

ICLARM-SPC/Small Boat/WP.7
21 October 1975
ORIGINAL : ENGLISH

SOUTH PACIFIC COMMISSION

ICLARM-SPC SMALL BOAT WORKSHOP
(Noumea, New Caledonia, 27 - 28 October 1975)

THE MODERN OUTBOARD AS APPLIED TO THE FISHING INDUSTRY

by

Bryan Stafford
Outboard Marine Australia Pty. Limited

During the past half century, over eleven and ahalf million outboard motors have been sold in the U.S.A. alone. Two thirds of these are still in use today.

There are over 400,000 outboards in use in Australia, New Guinea and New Zealand. With so many motors in the hands of so many people, it is obvious that outboard motors have a very wide variety of users.

In the American market, we have figures available which suggest that approximately 50% of motors still in use are employed for fishing purposes.

"Fishing" includes estuary as well as deep sea and commercial fishing. A figure of 20.1% was given in 1968 for hunting and 10% of total sales for that year were used for defence purposes.

The figures whilst nearly ten years old are indicative of the swing to outboard powered craft.

In 1976 the model range of outboard motors will commence with a 2 h.p. motor and at the top of the range will be an all new 200 h.p. V6 motor.

The engineering behind all of the various models is directed toward the many applications of both commercial and social usage.

The following description of the major components of most outboard motors available will afford you a further insight into the construction and reliability of our outboard motors.

The first formal description of an outboard motor was given in 1866 by T. Reece of Philadelphia in his application for patent of a screw propeller. In his application he stated "the object of this invention is to provide small vessels, such as Whale Boats, Yawls, Trolley Boats, Skiffs and the like, usually propelled by oars and small sails with a propelling apparatus to be operated by manpower, that may be attached or detached from its position as may be required". With the exception of the word "manpower", this aptly describes today's modern outboard.

Almost all modern outboard motors employ 2-stroke (cycle) gasoline engines. This concept has been slavishly followed and improved on for several reasons.

The 2-stroke (cycle) engine even in its most refined form when compared to the 4-stroke (cycle) engine is still relatively simple. The piston in a 2-stroke engine does most of the work for which a 4-stroke requires a large quantity of parts. In a 2-cycle engine one up-stroke and one down-stroke of the piston compresses the gas for combustion, opens the exhaust, allows the burnt gas to escape, draws in a fresh charge of gas, closes the exhaust, closes the inlet and once again compresses the gas. This simplicity has a beneficial effect on the weight and the cost of the unit.

Weight is an important factor in outboard motor design, most outboards of below 60 h.p. are light enough to be either portable or semi-portable.

An output of 135 h.p. can be obtained from a power-head complete with starter, generator, automatic choke, ignition components and carburettor with a weight of less than 130 lb. This favourable power-to-weight ratio is achieved by having relatively few moving parts; by having a high output per cubic inch of capacity; by extensive use of aluminium; by using lightweight components made possible by low compression ratios, with subsequent lower pressures.

Although the tolerances on most of the machine components are very tight, die cast aluminium used to its best advantage, coupled with the high volume output and the inherent simplicity of 2-stroke design brings the price of an outboard motor within the reach of the man on the street.

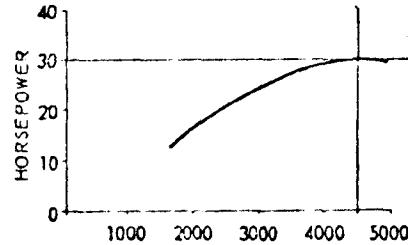
The outboard motor manufacturers' H.P. ratings are a continuous rating and are a true representation of the horsepower claimed. This is controlled by an organisation known as the Boating Industry Association which employs horsepower certification procedures that conform to SAE procedures accepted throughout the world.

A manufacturer who is a member of this American organisation submits sample power-heads to independent testing laboratories to measure and certify the H.P. output in the presence of competitive manufacturers.

