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Optimum Hydraulic Systems for Fishing Vessels

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Abstract

Hydraulic drives for deck machinery, net and line haulers, fish pumps and circulating bilge pumps are commonly used throughout the major fishing industries of the world. Power transmission on trawlers, seiners, gill net and pot fishing vessels under 100 feet in length not exceeding 100 hp makes the use of standard mobile hydraulic components, combined with available gear reducers, ideal. Fixed displacement systems have the advantage to the fisherman of dependability, ease of installation and maintenance, good speed and load control, and low cost. A typical example of the application of hydraulic power can be found in vessels operating in the Gulf of Mexico and off the Pacific coast of South America. One of the best examples is the modern Peruvian anchovy seiner with complete hydraulic powered system for purse seining winch, Puretic power block, main boom topping, fish pump drive, bilge pump drive, and anchor winch, all driven from a central pumping source connected to the power takeoff of the main engine. Menhaden purse boats and carrier vessels are well equipped with hydraulic power blocks, crane, boat hoist and strapping winches. Hydraulic drives for trawl winches, although not common in the shrimp industry in the Caribbean, are very much in use on vessels of similar size in the Pacific. This paper summarizes the types of motor drives, the control circuits, and installation standards for practical fishing vessel service in the Caribbean area.

INTRODUCTION

THE DEVELOPMENT of the use of hydraulic power on fishing vessels in the United States began after the Second World War when a large amount of military surplus equipment became available. Until the mid 1950's hydraulic drives on mechanical winches, net rollers and line haulers were primarily applied by the fishermen utilizing this surplus hydraulic equipment, or farm type hydraulics in the 800 to 1,000 pounds per square inch (psi) range. Concurrently in Europe the use of hydraulics on fishing vessels was progressing much faster as the equipment manufacturers had developed a low-pressure, vane-type motor design which was directly coupled to the drums and gurdys. These manufacturers actively built deck machinery incorporating hydraulic drives of this type. Today in Europe, particularly Scandinavia, the low pressure hydraulics, 350 to 600 psi, are still very popular on deck mounted machinery, while the development in North America has followed a course set by the higher pressure (1000-2500 psi) mobile and industrial component manufacturers. The limitations of size and weight are causing a rapid trend in Scandinavia toward the type of components and systems used in American vessels today, particularly on purse seiners where portable, remote controlled equipment is required.

About 1953, hydraulic drives were being engineered on new equipment in the United States' salmon fishery in the Pacific Northwest. Large reels on which the entire purse seine net is stored were driven hydraulically. A flexible connection to the hydraulic drive was necessary because the reels which turn on a horizontal axis must be mounted so that they also can be turned to face the direction from which the net is being hauled. Shortly thereafter came the Puretic power block which, because of the mounting position at the end of the boom, required a light weight, high torque drive that could be remote controlled. Since that initial acceptance, the maximum horsepower (hp) available in the type of hydraulic components practical on fishing vessels has increased from 30 to 150 hp. During this period the introduction of higher horsepower winch drives has followed closely the development of higher horsepower hydraulic motors and valves. Today many manufacturers of net hauling equipment and winches utilize hydraulics in the basic design of the equipment.

The fishermen have readily accepted hydraulics on their vessels as it has numerous distinct advantages over the other forms of power transmission. These alternate forms of power transmission are air, electricity and mechanical drives.

In such applications as the hanging gurdys for pot fishing and the Puretic power blocks, the most obvious advantage of *size* and *weight* are a prime requisite for choosing hydraulics. In comparing motors of the same speed (1800 rpm), the electric motor weighs 20 to 30 pounds per horsepower while the hydraulic motor weighs one to two pounds per horsepower. The dramatic difference in size can be seen in Fig. 1 which shows an electric motor driving a hydraulic pump of comparable horsepower. Therefore when size and weight are a consideration, hydraulic motors, pumps, and controls have a distinct advantage.

Variable speed and *torque control* are major functions which interest the fishermen. Vessels operating in a sea condition are subject to accelerations which, when applied to nets and lines, often cause considerable damage. When the nets are full and the catch is large this damage is the greatest. Therefore, the ability to control the speed and the pull on the line, net or cable adds considerably to the safety and reduces the strain on the gear. The nature of hydraulic drives makes it possible to maintain tension on the net or lines, even in the stalled condition. A typical example occurs in purse seine fishing where the net is concentrated at the side of the vessel during brailing or pumping. Tension must be applied to the net by winches or power block so as to maintain a high concentration of fish. Overstraining of the net, even under the normal sea conditions, is a very real problem. It is here that the hydraulic

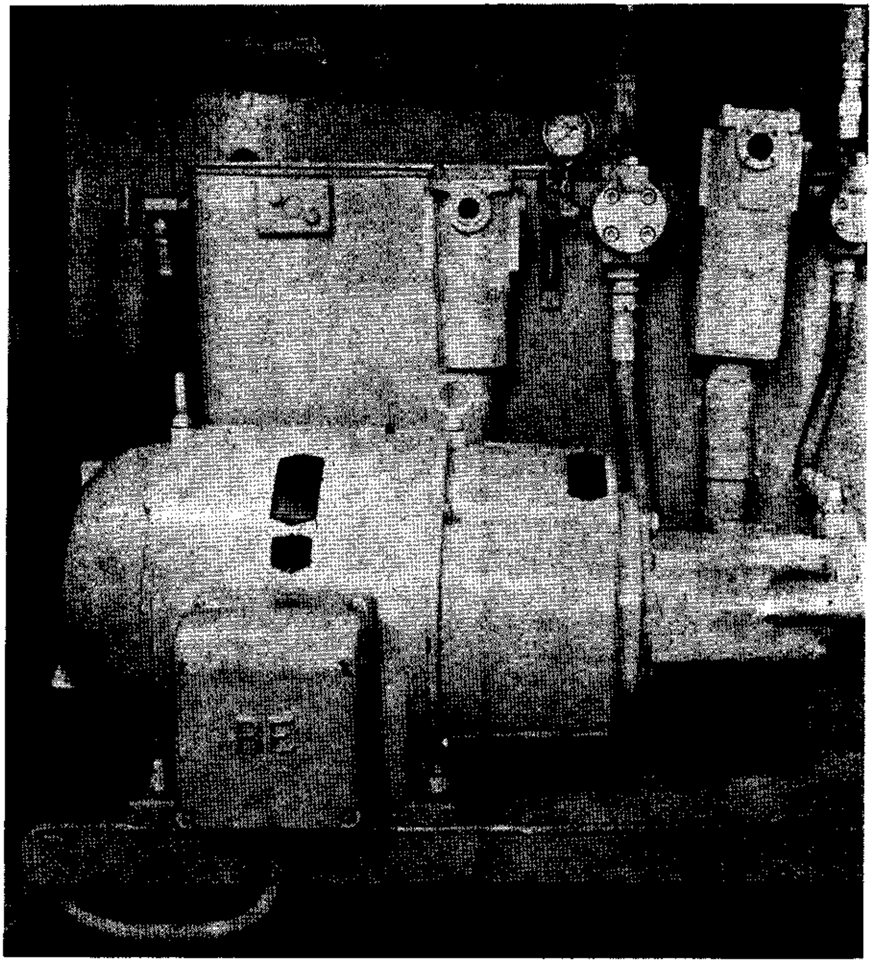

FIG. 1. Electric driven 40 hp hydraulic double pump mounted on a common base with 55-gallon oil tank, filters and relief valves.

drives, applying a constant tension to a winch, reversing when the ship rolls away from the net and the maximum strain is exceeded and hauling in again as the vessel rolls toward the net, will minimize the chance of loss of the catch. Tension control can be accomplished with an air system, but electric or mechanical drives are not practical solutions to this problem.

The economic pressure to reduce crews on fishing vessels necessitates a concentration of winch and fishing equipment control, either in the pilot house or in some convenient location on deck. Medium pressure hydraulic drive lends itself to this type of *centralized control.* Normally speed, direction and maximum pull can be controlled with standard available components. The valves are also available through which the operator can sense application of pressure to the remotely located clutch or brake.

The *dependability* of hydraulic systems in the marine atmosphere has been well established where the installations have been made in accordance with good marine and hydraulic practices. Having been involved with the application of hydraulics to over 6,000 vessels, and being associated with a vessel operating company, I can truthfully say that the hydraulic deck machinery system has been the least problem of any of the power transmission systems found on fishing vessels. Components in the optimum systems can be easily understood and maintained by the fishermen. Valves, motors and pumps have few working parts. Because the hydraulic oil is under pressure, the most common problem is leakage and the remedy is self-evident. Failures caused by excessive dirt and wear in the system are usually manifested by a slow reduction in torque and speed which does not create a crisis in normal operation.

With advantages of sizes and weight, variable speed and torque, remote control and dependability, hydraulic power transmission is worthy of consideration for all fishing deck machinery drives.

APPLICATIONS OF HYDRAULICS TO VARIOUS FISHING METHODS

Purse Seining

Hydraulic deck machinery and net hauling equipment has been most popularly applied on purse seine vessels. In fact, there are probably no major purse seine fisheries throughout the world which are not using hydraulics. Figs. 2 and 3 show the latest vessels of this type in the 85- to 90-foot size. This style

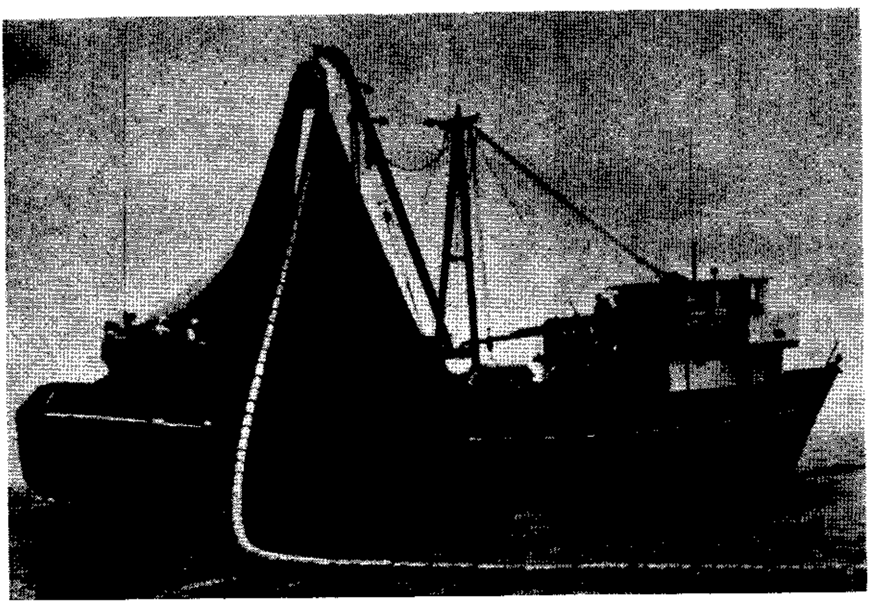

FIG. 2. One of over 1000 Peruvian anchovy seiners with hydraulic deck machinery systems.

