THE PETROLEUM HANDBOOK

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COMPILED BY
MEMBERS OF THE STAFF OF
THE ROYAL DUTCH-SHELL
GROUP

THIRD EDITION

LONDON
THE SHELL PETROLEUM COMPANY LIMITED
1948

The construction of these lines followed soon after the completion of the Plantation Pipe Line Co.'s 8 to 12-inch pipeline, which runs 1,236 miles from Louisiana to North Carolina and is partly owned by Shell Union Oil Corporation. Two others, in which Shell has a major interest, are the 500-mile 20 to 24-inch line from New Mexico to Oklahoma, and the 440-mile 20-inch line on to Wood River, Illinois. The total length of crude oil and finished products lines in the U.S.A. alone is now approximately 140,000 miles, while the natural gas pipeline system is even longer. Included in the outstanding pipeline constructions in recent years outside the U.S.A. are one line in Colombia, over 365 miles in length, which reaches the seaboard after crossing the Andes, the war-time lines laid down from Assam into China, some 2,000 miles in length, and that in Alaska and Canada, 577 miles long. A war-time development was the portable pipeline, devised by a Shell engineer, used in the campaigns in North Africa and Europe.

From the point of view of international trade, the most important means of transportation employed is the ocean-going tanker. It is designed solely for carrying crude oil or petroleum products and is usually a one-way carrier only. Shell tankers returning to Curaçao frequently carry fresh-water supplies to meet the shortage of water in the island for human needs and for refinery working.

Before the war, the typical ocean-going tanker had a carrying capacity of between 8,000 and 12,000 tons and a speed of 10 to 12 knots. But in the years immediately preceding the war, and since, some tankers have been built, of which a number are now in service, with a capacity of about 16,000 tons and of about 17 knots. Shell is now building tankers of 28,000 d.w.t.

The table on page 15 gives an indication of the sizes of the tanker fleets of the principal countries in 1939 and 1947. The reduced percentage accounted for by the British, Norwegian and Dutch fleets is due to the severe losses suffered by these countries during the war years. The United States also suffered very severe losses, but was able during the war to build many more vessels than she lost.

Tankers now represent about 24% of the world's ocean-going shipping. All ocean tankers are oil driven.

WORLD TANKER FLEETS

Ocean-going Vessels of 3,000 Dead Weight Tons (D.W.T.) and over

	September 1st, 1939			October 1st, 1947			Building and Orders for Owners in Countries named at July 1st, 1947	
	No.	D.W.T.	% of Total	No.	D.W.T.	% of Total	No.	D.W.T.
WESTERN HEMISPHERE								
United States	383	4,434,100	26.0	744*	11,171,400	47.4	4	45,200
Panama	53	732,800	4.3	132	1,688,500	7.2		
Others	56	338,000	2.0	77	577,800	2.4		
Total Western Hemisphere	492	5,504,900	32.3	953	13,437,700	57.0	4	45,200
EUROPE								
Great Britain	442	4,704,000	27.8	436	4,789,500	20.3	39	475,615
Norway	263	3,125,400	18.3	195	2,517,300	10.7	51	839,050
Netherlands	105	740,000	4.3	80	570,700	2.4	6	44,300
France	44	462,300	2.7	33	410,500	1.7	13	211,180
U.S.S.R.	17	162,500	1.0	25	266,800	1.1		
Germany	34	387,700	2.3	4	50,400	.2		
Italy	80	618,700	3.6	35	374,000	1.6	6	54,845
Sweden	20	257,000	1.5	36	491,100	2.1	5	57,900
Others	50	458,000	2.7	57	556,000	2.4		
Total Europe	1,055	10,915,600	64.2	901	10,026,300	42.5	120	1,682,890
FAR EAST								
Japan	47	612,500	3.5	9	68,500	0.3		
China				4	46,000	0.2		
Total Far East	47	612,500	3.5	13	114,500	0.5		
Egypt				1	7,300			
TOTAL WORLD FLEET	1,594	17,033,000	100.0	1,868	23,585,800	100.0	124	1,728,090

* Includes tankers laid up. A number of these have since been recommissioned and some transferred to other flags.

