fine piece, which in turn found its way between the pintle and the shoe piece then disappeared.

**10-7-8 Corrosion of pintle**

The copper alloy sleeve is shrinkage-fitted on the bearing surface of the forged steel pintle, therefore, the ends of the sleeve are likely to be subjected to galvanic action. Sometimes the tapered end of the pintle corrodes circumferentially and its thickness is reduced only at the corroded part. Moreover, the tapered part of the pintle is in metallic contact with the cast parts of the pintle. If the sea water enters into the small clearance, the tapered part corrodes; therefore, O-rings are generally fitted at both ends of the sleeve. If O-rings are not fitted, or no longer exist, the tapered part gradually corrodes due to the effects of the sea water, and finally, the hair crack appears around the taper end of the pintle. During long years the crack increase and the pintle will broken.

This defect cannot be detected unless the pintle is removed. There have been instances where the pintle was removed because it had become loose, and it was found that the tapered part had corroded excessively.
If the sea water has entered into this clearance between the sleeve and the pintle itself, the shrinkag-fitted sleeve becomes slack because of pintle corrosion; if this situation is not rectified for a long period, the sleeve will work loose and fall off. We have found initial corrosion in the pintle occurring circumferentially in the tapered part and then after the hair cracks will appear at this location. The next stage is corrosion due to sleeve slack, followed by corrosion in the tapered part.

Fig. 10-32 Corrosion of pintle (1)

(1) Pintle corrosion
(2) Pintle corrosion and sleeve slack
(3) Corroded bush support
(4) Corroded bush (large clearance)

Fig. 10-33 Corrosion of pintle (2)
10-7-9 Repairing corroded pintle

An excessively corroded pintle should be replaced, but if the corrosion is not heavy, the pintle can be repaired by welding depending on the material.

(1) Pintle material
In principle, welding repairs should not be carried out on forged steel pintle. However, if the carbon content of forged steel is less than 0.23%, welding repairs may be carried out. Therefore, the carbon content should be confirmed before carrying out welding repairs; if it is greater than 0.23%, welding repairs should not be carried out.

(2) Procedure for welding repairs
Fig. 10-33 is a flow chart for welding repairs for forged steel materials. At firstly, the carbon content is checked and if the carbon content is less than 0.23%, the rust is de-scaled. Very small flaws are checked by ultrasonic testing. If cracks are found, they are chipped off. Next, the defective surface is welded all around. After heat treatment, the surface is machined up. After machining, a dye penetration test may be carried out as the final check. Then new sleeve after hydraulic test is shrinkage fitted.

Fig.10-33 Procedure for repairing of corroded pintle
10-8 Lifting and Lowering Rudder
The rudder weight is supported at the top or the bottom. It is suspended from a thrust bearing in the rudder carrier in the steering gear room. However, in small ships, the rudder is supported with a heel disk below the rudder. If the thrust disk or the heel disk wears out, the rudder itself comes down. If the rudder comes down excessively, its connection with the steering gear becomes defective; therefore, the clearance between the shoe piece and the rudder should be checked carefully during a bottom inspection. Generally, the designed clearance between rudder bottom and shoe piece is 20 mm to 30 mm. If the clearance is between 0 and 10 mm, the heel disk should be renewed, or the rudder carrier should be opened up and the surface of bearing disk should be examined.

10-8-1 Wear to heel disk
Generally two hard, semi-circular steel disk is fitted in the shoe piece and the bottom of pintle, one above the other so that a point contact is obtained; however, the upper heel disk is sometimes part of the pintle. In this case, the lower part of the pintle is semi-circular. This heel disk rotates together with the rudder and has a box-shaped spigot. The semi-circular shape of the heel disk becomes flat when it wears out, causing the rudder coming downwards. If the heel disk becomes thin due to wear, it should be renewed.
Fig. 10-35 Support of rudder weight
(left: Bottom support, right: top support (hanging))

Fig. 10-36 Clearance between rudder shoe piece

Fig. 10-37 Heel disk

10-8-2 Thrust disk
The thrust disk is a copper alloy disk with etched oil grooves. Because the area of the
disk is large, the bearing pressure acting on the disk is small. Consequently, the disk does not wear out easily. However, major abrasive scratches appear on the disk when oil lubrication is insufficient. In case of the aged ships, the surface of disk has been found to badly scratched and the thickness has been considerably thin.