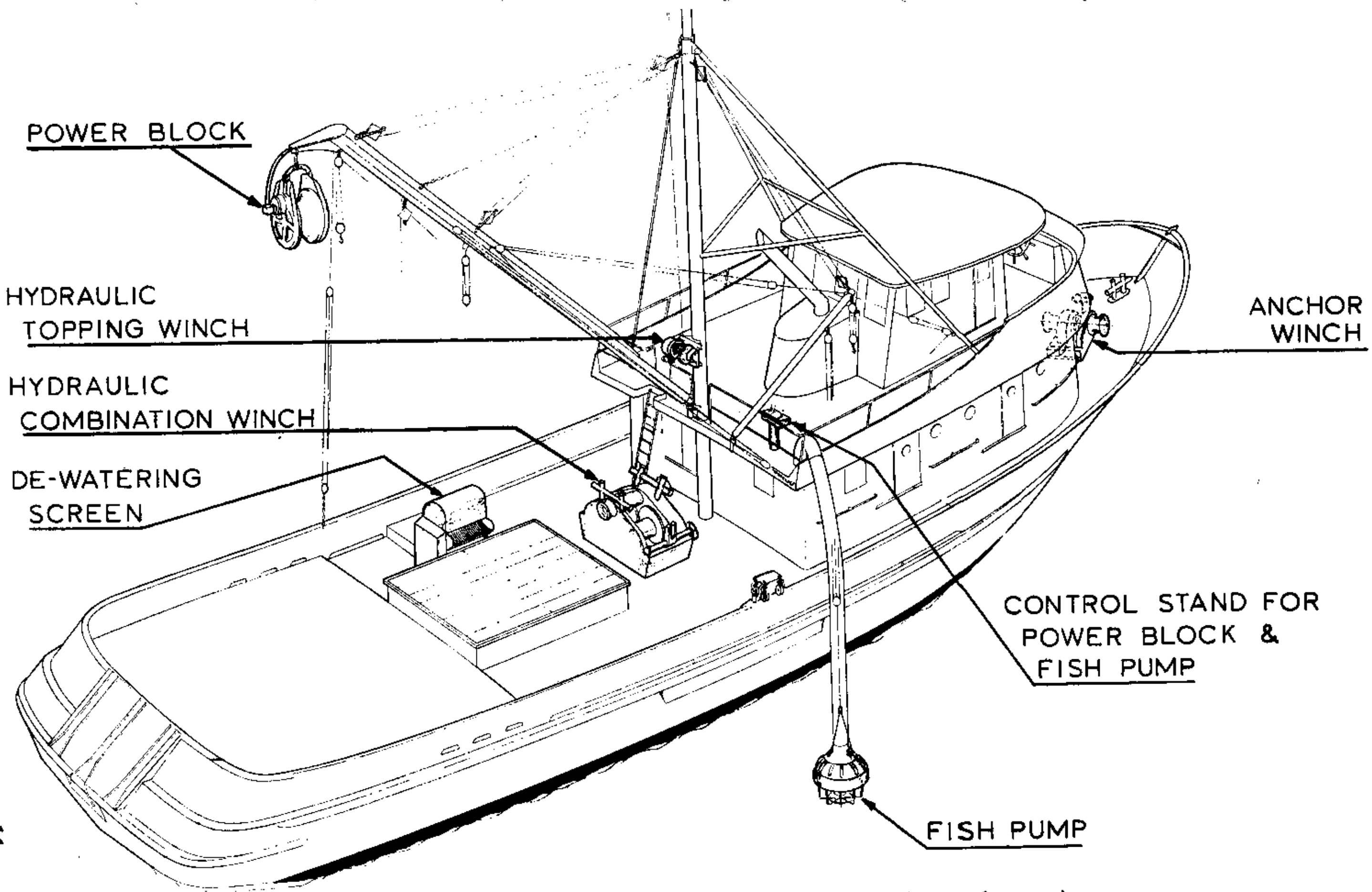

FIG. 3. Modern hydraulic deck machinery system on a Peruvian anchovy seiner driven from central system (see Fig. 13) and controlled from upper deck.

of purse seining is used on over 2000 vessels on the Pacific coast of North and South America. The vessels are totally equipped with hydraulic deck machinery. Such a system includes the main purse winch (either drum or gypsy type), the Puretic power block for net hauling, the boom topping winch, the fish pump drive, the anchor winch, and, in some cases, the bilge pump, and refrigeration circulating pump drives. As the fisheries, particularly in South

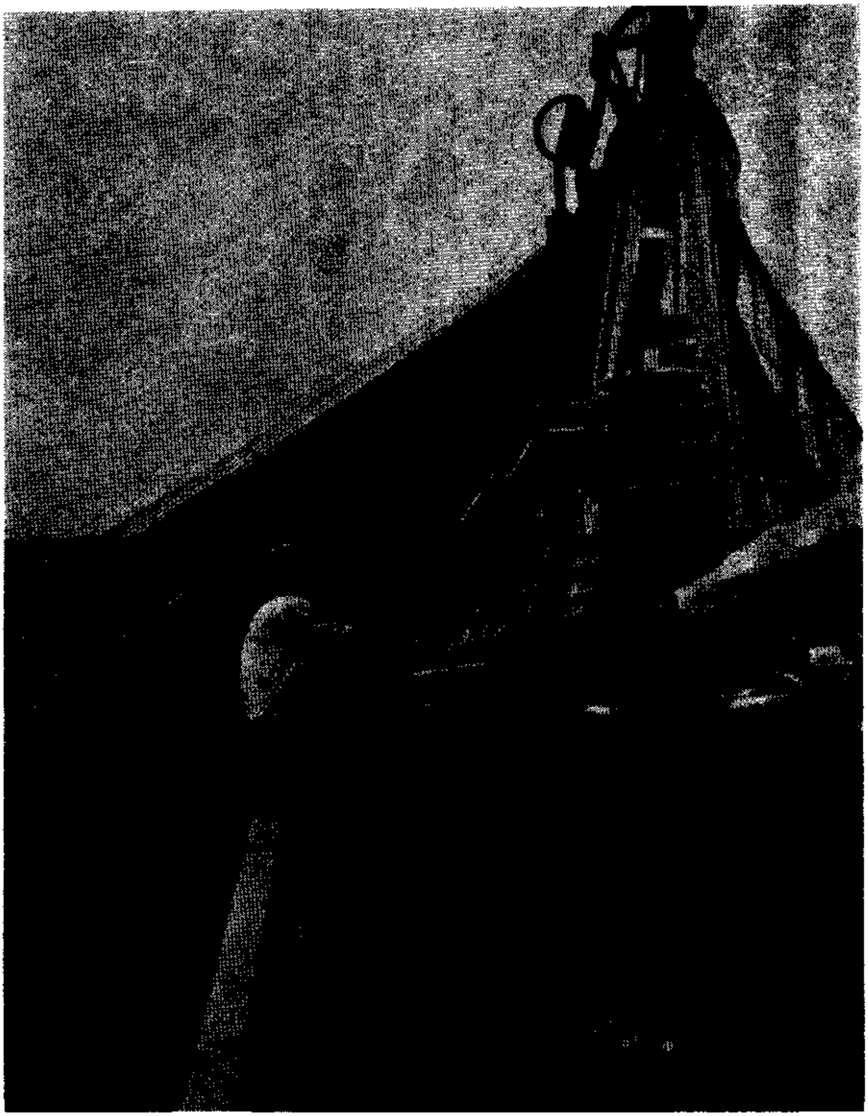

FIG. 4. Hydraulic crane, power block and purse line reel in menhaden purse boat.

America, have expanded rapidly and experienced crews are not available, hydraulic systems have proven to be a saving grace on many occasions when the winches and gear might otherwise be overloaded. As the equipment in a purse seine system is not all used at full power concurrently, it is possible to devise a relatively simple hydraulic system to accomplish the various tasks throughout the fishing cycle. Further discussion of the circuit design will follow.

Fig. 4 shows a typical menhaden purse boat. Beginning in 1959 these boats were equipped throughout the entire industry on the Atlantic and Gulf coasts with hydraulic power blocks, cranes, and purse line reel drives. The hydraulic system in the purse boat has been engineered specifically for this job and has several unique features which enable quick installation and dependable operation. The crane column contains the oil storage reservoir onto which the valving for swinging and hoisting, and the boom and power block speed and direction control are directly mounted. The piping in the boat itself is therefore reduced to the installation of a hydraulic pump on the main engine power takeoff and the piping from this pump to the crane. Some of the purse boats are also equipped with hydraulic purse winches, but this function is normally provided through a chain drive reduction to the main engine. This system has played a large part in the reduction in the fishing crew which has kept the menhaden industry competitive in the world fishmeal industry. On the menhaden carrier vessels the hydraulic system is used to hoist the purse boats, to strap the net, and to hoist the fish pump's suction hose into the net. In the chilled sea water refrigeration systems, hydraulic drives for the chilled water circulating system and condenser cooling water are often driven hydraulically through a system connected to the same auxiliary engine driving the compressor.

The size of purse seiners seems to be increasing in almost every fishery not subject to governmental size restrictions. The largest nets utilizing this method of fishing are found in the tuna industry where hydraulic-drive winches, capable of pursing net up to 1400 fathoms in length and 150 fathoms depth on vessels up to 200 feet in length, are now in use. In addition to the equipment on the smaller purse seiners, tuna vessels are also now being equipped with hydraulic-driven bow thrusters to maintain a proper position during the pursing and net hauling phases of the fishing operation, as well as a number of auxiliary drum and capstan winches. As bow thrusters are used at the time during the cycle when the purse winch is being utilized at maximum power, a separate hydraulic pump drive is usually employed.