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SEA TRANSPORT

HISTORICAL

THE first cargo of petroleum to be transported across the Atlantic ocean was carried in wooden barrels stowed in the single hold of the brig "Elizabeth Watts" in the year 1861. This method was employed for some years afterwards, and the price of petroleum to the consumer in the United Kingdom included the cost of filling and emptying the barrels, returning the empties and loss of freight due to the circular shape of the barrels requiring large space in proportion to the amount of oil carried.

Ships of that period were mostly made of wood, and the first attempt to reduce the price of petroleum sold in the United Kingdom took the form of fitting iron tanks of comparatively large capacity into the cargo holds, and subsequently the wooden hulls were lined with felt on cement. In this way, the idea of transporting oil in bulk progressed.

The "Shell" fleet of tankers was inaugurated in the year 1892 by the steam engine propelled tanker "Murex" of 5,010 tons carrying capacity. This pioneer tanker, built at West Hartlepool, would not compare favourably with modern ships of this class, but at the time she represented the last word and in many respects was a great advancement upon the 60 to 70 tankers then sailing under British, American and Russian flags. The "Murex" was the first ship to carry oil in bulk through the Suez Canal. This chapter in history was written during the latter part of 1892.

TANKER CONSTRUCTION AND EQUIPMENT

Arrangement of Cargo Tanks. Because of the fluid nature of oil cargoes and the liability of ships to pitch and roll in adverse weather, the cargo space of the earliest bulk oil carriers was divided into two symmetrical parts by providing a centre-line bulkhead extending fore and aft for the whole length of the space, which has the effect of controlling the position of the centre of gravity of the cargo and preventing the stability of the ship being adversely

affected. The length of the cargo space was divided into a number of compartments by the provision of athwartship* bulkheads, which prevented surging of the cargo in heavy weather and damage to the ship. These bulkheads also give added strength to the ship and enable different grades of cargo to be carried at the same time. A typical cross-section of such a tanker is shown in fig. 1.

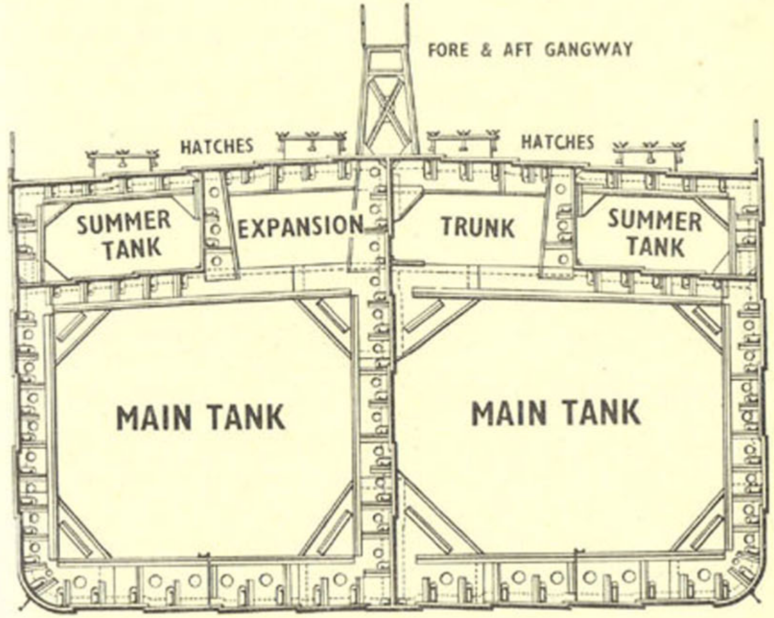

Fig. 1. Cross Section of Summer Tank Tanker.

The summer tanks on each side of fig. 1 run longitudinally between the main and upper decks and extend from the ship's side to what is called the expansion trunk of the main tanks. The object of this form of construction is to reduce to within narrow limits the free surface of the liquid in the main tanks. The free surface could of course be eliminated if the tanks were completely filled, but this is impracticable as oils have a relatively high coefficient of expansion and space must be provided to allow for increase in volume, which may amount to 2% under certain conditions.

