SEAFDEC Training Department

Text/Reference Book

Southeast Asian Fisheries Development Center

March 1978

HANDBOOK FOR FISHERIES SCIENTISTS AND TECHNOLOGISTS

Fishing Gear and Methods

Fishing Boat

Marine Engineering

Refrigeration

Oceanographic Survey Methods

Issued occasionally from the Training Department, Southeast Asian Fisheries Development Center.
P.O. Box 4, Phrapradaeng, Samutprakarn, Thailand.

PREFACE

When the Training Department of SEAFDEC was approached at the beginning of this year by Professor Rapee Sagarik, the Rector of Kasetsart University, requesting us to provide an intensive course of training in fisheries for students of the Faculty of Fisheries of the University we gladly agreed to his request. And to help the understanding of the students we prepared this handbook, based on the lecture notes used by our instructors during the past decade.

We hope that the material contained in this small handbook will prove useful, not only to the students who attend the SEAFDEC Special Courses in Fishery Science and Technology but also to all those interested in these subjects.

Bangkok
March 1978

Deb Menasveta
Chief, Training Department

Foreward

The Training Department, Southeast Asian Fisheries Development Center was given the opportunity to conduct a special course of training for the students of the Faculty of Fisheries, Kasetsart University, during the period Tuesday, 21st March to Thursday, 6th April, 1978. In preparation the Department compiled this textbook in fisheries science and technology, which covers fishing gear and method, fishing boat, marine engineering, refrigeration and oceanographic survey methods. The five sections of the first chapter were written by Dr. O. Suzuki (1.1), Messrs. T. Yamazaki (1.2 and 1.3), C. Miyata (1.4) and P. Masthawee (1.5). Most of the second chapter was the responsibility of Mr. T. Yamamoto, though a part of section 2.2 was covered by Mr. A. Wada. Mr. M. Tanaka and Capt. V. Sudhasaneya RTN. collaborated to produce the third chapter. The fourth chapter was written by Mr. T. Yamamoto and the final chapter by Dr. O. Suzuki.

Comments and suggestions are welcome and the Department hopes to be able to publish a revised edition in the near future.

Finally, we wish to thank Mrs. Francesca Sreesangkom for her assistance in the laborious compilation of the present textbook.

Bangkok
March 1978

O. Suzuki

Otohiko Suzuki
Chief, Fishing Section
and Editor of SEAFDEC TD textbook

Contents

Contents (cont'd)

Contents(cont'd)

Contents(cont'd)

List of Tables

List of Figures

1. FISHING GEAR AND METHOD

1.1. Basic Fishing Gear Technology.

1.1.1. Twine and rope construction.

Considering their construction, twines and ropes are classified into two major categories, viz., (1) twisted and (2) braided. The first group is subdivided into textile (including two stranded, three stranded, four stranded, three-by-three stranded and compound) and wire (including flexible and non-flexible). The second group is subdivided into crossing-laid and tube-shaped.

Most twines and ropes belong to the twisted variety, and are composed of a certain number of threads or strands twisted together, each thread or strand being composed of the original fibers. Braided twines are fabricated by plaiting several threads or strands.

Referring to the number of strands used to form a completed twine or rope, the terms of two, three and four stranded twine or rope are used. In making the three-by-three stranded, three smaller three stranded twines or ropes are twisted together to make a larger three-stranded one. Compound twist is made up of textile fibre and wire. Wire rope manufacturing is basically the same as the compound rope, except that it is made almost wholly of wire.

Crossing-laid braided twines or ropes are produced by interweaving two or four strands alternatively, and tube-shaped braided is made by knitting together several strands into a tube-shaped twine whose centre space is sometimes packed full of bundled fibres like a compound rope.

Most twisted netting twines and ropes are three stranded. Usually, the directions of twists inserted into strand and twine are contrary to each other. The direction of twist in twine or rope is commonly clockwise, and is called Z-twist. Contrary to this that of anti-clokwise is called S-twist.

1.1.2. Twine or rope size.

The size of fine twine is indicated by the combination of the size of yarn used in making up a twine and the designation of twine construction, e.g., 120D/5/3. The first part of the specification 120D, signifies the yarn size. The following figures 5/3 shows the twine construction, that is, 5 yarns per strand and 3 stranded construction. The yarn size is indicated either by the weight per length or the length per weight. The main designations of yarn size are listed as follows:

Material	System	Designation	Measurement
Cotton, synthetic spun yarn	English cotton number	(S, 'S, /S Nec)	Yards per lb / 840
Flax, hemp, ramie, etc.	English linen number	(Nel)	Yards per lb / 300
Silk, continuous filament synthetic yarn	Denier number	(D, d, Td)	9000 / meter per gram
All	Tex number	(Tex)	1000 / meter per gram

The relations among the designations of yarn size are rather complicated. Denoting the English cotton number, the English linen number, the denier number and the Tex number by X_1, X_2, X_3 and X_4 respectively, we have the following relations:

$$(5.9/X_1) \times 10^2 = (1.65/X_2) \times 10^3 = 0.11_1 X_3 = X_4$$

$$2.8 X_1 = X_2$$

Sometimes, a convenient indication for twine size such as No.15 or # 15 is used among fishermen. This implies that 210 denier yarn is used, i.e., 210D/5/3, if the twine is three stranded.

The size of heavy twine is usually shown by either the weight per length or the length per weight of the completed twine. The designations for the size of heavy twine are summarized below:

Material	System	Designation	Measurement
All	English number	(Yds)	Yards per lb
All	Japanese number	(M)	5 / feet per monme
All	Resultant Tex	(R Tex)	1000 / meter per gram

Note: One "Monme" is equal to 3.75 grams.

The rope size is shown by either the diameter or the circumference of the rope, and such values are expressed in millimeters or inches. Because this measurement is very distinct, confusion never occurs in use.

1.1.3. Webbing.

A mesh is a rhombic opening enclosed by four bars of twine of equal length firmly knotted at the four corners. Each corner is called a "knot". There are many different types of knots used in net construction. Webbing is divided into two major groups, i.e., (1) knotted and (2) knitted or knotless. The first group is subdivided into sheet bend, double sheet bend and reef knotted. The second group is subdivided into knotless (including straight type, zigzag type and tortoise type), minnow (including ordinary type, twined type and woven type) and russel.

Usually the edge with cut meshes of webbing is called "length" while that with clean meshes is called "depth". Pulling lengthwise tightens the knots of webbing, and is called a pull "with the knots". A pull depthwise, called a pull "against the knots", tends to loosen the knots.

The edge along the length of webbing usually has a double twine for the outside one tier or round of half meshes. This forms the edge and is called a "double selvedge". Occasionally double twine is used in making each whole mesh at the edge of the webbing. In this case, the selvedge is called a "double mesh selvedge". No selvedge is sometimes called a "single selvedge". The purpose of making a selvedge is to reinforce the webbing itself.

Webbing size is shown by the depth and the length. The depth of webbing is indicated by either (a) the number of meshes or (b) the number of rows. The length of webbing is shown by either (a) the number of meshes, or (b) the length in meters, feet, yards or fathoms. In the latter case it is understood that the length is to be measured by fully stretching the net lengthwise.

1.1.4. Mesh size.

There are many methods of measuring mesh sizes. The following is a list of the methods used to indicate mesh size.

System	Locality used	Measurement
Stretched	International	Length of two bars
Square or Bar	Some European countries	Length of one bar
Pasada	Spain, Portugal	Mesh number per 20 cm
Omfar	Norway, Sweden	Half mesh number per one "Alen"

System	Locality used	Measurement
Row	Holland, England	Row number per yard
Knot	Spain, Portugal	Knot number per meter
Setsu or Fushi	Japan	Knot number per six inches

Note: One "Alen" is 0.628 m in Norway and 0.594 m in Sweden. Measurement should be made when stretched.

Converting the traditional systems for indicating mesh size into the international standard system, viz., the stretched measure, the following formulae (in cm unit) can be used:

$$2L = \frac{20}{P} = \frac{126}{0_n} = \frac{119}{0_s} = \frac{183}{R} = \frac{200}{K-1} = \frac{30}{F-1}$$

where L is the length of a bar, P, 0_n, 0_s, R, K, and F indicate the pasada, Norwegian Omfar, Swedish Omfar, Row, Knot and Fushi numbers, respectively.

1.1.5. Hanging.

Putting together pieces of webbing to make up a net and connecting them to the ropes is called "hanging". Upon skilful hanging depends the right degree of fullness in all parts of the net, the proper relief of tension by the selvedge, and on the whole, the proper behaviour of the gear in water and the fishing success of the completed net.

When the completed length of a net is denoted by ℓ_c and the stretched length of the webbing used by ℓ_s the hanging coefficient ξ is expressed as

$$\xi = \frac{\ell s - \ell c}{\ell s} = 1 - \frac{\ell c}{\ell s} \tag{1}$$

Letting 2L be the mesh size of the webbing in stretched measure, and n and m be the number of meshes lengthwise and deptwise respectively, then the stretched length ℓ_s and the stretched depth d_s of the webbing are

$$\ell_s = 2 \text{ n L} \tag{2}$$

and

$$d_s = 2 \text{ m L} \tag{3}$$

respectively. Therefore, from the equations (1) and (2), we have

$$\ell_c = \ell_s \;(1 - \xi) = 2\, n\, L\, (1 - \xi) \qquad (4)$$

Focussing our attention on a mesh opening in the webbing hung homogeneously with the hanging coefficient ξ, it is easily understood that the length of a mesh opening is $2L(1 - \xi)$. Since a mesh opening is a parallelogram, the depth of a mesh opening is

$$2L\sqrt{1 - (1 - \xi)^2} = 2L\sqrt{2\,\xi - \xi^2}$$

Thus, the depth of the net is theoretically as follows:

$$d^* = d_s\sqrt{2\,\xi - \xi^2} = 2\,mL\sqrt{2\,\xi - \xi^2} \qquad (5)$$

the above d^* is called theoretical net depth.

It will be noticed that a net constructed with its length and depth given by the equations (4) and (5) respectively is like a curtain or a plane sheet in shape. The net so made has not any slackness. However fishing gear such as a purse seine has some degree of slackness, which may vary in different parts of the net. This makes the taper in the wings and at the same time the fullness in the webbing which prevents the fish from escaping out of the net during pursing operation. When a net is required to have some slackness or fullness, the actual depth of the net d_c which is represented by the length of each breast line should be shorter than its theoretical depth d^*. The degree of slackness ε is given by

$$\varepsilon = 1 - \frac{d_c}{d^*} = 1 - \frac{d_c}{2mL\sqrt{2\,\xi - \xi^2}} \qquad (6)$$

The above ε may be called the slackness coefficient.

1.1.6. Shaping.

Consider a uniform sheet of webbing which is tapered in shape, with the rate of loss of n meshes in length against m meshes in depth. Now let B, P and M be the number of "BARs", the number of "POINTs" and the number of "MESHes" in cutting respectively. Then, the following relations are satisfied:

When $m > n$,

$$\left.\begin{array}{l} B = 2n \\ P = m - n \end{array}\right] \quad \text{and} \qquad (1)$$

When $n > m$,

$$\left.\begin{array}{l} B = 2m \\ M = n - m \end{array}\right] \quad \text{and} \qquad (2)$$

Now, denoting the hanging coefficient of the webbing by ξ, the length and depth of the sheet of webbing are $2nL(1 - \xi)$ and $2ml\sqrt{2\xi - \xi^2}$ respectively, where 2L is the mesh size. On the other hand, if we denote the degree of taper by the angle θ, then, we have

$$\tan\theta = \frac{n(1-\xi)}{m\sqrt{2\xi - \xi^2}} \qquad (3)$$

Introducing the equations (1) and (2) into the above equation,

when $m > n$

$$\tan\theta = \left(\frac{1}{\frac{2P}{B} + 1}\right)\frac{1-\xi}{\sqrt{2\xi - \xi^2}} \qquad (4)$$

and when $n > m$

$$\tan\theta = \left(\frac{2M}{B} + 1\right)\frac{1-\xi}{\sqrt{2\xi - \xi^2}} \qquad (5)$$

1.2. Purse Seine Fisheries.

The surrounding net, especially the modern purse seine, is an important type of sea-fishing gear for catching pelagic fish. This type of fishing gear is classified into two major groups: surrounding nets with bag net and those without bag net. The second group can be subdivided into the nets without purse line (including the one boat and the two boat type) and those with purse line (including the one boat and the two boat type).

(1) Surrounding net with bag net: The Japanese semi-surrounding net is a typical example. The bag net is attached to a pair of wing nets. After a boat with luring lamps has attracted a fish school, netting boats towed by other small boats set the net around the fish school.

(2) Surrounding net without purse line: The lampara type net belongs to this category. It has neither purse rings nor a purse line in the lower part of the net. Regarding fishing operations, this type of gear is subdivided into the one boat and the two boat types.

(3) Surrounding net with purse line: There are various purse seines according to the species of fish aimed at. The net is set around a fish school and then the purse line is quickly pulled onto the boat so pursing the bottom margin of the net.

(3-1) One-boat type purse seine: The seiner holding one end of the net, surrounds a fish school laying down the net at full speed in such a way as to block the passage of the fish school while a skiff is standing by holding the other end of the net. After completion of the setting of the net the seiner receives the other ends of the purse line and the bridle from the skiff, and the net is hauled onto the deck as soon as the pursing operation is completed.

(3-2) Two-boat type purse seine: The purse line or the wire rope for pursing the bottom of the net are attached to the sinkers in almost the same manner of construction as in the one-boat type purse seine, but the fishing operation is made by two boats. Considered in detail, however, the one-boat and the two-boat type purse seines are of different construction; the twine sizes, the mesh size, the length and the depth of net and the ratio of the length to the depth are different. Sardine, mackerel, horse mackerel, skipjack, and tuna are the main objectives of these purse seiners.

1.2.1. Necessary conditions for purse seining.

In the one-boat type horse mackerel and mackerel purse seine, the netting twine size for the cod end ranges from No.21 to No.24 (number of yarns) and the mesh size ranges from 5 to 6 cm in stretch measure. While in the one-boat sardine and small horse mackerel purse seine, the netting twine for the cod end ranges from No.18 to No.24 and the mesh size is 3.3 cm in stretch measure. In the two-boat horse mackerel and mackerel purse seine, netting twine in the range of No.18 to No.21 is used for the cod end and the mesh size is from 5 to 6 cm; while in the sardine purse seine, netting twine of No.6 is usual with mesh size of 1.7 cm for the cod end, though sometimes twine size ranging from No.4 to No.6 and mesh size of 1.1 cm are employed for seiners operating in bays and inlets.

In Thai purse seiners, the webbings of twine size range from No.4 to 6 with a stretched mesh size of 3.3 cm for catching Indo-Pacific Mackerel, for bonito, a twine size between No.9 and No.12 with a stretched mesh size between 3.8 and 4.5 cm are used.

Generally speaking, a purse seine has 2 to 4 times of buoyancy against the total sinking power. This is to prevent the float line from sinking below the surface of the sea during pursing operations. During an operation it is important to prevent the fish school from escaping from the lower part of the wings. This is possible to some extent if the net is allowed to develop depthwise as fast as possible while it is being set. Therefore, the net must have a fast sinking speed. In other words, the net should have remarkably heavy weight in water and low hydrodynamic resistance.

Table 1.2.1 shows the particulars of various kinds of purse seine. In Table 1.2.2 a comparison of sinking velocity for several kinds of purse seines is given. As seen from the table the average sinking velocities of purse seines are in the range of 11.0 to 17.0 cm/sec. In extreme cases, the highest sinking velocity reaches a record of 27.5 cm/sec and 4.2 cm/sec is the lowest. Table 1.2.3 and 1.2.4 show the weight of sinker used per meter of the sinker line for purse seines in Japan and Europe respectively. From the tables, we can conclude that the average sinking power per meter ranges from 1.1 to 2.8 kg/m. It is reported, however, that some herring purse seines in Iceland are using heavy sinkers ranging from 9.2 to 9.9 kg/m.

For webbings for purse seine Tetoron or Vinylon are recommended, because of their large specific gravity. Though nylon have to be treated with resin to increase apparent specific gravity, it is still in use. Sinking velocity can be increased by increasing the sinker. However, we must take into consideration the fact that the tension acting on the net becomes greater with increasing sinking power. Fatigue of the net becomes evident sooner with increasing tension. With an increased number of sinkers, floats must also be increased to prevent the float line from sinking below the surface during the fishing operation, making the net more bulky for handling. Fig. 1.2.1 shows the result of an experiment by Nomura and others. Even if the weight of sinkers is increased to twice or three times the original weight, the ratio of sinking velocity increases only by 1.35 and 1.50 times respectively.

1.2.2. Necessary factors for fishing gear design.

Fishing gear in standing water keeps its shape under the balance of the upward force (buoyancy) of the floats and the downward force (sinking power) of the sinkers and the net. The shape of the net should be maintained even when a current is acting on the net.

(1) Float: Wooden floats, bamboo floats, glass floats, synthetic floats and metal floats are common. A buoy or a float should have a low specific gravity and as a whole should be sufficiently water-tight. The material used should be cheap and easily obtainable. It should also allow for mass production method as well as being easily formed into the desired shapes. Cork, pine paulownia, cryptomeria have been widely used. Synthetic buoys and floats are now in common use instead of the above natural materials. The floats used in deeper layers as in bottom gill net or bottom trawl net should be able to withstand great pressure.

(2) Buoyancy: The buoyancy F of a float is expressed as $F = V - W$, where V is the volume of the float and W is the weight in air. Denoting the specific gravity of the float by C, we have

$$F = W\left(\frac{1}{C} - 1\right) = V(1 - C)$$

The buoyancies of various types of float are shown in Table 1.2.5.

(3) Sinking power: Lead, iron, brass, stone, brick, concrete, etc. are commonly used as sinkers. The sinking power F_s is given by $F_s = W - V$, where W and V are the weight of sinker in air and the volume of sinker respectively. Denoting the specific gravity of the sinker by C, we have

$$F_s = W\left(1 - \frac{1}{C}\right) = V(C - 1).$$

The sinking powers of the various sinkers are shown in Table 1.2.6.

(4) Calculation of twine weight: The weight of twine for different materials can be obtained by the following empirical method within a range of practical accuracy.

Nylon twine: (Number of yarn given) x 3 x 0.9 gives weight in gram per 100 m in length.

Vinylon twine: (Number of yarn given) x 4 x 0.9 gives weight in gram per 100 m in length.

Cotton twine: (Number of yarn given) x 4 gives weight in gram per 100 m in length.

1.2.3. Purse seine in Thailand.

One-boat type purse seine fishery in Thailand originated from the traditional Owan-Dam, which was a Thai surrounding net operated by man-power using a single row-boat. Two-boat type purse seine fishery came originally from China. This fishery consists of an engine-powered mother boat (15-30 tons) and two smaller non-powered boats. When locating fish schools, the master fisherman keeps a lookout with some of the crew from the top of the mast of the mother boat. When a fish school is found, the two small boats start to shoot out the seine surrounding the fish school. Finally the fish are caught by pursing the seine net. However, with this type of purse seine the gear size is limited by the boat size, and therefore a large catch cannot be taken in each operation. For the above reason, the two boat purse seiners are at present decreasing in numbers.

Most purse seiners in Thailand are powered by diesel engines, and operate their gear from the foredeck. For pursing the purse lines and other purposes, drum type winches are installed on board. Purse seines are now made chiefly of nylon for the main part of the net and polyethylene for the selvedge part. Polyethylene crossing laid rope is used as a purse line instead of wire rope, because it is easier to handle during operations.

To detect fish schools, the following methods are adopted by Thai fishermen.

(1) A master fisherman keeps watch from the mast during the evening and early morning.

(2) Even on a dark night, fish schools can be detected by looking for the luminous effect on plankton made by swimming fish.

In the Gulf of Thailand, fish schools are small and occur over a wide area. Consequently, the above methods are popular and are widely adopted here.

The following methods are in use for fish luring;

(1) Utilizing the natural behaviour of fish to gather in a shady place. For this coconut leaves are suspended at various depths in water to attract fish.

(2) At night, three or four lamps are suspended just above the water on one side of the fishing boat to attract fish. At present, kerosene lamps installed on rafts are used by purse seiners for attracting fish. These rafts with lamps are aligned at regular intervals of 70 m, connected to one another with rope and anchored to the raft furthest upstream or on the side most exposed to the weather. Usually 5 to 10 rafts are used at a time.

As fishing operations are usually carried out in areas not affected by the monsoon, fishing grounds are changed according to the season. Because of this, purse seine fishermen know well the migratory routes of fish schools. Fishing operations take place throughout the year except during the spawning season, when fishing is prohibited by law. Fishing grounds are usually within 30 nautical miles from the shore and at depths shallower than 40 m. The major fishing bases for purse seiners are shown in Fig. 1.2.2. A design diagram of the gear used is shown in Fig. 1.2.3. and particulars of a webbing unit are shown below:

Name of Part	Twine size	Mesh size	Depth	Length
Selvedge	210d/18	1 3/4" (4.4 cm)	6 meshes	40 m in float line length 44 m in sinker line length
Webbing	210d/9 (for main net) 210d/12 (for cod end)	1½" (3.8 cm)	800 meshes	1,400 meshes

Main dimensions of the completed set of gear are as follows:

Name of Part	Hang-in (%)	Constructed depth(m)	Constructed length(m)
Upper part	25	20	600
Lower part	18	27	600

Details of ropes used are shown below:

Name of part	Diameter (mm)	Length (m)	Remarks
Float line	6	600	S and Z twist of ropes are used together
Sinker line	6	660	- ditto -
Purse line	24	700	Cross laid rope (braided rope)

Two thousand synthetic floats (Naigai No.8) are attached to the float line. Their weight in air, specific gravity and buoyancy are 70 g, 0.25 and 210 g respectively. Therefore total buoyancy corresponds to 420 kg. Two hundred and twenty pieces of lead sinker, each 500 g in weight, are attached to the 600 m sinker line at regular intervals of 3 m. The weight of each piece of lead in water is 455 g, therefore the total weight of the sinkers in water is 100 Kg. The same number of purse rings as the lead sinker are set at the same regular intervals. Each 10 cm diameter ring is made of bronze (specific gravity : 7.8) and weighs 500 g in air. The weight of each ring when in water is 435 g so making a total weight in water to 95.7 kg. The weight of the net in water is 86 kg. Therefore, the final surplus buoyancy left is equal to 138.3 kg.

1.3. Gill Net Fisheries.

The gill net is an important type of fishing gear in commercial fisheries. In actual fishing operations a number of net units are used, sometimes a full set of nets extends thousands of meters in length. The gear is allowed to drift near the surface with one end of the net connected to the fishing boat. Sometimes it is set near the bottom and anchored at both ends. Gill nets are effective for catching many pelagic fish, such as herring, salmon, sardines, mackerel, tuna and sharks. They are also useful for catching many demersal fish such as cod, bream and flat fish.