Therefore, on purse seiners hydraulic drives are the most common form of present day power transmission. As this fishing method increases in popularity in the Caribbean, the hydraulic systems will undoubtedly follow the current trends in other fishery areas.

Trawling

Until the last few years, hydraulic driven trawl winches had not been popularly accepted throughout many fisheries. On smaller vessels, the trawl winch functions have been directly coupled to the main engine power take off. On larger vessels, such functions are powered by auxiliary diesels or direct current electric motors. In the shrimp industry hydraulic drives for trawl winches are just beginning to appear. On larger horsepower vessels with larger trawl winches a separate drive for the frequently used try-net winch would save

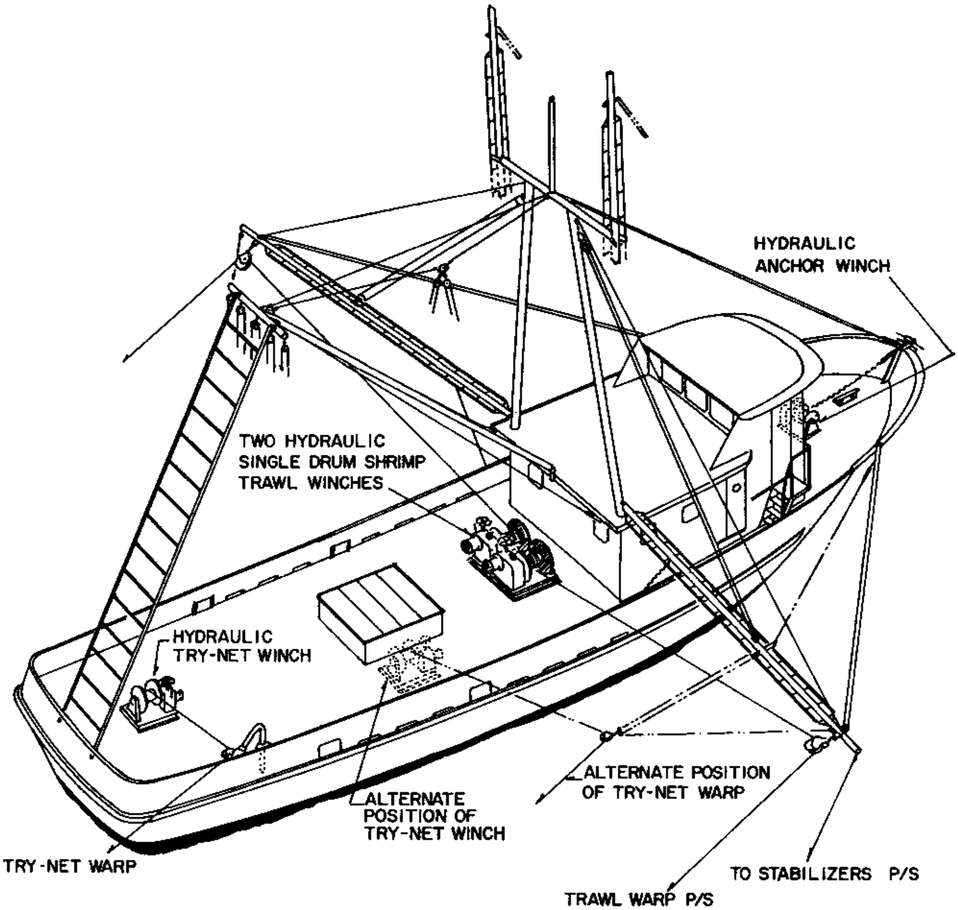

FIG. 5. Flexible arrangement of shrimp trawl gear with hydraulic drive winches.

the continuous running and wear of the main trawl drum drives. Such a split drive could easily be accomplished hydraulically. Fig. 5 shows such a system. In other areas, such as off the coast of Chile, the single rigged, deep water shrimp trawlers (Fig. 6) have all converted their mechanical winches to hydraulic drive after a period during which they tore up the mechanical transmissions all the way from the engine crank shaft to the trawl warps. The fluctuating strain in the rough sea conditions and the inability to adjust the winch pull and speed independent of the revolutions per minute (rpm) of the engine were the main causes for the damage. A two-motor hydraulic drive gear box was devised for mounting on the shaft of the mechanical winch. This enabled the fishermen to control the maximum line tension which could be applied to the trawl warps during hauling, reducing greatly the strain on the cables and gear. Speed and directional control of the winch (Fig. 7) enable

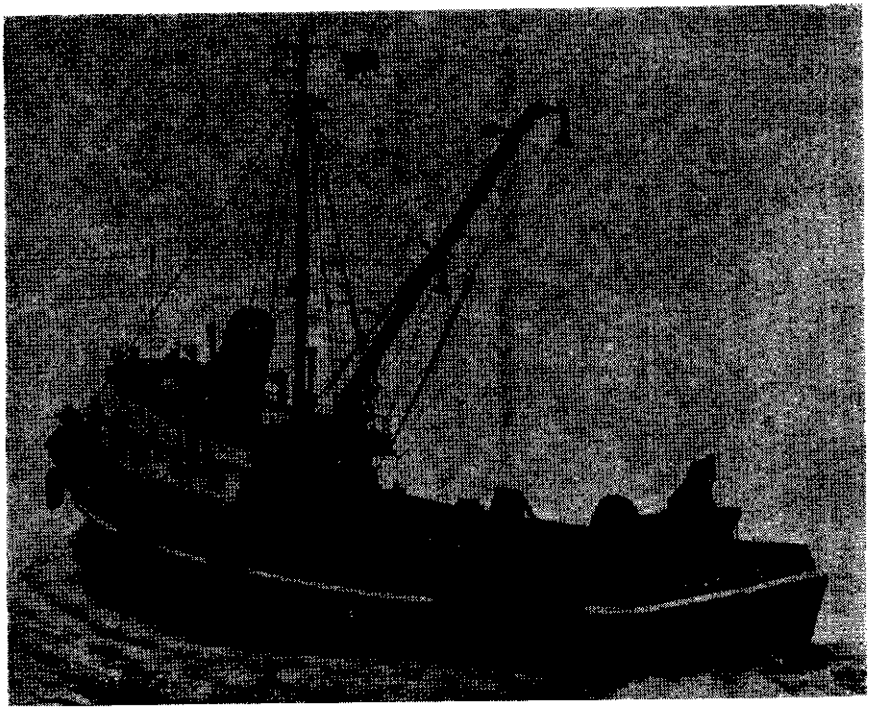

FIG. 6. Single rigged South American shrimp and langostino trawler uses hydraulic drives on main winch, net reel and anchor winch.

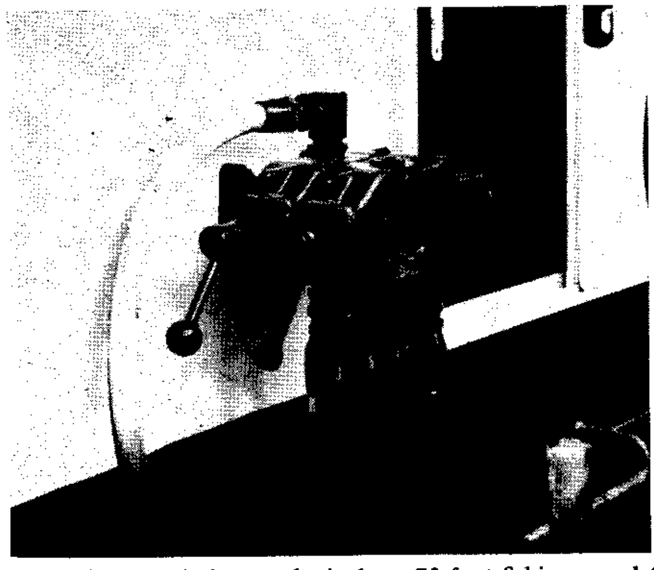

FIG. 7. Hydraulic controls for trawl winch on 73-foot fishing vessel (Fig. 6).

the operator to maintain a more constant hauling speed, even though the wire builds up on the drums increasing the hauling speed. With heavily loaded nets another control valve shifts half of the oil flow to a second motor drive, doubling the line pull of the winch. The total results have been most satisfactory in the saving of gear and equipment so that the further use of mechanical winch systems is not contemplated.

Gillnetting

In the gillnet field several types of hydraulic rollers, reels and power blocks are available to assist the fishermen in bringing the nets on board. Usually the vessels in this type of fishing are small (from 20 to 40 feet) and light weight equipment and drives are required. Fig. 8 shows a modern fiberglass one-man gillnetter equipped with two different devices (used at different seasons of the year but shown concurrently on the vessel). As many of these vessels are driven by gasoline engines, the hydraulic pumps are commonly the automotive steering pump type which delivers 2 to 6 hp at high engine speeds.

Pot & Line Fishing

Hydraulic gurdys now available on lobster, crab and crayfish boats con-

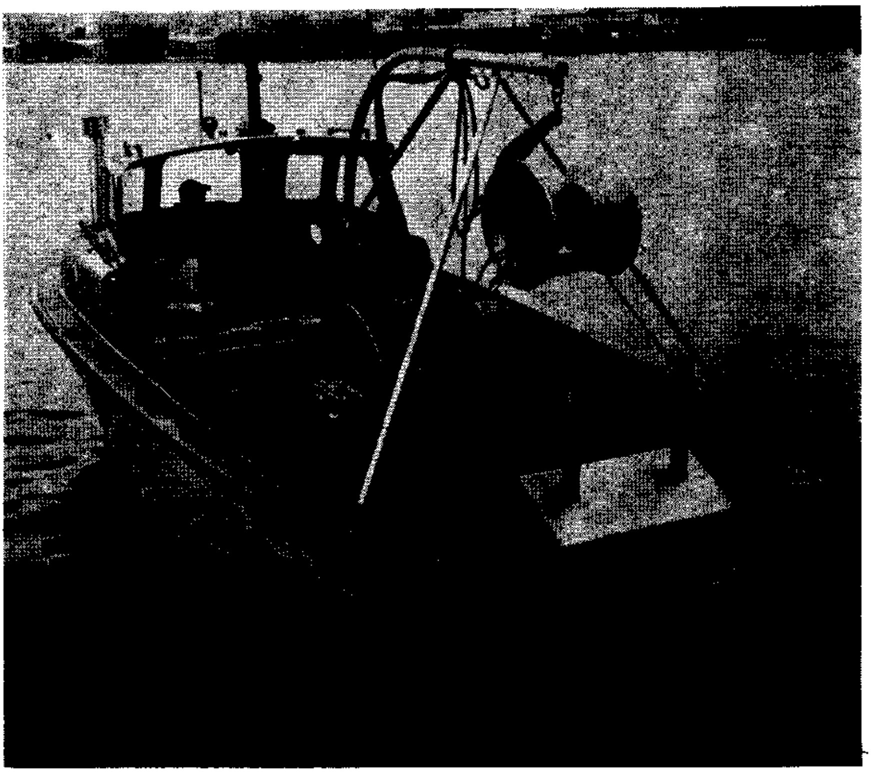

FIG. 8. Thirty two-foot gillnet boat with hydraulic reel and power block. Automotive hydraulic pumping unit driven from main engine produces 10 hp.

