TUG DESIGN

F. WESTHORP
F.R.I.N.A. ; A.S.T.C.

Bearing in mind that you gentlemen listening are all professionally engaged in the design and construction of ships, I do not propose to weary you by repeating matters of common shipbuilding knowledge. Nor do I propose to try and teach you Naval Architecture It is my intention to discuss in fairly general terms matters which contrubute to the making of a good tug - to deal rather with the philosophy of the design than with the actual design process, with the intent that, if you are called upon to act in the generation of a set of requirements for a new tug, this paper may, perhaps, be of some assistance to you. It is in this hope that it is offered for your consideration.

It must be appreciated that much of the material which I proposed to put before you is general in its application to all types of tugs - it will be necessary for you to keep this in mind as I do not propose to make the paper unduly long by repetition.

Caldwell, in his book on tug design opens with the observation that "The function of every tug is to tow" and sight of this feature is frequently lost during the process of stating basic design parameters. This statement forms an excellent point of departure for our discussion.

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Since tugs are required to perform their function under widely varying circumstances these may be used as a basis of classification of types - and we shall see the effect of these varying circumstances upon overall design as we proceed. Tugs, then, fall into three main classes:-

(1) Harbour Tugs.

(2) Coastal and Estuary Tugs.

(3) Ocean Going Tugs.

It must be remembered that the term "Tug" includes a "pusher type vessel," and these are now coming very much into prominence throughout the world. Hence to each of our three main types we may add sub types

(a) "Pulling" and (b) "Pushing".

In addition to these basic performance classes, tugs are frequently required to fulfil one or more of three other tasks - these are

(f) Fire-Fighting.

(s) Salvage.

(w) Water carrying.

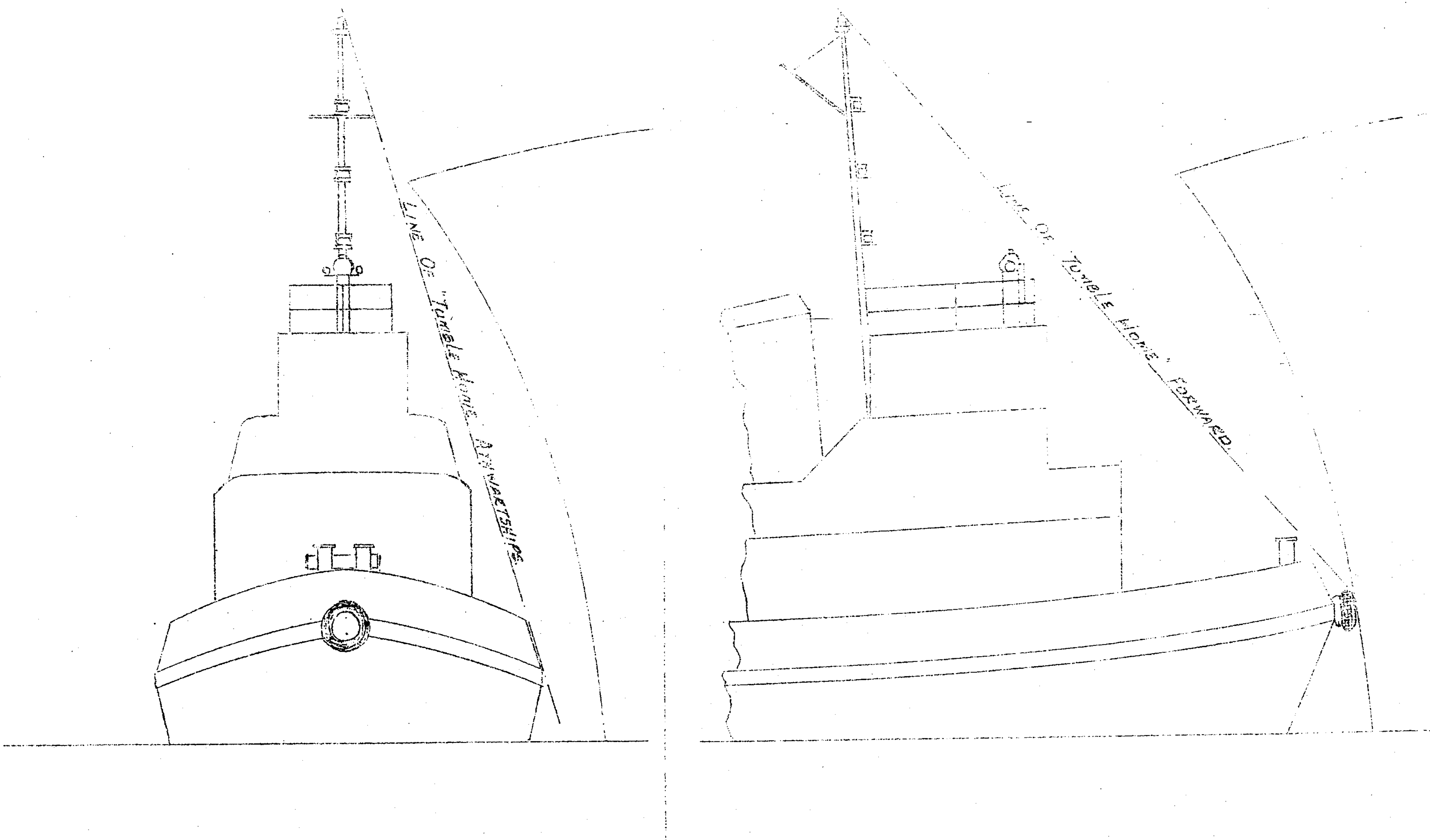
We shall dicuss these points later.

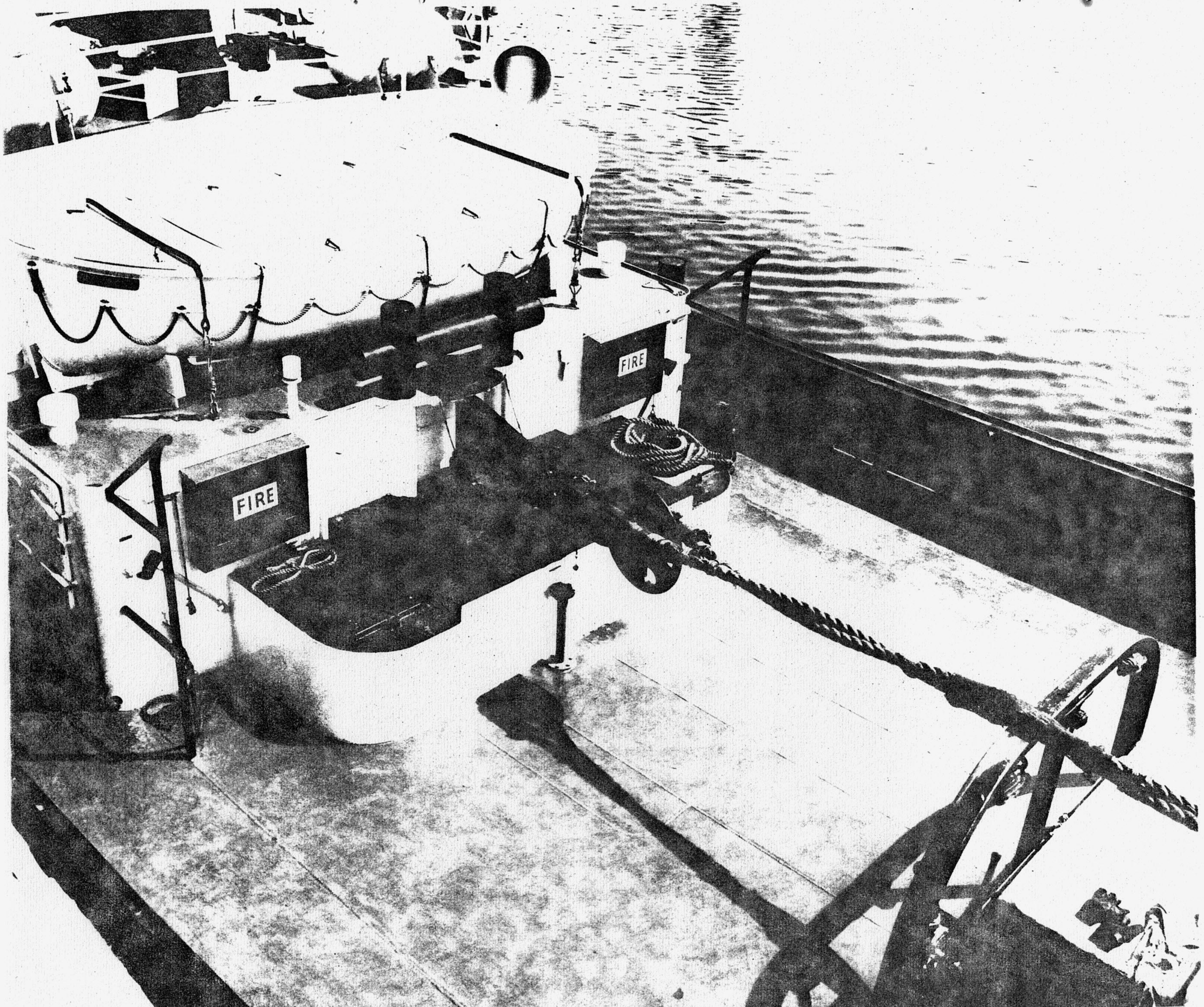
There are some basic features common to all tugs which may be discussed at the outset, before considering our various types in detail.

The nature of a tug's duties bring her into close proximity with other ships and marine structures at frequent intervals. It follows that contact, and sometimes violent contact, is inevitable. The tug must, therefore, be sufficiently strong both generally and locally to accept this punishment over long periods of time, but yet not so strong that she invariably does more damage than she sustains. Good fendering is essential all

"TUMBLE HOME"

FIG 2.




FIRE
FIRE

F. WESTHORP M.R.I.N.A. A.S.T.C. NAVAL ARCH

8 McPHERSON ST., CLAPHAM. STH. AUST. 5062 PH.

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Tchebycheff's Body Section

60'-0" WL - 7 ord. Rule

SCALE	½" = 1'	DATE	10.6.72	DRG. No

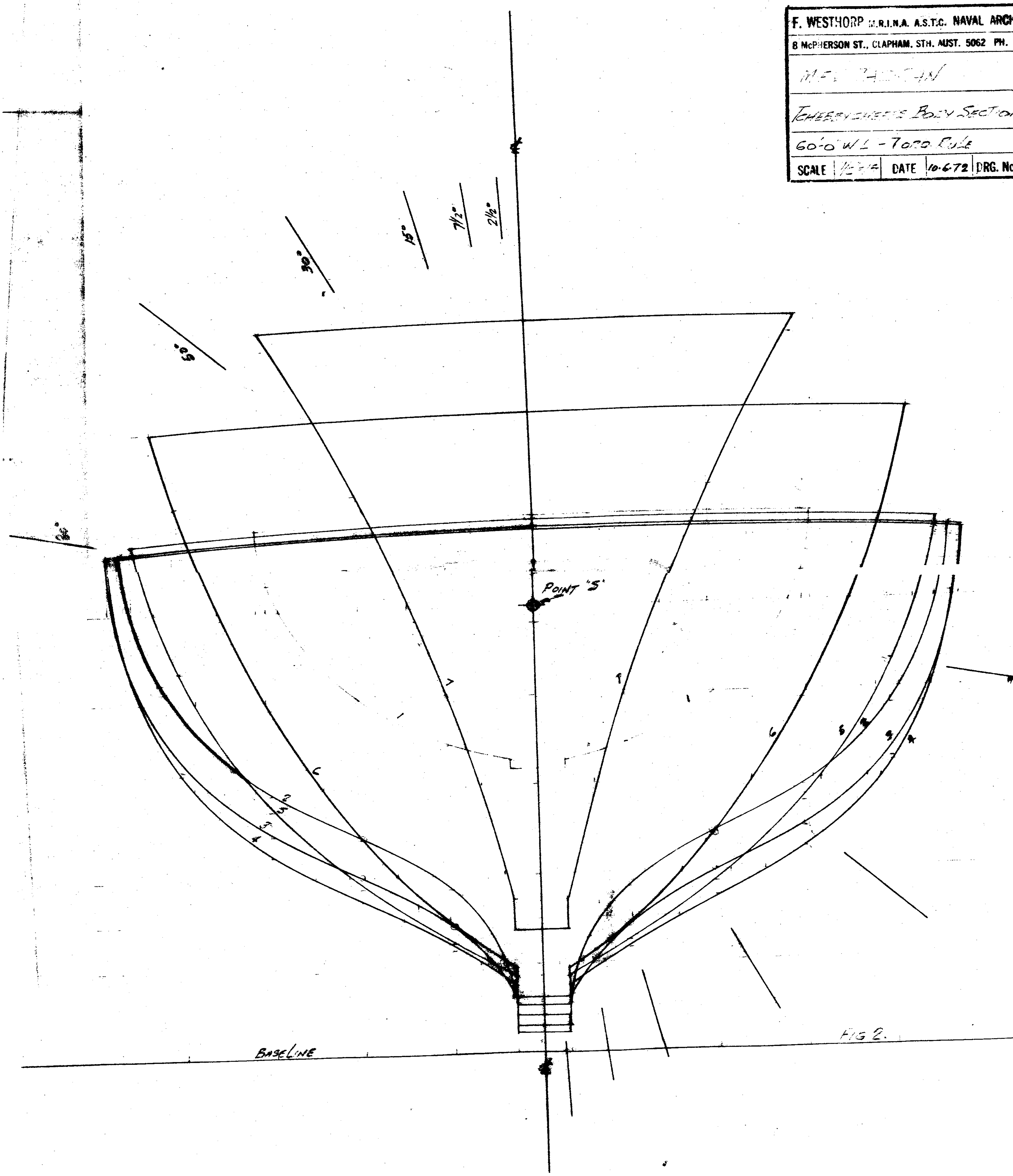
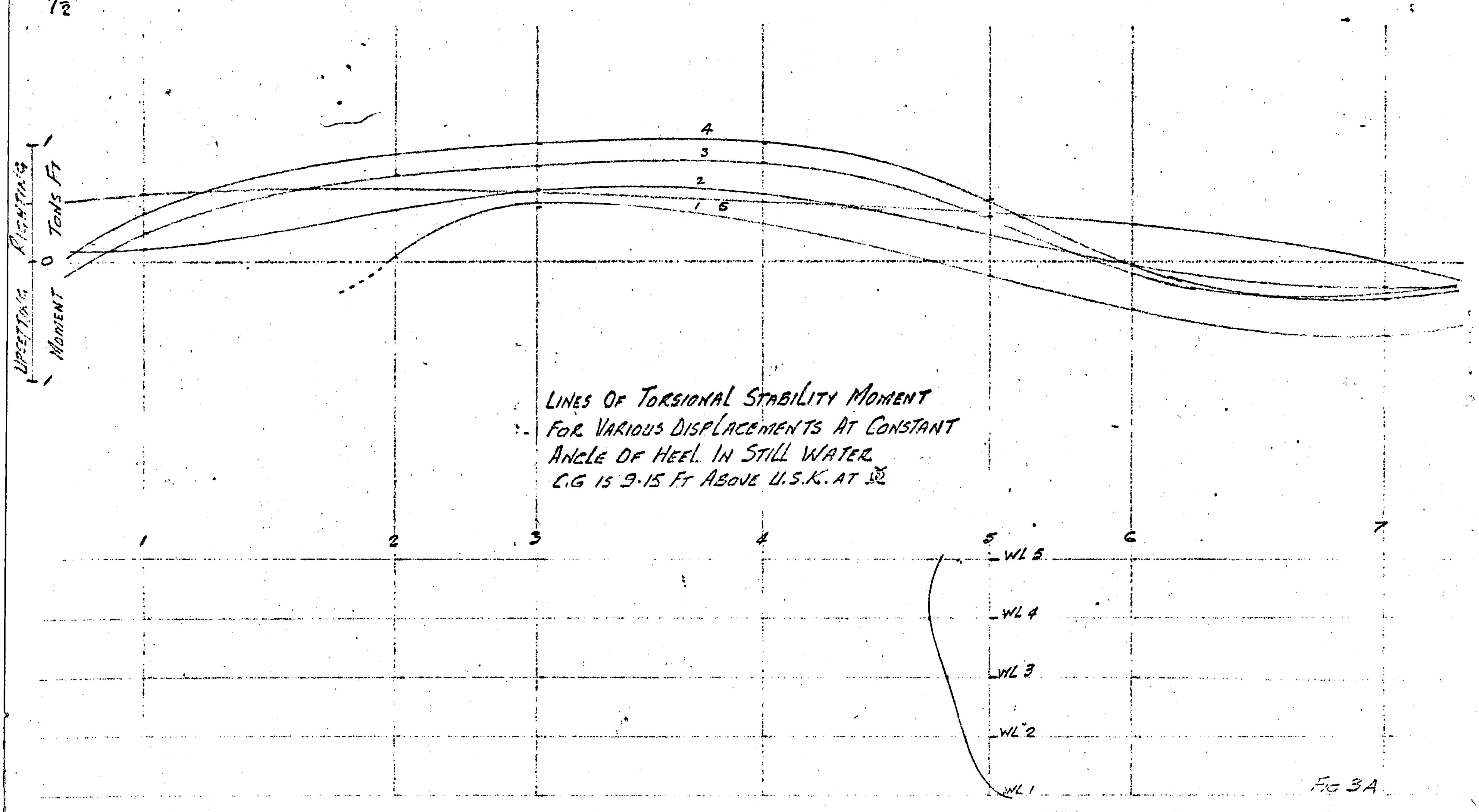
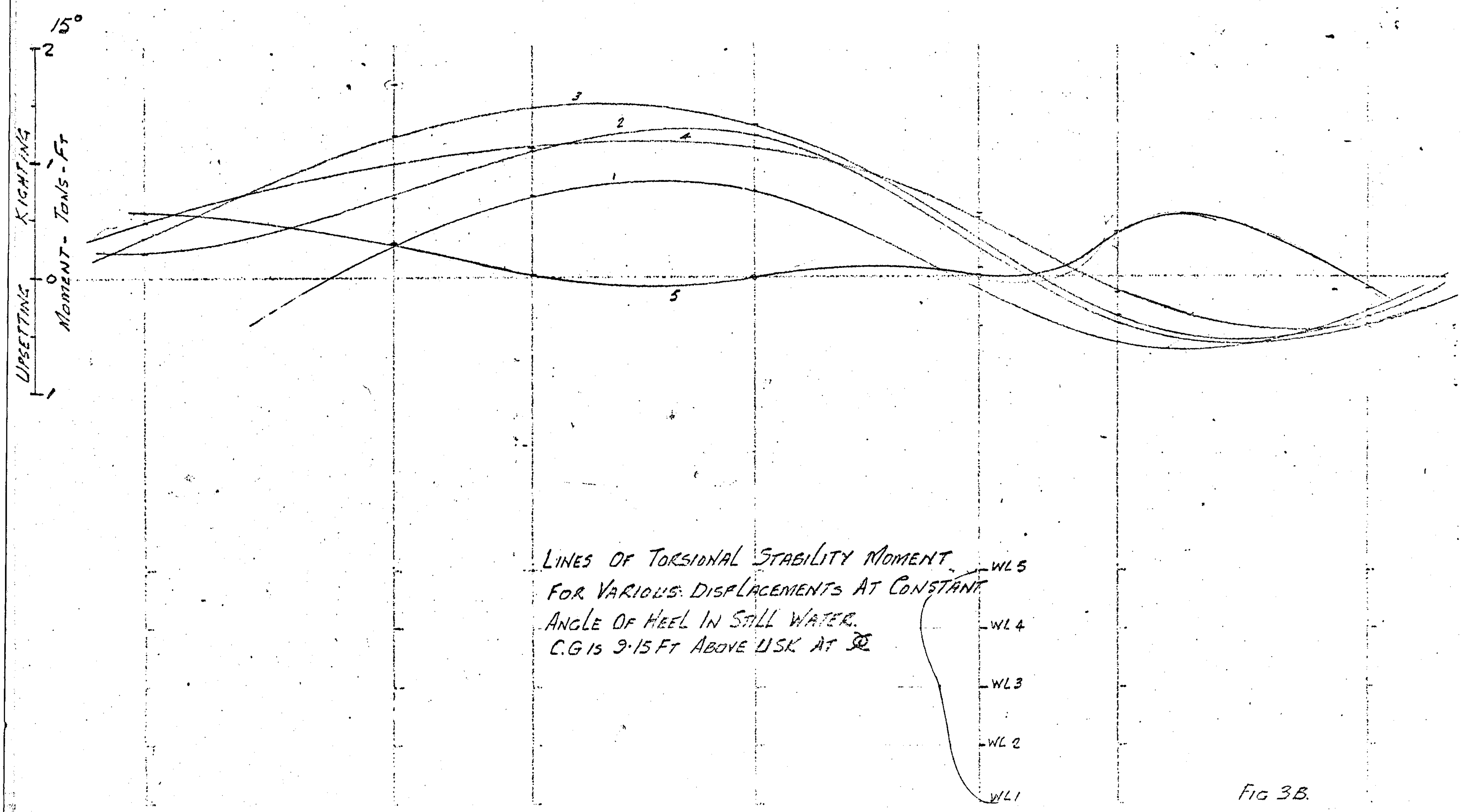


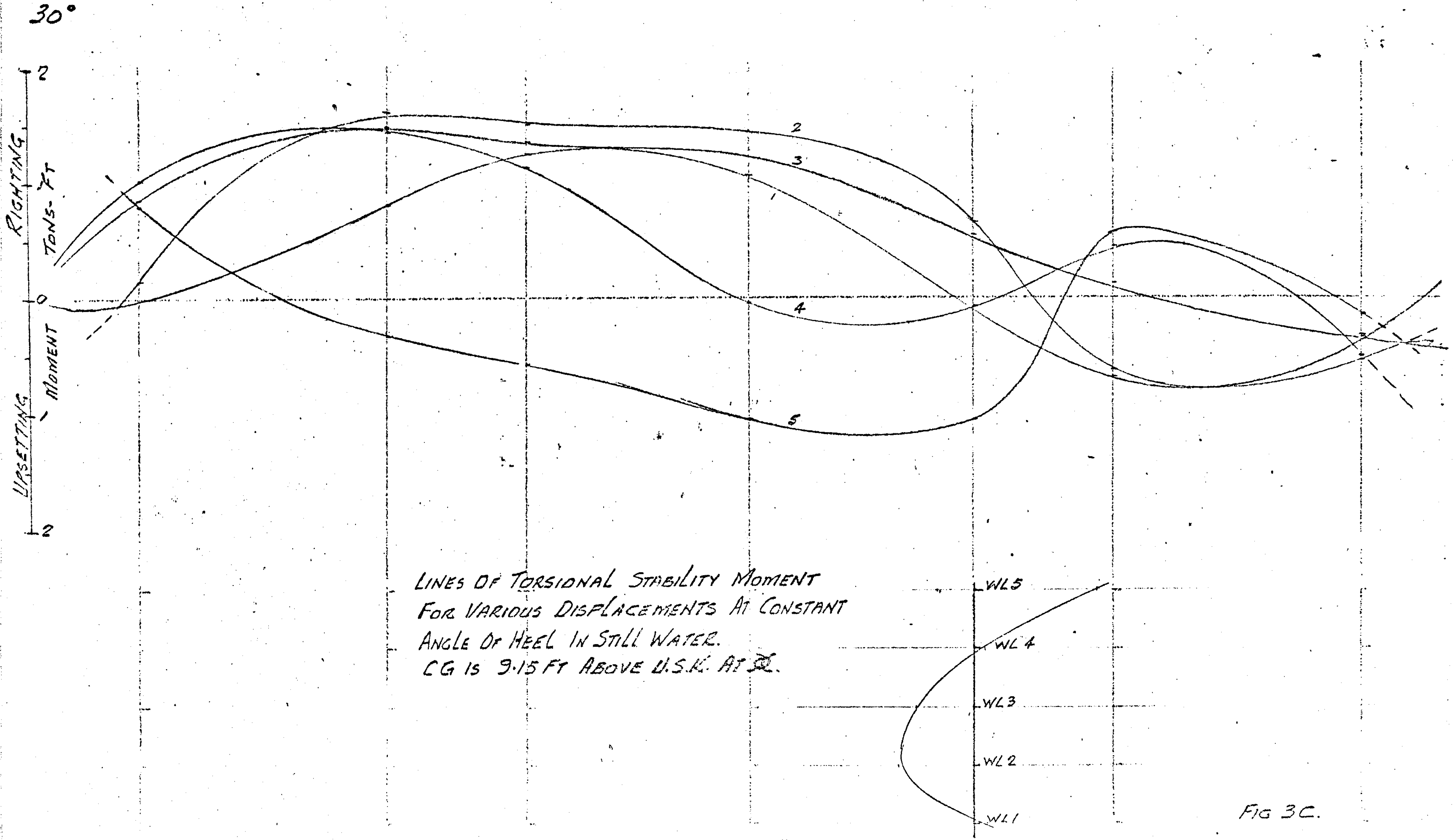
FIG 2.


7½°
RIGHTING
UPSETTING
TONS FT
MOMENT
1
0
1
4
3
2
1
5
LINES OF TORSIONAL STABILITY MOMENT
FOR VARIOUS DISPLACEMENTS AT CONSTANT
ANGLE OF HEEL IN STILL WATER
C.G IS 9.15 FT ABOVE U.S.K. AT 㐅
1
2
3
4
5
6
7
WL 5
WL 4
WL 3
WL 2
WL 1
FIG 3A



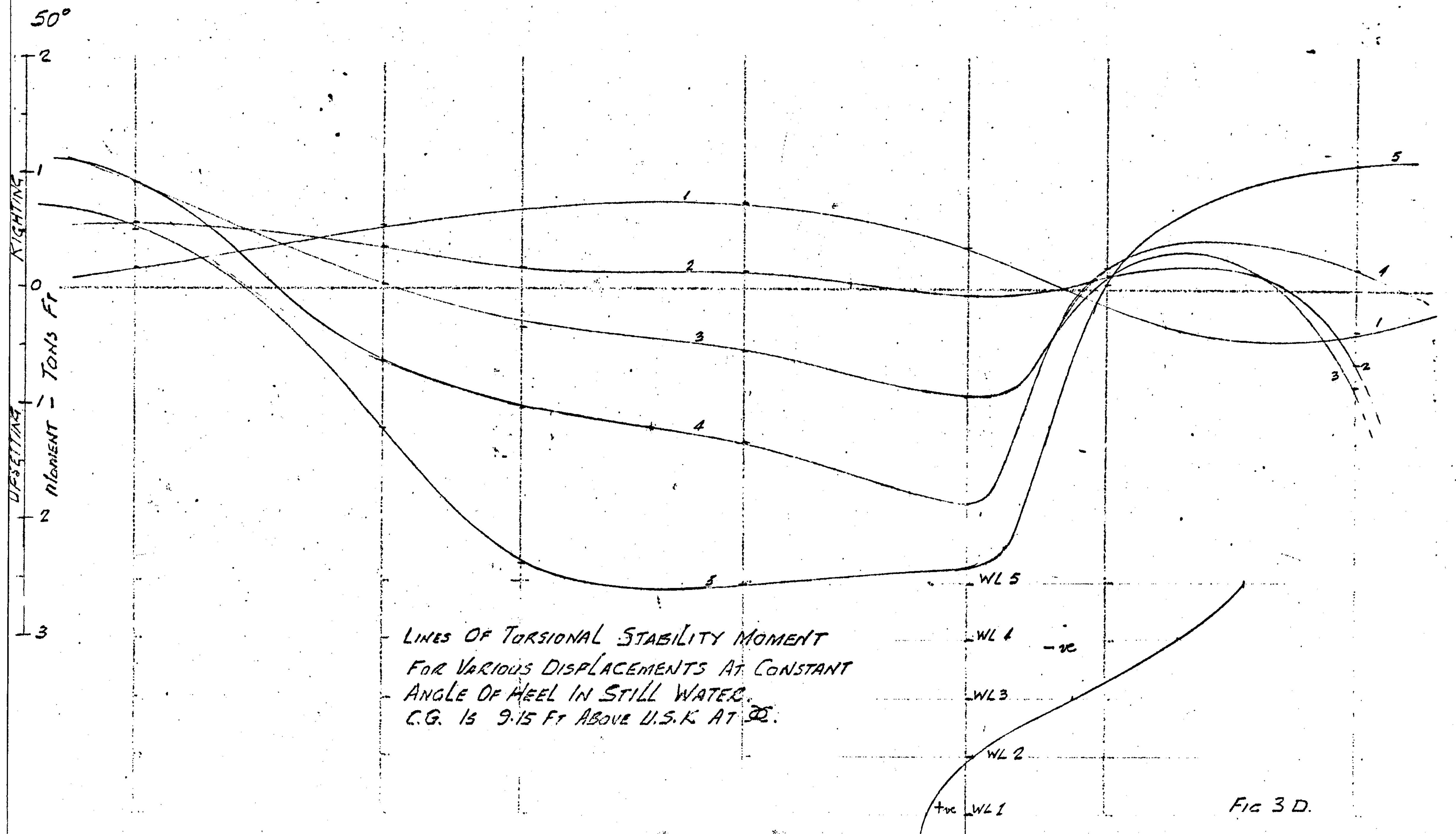
Lines Of Torsional Stability Moment
For Various Displacements At Constant
Angle Of Heel In Still Water.
C.G is 9·15 Ft Above USK At ℄

Fig 3B.