Salmon drift net is a type of gill net which is the most developed in the gill net fisheries. In salmon fishery, drifters commonly set more than 400 units, each one about 60 meters in length. Thus a full set of drift nets sometimes reaches 25 to 30 km. The nets are set late in the afternoon and allowed to drift until midnight. The drifter will stay nearby. Hauling the nets is done with the aid of a hauling machine, beginning at midnight, continuing until late the next morning. The fish gilled in the nets are released from the meshes by hand. The catch is then transferred to a mother boat. In the North Pacific Ocean the salmon drift net fishery continues for three months from late spring to early Summer.

Entangling nets comprise the single and the double walled and the three walled trammel nets. These are used for catching hake, shark, ray, bream, spanish mackerel, shrimp, etc. The single walled nets are used in the Southern Caspian Sea to catch sturgeon by entangling. About 150 units, set perpendicular to the shoreline, are used in an operation.

1.3.1. Necessary factors for effective gill netting.

At present, synthetic fibers such as nylon multifilament and nylon monofilament are most commonly used for gill nets because of their flexibility, strength, elongation, durability, etc. Table 1.3.1. shows the comparison of physical properties of several kinds of synthetic fiber, and those of cotton are included for reference.

By looking at Table 1.3.1., we can conclude that nylon has many superior properties compared with the others. It has high tenacity, high elogation, excellent elastic recovery, and is on the whole suitable for net construction processes. Nylon is comparatively cheap. Nylon monofilament is almost transparent so that it cannot easily be seen in water.

Tension acting on each mesh is closely related to the catchability of the gill net. If the net is constructed with too many floats and sinkers, strong tension acts on the legs of the meshes. Therefore, the netting twine forming the meshes becomes more taut, leading to poor catch.

The breaking strength of twine used in gill nets should be sufficiently high to prevent breaking during operation. A proper elongation in netting twine is required for gill net, i.e., 25 to 30% elongation ratio would be appropriate. The colour of net is an important factor and recommendations are given for the colours to be used in salmon gill net and flying fish gill net fisheries. Salmon gill net fishing in the North Pacific Ocean, where the transparency is very low, is conducted at twilight and the preferred colour is greenish black. In flying fish fisheries conducted in highly transparent water, blue is recommended. Using the proper mesh size will result in high fishing efficiency of the gear. Mesh selection is particularly important for gill nets and so in deciding mesh size, consideration should be given to the body size and shape of the fish sought. The shape of the mesh is determined by the hang-in ratio. Generally the hang-in ratio of a drift net is in the range of 30 to 40%, while a bottom gill net has more hang-in ratio. For a trammel net a hang-in ratio of 40 to 60% is used.

Table 1.3.2. shows particulars of some typical gill nets. As seen from the table, the drift gill nets are narrower in mesh size range, whereas the bottom entangling nets are much wider. The depth of a drift gill net is much greater than that of a bottom entangling net.

1.3.2. Spanish mackerel drift net in Thailand.

Drift nets are used for catching spanish mackerel in Thailand. However, this species of fish is caught mostly not by enmeshing but by entangling. The hang-in ratio of the net used is about 38 to 40%. The netting twine used is nylon 210 d/18 yarn (very soft twist) and the stretched mesh size is 10.2 cm. The depth of the net is 125 meshes and the length of a unit is 200 m when stretched. Buoys are fixed on the gear but sinkers are not used at all. Instead of sinkers, a 25 mesh depth of heavy saran selvedge (specific gravity : 1.71) made of 380 d/18 yarn is attached at the bottom of the nylon netting. The mesh size of this saran net is the same as the main net. The net is made in this way in order to catch fish not only by enmeshing but by entangling as well. Since there are no sinkers, tension acting on the meshes is remarkably small and therefore these loosely hung meshes give more entangling efficiency. This type of fishing usually employs about 15 to 30 units of net and the boats carry 3 to 5 crew members on board. The net is laid out in the evening. After shooting the gear, the boat returns to the initial position from where it started shooting and then picks up the buoy line. After about two hours the crew begins to haul in the net manually on board. The operation is repeated 2 to 3 times during the night. In the morning after the fishing operation the boats return to their fishing port. This fishing operation is done throughout the year shifting from one fishing ground to another. The nets used are usually green in colour.

Particulars of the gill net used are as follows (for illustration of details refer to Fig. 1.3.1.):

Netting material	: nylon and Saran multifilament.
Type of knot	: Double English knot (Double Reef Knot).
Colour	: Green.
Twine size	: nylon 210 d/18 yarn and Saran 380 d/18 yarn.
Stretched mesh size	: 10.2 cm (4").
Length and depth of a unit of net	: 200 m x 150 meshes (include 25 meshes of saran selvedge net).
Hang-in	: 38-40%
Float line	: Polyethylene rope of 8 or 10 mm in dia., S- and Z-twist.
Buoy line	: Vinylon $20^{s}/45$ yarn, 5-15 m in length (length of buoy line is adjustable to a desired layer).
Float	: Plastic cylindrical type, 40 cm in length x 10 cm in dia.

1.4. Line Fisheries.

Line fisheries can be classified into six major groups: pole and line, tuna long line, bottom long line, squid angling, trolling and vertical long line fisheries. However, our discussion will be confined to vertical long line fishery, considering the time given. Demersal fish resources in narrow belts along the upper margins of continental slope, around reefs and banks where trawlings are not possible have not been fully explored and developed so far. Vertical handline is one of the effective fishing gears in such untrawlable waters and the results of experimental fishing have revealed that vertical handline fishing is promising in untrawlable grounds. Although the total catch may be less than that of trawl fishing and, in the South China Sea and the Andaman Sea, the stock size may be smaller than that in trawlable grounds, the catches of vertical handline fishing are almost exclusively of highly marketable fishes in the Southeast Asia.

1.4.1. Fishing gear.

1) Ordinary type fishing gear. This type of fishing gear consists of eight parts.

a) Lead Line: Dacron "Sebato" Super 70, breaking strength 79-93 kg in water, 200 m in length one end fastened on the drum, and the other end connected with a brass barrel swivel which is attached to the end of a rubber spring.

b) Rubber Spring: 7 mm in diameter 30 cm in length, two ends fixed with brass swivels, one of them joined to the lead line, the other end for the main line. Swivels are 5 cm in length, code 5/0.

c) Main Line: Mono-filament nylon No.60, 80 cm in length, total 6-14 pieces.

d) Swivels: Brass three-way swivel or galvanished triangle swivel. The swivels are fixed at intervals of one meter on the main line. Total 6-14 pieces.

e) Branch Line: Monofilament nylon No.40, 80 cm in length, fixed on the horizontal eye of the three-way swivel, total 6-14 pieces.

f) Hooks: No.26, 6-9 cm in length, 2.4 mm in diameter, or "Mustad" No.7, stainless steel hook, 5.7 cm in length, 2.0 mm in diameter. The number of hooks depends on the number of branch lines.

g) Sinker: Cast iron, bank-shaped, 1.3-1.5 kg per piece.

h) Bait: Squids, horse mackeral, and saury.

2) Handkerchief type fishing gear. This type of fishing gear consists of the following ten parts.

a) Lead Line: Dacron "Sebato" super 70, breaking strength 79-93 kg in water, 200 m in length, one end fitted with a brass barrel swivel.

b) Marks: A safety mark or swivel at the first five meters, and the lead line marked at intervals of 10 m if necessary.

c) Swivel: Heavy duty swivel, brass barrel swivel 5 cm in length.

d) Snap swivel: The bigger sized swivels (total length 10 cm) are used for joining the main line and the lead line.

e) Packing Line: Vinylon, in 3 mm diameter, 1.5 m in length eye-spliced at both ends and a snap swivel is put in one eye, the other eye fitted with a three-way swivel, sewed onto a canvas handkerchief, one way for sinker, and the third way for main line branch lines with hooks.

f) Handkerchief: 30 x 30 cm in size, canvas dyed brown in colour.

g) Main Line: Monofilament nylon No.60-No.100, the length depending on the current; longer than 2 m for strong current, shorter for the weak current.

h) Branch Line: No.30-No.40 Monofilament nylon 1.5 m in length.

i) Hooks: No.26, 4.5 cm in length, 2.4 mm in diameter or "Mustad" No.7, stainless steel hook, 5.7 cm in length, 2.0 mm in diameter.

j) Sinker: Lead, 1.5 kg per piece.

3) Drifting type fishing gear. This type of fishing gear consists of seven parts.

a) Plastic Basin: 45 cm in upper outer diameter, 25 cm in height, and 40 cm in bottom diameter, a hole drilled on the bottom, a bolt and nut is put in, and packing for water tightness, and a hole on thread portion of the bolt, for fastening the end of the line.

b) Straw Bar: 2.5 cm in diameter, 60 cm in length, fitted on the rim of the basin, for hanging the baited hooks.

c) Lead Line: Vinylon 20S/24 x 2 x 2, first section on the lead adjusted to the depth of water, one line is fixed at 50 m and the other section of the line to be adapted to the depth.

d) Branch Line: Multifilament nylon, 2 mm in diameter, 15 cm in length, one end fixed with lead line (main line), the other end tied with an eye for the monofilament branch line with fishing hook, its length is 70 cm, size is No.40, total 8-20 pieces of branch line, at intervals of 1.5 m.

e) Main Line: Use the same size as lead line, one end of the main line with a loop for the tube sinker.

f) Tube sinker: Plastic tube, 14-16 mm in inner diameter, 1.5 m in length, the upper end fixed with a snap for connecting the loop on the main line. Iron bars, 15 cm in length, 12 mm in diameter, weight 300 g per piece, four pieces were put into the tube, one of them indented for tightening purposes.

g) Hooks: "Mustad" No.7, stainless steel hook, 5.7 cm in length, 2.0 mm in diameter. The number of hooks depends on the number of branch lines.

1.4.2. Method of operation.

When a fish school is found by acoustic searching, hooks with bait are cast as quickly as possible into the school and are raised when fish are caught, and the process is repeated.

1) Ordinary type. There are three different methods of fishing operation using this type of gear: the drifting, the spanker and the anchoring operations.

Drifting operation: Stop the vessel just weather side or upstream side of the fish school found and continue angling while drifting. When the fish school scatters or moves away from the area, move the vessel to look for the fish school or for another school.

Spanker operation: This is a modification of the above method. Under strongly windswept conditions and in a rough sea, the spanker helps the vessel head the wind and is utilized, therefore, in various kinds of fishing operations.

Anchoring operation: Anchor the vessel just above or near the fish school found, and lower hooks to angle fish.

2) Handkerchief type. This type of gear is used in most cases during anchoring. Anchor the vessel just above or near the fish school, scatter the chopped meat originally wrapped with the

handkerchief of the gear in a layer above the school and lure the fish school up to around the mid-layer. Then, let the school stay in that position as long as possible and repeat the above procedure to angle them.

3) Drifting type. Set the gear by aligning the gears at appropriate intervals, and taking care not to let them become entangled. The gear should, of course, be set in such a manner that the aligned gears encounter the fish school found. After completion of setting, the gears are collected one by one starting from the gear first set, and the process is repeated.

1.4.3. Fishing grounds and seasons.

Good fishing grounds are usually found in an upwelling area near the shoulder of a continental slope and near reefs. The depth considered preferable is in the range of 60 to 130 m, and above 3 in the water colour scale would be moderate. Some of the promising grounds found so far are shown in Fig. 1.4.1. There are thought to be some wide and prosperous fishing grounds in Philippine and Indonesian waters.

In this region, there is little seasonal change in climate. However, the location of a fishing ground depends upon the monsoon.

1.4.4. Comparison of the three different types of gear.

Each type of gear possesses its own characteristics, the selection of gear should be made considering the season, the ground, and the size of the vessel employed.

1) Ordinary type.

This type of gear is easy to use and to move from place to place. Therefore it is convenient for a fishing ground survey. Its use is also strongly recommended in an area of strong currents.

2) Handkerchief type.

This type of gear is usually very effective, but it is not recommended in an area where the current is stronger than two knots.

3) Drift type.

To prevent entangling of gears, in the above two methods the gears are set on one side of the boat at regular intervals of 2.5 to 3.0 m. The gears employed are limited in number, depending on the size of the vessel.It is a merit of this type of gear that several sets can be employed on board a small boat and with a limited number of crew members.

1.5. Trawl Fisheries.

Considering the areas of operation and the position of the fishing gear in relation to the sea bottom when fishing, trawl fishing gear can be grouped into four major categories : 1) surface trawls (two-boat type), 2) mid-water trawls (one-boat and two-boat types), 3) bottom trawls (small size trawl, medium size trawl, large size trawl and factory ship type) and 4) other towing nets (beach seine, boat seine, etc.).

Surface trawl or floating trawl: To catch small fish such as sardine, anchovy, etc. surface trawl nets are sometimes used, because these groups of fish often appear near the surface and swim slower than the larger pelagic fish. The nets used in Japan are rather long, and they have a headrope of 120 m in length. The net is towed by two boats with 90 m of warp each side, keeping a distance of 150 m between the two boats. According to observations, the net does not open fully at very slow speeds, but with speeds between 0.4 to 1.0 knot, the net maintains good mouth opening.

Mid-water trawl: To catch pelagic fish in middle layers, (middle layers here means water layers in between the first few metres below the surface and the first few metres above the seabed) mid-water trawls are sometimes used. Usually mid-water trawling is carried out on the high seas. The boats are quite big, belonging to the same class as those big modern stern trawlers of the North Atlantic. Their engines are high powered (200-400 H.P.) for tactical fishing at high speed. Mid-water trawls can be subdivided into one boat and two boat trawls.

Bottom trawl: This comprises a variety of trawl nets. Considering the nature and depth of areas operated, this type of trawl can be subdivided into three groups.

1) Small size trawl (in inshore areas) includes the following: Danish seiner or anchor dragging with low power diesel engine. Diesel-powered beam trawler for shrimps and flatfish and dredger for shellfish and other sea animals. Sailing drag netter using beam trawl net.

2) Medium size bottom trawl (in off shore areas), includes the following: Danish and Scottish seiners, otter trawlers, wooden or steel construction ranging 20-100 G.T. with diesel engine in the range of 30-100 H.P. Pair trawlers, wooden or steel construction ranging 50-60 G.T. with diesel engine in the range of 200-300 H.P.

3) Large size bottom trawl (on the high seas) includes the following: Pair trawling boats, wooden or steel construction

ranging 90-200 G.T. with diesel engine in the range of 320-1,000 H.P. Otter trawlers, wooden or steel constructio of 500 G.T. with engine of 750 H.P. Factory ship type trawlers, steel construction in the range of 90-200 G.T. with diesel engine ranging 300-1,000 H.P. One fleet consists of one mother ship and five to six pairs of trawlers.

The modern stern trawler can be one of the most modern otter trawlers with sophisticated equipment for fish detection and for its actual fishing operation. The general arrangement of the trawl gear is illustrated in Fig. 1.5.1. The combination of such panels varies according to the construction, such as two-seamed, four-seamed, six-seamed, etc.

1.5.1. Design diagram and specification of two-seamed net.

The trawl net used on board M.V. Paknam during the orientation cruise was a German type trawl net. It is a two seam net as shown in Fig. 1.5.2. As can be seen from the diagram, the headrope and the ground rope are 37.7 and 47.6 m respectively. The mesh sizes of the net differ depending on the different parts of the net. The mesh sizes of the wings and the square are 180 mm both for the upper and lower nets, while the belly and baiting use those of 120, 80, 60 and 40 mm. The cod end uses a mesh size of 40 mm.

The cutting pattern for this net is as follows: The upper wing, cut 1 point 2 bars for the outside (to join with the lower wing) and the inside cut all bars (join with the head rope). For the lower wing, the outside trim is 1 point 4 bars (joint with the upper wing) and inside trim is all bars (join with the ground rope). For the body of the net (both in upper and lower) cut 1 point 2 bars and the cod end cut all points.

The number of meshes in length and depth of each part of the net are shown in the following table.

Parts of net	Size of twine	Mesh size (mm)	No. of mesh (Depth)	No. of mesh (Length)	No. of Pieces
TOPWING	380d/48	180	12	1- 19	4
UPPER WING	380d/48	180	69	19- 55	2
LOWER WING	380d/48	180	91	19- 50	2
SQUARE	380d/48	180	22	160-136	1
BELLY	380d/48	180	9	136-128	2

Parts of net	Size of twine	Mesh size (mm)	No. of mesh (Depth)	No. of mesh (Length)	No. of Pieces
BODY 1	380d/48	120	10	192-180	2
" 2	380d/18	80	50	270-213	2
" 3	380d/18	60	100	284-184	2
EXTENSION	380d/18	40	126	275-155	2
COD END	380d/21	40	220	155-155	2
COD END COVER	380d/60	80	50	75- 75	2

Remarks: All parts are joined together with cremona twine.

Specifications of ropes and other accessories are, as follows:

Name	Material	Size/weight	Remarks	Quantity
Head rope:	wire	12 mm in dia.	wrapped with twine of 3 mm	1
Fishing line:	wire	12 mm in dia.	wrapped with twine of 3 mm	1
Ground rope:	wire	14 mm in dia.	wrapped with rope of 8 mm	1
Lacing line:	Polyethylene	15 mm in dia.		2
Float:	Plastic	20 mm in dia.		25
Sinker:	Iron	5 kgs. (each)		2
Sinker:	Chain	2 kgs. (each)		15

The hanging of the netting to the ropes and the arrangement of accessories used are very important and all should be connected together appropriately. Rope and net construction are described below.

Lacing line: Usually made of compound rope and used for joining the belly (or baitings) and the sides together. This helps to absorb increased external forces acting on the netting.

Bolch line and stapling twine: These are used for the construction of the wings which are connected with the groundrope and the headrope.

Fishing line (foot rope): Usually made of compound rope. Flymeshes of the lower wings are joined to the bolch line and the line is attached to the fishing rope. The foot rope is connected to the groundrope by the hanging chain to lessen the tension acting on the groundrope.

Groundrope: The groundrope, constructed of wire, is covered with small wheel tires, steel bobbins, rubber rollers, wooden-sinkers, iron sinkers, etc. The ends of the groundrope are connected with the ground pennants, and the quarter ropes and the fixing root of the lacing ropes are fixed to the joining point of the wing and the central part of the groundrope.

1.5.2. Trawl fishing operation.

Preparation for shooting out: All hands take their working positions and the cod-end is suspended by the cod-end stopper, over the slipway (Boat running speed is kept at 3 kt).

Shooting out the trawl net: The cod-end is released into the sea by loosening the stopper on the order, "let it go" (3 kt). The net is dragged into the sea from the cod-end right up to the wings until both the net-pendants spread out. Stop the winch just after the triangle iron danleno touches the sea surface. Check that the net is balanced and taking its proper shape at the surface (3 kt).

Paying out of ground cable (hand ropes): Release the brake until the kellys eye come out of the winch drum (2 kt). Fasten the kellys eye to the back strop of otter pendants (2 kt). Release brake again until the stopper(joining blocks) come out.

Preparation for shooting out otter boards: Independent rope is released from towing warp, and is joined to the top of the otter bracket with the G link. Then, join the warp ring of the towing warp to the top of the towing chain. Starboard warp is wound up gently to the point when the otter board stopper can just be released. Repeat the same process for releasing the port otter board stopper.

Shooting out otter boards: Both otter boards are shot out together into the sea in the same manner. Release the winch brake partially (5 kt). Paying out of warps is temporarily stopped at the 30 m mark from the otter boards and the spreading performance of the boards are judged. Test brake two or three times. Then the warp is paid out again with two or three temporary stops in between to allow for the spread of the otter board.

Towing the net: After a predecided length of warps (which is approximately 3 times the depth) is set, the actual towing begins (3 kt). Observe the state of towing; measure the slope angle, the opening angle of the warps and the warp tension.

Preparation for hauling in: The call "Stand by hauling" is announced usually after about two hours of towing: All hands then take up their respective working positions for hauling in the net (3 kt).

Hauling in the warp and the net: Start to wind up the warps (2 kt). When the otter boards come up to the stern bulwark, they are stopped by the otter board stoppers. One by one they are fastened and the warps are then slackened. The towing warps are released from their respective towing chain shackles and are joined to their respective independent rope. Thus the shackles at the back strop terminals of the otter pendants are released from their respective kellys eye. The independent ropes, ground cable and net pendants are hauled in until the wings appear on the slip way. Each wing is hauled onto the deck by the side drums then the square, belly and baitings are hauled onto the deck. The cod-end is lifted by a cod tackle and the catch is released onto the deck side compartment by opening the cod end (0 kt).

1.5.3. Fishing Ground and Season.

Demersal fish are the most important for bottom trawling. Continental shelves, whose depths are less than 200 m in most cases, provide trawlable fishing grounds.

Coastal and inlet waters are ideal fishing grounds for shellfish and seaweeds, they are also good for small fishes caught usually by means of bottom drag-nets. Some pelagic species may be fished in these waters too. The main fishing grounds for the high-sea trawl fisheries are the Okhotsk Sea, the Bering Sea, the Yellow Sea, the East China Sea, the Labrador Sea, offshore waters of West Africa, northern offshore waters of South America and western offshore waters of Australia and New Zealand. Trawling can be operated throughout the year except in rough sea conditions at certain seasons.

The fishing grounds of Thai trawlers are shown in Fig. 1.5.3, and the seasonal pattern for trawling depends on the monsoons. During the northeast monsoon season vessels trawl around the east coast of the Gulf of Thailand and in the Andaman Sea. During the southwest monsoon they trawl around the west coast of the Gulf or near the coast of the Malay peninsula.

2. FISHING BOAT

2.1. Definition and Fundamentals of Fishing Boat.

2.1.1. Definition of fishing boat.

The fishing boat is defined by SOLAS (International Convention of the Safety of Life at Sea) as a vessel used for catching fish, whales, seals, walrus or other living resources of the sea, but there is no clear definition. According to the Fishing Vessel Law of Japan, the fishing boat is defined as a vessel (1) exclusively and directly used for fishing, (2) exclusively used for fishing with facilities for preserving or processing fish catch, (3) exclusively used for carrying fish catch or its products from the fishing ground, and (4) exclusively used for experiment, research, instruction, training, or inspection related to fishing, with fishing gear.

2.1.2. Characteristics of fishing boats.

A fishing boat unlike vessels for passenger or freight transportation should have the following characteristics: high speed, good maneuverability, seaworthiness, wide range of cruising, tough construction, appropriate machinery, refrigerating facilities, fishing equipment, etc.

2.1.3. Principal dimensions and tonnage.

The principal dimensions of a fishing vessel are the length, breadth, and depth of the vessel, which are usually expressed as L.B.D. These L.B.D. and particularly the ratio of L.B.D. are very important elements for determining the vessel's capacity and performance ability. L/B, L/D, and B/D are closely related with the propulsion efficiency, strength, and stability of the vessel, respectively.

2.1.3.1. Principal dimensions.

1) Length, L (Fig. 2.1.1.).

   a) Length overall, LOA: This is the horizontal distance between the fore end and the aft end of the boat.

   b) Length between perpendiculars, Lpp: This is the horizontal distance between the fore perpendicular (FP) and the aft perpendicular (AP) at the designed waterline (LWL).

   c) Registered length: This length varies according to the regulations of each country.

2) Breadth, B (Fig. 2.1.2.).

This is the horizontal distance of the breadth in the widest part of the vessel.