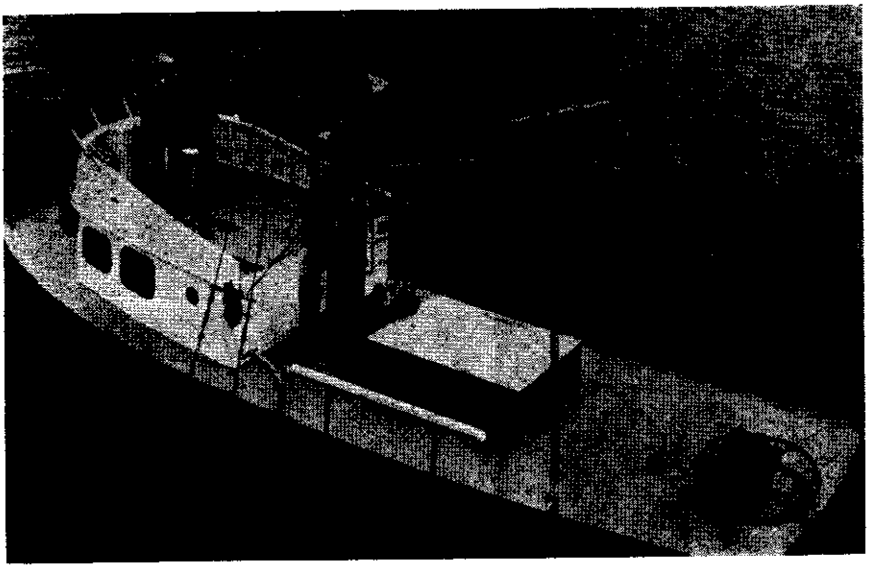

FIG. 9. Hydraulic winches and gurdy for king crab fishing vessel are controlled at panel on back of house.

siderably speed up the trap hauling operation. Fig. 9 shows such a vessel equipped with a hydraulic boom which is topped during the fishing cycle and a hydraulic crab pot hauler which enables a three-man crew to handle up to 400 pots per day, each individually set with a 20-fathom pot warp. Hydraulics has provided a major contribution in this fishery as lines previously hauled on gypsy winches often broke when the traps were silted in the sand, because the mechanical drive was unable to sense the maximum safe line tension on the pot warp. Such equipment is used experimentally in the Caribbean and commercially along the coast of Brazil.

On line fishing boats, utilizing trolling or longlines, gurdys can easily be driven by hydraulic motors in a manner shown in Figs. 10 and 11. Fig. 12 shows another application, the fish unloading hoist, ingeniously devised from gear reducers and with hydraulic motors.

In summarizing the applications, it appears that there is very little limit to the use of hydraulics for any winch, line, or net hauler on fishing vessels, regardless of size or the type of fishing method so long as power is available to drive the hydraulic pump.

HYDRAULIC SYSTEM COMPONENTS AND THEIR SELECTION

Considering the major advantages to the fisherman of size and weight, speed and torque control, dependability of operation and cost, it is possible to select with the various types of hydraulic equipment available today a system and components which will produce the optimum results. Motors and pumps that are working out most satisfactorily on fishing vessels are the mobile class of hydraulics. This type of equipment is found on heavy earth

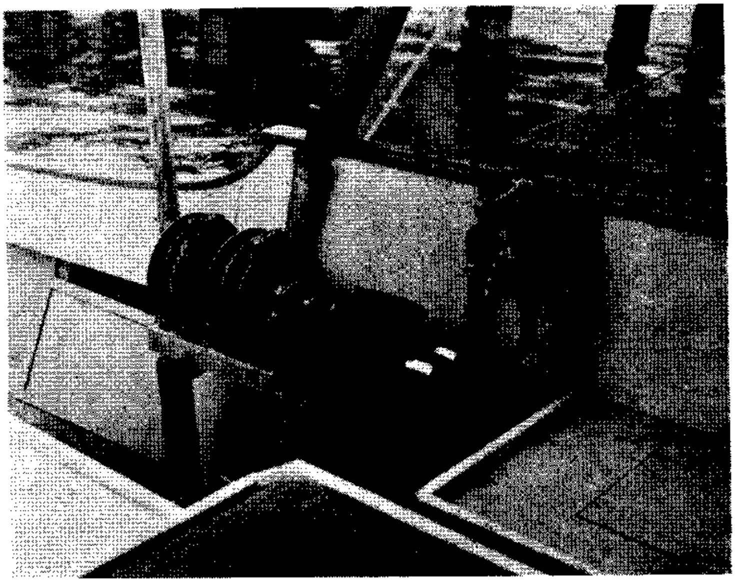

FIG. 10. Hydraulic motor and control valve driving a trolling gurdy.

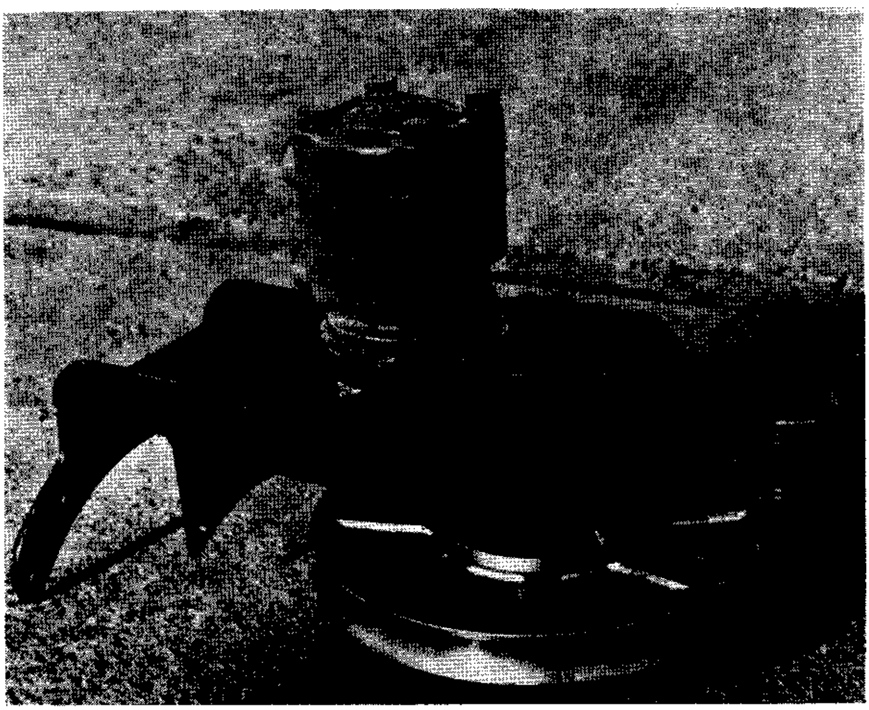

FIG. 11. Hydraulic motor and gear reducer applied to a long line gurdy.

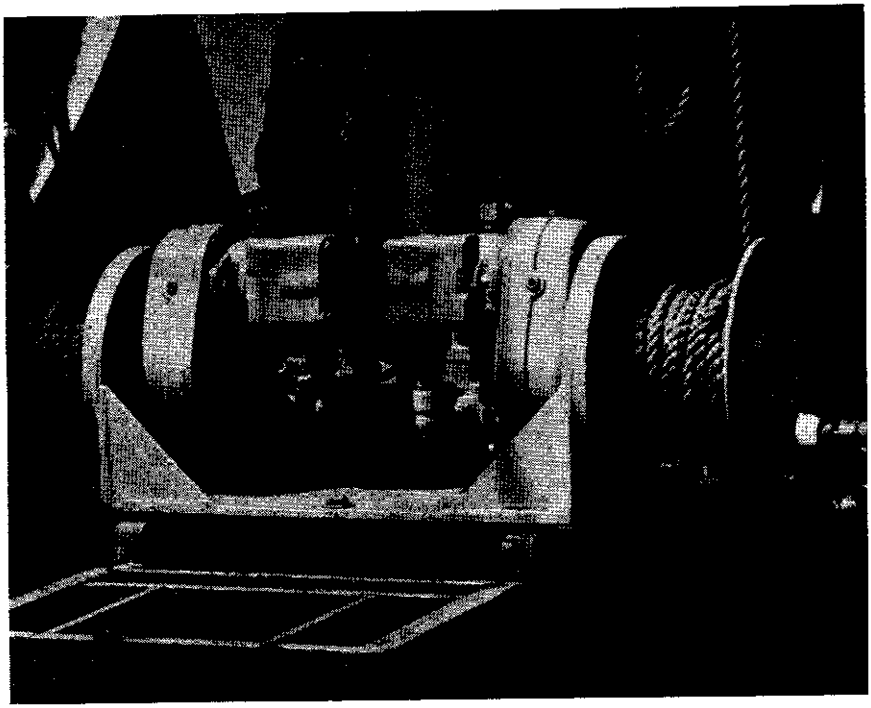

FIG. 12. Hydraulic motor and marine gear reducer made into two small fish unloading winches.

moving machinery, cranes and trucks. It operates at pressures of 1000 to 2500 psi and has a fixed flow of oil at a given speed. It is known as *constant displacement equipment*. The vast vehicle market has enabled valve manufacturers to develop specialized valves combining a number of functions into a single control package with many selections and configurations available at reasonable prices. The mobile components are designed to operate in a highly contaminated atmosphere and have a higher level of dirt tolerance within the oil than industrial hydraulic equipment. Control valving for mobile applications is often the smoothest available for fixed displacement systems. The general range of operating pressures on mobile equipment has increased from 800 psi 10 years ago up to 2500 psi today. The marine industry applications are following this trend.