The summer tanks are filled only when cargoes of very low specific gravity are carried, and although this form of construction is now obsolete the principle is applied to certain classes of

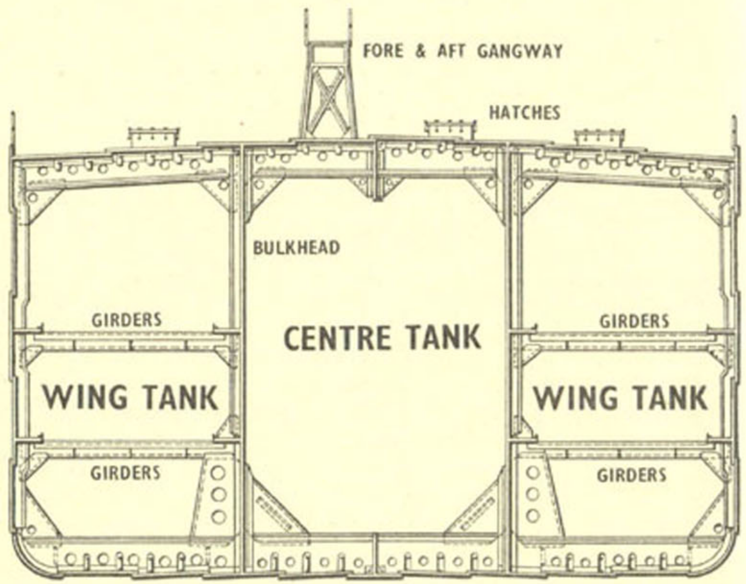

Fig. 2. Cross Section of Modern Tanker.

tankers, chiefly small coasters. In such ships the summer tanks are eliminated, the expansion trunk protruding above the upper deck.

After the 1914/18 war the form of construction of tankers was changed, and in this new development the Group's marine technicians again played a leading part. The new form comprised two longitudinal bulkheads and no summer tanks. This resulted in

greatly increased strength for the same weight of steel used and more flexibility in the carriage of cargoes, as the centre tanks only required to be loaded to 98% capacity; the wing tanks could be loaded similarly to any desired ullage* without adversely affecting the stability of the ship in bad weather. The arrangement of the bulkheads in a modern tanker is shown in figs. 2 and 3.

Cofferdams. The transverse and longitudinal bulkheads are made oil-tight and form a sufficiently safe division between different grades of oil in adjacent tanks. In time, however, ships which must of necessity be flexible to a certain degree in order to reduce intensity of stress, during periods of unequal weight distribution or bad weather, become strained and the divisions become less reliable. Also, with certain grades of cargo the slightest admixture would be disastrous, and to ensure absolute separation under all conditions of weather cofferdams are provided. Cofferdams comprise a space between two cargo tanks enclosed by the transverse bulkheads of adjacent tanks. In other words, the adjacent tanks are separated by two oil-tight transverse bulkheads instead of one.

Cofferdams are always provided at each end of the cargo space. In some cases the after cofferdam is made large enough to accommodate the cargo pumps, but generally the cargo pumps are installed in cofferdams situated in the cargo space and are called pumprooms. When there are two pumprooms, as in fig. 3, the cargo space is divided into three completely isolated portions, and three different grades of cargo could be carried without the least possibility of admixture and, as such tankers are provided with at least three cargo pumps, the three grades can be loaded or discharged simultaneously through separate pipelines.

Forward of the fore cofferdam is a deep tank for a portion of the ship's bunkers, with a hold above for the carriage of dry cargo and stores. The bulkhead dividing the deep tank and the fore peak, in which is usually carried domestic water, is termed the collision bulkhead. Storerooms are situated over the fore peak, as is the anchor chain locker.