3) Depth, D (Fig. 2.1.2.).

This is the vertical distance from the base line to the upper surface of the upper deck beam on the ship's side.

2.1.3.2. Fineness coefficients.

Some vessels are fat in shape while others are thin; Ship's shape is compared by fineness coefficients. The fineness coefficients comprise block coefficient, prismatic coefficient, midship coefficient and water plane coefficient, (Figs. 2.1.3. (a) - (d)).

1) Block coefficient (C_b)

$$C_b = \frac{V}{L \times B \times d}$$

Where, V, L, B and d are the displacement (m^3), the length (m), the breadth (m) and the draft (m), respectively.

2) Prismatic coefficient (C_p)

$$C_p = \frac{V}{A_{\otimes} \times L}$$

where, $A_{\otimes}$ is the midship section area (m^2).

3) Midship coefficient ($C_{\otimes}$).

$$C_{\otimes} = \frac{A_{\otimes}}{B \times d}$$

4) Water plane coefficient (Cw).

$$C_w = \frac{Aw}{L \times B}$$

where, Aw is the water plane area (m^2)

5) Relation between the coefficients.

$$C_b = C_p \times C_{\otimes} \text{ and } C_b < C_p < C_{\otimes}$$

6) Fineness coefficients of fishing boats

The fineness coefficient of a fishing boat varies with the type of fisheries. (Table 2.1.1).

2.1.3.3. Tonnage.

1) Gross tonnage (G.T.).

The size of a fishing boat is usually expressed in terms of G.T. The method of tonnage measurement differs considerably from country to country. For large size fishing boats, however, the international method for tonnage measurement is coming into force (International Convention on Tonnage Measurement of Ships, 1970).

a) International formula for GT measurement of fishing boat more than 24 m in length.

$$GT = KV$$

where, V is the total volume of all enclosed spaces of boat (m^3) and $K = 0.2 + 0.02 \log_{10} V$ (Table 2.1.2.).

b) Current formula for GT measurement of small fishing boats.

The following formula is used only in Vietnam and Thailand.

$$GT = \left(\frac{P + B}{2}\right) \times L \times C$$

where, P is the periphery measured around the midship section of the hull. In Vietnam, P is directly measured, while in Thailand, P is derived from the following formula:

$$P = (B + 2D) \times C_b$$

where, C_b is 0.85 for displacement hull, and 0.90 for flat bottom hull construction. C is defined as follows: in Vietnam, 0.060 for a wooden boat and 0.064 for a steel boat, while in Thailand 0.058 for a wooden boat and 0.070 for a steel boat.

2) Net tonnage (N.T.).

By the net tonnage is shown the vólume of a boat which is directly used for the purpose of the operation of the boat, whereas by GT is shown the total volume of the boat herself. Therefore, NT is obtained by subtracting the volume of the following spaces from the total volume of the boat (m^3): accommodation, chart room, steering gear room, engine room, etc.

3) Displacement tonnage ($\triangle$).

Displacement tonnage implies the weight of a boat and varies with the quantities of fuel, water, crew, fish catch, etc. loaded aboard the boat. Therefore, displacement tonnage should be discussed considering the loading conditions such as light or full loaded.

4) Dead weight tonnage (DW).

Dead weight tonnage is the maximum weight of fuel, water, crew, fish catch, etc. capable to be loaded on board. In other words, the dead weight tonnage is the difference between the displacement tonnages at light and full load condition.

2.1.4. Terminology.

Listed below is the essential terminology used for fishing boats.

1) Sheer: Sheer refers to the upward curvature of both fore end aft deck (Fig. 2.1.1.).

2) Beam camber: The arc-shaped curvature of a vessel deck is called beam camber (Fig. 2.1.2.).

3) Rise of floor: Rise of floor refers to the distance between the base line and the intersection of the side plate and the bottom plate (Fig. 2.1.2.).

4) Bilge circle: At the midsection of a vessel, a part of a circle is used as the curve as shown in Fig. 2.1.2 and is called the bilge circle.

5) A.P. and F.P.: A.P. refers to the after-perpendicular and F.P. the fore-perpendicular at the ends of the designed water line of the boat. (Fig. 2.1.1.).

6) Superstructure and deckhouse: Superstructure and deckhouse are built on the main deck, the former strengthens the vessel and extends from port to starboard, forming a continuous floor deck. The latter is also built on the deck but does not touch either side of the vessel.

7) Bulwark and hand rail: Bulwark is a fence-like structure built on the weather deck along the vessel side, which has stays and outer plate. Hand rails are made up of metal bars and pipes.

8) Hatch and companion: Hatches are the openings on the deck right above the holds. Companions are the stairways through which crew members pass directly from a lower deck to the weather deck, doors are provided for it.

9) Draft and freeboard: Draft is the vertical distance measured between the water surface and the deepest part of the hull lying under water. The draft may be measured at any specified position such as the fore, aft or midship. Freeboard means the vertical distance measured between the upper deck gunwale and the water surface at midship.

10) Deeptanks and ballast tanks: Deep tanks are the extremely deep tanks built-in as an integral part of the hull. Ballast tanks are those in which sea water or fuel oil is loaded to adjust the vessel's center of gravity.

2.2. Installations on Fishing Boats.

2.2.1. Equipment and installations.

General arrangements of fishing boats are shown in Fig. 2.2.1. Major equipment and installations fixed aboard a fishing vessel are:

1) Steering gear; rudder, steering machines, steering engines,
2) Mooring arrangements, anchor, chain, windlass, fair leader, mooring pipe, bitt, bollard, capstan,
3) Life saving appliances: life jacket, life buoy, life raft, life buoy flare, life boat, boat davit,
4) Cargo gear; derrick, cargo winch,
5) Piping arrangements; bilge, ballast, air, sanitary water, fresh water, sounding, scupper, hydrant,
6) Fire existinguishing appliances; fire alarm, fire existinguisher,
7) Ventilation and lighting arrangements; natural ventilation, mechanical ventilation, lighting, air conditioning,
8) Engine room arrangements; main engines, auxiliary engines, electric generators, pumps, shafting, propeller, etc.
9) Electric installations; motors, switch boards,
10) Radio installations; wireless telegraph, wireless telephone, direction finder, rader, loran, facsimile, radio buoy, etc.
11) Navigation instruments; gyro compass, magnetic compass, track recorder, draft gauge, pressure log, electric thermometer, clear view screen, helm indicator, etc.
12) Fishing gear; trawl winch, net hauler, line hauler, etc.

2.2.2. Electronic Equipment.

Since the first use of a radio direction finder at the beginning of the 20th century, other important radio equipment has been developed. This includes Radar, Loran, Decca, Omega, etc., all of which are widely used in fishing boats to-day to ensure safe navigation and to contribute to the efficiency of fishing operations.

Fish finding techniques by means of acoustic devices such as fish finder, sonar, net monitoring devices are also rapidly developing and are widely used throughout the world.

2.2.2.1 Radio direction finder.

A radio direction finder (RDF) consists of a loop antenna and a radio receiver. Almost any radio with a loop antenna can be used as a RDF. For example, when a loop-equipped table model or portable radio is rotated 360 degrees, the signal picked up will be minimum at two points. This is due to the directional characteristics of loop antenna. By taking the bearing from two or three radio stations located at known positions we can provide a point intersection on the sea chart.

A ship or a radio buoy transmitting radio signals can be located by using a RDF. This is very useful in rescue work because the ship in distress which is sending emergency or distress signals can be located. Ocean going ships larger than 1600 G.T. must install RDF according to an International Convention, "SOLAS".

On the other hand, RDF is used not only as navigation equipment but also for finding fishing grounds because the fishermen can know the direction of other boats which are sending information about fish catch or fishing grounds.

2.2.2.2 Radar.

The term RADAR is derived from Radio Detecting And Ranging. By this, it is possible to detect the presence of objects and to determine their velocity, direction, and range (distance). In addition, rough analysis is possibly made by some types of radar systems on the composition of the detected object. Radar aids a number of ships to navigate in an area of poor visibility, because with radar the objects can be seen on the screen through the dark, as well as through rain and fog.

Main uses of Radar:

1. Watching the sailing route of own ship and those of other ships.
2. Confirmation of ship's position.
3. Prevention of collisions.

If the time T sec. is required for radio waves to reach and bounce back from such an object as a mountain, the round trip distance traveled would be T x (3×10^8) m, because the speed of a radio wave though the air is 3×10^8m/sec. Then the distance D between the radar and the object can be calculated by the following formula;

$$D = \frac{T \times (3 \times 10^8)}{2} \quad \text{(in meter)}$$

2.2.2.3 Loran.

Loran is an abbreviation of Long Range Navigation and is classified into two systems (Loran A and C Systems). The Loran system is based on the principle that the radio wave goes through the air with a known constant speed.

Determination of position by Loran system:

1. From the two known Loran stations located on shore, synchronized constant repetition rate pulse signals are transmitted with the same frequency.

2. A ship installed Loran receives the above signals and the time difference between individual pulse signals is measured.

3. From the known positions of the above land stations and their synchronous relation, the loci of pulse arriving time difference is calculated and are prepared on the Loran chart or the table for practical use.

4. By obtaining another LOP (line of position) separately from the line obtained by astronomical observation, RDF, Radar, etc. an intersection with the LOP given from Loran can be plotted. This intersection provides the ship's position.

The servicable range of Loran systems for position determination is normally within 700 miles in daytime and 1400 miles at night time.

2.2.2.4. Decca.

The Decca navigation system was introduced for practical use in 1948. This system consists of three to four shore radio stations arranged to form a chain. The first chain of stations was established in England in 1948 and was followed by chains in other European countries such as Germany, France, Sweden, Spain and Italy. In the East, most of Japan is already covered with Decca system service areas. If the Decca chain is set up in the Southeast Asian area, it will be of great help to every ship operating in the region.

The principle of Decca navigation system is one of the hyperbola navigation systems like the Loran A and C systems. Three colored LOP is printed on a chart, called the "Decca chart". The point of intersection will be given by reading two or three figures indicated on the receiver. This gives the ship's position.

2.2.2.5 Fish finder.

A fish finder is used to measure the depth of the ocean and to detect the fish shoals. This apparatus is designed to radiate sound waves through the water, and the reflections from the bottom and fish shoals are sent back to a recorder or an indicator. The return time is processed electrically and recorded on a paper or displayed on CRT (cathode-ray tube). The principle of echo is adopted the same as in Radar.

2.2.2.6 Sonar.

The term SONAR stands for Sound Navigation and Ranging, and it includes all under water acoustic systems used for detection and location of under-water objects, though, recently the term Sonar has been used as an echo sounder for horizontal detection in a narrow sense.
The Sonar records or displays the reflected wave from an object under the water on a recording paper or a cathode-ray tube (CRT) by scanning the transducer horizontally. Recently, most Sonar has been designed to use in either way, horizontal or vertical.

2.2.2.7 Net monitoring system.

For successful trawling, it is important to know the net mouth performance under towing. This system gives information concerning both the net mouth height and the fish shoals entering the net and records it on a recording paper or displays it on a CRT.

2.2.2.8 Other equipment (Omega, Facsimile, Satelite Navigation System).

These pieces of equipment have already been adopted in some deep-sea fishing boats.

A variety of electronic equipment has been adopted in many kinds of fishing boats. However, the most suitable equipment should be chosen in a proper manner considering the purpose of use and economical investment, otherwise the equipment will be a useless possession.

2.2.3 Relation between length and speed.

The term "knot" is used as the unit speed of a vessel. One knot is the speed travelling 1 nautical mile per hour, and is 1,852 m/hr in the metric system.

Among existing vessels, destroyers can reach as high a speed as 40 knots (approximately 74 Km/hr) and ocean liners 33 knots (approximately 61 Km/hrs). The fastest fishing boat has a speed of more than 20 knots, while most fishing boats have maximum speeds in the range of 8 to 12 knots.

The speed of vessels cannot be compared in absolute value because the problem of whether a vessel is faster or slower has to be discussed in comparison to vessel size. Here, the speed length ratio ($\frac{V}{\sqrt{L}}$, where V is the speed in knots, and L the length in m. or feet) is used. The value of $\frac{V}{\sqrt{L}}$ shows that when $\frac{V}{\sqrt{L}} = 1.448$, (0.8 in ft. unit) the speed is below the average (slow), when $\frac{V}{\sqrt{L}} = 1.811$, (1.0 in ft. unit) the average (normal), and when $\frac{V}{\sqrt{L}} = 2.173$, (1.2 in ft. unit) above the average (high).

There is a limit to the speed to be obtained. It may be attained probably up to $2.7 \times \sqrt{L}$, (m) in knot if care is taken of boat shape and a high powered engine is used. However, it is almost impossible to get the speed of $3.6 \times \sqrt{L}$, (m) in knot. The lengths required for a boat calculated for different speeds using $V/\sqrt{L} = 1.0$ are tabulated below:

Speed (knot)	Length required for boat (ft.)
6	6 x 6 = 36
7	7 x 7 = 49
8	8 x 8 = 64
9	9 x 9 = 81
10	10 x 10 = 100
11	11 x 11 = 121

For increasing the speed of a boat, it is desirable to increase the length of the boat rather than the power of the engine. Here let us consider the following example using M.V. Queen Mary (U.K. Ocean liner). Given conditions are gross tonnage: 80,000 tons length: 975 ft., and speed: 31.6 knots. The value of $\frac{V}{\sqrt{L}} = \frac{31.6}{975} = \frac{31.6}{31} = 1.02$.

Therefore, 31.6 knots is an economical speed for such a huge length of boat.

Although the absolute speed values of a fishing boat seems to be low, the speed is relatively high because the length is small. Table 2.2.1 shows this relationship.

2.2.4. Relation between horsepower and speed.

The relation between horsepower and speed can be given by the following equation:

$$IHP = \frac{\Delta^{\frac{2}{3}} V^{3}}{C}$$

$$\text{or} \quad V^{3} = \frac{IHP \times C}{\Delta^{\frac{2}{3}}}$$

where IHP, Δ , V and C are the indicated horsepower, the displacement in ton, the speed in knot, the admiralty coefficient (nearly 80) respectively.

The admiralty coefficient is an important constant used in estimating the horsepower when planning a new vessel, and is usually obtainable from the data of similar existing vessels in which are installed similar engines.

With increase of speed, horsepower increases proportionally to the cube of the speed. This relation is well presented by a horsepower curve against speed in Fig.2.2.2, here the slope of HP becomes steeper and steeper with increasing speed. It is understood that there exists a maximum speed limit for the size of vessel, and that finally speed does not increase at all even though the horsepower increases.

To increase horsepower to more than the usual level leads not only to overload of the engine, but also to excessive consumption of fuel oil without any appreciable gain of speed. Therefore, it is always necessary to bear in mind the relation between reasonable horsepower and speed.

The application of $\frac{BHP}{\Delta} \sim \frac{V}{\sqrt{L}}$ curve, given by Table 2.2.2 (a) is very useful for immediate finding of the relation of speed, horsepower, length, and displacement. Table 2.2.2 (b) can be applied for this calculation as well.

2.3. Various Types of Fishing Boats.

2.3.1. Trawl boats.

2.3.1.1. Trawler.

Trawl boats have long L, slightly narrow B, and deep D. The block coefficient C_b should be as small as possible, and the aft draft as deep as possible. Longer L signifies an advantage for keeping high speed and so does the narrow B, though this results in uneasiness in stability. Deep D gives enough power to drag the net and good stability. The center of gravity G is placed as low as possible in any case. When dragging a trawl net, the resistance due to net increases. Therefore the propeller should be large in size to give enough thrust for dragging the net. Considering the above, a low-speed engine with controllable pitch propeller is recommended.

Characteristics required for Trawler: The value of GT/(L x B x D) is between 0.24 to 0.30. For better stability, the center of gravity should be located as low as possible, and draft should be as deep as possible. Some other characteristics are given in Tables 2.3.1. and 2.3.2.

Machines and apparatus for fishing include trawl winch, gallows roller (center and side), gallows top roller, fish tackle.

2.3.1.2. Pair trawlers, and medium size trawlers.

The pair trawler and the medium size trawler have developed from the traditional small sized trawlers which have fished by sailing or rowing and hauling nets manually for hundreds of years. Pair trawlers operating in the East China Sea are mostly of 75, 95 and 130 gross tons. On the other hand, medium size trawlers are slightly smaller than the former and range from 15 to 100 gross tons. Generally speaking, this type of boat has comparatively narrow breadth and large draft especially aft to assure powerful drag. The propeller, therefore, should be large in diameter and the rotation number should be smaller. This type of boat has a small fineness coefficient. The characteristics of these trawlers are given in Tables 2.3.3. and 2.3.4.

These two types of trawler sometimes encounter sea accidents because of rough weather, poor stability and overloading of fish. Moreover, fishing gear and fish storage boxes are placed on the upper deck and this makes the position of G higher. Navigational instruments such as direction finder, loran, radar, etc. are installed above deck level. By regulation, Japanese trawl fishing boats are required to fulfill the condition that the metacenter height GM should be larger than the two quantities, defined as follows:

$$GM > B \times \frac{1}{25} + 12 \text{ (in cm)} \qquad (1)$$

$$GM > L \times \frac{1}{150} + 12 \text{ (in cm)} \qquad (2)$$

The above relation is applicable to other types of fishing boat excluding purse seiners and bonito angling boats.

For the boat whose breadth B is more than 7 meters, the following are applied:

$$GM > (B - 700) \times \frac{1}{12} + 40 \text{ (in cm)} \qquad (3)$$

$$GM > (L - 4200) \times \frac{1}{72} + 40 \text{ (in cm)} \qquad (4)$$

Freeboard should be greater than $(D \times \frac{1}{25} + 15)$ in centimeter for steel boats, and should be greater than $(D \times \frac{1}{15} + 20)$ in centimeter for wooden boats.

2.3.2. Purse seiners.

The size of purse seiners ranges from 5 to 250 tons, though most of them are less than 100 tons. In order to keep good maneuverability it is desirable that the length of the boat is not too long. During fishing operations the stability of the boat is particularly important because most fishermen assemble on one side of the deck and moreover pursing is done on the same side. Therefore, the breadth of the boat should be large enough. The depth should not be very deep, because shallow free board is preferable for the purse seine operation. This shallow freeboard serves to keep the position of G (center of gravity) lower.

Characteristics required for purse seiner: Characteristics required for purse seiners are given in Fig. 2.3.1.

The length of GM should fulfill the following requirements:

$$GM > \frac{B}{23} + 27 \quad \text{(in cm)} \qquad (5)$$

$$GM > \frac{L}{120} + 27 \quad \text{(in cm)} \qquad (6)$$

Turning circle capacity is most necessary and some examples are shown in Table 2.3.5.

2.3.3. Tuna long liners and skipjack fishing boats.

These boats range in size from about 20 tons for small boats to about 800 tons for large steel boats. They are comparatively large in length and depth. The principal dimensions and characteristics are listed in Table 2.3.6. and 2.3.7.

3. MARINE ENGINEERING.

3.1. Introduction and Ship's Construction.

3.1.1. Introduction.

Marine engineering is that part of engineering technology dealing with the machinery used on board a ship. A ship may be defined as a vessel which is capable of independent operation.

3.1.2. Ship construction.

A ship is essentially a watertight box. In a metal ship, both the sides and the bottom consist of shell platings, and the line where each side and the bottom meet is called the turn of the bilge.

The top of the box is the main deck which is the upper most continuous deck. The main deck meets with the sides at the gunwale. Shell plates are joined together to form long horizontal strips of plating, and each strip is called a strake. Essential strakes are the bilge and sheer strake. The following are common terms used for the parts of a ship:

1) Hull: The hull is the ship's shell from the keel to main deck.

2) Framing: Framing is the skeleton structure of a ship. The keel and frames form the backbone and the ribs of this skeleton, respectively.

3) Double bottom: A double bottom forms the interspace between the inner and outer bottom layers of a ship.

4) Bulkheads: Bulkheads are vertical partitions of a ship, and are classified into two groups: watertight structural bulkheads and non-watertight bulkheads.

5) Deck: Decks are horizontal divisions in a ship, and include main deck, forecastle deck, poopdeck, superstructure deck, etc.

6) Bridge: The bridge is the most important part of a ship. A ship is controlled from the bridge.

7) Engine room: The engine room is a compartment where the main and auxiliary machinery is installed.

8) Tanks: Tanks for particular purposes are installed on board; i.e., forepeak tank, aftpeak tank, double bottom tank, deep tank, fresh-water tank, sea-water tank, fuel-oil tank, lubricating-oil tank, etc.

3.2. Main Engine and Auxiliary Engine.

Marine engines can be classified into two groups: main engines and auxiliary engines.

3.2.1. Main engine.

The main engine is used for the propulsion of a ship. This includes (1) steam engine (reciprocating engine and turbine with boiler), (2) diesel engine, (3) gas turbine, and (4) nuclear powered engine.

3.2.2. Auxiliary engine.

An auxiliary engine is always operated at a constant speed for driving an electric generator.

3.3. Standard Cycles for an Internal Combustion Engine.

As stated previously, various types of marine engines are in use on board. The internal combustion engine (IC engine) is commonly used for medium size ships. As the working media passes through the engine and combustion takes place, thermal and physical changes occur in the engine. These changes may be carried out in a different manner according to the respective cycles described below.

3.3.1. Otto cycle. The Otto cycle is a cycle for the spark ignition engine (SI engine). This cycle is graphically shown in Fig. 3.3.1. The processes of the cycle are:

a) Isentropic process, 1-2 (Fig. 3.3.1), Compression takes place.

b) Constant volume process, 2-3 (Fig. 3.3.1), Heat is supplied instantaneously.

c) Isentropic process, 3-4 (Fig. 3.3.1). Expansion takes place.

d) Constant volume process, 4-1 (Fig. 3.3.1), Heat is rejected instantaneously.

The exhaust stroke, 1-a (Fig. 3.3.1), and the intake stroke, a-1 (Fig. 3.3.1) follow the same path but in opposite directions and appear as a horizontal line on the p-v diagram. Therefore, the effects of these two processes do not show any loss or gain in energy. These two strokes are not usually shown on the p-v diagram.

3.3.2. Diesel cycle. The diesel cycle is the cycle for compression ignition engine (CI engine). The cycle is shown graphically on the p-v diagram in Fig. 3.3.2. The difference between the Otto and Diesel cycles occurs in the heat supply process. In the Otto cycle heat is supplied at a constant volume, whereas in the Diesel cycle heat supply is made at a constant pressure. The actual SI and CI engines have other differences in compression ratio, one of which is that the diesel engine is higher in comparison with that of the gasoline engine. The Diesel cycle has the following processes:

a) Isentropic process, 1-2 (Fig. 3.3.2). Compression takes place.

b) Constant pressure process, 2-3 (Fig.3.3.2). Heat is supplied.

c) Isentropic process, 3-4 (Fig. 3.3.2). Expansion takes place.

d) Constant volume process, 4-1 (Fig. 3.3.2). Heat is rejected.