One of the prime pitfalls in selecting hydraulic equipment for marine service is the overemphasis on efficiency and accurate speed control. This results in a tendency to use industrial variable displacement components that require sophisticated pumps, motors and valves with finer tolerances. When such systems are assembled under the conditions found in most of the shipyards serving the fishing industry, rather than in the factories manufacturing machine tools for which these components were designed, the results are often far from satisfactory. To comply with the low tolerance requirement for dirt in such a system is far beyond the capacity of the installing personnel and beyond

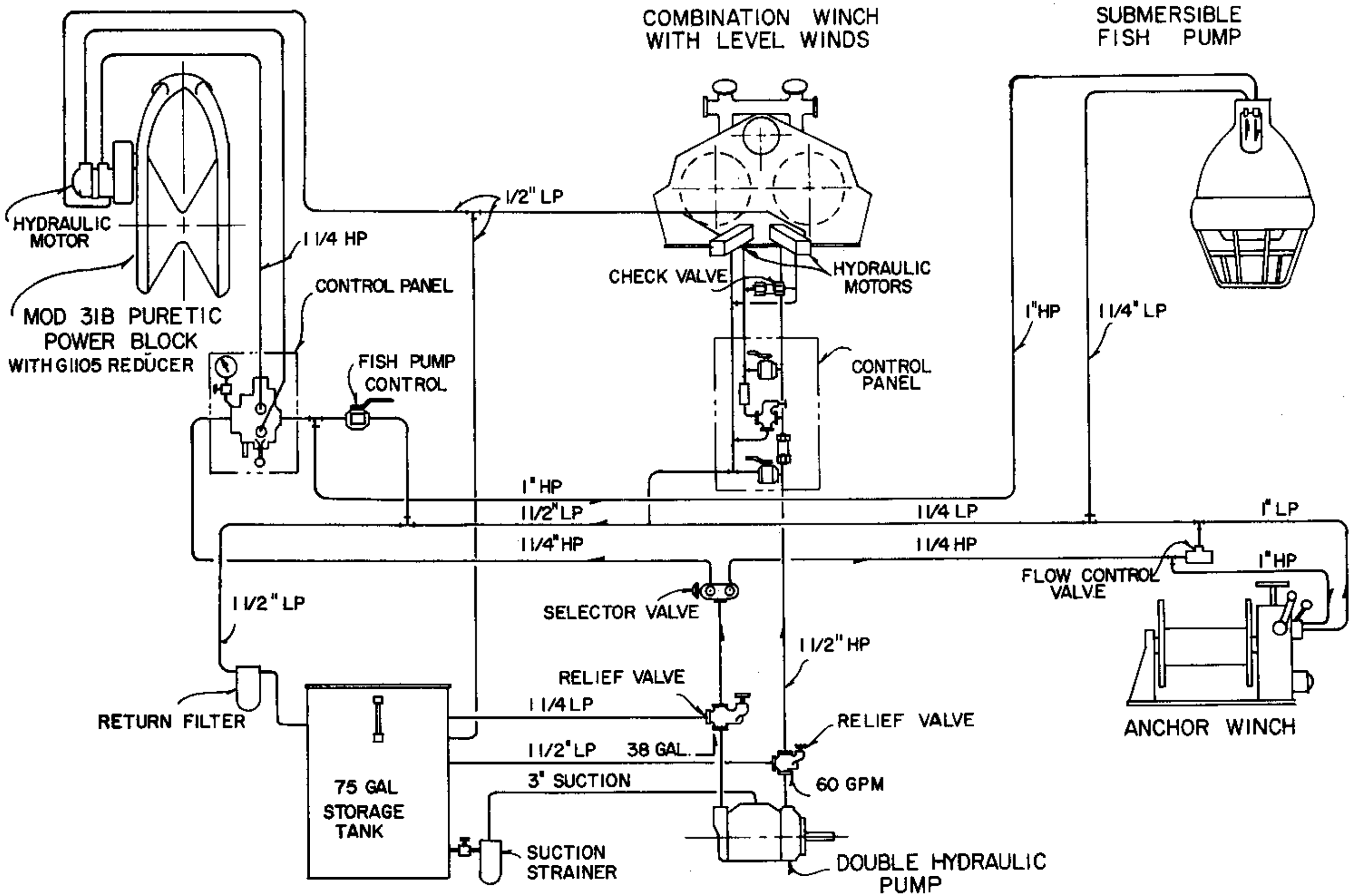

FIG. 13. Hydraulic piping system for Peruvian seiner shown in Figs. 2 and 3 is driven from main engine as shown in Fig. 17.

the capability of operating personnel. The cost of the components is accordingly higher and the effect of corrosion in the marine atmosphere further accentuates the problems of dependability.

Problems can also arise by using equipment which is not designed to withstand marine service. This problem is less of a hazard to the fishermen than the hydraulic system with overly sophisticated components. In general, the least expensive components are those sold in the farm industry in the low horsepower range. Their objectionable characteristic is the wear which causes leakage and loss of power. Between these ranges lies the field of hydraulics, which has proved successful to the fishing industry. The problem then is to design circuits and select components within this range that give the desired results.

Circuit design on a fishing vessel requires a knowledge of the duty cycle of each piece of hydraulically driven equipment, as well as the duty cycle of the prime mover from which the pumps are to be driven. In most vessels less than 100 feet in length, the hydraulic pumps are driven from the front power takeoff of the main engine. Therefore the pumping system is subject to fluctuations in output in proportion to the change in engine speeds during the cycle when the equipment is being used. In the typical purse seiner circuit shown in Fig. 13 the hydraulic oil from the 38-gallon per minute (gpm) discharge of the pump is used to run the power block, the fish pump, and an anchor winch. Not all of this machinery is required to function at full load simultaneously, and it is possible to use the same oil for each purpose. A separate 60-gpm discharge is required for the purse winch as it will be used concurrently with the fish pump and power block. When the power block is in use this oil is available to the fish pump. However, little or no pressure is available to operate the fish pump and power block simultaneously unless they are both in a very low load level. Often in fishing vessels, equipment is required to turn at reduced loads simultaneously with other equipment and the type of circuit used in this system is called *"series circuit."* In a series circuit the valves in neutral position have an open passage through which the oil passes from the pump back to the tank. The pump requires only a small horsepower to overcome line friction until the valve is shifted and a load is applied to the winch. Note that the anchor winch drive is not in series with the power block or fish pump, but is on a completely separate circuit requiring the selector valve in the engine room to be shifted in order to energize the anchor winch circuit. Inasmuch as the power requirements of the anchor winch are less than the fish pump and power block, the oil flow to the anchor winch is reduced with a *flow control valve,* bypassing the excess oil not required back to tank. A common fault in many hydraulic circuits is to use such flow control valves throughout the entire system in order to use a single pump flow for various winches each requiring a different oil flow. These valves cause a considerable problem in overheating the oil and are not recommended except where the duty cycle is very short, and where the residual flow bypassing the winch will not result in excessive heating as the oil passes from high to atmospheric pressure through the valve. Such is the case of the anchor winch, which is only used occasionally but is *not* the case with the power block or fish pump which operate under heavy loads up to 30 minutes during the cycle.

Another type of hydraulic circuit often considered but seldom used is a charged line *closed center system.* In such a system the hydraulic pump is operating under the maximum system pressure to maintain pressure in a line which feeds oil to all of the control valves piped from a common header in parallel. Such a system requires a large pump which must discharge a flow equal to the sum of the requirements for each winch to be run simultaneously. A pump charging the system at full flow produces considerable heat in the system as the oil must flow over the relief valve when the winches are not in use, acting as a brake for the full power input to the pump. Therefore, it is necessary to provide such a system with an unloading valve and an accumulator or small pump to maintain the charge in the line caused by the leakage of the various control valves. Such a system is rarely used on fishing vessels except for low horsepower brake and clutch control circuits.

The third type of circuit considered for marine service is the *closed loop system* of a motor and variable delivery pump with the oil circulating between the two without going to the tank. Pumps for this system are variable rather than fixed displacement so that speed and direction are controlled not with valves, but by stroking the pump. A separate charging pump is required to make up oil seal leakage and oil vented to the tank over a relief valve. The fine tolerances in the variable piston pumps and motors in the closed loop circuit present problems in filtration which are difficult to solve on fishing vessels. This system is not recommended for fishing vessel drives due to the poor service experience and the high component cost.

As a guide to determining the oil flows required to drive various types of fishing equipment, it is necessary first to determine the amount of output horsepower which the hydraulic motor is required to produce. In the example of the winch, this can be determined by the load on the winch, or the power input specifications of the winch as provided by the winch manufacturer. It is preferable to attempt to determine the actual loads as these many times do not correspond with the manufacturer's specifications. This formula for winch output horsepower is:

$$\frac{\text{Line pull (lbs.) x Line speed (fpm)}}{33{,}000} = \text{hp}$$

It is then necessary to apply a factor for the efficiency of the winch drive itself. For mechanical spur or bevel-gear driven winches 90% is an average efficiency, or 2½% per gear mesh. If the winch is a worm-gear winch the efficiency is lower and varies according to the ratio from 50% to 80%. Therefore it is necessary to *divide* the wire horsepower by the efficiency to obtain the input horsepower required of the hydraulic motor.

With maximum system pressure, 1500 to 2000 psi, it is possible to roughly estimate that the hydraulic oil flow in gallons per minute is equal to the horsepower. Therefore a 15 hp drive would be approximately 15 gpm at a 2000 psi maximum system pressure, with allowance for normal system back pressure. The hydraulic motor manufacturer's data will allow a more accurate determination of pressure and flow.

With a known oil flow required to the various hydraulic motors, it is possible to size the piping and valving in the system. The valve manufacturer's specifications will indicate the maximum oil flow desirable to obtain a tolerable pressure drop in the control valves. With a given oil flow a pump must have the capacity to produce this flow at the speed that the prime mover will be turning during the fishing cycle. In many fishing vessels hydraulic pumps are driven at higher than engine rpm with a sprocket and roller chain drive, belts or a step-up gear box. Care must be taken to design the pump drive so that at maximum engine speed the pump will not be turning faster than the manufacturer's maximum rpm rating. Though the fishing gear is used at reduced engine rpm, the power takeoff may be inadvertently engaged during the long trip home when the engine is running at near maximum speed. Much of this type of misapplication comes as the result of not knowing really what the cycles are on the fishing vessel and what possibilities can occur when the fisherman for some extenuating reason does not follow the predicted theory.