Cargo Heating System. As some oil cargoes require to be heated whilst in the ship to ensure a reasonably high discharge rate, steam-heating pipes in the form of grids are arranged over

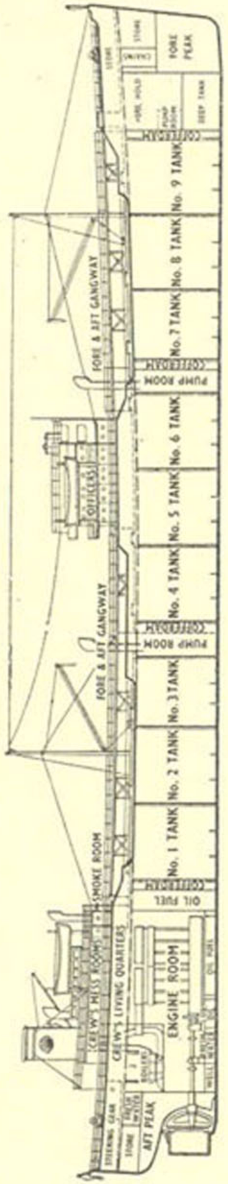

Fig. 3. Longitudinal Section of Modern Diesel Engined Tanker.

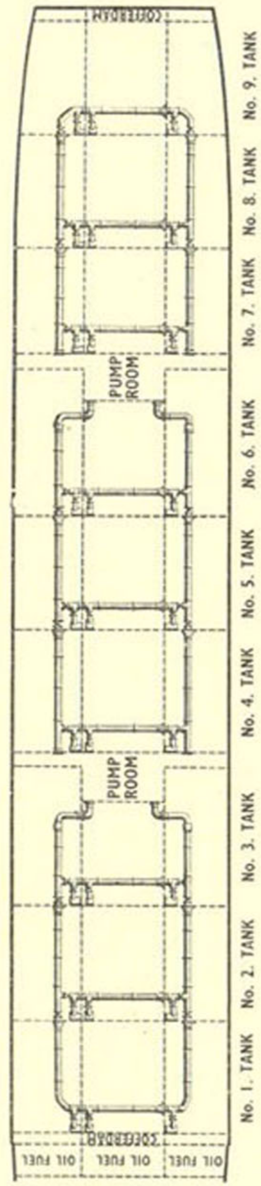

Fig. 4. Plan of Cargo Suction Pipeline in Modern Tanker.

the bottom of each tank or compartment. The capacity of this heating system is sufficient to raise the temperature of the oil to 140° F. For specially heavy petroleum products, such as bitumen, the heating system must be of even greater capacity.

Location of Machinery. The propelling machinery of tankers is generally placed at the after end in order to avoid having to provide a long oil-tight shaft tunnel through the cargo tanks situated between the engine room and the after cofferdam, were the machinery placed amidships. From a safety point of view also it is an advantage to have the engine room clear of the cargo space. The space under the machinery is divided up to form tanks which contain fuel, lubricating oil and fresh water necessary for the operation of the machinery.

Freeboard of Tankers. Tankers are permitted by the Classification Societies to load more deeply than dry cargo ships. The reasons are that the cargo tank hatches are small and strongly constructed, there are no large ventilators opening into the cargo spaces through which seas could enter and cause flooding, and, moreover, if every cargo compartment of a tanker became filled with sea water the ship would still be buoyant. Because tankers are loaded so deeply it is necessary to have a fore-and-aft gangway between the three islands—namely forecastle, bridge and poop—to enable the personnel to pass from one island to another in safety during heavy weather when the decks are awash. This fore-and-aft gangway forms a suitable structure to which are secured the various pipelines, such as steam to windlass, steam-smothering line, wash-deck line, cargo-tank venting pipes, fresh-water line to amidship accommodation, electric cables, engine-room telegraph leads, etc., etc.

Aids to Navigation. A large proportion of the Group's fleet of tankers is equipped with up-to-date main and emergency wireless sets, gyro compasses, direction finders, depth sounders, electric engine-room telegraphs, telephone system, electric speed and helm indicators, etc. The officers are accommodated amidships and the crew live aft. Spacious and comfortably furnished smoke and recreation rooms are provided for both officers and crew. The temperature of the living accommodation is controlled by circulated air which is heated in cold climates.

Ventilation of Cargo Tanks. As oil enters the cargo tanks at a rate up to 2,000 tons per hour an equal volume of air is displaced, and as this air becomes mixed with petroleum vapours and forms an explosive mixture it must be conducted away to a point where it is not likely to become ignited. This is accomplished by providing a pipe leading from the hatch coaming* of each tank through a pressure-vacuum valve and into a much larger pipe running fore and aft, the ends of which terminate about 12 feet above the headlights on each mast.