3.3.3. Sabathé Cycle. A diesel engine's combustion process can be said to be the combination of the constant volume and the constant pressure process; in this sense, the cycle is called the dual combustion or the composite cycle. The cycle is also called the Sabathé :ycle and has the following processes:

a) Isentropic process, 1-2 (Fig. 3.3.3). Compression takes place.

b) Constant volume process, (2-3 (Fig. 3.3.3). A part of the heat is supplied.

c) Constant pressure process, 3-4 (Fig. 3.3.3). The remaining part of the heat is supplied.

d) Isentropic process, 4-5 (Fig. 3.3.3). Expansion takes place.

e) Constant volume process, 5-1 (Fig. 3.3.3). Heat is rejected.

The difference between this cycle and the previously mentioned two cycles is in the heat supply process; the Sabathé cycle's heat is supplied at both constant volume and constant pressure processes whereas in the other cases heat is supplied at the constant volume process or the constant pressure process.

3.4. Cycles of SI and CI Engines.

The SI and CI engines operate on the 2-stroke cycle (one power stroke for each revolution of the crankshaft) or the 4-stroke cycle (one power stroke for every two revolutions of the crankshaft). However, the engine always works on the same four processes, viz., intake, compression, expansion (power), and exhaust.

3.4.1. Cycle of 4-stroke cycle engine. (Fig. 3.4.1).

1) Intake stroke: Intake valves are opened and exhaust valves are closed. The piston, as it moves down, takes in a fresh mixture of fuel and air (in diesel engines only fresh air is taken in).

2) Compression stroke: Both valves are closed and the charge is compressed by the upward motion of the piston.

3) Expansion stroke: Both valves are closed, and the compressed charge is iginited by the spark plug (in a diesel engine, fuel is injected into the compressed air), and the expanding gases force the piston to move downwards.

4) Exhaust stroke: Exhaust valves are opened and intake valves are closed. The products of combustion are forced out through the exhaust valves by the piston's upward motion.

3.4.2. Cycle of 2-stroke cycle engine. (Fig. 3.4.2)

1) Intake and compression strokes: The exhaust valves are opened as the piston moves toward the bottom dead center, the intake port is uncovered and air is introduced into the cylinder under the pressure which is forcing the remaining exhaust gases out through the exhaust valve. Then the exhaust valve closes. The piston travelling on the succeeding stroke toward the top dead center closes the intake port and compresses tha air-fuel mixture trapped in the cylinder (only air in diesel engine).

2) Expansion and exhaust strokes: The spark of the plug (fuel injection in a diesel engine) ignites the compressed mixture and the expansion forces the piston to move downwards. Just before the piston uncovers the intake port, the exhaust valve opens and a part of the exhaust gases escapes through the exhaust valve owing to the pressure difference inside the cylinder and the exhaust manifold. The remaining part of the exhaust gases are cleared out by the pressure of the incoming air. Thus the cycle is repeated.

Owing to the excessive loss of combustible mixture escaping with the gases, the 2-stroke cycle SI engines are not widely used, except in some outboard motors and motorcycles. Therefore, most SI engines operate on the 4-stroke cycle.

On the other hand, 2-stroke cycle CI engines take in air only, into which the fuel is injected after the exhaust valve is closed. Consequently the 2-stroke cycle CI engine is widely used as is the 4-stroke cycle CI engine.

3.5. Gas Turbine.

The gas turbine is used for the propulsion of a ship and for the driving of electric generators on board. The principle of the gas turbine working cycle is similar to that of the IC engine. The gas turbine consists of a rotary compressor, combustion chamber, gas generator, and power turbine.

The construction of the gas turbine is as follows (Fig. 3.5.1):

1) Compressor: The compressor is of the impeller type or the rotor type with numerous blades on it. The steam expanded in the turbine rotates the turbine itself, and for the same reason air can be compressed and can drive the compressor when passing through it.

2) Turbine: The turbine's most important element is the turbine wheel which has one or more rows of blades. The turbine is fitted with a governor to regulate the speed of rotation.

3) Combustion chambers: The combustion chamber consists of a double tube. Part of the compressed air, passing through the inner tube, serves to burn the fuel which is sprayed into the tube. The remaining part of the compressed air passes through the interspace between the inner and outer tubes, and mixes with the burning gases, making the inner tube cool on the way to the turbine. Once the fuel is ignited burning continues because of the continuous supply of air and fuel without further ignition.

4) Fuel pump: This pump delivers fuel to the burners and is driven by the turbine. Delivery of fuel is controlled by the governor. In emergencies, such as overload, overheat, lubricating oil pressure down, etc., the supply of fuel oil is automatically cut off.

5) Igniter system: This system is used only when starting-up and consists of a spark-ignition system operated by a magneto driven by the turbine or external electric power.

6) Cooling air from the compressor: Cooling air passes around the outside of the turbine to prevent overheating of the combustion chambers and the turbine casing. This also passes through the center of the turbine to cool the rotors and turbine blades.

3.6. Propulsion System.

The propeller of a ship is driven by steel shafts joined with the couplings. The inboard end is coupled to the shaft which transmits the propeller thrust to the ship. The shafting inside the ship is supported by plummer-block bearings and stern-tube bearings, passing through the hull. In the case of ships fitted with two or more shafts, the outboard end of each shaft is supported by an 'A' bracket bearing (Fig. 3.6.1).

3.7. Auxiliary Machinery.

Various kinds of auxiliary machinery are required to supply multi-purpose services on board. These pieces of machinery and their purposes are classified below.

1) Electric generators and alternators: To supply electric power and lighting. Usually driven by diesel engines.

2) Distilling plants: To produce fresh water from sea water for human consumption and other uses on board.

3) Refrigerating machinery: To preserve food, cargo, etc.

4) Air conditioning machinery: To cool the ventilated air, etc.

5) Air compressors: To provide compressed air for starting diesel engines, pneumatic controls, etc.

6) Steering gear: To operate the rudder.

7) Capstan engines or windlass: To wind the anchor cable, etc.

8) Winches: To operate wires, cargo gears, or fishing gears.

9) Fire-and-bilge pumps: For fire-fighting and for pumping out flooding, etc.

10) Pumps: For various purposes such as oil transfer, water transfer, etc.

4. REFRIGERATION

4.1. Introduction to Refrigeration.

4.1.1. Definition of refrigeration.

Refrigeration is defined as the technique delaing with the process of cooling and maintaining a space or material at low temperature as desired, insulating those from the surroundings.

4.1.2. Refrigerating capacity.

The capacity of a refrigerating system is the rate of removing heat from the space to be refrigerated and is usually expressed in Kcal per hour (Btu per hour) or in terms of its ice-melting equivalent. The standard unit used in the rating of a refrigerating system is the ton of refrigeration, defined as the removal of heat at the rate of 3,320 Kcal per hour or 12,000 Btu per hour.

These terms have their origin from the concept of the amount of heat absorbed by a ton of ice when melting from the solid to the liquid phase at $0^{o}C$ ($32^{o}F$). This derivation assumes a latent heat of ice of 79.68 Kcal/kg (144 Btu/lb).

4.1.3. Refrigerants.

In the refrigerating process the body employed as the heat absorber or cooling agent is called the refrigerant.

When the absorbed heat causes an increase of temperature in the refrigerant, the cooling process is said to be sensible, whereas when the absorbed heat causes a change in the physical state of the refrigerant (either melting or vapourizing), the cooling process is said to be latent.

In either process, in order that the refrigerating effect continues, the temperature of the refrigerating agent must always be maintained below that of the space or material being refrigerated.

It should be remembered that as yet no one substance has proved the ideal working medium under all operating conditions. Therefore, in selecting the proper refrigerant it is necessary to determine those properties which are most desirable and to choose the one most close to the ideal one for the particular application. The properties of refrigerant to be considered in its selection are evaporating and condensing, pressure, freezing temperature, latent heat, specific volume, stability and inertness, corrosiveness, dielectric strength, viscosity, thermal conductivity, oil miscibility, toxicity, explosiveness, leakage tendency, and cost. Table 4.1.1. lists some fluids having suitable properties for use as refrigerants.

Refrigerants with the widest application at present are ammonia, the Froen group (F-12 and F-22), methyl chloride, and water vapor. These are called primary or direct refrigerants.

Brines are used as secondary refrigerants (indirect refrigerants) as shown in Fig. 4.1.1. Brines, to be suitable as a simple refrigeration carrying medium, should (a) remain liquid under all temperatures to which they are subjected, (b) be essentially noncorrosive when in contact with metals, (c) have a sufficiently high specific heat to preclude the use of excessive quantities, and (d) undergo no changes when in contact with refrigerants or other gases indigenous to the application. The most common brines which meet these requirements to some extent are calcium chloride ($CaCl_2$), and sodium chloride (NaCl).

4.2. Refrigeration Cycles.

4.2.1. Definition of a cycle.

As the refrigerant circulates through the system, it passes through a number of changes in state or condition, each of which is called a process. The refrigerant starts from an initial state or condition, passing through a series of processes in a definite manner of sequences, and finally returns to the initial condition. This series of processes is called a cycle.

The simple vapor-compression refrigeration cycle is composed of four fundamental processes: (1) expansion, (2) vaporization, (3) compression, and (4) condensation.

4.2.2. Simple saturated refrigerating cycle.

A simple saturated refrigerating cycle is a theoretical model, wherein it is assumed that the refrigerant vapor leaves the evaporator and enters the compressor as saturated vapor (at the vaporizing temperature and pressure), and the liquid leaves the condenser and enters the refrigerant control as saturated liquid (at the condensing temperature and pressure). This is greatly simplified by the use of tables, charts and diagrams upon which the complete cycle may be shown numerically or graphically.

The diagram frequently used in the analysis of the refrigeration cycle is the pressure-enthalpy (Ph) diagram (Mollier diagram or chart). A pressure-enthalpy diagram for ammonia is shown in Fig. 4.2.1. and the characteristics of saturated ammonia are given in Table 4.2.1. The pressure-enthalpy diagram for each refrigerant is different, depending upon the properties of the particular refrigerant. The condition of the refrigerant in any thermo-dynamic state can be represented as a point on Ph diagram. As shown by the skeleton Ph diagram in Fig. 4.2.2. the diagram is divided into three areas which are separated from each other by the saturated liquid and saturated vapor curves. These are called the subcooled region, the region of phase change and the superheated region. At any point in the subcooled region the refrigerant is in the liquid state and its temperature is below the satulation temperature corresponding to its pressure. In the superheated region the refrigerant is in the form of superheated vapor. At any point between the two curves the refrigerant is in the form of liquid-vapor mixture. Explanation on the curves and lines illustrated on the diagram is shown in Fig. 4.2.3.

The simple saturated cycle for ammonia is plotted on a Ph chart in Fig. 4.2.4. The system is assumed to be operating under such conditions that the vaporizing temperature in the evaporator is -20°C and the condensing temperature in the condenser is 30°C. The points A.B.C.D. and E on the Ph chart correspond to the points in the refrigerating system as shown on the flow diagram in Fig. 4.2.5.

1) Expansion process. The process shown by A-B in Fig. 4.2.4. occurs in the refrigerant control when the pressure of the liquid is reduced from the condensing pressure to the evaporating pressure as the liquid passes through the control. When the liquid is expanded into the evaporator through the orifice of the control, the temperature of the liquid is reduced from the condensing temperature to the evaporating temperature by flashing into vapor of a small portion of the liquid. Process A-B is a throttling type of adiabatic expansion, frequently called "wire drawing". At the point A, the refrigerant is a saturated liquid in the condenser and its properties are:

$p = 11.895\ Kg/cm^2$	(condensing pressure)
$t = 30^{\circ}C$	(condensing temperature)
$h_a = 133.84\ Kcal/Kg$	(enthalpy)
$v = 1.6800\ l/Kg$	(specific volume)
$s = 1.1165\ Kcal/Kg/^{\circ}K$	(entropy)

The refrigerant at the point B is liquid-vapor mixture whose properties are:

$p = 1.940\ Kg/cm^2$	(vaporizing pressure)
$t = -20^{\circ}C$	(vaporizing temperature)
$h_b = 133.84\ Kcal/Kg$	(enthalpy)
$v = 0.11\ m^3/Kg$	(appriximate)
$s = 1.3\ Kcal/Kg/^{\circ}K$	(approximate)

2) Vaporizing process. The process B-C is vaporization of the refrigerant in the evaporator. Since vaporization takes place at constant temperature and pressure, B-C is isothermal as well as isobaric. At the point C the refrigerant is completely vaporized and is in saturated vapor at the vaporizing temperature and pressure. The properties of the refrigerant at the point C are:

$p = 1.940\ Kg/cm^2$	(vaporizing pressure)
$t = -20^oC$	(vaporizing temperature)
$h_c = 395.46\ Kcal/Kg$	(enthalpy)
$v = 0.6236\ m^3/Kg$	(specific volume)
$s = 2.1710\ Kcal/Kg/^oK$	(entropy)

The quantity of heat absorbed by the refrigerant in the evaporator is called refrigerating effect (q_1) and is given by the difference between the enthalpy of the refrigerant at the point C (h_c) and B ($h_b = h_a$) viz., $q_1 = h_c - h_a$.

3) Compression process. Process C-D takes place in the compressor as the pressure of the vapor is increased by compression, changing from the vaporizing pressure to the condensing pressure. The compression process C-D is assumed to be isentropic, which is a special type of adiabatic process taking place without friction. It is sometimes espressed as a "frictionless adiabatic" or "constant-entropy" compression. At the point D, the refrigerant is in superheated vapor whose properties are:

$p = 11.895\ Kg/cm^2$	(condensing pressure)
$t = 108^oC$	(approximate)
$h_a = 458\ Kcal/Kg$	(approximate)
$v = 0.23\ m^3/Kg$	(approximate)
$s = 2.1710\ Kcal/Kg/^oK$	(same as at point C)

The heat energy equivalent to the work during the compression is often referred to as the heat of compression (q_2) and is equal to the difference in the enthalpy of the refrigerant at the points D(h_d) and C(h_c) viz, $q_2 = h_d - h_c$.

4. Condensing process. Usually, both processes D-E and E-A take place in the condenser as the hot gas discharged from the compressor is cooled down to the condensing temperature and condensed. Process D-E represents cooling of the vapor from the discharge temperature to the condensing temperature as the vapor rejects heat to the condensing medium. At the point E the refrigerant is in saturated vapor at the condensing temperature and pressure. Its properties are:

$p = 11.895\ Kg/cm^2$	(condensing pressure)
$t = 30^{o}C$	(condensing temperature)
$h_e = 407.43\ Kcal/Kg$	(enthalpy)
$v = 0.1107\ m^3/Kg$	(specific volume)
$s = 2.0191\ Kcal/Kg/^{o}K$	(entropy)

Process E-A is condensation of the vapor in the condenser. In returning to the point A, the refrigerant completes one cycle and its properties are the same as those previously mentioned at the point A. The total heat (q_3) rejected by the refrigerant in the condenser is the difference between the enthalpy of the superheated vapor at the point D(h_d) and the saturated liquid at the point A(h_a) viz., $q_3 = h_d - h_a$.

4.3. Refrigeration System of Fishing Boats.

4.3.1. Variety of refrigeration systems.

Refrigeration systems applied for preserving fish catch are classified into three major groups (1) chilling (2) freezing and (3) cold storage. These systems are further classified into those used in fishing boats as given in Table 4.3.1

Table 4.3.1. Refrigeration systems on board a fishing boat

Cold storage	With ice	storage with crushed ice (dry type)
		storage with sea water chilled with ice (wet type)
		storage with ice and chilled water by ref. machine
	Without ice	storage in chilled sea water
		storage in chilled air by cooling coil in fish holds

Freezing	Air	Semi-air blast	freezing with forced chilled air
		Air blast	freezing with the blast of chilled air
	Brine		freezing with chilled brine
	Contact freezing	Brine flat tank	freezing with flat tank in which chilled brine is circulated
		Direct expansion flat tank	freezing with flat tank in which refrigerant is circulated

1) Storage with ice. The temperature of so-called green ice just taken out of ice storage is about $-5^{\circ}C$. It is desirable, however, that the temperature in the fish holds is kept at $-12\sim-18^{\circ}C$, because of easy handling and longer effectiveness. The quantity of ice must be sufficient for preserving a fish catch and usually as much as a half of the fish catch in weight is required for storage. When ice is used in sea water, timely and proper addition of ice and salt is essential.

2) Storage in chilled sea water. Heat quantity of chilled sea water usuable for cooling is very small in comparison with that of ice. The latent heat of ice is 80 Kcal/Kg, while in the case of chilled sea water 5 Kcal/Kg. This heat quantity corresponds to a temperature rise of $5^{\circ}C$ from $-2^{\circ}C$ to $3^{\circ}C$.

Since the weight of ice is 500 Kg/m^3 (a half of sea water in weight), available heat is only $\frac{1}{8}$ as shown in the following:

$$80 \text{ Kcal/Kg} \times 0.5 : 5 \text{ Kcal/Kg} \times 1 = 8:1$$

In order to overcome this disadvantage, a flake-ice machine is commonly in use on board.

3) Freezing. Cold air blast below $-30^{\circ}C$ in temperature with the speed of 2 to 3 m/sec is applied to the fish catch for freezing in the air blast type freezing. Time for freezing ranges from 10 to 40 hrs, depending upon the size of fish. Temperature at the center of a fish body reaches $-18\sim-35^{\circ}C$.

In brine freezing, temperature of the brine is about $-14\sim-17^{\circ}C$ by this method the center of a fish body is lowered to less than $-10^{\circ}C$. After this process, the fish is further cooled down to $-18\sim-35^{\circ}C$ by the chilled air of $-25\sim-40^{\circ}C$ in the dry fish hold. In contact freezers, liquid refrigerant of $-25\sim-40^{\circ}C$ or brine is circulating. Time for freezing is about 4-5 hrs, so freezing can be carried out 3-5 times a day.

3.2. Refrigeration systems by kinds of fisheries.

Application of refrigeration systems is given in Table 4.3.2. for the respective fisheries.

Table 4.3.2. Refrigeration systems by kinds of fisheries

Refrigeration / Kind of fishery	Storage					Freezing			
	Ice	Water with ice	Ice & chilled water	Chilled water	Air	Semi air blast	Air blast	Brine	Contact freezing
Small fishing boats less than 10 G/T	0	0		0					
Skipjack pole and line fishing boats		0	0	0	0			0	
Squid angling boats	0				0	0			0
Purse seiners		0		0				0	
Fish carriers (for purse seiners)			0	0					
Tuna long liners					0	0	0		
Off shore trawlers	0								
Deep sea trawlers					0				0

5. OCEANOGRAPHIC SURVEY METHODS

5.1. Instructions for Recording and Treating Data.

5.1.1. Field observation notebook. Several types of field observation notebook and form are in use according to the respective purposes of observation. In any case, the following requirements should be fulfilled for the notebooks and forms:

1) A field notebook should be bound firmly.

2) If possible, a durable cover should be provided for it.

3) While on board, the notebook should be clipped to a wooden board so that it will float even if it is dropped into the sea accidentally.

5.1.2. Observation diary. An observation diary is a useful reference for making reports later and for planning observation schedules. The use of this diary is strongly recommended especially for a chief scientist who is responsible for a research cruise.

It contains records on processes and events during the observation, and unusual phenomena occuring during the cruise or the period of observation. For example, oceanographic and meteorological conditions, personal divisions of observation, locations of observation, date, time of start and finish, and troubles with instruments should be included.

When recording such matters, it is desirable to acquire the habit of recording the time and date together with the descriptions.

5.1.3. General rules for introductory part. Date and time are very important for observation records and these must always be filled in prior to any observation. These data are so familiar to the observers that they are apt to think they could record them later on. In most cases, however, the more clearly known the fact the easier to forget recording it.

Needless to say, the year should be included as well as the day and month when recording dates. Recordings of time should clearly discriminate between the morning and the afternoon. The time in the afternoon can be conveniently expressed by adding 12 hours to it, e.g., 03.30 p.m. is best expressed 15.30.

Information which can easily be obtained, for example, weather conditions, should also be recorded.

5.1.4. Recording of data. When recording data in a field notebook, it is not sufficient only to fill out the prescribed items. Any matter observed in the field should be recorded immediately and directly in the field notebook, even if it looks trivial. When only numerical data of prescribed items are recorded, and these are recorded in a disorderly fashion, the notebook cannot be regarded as a proper field notebook. As the proper method of making and recording observations has been established through bitter experiences of predecessors, the development of proper habits of observation and recording in the field is recommended.

1) Use of columns. The use of columns is essential for recording, especially for beginners. During the course of observation, data should be filled inside the columns in due order. The columns help in indicating if there is any ommission in recordings. The use of columns can, therefore, be regarded as a guide during observation.

2) Recording other relevant data. All matters observed, even if columns are not provided for them, should be recorded without ommission. Such descriptions sometimes give hints from which a new aspect of the problem can be developed. There should be no hesitation about recording these additional remarks.

3) Recording directly in notebook. The use of loose papers for recording observations in the field is not recommended. It is important that the data is recorded directly in the field notebook. When the data can not be recorded directly in the field notebook under special circumstances, the loose paper used for the record should be pasted in the notebook as soon as possible.

4) Care in recording. Recording should be made with a good quality pencil. When a wrong entry has been made, delete it with a faint line and record the correct value nearby. Do not obliterate the error.

5) Care in taking data. In the field of observation, usually one person takes the reading and another person makes the record. Under windswept conditions as on board, the communication between observers is sometimes misheard. To avoid trouble, the following method of communication should be adopted. The person who records must repeat the reading loudly and the person who reads must confirm it. During observation, these persons must interchange their roles of observation and confirm the results of each.

6) Recording non-mentally calculated values. Do not attempt to record mentally calculated values until all observed data have been recorded.

7) Recording unit of numerical data. During measuring, the unit may be known so clearly that it might often be unrecorded. However, some confusion could arise later on when the recordings are put in order. For example, length measurements in centimeters may be confused with millimeters.

8) Correction of observed data. The observed data should not be altered without sufficient reason. When doubt on the observed data arises, a second observation should be carried out immediately. If the first reading is incorrect, it should be deleted by a faint line and the correct value should be inserted nearby. Describe clearly the reason for the correction outside the column. The error should not be erased or rendered illegible.

9) Checking before completion. On completion of observations at the station, the entries should be carefully checked for any error or ommission. If an item was not observed, the space provided for it should be filled, for example, with 'x' or '-'.

10) Clear description. Since a field notebook is a valuable document, and should be kept for future reference, it is essential that all matters recorded in the field notebook should be easily understood by any person using it. Particular attention should be paid to style of writing especially when recording figures.

11) Care during cruise. Needless to say, field notes should always be stored in a safe place during a cruise.

12) Putting data in order. After observation, the field notes should be transferred into an appropriate form, e.g., a table or a diagram, while memories are still fresh.

13) Keeping of field notebook. The field notebook, even after it has already been put in order, should be treated carefully.

Recording of raw data in the field notebook must be regarded as still pictures in a movie sequence. It should be borne in mind that such raw data are quite different in quality from that obtained through calculation, and that they are also different from those of controlled experiments performed in laboratories. In the field experiment, it is never expected that identical data can be collected by subsequent observation.

In other words, the data obtained by the field observation should be regarded as unique at that instant and in that position.