Further consideration must be given to the power takeoff clutch size. As a general rule, the fishermen are using the front power takeoff up to the limit before they decide to make a change to hydraulic drive. Therefore the over-all system efficiency from the input of the prime mover to the output of the hydraulic motor of about 60% must be included in calculating the clutch requirement. The accurate information should be obtained from the pump manufacturer's data.

In summary, the circuits used by most fishing vessels are series circuits. Often more than one pump is used because of the variations in horsepower transmission to different winches. These systems require a full knowledge of the duty cycle of the equipment and of the prime mover's power source. In knowing the output horsepower of the various deck machinery it is possible, through the above estimating formula, to quickly determine the oil flows, line sizes and pumping requirements.

The optimum components used in fishing vessel systems must be selected from hundreds of manufactured products available in the hydraulics industry. The subsequent discussion is an attempt to outline the criteria for such a selection.

Hydraulic Motors

These are chosen for their constant torque characteristics over a long-life period. The four basic types available are gear, gerotor, vane, and piston (Fig. 14). The radial piston type is a variation. All but the radial piston type generally have a maximum speed of 2000 rpm. The radial piston type are large displacement motors which have a maximum of about 150 rpm, but are of considerably higher torque characteristics. Of the four types the vane motors are most commonly used because the design results in a most constant starting and running torque, highly desirable for winches which must start under load. The well-engineered vane motors are wear compensated so that throughout the life in a relatively contaminated oil atmosphere found on most fishing vessels they tend to hold their original design capabilities much better than the gear and gerotor types. In general the piston type of pumps are not recommended because of the susceptibility to damage due to dirt and wear particles in the system.

The gerotor type motors have the unique advantage of a built in gear ratio which in small sizes to about 15 hp makes them quite an economical solution to the fisherman's problems. They are becoming very popular for small winch and gurdy drives. Their use, however, is limited in applications requiring long shafts and overhung loads such as Fig. 12 where a small vane motor driving through a gear box provides the bearing and shaft strength for a cantilevered drum for a fish unloading winch.

As a result of the desirability of using high speed motors for marine service, various manufacturers have developed speed reducers that enable the fishermen to select various torques and output speeds to adapt hydraulic drives to existing mechanical winches. Such a unit suitable for shrimp trawl winch drive

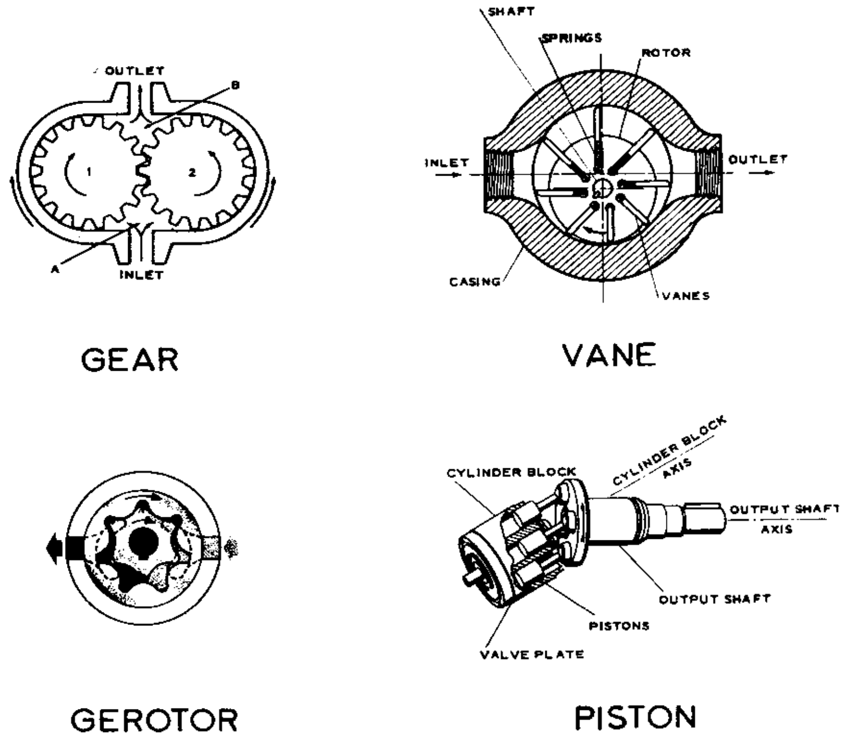

FIG. 14. Basic types of hydraulic motors and pumps considered for marine use.

is shown in Fig. 15. This solution is preferable to a large displacement, low-speed, radial piston hydraulic motor as it provides the torque at reduced expense and light weight. Should the hydraulic system utilizing the gear box and small motor become damaged through a poor installation or through the lack of maintenance, replacement of the worn parts in the high speed hydraulic motor would be a nominal expense to the fisherman as compared with replacement cost of a large comparable radial piston motor. Emphasis in selecting optimum components also includes minimizing the cost of the hydraulic components and obtaining equipment with a long life expectancy and high performance. Such equipment can operate with a relatively high tolerance for dirt in the hydraulic oil and can be repaired or replaced easily by operating personnel at a nominal cost.

Hydraulic Pumps

The types of available hydraulic pumps are the same as the hydraulic motors mentioned above. Pumps should be selected which have heavy bearings that can stand the side loads incurred with chain or belt drive unless a special pump base of a type similar to that as shown in Fig. 16 is used, or unless the pump is direct coupled as in Fig. 17. This base is designed for two double hydraulic pumps and is equipped with close coupled bearings in the base which take the side load of the roller chain. The vane-type pumps in a single

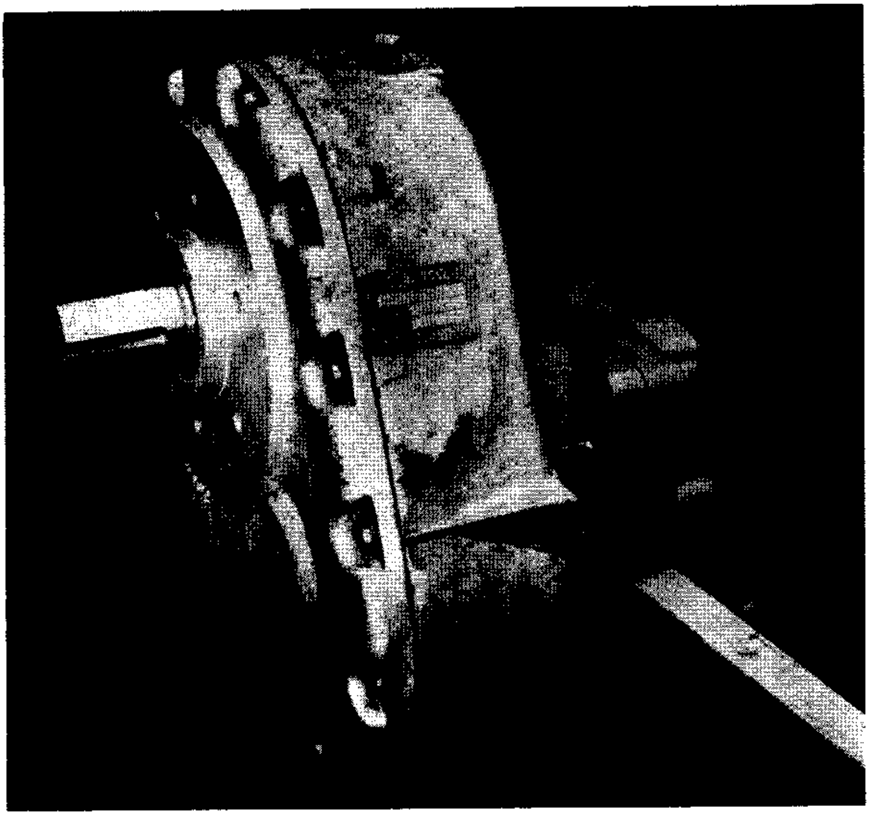

FIG. 15. Hydraulic motor and marine gear reducer provides economical low-speed high-torque input using standard hydraulic motors for converting a mechanical winch to hydraulic drive.

or double output configuration are undoubtedly the most common. As pumps are expected to perform in the 600 to 2000 rpm range, and are not subject to the starting torque of the hydraulic motors, gear pumps are sometimes used.

Pumps can also be driven in larger fishing vessels by electric motors as shown in Fig. 1. This is a typical unit used to drive winch systems on the large tuna fishing vessels where the electrical power is sufficient to handle the load incurred in the hydraulic system. Such pumping systems are therefore capable of being driven by several power sources if the vessel has more than one generator. On most of the large tuna fishing vessels additional pumps are available, driven by auxiliary engines, to provide additional security to retrieve the gear, even though the prime mover for the main pumping system is inoperative.