Lines Of Torsional Stability Moment
For Various Displacements At Constant
Angle Of Heel In Still Water.
CG is 9.15 Ft Above U.S.K. At [illegible].

Fig 3C.



LINES OF TORSIONAL STABILITY MOMENT
FOR VARIOUS DISPLACEMENTS AT CONSTANT
ANGLE OF HEEL IN STILL WATER.
C.G. IS 9.15 FT ABOVE U.S.K AT ⊗.

FIG 3 D.

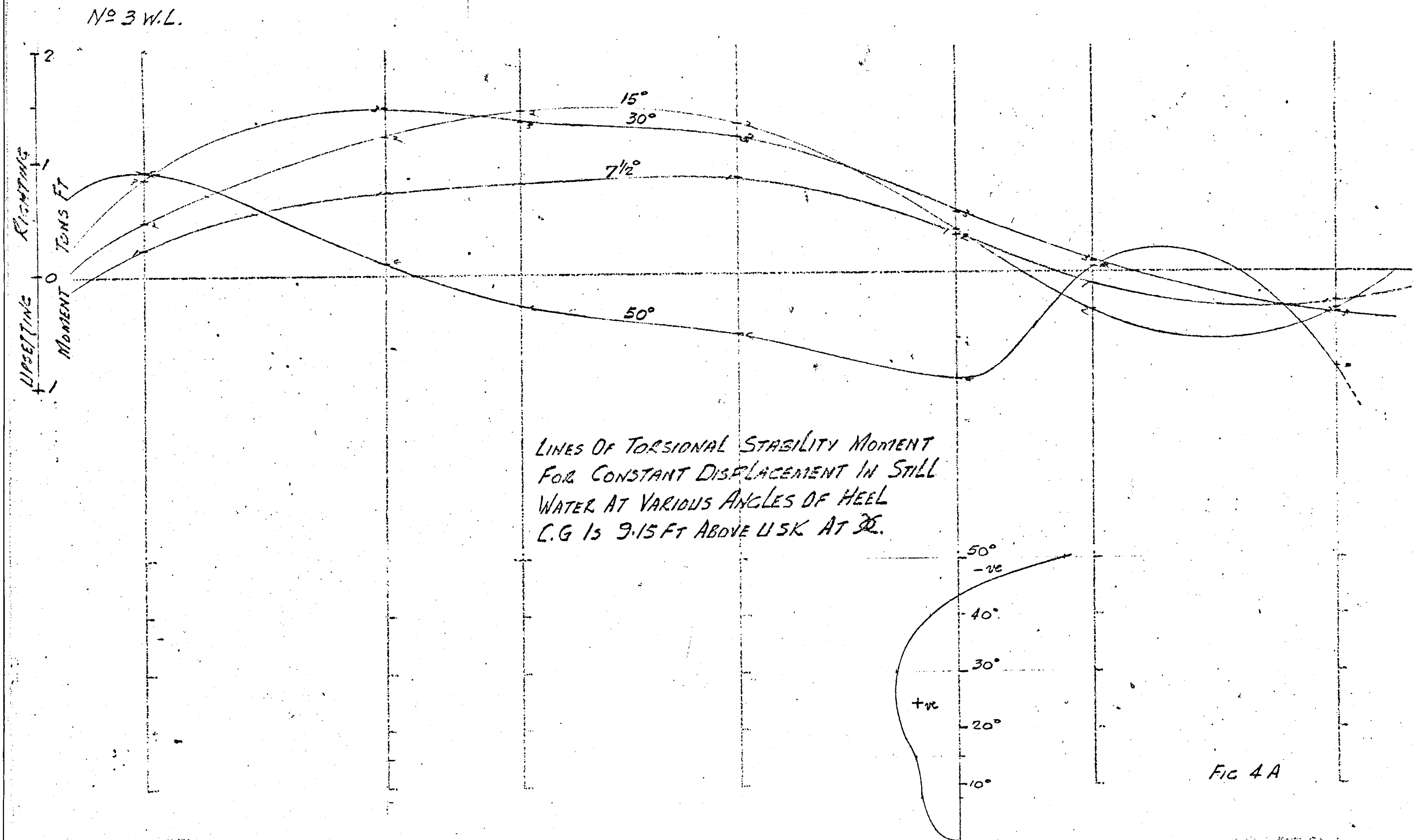
round, and, in addition, everything above main deck level must be given a good "tumble home" to avoid contact with flaring bows and must be applied not only to bulwarks, but also to such items as deckhouse, lifeboats and yardarms. Omission of this feature is one of the prime causes of repair bills.

The duties of pulling tugs, even in quiet harbours, lay them open to the possibility of being girthed by their own towlines, or being pulled bodily sideways through the water. This brings forward two requirements - first the ability to let go the towline under any forseeable conditions, and secondly the provision of sufficient stability to withstand this type of treatment.

I have recently been concerned with details of the stability of a particular fishing trawler. The sections are shown in this slide, and from these the data presented in the next few slides has been calculated. This is typical of many classes of ship.

In all these diagrams the point "S" is 9.15 feet above the keel, and is on No.4 w.l. Waterlines are numbered from below and spread 1'0" apart. All angles of heel are set with point S as centre in the usual manner when dealing with integrator work.

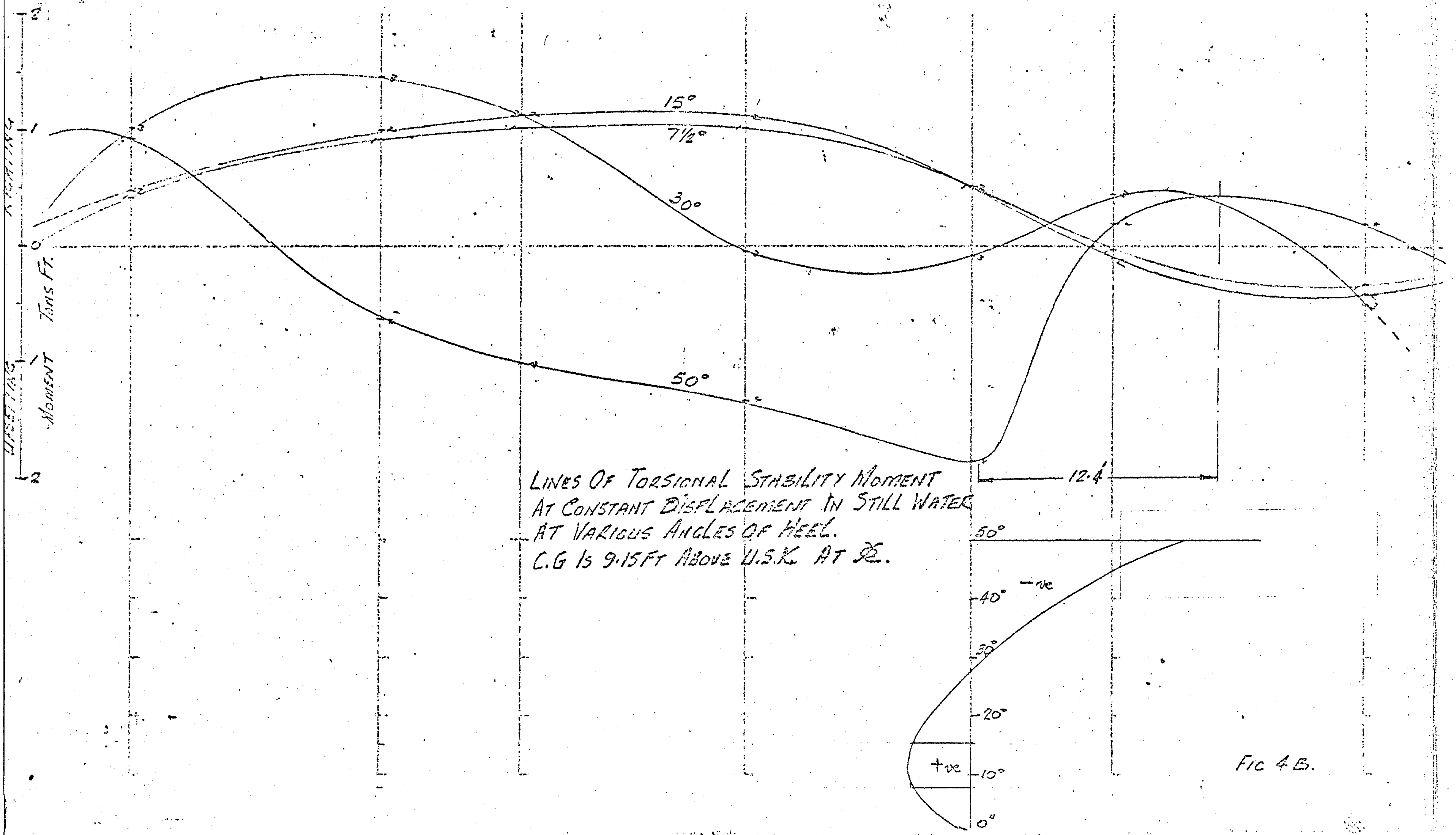
It may not be generally appreciated that the act of heeling a ship imposes quite large stresses throughout the hull, quite apart from the obvious loading imposed by the tow-hook in the case of a tug. When a ship is upright the hull is generally fairly free from stresses due to stability, but once it begins to heel this is no longer the case, and the greater the angle of heel, the greater the imposed stresses. Further, as angles of heel increase, the stablity of various sections in the length of the hull undergoes marked changes - some sections



Lines Of Torsional Stability Moment For Constant Displacement In Still Water At Various Angles Of Heel C.G Is 9.15 Ft Above U.S.K At ⊗.

Fig 4 A

No. 4 W.L.



RIGHTING
UPSETTING
MOMENT TONS FT.
2
1
0
1
2
15°
7½°
30°
50°
12·4
LINES OF TORSIONAL STABILITY MOMENT
AT CONSTANT DISPLACEMENT IN STILL WATER
AT VARIOUS ANGLES OF HEEL.
C.G IS 9.15FT ABOVE U.S.K. AT ℄.
50°
40°
30°
20°
10°
0°
-ve
+ve

FIG 4 B.

increase in stiffness while others become completely unstable, thus subjecting the hull to severe racking forces.

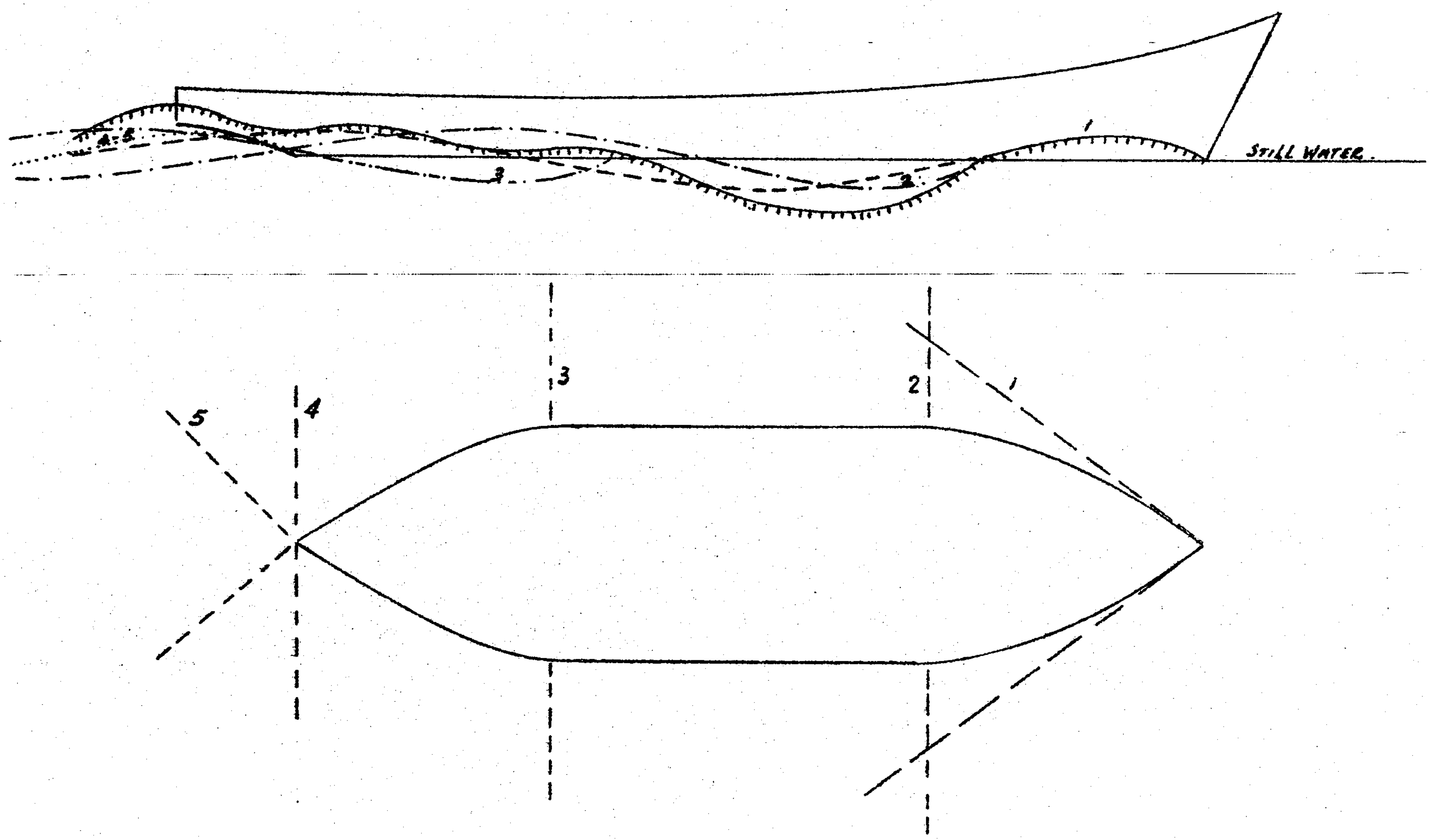
Changes in the depth of immersion of any section also cause the stability of that section to change markedly - hence the effect of waves, will tend to impose racking forces also, quite apart from those forces induced by variations in displacement, along the hull, and from wave impact.

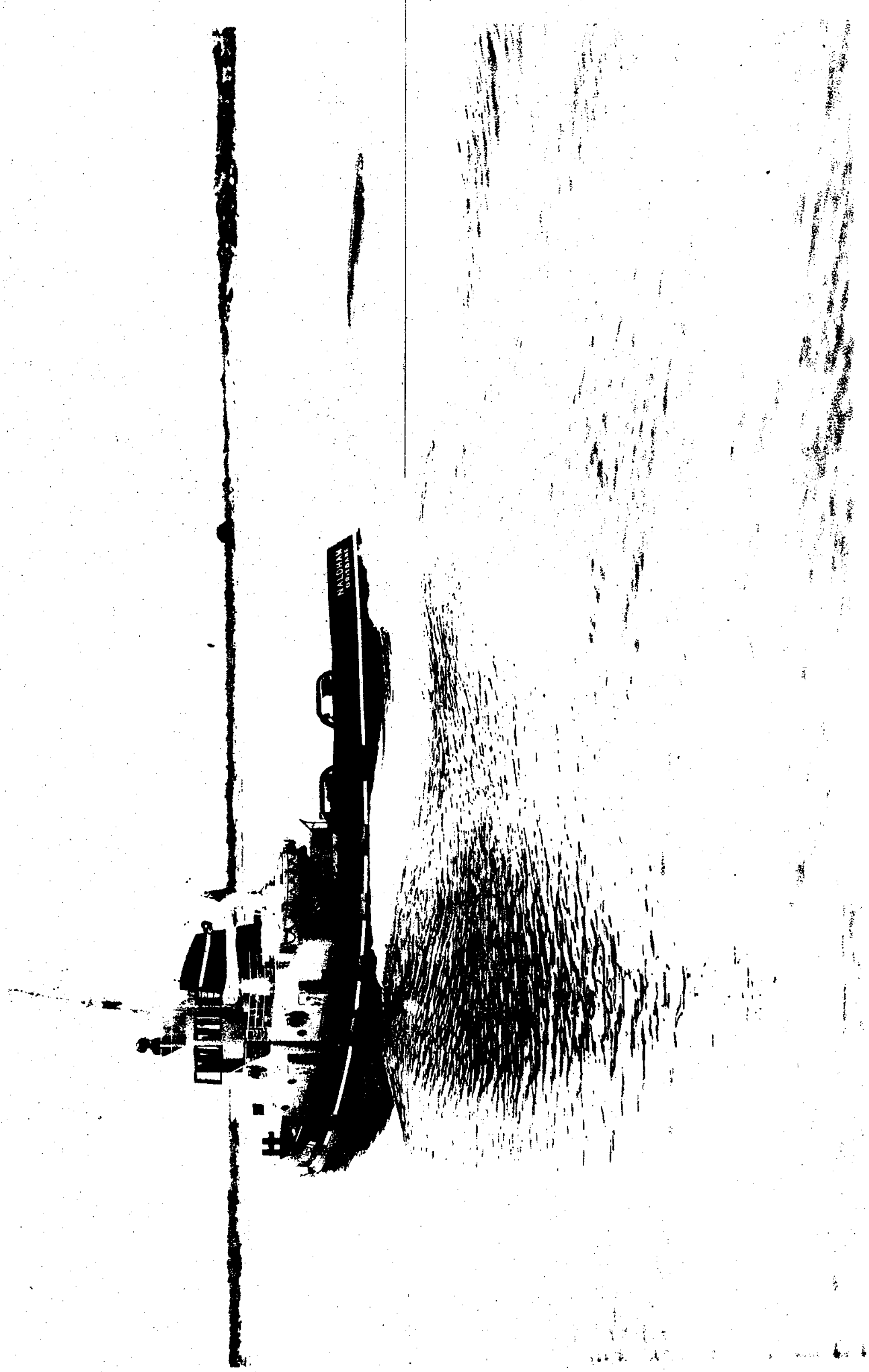
In thinking about this, remember that a stiff ship remaining fairly upright in a seaway, is subjected to similar heeling effects as waves strike upon one side, so that the water surface becomes inclined with respect to the centrelines of the ship, even though the ship may roll very little.

In any vessel intended to operate in close proximity to others - manoeuvrability at all speeds both going ahead and astern, is of vital importance, A tug must be capable of maintaining control when caught close in under the stern of a powerful ship and surrounded by that ship's propeller race, or when caught in the bow wave and thrown round so that she tends to cross the bow of the vessel being attended. Such situations are commonplace in harbour work when picking up towlines from fast moving ships. She must be capable of turning quite rapidly with full tow rope force on the hook, and this force may be imposed in almost any direction including vertically - remember that the tug may be being pulled bodily - rather than pulling.

It is vital to the operation of all tugs that the weather deck rails should be clear all fore and aft. Deckhouses extending to the ships side, awning stanchions, boat davits on bulwarks - shrouds and stays to masts - these things are anathema to tugmen. It is most difficult (and can be downright dangerous) to have to pass a heavy towline around such obstructions. No tug other than an ocean going type should be fitted

WAVE MAKING RESISTANCE





with a raised forecastle unless operational requirements demand it. Carrying a heavy towline up or down a ladder can be difficult even when the tug is not rolling in a seaway - and it slows down the job of getting the line on the hook.

Finally, before procedding to deal with various tug types - a few words on resistance and propulsion.

The question of the speed and power of ships is one upon which many volumes have been written. It is a most difficult subject, and far too complex for us to study in detail tonight. Let it be sufficient to say that every ship makes 5 separate wave systems around the hull, each of which has a definite area of origin in the length of the vessel. As the ship's speed is increased the wavelength of each system increases at the same rate, so that the wavelength is always $\frac{V^2}{1.8}$ (v being the ship's speed in knots). It follows that at some speeds the crest of one wave system must coincide with the crest of the next, and at other speeds the crest of one must coincide with the hollow of the next. The total height of the resultant wave system is the vectorial sum of each component, measured either above or below the still water surface line.

Now the kinetic energy of a wave system varies directly as the product of the length of the wave and the square of the height, and in a wave system created by a ship the wave train energy comes directly from the ship's passage - i.e. from the engines. It follows then that this component of resistance does not increase regularly with speed, but produces an undulating series of increasing values which are dependent upon the speed of the ship and the positioning of the points of origin of the various wave systems relative to each other. If we know the desired ship speed it is possible to determine an overall length

MARINE PROPELLER TOLERANCES ON I.S.O./T.C.8.

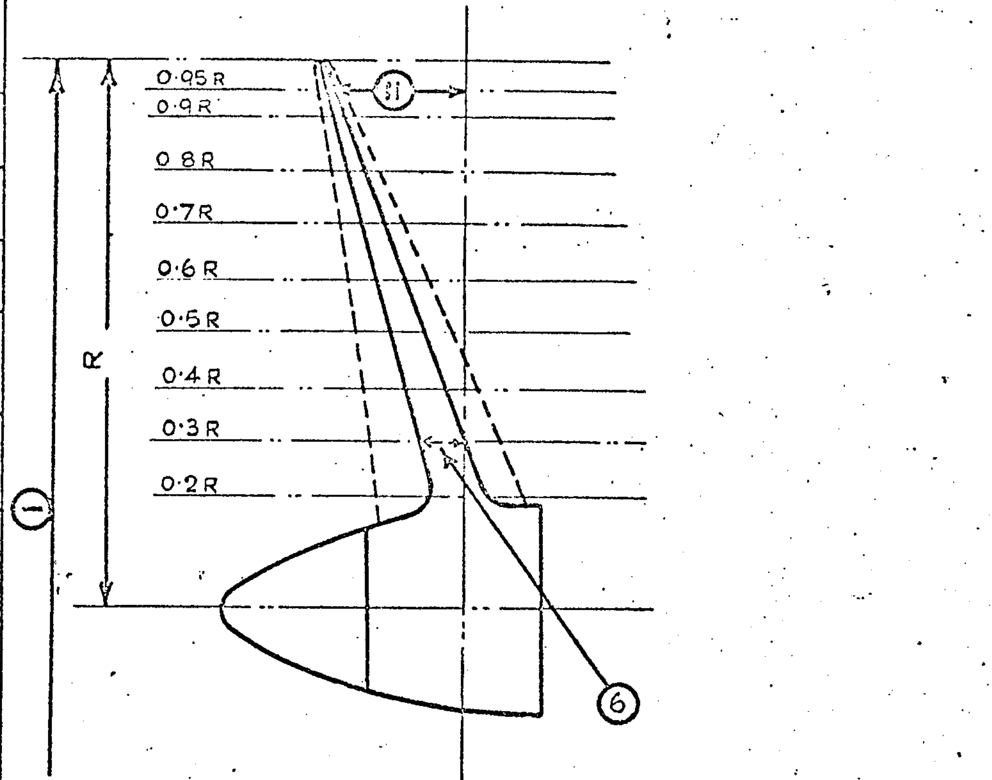
DESIGNATION OF CLASS.		BEST QUALITY FOR SPECIAL DUTY HIGH ORDER OF ACCURACY	FOR THE MAJORITY OF MERCHANT SHIPS. MEDIUM ORDER OF ACCURACY.		TOLERANCE NUMBER.
CLASS.		S	I	II	
MATERIAL.		BRONZE.	BRONZE.	BRONZE.	
DIAMETER.		±0·1% >0·04" <0·12"	±0·1% >0·04" <0·12"	±0·1% >0·04" <0·12"	1
PITCH TAKEN ON CONSTRUCTION PITCH.	BOSS - 0·4R FROM POINT TO POINT BETWEEN 0·4R & TIP.	± 1·5% ± 1·0%	± 3·0% ± 2·0%	± 4·5% ± 3·0%	2
	BOSS - 0·4R PER RADIUS - PER BLADE BETWEEN 0·4R & TIP.	± 1·125% ± 0·75%	± 2·25% ± 1·5%	± 3·0% ± 2·0%	3
	PER BLADE	± 0·625%	± 1·0%	± 1·5%	4
	OVER THE WHOLE PROP.	± 0·5%	± 0·75%	± 1·0%	5
MAX. BLADE THICKNESS. TO BE MEASURED ON AT LEAST 5 RADII (0·3, 0·5, 0·7, 0·8, 0·95R) & ON 3 POINTS		+ 2% >0·08" - 1% >0·04"	+ 3% >0·10" - 1·5% >0·06"	+ 4% >0·12" - 2% >0·08"	6
EDGE.		TEMPLATE LENGTH 15% OF SECTION LENGTH & AT LEAST 4"			7
AREA.		NOT YET DETERMINED.			8
BLADE WIDTH. BOSS - 0·4R TO BE MEASURED ON AT LEAST 5 RADII BETWEEN 0·4R & TIP.		± 0·75% >0·06" ± 0·5% >0·04"	± 1·5% >0·06" ± 1·0% >0·04"	± 2·25% >0·06" ± 1·5% >0·04	9
CIRCUMFERENTIAL SPACING OF DIRECTRIX LINES AT TIP.		± 0·5%D >0·2"	± 0·5%D > 0·2"	± 0·5%D >0·2"	10
RAKE. MEASURED FROM DATUM LINE AT 0·3R & 0·95R. BETWEEN 2 BLADES AT 0·5R.		± 0·2 D >0·12" ± 0·1%D >0·08"	± 0·4%D >0·12" ± 0·2%D >0·08"	± 0·6%D >0·12 ± 0·3%D >0·08	11
PERMISSIBLE OUT OF BALANCE (BY ARRANGING THE WEIGHT "g" IN HORIZONTAL POSITION THE PROPELLER MUST MOVE.)		C_K = 8·81	C_K = 13·22	C_K = 19·85	12
		"g" MAXIMUM = 0·01005 C_K. D. "g" MINIMUM = 0·01438 D^2 + 0·044			

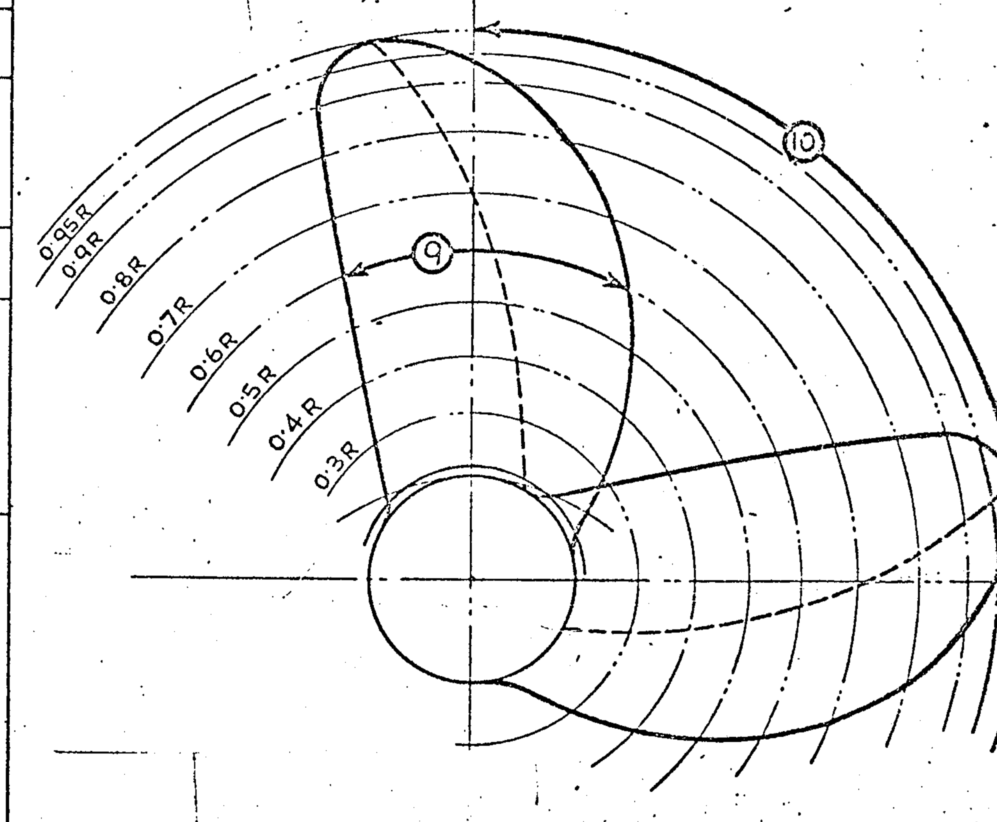
D = PROPELLER DIA. IN FEET.
R = BLADE TIP RADIUS IN FEET.
G. = PROP. WEIGHT IN TONS.
g = BALANCING WEIGHT IN LBS $= C \times \frac{G}{R}$

WHERE "C" MAY BE DEFINED
FOR PROPELLER R.P.M. < 160
FOR PROPELLER R.P.M. > 160

EXAMPLE:- TOLERANCE = ± x% ≥ $\frac{a}{b}$; THE SPECIFIED TOLERANCE IS x%
HOWEVER IF "x" IS SMALLER THAN "a"; "a" MAY BE USED.
IF "x" IS GREATER THAN "b"; "b" MUST BE THE LIMITING TOLERANCE.