From the above, you can understand the reason why in the field careful observations and recordings should be practised. Unnecessary mistakes can be avoided if one acquires proper habits during observations.

5.1.5. Calculation and data processing. Calculations on the raw data can be made by several methods such as mental calculations, ciphering, readings on numerical tables, slide rules and using calculators. The process of calculation should be such that it can be easily traced. A disorderly process of calculation is not encouraged.

It is generally difficult to grasp the general trend or relationship between sets of numerical data. However, the tendency can be seen clearly if the data were plotted on section papers. Graphs not only show trends but also serve as a means of checking the validity of the observed data. You should always draw graphs whenever possible.

The purpose of any observation is to reach a result. Even if it is only a graph or a numerical value, it is a valuable result. When a result is obtained, study the graph or the value visually and then review in mind repeatedly the whole process from the beginning to the final result.

Finally, if you have any criticism of the results, you should describe them. This includes any opinion as to modification of methods of observations, instruments, etc.

5.2 Water Sampling and Temperature Measurement

Water sampling and temperature measurement are most important and are basic items of oceanographic observation. Methods of sampling water and measuring temperature of deep and surface layers are remarkably different.

For the deeper layers below the surface, samples of the ocean water can be taken in Nansen reversing bottles. The cylindrical metal bottle is open at both ends, but has caps or seals that can be closed automatically. When attached to a wire and submerged, water flows freely through the bottle until it has reached the desired depths. A weight called a messenger is dropped down along the wire to a device which closes the top and bottom of the bottle, trapping the water within it. When this happens, the bottle turns over and this movement fixes the mercury column in a thermometer fastened to the outside of the bottle. The reversing thermometer thus records the temperature of the water at the instant when the bottle was turned over. In this way, the temperature of the ocean at any depth can be measured. As a rule, a number of such bottles are employed at the same time at various depths. Each bottle, as it closes, releases a second messenger which drops to the bottle below, repeating the process.

For the surface layer, the water sample is taken in the water sampling bucket. The temperature is measured immersing a rod type thermometer in the water sampled on board just after the bucket has been heaved up.

The water sampled is transfered from the Nansen bottle or the sampling bucket into water phials. These phials are stoppered and stored in a storage box upside-down.

5.2.1. Water sampling and temperature measurement for layers below the surface.

The selection of the observation layers is not always definite; the layers should be decided considering the circumstances. The following depths, in meters, have been recommended by the International Association of Physical Oceanography (1936);

0, 10, 20, 30, 50, 75, 100, 150, 200, (250), 300, ...

Procedure

1. After the ship has stopped at the station with her board of observation facing the weather, read the depth on an echo-sounder and then decide the layers to be observed.

2. Pay out the wire from the winch through the depth gauge suspended from the davit. Attach a weight to the end of the wire and lower the weight into the water so that it acts as a stabilizer to the wire. When the ship is rolling, it is preferable to pay out more wire.

3. When a sufficient length of the wire is paid out, attach the Nansen bottle to the wire. Before lowering, inspect each part of the bottle and set the hands of the gauge to zero. When inspecting, special attention should be paid to the thermometers, the seals and the screw of the device by which the bottle is attached to the wire.

4. Lower the bottle until it has reached the desired depth, then attach the second bottle to the wire. Inspection is the same as in the first instance, never forget to attach a messenger. The same process is repeated until the final bottle is attached. When the final bottle is attached, read the depth gauge before lowering the bottle.

5. Lower the final bottle until its middle part reaches the surface, then stop the winch and read the depth gauge. The difference of this reading from that when the final bottle was attached corresponds to the height from the level at which the bottles were attached to the wire to the sea surface. In order that each bottle reaches their desired depths, this length must be added.

6. Five minutes are enough for the mercury column of the thermometer to equilibrate. While waiting, measure the slope angle of the wire and carry out temperature measurement and water sampling for the surface water 1/. When 5 minutes have elepsed from the completion of the lowering of bottles, cast down the

1/ Refer to the related section.

messenger and confirm (by feeling the wire) if the messengers bump successively into the bottles.

7. When the wire is heaved up, a person must sweep off the water from the wire and another person must coat the wire with grease. Take care not to bump the bottle against the ship when it is coming up.

8. Detach the bottle and messenger from the wire and hang the bottle on the rack. Repeat the process.

9. After the temperature inside the thermometer has reached steady, read first the temperature of the auxiliary thermometer and then the main thermometer. Never give the thermometer any shock when it is in the reversed position.

10. When the observer is reading the thermometer, he should report loudly to the recorder and the recorder must repeat the value read. The observer must read again to confirm it. It is preferable for the temperature to be read again by another observer. The temperature must be read to the order of 1/100°C for the main thermometer and 1/10°C for the auxiliary thermometer. The order of reporting is as follows:

    (1) Depth ____________ m
    (2) Nansen bottle number ____________
    (3) Thermometer number ____________
    (4) Auxiliary thermometer (Aux.) ____________ °C
    (5) Main thermometer (Main) ____________ °C

11. After the temperatures of all layers have been read, the sample water of each layer should be transferred into phials. First pour out the water which has been kept in the phails 2/. Rinse the phial two or three times with the water collected. The rubber stopper must be cleaned when the rinsed water is poured out.

2/ The phial used for the salinity determination is usually a glass bottle which is brown in colour and can be plugged with a rubber stopper; never allow the bottle to dry up, some volume of sea water must always be kept in the phial, even after the salinity determination has already been completed. This will prevent the formation of salt particles in the bottle. On the other hand, do not rinse with fresh water. In either case, the salinity of the sample water will be effected.

12. Pour the sample water into the phial, leaving a little space. Never fill the phial to the brim.

13. Plug the phial firmly with a rubber stopper, then keep the phial in the box upside down. The phial number must be recorded. Care must be taken in reporting as in reporting temperatures.

14. After the temperature has been read and the sample water has been taken, the reversing thermometer must be kept in its normal position. Keeping it in the reversed position for a long time leads to trouble.

5.2.2. Water sampling and temperature measurement for the surface layer.

The term surface water generally means the well-mixed water down to 1-2 m below the surface.

Procedure

1. Collect the surface water in the water sampling bucket, then pour it out. Repeat the process two to three times. This process will allow the temperature of the sampling bucket to approximate that of the water.

2. Dip up the water again, then immerse the rod type thermometer into the water sampled and stir well in a shady place, away from winds. Water sampling is preferable from the weather side of the ship, near the bow. Never collect the water near discharge pipes.

3. Read the temperature just after it has become stationary, with the mercury column as fully in the water as possible. The time interval to reach steady is usually within 40-60 sec. Temperature reading from the surface water is taken to the nearest $1/10^{o}C$.

4. Temperature reading must be carried out as quickly as possible.

5. Sample water must be taken from the water from which the temperature has been measured. The method of reporting is the same as in the preceding section.

5.3 Plankton Sampling.

The most widely used apparatus for collecting plankton is a plankton net. Plankton net is essentially a cone made of fine mesh bolting silk or nylon. The front part of the net is attached to a metal ring by which the net is towed through the water and the terminal end of the net is attached to a bucket in which the plankton is allowed to settle. The net may be towed horizontally or hauled vertically through the water. If towed horizontally from on board, the depth can be set by depressors or paravanes. Vertical hauls may be continuous from the bottom or from a fixed depth to the surface, or divided, using a mechanism to close the net at a given depth.

Qualitative sampling at the surface is a simple matter. A suitable net is towed at about 1½ to 2 knots for ten minutes which usually suffices to give an adequate amount of plankton. However, the quantitative determination of plankton bristles with difficulties. To assess the amount of plankton in a given water column is never possible with any real accuracy. This is because some of the water is spilled out before it has been filtered during the operation. Particularly when working with a fine-mesh net in water rich in phytoplankton, the meshes get progressively clogged and so the filtration rate falls off in time with more and more water spilling from the front of the net as resistance increase. In order to overcome these difficulties, a flow-meter is placed in the mouth of the net so that the water passing into the net activates a small propeller attached to a counting mechanism. When properly calibrated, the number of revolutions of the propeller is taken to indicate the amount of water which has passed through the net. From this, the plankton biomass can be calculated. However, owing to unavoidable irregularities in filtration on analysis, the figures obtained usually are at best only an approximation.

5.3.1. Vertical hauling.

Procedure

1. Before the operation starts, firmly tie a flow-meter at the central part of the mouth of the plankton net and suspend a depth gauge under the davit which is projected from the hull at a right angle.

2. When the vessel has stopped at the station, switch on the echo-sounder and read the depth of the station from the recording paper.

3. Tie a chain of weights to the rope at the lower end of the plankton net.

4. Pay out the wire from the winch through the depth gauge and attach the net to the end loop of the wire.

5. Before lowering the net, inspect the tap of the bucket and the flow-meter to make sure:

   (a) The tap (opener) is parallel to the bucket position (i.e. the bucket is kept closed).

   (b) The flow-meter is set to zero.

6. Lower the plankton net into the sea until it reaches the desired depth. The depth desired is usually 3 m above the sea floor. Thus, the length of wire released depends on the sea condition. If the current is strong, it is preferable to pay out more wire to enable the plankton net to reach the lower water.

7. The plankton net takes 1-2 minutes to return to a straight vertical position in water. During that period, use the clinometer to measure the slope angle of the wire.

8. Haul up the plankton net at a speed of 1 m/sec. When heaving the wire, use a cloth to wipe the water from the wire and to grease it.

9. As soon as the plankton net is pulled up onto the deck, read the flow-meter immediately and record it.

10. Detach the plankton net from the wire and release the weight tied on the rope of the net.

11. Immerse the lower end of the plankton net in water contained in a plastic vessel for samples. Then wash off the plankton specimens attached to the net into the bucket. Open the tap of the bucket and let the water from the bucket drain into a 250 ml. plastic sample bottle. Close the tap and repeat the same procedure until all the specimens have been collected. (In case the tube of a bucket is blocked by jelly-fish or other macroplankton, press the cylindrical plastic tube of the bucket carefully. Then pour the bucket-water into the sample bottle).

12. Add neutral solution of formaldehyde to the sample to 4-5% of the total volume 1/.

13. Record the date, time, depth, wire length, station number and sample number on the record form.

.3.2. Horizontal towing.

Procedure

1. Connect the plankton net and weight to the towing rope which is tied at the davit projected from the hull.

2. When the vessel is at a uniform speed of 2 knots, lower the plankton net to the sea. The mouth of the plankton net must be adjusted to immerse completely in the surface water.

1/ The absolute foraldehyde solution is about 40%. Eight to ten times dilution of the solution will give a 4-5% concentration.

3. After towing for exactly 10 minutes, pull up the net onto the deck and read the flow-meter immediately.

4. Collect the plankton specimen in a 250 ml. plastic bottle and preserve the sample in 4-5% formaldehyde.

5. Record the date, time and period of towing, the station number, sample bottle number and flow-meter reading on the record form.

Note: In both vertical hauling and horizontal towing, after collecting the plankton sample, never forget to do the following:

(a) Wash the plankton net throughly.
(b) Set the flow-meter to zero.
(c) Turn the tap to parallel position to the bucket.

5.3.3. Calibration of flow-meter.

The revolution speed of a flow-meter is related to the lubrication of the propeller, thus, the flow-meter should be calibrated in every oceanographic survey cruise. The depth of the sea is preferably not less than 70 m. The calibration can be done when the sea is fairly calm.

Procedure

1. Test the revolution of the wings of the flow-meter by blowing before calibration.

2. The flow-meter is mounted at the centre of the mouth ring from which the net is removed.

3. Lower the mouth ring mounted with the flow-meter by paying out the wire to the desired length. The desired length is 5 m less than the depth of the sea or not exceeding 150 m.

4. As soon as the desired length of wire is paid out, measure the wire angle with a clinometer and haul up the wire at a speed of 1 m/sec.

5. When the ring is raised on deck, read the dial gauge of the flow-meter and record the reading. Angle of wire is recorded for information, but not for calculation of the depth of haul.

6. Repeat the above procedure until nearly constant revolutions are obtained.

7. The revolution rate, r_m, of the flow-meter is calculated as follows:

$$r_m = \frac{\text{revolution without net}}{\text{wire length paid out during calibration}}$$

8. Volume of water filtered by the net is calculated as follows:

$$V = \pi r^2 \times \frac{Rd}{r_m}$$

where V is the filtration volume, r the radius of net ring, and Rd the rotation of flow-meter in sampling with net from a depth d. CSK standard net is 45 cm in mouth diameter and Japan standard net is 23 cm, thus the mouth areas of the two nets are:

CSK	$\pi r^2 = 3.14 \times 22.5^2 = 1590\ cm^2 = 0.16\ m^2$
Japan	$\pi r^2 = 3.14 \times 11.5^2 = 415\ cm^2 = 0.04\ m^2$

9. If the mean revolution of the flow-meter without net for 80 m haul is 834 and the revolution of the flow-meter in a 75 m plankton sampling haul with CSK net is 700, then the filtration volume is:

$$r_m = \frac{834}{80} = 10.42$$

$$V = 0.16 \times \frac{700}{10.4} = 10.8\ m^3$$

APPENDICES

Appendix 1

(Tables)

Table 1.2.1. Particulars of various kinds of purse seine.

Particulars / Kind of purse seine	Net: Name of parts	Net: Kinds of materials	Net: Number of Yarns	Net: Mesh size (cm)	Float line side: Stretched length of net(m)	Float line side: Completed length (m)	Float line side: Hang-in (%)	Sinker line side: Stretched length of net(m)	Sinker line side: Completed length (m)	Sinker line side: Hang-in (%)	Remarks
Two boat/traditional	Cod end	Saran-nylon mix twist	6-9	1.9	390	312	20	390	312	20	-
	Wing		4	1.9							
One boat/horse mackerel	Cod end	Vinylon	18-24	5.4	1,212	735	39	1,363	818	40	Depth of net : 59 m
	Wing	"	12	6.0							Weight : 5,733 kg
- Ditto -	Cod end	"	18-24	3.0	1,027	690	33				Depth of net : 272 m
	Wing	"	12-18	3.0							Weight : 8,850 kg.
One boat/large size sardine	Cod end	"	16	2.6	570	342	40	570	400	30	Center part : 8 yarns
	Wing	"	8	3.3							3.3 cm , 82 pieces
One boat/medium size sardine	Cod end	"	16	2.0	480	288	40	480	336	30	Center part : 6 yarns
	Wing	"	6	2.2							2.2 cm , 100 meshed,82 p'cs
One boat/small size sardine	Cod end	"	12	1.7	420	252	39	420	294	30	Wing consists of 3 parts
	Wing	"	4-6	1.5 - 2.0							6 yans, 1.6 cm, 100 meshes,30p'cs 4 " , 1.5 ", " ,20 " 6 " , 2.0 ", " ,24 "
Two-boat/horse mackerel	Cod end	"	30	4.3	1,090	586	46				Depth of net :106 m
	Wing	"	24	6.0							Weight : 4,500kg
- Ditto -	Cod end	Saran nylon	18-21	3.0 - 3.8	1,162	833	28	1,182	994	16	Depth of net : 83 m
	Wing	nylon	9-12	6.0							Weight : 8,818kg
Two-boat/sardine	Cod end	"	6	1.3	727	520	28	727	568	22	Depth of net : 112 m
	Wing	"	4	1.3							Weight : 2,430kg
Two-boat/sardine	Cod end	"	6	1.6	517	273	47				Depth of net : 111 m
	Wing	"	6	1.6							Weight : 2,370 kg
Two-boat/tuna	Cod end	"	75	9.0	2,503	1,730	31	2,503	1,818	27	Depth of net :272 m
	Wing	Vinylon	24-36	15.0 - 18.0							Weight for nylon : 3,094 kg Weight for vinylon : 5,840 kg

Table 1.2.2. Comparison of sinking velocity for various kinds of purse seine.

Kinds of purse seine	Operation area	Actual length of float line (m)	Material	Average sinking velocity (cm/sec)	Weight of sinker per meter (kg)	Observer
One - boat/mackerel	East China Sea	640	Tetoron staple, Vinylon filament	15.5	2.30	Nomura and others
Two - boat/mackerel	Mie Prefecture, Japan	382	Cotton	11.7	1.82	Ishii, Kohase
One - boat/sardine	Bingo Strait, Japan	378	Vinylon staple	27.5	2.03	Kondo, Hamada
One - boat/tuna	Off Sanriku district, Japan	1,500	Nylon filament	13.1	2.07	Nomura
Two - boat/tuna	Off Sanriku district, Japan.	2,100	Nylon filament	Center part of net 10.6 Middle of wing 16.7 Edge of net 23.5	1.12 1.85 2.28	Hamuro
One - boat/bonito	Off Pranburi, Thailand.	600	Nylon filament	4.2	0.50	Nomura and others

Table 1.2.3. Weight of Sinker per meter (in Japan).

Kinds of purse seine	Average weight (kg/m)	Weight of individual sinker (g)
Two - boat type / sardine	1.05 (0.67 - 1.24)*	150 - 375
One - boat type / mackerel	2.12 (1.21 - 3.56)*	225 - 375
Two - boat type / mackerel	1.75 (1.58 - 1.89)*	225 - 338
One - boat type / tuna	1.71 (1.49 - 1.93)*	375
Two - boat type / tuna	1.67 (1.07 - 2.44)*	225 - 563

*) Figures in parentheses show the lowest and the highest values.

Table 1.2.4. Weight of Sinker per meter (in Europe and America).

Kinds of purse seine	Average weight (kg/m)	Weight of individual sinker (g)	Length of sinker line (m)
Purse seine/tuna (Norway)	1.8	250	698
Purse seine/cod (Norway)	1.6	250	379
Purse seine/herring (Iceland)	2.8	250	393
Purse seine/herring (Canada)	1.6	110	445
Purse seine/salmon (Canada)	1.1	110	400
Purse seine/salmon (Canada)	1.9	110	550

Table 1.2.5. Weight and buoyancy of floats.

Material	Specific gravity	Buoyancy per liter (gr)	Buoyancy per kg weight in air (kg)
Cork	0.175 (0.321)*	285 (679)*	4.71 (2.12)*
Paulownia	0.294 (0.785)*	706 (215)*	2.40 (0.27)*
Bamboo	0.500	500	1.00
Pine	0.598	402	0.67
Vinylon/Sponge (soft)	0.099	901	9.10
Vinyl/sponge (hard)	0.129	871	6.75
Synthetic rubber/sponge	0.243	757	3.03
Synthetic cork	0.294	706	2.40
Ebonite	0.375	625	1.66
Vinyl pipe	0.379	621	1.64
Glass/15cm in dia.	0.348	652	1.87
Glass/30cm in dia.	0.244	756	3.10

*) Figures in parenthesis show the values after being in water for 30 days.

Table 1.2.6. Sinking power of sinkers.

Material	Specific gravity	Sinking power per liter (kg)	Sinking power per kg weight in air (kg)
Lead	11.35	10.35	0.912
Iron	7.21 - 7.85	6.21 - 6.83	0.861 - 0.872
Brass	7.82	6.62	0.872
Glass	2.70	1.70	0.630
Stone	2.60 - 2.70	1.60 - 1.70	0.615 - 0.630
Brick	1.90	0.90	0.474
Sand	1.80	0.80	0.444
Soil	1.50	0.50	0.333
Porcelain	1.72 - 2.13	0.72 - 1.13	0.420 - 0.530
Concrete	3.00 - 3.15	2.00 - 2.15	0.666 - 0.682

Table 1.3.1. Properties of synthetic fibers and cotton.

Properties \ Fibers	Cotton	Nylon 6	Saran	Teviron	Tetoron	Poly-ethylene	Vinylon	Polypro-pylene
Specific gravity	1.55	1.14	1.71	1.39	1.38	0.95	1.30	0.91
Tenacity/dry (g/d)	2.5-4.0	6.4-8.4	1.5-2.6	2.7-3.7	6.5-7.5	5.0-9.0	4.2-6.0	5.0-9.0
Tenacity/wet (g/d)	-	5.9-6.9	1.5-2.6	2.7-3.7	6.5-7.5	5.0-9.0	3.2-4.8	5.0-9.0
Elongation at breaking Pt./dry(%)	7-10	16-22	18-33	15-30	7-13	10-40	17-26	25-60
Elongation at breaking pt./wet(%)	8	20-27	18-33	15-30	7-13	10-40	19-30	25-60
Moisture Regain 95% R.H. (%)	24.0-27.0	8.5	0-0.1	0.3	0.6-0.7	0.2	10.0-20.0	0.2
Young's Modulus (kg/mm^2)	800	320-510	100-200	500-800	2000-2500	300-850	300-800	330-1000
Elastic Recovery	Fair	Excel-lent	Excel-lent	Good	Excel-lent	Good	Good	Good
Resistance to Abrasion	Fairly good	Good	Good	Good	Good	Good	Good	Good
Softenting Point (° C)	-	180	140-180	60-100	238-240	105-115	200	140
Melting Point (° C)	-	215	-	200	260	125-130	200	140
Affinity to Dyes	Good	Good	Fair *	Fair *	Good	Poor *	Good	Poor *
Resistance to Acids	Poor	Fair	Excel-lent	Good	Excel-lent	Good	Good	Good
Resistance to Alkalies	Good	Good	Good	Good	Good	Good	Good	Good

*) Materials are dyed before the fibres making process is done.

Table 1.3.2. Particulars of several kinds of gill net.

Net Particulars / Fish Aimed	Kinds of Gill Net	Mesh Size (cm)		Number of Yarn		Depth (number of Mesh)	
		Range	Mode	Range	Mode	Range	Mode
Sardine	Drift gill net	2.5- 4.5	4.0	4- 6	4	140-700	-
Herring	"	5.5- 7.5	6.0	4- 9	6	60-200	200
Flying fish	"	4.5- 6.0	5.5	4- 6	4	40-200	-
Bonito	"	6.0-10.5	8.0	6-18	9	40-500	-
Mackerel	"	7.0-10.0	8.0	4-18	6	60-500	-
Salmon	"	11.5-13.5	12.0	12-15	15	60- 75	60
Trout	"	9.0-12.0	10.0	8-12	12	25- 75	55
Spanish mackerel	Drift gill net Entangle net	7.5-18.0	10.0	12-30	18	40-200	150
Horse mackerel	Drift gill net	5.5- 8.5	7.5	4- 9	6	20-100	-
Shark	Drift entangle net	15.0-30.0	20.0	15-45	27	20- 40	25
King crab	Bottom entangle net	35.0-55.0	45.0	15-24	21	6- 15	7
Crab	"	8.0-18.0	15.0	9-18	12	5- 80	-
Cod	"	12.0-17.0	12.0	9-12	12	15- 40	20
Bream	"	8.0-20.0	12.0	9-24	15	10- 45	25
Shrimp	"	4.0-10.0	5.0	3- 6	4	10-150	-

Table. 2.1.1. Fineness Coefficients of Fishing Boats.