Control Valves

Valves for fishing vessel service in the systems can be divided into the following categories:

Direction Control Valves: In most cases these are spool-type valves called three-way or four-way valves. This designation does not have anything to do with the handle position but denotes the ways in which oil can flow through the valve. The four-way valve has normally four ports marked; "P" for pump pressure connection; "T" for tank return port; and "Cyl 1" and "Cyl 2" which are the working ports to the motor or cylinder. There are a dozen or more different valve configurations which can be utilized in these circuits. In general, consultation with the valve manufacturers' representatives is necessary to determine the proper valve. The best valves for marine use are those which have good speed control in the valve handle itself. This requires a tapered or grooved spool. The determination of valve spool configuration is often difficult because the nomenclature does not necessarily appear on the valve body but on the spool itself. If identification of an existing valve cannot be made, it is possible to determine the configuration of the spool by blowing into the port and seeing where the air comes out when the valve is shifted in different positions. The normal valve configuration in the series and open center circuit requires that the inlet and outlet form an open passage through the valve body when the spool is in the neutral position. Valves used in series are subject to pressure on the tank return ports as a downstream load is applied. This must be considered in the valve selection as some mobile four-way valves are not designed for this condition. The valve handles can be shifted against a spring so that when the operator releases the handle it shifts back to the neutral position. This is called the *spring centered* valve and is used for topping, vanging, cargo hoists and any drive which needs the constant

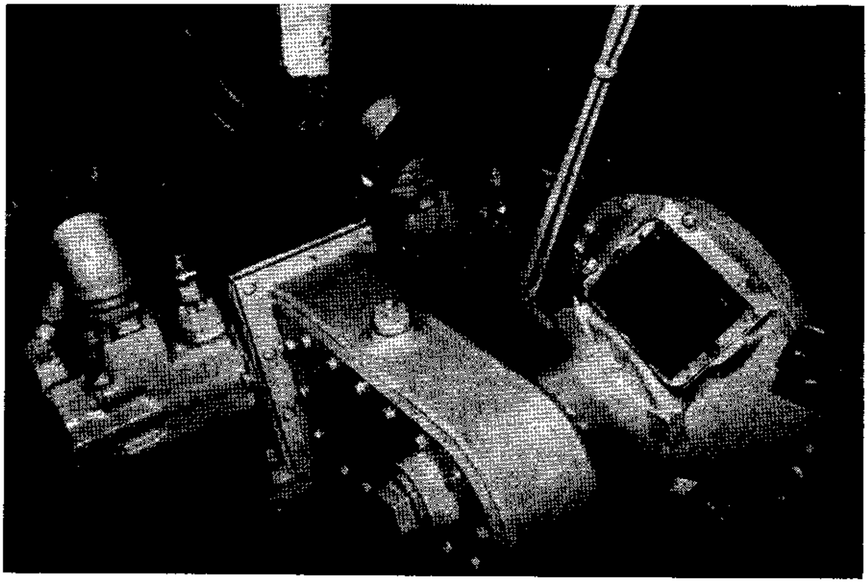

Fig. 16. Two double hydraulic pumps mounted on a common base driven from the main engine front power takeoff with roller chain drive in an oil bath (approximately 100 hp).

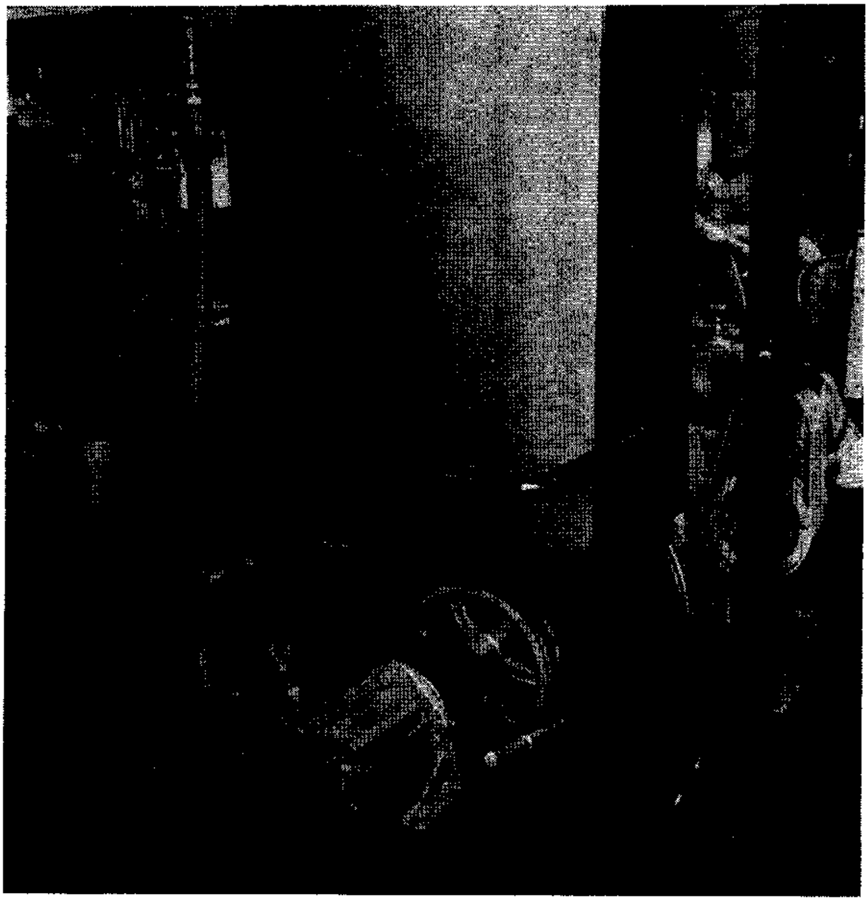

FIG. 17. Hydraulic tank (center), filter and relief valve (left) and hydraulic pump coupled to main engine (below) from power takeoff.

attention of the operator. Valves can also be supplied which remain in the position set by the operator. These are called *detented* valves and are used for power blocks, fish pumps, trawl winches and any continuous operating machinery. Combinations of detented and spring centered functions can be provided. A third configuration is the *rotary actuated* valve in which the positions can be determined by swinging the handle in an arc about the spool axis. This type of action is used most commonly where speed and direction control are required in a single lever, replacing detented valves that have a separate bypass.

Four-way valves for marine purposes are best equipped with protection for the valve spool where it enters the valve body seal. Chrome plated steel spools exposed to the weather will corrode and such corrosion will score the seals and induce leaking. Therefore, if this type of valve is to be used it should be mounted in the vertical position with the valve spool exposed on the bottom of the valve where the water will run off and any leaking will lubricate the spool. Stainless steel spools which eliminate this problem are available on certain valves for marine purposes. Other valve manufacturers are attempting to solve the problem by sealing this area with a rubber boot which more often than not tends to collect water rather than to expel it. A common misapplication of four-way valves is the use of a tandem centered valve, with the motor ports closed in the neutral position, to hold a suspended load. Such applications as cargo hoists and boom topping winches require a counterbalance valve as tandem center four-way valves do not provide a makeup oil supply to replace motor seal leakage.

FLOW CONTROL VALVES: The simplest flow control valve is a needle valve or ball valve which has an adjustable orifice for bleeding oil from a pressure line back to the tank so as to control the flow in that line. This type of speed control is normally used in fishing vessel circuits as it has the distinct advantage of softening the effect of sudden high pressure induced by load surge, a condition created by tension of the net when the boat rolls. Such a valve is used to good advantage in hauling purse seines with the Puretic power block in rough sea conditions, thereby reducing the hazards of tearing the net. Where load varies on a winch, due to the increasing drum diameter as the line is hauled in, it is necessary to continually adjust the bypass valve in order to maintain a constant speed. This is not overly objectionable in most fishing vessel circuits as it presents a simple form of making speed adjustments.

Where more accurate control is required, pressure-compensated flow control valves can be used. These valves modulate the orifice size so as to maintain a constant flow under varying pressures. Abuse in using these valves to match low volume applications with high volume oil flows was previously described. This is a common source of heat in the system. Bypass flow control valves result in large speed fluctuations in winches where the pump is driven by an engine operating at varying speeds.

PRESSURE CONTROL VALVES: These are relief valves which must be installed in every hydraulic circuit to protect the pump from excessive pressures. Relief valves are also found as a part of mobile four-way valves. If more than one four-way valve is to be used in a series, the reliefs on these valves do not protect the pump as it is possible to incur a pressure equal to the sum of the relief valve settings. Such a situation could occur if both winches were inadvertently used at full power at the same time. Therefore, engine room mounted relief valves are usually relied in series drive hydraulic circuits. In a number of circuits the relief valves are used as an on-off three-way valve, or a speed control valve. Pilot operation of relief valves is possible from remote locations, at a very nominal expense, by installing on-off buttons at various locations, any one of which would stop the winch system in an emergency by remotely venting a relief valve and shifting the flow directly to the tank. With the addition of the pilot operated relief it is possible to utilize the system relief valves in a similar manner as the ball or fixed orifice flow control valve.

CHECKS AND LOAD HOLDING VALVES: Check valves are used in many simple circuits to prevent hydraulic motors from reversing. In this function it is imperative that a relief valve be placed between the hydraulic motor and the check valve so as to protect the motor in the event that the winch to which it may be attached is overloaded. This relief valve is often overlooked until the motor housing cracks as a result of such overload. The load holding valves or counterbalance valves are required on any winch application where a load must be lowered under controlled conditions, such as on small cargo winches. For most applications it is not practical to just use the four-way valve to hold and lower an over-riding load. Counterbalance valves are therefore usually placed on the hydraulic motor ports to prevent any runaway load in the event of the loss of the system hydraulic pressure. Their use and application should be determined by an experienced hydraulic technician.

Cylinders

On occasion cylinders are used for boom swinging topping, or boat davit hoists and in steering systems. On all fishing vessel applications, cylinders should have stainless steel rods, not chrome plated rods. Chrome plated rods do not hold up sufficiently under salt water corrosive atmosphere. In estimating the size and use of cylinders it is well to recognize that the cylinder pulling force and push force is different due to the area of the cylinder rod on one side of the piston. Therefore the reaction time will be different. If it is necessary to have a constant speed or force in each direction, double ended cylinders are required.

Reservoirs

All open center hydraulic circuits with fixed displacement pumps require an oil reservoir, both for cooling and settling wear particles and foam elimination. Tanks are sized in accordance with the oil flow and the duty cycle and expected heat dissipation requirements of the system. A normal tank capacity is 1 to 2 gallons for each gpm of oil flow. A good hydraulic oil tank has certain considerations in the design which are not readily apparent. The location of return lines, baffles, suction and oil level, and the extreme care required in the cleanliness of the tank are very important. The suction intake should be one-quarter the depth of the tank above the bottom to prevent the settled particles from recirculating through the system. All such tanks should be pickled with a phosphoric acid wash to remove mill scale and carefully inspected to eliminate any welding slag, or dirt. In the marine atmosphere the tanks should have an anti-corrosive top such as aluminum as the moisture in the system collects there and will cause rust in the top of a steel tank. The tank must be located in such a position that the oil level in the tank is above the level of the input of the suction of the hydraulic pump so as to maintain a positive head on the pump and reduce the hazards of cavitation.

Filtration

Three types of filtration are generally applied to hydraulic systems.

(1) *A sieve* on the intake fill cap to the oil tank to prevent large particles from entering the tank.