SURFACE FINISH
THE SURFACE FINISH OF BLADES TO BE DETERMINED BY THE MEAN HEIGHT H_m
ROUGHNESS OF THE BLADES AT LEAST FOR THE RADII OF THE PROPELLER OVER 0·3





and the distribution of the areas of wave system origins which will produce minimum resistance at that speed. Unfortunately this configuration will not produce minimum resistance at all speeds below the designed speed, for the reasons outlined above. Underlying this undulating pattern of wave making resistance there is a fairly uniformly increasing pattern of skin friction resistance as speed is increased. This component of resistance depends upon the wetted surface of the hull as well as the speed.

From the foregoing it is seen that resistance (and hence the power demanded for propulsion) varies in its rate of increase as speed is increased. Experience shows that this variation is from a rate proportional to about V^2 at moderate speeds, to about V^3 at high speeds.

The propeller is, without doubt, the most important component of any tug. No matter how good the hull form, no matter how efficient the main engines, a bad propeller can utterly ruin the vessel's performance.

The cost of obtaining a good quality finish on a propeller is quite high, but it will be repaid many fold during the life of the vessel.

The International Standards Organisation has produced a standard No.R484, relating to the finish of propellers. No tug should be fitted with a propeller of less than Class 1 Standard. Remember always that the overall propulsive efficiency varies directly with the efficiency of the propeller. Thus a vessel fitted with a diesel engine having a brake thermal efficiency of 35% and a shaft efficiency of 97% will have an overall propulsive efficiency of 17% if the propeller efficiency behind the ship is 50%, and this will rise to 23.8% if the propeller efficiency is 70%. This represents a saving of 40% in fuel costs.

Now the various factors which principally detract from the efficiency of a propeller are - thick blade sections, variations of pitch across each blade and between blades at the same radius and surface finish. A propeller offered on one occasion as a "very high class job" had pitch variation of 17% across one blade at constant radius, which meant that one part of the blade section was trying to race its following parts by 1¾ knots in every 10. The other blades were nearly as bad. The propeller was returned to the manufacturer with thanks.

Surface finish has a much greater effect than one may imagine. In his classical text book Taylor states that at 20% slip ratio one propeller lost 17.5% efficiency when its surface was coated with paint which was "stippled" while wet. In the same reference he shows that at 20% slip the efficiency of a particular bronze screw "as cast" was about 62% while the same screw polished and made as smooth as possible returned an efficiency under test of 71% - a 9% improvement. This again represents 9% saving in fuel costs. Consider a tug using 1000 HP for 6 hour/day and 200 day/year (or 13.7% usage). The fuel consumption is usually found to be 0.37 lb/BHP/hr for propulsion only. The annual fuel consumption then would be 444,000lbs. A 9% saving in fuel represents about 38,980lbs of fuel (or 17.8 tons) saved during the year which also improves the environment due to reduction of exhaust emission. With the current cost of diesel fuel at about $35 per ton, the annual saving in money is $622 and this will surely pay for polishing the propeller and keeping it polished. Give a propeller a life of 20 years and the saving becomes $12,440! This will pay for the propeller, and leave a handsome profit as well.

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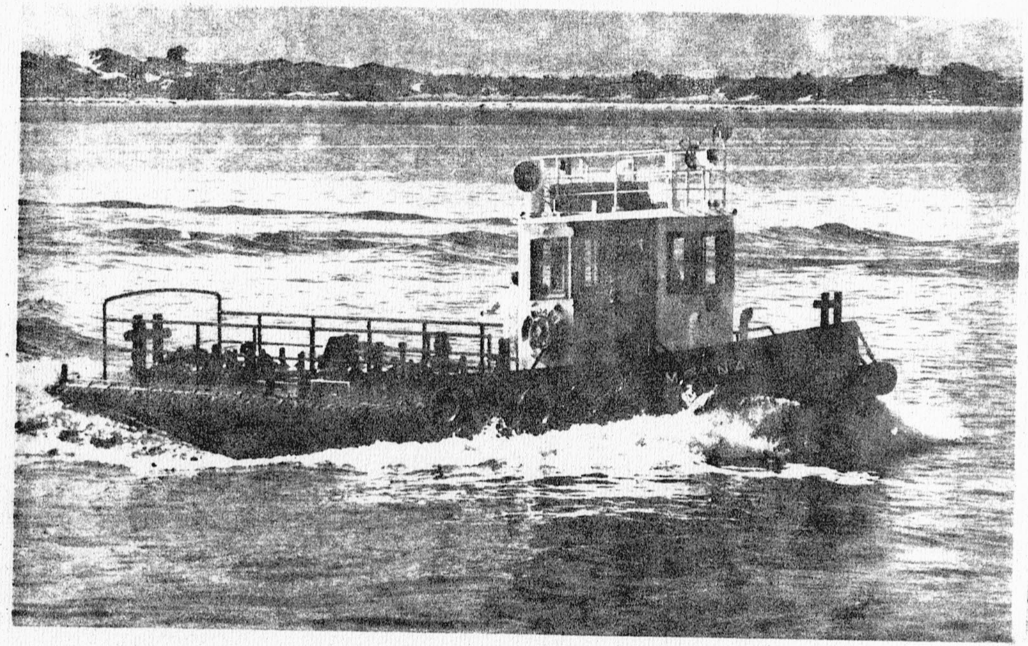
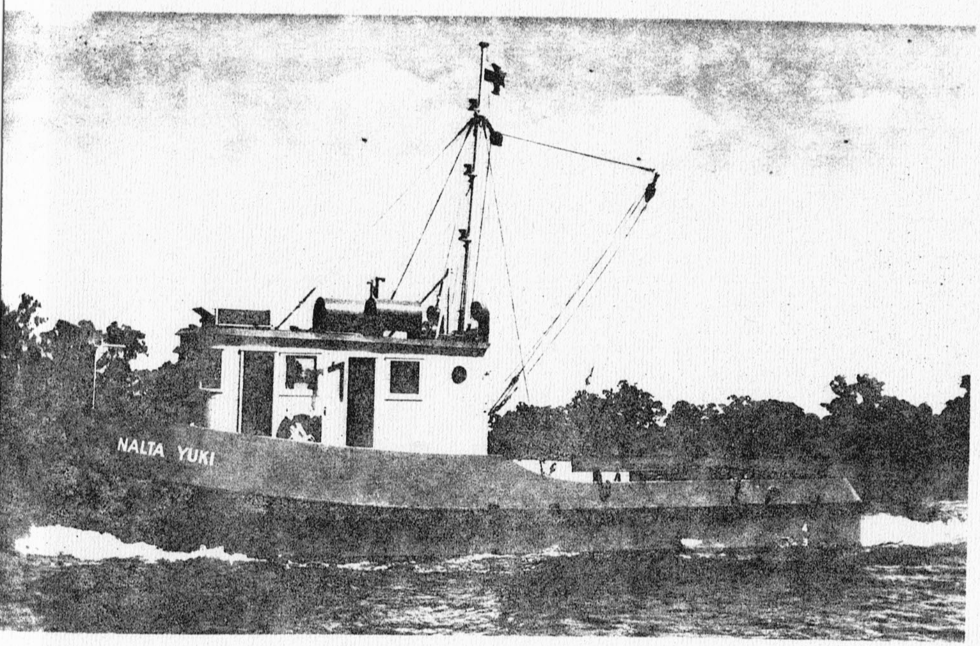
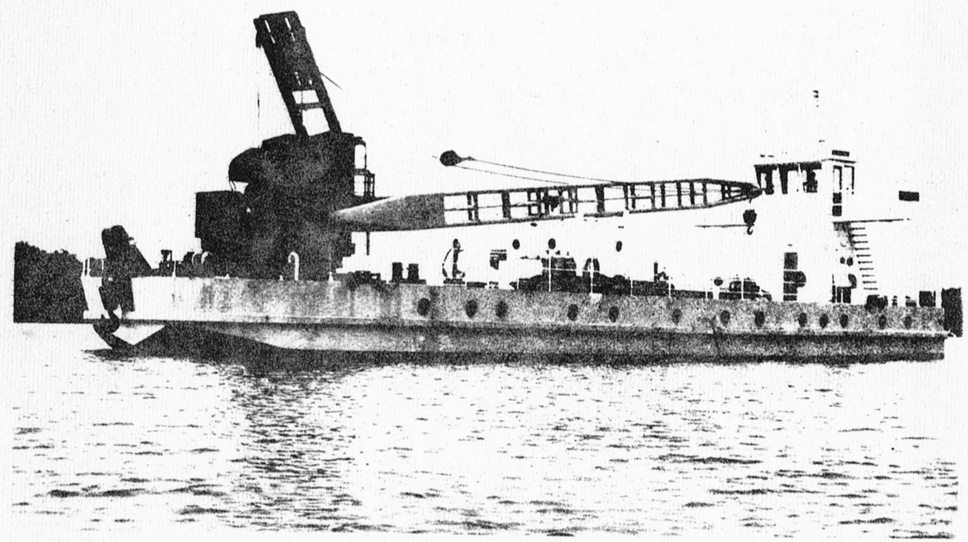


[illegible] Tug

[illegible] Tugs (2)

Nalta Yuki has [illegible]





A form of propeller which is sometimes used is the cycloidal propeller. These are characterised by a series of actuated vertical vanes set around the periphery of a rotating disc. During each revolution of the carrying disc each vane is caused to rotate by a system of adjustable cranks and levers so that its thrust force is constantly expended in any desired direction.

Experience proves vessels so fitted are extremely manoeuvrable, very quick to start and stop, and since full propeller thrust is available through out 360° they turn quickly and can travel sideways if desired. They have a most useful part to play in areas where narrow or confined docks need to be traversed - e.g. London - but are not so frequently used for deep sea work. In Canada, New Zealand and Continental ports there are a number of these vessels. Experience indicates that they are very useful as "steering tugs", but the headline is almost always handled by a vessel with a conventional type propeller.

In a very few places paddle tugs are still used - the paddle wheel is quite efficient and, for calm water, particularly if it is shallow, is worth some consideration. Paddle wheels are, generally, less easily fouled by submerged objects such as snags than are screw propellers. Due to the spread of side paddle wheels they provide excellent low speed steering capabilities, much better than normal twin screws.

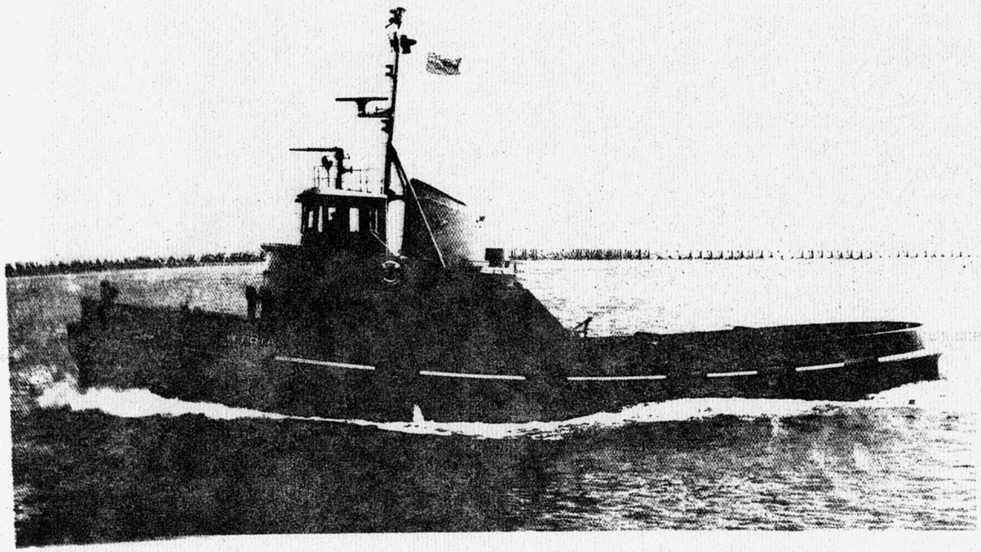
We are now in a position to talk about various types of tugs:-

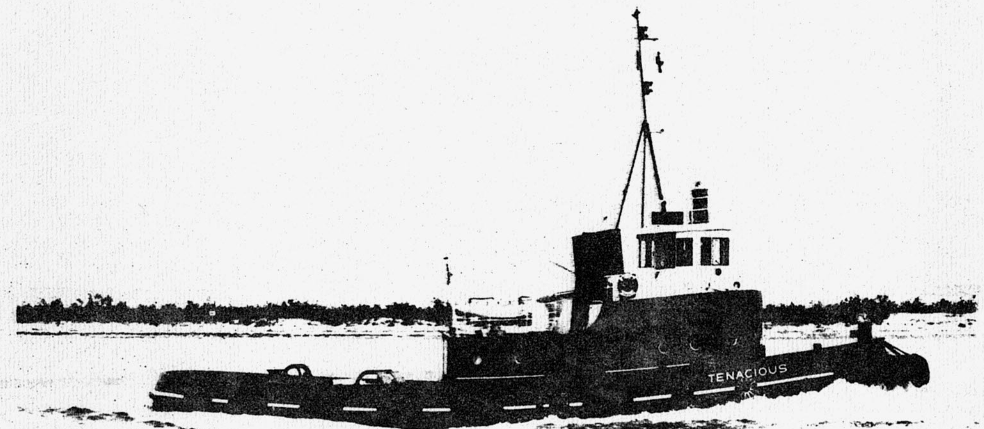
(1) Harbour Tugs.

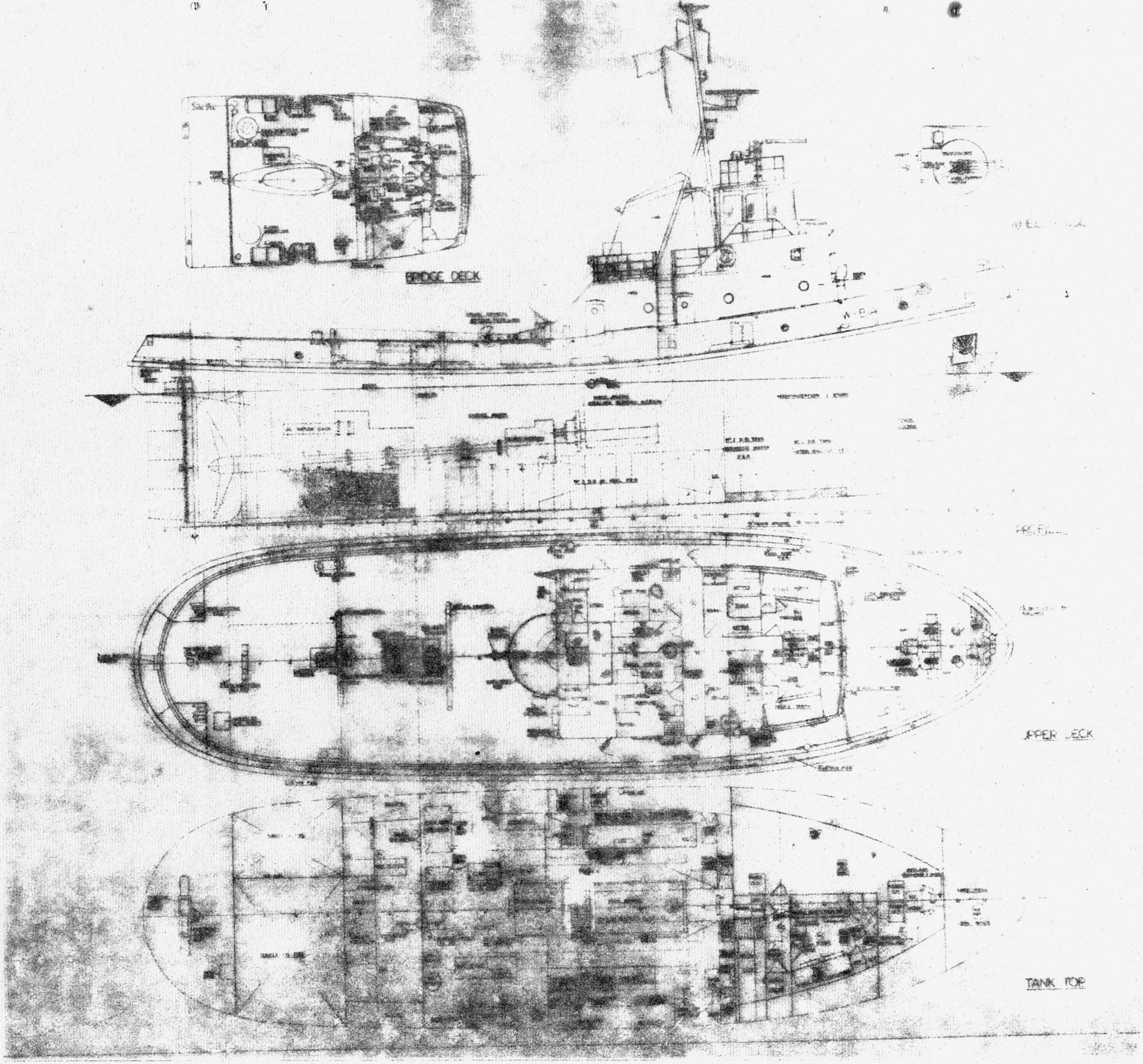
(a) Pulling type.

These should be the simplest type of craft. They are always handy to a repair establishment - hence the provision


KALGAN

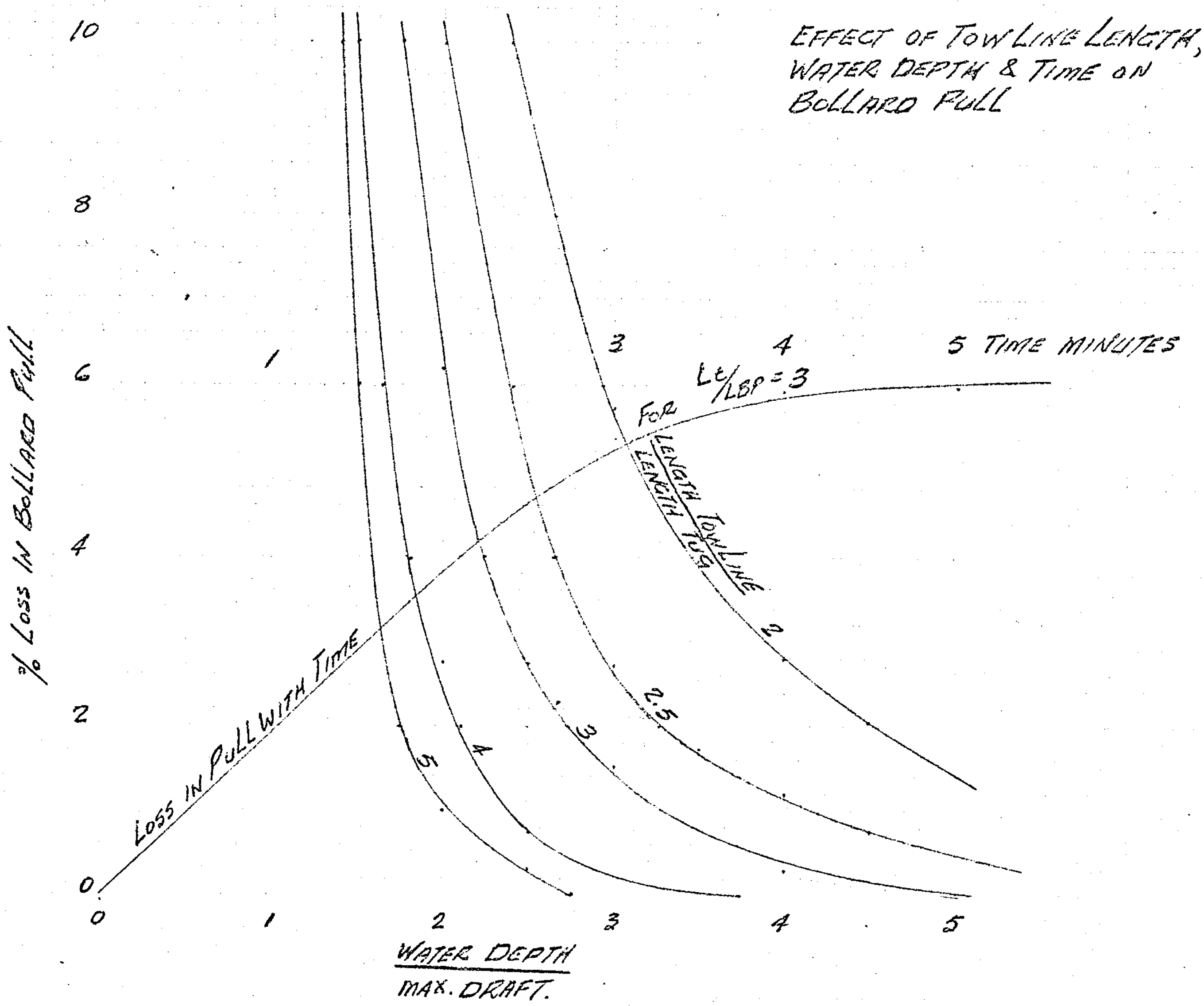


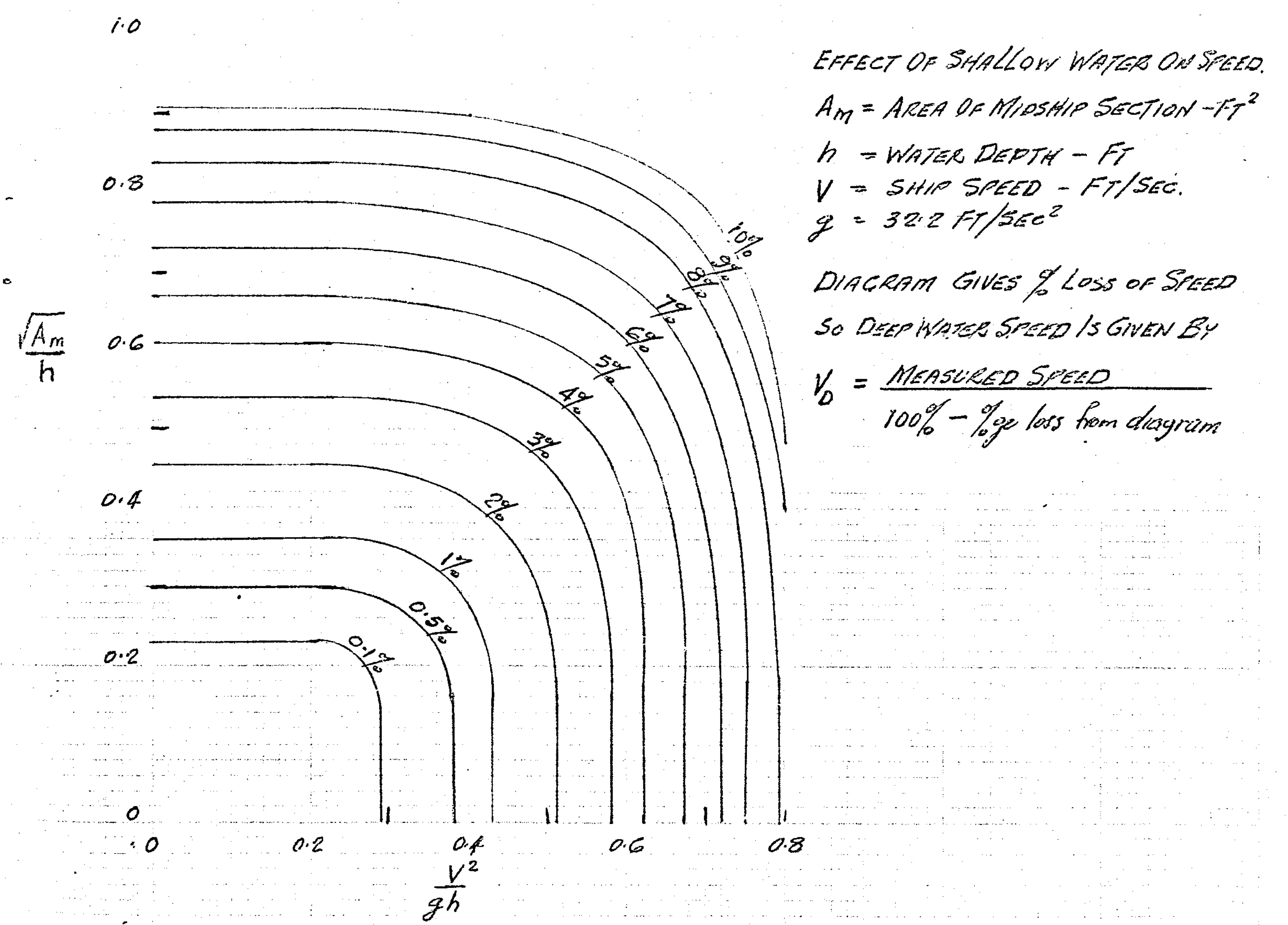

TENACIOUS



BRIDGE DECK
PROFILE
UPPER DECK
TANK TOP

EFFECTS OF WATER ENVIRONMENT UPON THE TRIALS OF TUGS.





of a great host of spare gear is not necessary. They only need to carry one watch - at any time - so no sleeping accommodation should be required.

Cooking and messing facilities can be reduced to the absolute minimum - a small gas stove and a small 2 to 3 cubic foot refrigerator should suffice. One messroom for all the crew is common practice, and here the crew can relax between jobs. The master can do all the necessary paper work in the bridge. Only a small bunker capacity is needed.

However, there are other considerations. Firstly that of speed. Most harbour tugs are not required to travel very long distances. In 10 nautical miles the saving in elapsed time for a voyage is 10 minutes if speed is increased from 10 to 12 knots. It is not economic to force the ship up to high speeds, but much is to be gained by operating at or below the economic speed for the hull length. The question of water depth plays a most important part in this consideration - The following data is fairly representative

Length of tug on Waterline	Economic Speed in deep water	Displacement (approx)	Depth of water in ft. required for economic speed without power wastage.
40 feet	7.2 knots	42 tons	60 feet.
60	8.8	131	86
80	10.0	298	114
100	11.3	538	143
120	12.5	800	172

From the above table the following points emerge. Firstly that economic speed is dictated by length of hull and is about $1.13\sqrt{L}$ where L is the waterline length, and second, that the water depth required for operation without power wastage increases rapidly with size of vessel and speed.

DIAGRAMMATIC REPRESENTATION OF
SPEED & POWER RELATIONSHIP FOR
100 FT TUG IN DEEP WATER & SHALLOW.

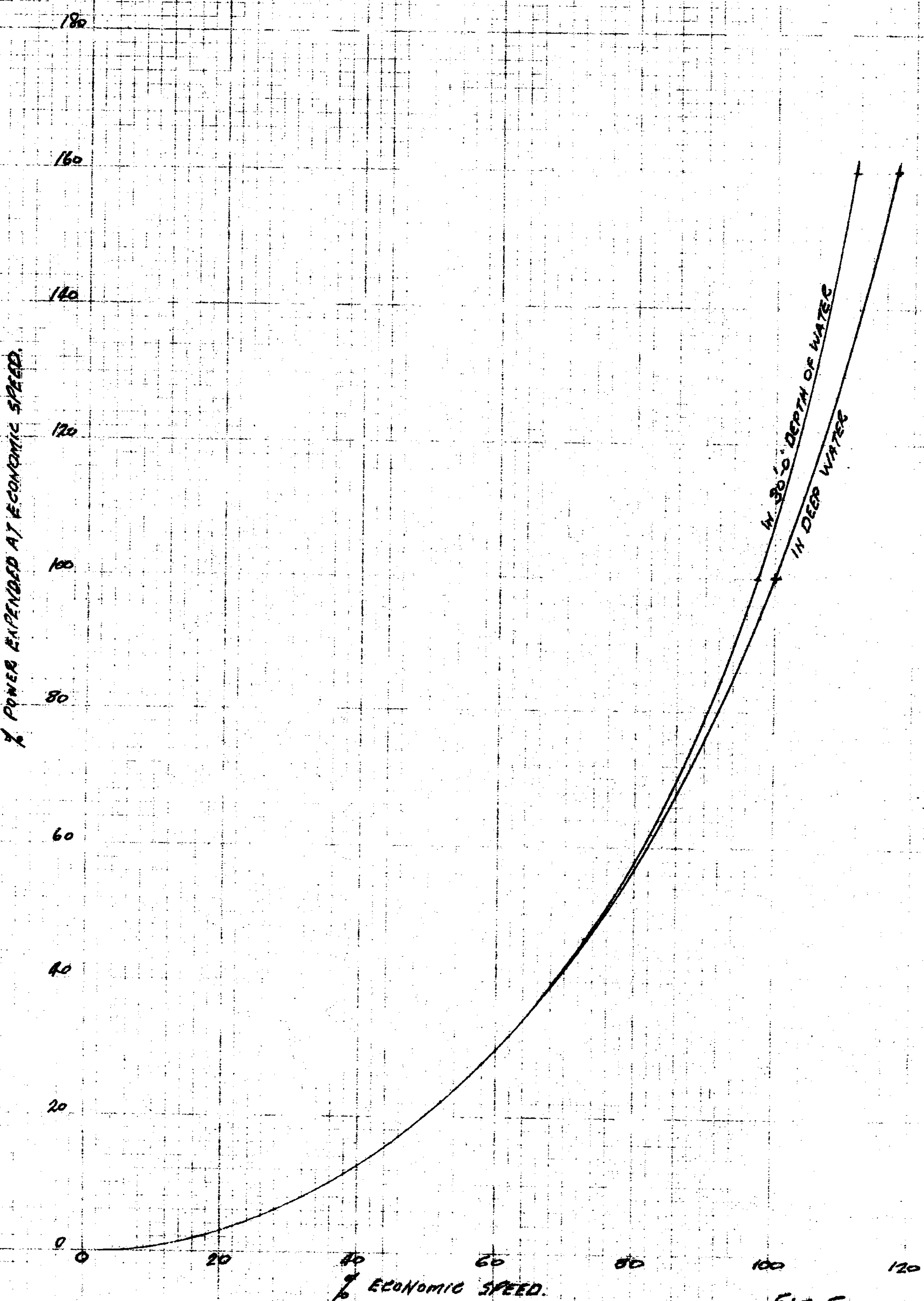


FIG. 6.