Type of Fishing Boat	Block Coefficient	Prismatic Coefficient	Midship Coefficient	Water Plane Coefficient
Fishery Patrol Boat	0.46-0.54	0.58-0.63	0.72-0.19	0.71-0.79
Whale Catcher Boat	0.48-0.56	0.60-0.65	0.80-0.88	0.76-0.83
Tuna- and Bonito-Fishing Boat	0.63-0.72	0.65-0.75	0.91-0.97	0.83-0.90
Trawler	0.59-0.66	0.66-0.71	0.91-0.93	0.81-0.86
Bull Trawler	0.61-0.70	0.66-0.77	0.88-0.96	0.83-0.92
Medium-size Trawl Boat	0.57-0.70	0.65-0.74	0.90-0.96	0.79-0.86
Roll Net Fishing Boat (Purse Seiner)	0.57-0.68	0.67-0.75	0.91-0.95	0.76-0.94

Table. 2.1.2. Coefficient K in International Formula of GT Measurement.

V	K	V	K	V	K	V	K
10	0.2200	45 000	0.2931	330 000	0.3104	670 000	0.3165
20	0.2260	50 000	0.2940	340 000	0.3106	680 000	0.3166
30	0.2295	55 000	0.2948	350 000	0.3109	690 000	0.3168
40	0.2320	60 000	0.2956	360 000	0.3111	700 000	0.3169
50	0.2340	65 000	0.2963	370 000	0.3114	710 000	0.3170
60	0.2356	70 000	0.2969	380 000	0.3116	720 000	0.3171
70	0.2369	75 000	0.2975	390 000	0.3118	730 000	0.3173
80	0.2381	80 000	0.2981	400 000	0.3120	740 000	0.3174
90	0.2391	85 000	0.2986	410 000	0.3123	750 000	0.3175
100	0.2400	90 000	0.2991	420 000	0.3125	760 000	0.3176
200	0.2460	95 000	0.2996	430 000	0.3127	770 000	0.3177
300	0.2495	100 000	0.3000	440 000	0.3129	780 000	0.3178
400	0.2520	110 000	0.3008	450 000	0.3131	790 000	0.3180
500	0.2540	120 000	0.3016	460 000	0.3133	800 000	0.3181
600	0.2556	130 000	0.3023	470 000	0.3134	810 000	0.3182
700	0.2569	140 000	0.3029	480 000	0.3136	820 000	0.3183
800	0.2581	150 000	0.3035	490 000	0.3138	830 000	0.3184
900	0.2591	160 000	0.3041	500 000	0.3140	840 000	0.3185
1 000	0.2600	170 000	0.3046	510 000	0.3142	850 000	0.3186
2 000	0.2660	180 000	0.3051	520 000	0.3143	860 000	0.3187
3 000	0.2695	190 000	0.3056	530 000	0.3145	870 000	0.3188
4 000	0.2720	200 000	0.3060	540 000	0.3146	880 000	0.3189
5 000	0.2740	210 000	0.3064	550 000	0.3148	890 000	0.3190
6 000	0.2756	220 000	0.3068	560 000	0.3150	900 000	0.3191
7 000	0.2769	230 000	0.3072	570 000	0.3151	910 000	0.3192
8 000	0.2781	240 000	0.3076	580 000	0.3153	920 000	0.3193
9 000	0.2791	250 000	0.3080	590 000	0.3154	930 000	0.3194
10 000	0.2800	260 000	0.3083	600 000	0.3156	940 000	0.3195
15 000	0.2835	270 000	0.3086	610 000	0.3157	950 000	0.3196
20 000	0.2860	280 000	0.3089	620 000	0.3158	960 000	0.3196
25 000	0.2880	290 000	0.3092	630 000	0.3160	970 000	0.3197
30 000	0.2895	300 000	0.3095	640 000	0.3161	980 000	0.3098
35 000	0.2909	310 000	0.3098	650 000	0.3163	990 000	0.3199
40 000	0.2920	320 000	0.3101	660 000	0.3164	1000 000	0.3200

V = Volume in cubic meters. Coefficients K at intermediate values of V shall be obtained by linear interpolation.

(derived from: N. Fujinami et al, Measurement of gross tonnage of small fishing vessels, IPFC/IOFC/ST 26, Nov. 1971)

Table. 2.2.1. Speed of Fishing Boats.

Type of Fishing Boat	Length of a Boat	Speed in Knots	Speed-Length Ratio
Fishery patrol Boat	24.50	12.21	2.29
Fishery Training Boat	68.00	15.00	1.82
Whale Catcher Mother Boat	176.32	16.56	1.25
Whale Catcher Boat	59.15	18.02	2.34
Tuna-Fishing Long-Lining Boat	52.00	13.78	1.91
Bonito-Fishing Boat	24.31	9.44	1.92
Trawler	41.70	12.50	1.78
Bull Trawler	25.51	11.04	2.19
Medium Size Trawl Fishing Boat	22.33	9.85	2.09
Purse Seiner	24.39	9.93	2.01
(Others for Comparison)			
Destroyer	126	40	3.60
Large Size Passenger Liner	330	33	1.82
High-Speed Cargo Boat	145	20	1.66
Regular Cargo Boat	130	15	1.32

Table. 2.2.2(a). BHP/$\triangle$ vs. $V/\sqrt{L}$ Curves.

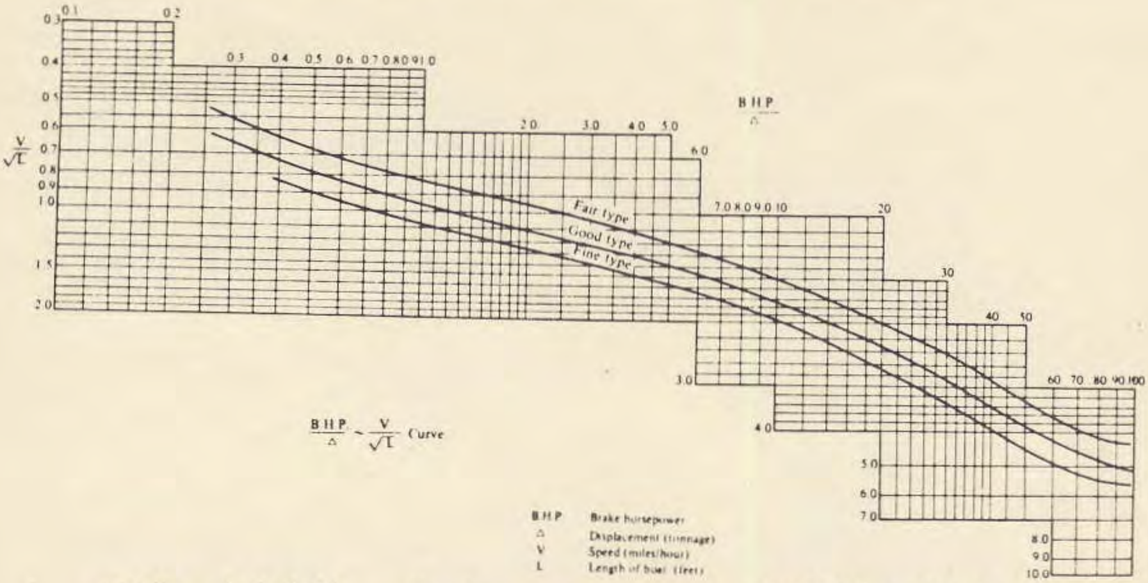


Table. 2.2.2(b). Various Coefficients of Fishing Boats.

	L/B	L/D	B/D	Gross ton / L.B.D.	$\triangle$ / L.B.D.	$\triangle$ (full load) / L.B.D.
Inspection or research boat (steel)	5.436	10.69	1.97	0.263	0.353	0.452
- ditto - (wood)	4.55	10.00	2.21	0.25	0.365	0.536
Whale catcher	5.788	10.56	1.85	0.254	0.376	0.477
Fish carrier boat (steel)	5.83	11.40	1.95	0.32	0.377	0.673
- ditto - (wood)	4.68	9.60	2.04	0.27	0.353	0.522
Tuna long liner (steel)	5.568	10.92	1.96	0.30	0.349	0.592
- ditto - (wood)	4.56	9.16	2.01	0.255	0.361	0.570
Skipjack boat (steel)	5.33	10.40	1.95	0.29	0.376	0.598
- ditto - (wood)	4.80	9.07	1.89	0.256	0.345	0.549
Trawler (steel)	5.95	11.15	1.87	0.27	0.363	0.500
2-boat trawler (steel)	5.13	10.34	2.01	0.263	0.362	0.540
- ditto - (wood)	5.20	9.30	1.79	0.245	0.337	0.552
Danish seiner (steel)	4.83	10.22	2.12	0.258	0.405	0.575
- ditto - (wood)	4.78	9.88	2.05	0.236	0.369	0.565
2-boat purse senior (steel)	4.274	9.27	2.16	0.21	0.360	0.473
Purse seiner (steel)	4.21	8.52	2.02	0.28	0.383	0.585
- ditto - (wood)	4.28	9.63	2.24	0.235	0.370	0.540
Stick held dip net boat (wood)	4.66	9.90	2.12	0.265	0.433	0.537
Long liner (wood)	4.68	9.70	2.07	0.242	0.325	0.468
Mackere angling boat (wood)	4.27	9.74	2.06	0.276	0.361	0.535
Squid angling boat (wood)	4.94	9.99	2.02	0.224	0.334	0.472
Spearing boat (wood)	4.67	9.80	2.10	0.234	0.344	0.487

Table. 2.3.1. Principal Demensions of Trawler.

L	L/B	L/D	B/D
40 M	5.5 – 5.8	9.7 – 10.3	1.7 – 1.9
45	5.6 – 6.0	10.5 – 10.9	1.7 – 2.0
50	5.8 – 6.2	10.8 – 11.6	1.7 – 2.1
55	5.8 – 6.2	11.2 – 11.8	1.7 – 2.2
60	5.8 – 6.2	11.4 – 12.0	1.8 – 2.3

Table. 2.3.2. Fineness Coefficients of Trawler.

Coef.	Light load	Full load
C_b	0.52 – 0.62	0.58 – 0.67
C_p	0.61 – 0.68	0.66 – 0.72
$C_{⊠}$	0.85 – 0.92	0.88 – 0.93

Table. 2.3.3. Principal Dimensions of Two-boat Trawler and Medium Trawler.

Kind	L	L/B	L/D	B/D
Two-boat type trawler operated East China Sea	22 M	4.8–5.2	8.4– 8.9	1.7–1.9
	24	4.9–5.3	8.7– 9.4	1.8–2.0
	26	4.9–5.4	9.6– 9.9	1.8–2.0
	28	5.0–5.6	9.8–10.2	1.9–2.1
	30	5.0–5.8	10.5–11.0	1.9–2.2
Medium trawler	18	4.1–4.6	9.5–10.0	2.0–2.6
	20	4.2–4.8	9.5–10.1	1.9–2.5
	22	4.4–5.0	9.6–10.2	1.8–2.3
	24	4.5–5.2	9.7–10.3	1.7–2.3

Table. 2.3.4. Fineness Coefficients of Two-boat Trawler and Medium Trawler.

Coef.	Two-boat type trawler		Medium trawler	
	Light load	Full load	Light load	Full load
C_b	0.50 – 0.58	0.58 – 0.67	0.52 – 0.60	0.58 – 0.64
C_p	0.58 – 0.65	0.66 – 0.71	0.58 – 0.67	0.63 – 0.71
$C_{⊠}$	0.83 – 0.92	0.87 – 0.95	0.88 – 0.91	0.90 – 0.93

Table. 2.3.5. Turning Capacity of Purse Seiner.

Length of boat (meter)	Time required for turning circle		Diameter of a circle to a boat length
	Up to 15° from initial course	Up to 360° from initial course	
22 >	8 sec	80 sec	3.0
22 <	10 sec	90 sec	3.5

Table. 2.3.6. Principal Dimensions of Tuna Long Liner.

(L)M	L/B	L/D	B/D
25 >	< 4.90	< 10.00	> 2.00
25 — 30	< 5.10	< 11.00	≥ 1.95
30 — 40	< 5.50	< 11.50	≥ 1.90
40 <	< 6.00	< 12.00	≥ 1.80

Table. 2.3.7. Fineness Coefficients of Tuna Long Liner.

	Coef	Light	Full
Steel	C_b	0.57~0.64	0.65~0.70
	C_p	0.63~0.66	0.69~0.73
	$C_⊠$	0.90~0.95	0.92~0.97
Wooden	C_b	0.57~0.64	0.61~0.72
	C_p	0.63~0.70	0.68~0.74
	$C_⊠$	0.85~0.94	0.88~0.98

Table. 4.1.1. Properties of Refrigerants.

	Ammonia	Methyl chloride	R - 12	R - 22
	NH3	CH_3Cl	CCl_2F_2	$CRClF_2$
Evaporating latent heat (-15°C) (Kcal/kg)	313.5	100.4	38.6	52.0
Boiling point (atm.p.) (°C)	-33.3	-23.8	-28.8	-40.8
Evaporating pressure (-15°C) (kg/cm.² abs.)	2.41	1.49	1.86	3.03
Condensing pressure (30°C) (kg/cm.² abs.)	11.9	6.66	7.59	12.27
Specific volum (saturated vapour -15°C) (m^3/kg)	0.509	0.279	0.093	0.078
Critical pressure (kg/cm.² abs.)	116.0	68.1	40.8	50.3
Critical temperature (°C)	133	143	115.5	96
Compression ratio (30°C, -15°C)	4.94	4.48	4.08	4.06
Freezing point (atm.p.) (0°C)	-77.7	-97.8	-158	-160
Refrigeration effect (standard cycle) (Kcal/kg)	269.0	85.4	29.6	40.2
HP per ton (at standard condition)	0.99	0.96	1.00	1.01
Corrosiveness to other metals effect to metals	Corrosive to Cu and Cu alloys	Corrosive, if contains impurities, to Al,	Corrosive, if contains water, to Mg. Al alloys,	The same as that of F-12
Oil miscibility	no	yes	yes	yes
Explosiveness (volume %)	16-25	8.1-17.2	no	no
Inflammability	slight	some	no	no
Toxicity	2	4	6	5
Smell	violent	almost no	no	no

Table. 4.2.1. Characteristics of Saturated Ammonia.

Temp. t C	Pressure (abs.) P kg/cm^2	Specific volume		Specific weight		Enthalpy		Latent heat	Entropy	
		Liquid v' 1/kg	Vapor v'' m^3/kg	Liquid r' kg/1	Vapor r'' kg/m^3	Liquid h' Kcal/kg	Vapor h'' Kcal/kg	r=h''-h' Kcal/kg	Liquid s' Kcal/kg°K	Vapor s'' Kcal/kg°K
-25	1.546	1.4895	0.7712	0.6714	1.297	72.78	393.72	320.94	0.8960	2.1896
-24	1.619	1.4923	0.7386	0.6701	1.354	73.86	394.07	320.22	0.9003	2.1853
-22	1.774	1.4980	0.6782	0.6676	1.474	76.01	394.77	318.76	0.9089	2.1784
-20	1.940	1.5037	0.6236	0.6650	1.604	78.17	395.46	317.29	0.9117	2.1710
-18	2.117	1.5096	0.5742	0.6624	1.742	80.33	396.13	315.80	0.9259	2.1638
-16	2.309	1.5155	0.5295	0.6598	1.889	82.50	396.79	314.29	0.9343	2.1567
-15	2.410	1.5185	0.5087	0.6585	1.966	83.59	397.12	313.53	0.9385	2.1532
-14	2.514	1.5215	0.4889	0.6572	2.046	84.68	397.44	312.76	0.9427	2.1498
-12	2.732	1.5276	0.4520	0.6546	2.213	86.85	398.06	311.21	0.9511	2.1430
-10	2.966	1.5338	0.4184	0.6520	2.390	89.03	398.67	309.64	0.9593	2.1362
- 9	3.089	1.5369	0.4028	0.6503	2.483	90.12	398.97	308.85	0.9634	2.1329
- 8	3.216	1.5400	0.3878	0.6497	2.579	91.81	399.27	308.05	0.9675	2.1296
- 7	3.347	1.5432	0.3735	0.6480	2.678	92.30	399.56	307.25	0.9716	2.1263
- 6	3.418	1.5464	0.3599	0.6467	2.779	93.40	399.85	306.45	0.9757	2.1231
- 5	3.619	1.5469	0.3469	0.6453	2.883	94.50	400.14	305.64	0.9798	2.1199
- 4	3.761	1.5528	0.3344	0.6440	2.991	95.59	400.42	304.83	0.9839	2.1167
- 3	3.908	1.5561	0.3225	0.6426	3.102	96.96	400.70	304.01	0.9880	2.1135
- 2	4.060	1.5594	0.3111	0.6413	3.216	97.79	400.98	303.19	0.9920	1.1103
- 1	4.217	1.5627	0.3002	0.6399	3.332	98.89	401.25	302.36	0.9960	2.1072
0	4.379	1.5660	0.2897	0.6386	3.452	100.00	401.52	301.52	1.0000	2.1041
+ 1	4.545	1.5694	0.2797	0.6372	3.576	101.10	401.78	300.68	1.0040	2.1010
+ 2	4.716	1.5727	0.2700	0.6358	3.703	102.21	402.04	299.84	1.0080	1.0979
+ 3	4.892	1.5761	0.2608	0.6345	3.834	103.32	402.30	298.99	1.0120	2.0949
+ 4	5.073	1.5796	0.2520	0.6331	3.969	104.43	402.55	298.13	1.0160	2.0919
+ 5	5.259	1.5831	0.2435	0.6317	4.108	105.54	402.80	297.26	1.0200	2.0889
+ 6	5.450	1.5866	0.2353	0.6303	4.250	106.65	403.04	296.39	1.0240	2.0859
+ 7	5.647	1.5901	0.2275	0.6289	4.369	107.76	403.27	295.51	1.0280	2.0829
+ 8	5.849	1.5936	0.2200	0.6275	4.546	108.87	403.50	294.63	1.0319	2.0799
+ 9	6.057	1.5972	0.2128	0.6261	4.700	109.99	403.73	293.74	1.0358	2.0770
+10	6,271	1.6008	0.2058	0.6247	4.859	111.11	403.95	292.84	1.0397	2.0741
+12	6.715	1.6081	0.1927	0.6218	5.189	113.35	404.38	291.03	1.0475	2.0683
+14	7,183	1.6156	0.1806	0.6190	5.537	115.59	404.79	289.20	1.0553	2.0626
+15	7.427	1.6193	0.1749	0.6175	5.718	116.72	404.99	288.27	1.0592	2.0598
+16	7,677	1.6231	0.1694	0.6161	5.904	117.85	405.19	287.34	1.0631	2.0570
+18	8.169	1.6308	0.1951	0.6132	6.289	120.11	405.57	285.46	1.0709	2.0514
+20	8.714	1.6386	0.1494	0.6103	6.594	122.38	405.93	283.55	1.0785	2.0459
+22	9.314	1.6466	0.1405	0.6073	7.119	124.66	406.27	281.61	1.0862	2.0405
+24	9.915	1.6546	0.1322	0.6043	7.564	129.64	406.59	279.65	1.0938	2.0351
+25	10,225	1.6588	0.1283	0.6028	7.795	128.09	406.75	278.66	1.0976	2.0324
+26	10.544	1.6630	0.1245	0.6013	8.031	129.24	406.89	277.66	1.1014	2.0297
+28	11.204	1.6714	0.1174	0.5983	8.521	130.54	407.17	275.64	1.1090	2.0243
+30	11.895	1.6800	0.1107	0.5952	9.034	133.84	407.43	273.59	1.1165	2.0191

Appendix 2

(Figures)

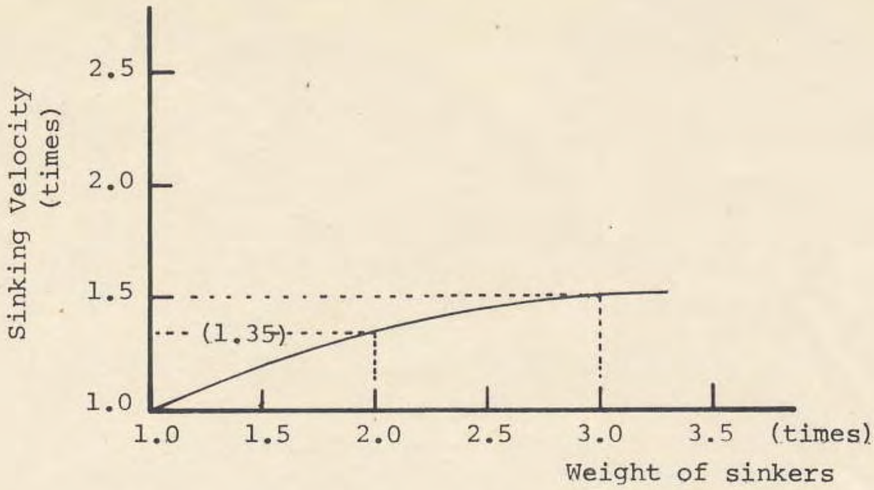


Fig. 1.2.1. Relationship between the sinking velocity and number of sinker.

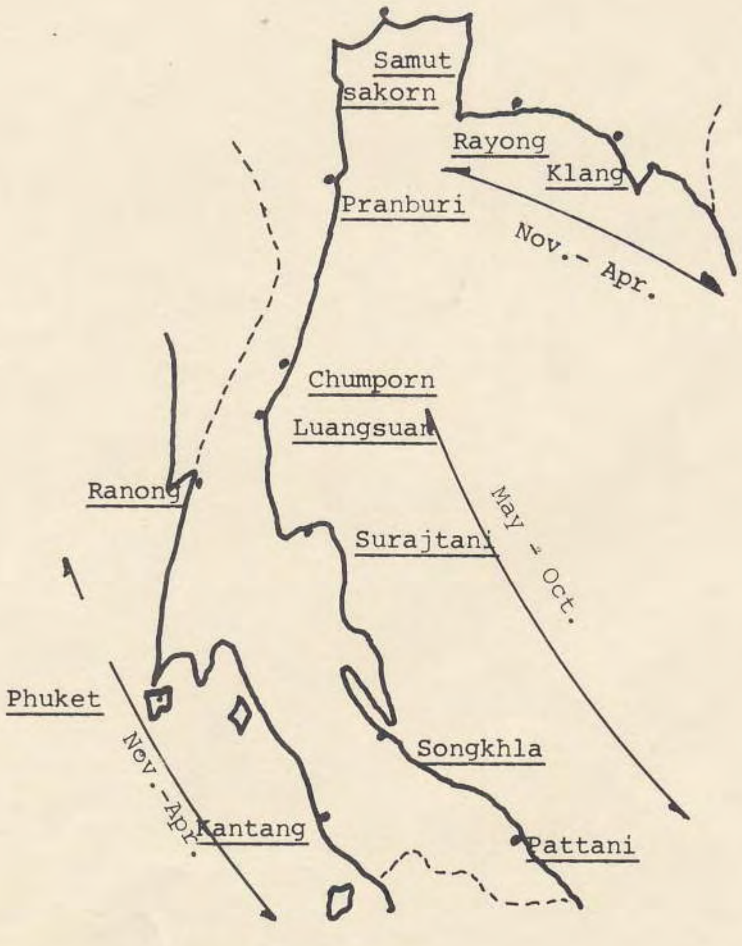


Fig. 1.2. 2. Major Fishing bases for Purse Seiners and seasons of operation.