If the rudder comes down and its base is likely to touch the upper surface of the shoe piece, in this case the thrust disk should be replaced. Thrust disks in large ships are very big so replacing such disk involves considerable labour, therefore, the recommended renewal work is usually carried at the next dry dock.

Fig.10-38 Rudder carrier

Fig.10-39 Rudder lift up after the jumping stopper overhauled
Thrust disk with integral bush is not recommended because when the disk is renewed the sound bush also renewed.

10-8-3 Jumping stopper

If the rudder is lifted when underway due to the wave impact or the contact with floating objects, and or bottom contact, the steering gear may be damaged. To prevent such damage, a jumping stopper is provided. The jumping stopper, as shown in Figure, may be fitted over the gudgeon or assembled in the rudder carrier. The designed clearance is 2.0 mm maximum.

There are no instances of damage or corrosion to the jumping stopper itself. However, if the clearance measured is found to be large, it can be concluded that the rudder has moved down. Because a hanging rudder does not have a shoe piece, one does not know whether the rudder has moved down or not; therefore, we recommend that you enter the rudder trunk and measure the clearance between the base of rudder carrier and the jumping stopper.
Fig. 10-41  Jumping stopper on the gudgeon

Fig. 10-42  Jumping stopped under rudder carrier
10-9 Rudder Corrosion

10-9-1 Corrosion of rudder plate

In old ships, the rudder plate corrodes and its thickness decreases, similar to wear to the shell plate. However, the rate of wear of the rudder plate is gradual and is much smaller than that of the shell plate; instances where the worn rudder plate has been cut out and replaced after measurement with a thickness gauge are very rare. This is attributed to the large number of zinc anodes fitted for preventing corrosion of the rudder plate.

If the worn rudder plate is cut out for replacement, or a large thick double plate has to be provided. Unlike the hull structure, centring of the rudder is likely to be adversely affected because of welding the deformation.

Therefore, the rudder plate should be removed, placed on a level block, and welding work carried out while the centring of the rudder is checked.
10.9.2 Corrosion due to erosion
Irrespective of the age of ships, the upper, middle, and lower parts of the rudder plate and the gudgeon in fine high-speed ships sometimes suffer from excessive spongi form corrosion. This phenomenon is called erosion. The water flow generated by propeller rotation generates air bubbles in the flow at local locations where flow rate is high. When these bubbles impinge on the rudder, they burst and disappear, but cause microscopically large impacts on the rudder resulting in local corrosion of the rudder plate.
If the surface is eroded, and there is continuous flow of water over this surface, corrosion advances further. There are no fool-proof measures against corrosion; the rudder plate is sometimes built up by welding, and forged parts such as the gudgeon are sometimes covered with cement or Devcon, but at the next drydocking, similar corrosion can also be found in the cement; therefore, effective repair methods have not yet been discovered. However, as corrosion is localised, the strength of the rudder is not affected significantly, provided there is no hole in the rudder through which water can enter; therefore, this form of corrosion should not be of much concern.

10-10 Twist in Rudder Stock
Among the damages of rudder the most troublesome damage is twisting of the rudder stock. In furthermore, In most cases twisting is accompanied with by bend of the rudder stock.

As mentioned in (9) of Section 8., When we watch the rudder just aft in the dry dock and the rudder is found to have swung to any P or S side, then the rudder stock is likely to have twisted. Because when the ship is in dry dock always the rudder is kept just midship.

Twisting is caused due to the external force to the rudder plate in case of grounding, touching with mud, rock or floating objects. Without knowing that the rudder is fixed, when the rudder is taken by force of steering gear the rudder stock will be twisted. While sailing, if the rudder suddenly responds strangely and becomes heavier than usual, the rudder stock has probably twisted. However, if the angle of twist is small, there is practically no effect on steering; When the twisting angle is less than two degrees, there is no problem.

But when the ship heavily stranded, the twisting combined with bending of rudder stock.

10-10-1 Position of twist
Not the same as dents and cracks, It is very difficult to find the position of twist.
The rudder stock above the neck bearing is slender, so the most cases it may be assumed that this part of the rudder stock will be twisted, But it is very difficult to check a position correctly.
The twisting angle is measured after the rudder stock is oberhauled and placed on the level block. The difference of the position of key way on the top of rudder stock and the position of rudder flange. In this case only we recognize the twisting angle but we can not find the position of twisted area because there is no reference longitudinal line on the rudder stock.
The rules of the Germanischer Lloyd (the German classification society) prescribe the replacement of the rudder stock when the angle of twist is greater than 10 degrees.