The horsepower output of the modern outboard is high relative to cubic capacity. In fact, it is common to have greater than 1 h.p. per cubic inch and this is achieved with the engine speed down around the 4,500 - 5,500 rpm range.

The torque curve of the engine is relatively flat which means that propeller rpm can be kept high at relatively low boat speeds. This characteristic is ideal for putting boats onto the plane rapidly without subsequently overspeeding the engine, without needing to change over when the boat reaches its full speed.

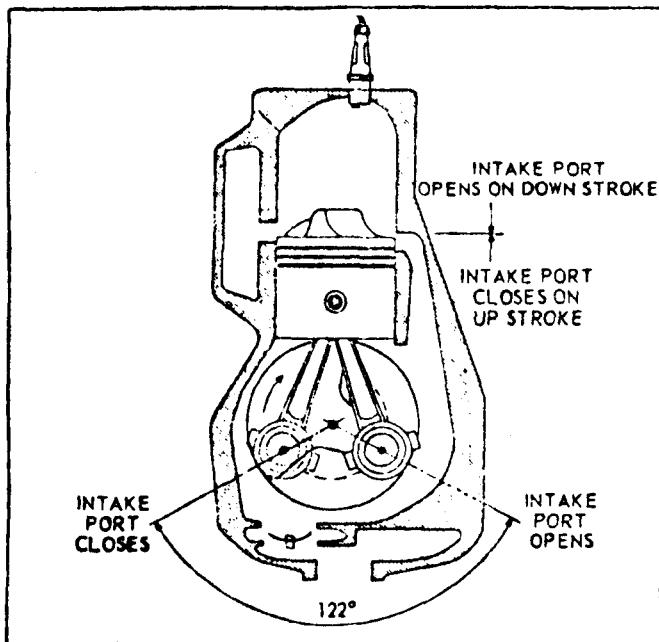
The h.p. curve shown is indicative of a flat torque curve. The h.p. generally falls off quite rapidly after maximum brake horsepower is reached, which is an advantage because it means that to get the best speed from the boat-motor combination, A PROPELLER SHOULD BE FITTED THAT WILL ALLOW THE MOTOR TO RUN UP TO MAXIMUM H.P. R.P.M. There is no advantage in fitting a propeller that allows a motor to run to high rpm, because performance will drop off. The outboard motor owner has relatively few limitations imposed on him when he uses his outboard motor. There are a few areas where speed limits are in force, but there are vast areas of water. No pedestrians, no stop signs and no red lights spoil his fun. For these reasons the outboard user may with safety, run his outboard motor at full throttle for very long periods, so the powerhead must be designed to accommodate this.



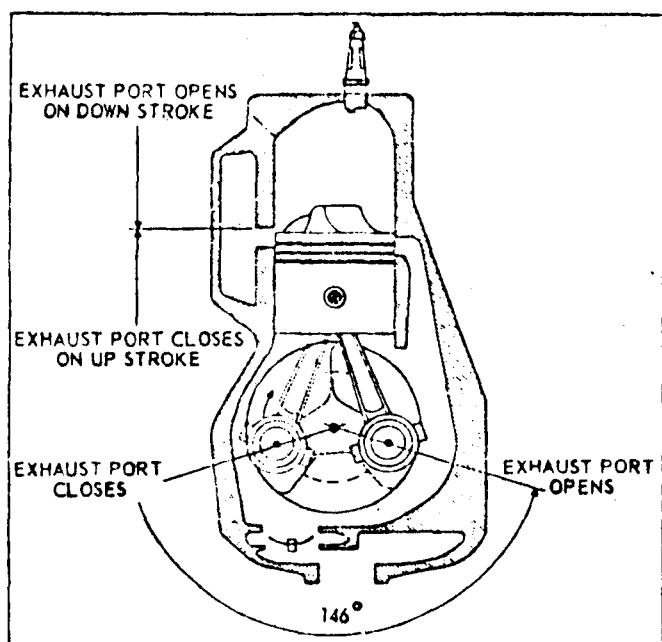
On all but the very small motors every bearing in the powerhead is a ball or needle roller-type, the con rod big end bearings are needle rollers, the little end or wrist pin bearings are needle rollers and the crankshaft main bearings are either ball or roller bearings. The use of these bearings means that considerably less friction and subsequently less heat is generated than the plain bearings most 4-cycle engines have. Although with the needle bearings the friction and heat is low, further steps are taken to dissipate what little heat is generated. The con rod big ends and the needle roller cages are silver-plated, the pistons are tin-plated and the piston rings are molybdenum filled.