An increase of two knots in the speed of a 100ft. tug from 11.3 to 13.3 knots in deep water may well require an increase in expended power of up to 60%. Now there are not many harbours in Australia with depths much over 30 feet in the average, and in this depth of water a 100'-0" tug operating at power for the deep water economical speed of 11.3 knots will suffer a speed loss of about 0.3 knots, being reduced to 11knots, and this represents a power wastage of over 7%. If operated at power for a deep water speed of 13.3 knots the speed loss in 30 feet of water would be in the order of 0.6 knots, reducing speed to 12.7 knots, representing a power wastage of over 12½%.

From this argument it follows that the size and power of tugs should be dictated, not primarily by speed requirements but by the pull required to handle the ships which frequent the harbour in question, and the prevailing weather conditions. In a harbour ships do not often go ashore, and, generally speaking tugs of moderate pulling power are adequate. The tugs are not required to move the ships at high speeds - the general duty being to assist them into and out of their berths and to aid them in swinging in narrow waterways. At low speeds - i.e., under 3 knots, the water resistance of quite large ships is very small, the principle cause of resistance being windage. The resistance of a ship to windage may be expressed as $0.004 \frac{B^2\ Vw^2}{2 \times 2240}$ tons, in which B is the beam, in feet, of the ship to be towed, and Vw is the wind velocity in knots. Hence in a port frequented by ships having a beam of 100ft. and in which wind velocities of say 50 knots may be expected, the wind resistance of such a ship would be $0.004 \times \frac{100^2 \times 50^2}{2 \times 2240} = 22.35$ tons, and the tugs in such a port should be designed with this as a basic parameter.

Depending upon the type of tug designed, the expected

/11. bollard.

bollard pull may range from 1 ton per 100 bhp to 2 tons per 100 bhp: Hence to produce a static pull of 20 tons the tug would need between 1000 and 2000 bhp installed.

It now remains to see how the maximum pull may be obtained from any given power plant.

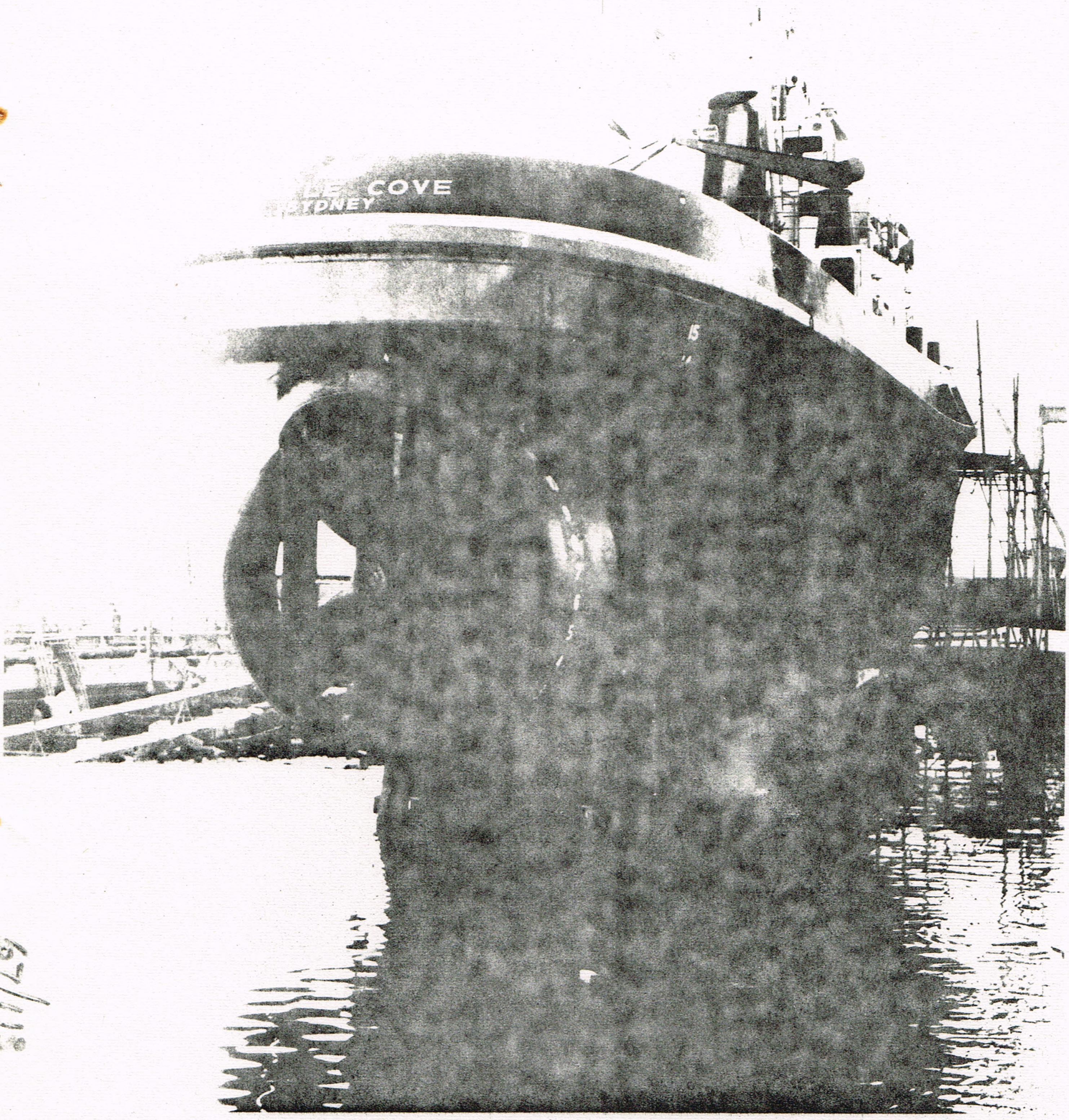
In the first place it must be recognised that this pull is to be exerted at or near zero speed of advance. The most important feature of the underwater hull form is that it should permit the maximum possible flow of water in straight parallel strea lines into the propeller disc. The propeller disc should be of the maximum practicable diameter, since this leads to the greatest pull per bhp.

Since, as mentioned earlier, speed should not be a determining factor in this design, the propeller should be designed purely as a "towing propeller".

Three possible variations enter our thinking at this point - one: whether to use a fixed pitch or a controlled pitch propeller: - two: whether to use an open propeller, or one operating in a propulsion nozzle, and three: whether to use a multiple rudder system or a single rudder.

So far as controllable vs. fixed pitch propellers are concerned - the controllable pitch propeller is rather more expensive, especially when the cost of hollow shafting, hydraulic pumps, oil injection boxes and remote control gear is taken into account. Such propellers have a boss of greater dia. than a comparable fixed pitch propeller, and large bosses are detrimental to efficiency. However, the fixed pitch propeller can only be designed to produce maximum efficiency under one set of conditions, and losses occur at all other conditions. The controllable pitch propeller will produce thrust at nearer to optimum efficiency over a greater range of operational conditions

/12.

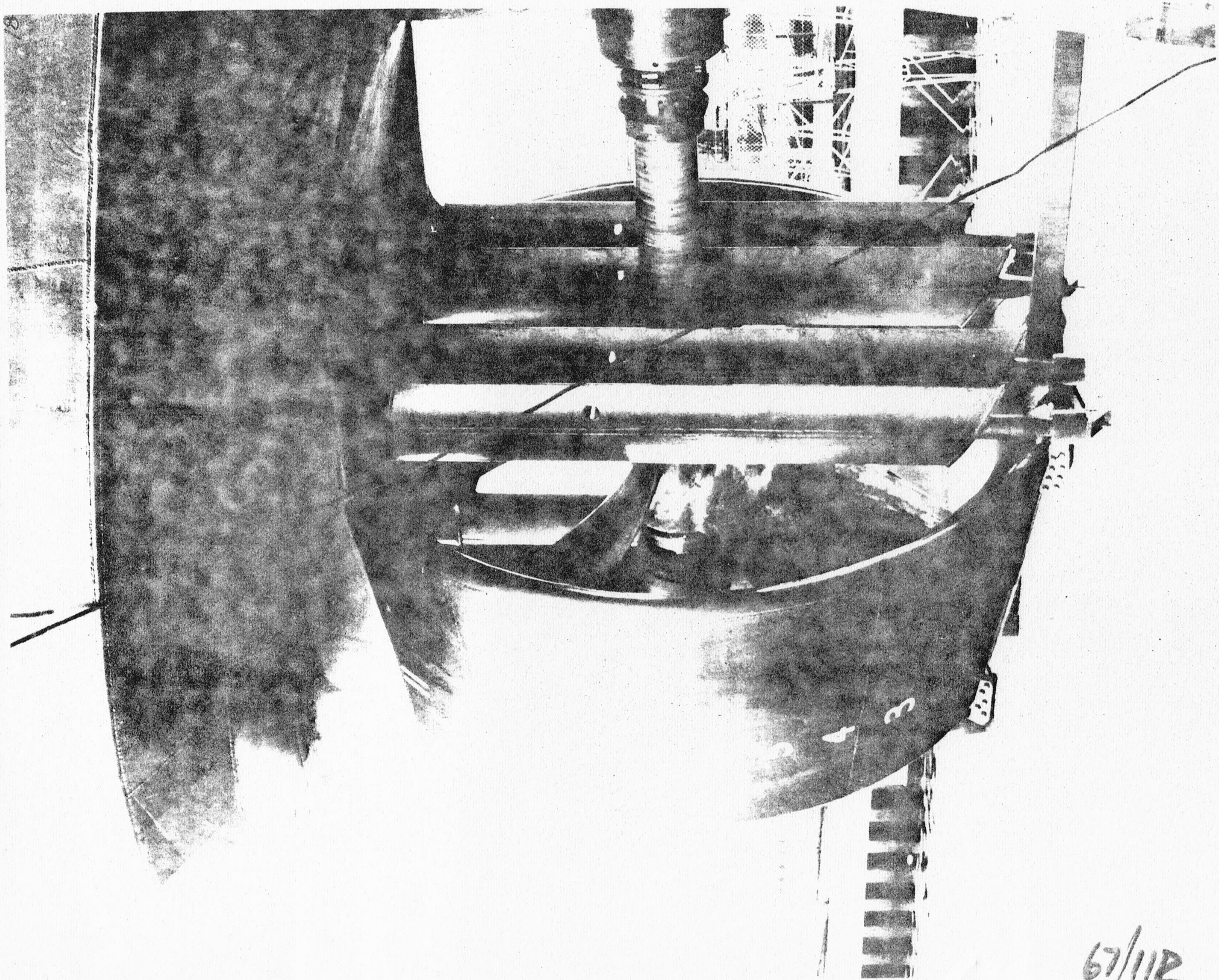

COVE

The greatest argument in favour of the CP propeller is that the tug is very seldom required to produce its maximum pull - hence a fixed pitch propeller very seldom operates under ideal conditions. The design efficiency of a fixed pitch propeller is higher than a CP propeller but, generally, the CP propeller will produce better results because designed conditions for the fixed pitch propeller are so seldom realised in practice whereas the CP propeller can be adjusted, within limits, to operate more nearly at optimum pitch.

The question of the propulsion nozzle is rather more clear cut. This device will cause an increase of static bollard pull - which may be of the order of 40-50% but again this can only be achieved under one set of conditions. Since speed should not be a factor in this type of ship, the nozzle can be a pure "pull type" - it will add to bollard pull but will detract from speed. It is considered by some tug operators that a propeller in a nozzle is more prone to damage from floating timber - others as hotly deny this argument. The nozzle may be either fixed or rotating about a vertical axis, in which latter case it acts as a very powerful rudder (no other being fitted) while in the former case it tends to detract from steering qualities. Since blade tip clearnaces <u>must</u> be kept very small, errors of manufacture cannot be tolerated and expensive jig work is required. Wear in the bearings of a steering type nozzle can result in blade tip fouling of the ring. Propeller accessibility is reduced - hence repairs and surveys tend to be more expensive.

The higher bollard pull available means a reduction in installed horespower, and, generally, a smaller dia. propeller both of which savings can be offset against the first cost of the nozzle. The savings in engine and propeller prices seldom

/13. equal



67/112

equal the cost of the nozzle however.

The use of multiple rudders has something to commend it. These are usually installed in conjuction with a fixed propulsion nozzle. Sometimes a number of rudders are installed abaft the nozzle and sometimes, in addition to these, others are installed, on either side of the propeller shaft, forward of the nozzle. In either case, the manoeuvering qualities of the tug are improved, and in the latter case, the manoeuverability of the tug going astern is really something to behold. The normal single single screw open propeller type tug will very seldom steer when running astern and usually goes into a circle which nothing short of a "kick ahead" with the main engine will break. With "shutter" rudders ahead of the nozzle, a figure of 8 manoeuver while going astern in confined waters is an everyday occurence. Since the multiple blades are smaller, and rudder head torques may be balanced one against the other, a much smaller steering gear may be fitted than in the case of a single rudder - but there are a number of rudder head links which add to the cost, complexity and maintenance of the system. Some owners add that they also add to the possibility of mechanical failure since all rudders operate off one "master" rudder stock.

The final point requiring decision is "single or twin screw". Single screw should take preference under most circumstances. There are less moving parts - single screws are more efficient than twin screws - there is less possibility of "air drawing" or of damage - fewer engine room personnel are required and the added reliability of having two engines is not really necessary. The total power to be installed generally can be delivered by one engine and accommodated by one propeller. Initial costs, maintenance costs, survey costs, manning and fuel costs

/14.

are all usually lower. The only cases for twin screws is that of continuous shallow water operation, or where high manoeuvrability is required.

At this stage we are in a position to state our prinicpal design parameters in regard to bollard pull, engine power, number of screws, open propeller or propulsion nozzles, fixed or steering nozzle single or multiple rudders, bunker capacity, and are ready to investigate the question of manning in detail.

Under the provisions of an Order in Council made under the Navigation Act, tugs are exempt from determination by the Manning Committee - hence the manning becomes a question of individual consideration and compromise between tug owners and maritime unions. Conditions vary from port to port, and so it is impossible to be precise at this juncture. It is wise, therefore, to get the question of manning settled early, as it may be next to impossible to add extra accommodation to a completed vessel, and no-one whishes to build in unnecessary cabins. Harbour tugs, generally, run with a crew of 5 or 6 men; Master, Engineer, and greaser always being carried, and either a Mate and 1 deckhand, or no Mate and two deckhands. In two ports a cook is also required, but since the vessel operates as a day job, this is not really necessary in the view of the tug operators.

Clearly, the manoeuvering of the main engine should be left to the Master, but starting and stopping of the main engine should be an "engine room" function - so that the Engineer is compelled to see the machinery before starting up - this can avoid costly mistakes. He is also compelled to be present at shut down - so that the machinery should be properly cared for.

So far as Navigational aids are concerned - a good compass is a must - preferably situated on the wheelhouse top with a periscope-type reading tube into the wheelhouse - radar may be

/15. fitted.

fitted if the port is subjected to fogs and very little else is necessary. Echo sounders, radio direction finders etc. are completely out of place in this type of craft. The wheelhouse should be small but with excellent visibility all round and ventilated to prevent fogging of windows. Kent clear view screens are not usually required - a single window wiper suffices. Remember that the best clear view screen is an open window.

The deck arrangement should be such as to give the tug the greatest possible versatility. The towhook is usually placed fairly close to the centre of flotation - i.e. about 4%L abaft amidships. These tugs seldom have either a towing bollard or a towing winch. There should always be a bollard right at the bow so that the tug may be used for steering purposes. There should be a bollard on each shoulder forward and one amidships on each side. With these the tug may be "lashed up" alongside the vessel towed and used to help in steering or to give either headway or sternway to the tow. This is a very common method of river and harbour towage for vessels with comparatively low freboards. There should be a bollard on either quarter aft and/or a gog bollard on the centreline from which a strop may be passed around the towline to prevent it running off over the side. All bollards should be of cruciform type or should be fitted with most substantial kevils.

The anchor windlass forward usually has at least one warping drum, and a capstan is installed aft to aid in getting heavy lines on board. It is desirable to fit a three roller fairlead at the stern for use with the capstan and this is generally set down into the bulwark with a portable section of rail over it. This arrangement was illustrated in the slide showing the stern of the "Castle Cove ". Two molgoggers at the quarters prevent the towwire from running off over the side while being streamed -

and these are either portable or retractable.

A series (usually either 2 or 3) of towbows or "horses" are used to keep the towline clear of the deck, and all sounding and air pipes, fuel fillings pipes, fire hose connections etc. should be tucked in under the bulwark where they will not foul the tow line if it should break or be cast loose.

Within the engine room the plant should be reduced to the aboslute minimum - main engine and gearbox, this latter fitted with a shaft brake for quick manoevering, and with the engine throttle and reverse mechanism interlocked so that stalling is prevented while clutch wear is kept low, these are essentials. Automatic lubriacting of all machinery is desirable so that the greaser may be employed as a "day-man" only. Engine and gearbox ancilliaries, fresh and salt water circulating pumps, lub oil pumps and the like, should be driven by the plant they serve. It is sometimes arranged that steering gear pumps are driven off the main shaft - but this is not a good feature from several aspects. The added expense of separately driven pumps is well worth incurring.

Since the vessel operates in a harbour the fitting of evaporators, oily water separators etc. is not necessary. A small sludge tank and dirty oil pump discharging to a wharf connection is sufficient. There are very heavy penalties for discharging or spilling oil into navigable waters.

The engine room plant then, consists of the following items:- Main engine, gearbox, shaft brake, shafting and bearings with tachometer generator. Auxiliary engine with electric generator and either air compressor or pump, clutch coupled. Two sets may be fitted if thought necessary. Two air compressors, one must be operable under "dead ship" conditions - usually driven by a small diesel - discharging to two air receivers.

/16.

Bilge pump, General Service and fire pump (about 70% of bilge pump capacity), doublesras emergency bilge pump and acts as ballast pump. Steering gear pumps (2), lub oil filters - duplex, Dirty oil pump, Main switchboard, E.R. Alarm panel, Spark arrester type silencers, Remote operated skylights (no glass).

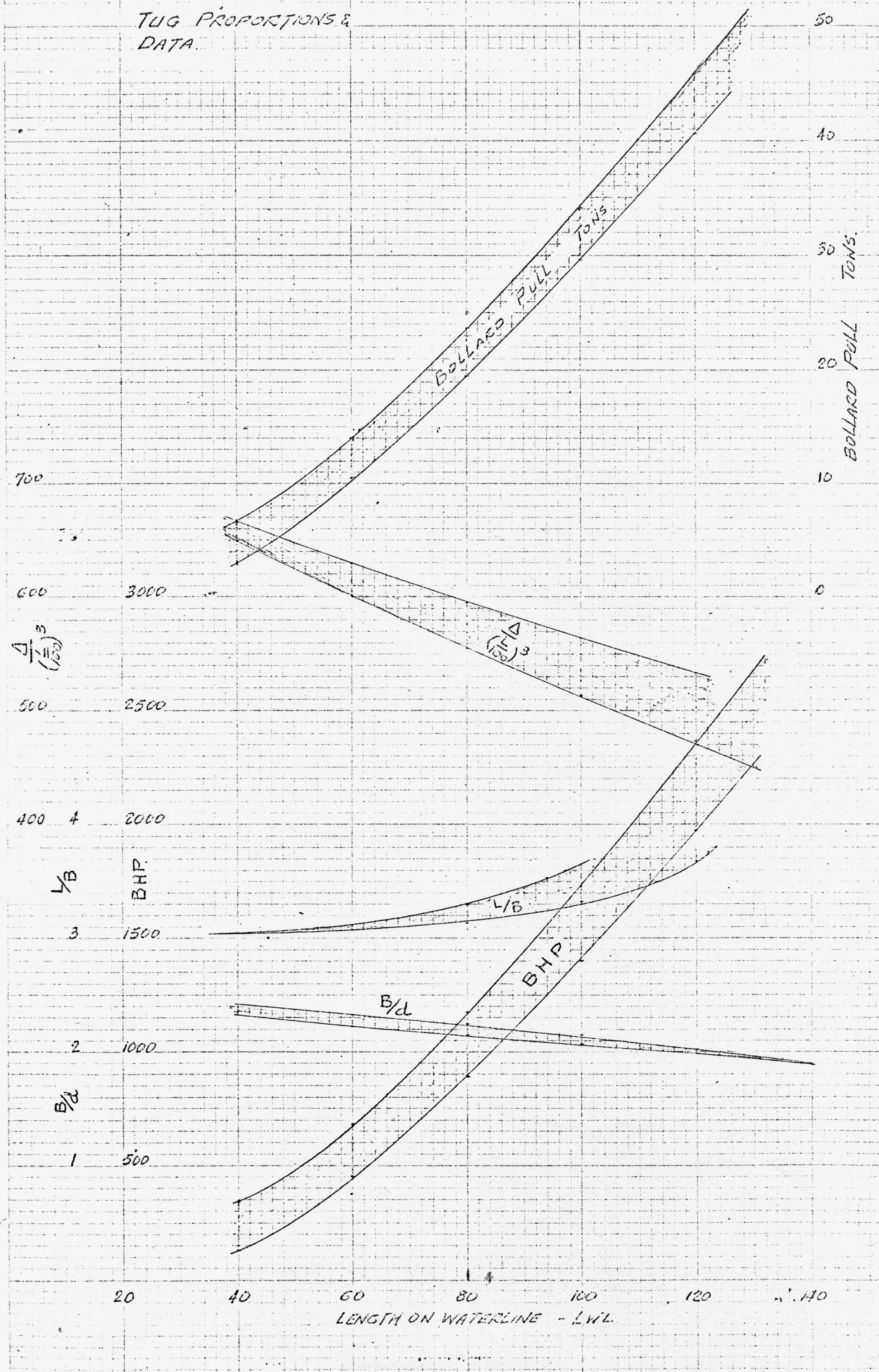
One final point - the ventilation to all engine rooms should be such that 150% of the air requirement of all "air breathing" machinery is available under "fully battened down" conditions;

Failure to attend to this item can result in death to the engine room crew, due to partial evacuation of the engine room air by turbo-charger suction if insufficient ventilation is available. Lack of sufficient ventilation can cause machinery to starve - hence to lose power - as well as causing the engine room to become overheated - once again resulting in a serious power loss which may be sufficient to cause the vessel to fail to meet contract requirements.

If the vessel is required to carry out firefighting or water carrying duties additional pumps will be necessary for these s rvices, and, in addition, for firefighting duties, a foam tank with suitable foam proportioning equipment will be required to handle oil fires. Foam compound is very corrosive andspecial care is necessary in constructing tanks to contain it. Pressure/vacuum relief valves are essential, and tanks are frequently lined with G.R.P. materials. Foam/water monitors should be installed above bridge level and hose points on the main deck. Hoses should also be connected to both water and foam systems. Hose holders, bulwark mounted, are very desirable.

If potable water is to be carried for sale, the system should be completely independent of all other piping systems on board, so as to avoid possible contamination. If large bore hose

/18.


TUG PROPORTIONS & DATA.
BOLLARD PULL TONS
$\frac{\Delta}{(L/100)^3}$
L/B
BHP
B/d
700
600
500
400
4
3
2
1
3000
2500
2000
1500
1000
500
50
40
30
20
10
0
BOLLARD PULL TONS.
20
40
60
80
100
120
140
LENGTH ON WATERLINE - LWL

for discharge to other vessels is required a small derrick or crane is necessary to handle this, and it should be mounted forward of the tow hook.

Lifeboats are not fitted to harbour tugs, liferafts being substituted, but lifebuoys and lifejackets are still required. In ports where oil storage areas exist it is wise to do away with the "Holmes" light on lifebuoys and substitute an electrically operated light which will not ignite oil on the water, nor will it burn the man using the gear, which a pyrotechnic type light may do.

We are now ready to proceed to the determination of dimensions. Analysis of a large number of tugs - diesel powered - shows that their proportions lie generally within the shaded areas shown, and this will enable a preliminary set of dimensions and displacement to be taken out to suit a required pull. Obviously one must not hope to beat all records if a pull (say) of 30 tons is desired from a minimum size of tug then the tug must be about 92'-0" in waterline length and will need not less than 1500 installed SHP, this being measured at the gearbox output coupling NOT AT THE ENGINE.
Gearboxes may be reckoned to have an efficiency of about 0.95 hence the engine power would need to be a minimum of 1580 BHP. Since we are looking for maximum output we must provide a generous hull capacity, so we may expect a displacement of about 450 tons, the $\frac{\Delta}{(\frac{L}{100})^3}$ ratio being 577

Similarly the L/B ratio must be about 3.50 giving the vessel a beam of 26.3 feet and B/d ratio will be about 2.1, hence the moulded draft would be 12.5 feet. Tugs are usually assigned loadlines very close to 0.85D so we could reasonably assume a moulded depth of about 14.75 feet. These proportions will produce

/19. a block.

a block coefficient of 0.52. A prismatic coefficient of 0.6 used with the previously determined dimensions would give a midship section coefficient of 0.87 so producing a submerged midship section area of 236 sq. feet.

A check on weights of steel, outfit and machinery will show how much displacement is left to accommodate fuel, stores, crew and ballast. Ballast (in the form of water) is most useful as the vessel needs to take advantage of the kinetic energy equation $E=\frac{1}{2}mv^2$ when working. Since speeds will be low, mass must be high.

The principal point now to be settled is propeller diameter. The loading of a screw cannot be carried far beyond 0.25 to 0.26 ton/sq. foot of disc area, hence, for this tug at 30 tons pull a disc area of 120 sq. ft., is necessary - so the propeller diameter must be 12.35 feet. Add to this a minimum of 3" clearance at the blade bottom tips, and arrange to keep the upper tips nicely below water by making the draft aft about 1.2 x prop diameter and we have a draft aft of 14.8'. We now have a rake of keel of 2(14.8 - 12.50) = 4.6ft., and a centre line of shaft fixed at $\frac{1}{2}$(12.35)+3"+thickness of sole piece and proportion of rake of keel above the maximum draft. The propeller post will usually be about 1/10L from aft, so we may set the centreline of shaft at 6.17' + 0.25' + 0.33' + 0.46 = 7.21' (say 7'3") above the maximum draft line.