If the twist is 10 degrees, the case where the twist has occurred throughout the length of the rudder stock, say over a range of 3 m, is quite different from the case where the twist has occurred in a range of 50 cm in the rudder stock; while the twist in the former is 0.3 degrees per unit length, the twist in the latter is nearly six times this value. For instance, the report does not have an entry such as "twist was found over a distance of 1,500 mm from a point 2,000 mm above the coupling in the upward direction", because nobody knows the range of twisting. One reason for this is that permissible values of twist have not been decided. In the new building a reference line in the longitudinal direction should be marked on the rudder stock.

10-10-2 Actual examples of twist
As mentioned above, GL requires replacement of rudder stock if the twist exceeds 10 degrees, but we are inclined to think that this requirement has been simplified beyond our reasoning. Results of damage and repairs of twisted rudded stock experienced during survey are as follows;

10-10-3 Repairing twist
Twist occurs because of stranding and bottom contact, therefore, repair costs are generally covered by insurance. For this reason, there are many instances of renewing the rudder stock. However, as the rudder stock is a large forged block, a considerable time is required to procure materials. It is customary to carry out temporary repairs and renew the rudder stock later.
The following precautions should be taken during repairs:

1) The keyway was subject to large forces, therefore, confirm using ultrasonic testing that cracks are not present.
2) The entire rudder stock is subjected to twisting forces, therefore, examine the entire surface of the rudder stock for very small flaws.
3) For details of welding the keyway, see 10-7-9(2) “Procedure for Welding Repairs”

<table>
<thead>
<tr>
<th>L × B × D:</th>
<th>G/T</th>
<th>Twist angle</th>
<th>Repair method</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A 137.45 × 18.90 × 11.75</td>
<td>8.617</td>
<td>35°, bend</td>
<td>Keyway machined, bend fairied by heating</td>
<td>Impact with floating object</td>
</tr>
<tr>
<td>B 63.50 × 9.70 × 5.20</td>
<td>987</td>
<td>10 degrees, bend</td>
<td>Keyway machined, bend fairied by heating</td>
<td>Impact with floating object</td>
</tr>
<tr>
<td>C 63.50 × 9.70 × 5.20</td>
<td>988</td>
<td>37°</td>
<td>Rudder stock replaced</td>
<td>Stranding</td>
</tr>
<tr>
<td>D 93.60 × 14.02 × 8.70</td>
<td>5.571</td>
<td>12°</td>
<td>Keyway machined, replaced with a new one next year</td>
<td>Impact with barge</td>
</tr>
<tr>
<td>E 60.00 × 8.50 × 5.54</td>
<td>912</td>
<td>30°, bend</td>
<td>Piece added to quadrant</td>
<td>Impact with quay</td>
</tr>
<tr>
<td>F 85.00 × 13.40 × 7.20</td>
<td>2.202</td>
<td>25°, bend</td>
<td>Keyway machined, replaced with a new one next year</td>
<td>Impact with ground</td>
</tr>
<tr>
<td>G 98.00 × 15.00 × 7.70</td>
<td>3.369</td>
<td>38°</td>
<td>Keyway machined</td>
<td>Impact with floating object</td>
</tr>
<tr>
<td>H 136.00 × 18.90 × 11.85</td>
<td>8.545</td>
<td>46°, bend</td>
<td>Keyway machined, bend fairied by heating</td>
<td>Contact with floating object</td>
</tr>
<tr>
<td>I 69.00 × 11.70 × 5.89</td>
<td>1.324</td>
<td>30°, bend</td>
<td>Keyway machined, bend fairied by heating</td>
<td>Grounding</td>
</tr>
<tr>
<td>J 128.00 × 17.30 × 9.82</td>
<td>6.210</td>
<td>18°, bend</td>
<td>Keyway machined, bend fairied, replaced with new one next year</td>
<td>Not known</td>
</tr>
</tbody>
</table>

Table 10-2 Example of repair works on the twisted rudder stock

(1) If the twist angle is comparatively small as shown in the figure, the keyway for the rudder stock and the tiller is machined to increase its size so that a larger key can be fitted.
The method of retaining the original keyway and adjusting the position of the steering gear may also be considered, but I have not heard of actual examples of such a practice. For the ship in. E on the Table 10-2, however, the quadrant was increased in size by adding an extra piece and the rudder angle was corrected; this is an example of adjusting the steering gear.