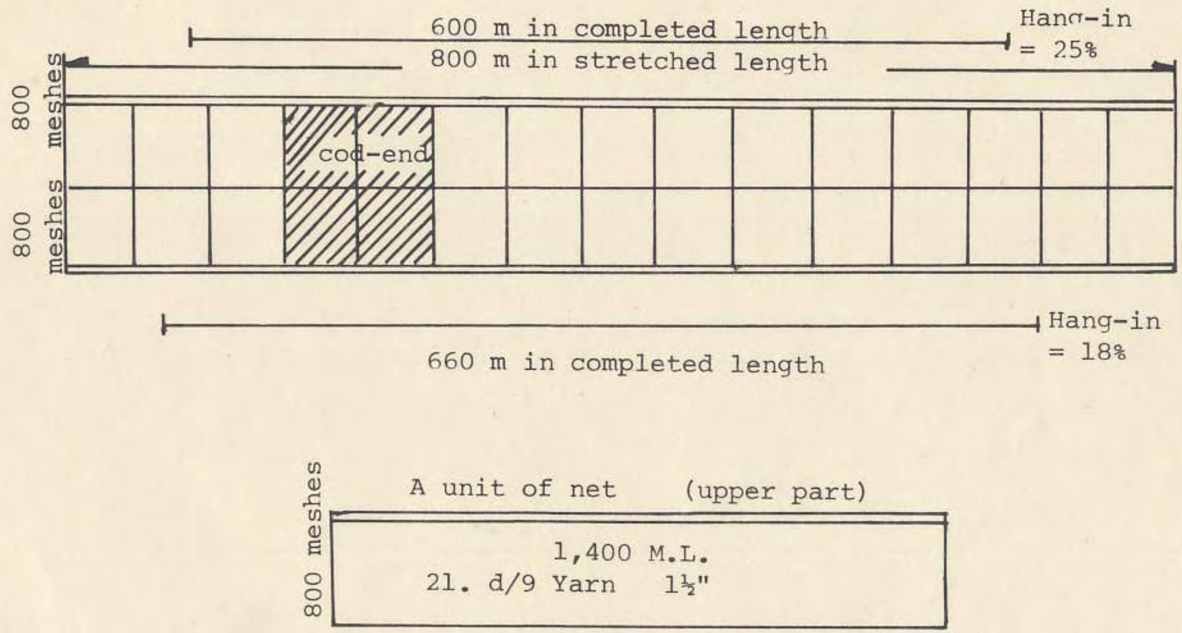


Fig. 1.2.3. Design diagram of bonito purse seine.

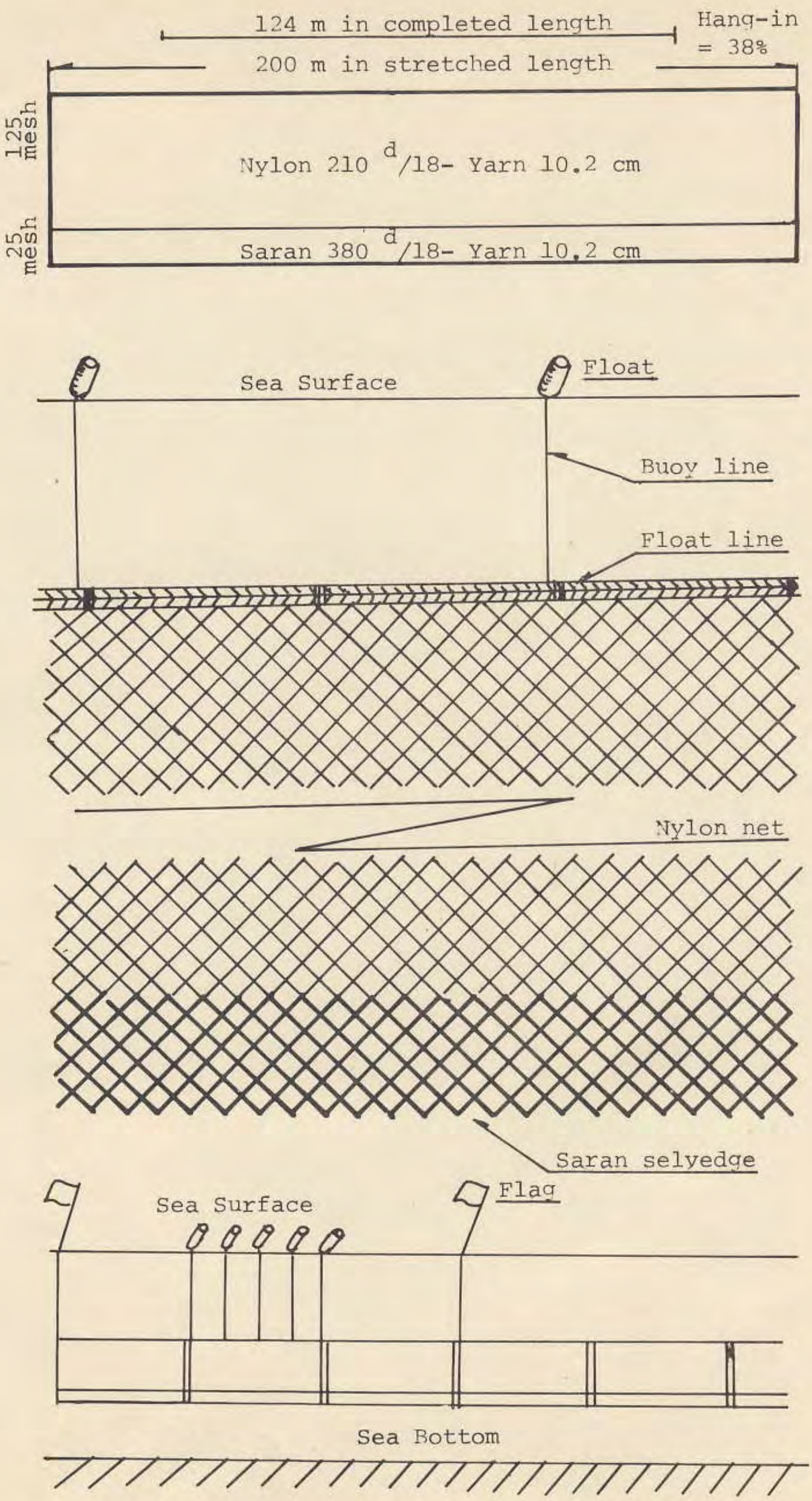
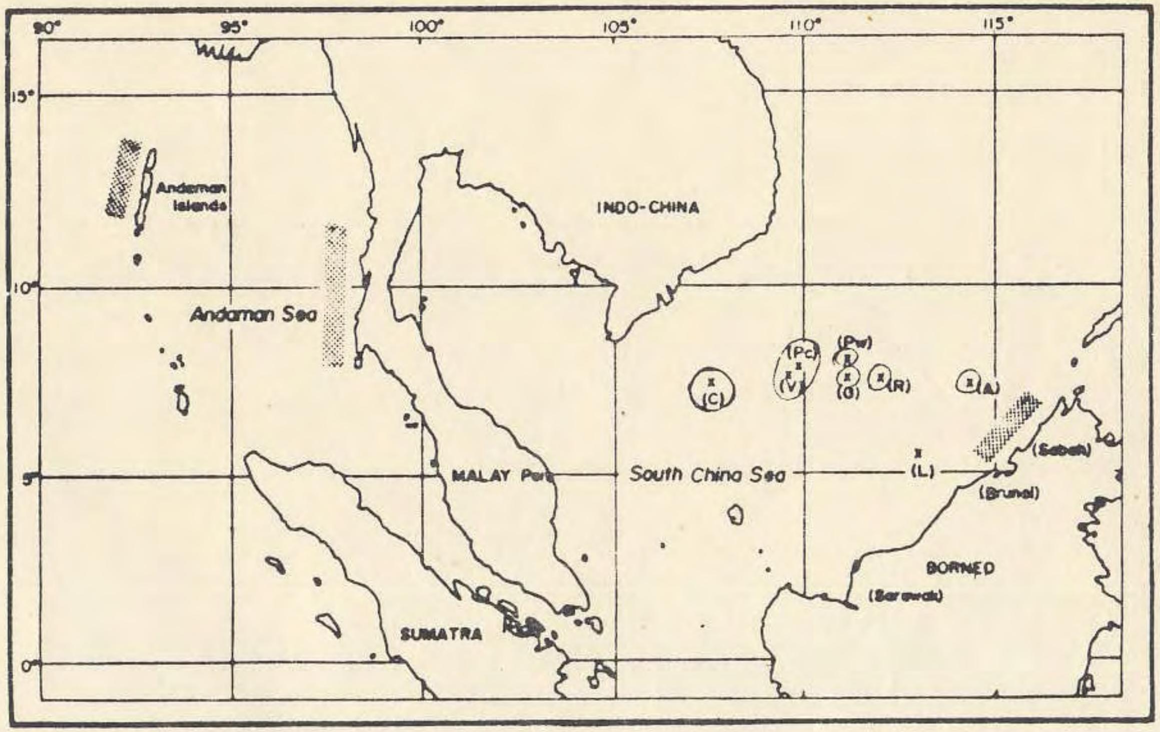


Fig. 1.3.1. Diagrams of spanish mackerel gill net.



---- Fishing ground

Fig. 1.4.1. Promising fishing grounds for vertical long lining.

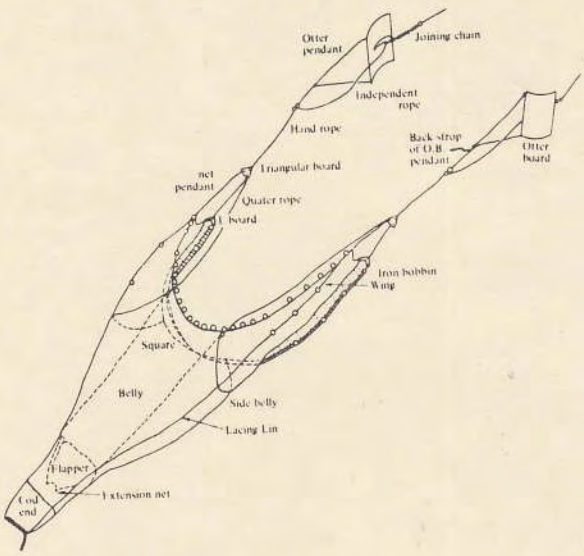


Fig. 1.5.1. General arrangement of trawl gear.

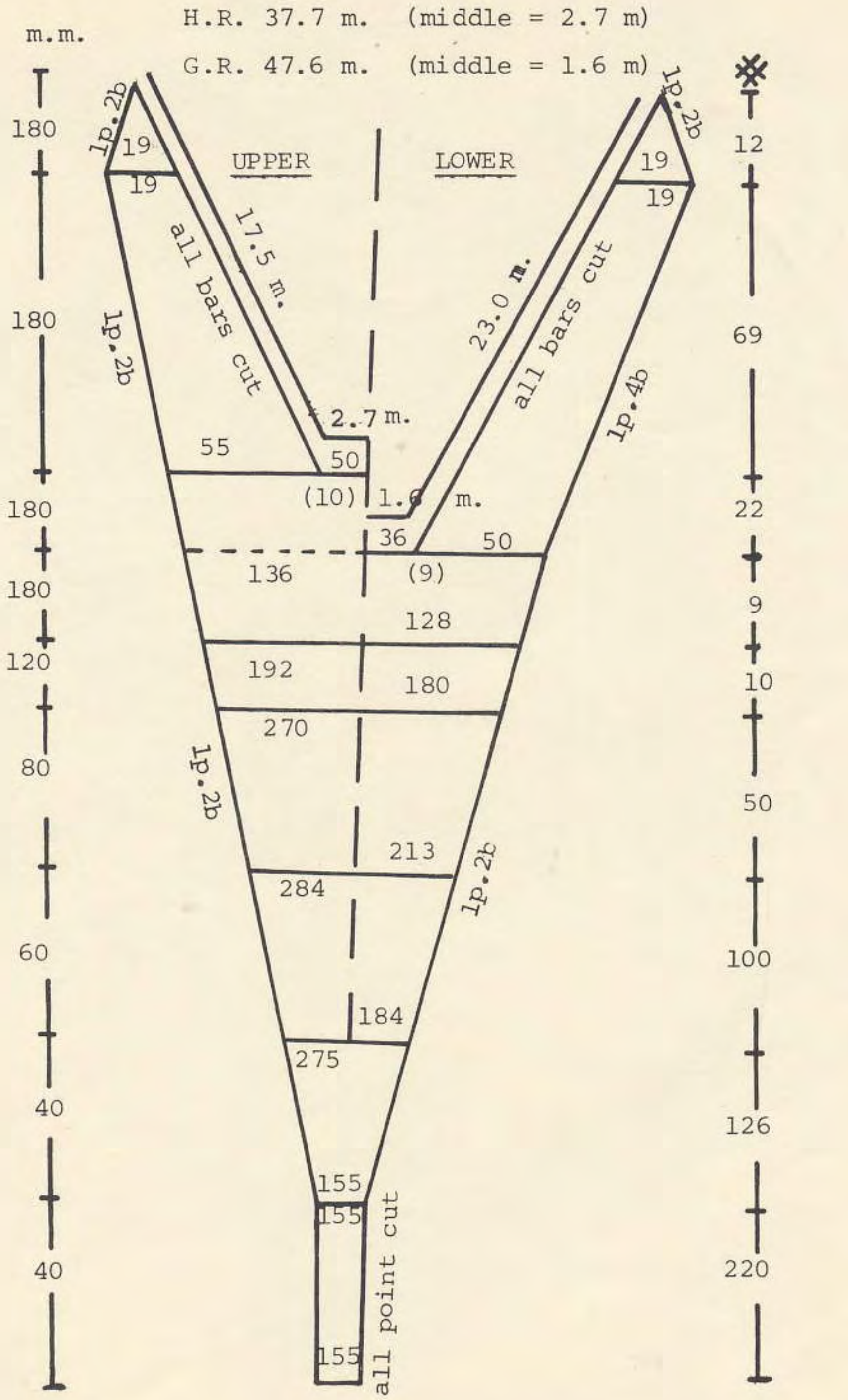


Fig.1.5.2. Design diagram of two-seamed trawl net.

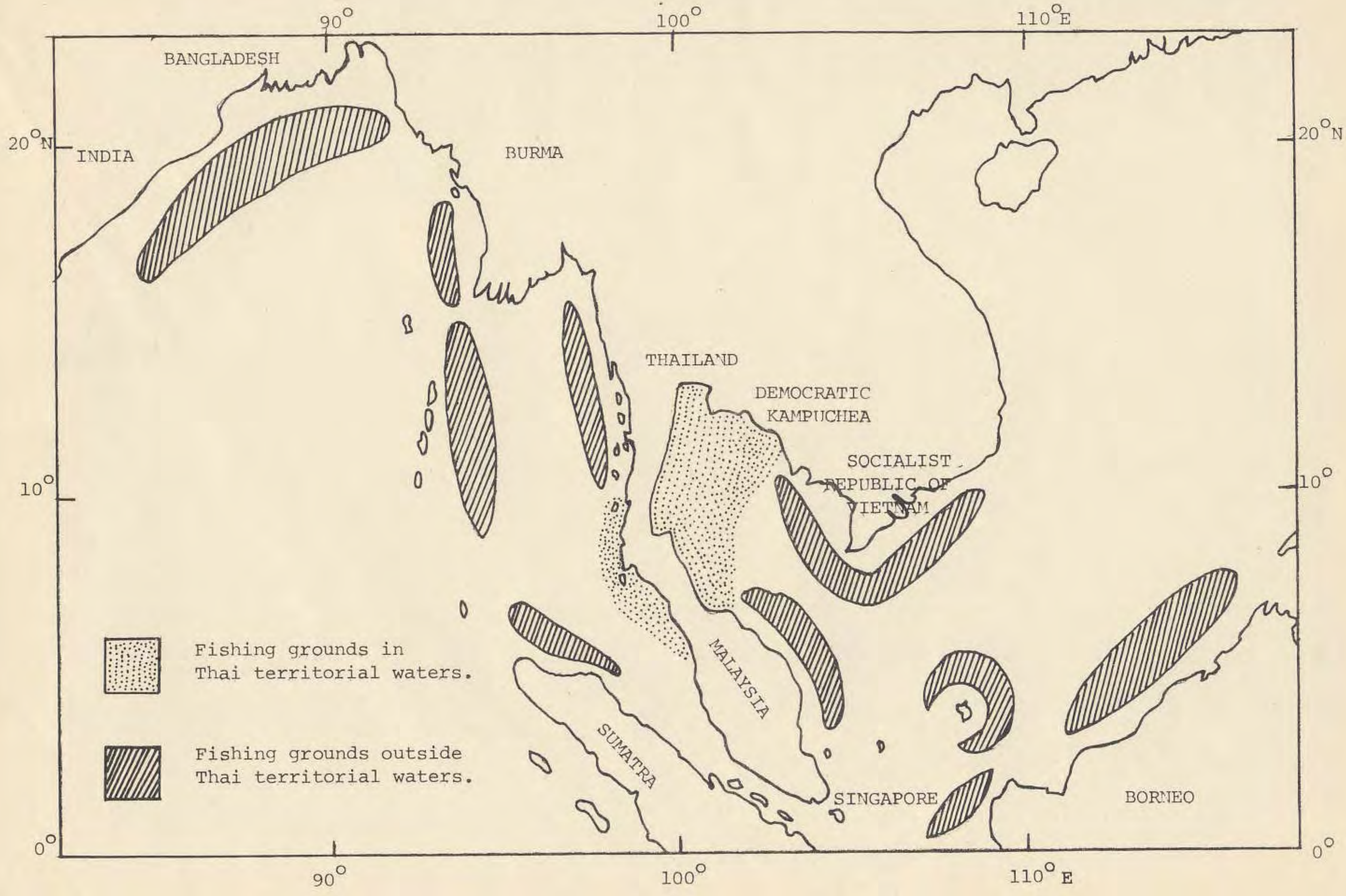


Fig. 1.5.3. Fishing grounds of Thai trawlers

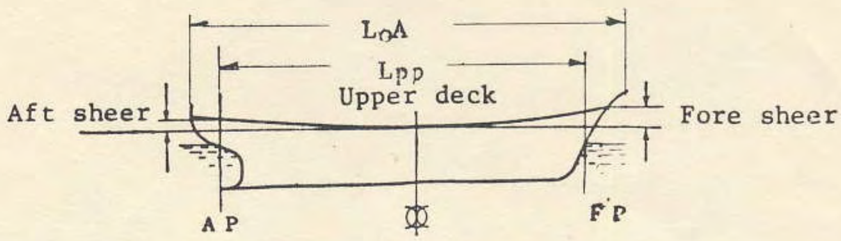


Fig. 2.1.1. Longitudinal Cross Section of Fishing Boat.

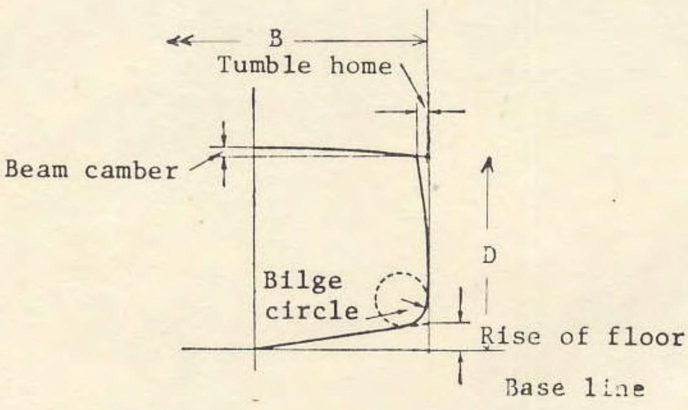


Fig. 2.1.2. Lateral Cross Section of Fishing Boat.

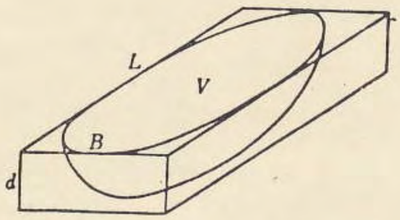


Fig. 2.1.3(a). Principal Dimensions for obtaining Block Coefficient.

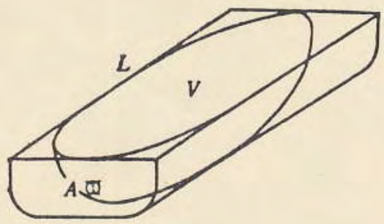


Fig. 2.1.3(b). Principal Dimensions for obtaining Prismatic Coefficient.

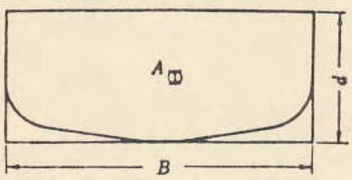


Fig. 2.1.3(c). Principal Dimensions for obtaining Midship Coefficient.

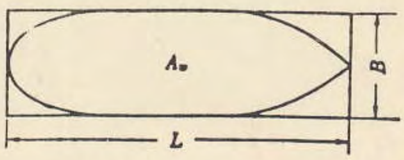
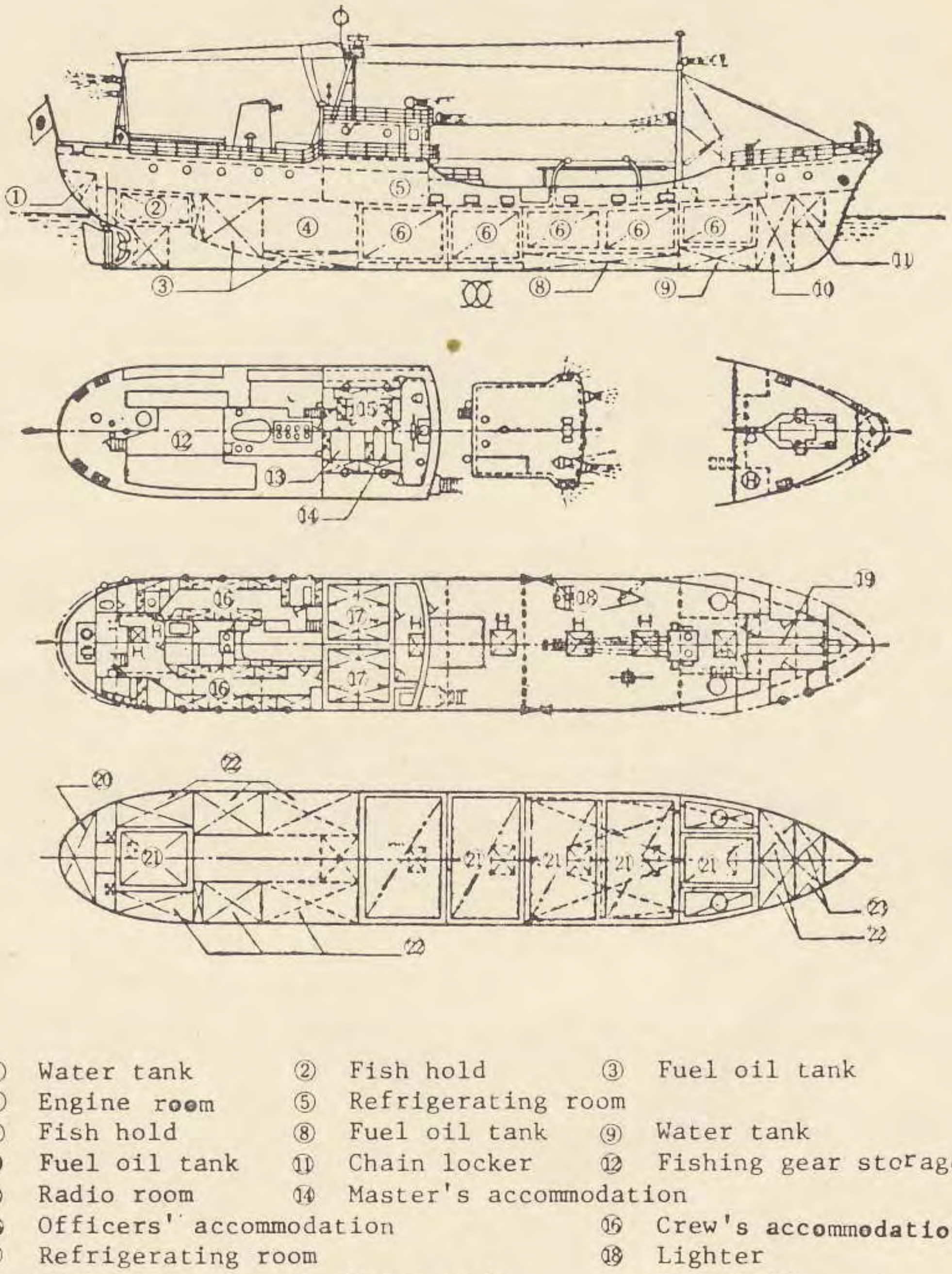


Fig. 2.1.3(d). Principal Dimensions for obtaining Water Plan Coefficient.