The depth of the bottom tanks is determined by the required fuel capacity, and it has been found most undesirable to continue these tanks across the centreline under the engine. It is usual to make the engine girders the oiltight tank boundary leaving a clear well between girders for the engine sump. The height of floors across the centreline may be determined from

/20. Classificatio

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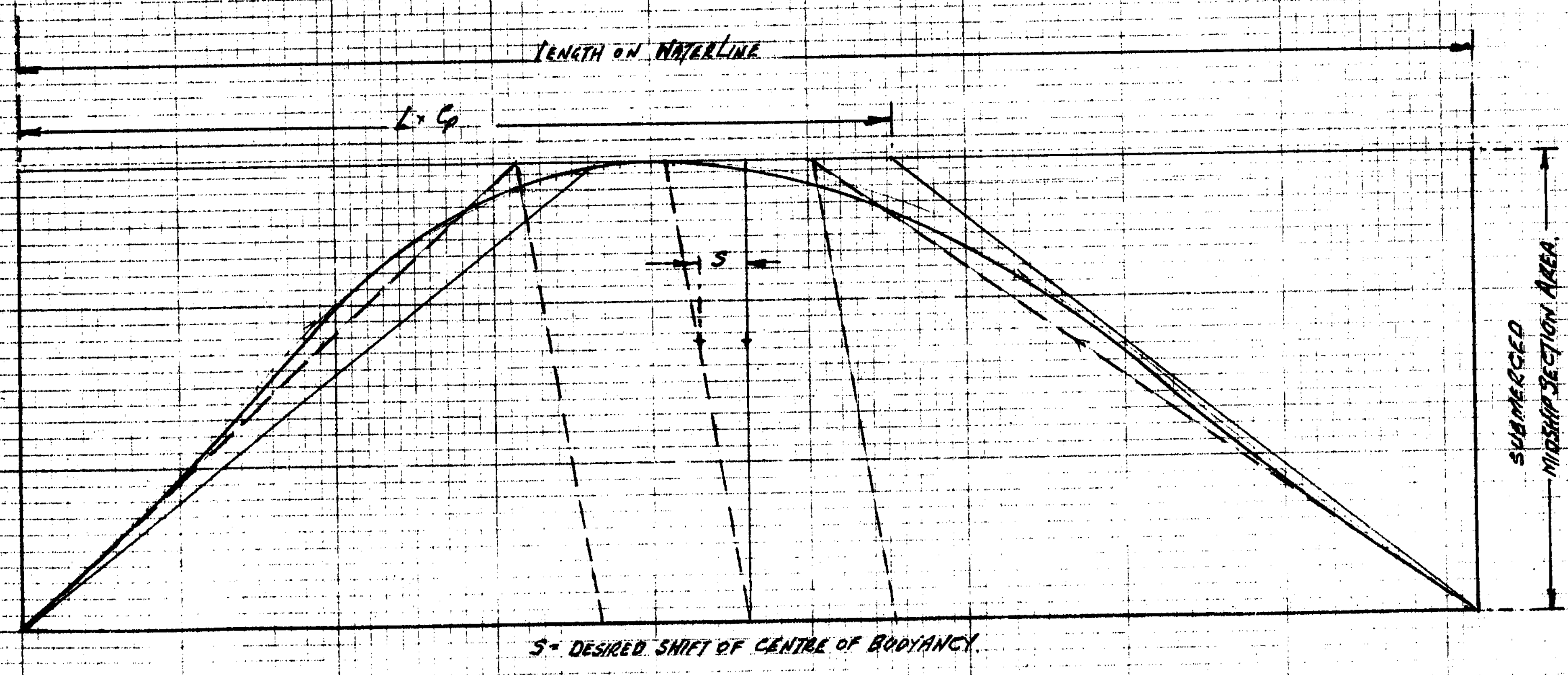
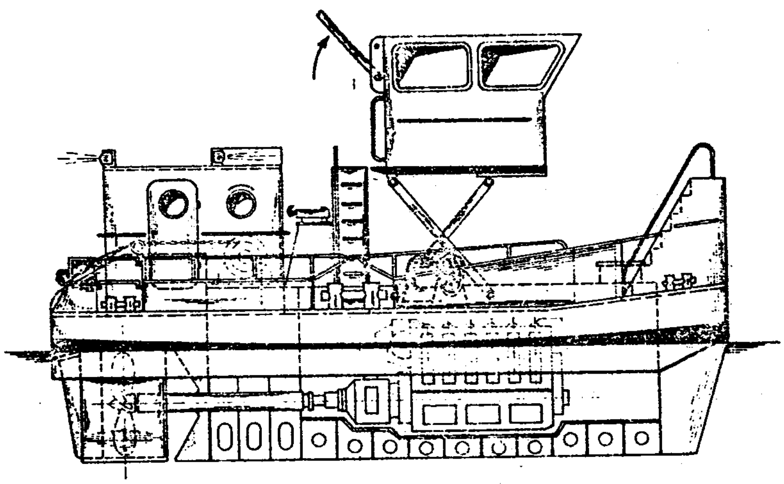
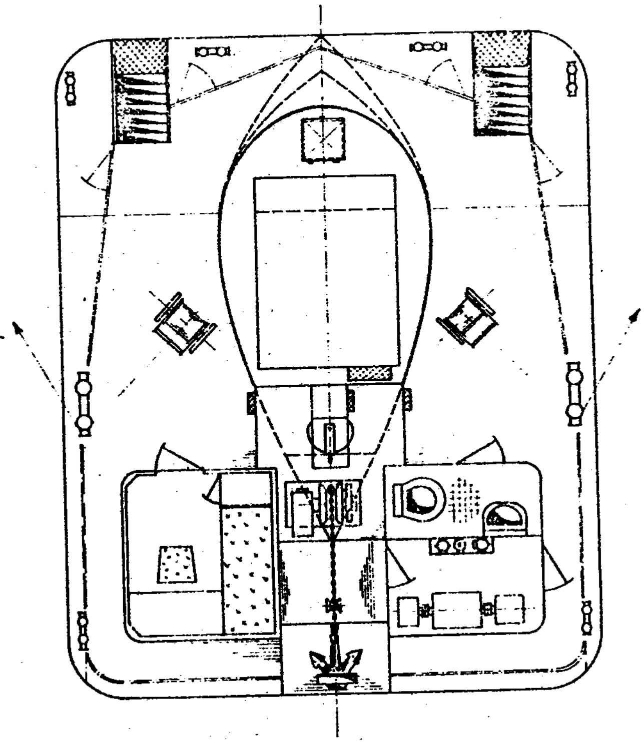
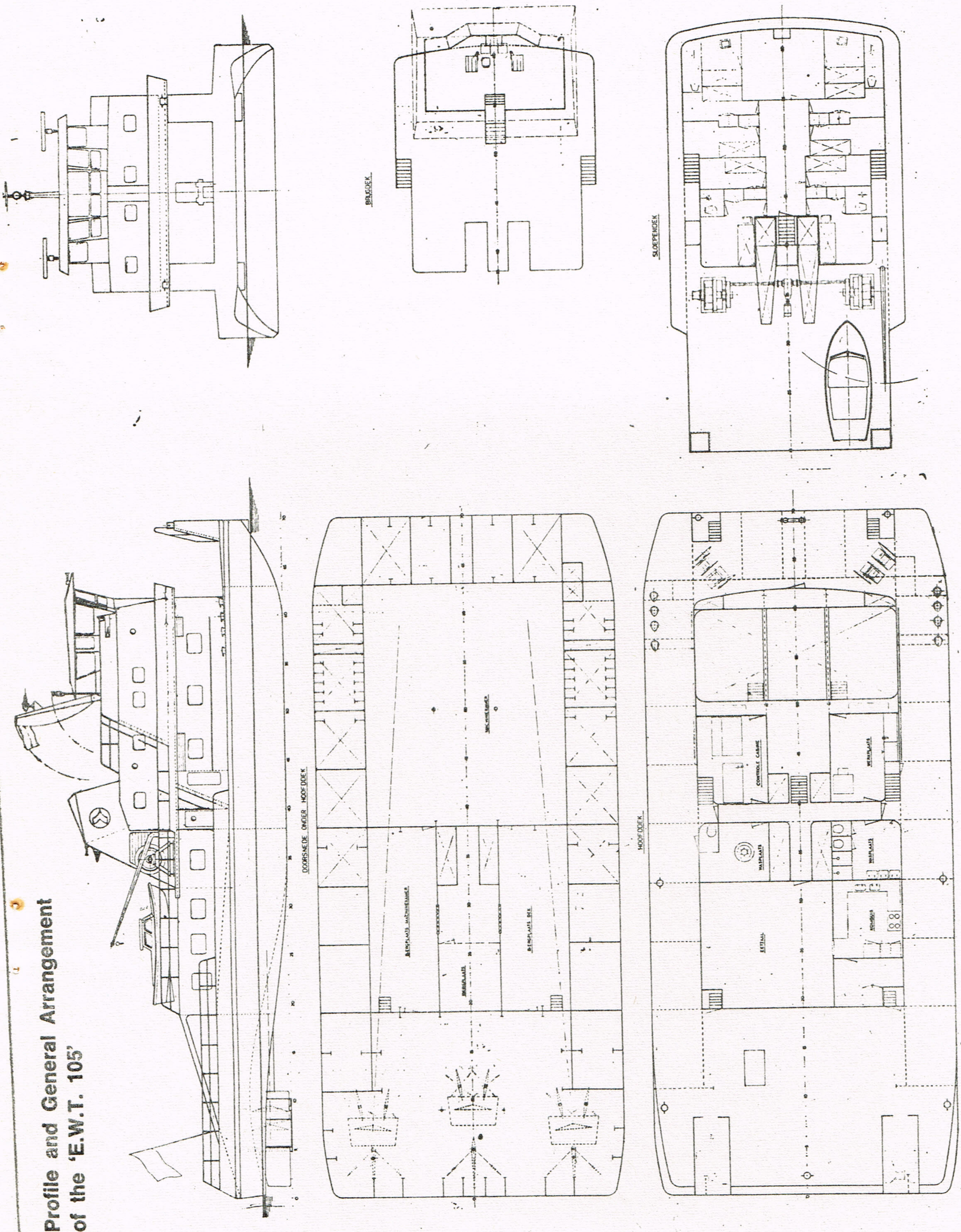

LENGTH ON WATERLINE
L × Cp
S
SUBMERGED
MIDSHIP SECTION AREA.
S = DESIRED SHIFT OF CENTRE OF BUOYANCY.







Profile and General Arrangement of the 'E.W.T. 105'

Classification Society rules, and this height, together with the height of the engine crankshaft centreline above the gearbox sump plus a clearance of about 3" will determine the run of the propeller shafting.

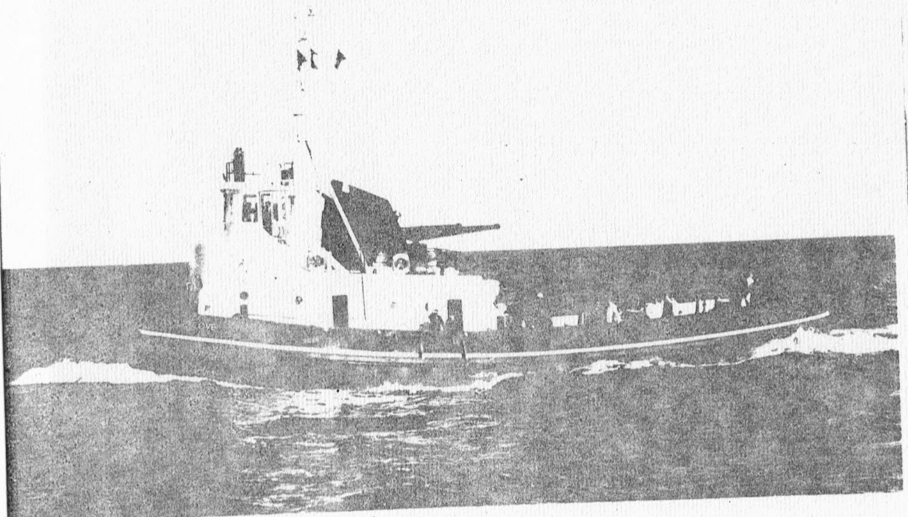
The longitudinal disposition of the displacement may be made in the usual manner indicated in this figure, with which I am sure you are all familiar.

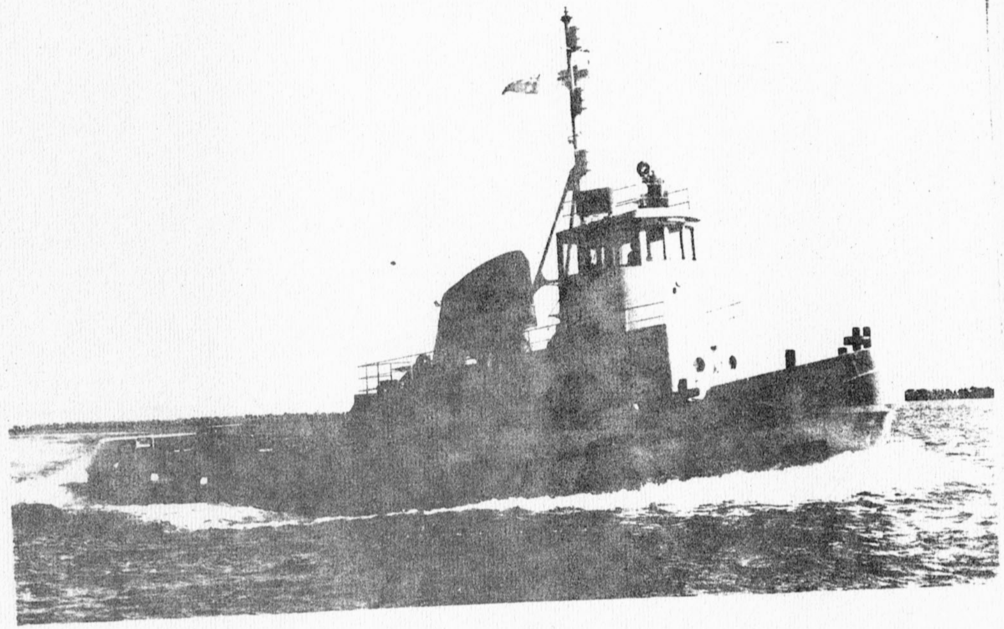
Pusher tugs, known in America as "Towboats" are rather different in appearance. They are intended to form the rearmost unit of a close coupled tug/barge train, and do not have a normal "ship shaped" forward end. This end is usually quite blunt and square and because the mid-section area is carried right forward the tug is short, and some are very short in fact. The wheelhouse is situated right forward with only a very narrow walkway forward of it, so that mooring operations to the barge may be carried out. The object of the exercise here is to make the tug and barge act as one hydrodynamic unit, so they must be designed together.

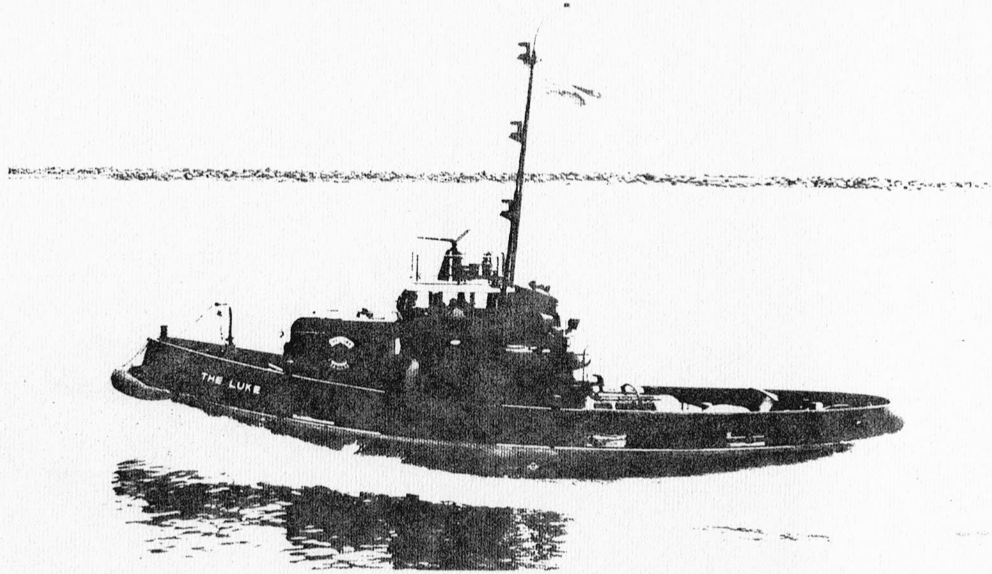
Characteristic of these vessels is a rather high, very strong tower at the port and starboard forward corners - and these act in the same manner as the overriders on the fenders of a car. These vessels do not have a towhook.

When running free between jobs these pusher tugs are most ungainly and are quite inefficient, but they are not designed to run free for any distance. They are in fact, little more than a floating and removable engine room. It is usual to design these vessels for a specific duty, and they frequently have a number of barge trains for each pusher tug, so that while one set is in transit another is discharging and a third is loading. The machinery is thus used to the maximum practicable extent.

Tugs



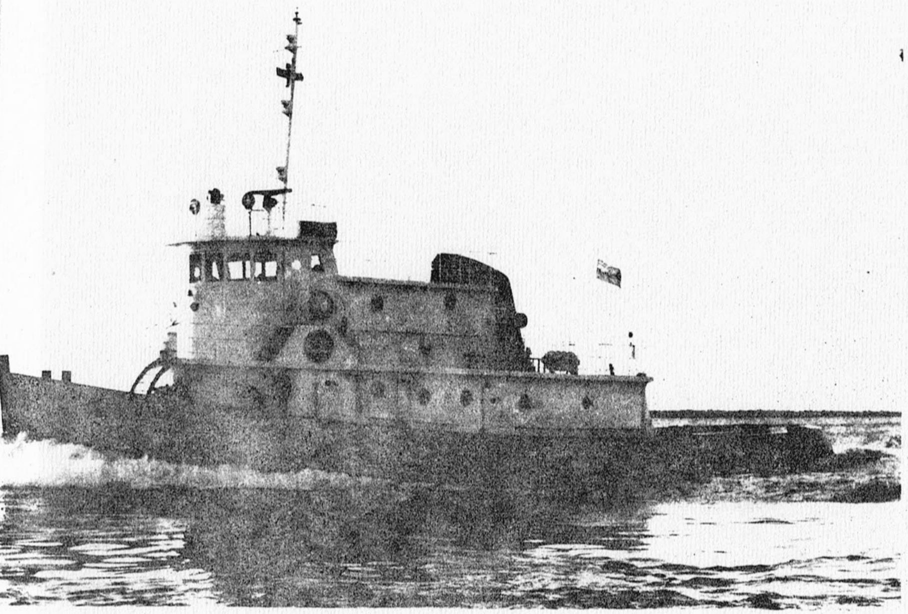


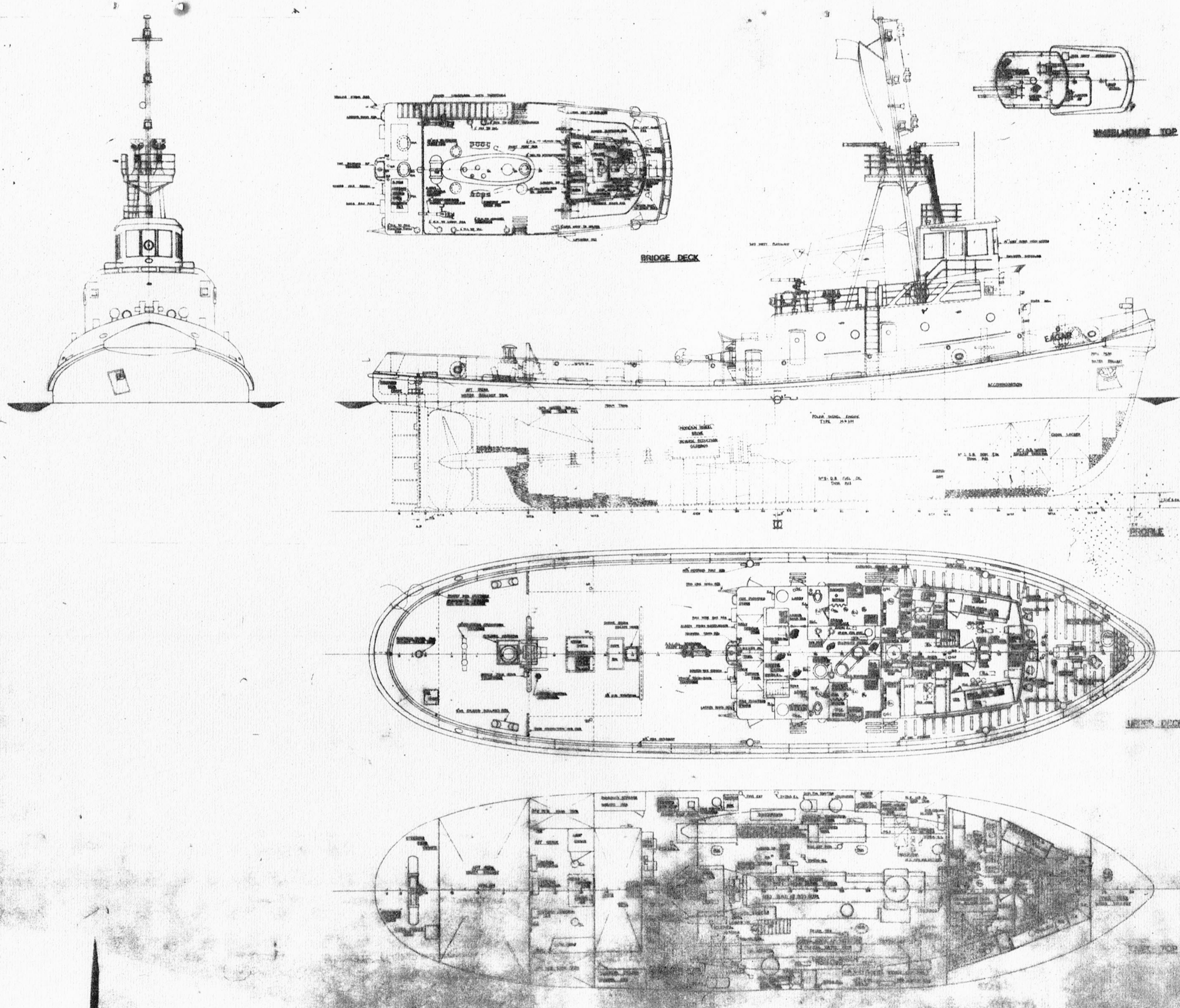


Dep[illegible] Co[illegible] Tug

Aus[illegible] Bu[illegible] To Amer[illegible]

D[illegible] Deckhouses.




WHEELHOUSE TOP
BRIDGE DECK
PROFILE
UPPER DECK

Push tugs have virually no sheer forward, and very little aft. Their freeboard is determined by the design of the barges they handle and the necessity for good vision in all directions. Those which handle large barges have quite powerful winches on the corners of the foredeck so that they may be hove up tightly to the barges.

Where very high barges, or very long barge trains have to be handled it is sometimes found expedient to fit these towboats with elevating wheelhouses (usually hydraulically operated) for improved visibility. Their own mooring arrangements are simple, usually a pair of bollards at each end suffices.

COASTAL AND ESTUARY TUGS

(A) Pulling Type

These tugs are designed to operate outside harbour limits on short voyages. The word "short" here indicates non-international voyages, and any long open sea passages such as Melbourne to Perth would be completed fairly close into the coast.

These ships may be required to operate 24 hours a day for several days at a time. They must, therefore, have provision for three watches. Economies in manpower can be effected by arranging for partially unmanned operation of the engineroom, and this will be reflected in fewer cabins, a smaller galley and mess rooms, smaller lifesaving appliances, and a smaller wages bill. It is usual for these tugs to carry a Master, two Mates, a Chief Engineer and one other engineer, a dayman greaser, three seamen and a cook. The wireless is usually of the radio-phone type requiring only a class 3 licence and most tug masters and officers have this qualification. When operating in harbour as a harbour tug these vessels are manned in the same manner as other harbour tugs. Cabins for the crew are usually two berthed, the Master and Chief Engineer frequently having a single berth cabin.

/22. Stores,

Stores, both edible and mechanical require much more room than in Type 1 tugs and it is essential that they be available without the necessity for going out on the open deck. For this reason a gas tight door is frequently fitted leading from the accommodation (forward) into the engine room, and another from the aft end of the engine room into the bosuns store aft. Since this store usually gives access to the stern gland, the engineer is thereby saved the necessity of going on deck to reach this gland space. This arrangement gives "under deck access" to almost the whole of the ship except the forepeak and steering flat.

Larger bunker tanks and domestic fresh water tanks are necessary than are required in harbour tugs, and the pipe ranges are generally a little greater in diameter to allow for quicker filling. In all cases the air pipes to tanks must have an area equal to at least 1½ times the area of the filling pipe - and air pipes to oil tanks must be fitted with a protected flameproof gauze.

In such cases the vent area is calculated on the area of the holes in the gauze - not on that of the pipe itself. To achieve this area the gauze is made in the conical form of a dunce's cap. Combined sounding and air pipes are not usually allowed. Air pipes must be fitted with a cover which will open to small internal pressures and close to external pressure. The long familiar wood plug and canvas cover is no longer acceptable. Means of closure must be permanently attached to the pipe.

Internal access to the wheelhouse is frequently provided, in which case the access hatch must be fitted with a weathertight cover, or the wheelhouse windows with storm covers, either of which may be positioned if the glass is broken. Shatterproof glass is required in the front windows at least, but it is usually fitted at the sides as well.

/23. Doors

Doors to the deckhouse and engine room must be weathertight - this word meaning that, in any conditions of the sea, water will not penetrate inwards through the closed door - in the case of a watertight door the passage of water in both directions through the door is prevented.

Navigational aids are a little more complex. In some echo-sounders are fitted, while radar is almost invariably present. Radio direction finders are unusual in this type of tug. Some are fitted with an auto-pilot, and some of these work from a gyro compass, while others are actuated by the magnetic compass. One magnetic compass, with inverted reading from the sheelhouse, is usually fitted and a spare bowl must be carried. Bridge control of the main machinery is usual. Either clear view screens or marine type "straight line" window wipers are fitted. It is desirable to fit a fresh water jet in front of a window having a wiper, as salt spray leaves the windows encrusted and that plays havoc with wiper blades. A navigation light alarm panel is required having double sources of supply, and an emergency source of power situated above the bulkhead deck, and outside the engine room is mandatory. A morse light is fitted at the masthead and this is connected to the whistle pull - so that both visual and audible warnings of intended manoeuvres are given simultaneously. This is important, since priority of giving warning does, in some cases, confer priority of action. A full set of signal flags is carried - a total of 41 flags which includes 26 letters, 10 numbers, one answering pennant, three substitutes and an ensign.

A word about signals. Today these are made in "hoists" a hoist consisting of one, two, three or four flags. (The one flag hoists are the emergency signals, the two flag hoists are the navigational signals, three flag hoists are meteorological signals or derived signals, and four flag hoists are conversational signals -

all of these being coded. In a case where a code group such as "ABBA" is required it is necessary to use two of the three substitute flags - the signal hoisted being A,B, second substitute, first substitute, which means "AB, repeat second letter, repeat first letter.") By the very simple device of carrying the first second and third substitute pennants, the 41 flags become the equivalent of one hundred and forty six flags which would otherwise need to be carried.

The mast should be of sufficient height to display the signal flags - bearing in mind that each has a tail line about three feet in length. Hence if the signal flags are 3'-6" by 2'-6", a four flag hoist requires 23 feet 6 inches of height between the highest obstruction and the yard arm to fully display them. These tugs must carry three lights on the mast, and the lowes of these must not be obstructed by any object or person standing on the wheelhouse top - it must therefore be about 7 feet above this level. The spacing of these lights is 6 feet, and that used as the steaming light when running free must be a height above the hull equal to the beam of the ship. It follows that the space required to fit the lights will be about 19 feet minimum. For these reasons it is usual to fit the signal yard under the topmost light. All navigation lights must be either duplex electric or a spare set must be carried. Oil lamps are no longer mandatory.

In order to keep the decks as dry as possible these vessels are given more generous sheer forward than most ships. Standard sheer forward expressed in inches is 0.2L + 20", where L is the length in feet. So a 100ft. ship would have a standard sheer of 40 ins. A tug may have this increased by 50%. It is also usual to fit storm boards adjacent to the forward end of the deckhouse - and these should be abaft a freeing port and forward

/25 of the

of the entrance doors. Freeing ports forward should not be fitted with doors, but, due to the low freeboard and flat sheer aft it is sometimes thought desirable to fit doors to the after freeing ports, as this assists in preventing the water swilling over the deck when a wave of height between deck and bulwark rail sweeps along the side. Doors to the freeing ports may not have securing devices, and consequently are likely to bang about in a seaway.

These tugs are sometimes fitted with a towing bollard as well as a hook, and the hook must be fitted with some means of restraint to prevent it swinging wildly at sea. This may be in the form of lashings, or of a permanent stowage position in which it is locked, or, by a more recent invention, an hydraulic damper and brake device may be fitted. Other than this, there is very little difference between a harbour tug and an estuary or coastal tug as far as deck arrangement is concerned.