Fig.10-46 Adjustment using a new bigger key
(2) Big twist angle

If the twisted angle is so large that repairs to the key alone are inadequate, the keyway can be built up by welding, the welded part checked for flaws by ultrasonic tests, and a new keyway cut to suit the twisted angle. The rudder stock can be used even though it is twisted. However, because of the twist, the rudder stock might have flaws that are not visible to the eyes; therefore, it should be examined by non-destructive tests such as ultrasonic flaw detection, magnetic particle test or dye penetrant test (colour check). If very small cracks are detected, depending on the sizes of the cracks, they may be chipped out or other measures adopted to eliminate them. This is a temporary repair method; after repairs are carried out, the shipowner has to procure a new rudder stock and replaced. However, these repairs may be accepted as permanent repairs.

The wire rope test is described here for reference. In addition to the breaking test of the wire rope, after individual core wires of the rope is subjected to twisting test and coiling test. In the twisting test, one end of each core wire is fixed and the other end is rotated to twist the wire. If the core wire breaks before reaching a specified number of turns, the rope is considered to be defective, irrespective of its tensile strength. For example, in a 53 mm diameter, No. 3 rope (6 x 19) used for mast stays, the diameter of one core wire is 4 mm. If the core wire is gripped at a length of 400 mm and the twisting test performed, it should withstand at least 17 turns before breaking. That is, the 4 mm diameter core wire should not break before 17 rotations (17 x 360 degrees) over a length of 400 mm span. The material of the rudder stock and each individual wire are different; so does the surface layer; therefore, these two items cannot be compared directly. However, even if the rudder stock is twisted to 360 or 760 degrees, it may not break in my opinion.
the speed at which the wire is turned is also a factor to be considered: it should be 60 tuenes per minute.

Fig. 10-48 Adjustment of twisting
The old key way (shown in full line) is built up by welding; a new key way (in dotted line) is cut to suit the twist of the rudder stock (θ theta) and the tiller position is adjusted to suit the rudder.

10-11 Others
10-11-1. Flap rudder
In order to improve the response of the rudder. The flap is fitted behind the rudder plate. This rudder is called Becker rudder. The point of the inspection is as follows: The link mechanism and the connecting hinges including the flange are to be carefully inspected. If necessary, wear in the bearing may be measured at an overhaul inspection. At Special Survey, in addition to above inspection, operation tests are to be carried out.

Fig. 10-45 Flap rudder

10-11-2 Intermediate bearing
The rudder is generally supported at three points; in case of a hanging rudder, the supporting point is two. However, in rare cases, some ships have rudders supported at four points, with an additional intermediate bearing below the uppermost support, namely the rudder carrier.
The bush in the intermediate bearing always shows abnormal wear and at the every docking, bush is renewed. This is because the centring of the rudder is incorrect. In this case it is better to abolish this bearing to take off the bush and change from four point supports to three points. After removal of the intermediate bearing there is no problem in rudder operation. Three support points are adequate for a normal rudder.

10.11.3 Rudder carrier
Although no relationship to bottom inspection, the rudder carrier is an important part connecting the rudder and the steering gear in the steering gear room. Fig. 10-8-2 shows an example of the construction of a rudder carrier; the construction of the thrust disk (carrier disk) has already been described. The points for inspecting the rudder carrier are listed below.

1. Looseness of bolts connecting rudder carrier to deck are to be examined with the test hammer.
2. Cracks in deck connection part

In the construction shown in the figure on the left, crack will not appear in the deck. But in the figure right, cracks might appear in the welded joint at the inserted liner to the deck, when the thicker liner plate is welded to deck. Sometimes circumferenced cracks might be appeared in the weld joining to the deck.

3. Loose of wedge
Where reamer bolts are not used but a wedge is used for securing the rudder carrier to the deck, if the wedge becomes loose, or the direction in which the wedge is driven is incorrect, the carrier might turn; therefore, confirm that the wedge has been secured correctly.
Fig. 10-48 Fixing the rudder carrier fixed with edge

(4) Wear to thrust disk (carrier disk) cf. Photo 10-4
Examine wear and scratch to the thrust disk and the conditions of securing screws, as described in Section 10-8-2. When the wear of the disk is minor but there is local scratch on the carrier disk because of inadequate lubrication, the disk may be reversed, oil grooves newly cut into the disk, and the disk reused, depending on the scratch.

In ships equipped with electrohydraulic steering gear, always check the following points when inspecting the rudder carrier:
1) Loose studs for gland of the hydraulic cylinder and oil leakage
2) Are there any flaw or scratch in the ram?

Photo. 10-6 Scratches on the ram