① Water tank	② Fish hold	③ Fuel oil tank
④ Engine room	⑤ Refrigerating room	
⑥ Fish hold	⑧ Fuel oil tank	⑨ Water tank
⑩ Fuel oil tank	⑪ Chain locker	⑫ Fishing gear storage
⑬ Radio room	⑭ Master's accommodation	
⑮ Officers' accommodation		⑯ Crew's accommodation
⑰ Refrigerating room		⑱ Lighter
⑲ Deck store	⑳ Water tank	㉑ Fish hold
㉒ Fuel oil tank	㉓ Chain locker	

Fig. 2.2.1. General Arrangement of Fishing Boat.

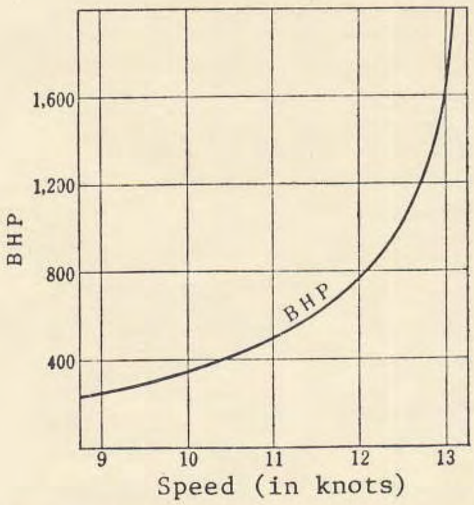


Fig. 2.2.2. Speed vs. Horsepower Curve.

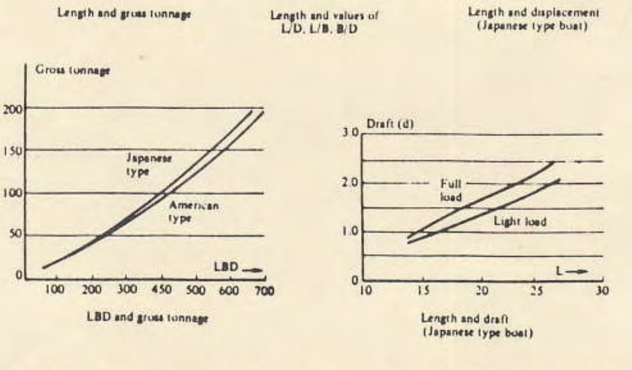


Fig. 2.3.1. Characteristic Index of Purse Seiner.

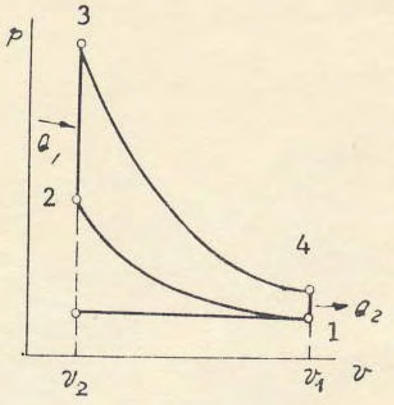


Fig. 3.3.1. Otto Cycle of Internal Combustion Engine.

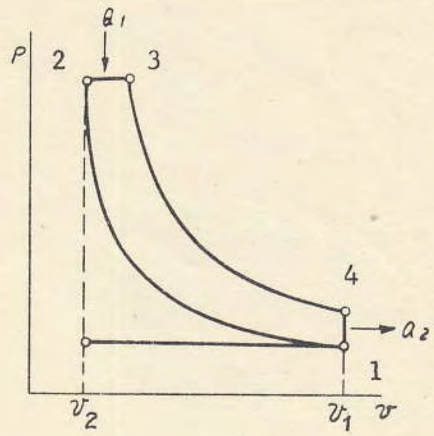


Fig. 3.3.2. Diesel Cycle of Internal Combustion Engine.

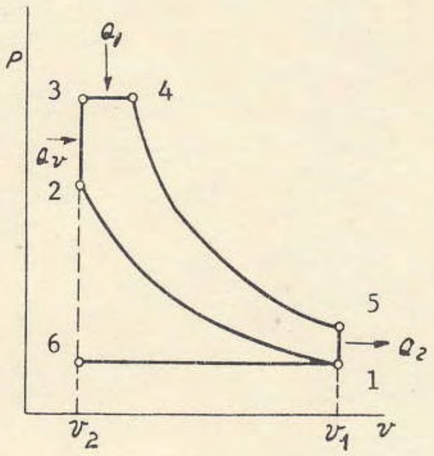
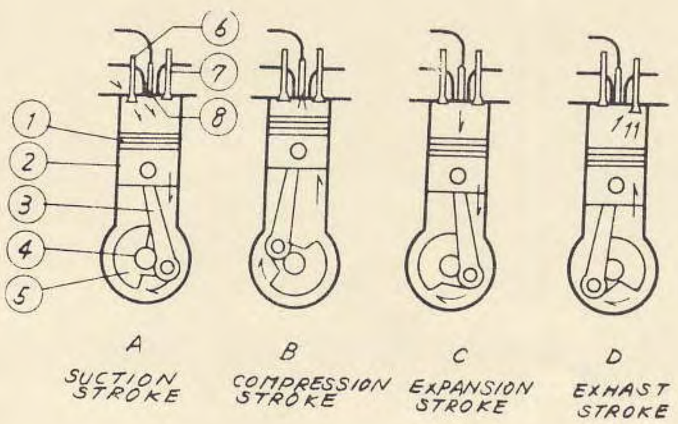


Fig. 3.3.3. Sabathe Cycle of Internal Combustion Engine.



1. Piston
2. Cylinder
3. Connecting rod
4. Crank shaft
5. Balancing weight
6. Suction valve
7. Exhaust valve
8. Fuel valve

Fig. 3.4.1. Strokes of Four-stroke-cycle Diesel Engine.

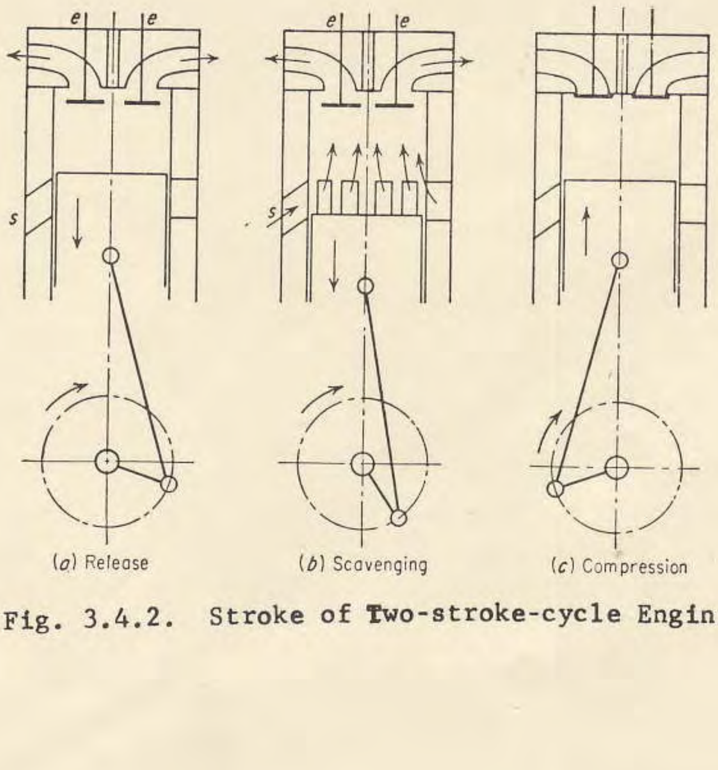


Fig. 3.4.2. Stroke of Two-stroke-cycle Engine.

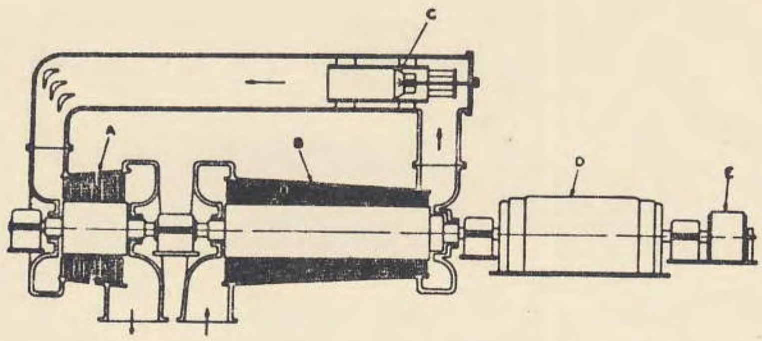
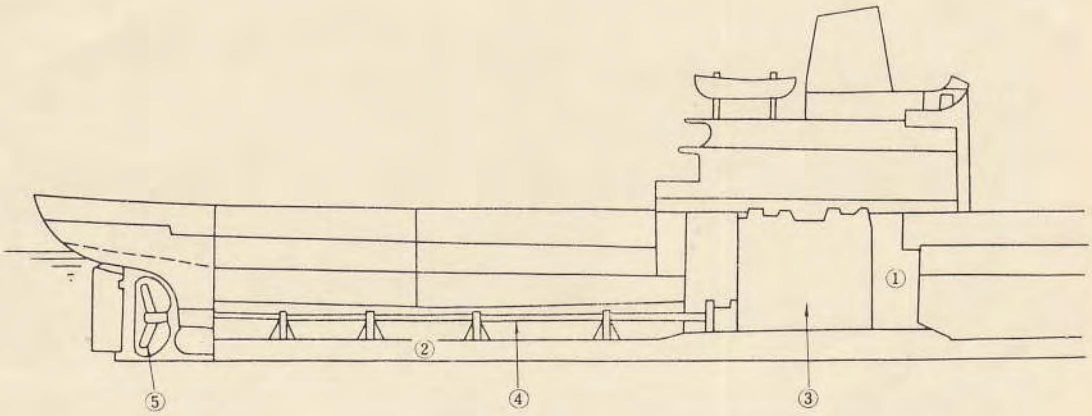


Fig. 3.5.1. Schematic Representation of Combustion Turbine.



(1) Engine room (3) Main engine (5) Propeller

(2) Shaft tunnel (4) Shafting

Fig. 3.6.1. Schematic Representation of Propulsion System.

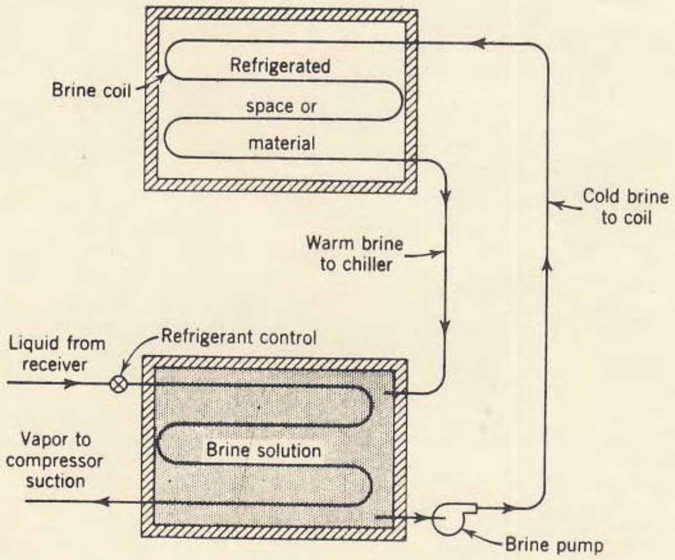


Fig. 4.1.1. Indirect Refrigeration System.

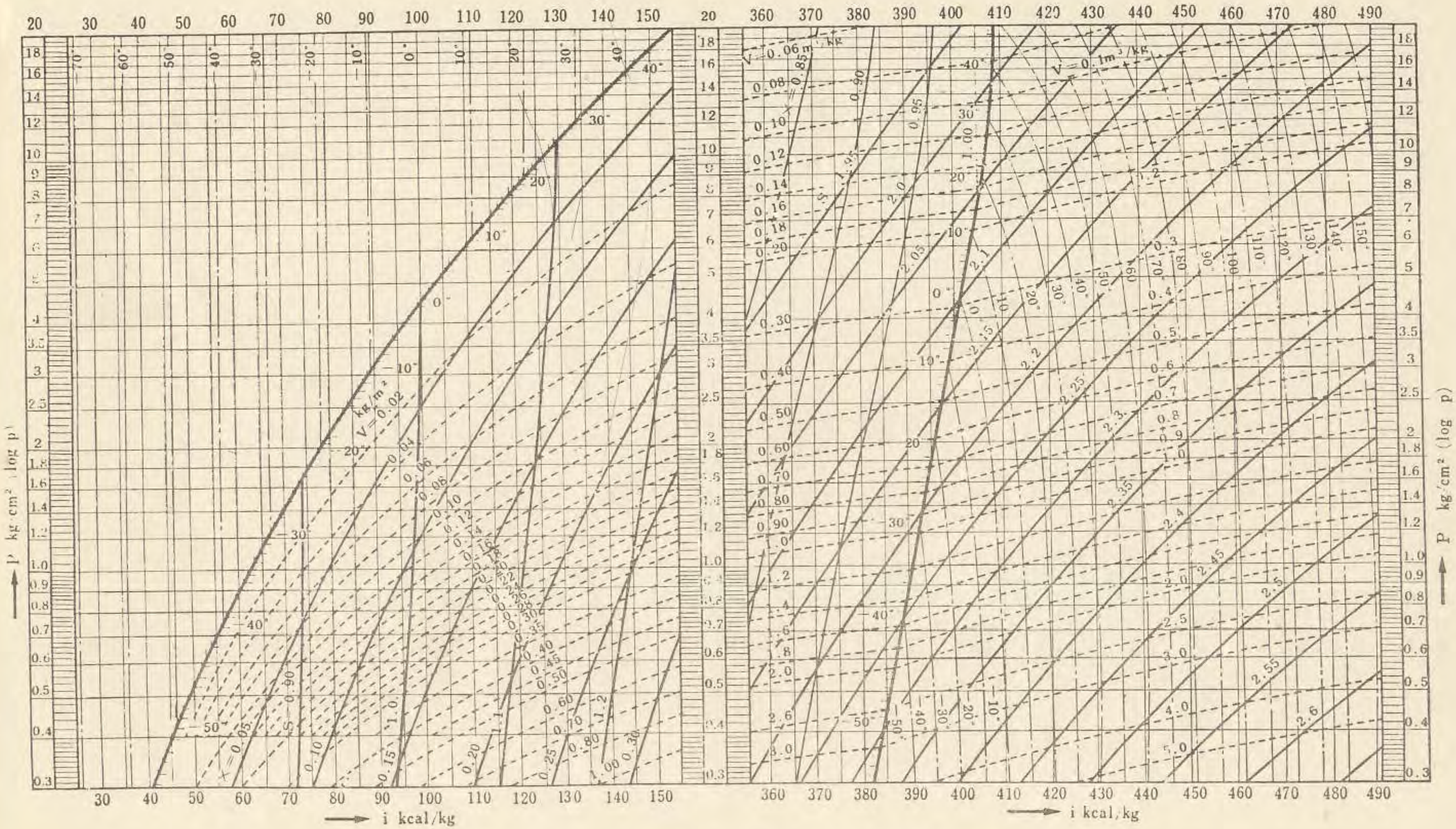


Fig. 4.2.1. Ammonia Pressure vs. Enthalpy Diagram.

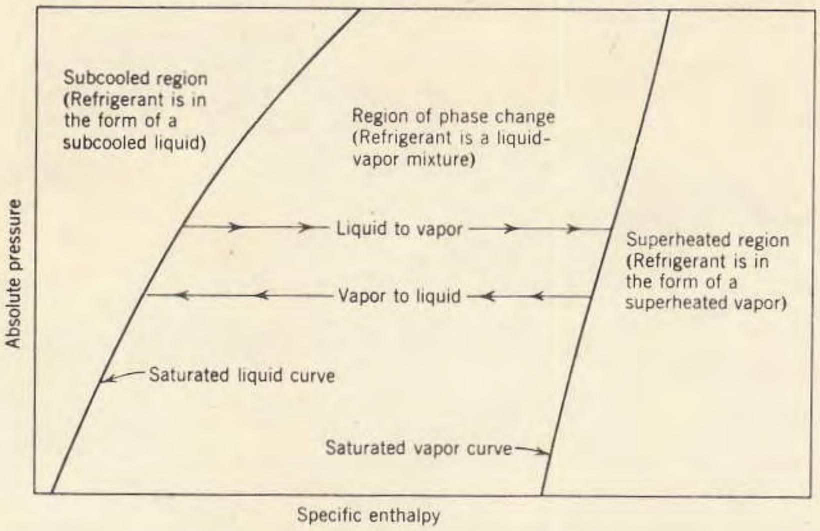


Fig. 4.2.2. Skelton Ph Chart illustrating Three Regions and Direction of Phase Changing.

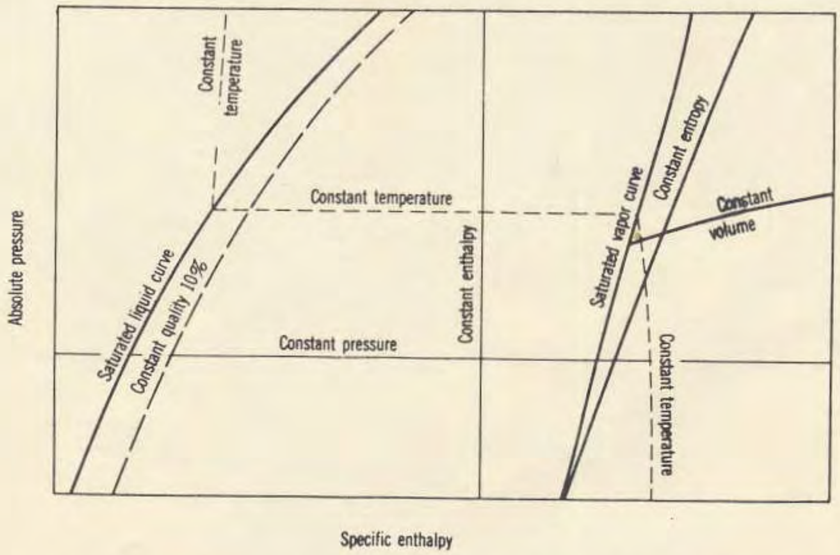


Fig. 4.2.3. Skelton Ph Chart showing Paths of Constant Pressure, Constant Temperature, Constant Volume, Constant Quality, Constant Enthalpy, and Constant Entropy.

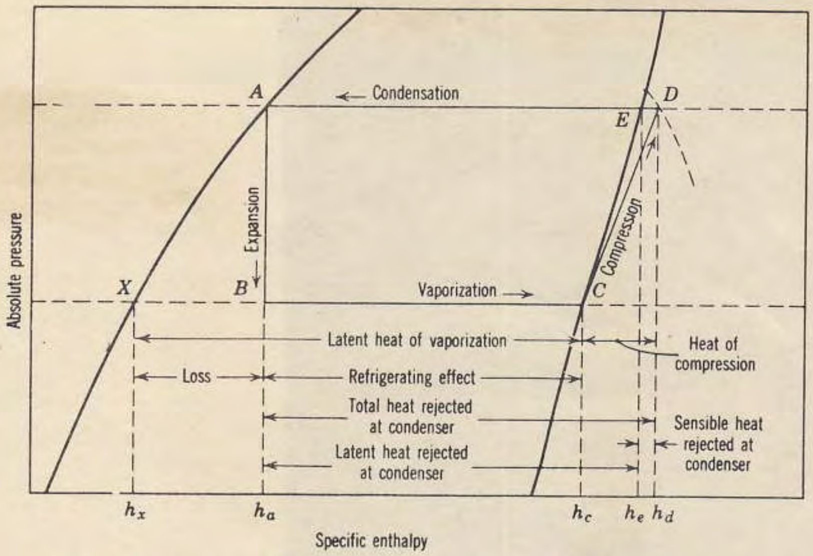


Fig. 4.2.4. Pressure vs. Enthalpy Diagram of Simple Saturated Cycle.

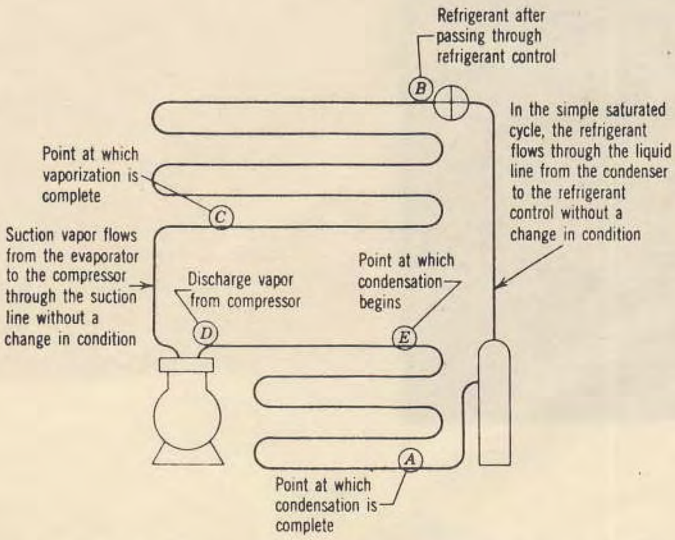


Fig. 4.2.5. Flow Diagram of Simple Saturated Cycle.