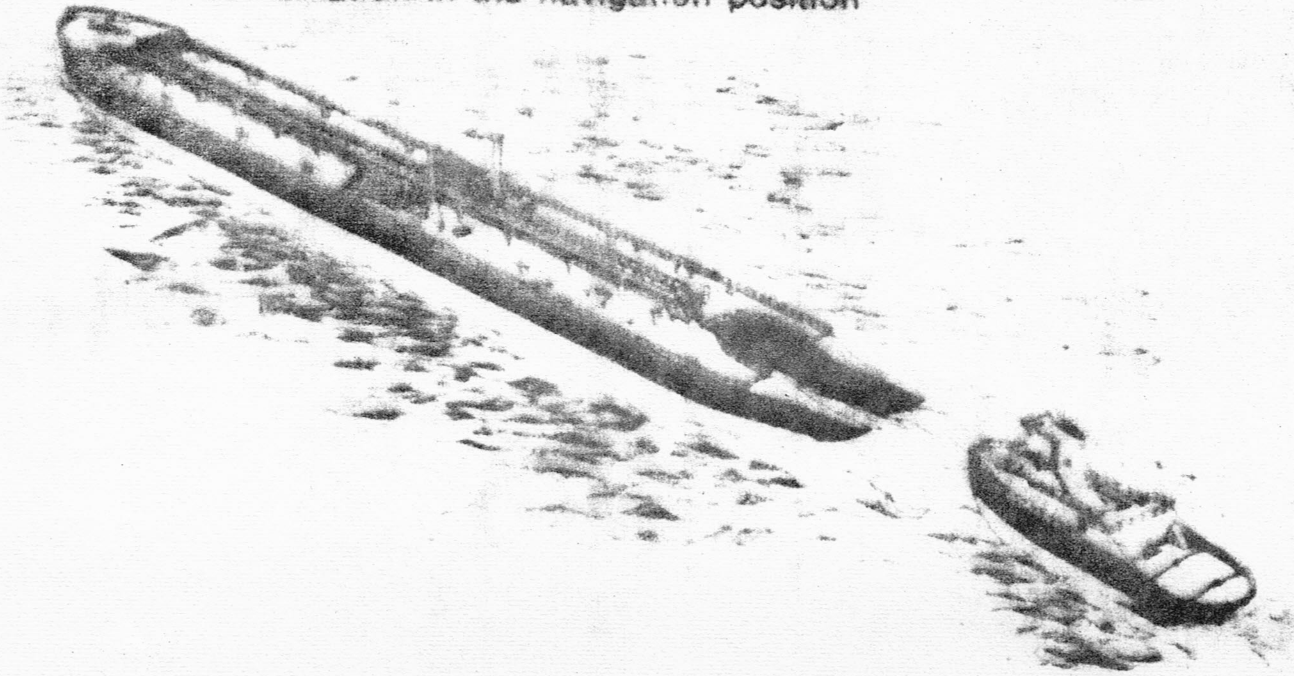
In the engine room we usually find two electric generators either one of which can sustain the full electrical load, and an oily water separator is mandatory. This then involves the installation of a sludge pump and sludge tank. A calorifier is fitted to provide hot water for domestic use and it is desirable to fit a cold fresh water tap in the engine room - Calwell remarks that engineers occasionally drink water!! Fuel oil and lub oil purifiers are frequently fitted and pressurised domestic water systems. Sufficient fresh water can usually be carried to permit use of this commodity for showers and toilet use as well as for drinking and cooking.

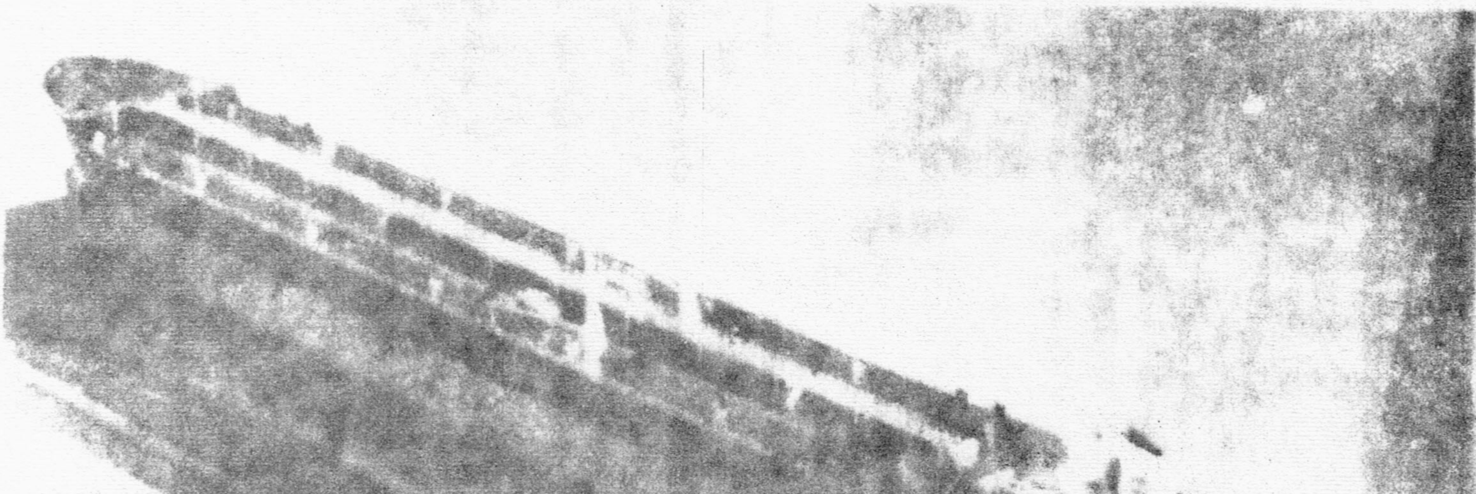
(B) <u>Pusher Types</u>.

The coastal tug of the pusher type is nothing like its harbour counterpart. It is, in fact, a seagoing ship in its own right, but has a rather rounder stemhead.

NEW INTERSTATE TUG: The 136-foot tug M/V Navigator (shown above) was recently delivered to Interstate Oil Transport Company of Philadelphia. Designed and built by Main Iron Works, Inc. of Houma, La., the new tug will push or tow Inter-Cities Navigation Corporation's 261,000-barrel-capacity barge Ocean Cities between Gulf and East Coast ports. Powered by twin EMD 16-645E5 diesels with Falk reduction gears, the 5,750-hp twin-screw Navigator is classed ABS Maltese Cross A-1, Ocean Service. Her dimensions are 136 feet 6 inches by 36 feet 2 inches by 19 feet. Electric power is supplied by two Detroit diesel 75-kw generators. She is equipped with a Markey towing winch. The tug has comfortable accommodations for 11 men, and is air-conditioned by Carrier. A unique feature is an elevator between upper and lower pilothouses.

Artist's impression (top) of the ocean-going barge and tug and (below) a model of the combination in the navigation position





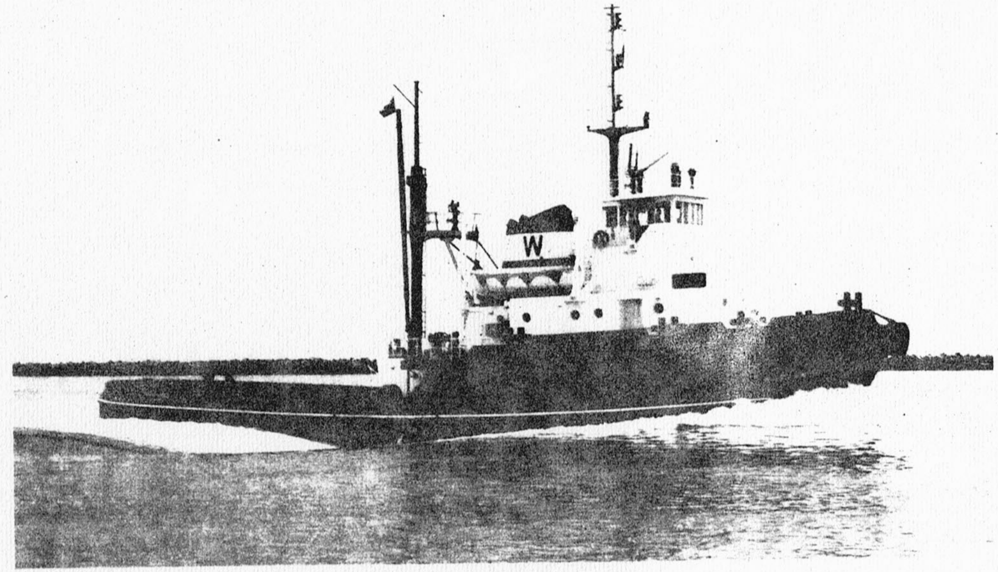
Otherwise there is not very much to distinguish it at first glance from a pulling type. However, on second looks we find that it has no towhook, but it fitted with a towing winch and/or a powerful capstan aft, they very frequently have either raised or elevating type wheelhouses, and there is a good deal of very heavy fendering forward.

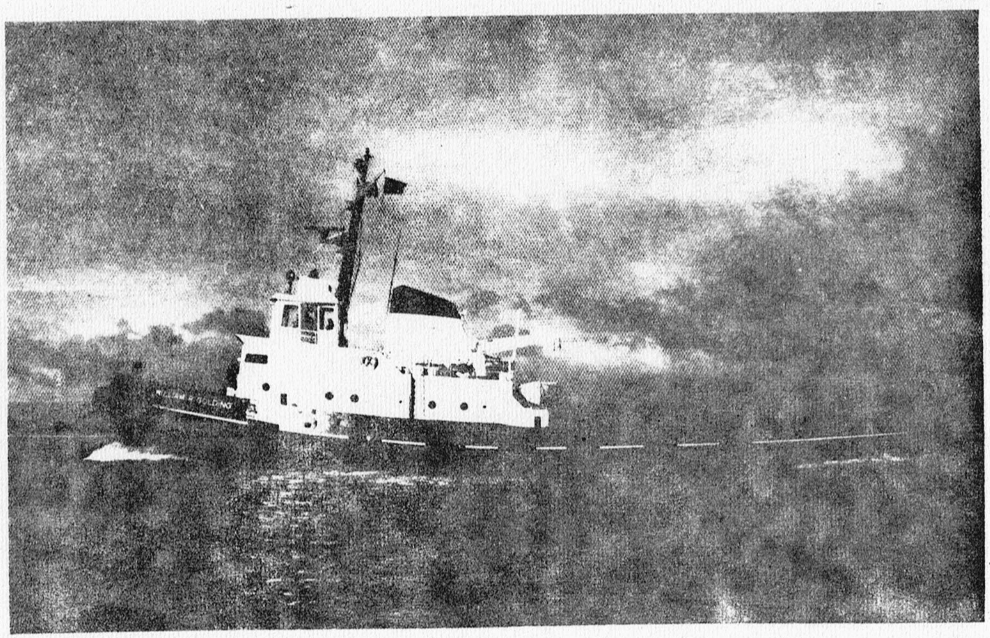
The barges which these tugs push have a notch built into their stern ends, into which the bow of the tug is placed. The tug is then hove up tightly and made fast with heavy wire hawsers. Natually, in a seaway there is some relative motion between the barge and tug, hence the fendering. In order to impart directional control, wires are carried aft on the tug from the barge, and then broughtback to the capstan where they are set up tight. Great care is necessary to see that wires do not chafe or stretch as the tug and barge may collide violently if any slackness develops.

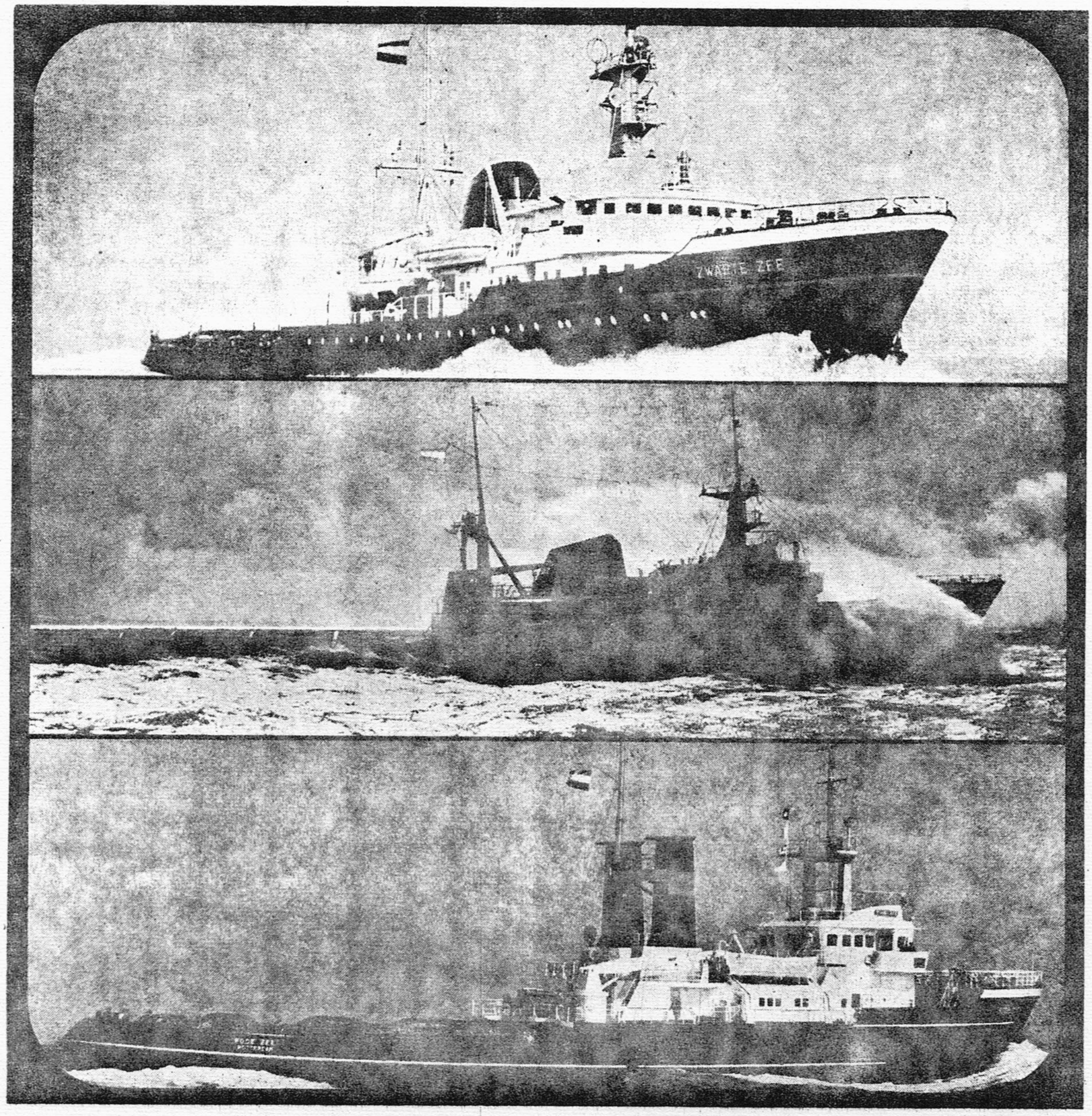
One of a number of recent developments in the connection of pusher tugs and barges is the Sea-Link System, in which the connection is made by a series of hinged rigid members, which are normally carried by the tug in a raised position (looking rather like a praying mantis about to strike) and these are dropped on to prepared fixing points on the barge when connection is made. By this means the two vessels are kept out of contact, but the designers claim relative freedom of motion between them while the barge is kept under complete directional control.

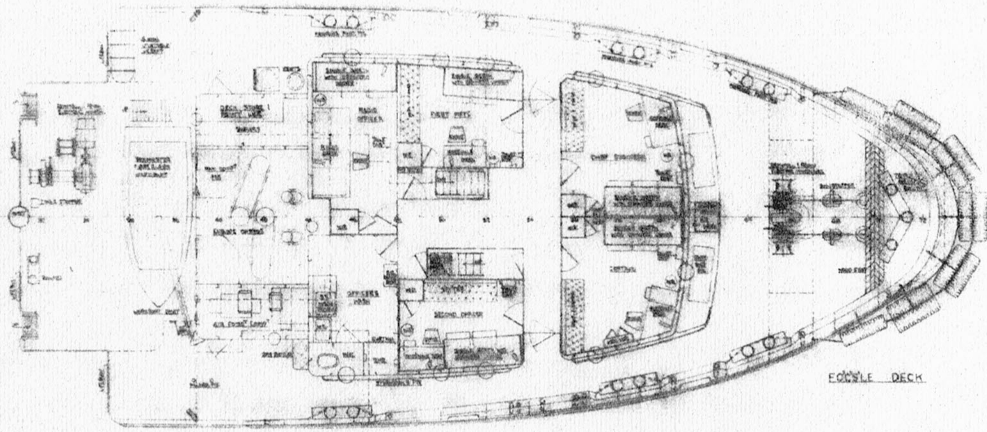
The advantages of push towing as compared to pull towing are; a greater degree of control of the dumb vessel, less weighty equipment, and less chafe on ropes etc. There is no need to shorten up on a long ocean towline when entering a busy waterway or harbour and hence a smaller deck crew is required. In areas of heavy seagoing traffic it is clearly impracticable to have a large barge yawing about on the end of a long line. The close

Ocean Going Tugs.

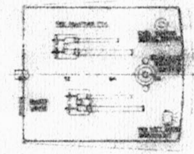




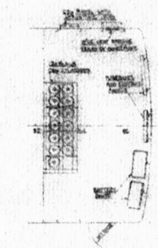




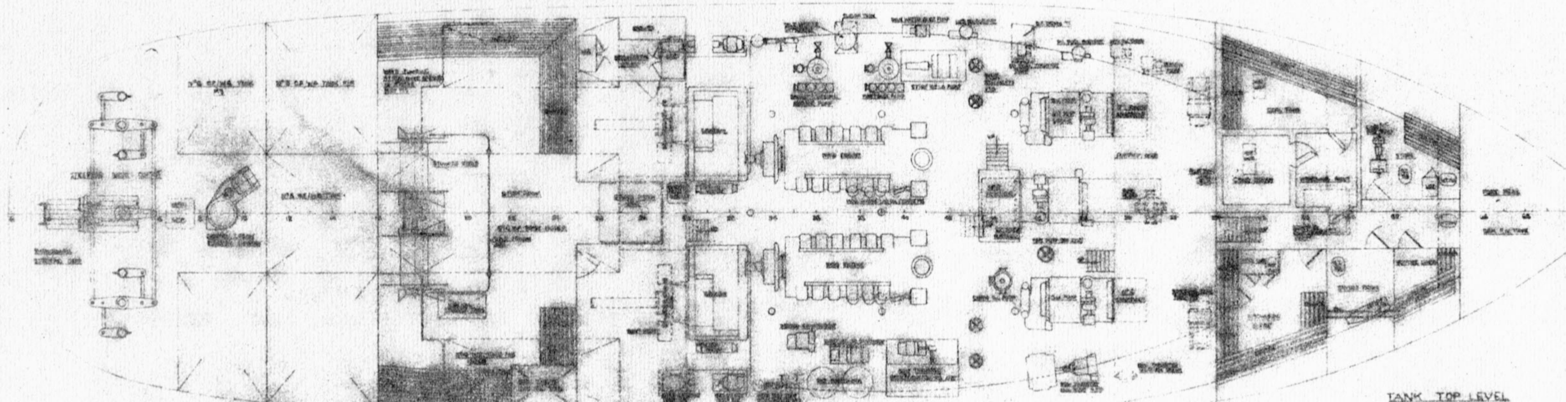
FO'C'SLE DECK



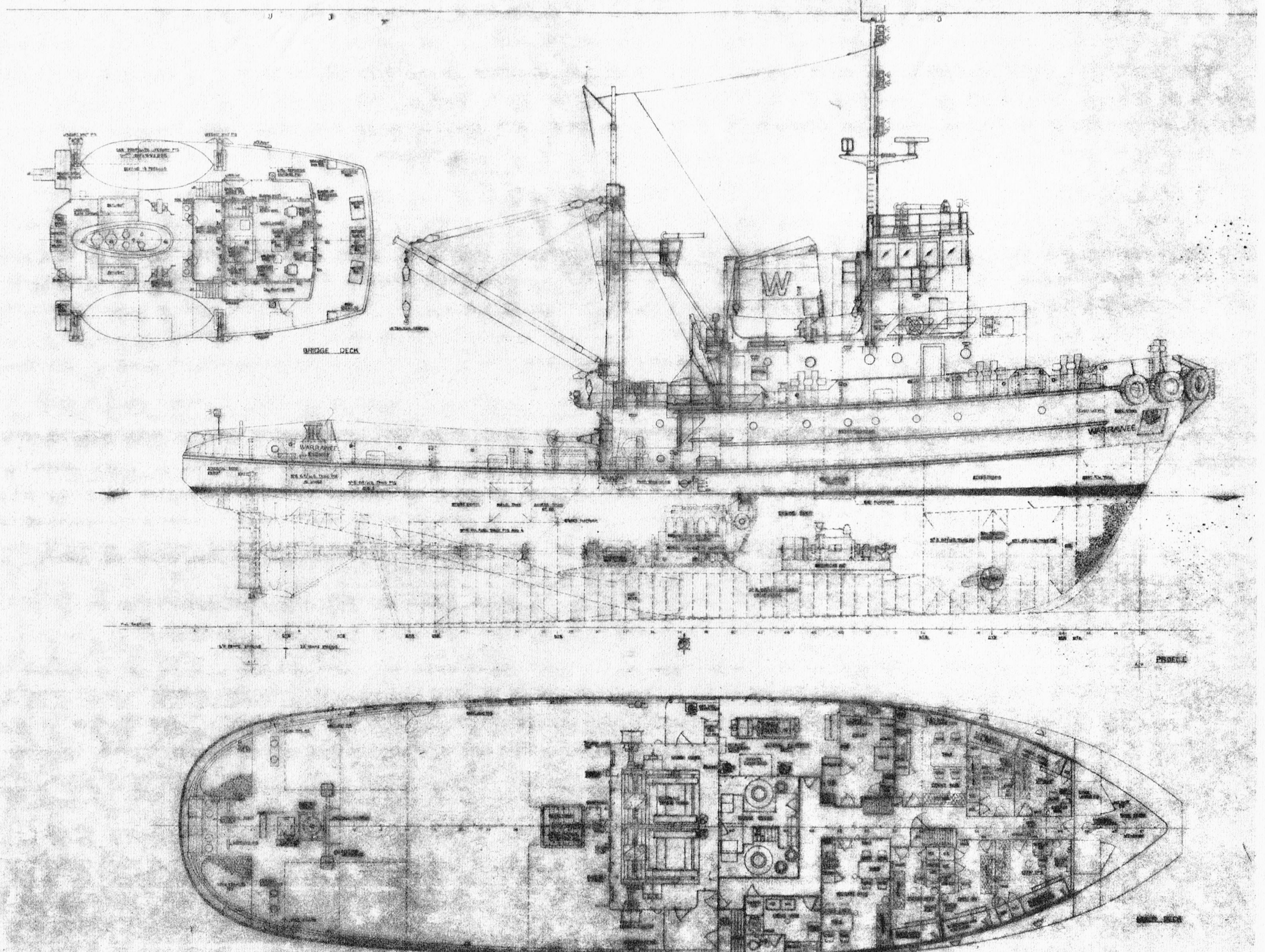
WHEELHOUSE TOP



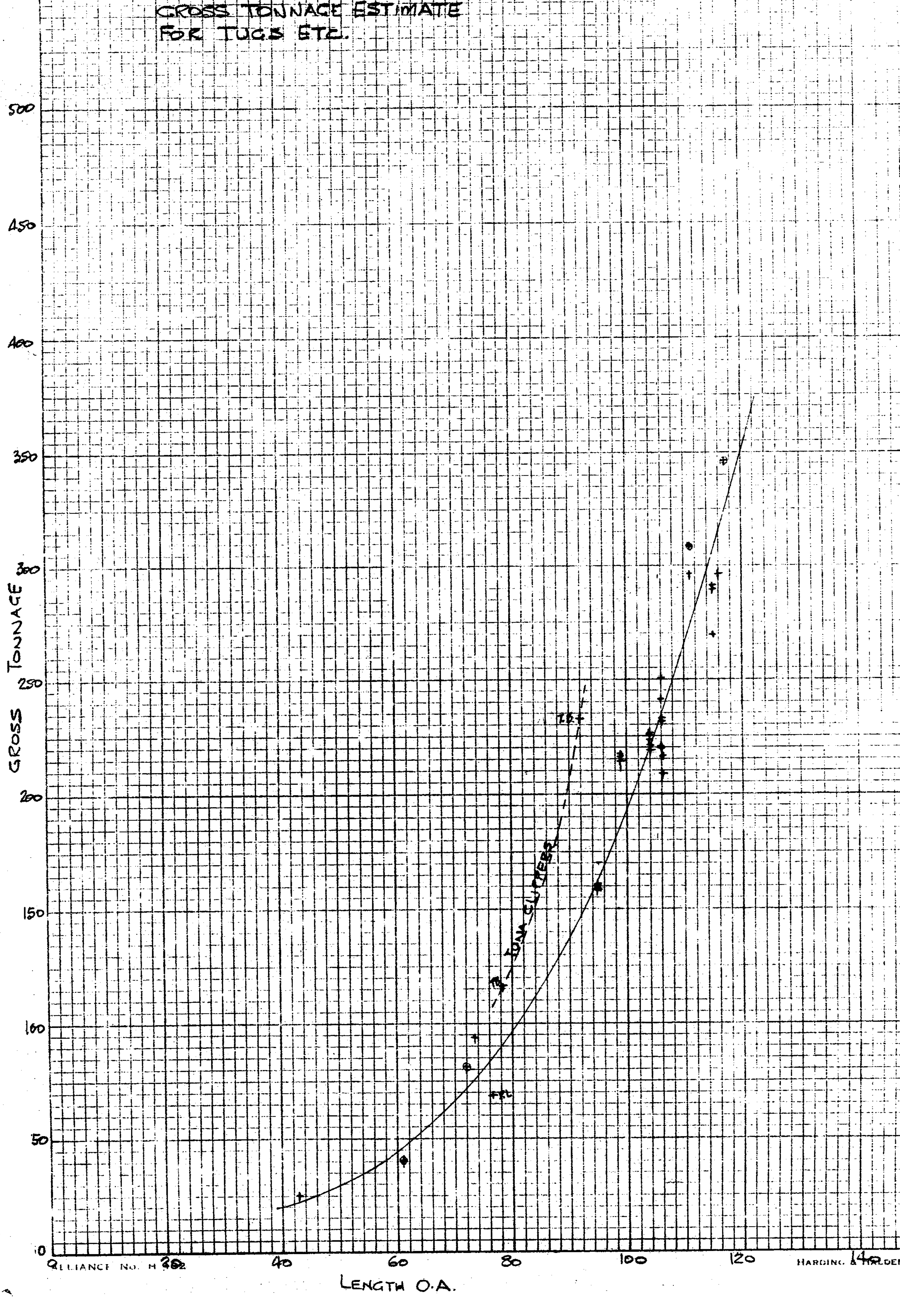
CO2 ROOM



TANK TOP LEVEL



BRIDGE DECK
WARRANEE
W
PROFILE



GROSS TONNAGE ESTIMATE
FOR TUGS ETC.
GROSS TONNAGE
500
450
400
350
300
250
200
150
100
50
0
30
40
60
80
100
120
140
LENGTH O.A.
IONA CLIPPERS

proximity of barge and tug causes them to tend to act as a single hydromatic unit, thus cutting down on the wavemaking resistance (which can be 60% of total resistance at or near the economical speed for each vessel alone.). Another small saving (but one which multiplies where a fleet is concerned) is that only the tug needs to carry navigation lights and associated power source and this is suprisingly expensive. Finally there is ready access to the barge without the necessity to launch a boat and make a difficult ascent over the side of the barge. It is natural that one only needs to do this in the heaviest of weather.