The pressure-vacuum valves are set to act automatically when the pressure in a tank exceeds 3 lb. per square inch, and explosive gases are expelled into the atmosphere at a point where they can do little harm. Conversely, if during discharge a partial vacuum is created in the tanks, these valves operate and allow air to be drawn into the tanks through a double-gauze safety screen. It will thus be seen that the expansion of the cargo due to a rising temperature and contraction consequent upon a falling temperature is taken care of by these pressure-vacuum valves, and the ship is safeguarded against damage from internal or external pressure during a voyage from a cold to a hot climate, or vice versa.

Cargo Pipelines. The cargo pipeline system in a modern tanker is a simple but ingenious affair which enables liquid to be drawn from any compartment and pumped into any other compartment. Also it is possible to draw from any compartment and pump to the sea or draw from the sea and discharge to any compartment without passing through the discharge line on deck. From fig. 4 it will be seen that the main lines are led forward and aft from the pump-rooms through the side tanks, the port and starboard lines being joined in each tank by crossover lines, from which a suction pipe with valve is fitted in each compartment, the open end of the suction pipe terminating within half-an-inch of the bottom of the tank. A master valve is provided at each athwartship and longitudinal bulkhead which enables sections of the pipeline to be isolated as desired.

Gas Freeing. Cargo tanks require to be entered during ballast voyages in order to attend to valves and expansion joints in the pipelines, as well as to remove scale when light oils are carried, and sediment when the cargoes are black oils. It is necessary,

therefore, to expel the petroleum vapours left after the cargo has been discharged in order to avoid the possibility of explosion. The Group's marine technicians have given the gas-freeing operation considerable thought and have evolved a procedure which enables all traces of gas to be removed in about four hours without opening the tank hatches. Moreover, all Group tankers are provided with a sensitive recording instrument which registers at a glance the condition of the atmosphere in the tanks.

Fire-fighting Appliances. Good provision is made for fighting fires should they occur. The cargo compartments are provided with a steam-smothering system comprising a steam supply pipe running the whole length of the ship, with a branch to each compartment. The supply of steam is remotely controlled and can be instantly operated when the alarm is given. Although much attention has been given to facilities for extinguishing fires, the Group's policy is to do everything possible to prevent fires occurring. Much in this direction can be and has been done in the construction of tankers and the enforcement of rigid rules and regulations relating to the handling of cargoes and the operation of boilers and galley stoves where naked lights must be employed.

The nature of the cargo is generally noticeable when a tanker is loading and, but to a much lesser extent, when discharging, owing to small openings in the tops of the tanks having to be uncovered to enable samples to be obtained and ullages ascertained, but when Group tankers are at sea, even when there is "hardly a breath of air", the presence of thousands of tons of highly volatile petroleum spirit beneath one's feet is not in the least discernible.

Galleys. The galley stoves are oil fired, but when it would be dangerous to have such fires in operation, owing to the presence of explosive gas, steam cookers, which can be operated by ship's steam or steam from the shore, are provided. These cookers are capable of providing a three-course meal for the whole of the personnel for an indefinite period. The galleys are also provided with various labour-saving devices, while particular attention is given to the design and location of cupboards and the like so as to avoid accumulation of dirt and homes for insects. Forced ventilation is employed, so that even in the hottest climate the galleys are reasonably cool.

Life-saving Appliances. Life-saving appliances on tankers receive very special consideration. Lifeboats are made of steel. There are usually four such boats in a deep-sea tanker, two of which are engine-propelled. The usual practice is to locate two boats amidships, one hand-propelled and one engine-propelled, and the remainder aft, the engine-propelled boat aft being on the opposite side of the ship to its counterpart amidships. There is sufficient accommodation for the whole of the personnel in the boats on either side of the ship, so that in the event of fire occurring at one side of the ship as the result of collision with another ship the personnel can escape in the boats on the opposite side. Lifeboats are provided with skates or skids which enable them to be launched satisfactorily even when a ship is heeled over to 30°, and mechanical lowering gear is provided which ensures the boats being lowered on an even keel. In the past, many seamen have lost their lives due to lifeboats up-ending when lowered by hand. The lifeboats are provided with battery-operated wireless sets with a range up to 500 miles during the hours of darkness, and equipment which will protect the occupants from exposure.