(2) A 150 micron *suction line strainer* between the tank and the pump. This must be sized in accordance with the maximum flow possible when the pump is running at the maximum prime mover rpm. This may be for larger than the normal flow during the fishing cycle, but the possibility should be considered. The suction strainer must be mounted in such a manner that the filter element can be removed without allowing the dirt collected thereon to drop into the pump suction. The manufacturers generally recommend a horizontal position for the filter cartridge element section. Further, it is

necessary to provide shutoff valves, or to break the connection to the tank in order that the filter cartridge can be removed without excessive loss of hydraulic oil.

(3) *The return line filter* of 10 microns will remove many of the wear particles that are the result of pipe contamination prior to installation. This type of filter is equipped with a bypass when the filter is dirty. It is the best indication of the condition of the hydraulic system.

Heat Exchanger

Large hydraulic systems do not have tank sizes sufficient to dissipate the heat created in the system. Therefore heat exchangers are generally recommended for circuits exceeding 50 gpm unless it has been previously determined that heat is not a problem. In tropical conditions the heat exchanger is even more necessary as the ambient temperatures in the engine room are generally quite high. The typical hydraulic system operates at 160° to 180° F. A system which circulates 75 gpm at 2000 psi would probably require a heat exchanger of sufficient size to remove about 30 hp in heat. The required size can be determined from the heat exchanger manufacturer's data. Where such a heat exchanger is to be raw water cooled with sea water, copper nickel tubes or stainless steel tubes and zinc anodes are required.

Piping

By and large most of the problems in hydraulic systems have to do not with components but with the piping. In the size and horsepower ranges described for these vessels, systems are usually piped with a mixture of hydraulic hose and iron pipe. Pipe is used in long runs with short lengths of hose connecting all pumps and control panels and winches. The pipe sizes for various oil flows are determined in accordance with the pressure drop which can be tolerated without large efficiency losses. The following standards for pipe size are used on fishing vessels.

	2000 PSI Working Pressure		Return Lines		Suction Lines	
Oil Flow	Nominal Diameter	Strength* Schedule	Nominal Diameter	Strength* Schedule	Nominal Diameter	Strength* Schedule
12 gpm	½"	80	¾"	40	1¼"	40
20 gpm	¾"	80	1"	40	1½"	40
30 gpm	1"	80	1¼"	40	2"	40
60 gpm	1¼"	80	1½"	40	2½"	40
100 gpm	1½"	160	2"	40	3"	40

*Schedule 40=Standard Pipe, 80=Heavy Pipe, 160=Extra Heavy Pipe.

It is imperative that black iron pipe be used in the system and not galvanized pipe. Galvanized pipe will flake off and ruin the hydraulic components. Extreme care should be taken to obtain pickled and oiled clean pipe for hydraulic installations. When cutting threads on the ends of the pipes further care must be taken to care for the inside edges and to remove any burrs and trace of metal filings. This is the major source of contamination in the hydraulic system. This particular fact cannot be over emphasized.

Where hydraulic hose is used in the system the standards for 2000 psi are as follows:

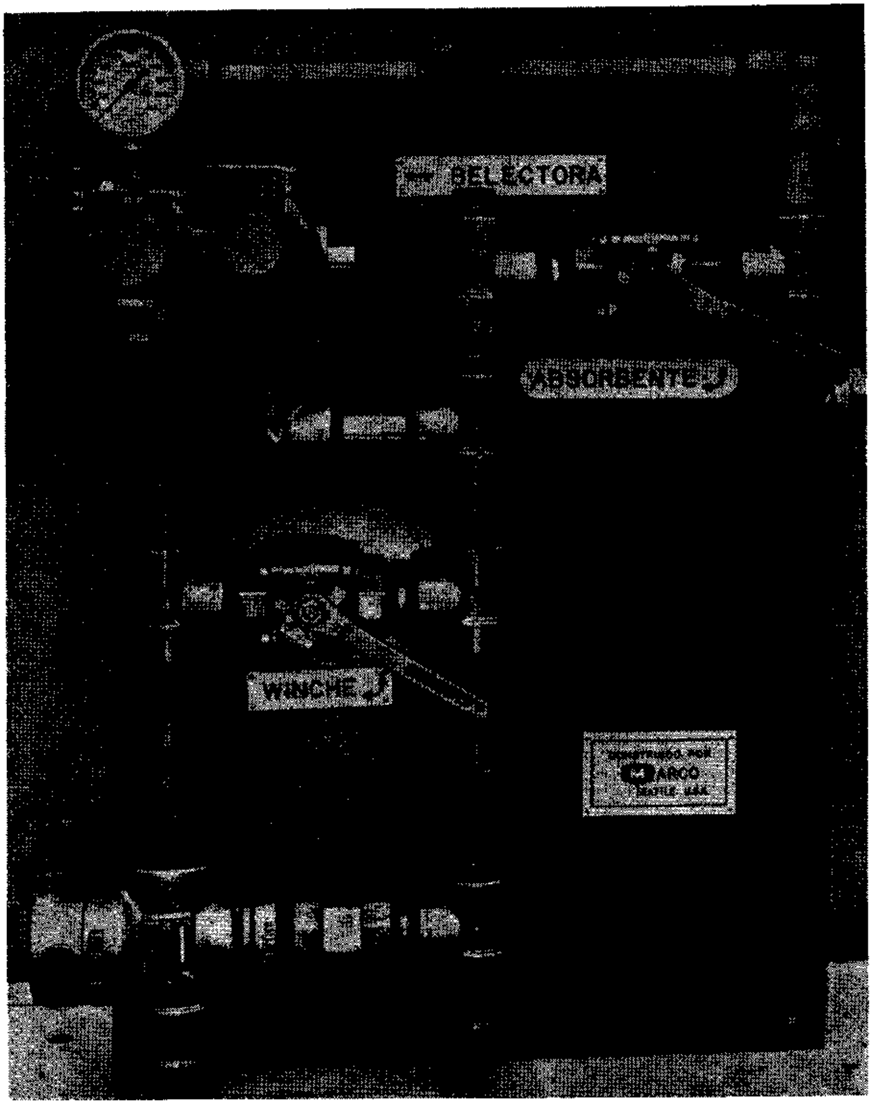

FIG. 18. Typical hydraulic control piping assembly with forged fittings and heavy screwed pipe.

2000 PSI Working Pressure			Return Lines		Suction Lines	
Oil Flow	Nominal Diameter	Hose Type	Nominal Diameter	Hose Type	Nominal Diameter	Hose Type
12 gpm	½"	Sgl wr braid	¾"	Dbl fab braid	1¼"	Spiral wire
20 gpm	¾"	Dbl wr braid	1 "	Sgl wr braid	1½"	Spiral wire
30 gpm	1 "	Dbl wr braid	1¼"	Sgl wr braid	2 "	Spiral wire
60 gpm	1¼"	3-wire braid	1½"	Sgl wr braid	2½"	Spiral wire
100 gpm	1½"	3-wire braid	2 "	Sgl wr braid	3 "	Spiral wire

Hydraulic hose fittings commensurate with the hose manufacturer's specifications must be used. It is much preferred to utilize the type of fitting which does not require the hose to be cut to the wire braid. This wire braid is steel and in the long run will rust within the fitting and result in failure in the salt water atmosphere. The correct fittings are called "No-Scive" fittings.

Flanged couplings are best used for large piping systems of 1¼-inch to 1½-inch diameter. Where pipe is butt welded in these systems backing rings must be installed prior to welding. Fig. 18 shows a small prepiped control panel for a winch and fish pump installation. You will note the pressure fittings are forged, 2000-lb water-oil-gas fittings (wog). Standard cast pipe fittings are used only on return and suction lines.

Occasionally steel tubing is used in piping hydraulic systems. The console shown in Fig. 19 is so piped. However, these fittings and tubing are stainless steel as the wall thickness in steel tubing is not sufficient to stand the pressure very long in marine corrosive atmosphere. Mild steel tubing is not recommended for this service.

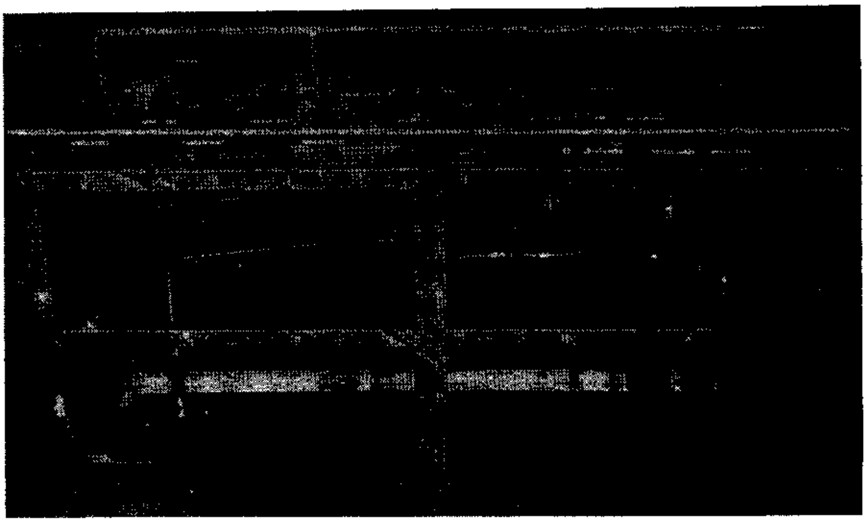

Fig. 19. Control console for large tuna purse seiner with cover plates removed to show internal tubing connections. Note the number of winch functions that are controlled by the operator.

In general, piping runs up through the fish hold and on the exterior of the vessel and should be located in such a manner that it can be painted on all sides. Piping should not be run behind insulation through fish holds and inaccessible locations. It must be remembered that the ship is subject to considerable vibration, and in many cases the hydraulic system shock might result in a piping leak, particularly in newly installed systems. It is not a happy situation to remove insulation or panelling for such maintenance.

CONCLUSIONS

There is much more which could be said about current practice in hydraulic installations. As any good doctor recommends the specialist, so in the case of hydraulics, best results are going to come from the people with the practical and technical experience in the field. Fishing vessel problems are somewhat unique because of the variation in requirements brought about by unpredictable catches, by sea conditions, and the idiosyncrasies of the fishermen. The system components are subject to severe corrosion problems and it is truly amazing that hydraulic systems in such an atmosphere are so dependable and work so well. With all of the advantages properly combined, the deck machinery system will be a joy to operate and a faithful servant throughout the life of the vessel.