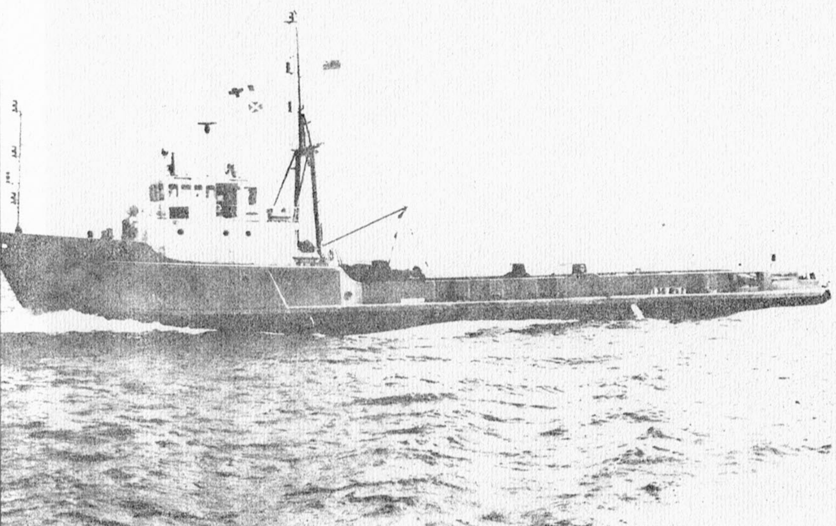
OCEAN GOING TUGS

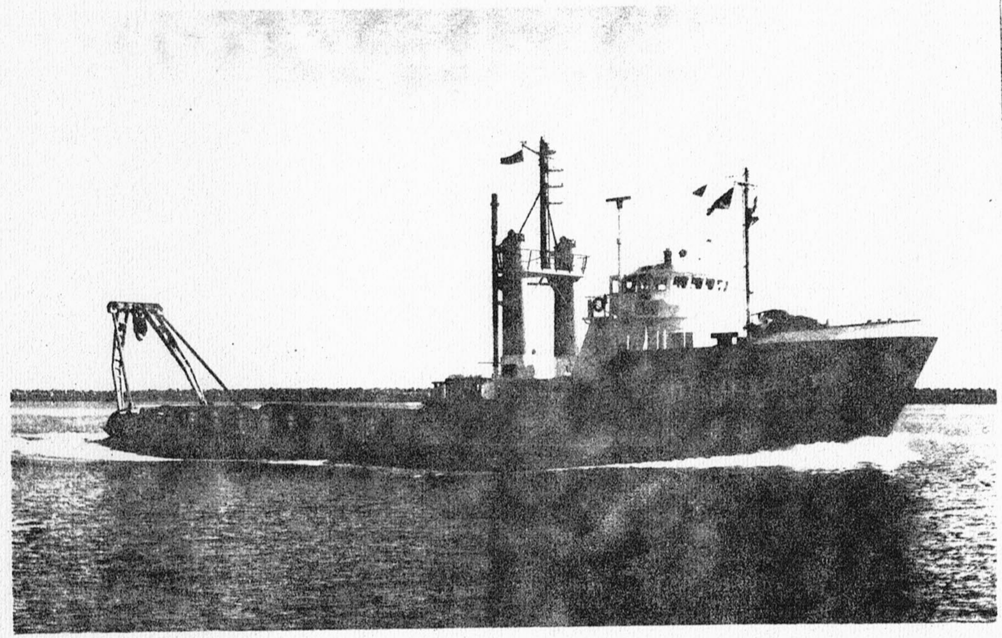
(A) Pulling Types

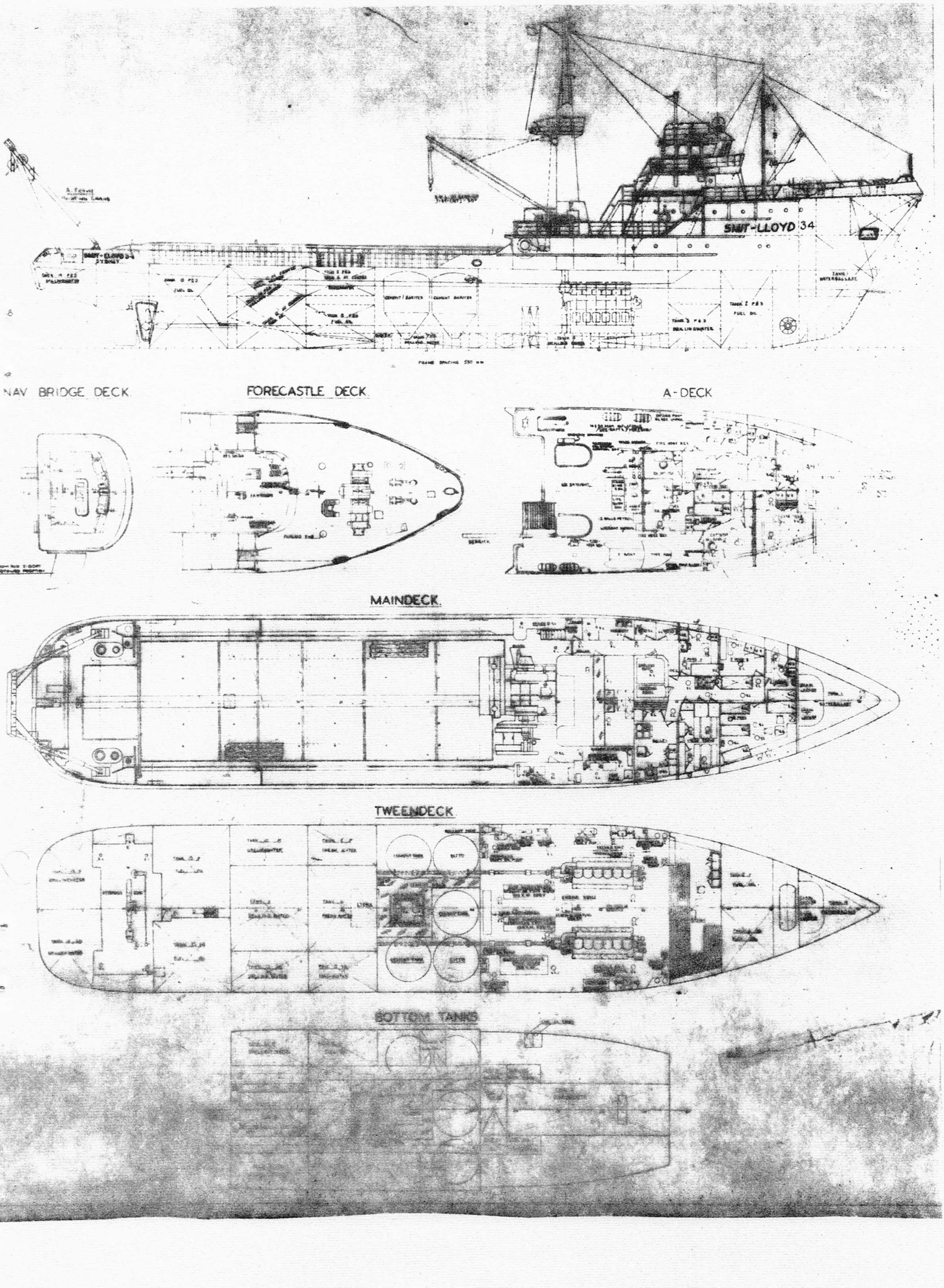
In this group we meet with the greatest variety of craft. In general these are the largest of tugs and the most powerful. They require long endurance at high power, and exceptional sea keeping qualities. It is not so frequently necessary to handle lines from end to end - and in any case the majority of the lines are too heavy to be manhandled - and so to provide adequate accommodation space, and good seakeeping qualities, they are fitted with long forecastles, generally extending aft to the area around the towhook. These vessels are adequately described as small, sturdy, powerful seagoing ships.

The crew requirements are determined with an eye to operational requirement, and also to the tonnage of the tug. Each watch on these vessels typically consists of one deck officer and either two or three seamen, an engineer officer and a greaser. Together with the Master, Chief Engineer, and the boatswain, this may mean a complement of up to 28 men - which, of course, may be reduced on short voyages. It is common in some trades to carry a number (usually up to 12) of "runners". These are men whose duty

Tug-[illegible] Vessels.






SMIT-LLOYD 34
NAV BRIDGE DECK
FORECASTLE DECK
A-DECK
MAINDECK
TWEENDECK
BOTTOM TANKS

it is to man the vessel being towed - in order to tend the towing gear and the navigation lights etc., and to have enough men on board to anchor if the tow should be lost - thereby saving on possibly very heavy salvage claims. In certain other trades, e.g. the oil rig supply trade, it is usual to carry up to 12 passengers these being relief crew for the rig being serviced. Hence the necessity for the long focsle to provide space for all these persons.

In these vessels a crew's recreation room is sometimes fitted in addition to the messroom, and a Master's and a Chief Engineer's office are usual. Other items usually found on board are a well equipped laundry, a deep freeze locker, with a complete refrigeration complex of cold and cool rooms for normal refrigeration and full air conditioning of the accommodation. In the larger vessels the chart room and/or wireless room are separated from the navigation bridge. Certain of the oil rig supply vessels, which are also tugs, sometimes engage in oil search operations, and these are usually fitted with satellite navigational equipment which is very complex. By means of this gear it is possible to position a ship within about 200 ft on the global surface, - this is pretty close work.

On deck, the towhook is seldom fitted, being replaced by a towing bollard and/or towing winch. The latter are quite substantial pieces of equipment - sometimes of the self-tensioning type, with rendering loads of up to 100 tons, and are most usually hydraulically operated. In these cases it is usual for the anchor windlass to be hydraulic also - but a capstan is not fitted. Lifeboats are sometimes carried although the inflatable raft is rather more common, but a small work boat is almost invariably found. This is used for transporting the runners from tug to vessel towed. In cases of large tugs some of the mooring bollards,

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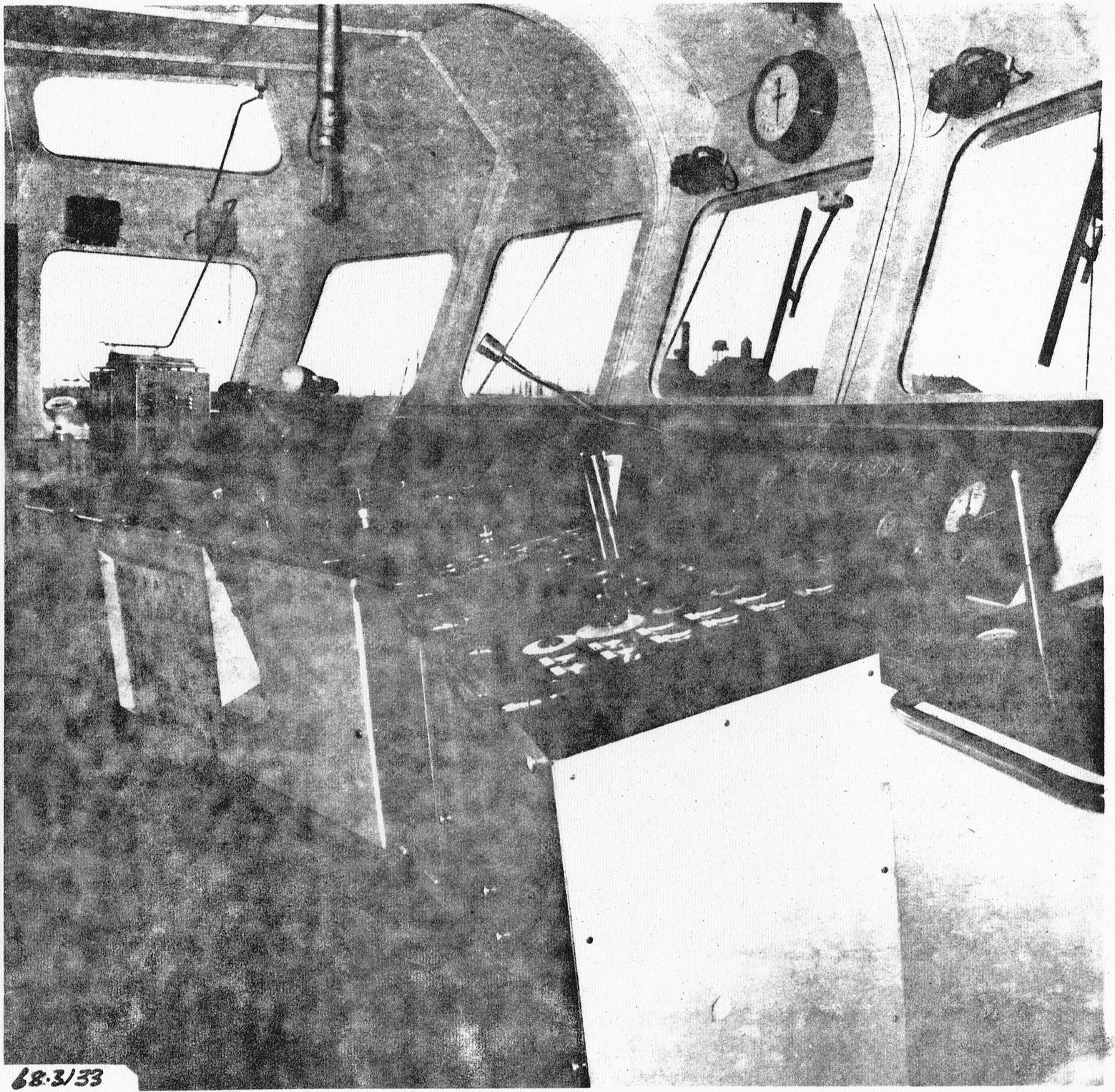
usually aft, are made in the form of a capstan, one post of the bollard itself rotating when bringing the line inboard, and then being hydraulically locked, so that the line may be belayed in the usual figure 8 manner.

Since these tugs are almost always outfitted for rescue or salvage duties a derrick is commonly fitted and the winch is hydraulic to meet up with the other items of deck outfit.
The derrick is used for handling stores, boats, and salvage hoses.

If the tug exceeds 150 feet in length it must, in common with other ships, carry two masthead steaming lights separated vertically by 15 feet and horizontally by 45 feet as a minimum. All tugs carry three lights on the Foremast as has been mentioned earlier. One of these is used as a steaming light, and and its height is fixed by regulation - the second, either above or below it is lit when any tow is being undertaken, and the third when the stern of the vessel towed or if more than one vessel is being towed, then the stern of the last vessel, is more than 600 feet abaft the stern of the tug. Also, tugs must be fitted with a stern light when running free, but this is not illuminated when towing - and for this reason is frequently made portable - a small light being carried abaft the funnel "for the vessel towed to steer by".

Deep sea towage is totally different from harbour towage The first and most obvious difference is in the length and weight of the towline. A towline of half a mile in length is not uncommon. The idea of the long towline is to provide a natural "spring" to absorb shock loads - these, with a short towline, would be of such magnitude that tug, tow, and gear could soon break up. Whenever the towline is in contact with steel it must be protected from chafe, and it is usual to rig wooden chaffing boxes in which the line

33A



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lies while the wood takes the wear - boxes being much cheaper to replace than towlines - It is a common function to secure the towline to the end of the anchor cable of the ship being towed, a few cable lengths (each 15 fathoms) then being run out and then made secure on the ships windlass and cable stoppers. The weight of anchor cable adds to the spring effect - the wear is taken in a place especially designed for it and no loads are put on bollards etc., - the windlass bed is usually strong enough to take this punishment. Because of these factors all deck gear connected with line handling and with towing is made extremely strong in itself and in its seating and the reinforcing in way.

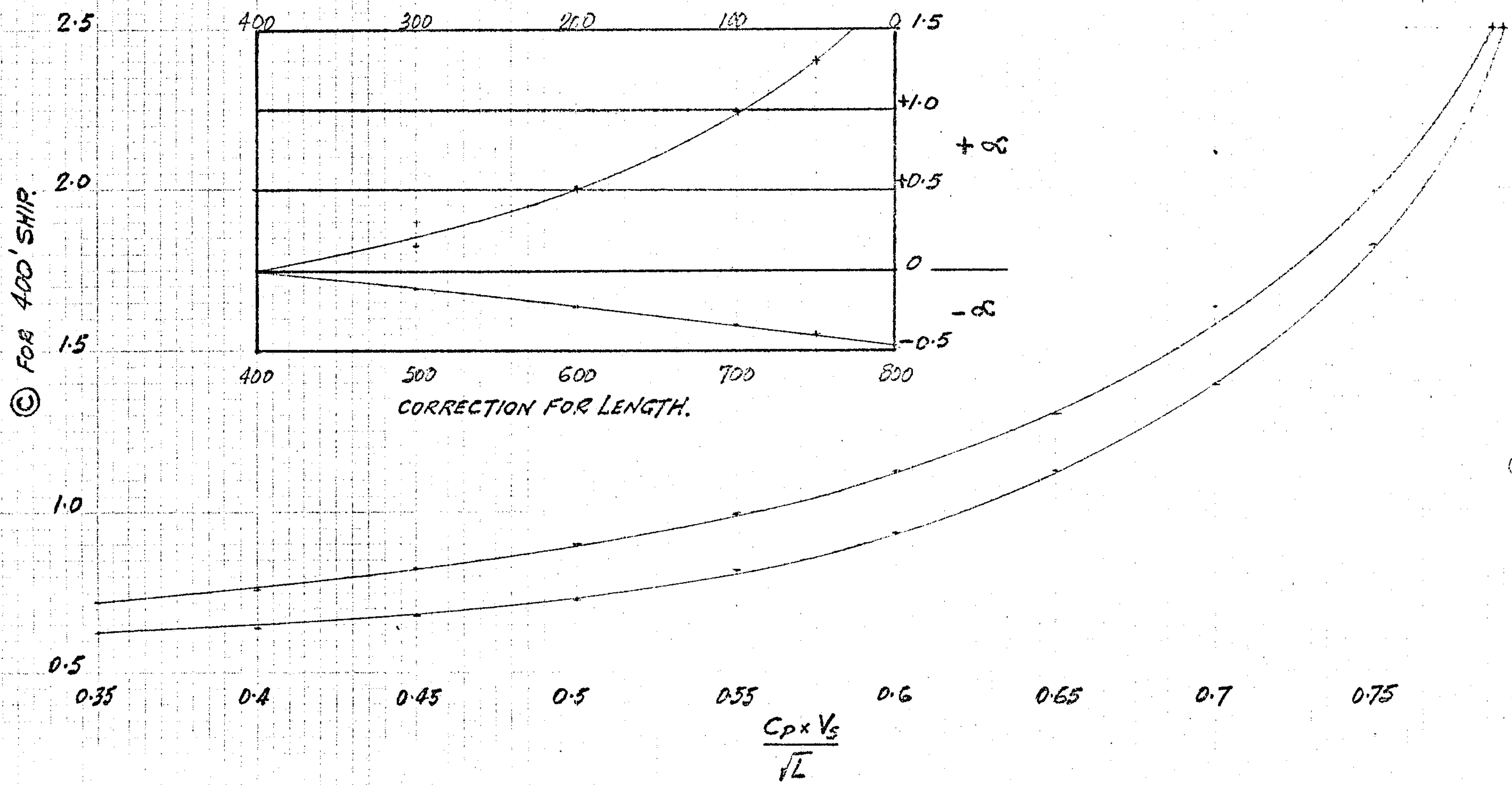
Navigation fittings are most comprehensive. Echo sounders, radar, radio direction finders, auto pilots, magnetic and gyro compasses, with strategically placed repeaters, and in the northern hemisphere, a position fixing device such as a loran - all these are to be found on the bridge together with short range VHF radio phone, fire detection equipment, navigation light alarm box and, frequently, a full set of both windlass and towing winch controls together with the engine controls. These controls may be mechanical, although hydraulic or pneumatic types are most favoured. Electric controls are very seldom seen. These tugs are frequently fitted with a transverse bow thruster propeller situated in a submerged tunnel forward, and this is also controlled from the bridge. One vessel in the writers experience has had a 360° rotatable jet unit mounted at keel level for this purpose. This can be used as an auxiliary propulsion or towing device.

The engine room outfit is extensive. At least two auxiliary engines - more often three, are fitted and equipped with electric generators - and it is usual to find at least one of these having a bilge pump clutch coupled - so that electrical failure does not put all pumps out of action.

APPROXIMATE DETERMINATION OF NAKED EHP FOR TUGS.

EHP = NAKED EFFECTIVE HORSEPOWER

EHP_T = TOTAL EFFECTIVE HORSEPOWER
= NAKED EHP + ALLOWANCES FOR APPENDAGES (ABOUT 8%)
AIR RESISTANCE (ABOUT 1·5%)
SKIN ROUGHNESS (i.e. FOULING) (ABOUT 10% FOR CLEAN HULL)
AND WEATHER (ABOUT 5%)



$Ⓒ_{SHIP} = Ⓒ_{400} \pm \alpha$

$$EHP_{NAKED} = \frac{Ⓒ_{SHIP} \times V^3 \times \Delta^{2/3}}{427\cdot 1}$$

WHERE

EHP = EFFECTIVE HORSEPOWER

V = SHIP SPEED IN KNOTS

Δ = DISPLACEMENT IN TONS

BHP = EHP_T ÷ PROPULSIVE COEFFICIENT

(P.C) = HULL EFFICIENCY × OPEN PROPELLER EFFICIENCY × RELATIVE ROTATIVE EFFICIENCY × FRICTIONAL EFFICIE[NCY]

AS A FIRST ROUGH APPROXIMATION (PC) MAY BE TAKEN AS ABOUT 0·5.

C_P = PRISMATIC COEFFICIENT

L = LENGTH ON LWL. (FOR CRUISER ST[ERN] ADD 2·5% L)

Another frequently has an air compressor coupled in. "Dead Ship" start up is usually achieved either by a small diesel driven compressor, or by the auxiliary with compressor attached having an auxiliary means of starting - explosive charge or burning film types are fitted. All the items found in the engine room of an esturial tug are found in these larger tugs, with the addition of large lub oil purifiers and filters with associated clean and dirty oil tanks and, of course, a sludge tank. It is usual to carry three complete charges of lubricating oil - one in use, one clean and ready for use, and one in the process of being purified.

The question of single vs. twin screw require careful consideration when contemplating this type of craft. Due to the very high horsepowers installed the propeller diameter necessary becomes excessive for single screw operation, and, in these cases, twin screws must be fitted. This results in each of the main engines being smaller individually than one of equal total power, but the two together, taken in conjunction with the duplicated services required, occupy considerable space, and space is at a premium in these ships. Twin screws have decided advantages in connection with safety, as an engine breakdown does not immobilise the tug, and the service may be arduous, especially in rescue work. They also confer considerable manoeuverability on the vessel as the propellers can be made to assist the rudders in turning - in deed the vessel may be steered (albeit rather clumsily) by propellers alone. Further, by judicious use of propellers and rudders it is possible to "walk" a twin screw ship bodily sideways.

Since twin screws are of smaller diameter than single scres accepting the same total horsepower they may turn rather more quickly - hence the gear reduction does not need to be quite so severe - or, alternatively higher revving engines can be tolerated, these being of smaller overall dimensions and weight than slower engines. There are another three advantages of twin screws which are not generally appreciated - these are:-

(1) By "winging out" the main weights in the ship the overall radius of gyration is increased, and hence the rolling period is increased, and violence of rolling motion is diminished. Since no ship (except a cylindrical one) can roll without heaving, this also reduces the velocity of heave and hence the amplitude, and also hence the tendency to induce sea-sickness!!

(2) Since twin screws should always be arranged to rotate in opposite directions the effects of gyroscopic precession are cancelled out. In any single screw ship it will be found that:-

(a) The effect of pitching is to cause the ship's head to turn off to one side, so producing a slightly sinusoidal course and incurring greater resistance.

(b) The effect of turning is to cause the ship's head to rise or fall depending upon the directions of turn and of shaft rotation, and

(c) The ship will always turn more readily to one side than the other. The higher the reves of both engine and propeller and the greater the rotating masses in relation to the weight of the ship the greater these effects will be. This is one reason why in a single screw ship it is desirable to havethe propeller shaft turning in the opposite direction to the crankshaft.

(3) The tendency of the propeller to "walk" the stern to one side continuously is avoided. This causes single screw ships to carry a small degree of helm when running straight - hence

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there is always a small augment of resistance.

Again depending upon the power transmitted and upon the diameter and rpm of the propeller it is found that single screw ships always tend to heel to one side when transmitting high power - twin screws avoid this effect.

In arranging the engine room of any ship, great care must be taken to see that accessability of parts requiring removal for overhaul is not destroyed. Ample clear height over cylinders to allow for withdrawal of pistons and con-rods is essential - and do not forget the space requirements of the chain block - the eyeplates, the trolley and the lifting beam. This applies equally to auxiliary engines as it does to the main machinery. It should be possible to remove any item (including a full generator set) without having to first dismantle the main engine. So far as is practicable, piping systems, electrical systems and ventilation systems should be kept clear of areas where maintenance lifts are to be carried out. Experience of one case showed that the generator and switchboard were on opposite sides of the engine room - the heavy main cables took the shortest route, over the top of the main engine and when it was necessary to remove the No.3 cylinder head one night, the whole ship was blacked out because these cables had to be removed first!! It is most unwise to put fuel tanks between the main engine girders - accessability for maintenance is the keynote. If tanks must be fitted in this area it is preferabe to have a full width, full height fuel tank with internal crawlways via manholes through structure, rather than small lub oil tanks which can neither be entered nor moved past at the sides or between tank top and engine sump.

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The tendency is to move to 415V electrical supply today. and in a vessel as small as a tug it is seldom worthwhile spreading the generating machinery on both sides of the engine room, although ten to fifteen years ago this was almost invariably done if two sets were fitted. Today they are put close together and adjacent to the switchboard. Tugs needing an emergency supply must have this located above the freeboard deck and outside the machinery casings. It is also rather foolish to put the emergency electrical generator, or the emergency fire pump, on deck above the engine room - it should be forward - that is where the crew live, and mostly where they work - so that a red hot engine room crown will not stop someone getting at the pump, or operating the generator in case of an engine room fire - also remember that the forward end is the most likely source of a domestic type fire - and hence hoses may be shorter and manual pumping effort smaller if the pump is nearer the source of fire. It is permissable and desirable to make this pump portable and to use a flexible hose for suction as well as discharge. In this manner the fire pump can double as an emergency bilge pump, but do remember to fit an inlet strainer. Also because of the fire risk, the engine room and accommodation ventilation systems should be completely separated and supplied by different fans. This prevents the spread of fire as well as the propogation of noise and heat. Accommodation may be air condtioned, but engine rooms are not.

In connection with earlier remarks regarding engine room ventilation it should be noted that an air pressure differential of 1 psi causes a total load of just on 1 ton on a normal door. While this is not sufficient to cause harm to machinery or to personnel, it is sufficient to prevent a door from being opened readily and a further pressure drop acting on a trapped crew can

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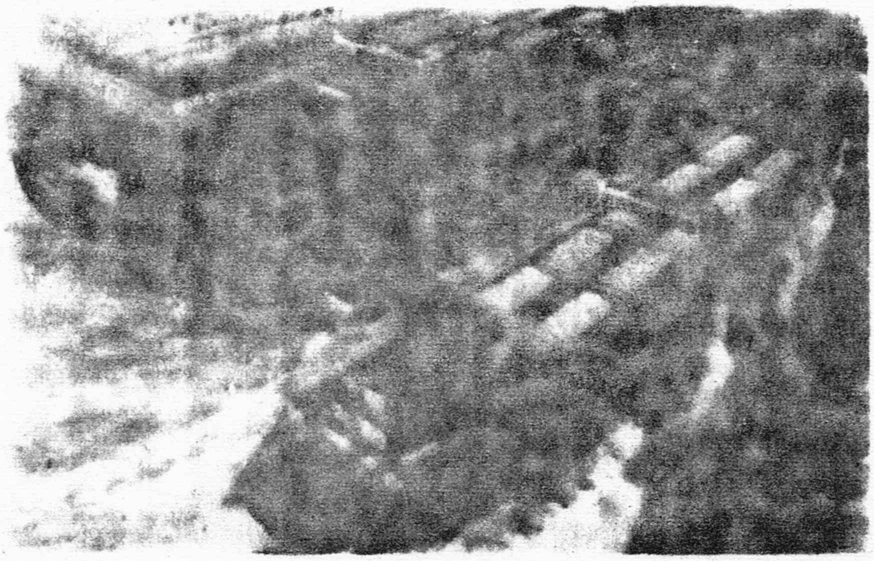
Deep-sea barge design complete

Vickers develop latch device to overcome seaway working problems



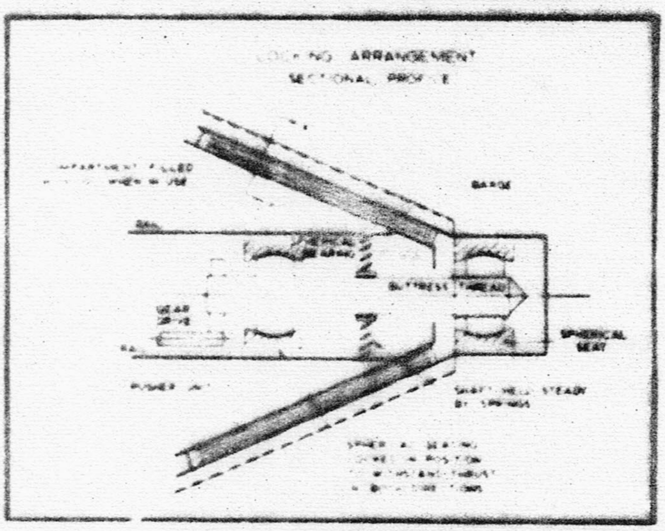
Impression of Murvicker system in operation. Locked at the forward extremity and at each side, the tug virtually becomes a rigid part of the whole structure

DURING THE LAST DECADE an enormous amount of slow but sure development work has taken place towards the production of the ocean-going tug barge system. Of recent years the high cost of crews and greatly increased port costs have given a powerful new incentive to the designers. Particularly in the British Columbian coastal trades and increasingly the Eastern Seaboard of the U.S. the tug barge concept has been proven in practice. Although pusher tugs have long proved a practical proposition in the U.S. and European rivers and sheltered waters line towing has been common practice in the open sea due to the many problems of successfully joining the pusher tug to the barge. Line towing has many disadvantages, not least the size limitations it imposes on the operation, poor control and its vulnerability to heavy weather. Flexible joints, fenders and lashings and mechanical connections have been recently developed to obviate some of these difficulties.

One of the most interesting new developments in this branch of shipping technology is the Murvicker tug barge system developed by Tugbarges International Corp. to the design of its President Ing Reuben Murphy. The Tugbarge design has been the subject of a design and feasibility study by Vickers of Barrow who have, with Mr. Murphy, developed the unique latching device that is the subject of a number of patents and the means of providing a rigid connection between tug and barge. A highly practical design which demands only existing shipbuilding and shipping techniques, the idea of Mr. Murphy is shortly to come partially to fruition as the transport link in a giant integrated timber project bringing forest products from French Guiana to U.S. and European ports. The project is in its final stages of planning and it is expected that the first Tugbarge orders will be placed competitively at the end of this year or the beginning of next. Initially, tugs with 15 000-30 000 dwt barges will be used in the first phase to move timber products to Europe at the rate of 442 560 tons per annum the maximum capacity of one Murvicker unit of a tug and three barges. Production will be stepped up in four annual increments of 442 560 dwt as further Murvicker units are brought into operation. There is presently a limitation on draught at the port on the Approuage River, French Guiana, which will restrict draught of the first vessels to 21ft and a cargo deadweight of 15 000 dwt is required. However, to take advantage of deep water loading the design is based on a scantling draught of 30ft, at which draught the service speed of each unit is to be 17 kts.