Trimming. Locating the engines aft in a tanker makes trimming difficult, as in ballast condition the weight of the machinery gives the ship a pronounced trim by the stern, while the ship must, of course, be on an even keel when loaded. This calls for very careful consideration of the loading arrangements when part cargoes have to be discharged at different ports. Another trimming problem results from the consumption of bunker fuel on a voyage, amounting to from 300 to 1,000 tons, depending upon the size of ship and type of machinery. This difficulty is overcome by splitting the bunkers and storing them at both ends of the ship. As the fuel from the aft bunker is used that contained in the forward deep tank is transferred aft and the ship maintained on an even keel. In dry cargo ships the bunker fuel is kept in the double-bottom tanks extending practically the whole length of the ship, and the maintenance of an even keel is a comparatively simple matter.

Fuel Consumption and Speed. The great bulk of the Group's products is transported in tankers of 12,000 tons deadweight*, which have a speed of 12 knots. These ships are propelled by oil

engines of 3,600 b.h.p., and the fuel consumption is 12 tons per day. Carrying 12,000 tons at 12 knots on a fuel consumption of 12 tons daily, the great economy of these ships is best illustrated by simply calculating the expenditure of fuel to transport 12,000 tons of cargo one mile: and the amount is 8 lb., or less than 1 gallon. This reflects credit upon these Group-designed ships as well as on the thermal efficiency of the oil engines employed.

The conditions governing the operation and the maintenance of tanker machinery differ widely from those ruling in dry cargo ships. Normally, tankers load or discharge a full cargo and discharge or take on ballast in 48 hours. In normal times a tanker spends roughly 320 days at sea every year, which is about 50% more actual steaming time than dry cargo ships. Moreover, owing to the nature of certain cargoes carried by tankers, it is not permissible to do running repairs concurrently with loading or discharging cargo, owing to the presence of explosive gases. All running repairs, overhauls, examinations and adjustments must therefore be in strict accordance with a carefully thought out schedule and, if breakdowns at sea are to be avoided, examination of every part of the machinery has to be carried out as a matter of regular routine, all data relative to these examinations being recorded and analysed by the Group's marine technical staff.

The propelling engines most employed are of the four-stroke cycle single-acting supercharged type having eight cylinders. The length of such an engine is about 45 feet, and the weight in the region of 300 tons. The weight/power ratio of marine engines is high because the revolutions rarely exceed 120 per minute, the usual rate being 110 per minute. Higher rotational speeds result in a rapid falling off in the propeller efficiency and are only employed in special cases, such as when the type of ship allows only limited space for machinery. The latest practice is to cool the cylinders and pistons by means of fresh water, the fresh water amounting to about 100 tons being cooled by sea water and used over and over again. Pistons are sometimes cooled by lubricating oil, which is very effective and has advantages over water as a cooling medium. After the exhaust gases leave the engine they are directed through a boiler in which steam is generated and used to operate the steering gear and other auxiliary machinery.