Further applications of the Murvicker system presently in the design stage includes a small barge carrying unit for the European short sea trades.

Completely different from the earlier flexible or mechanical means of joining tug to barge, the Murvicker rigid connection developed in conjunction with Vickers depends upon the forward half of the tug being shaped and tapered to fit into a corresponding recess in the



Sectional profile of one of the three locking devices that hold the shoulders into their matching sockets. Massive greenheart timber baulks prevent a metal to metal contact between the two craft

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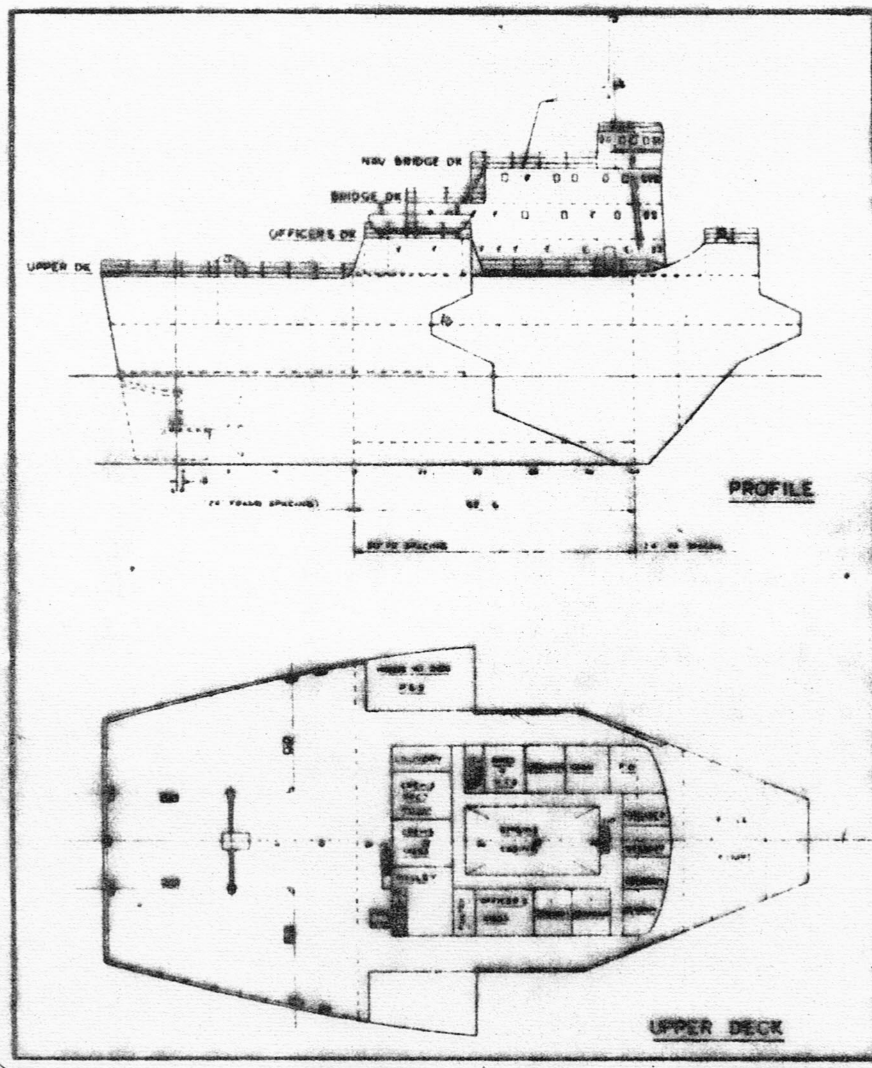
THIS PART ONLY PL

afterpart of the barge. Precise alignment of the two craft is effected by means of three shoulders which fit into matching sockets on the other portion. These shoulders are arranged in a triangular pattern, as seen from above, one being at each side of the tug at about its half-length, the matching sockets being on the tug itself and the shoulders protruding aft from the barge, and one at the forward end of the tug on the centreline protruding into a socket on the barge.

Each shoulder is tapered both vertically and horizontally and actual contact between all mating surfaces is between massive timber baulks secured to the crests of large scale corrugations on the faces of the socket and the flat plating surface of the shoulder. An air/water jet system is incorporated to keep the channels and interlocking faces free of debris when plugging in. As the channels are large enough to accommodate a diver, replacement of baulks, when necessary, is not a problem. The actual locking mechanism consists of a hydraulically driven shaft which locks two barge bearings into two spherical seatings. There is one of these units in each of the three bearing shoulders that hold the two craft rigidly as one vessel.



When plugging in, the tug ballasts to the same draught as the barge and assumes a slight trim by the head. After checking that all channels are free from debris she then moves gently into the barge recess. Contact is first made at the top mating surfaces and at weather deck level and on the wing shoulders of the tug hydraulic restraining links gently close around bollards on the barge. Continued pressure on these restraining links ensures contact over the full area of the mating surfaces and the connecting mechanism is operated drawing the tug and the barge together. With all mating surfaces in firm and continuous contact the connecting mechanism is locked thus effectively merging tug and barge into one rigid unit. When wishing to disconnect, after adjusting ballast in the tug, the deck restraining links are opened up and the locking mechanism withdrawn to force the two sections apart.

In the design, the principal criteria that were taken into consideration were as follows: Firstly the connection had to be sufficient to counter the structural stresses involved in the heaviest weather, while the various interfaces between tug and barge were made capable of transmitting these forces and able to resist the vibrations. It was clearly important that the tug must be able to function as an independent seagoing unit even though such journeys would be normally short, coastal and infrequent. The surfaces must be permanently held under compression, but the locking mechanism had to be sufficiently simple to allow a fast plug in and withdrawal.

Although the Murvicker system is adaptable to the carriage of all types of cargo and may be scaled up or down as required, its initial application at the French Guiana forest products development show many convincing advantages over conventional methods of shipping in this hitherto undeveloped area. The use of a barge as a continuously available warehouse saves considerable investment in handling and storage facilities while the barges themselves, being fitted with inert gas equipment actually condition and protect stored timber. And without much expenditure the project site would not be accessible to an equivalently sized vessel.

Three operating methods for the Murvicker tugbarges have been identified, the captive method, where the tug is kept locked into the barge during port times, suitable for fast handling cargoes and the circulation method where as in the French Guinea project, one tug will be used with three barges continuously circulating. A third method, the random method enables barges to be disposed in a number of ports as required. The economics of this method depend on ensuring that the tug is continuously pushing barges.

The invention of Mr. Murphy is an exciting development and one that merits the urgent consideration of all those concerned with the building and operating of shipping.

PLAN SECTION ONLY PLEASE

CONDITION Nº 2

NORMAL FULL LOAD DEPARTURE

ITEM	WGT	V.C.G.		L.C.G. AFT.		L.C.G. FOR'D		F.S. MMT
		LEVER	MMT	LEVER	MMT	LEVER	MMT	
FORE PEAK W.B.	17·87	17·79	317·91			43·42	775·92	—
Nº 1 W.B. D.B. P & S	30·16	8·26	249·12			29·64	893·94	—
Nº 2 DOM F.W. DB ℄	24·77	7·74	191·72			21·15	523·89	—
Nº 3 O.F. D.B. P & S	19·56	5·40	105·62			5·24	102·49	24·0
Nº 4 O.F. WINGS P & S	12·36	13·81	170·69	26·62	329·02			6·2
AFT PEAK W.B. P.	10·68	15·25	162·87	37·83	404·02			—
AFT PEAK W.B. S.	23·02	14·74	339·31	37·72	868·31			—
M.E.F.W. HEADER TK.	0·27	22·63	6·11			4·82	1·30	—
F.W. GRAVITY TK P & S	1·64	29·28	48·02			24·14	39·59	—
DAILY SERVICE O.F. TK	1·92	18·30	35·14	6·44	12·36			4·1
M.E.O.F. HEADER TK	0·09	15·08	1·36			17·15	1·54	—
M.E.L.O. STORAGE TK P&S	2·06	18·50	38·11	5·56	11·45			—
M.E.L.O. SUMP TK	2·11	10·94	23·08			12·94	27·30	—
G.B.L.O. STORAGE TK	0·10	13·87	1·39	21·73	2·17			—
C.P.L.O. STORAGE TK	0·25	13·56	3·39	21·42	5·36			—
STERNTUBE L.O. HEADER TK.	0·05	22·25	1·11			8·31	0·42	—
STORES & ROPES.	3·00	14·75	44·25	12·00	36·00			—
CREW & EFFECTS	1·25	15·25	19·06			25·00	31·25	—
DECK CARGO, STORES.	NIL							
TOTAL DEADWEIGHT	151·16		1758·26		1668·69		2397·64	34·3
LIGHTSHIP	271·43	14·05	3813·53			1·11	302·39	—
SHIP LOADED	422·59	13·18	5571·79			2·44	1031·34	34·3.

HYDROSTATIC DATA.

DRAFT TO U.S.K. STN 0.	14′ – 5¾″
L.C.B FOR'D ⊗	2·56 FT.
L.C.F. AFT ⊗	3·89 FT.
T.P.I.	5·04 FT.
M.C.T. 1″	32·30 TON. FT.
K.M ABOVE BASELINE	16·24 FT.

TRIM = $\frac{B.G. \times \Delta}{M.C.T.1''} = \frac{422·59 \times ·12}{32·3}$

= 1½″ BY STERN

DRAFT AFT AT A.P. = 14′-5¾″ – 1′-7 5/16″ + 1′-7 11/16″ + 5/…

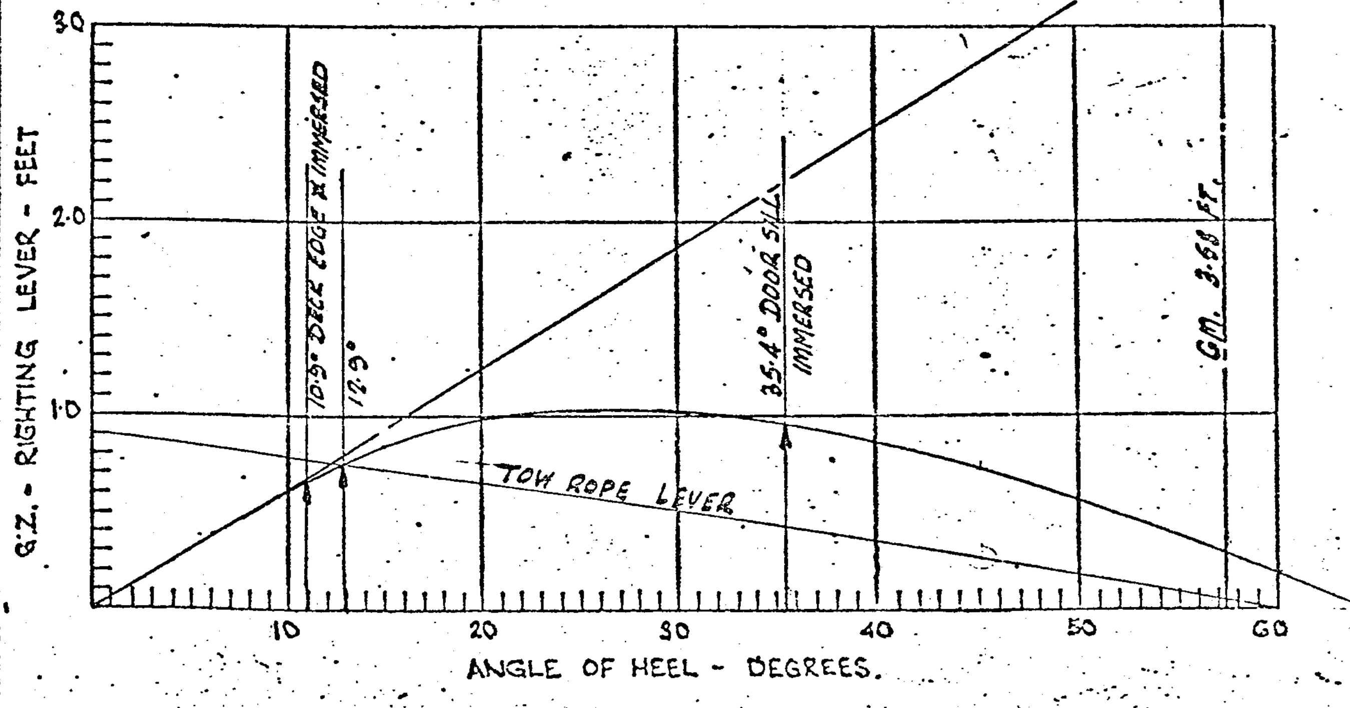
= 14′-6¾″

DRAFT FOR'D AT F.P. = 14′-5¾″ – 1′-7 5/16″ – 1′-7 11/16″ – 7/…

= 11′-1⅞″

CONDITION Nº 2

STATICAL STABILITY CURVE



then wreak havoc. External doors to engine rooms should open outboard and internal doors should open inwards into the engine room so that no matter which way the pressure differential acts at least one door will move (and will move very fast) once the clips are released.

Again, the force necessary to remove clips with a load of 1 ton on a door can be quite large, beyond the power of an unaided human hand, so means of assistance should always be stowed adjacent to the door on both sides of the bulkhead. It is also vital to provide a position for the operator to stand clear of the swing of the opening door - failure on this point can cause the death of the operator if he is behind the door when it opens.

Push Type

Ocean going pusher tugs fall into two types, one resembles the harbour pusher type, the other the esturial type. The principal points of difference lie in the attempts which are made to ensure that the tug/barge complex becomes and remains one integrated unit.

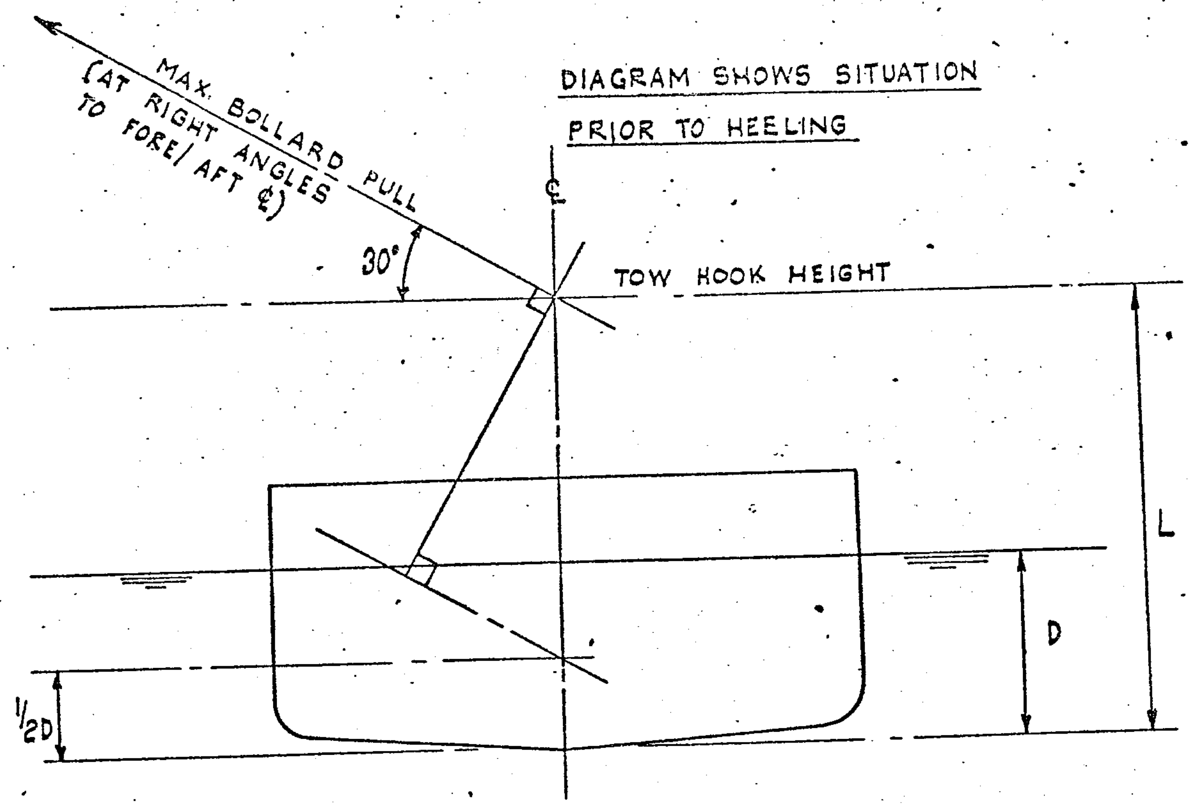
These photographs show a complicated series of wedge shaped notches and keys being built into such vessels in the hope that relative motion between them will be absolutely avoided - a very difficult result to achieve considering the magnitude and variety of the forces which may be brought to bear.

The final point which needs to be made concerns the overall stability of the vessel. The IMCO stability criterion applies to tugs and requires that

(1) The area under the curve of righting levers should not be less than 10.337 ft. deg. up to 30° angle of heel and not less than 16.915 ft. deg. up to 40° angle of heel, or to the angle of flooding if this be less than 40°.

The angle of flooding is that angle at which the sill of any

BASIC ASSUMPTIONS



$\phi°$ = ANGLE OF HEEL.

HEELING MOMENT (TO PRODUCE BASELINE TRANSVERSE TOW ROPE PULL)

MAX BOLLARD PULL × $(L - \frac{1}{2} D) \times \cos(30° + \phi°)$

MAX BOLLARD PULL	
TOW HOOK HEIGHT (L)	
HULL DEPTH @ ℄	

ANGLE OF HEEL FOR DECK EDGE IMMERSION

$$\tan \phi = \frac{\text{FREEBOARD}}{\frac{1}{2}\ \text{BEAM}}$$

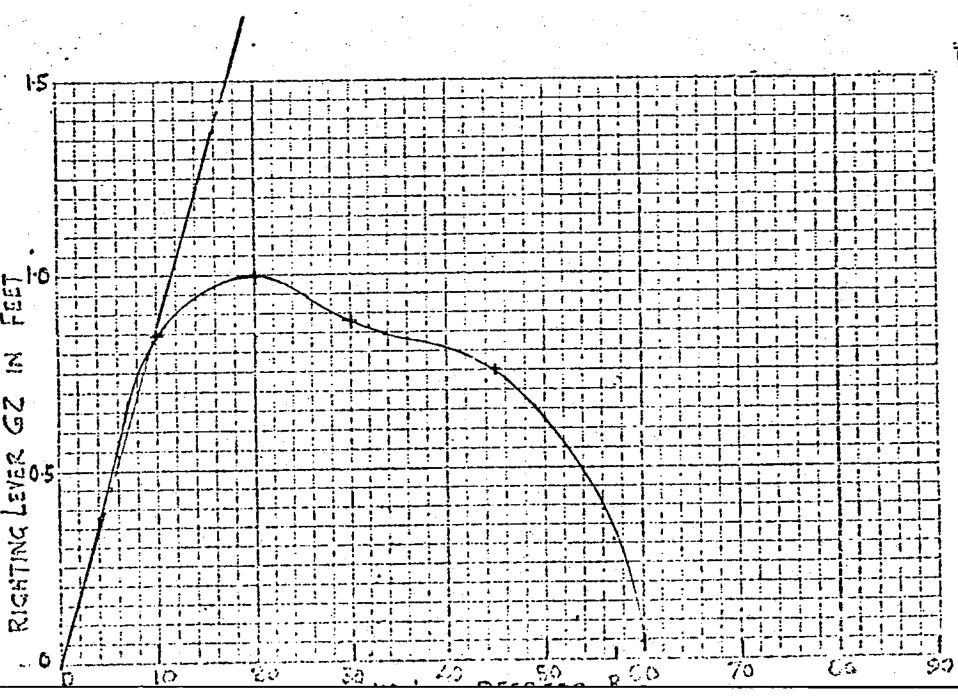
DESCRIPTION OF LOADING CONDITION:-
400 TONS DECK CARGO - CEMENT TANKS EMPTY - DEPARTURE

ITEM	MAT.L	WEIGHT	VCG	VERT.L MOM.T	LCG AFT	MOM.T AFT	LCG FOR.D	MOM.T FOR.D	F.S.C.
FORE PEAK	W.B.	—							
Nº 1 D.B. P & S.	W.B.	30	7.9	237			57.0	1710	–
Nº 2 D.B. P & S.	W.B.	84	7.3	613			48.0	4032	–
Nº 3 WINGS P & S	F.W.	30	6.0	180			32.2	966	0.01
Nº 4 WINGS P & S	O.F.	–							–
Nº 5 DEEP P & S.	O.F.	52	4.0	208			15.1	785	0.02
Nº 6 WINGS P & S.	O.F.	–							–
Nº 7 WINGS P & S.	F.W.	30	5.0	150	33.7	1011			0.01
Nº 8 DEEP P & S	W.B.	–							–
AFT PEAK P & S	W.B.	–							–
DAILY SERVICE ℄	O.F.	13	4.0	52			11.7	152	0.01
FOAM TANKS P & S	FOAM.	16	12.3	197			16.7	267	–
PROVISIONS		15	18.0	270			43.0	645	
CREW & EFFECTS		2	22.0	44			57.0	114	
PASSENGERS		1	15.0	15			57.0	57	
CEMENT TANKS	CEMENT	–							
DECK CARGO		400	20.07	8028	25.0	10000			
TOTAL DEADWEIGHT		673		9994				8728	
LIGHT SHIP		859	14.3	12284			0.89	765	–
SHIP LOADED.		1532	14.54	22278	0.99	11011		9493	0.05

DISPLACEMENT	TONS	1532
KM.	FT.	19.63
K.G.	FT.	14.54
G.M. SOLID	FT.	5.09
F.S.C.	FT.	0.05
G.M. FLUID	FT.	5.04
LCB	FT.	0.50A
LCG	FT.	0.99 A
B-G.	FT.	0.49A

MEAN DRAFT	FT.	13.42
MOM.T TO CH. TRIM 1"	TON.FT	142
TRIMMING MOMENT	TON.FT	751
TRIM TOTAL	BY STERN INS	5.3
LCF FROM ⊗	FT.	10.6 A
TRIM FORD	91.6/142 × 5.3	3.0"
TRIM AFT	70.4/142 × 5.3	2.3"
DRAFT FORD		13'-2"
DRAFT AFT		13'-7¼"

θ	10°	20°	30°	45°	60°	75°	90°
SIN θ	0.174	0.342	0.500	0.707	0.866	0.966	1.000
GM SIN θ	0.877	1.724	2.520	3.563	4.365	4.869	5.040
H.S.	¯0.030	¯0.730	¯1.640	¯2.810	¯4.320	¯5.900	¯7.180
GZ	0.847	0.994	0.880	0.753	0.045	¯1.031	¯2.140



G.Z MAX. 0.994 FT
θ GZ MAX 20°
G.M. 5.04 FT
θ FLOODING 76°
DYNAMIC STABILITY
To 30° 14.5 FT.°
To 30° —
To 40° or θF 32.1 FT°
20° 30° - 40° or θF 17.6 FT°

N.B. 1 METRE RADIAN
= 187.95 FT. DEGREES
OR 1 FT. DEG
= 0.00532 M. RAD.

opening in the hull, the superstructures or deckhouses which cannot be closed weathertight first submerges.

(2) The area between 30° and 40° of heel, or between 30° and the flooding angle should not be less than 5.638 ft. deg.

(3) The righting lever should be at least 0.656 ft. at an angle of heel of 30° or greater.

(4) The maximum righting lever should occur at an angle of heel preferably exceeding 30° but not less than 25°.

(5) The initial GM should not be less than 0.492 feet.

In addition, for tugs, the Australian Authorities require that a curve of overturning moments be drawn, produced by the effect of the full designed bollard pull of the tug, applied at right angles to the longitudinal centreline of the ship and at 30° elevation above the horizontal. This curve must cut the curve of righting levers in the worst loading condition and leave a positive moment against overturning.

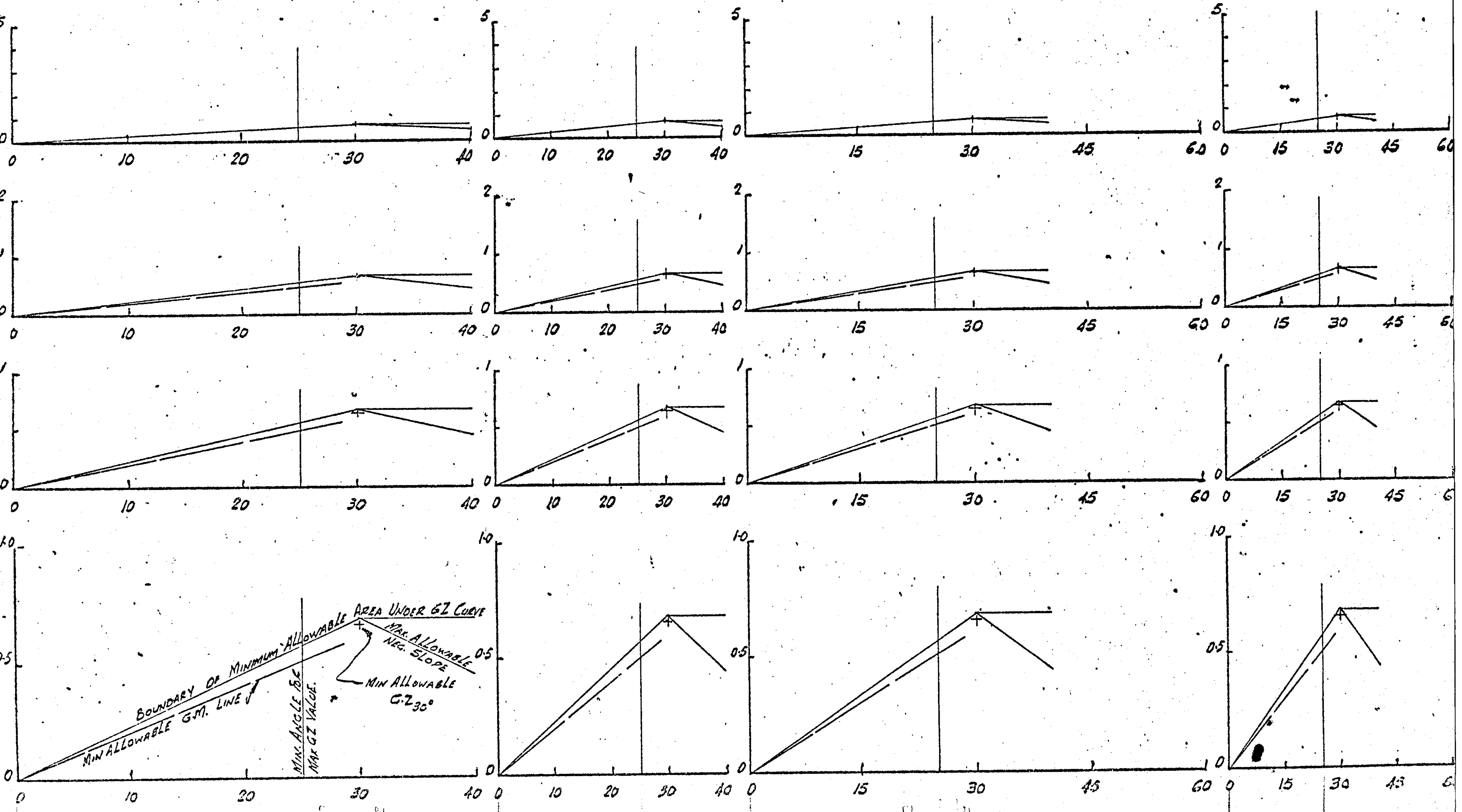
It may be noted that the oil rig supply industry refer to their craft as "Tug/Supply vessels" and their hull form is such that they cannot comply with these criteria - in such cases the following relaxations are permitted provided it can be demonstrated that the vessel is of such a type that compliance cannot be achieved.

(1) The area under the righting level curve should be 14.1 ft. deg. up to an angle of 20° when maximum GZ occurs at 20° or 10.34 ft. deg. up to 30° when maximum GZ occurs at 30° or above, with intermediate values in proportion; also

(2) The area between 30° and 40° or the flooding angle must still be 5.638 ft. deg.

(3) The maximum value of the righting level shall be at least 0.656 ft.

I.M.C.O. STABILITY CRITERION.
LIMITS FOR GZ CURVES.
DRAWN TO VARIOUS SCALES AS MARKED.



(4) The maximum value of the righting lever shall occur at an angle of not less than 20°.

(5) The initial GM shall be not less than 0.492 ft.

I trust that the foregoing will provide you with useful information in the discharge of whatever duties you may be called upon to undertake in connection with tugs.

Permission granted by Adelaide Ship Construction to display and re-produce photographs and plans of vessels of their construction is gratefully acknowledged.