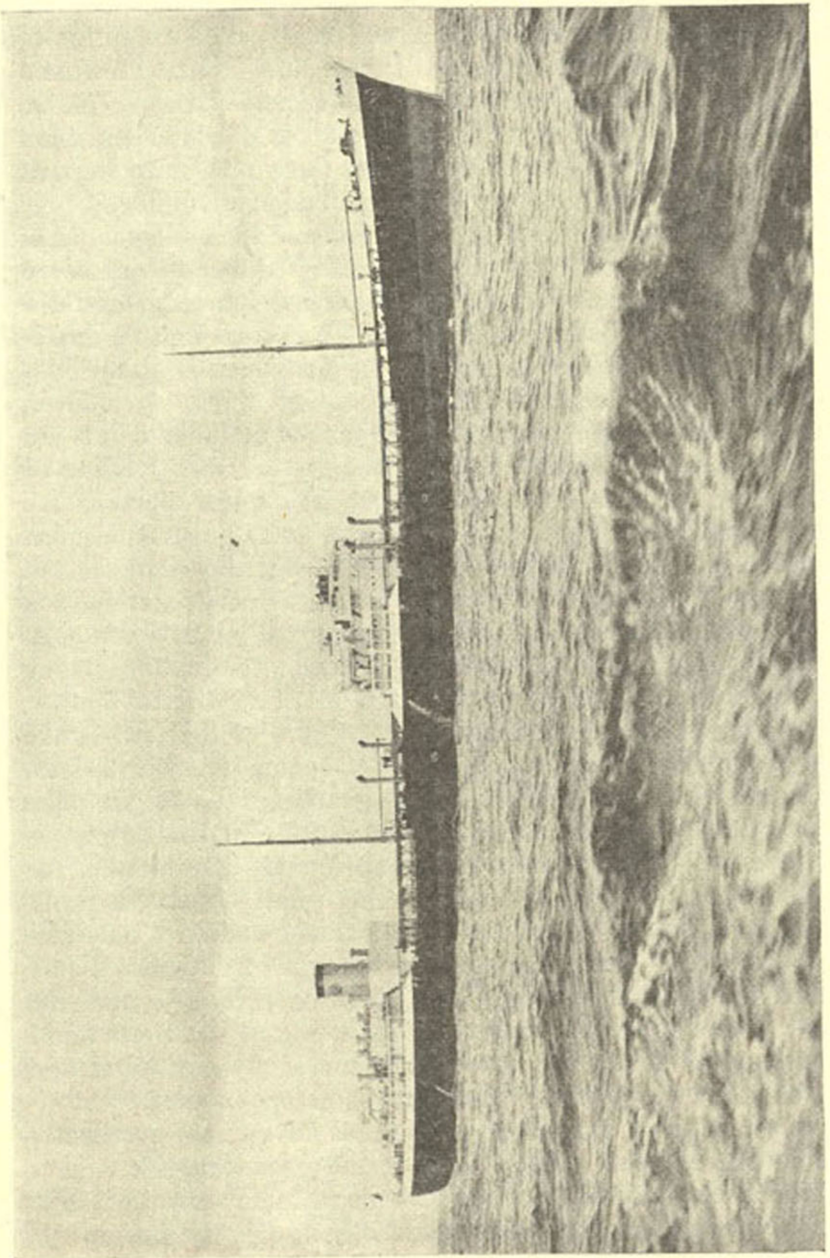

Fig. 5. Photograph of Modern Tanker.

Although the modern tanker is a highly compact and efficient carrier of bulk oil and capable of transporting dangerous cargoes with a remarkable degree of safety, research and investigation continue energetically, and, as a result, improvements in ship form, machinery and equipment are constantly being introduced, while Group tankers continue to take the lead in providing for the comfort and convenience of those who go down to the sea in ships.

FAST TANKERS

During the recent war the tendency was to build fast tankers, the purpose being to enable such ships to operate independently of the convoy system, which restricted the average speed of the vast majority of ships.

The Marine Technical Division of the "Shell" Group prepared designs for such tankers, and ultimately ordered two of 18,100 tons deadweight, a speed of 17½ knots and 90% welded construction. These vessels, "HELICINA" and "HYALINA", are propelled by turbo-electric machinery of 13,000 S.H.P., steam being supplied by Babcock and Wilcox water tube boilers at a pressure of 425 lb. per square inch and a temperature of 750° F., the over-all fuel consumption being 85 tons a day.

The British Admiralty also built a number of what could be considered fast tankers. These ships, of 12,000 tons deadweight, were given a speed of 15 knots by geared turbines of 6,800 S.H.P., steam being supplied by Foster Wheeler water tube boilers.

A further example of fast tankers built for war purposes are the American T-2s. A large number of these all-welded vessels were constructed, the power of the turbo-electric machinery being 6,000 S.H.P., which gives the ships a speed of 14½ knots on a fuel consumption of 50 tons a day. The deadweight of these ships is about 16,650 tons.

Since the war, the tendency has been to build larger tankers. The Shell Group has ordered three of 28,000 tons deadweight, but because of the deep draught of such ships the number of ports which they can enter when fully loaded is small.