As previously mentioned the power of the outboard drops off rapidly when engine rpm become excessive. One of the reasons for this is that breathing becomes inefficient because the inlet and exhaust ports are not open for long enough to allow enough time for the fuel vapour inertia and friction to be overcome and still effectively charge the cylinder or crankcase.

The intake port on a typical 2-cycle engine is opened during about 120° of crankshaft travel and the exhaust port about 145° . This allows the inlet port at 4,500 rpm only 1/220 of a second to charge the cylinder and the exhaust port 1/185 of a second to discharge the exhaust from the cylinder. If the rpm's were increased to 5,100 rpm, only 1,250 of a second would be available for intake and 1/210 of a second for exhaust.



ENGINE BREATHING-INLET



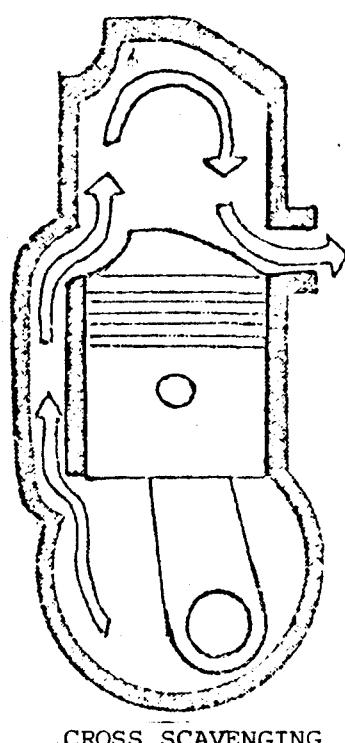
ENGINE BREATHING-EXHAUST

The incoming gas and exhaust is directed so that complete scavenging of the combustion chamber is effected with little loss of fresh unburnt gas. There are two different methods of accomplishing this deflection.

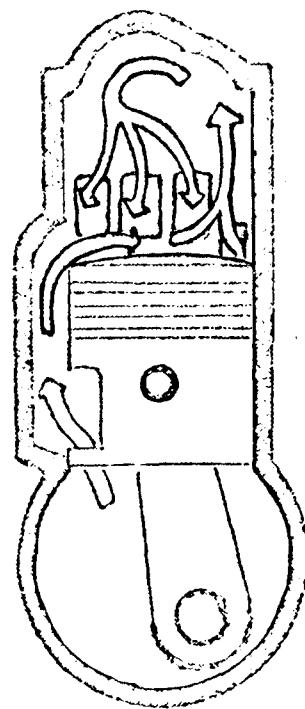
Most 2-cycle outboards use the cross flow principle. As the name implies, the intake and exhaust ports are positioned opposite each other in the cylinder walls. The incoming charge enters the cylinder through the inlet port, is deflected upwards into the combustion area via deflector cast on the piston crown, bounces off the cylinder head and outthrough the exhaust port.

The loop charging method has been popular in single cylinder air-cooled engines for quite some time and up till recently no one had devised a method of incorporating this design into a multi cylinder water-cooled engine. The idea is that two intake ports nearly opposite each other in the cylinder walls slant upwards and slightly back. The exhaust ports are on the side furthest away from the direction in which the inlet ports slant. The piston is very slightly domed and plays no part whatsoever in the operation of deflecting the gas. The two gasses come in through the opposed inlet ports, impinge and deflect upwards around the comed cylinder head and out through the exhaust port.

The method of manufacture in the single cylinder loop scavenged engines is to drill the ports in the cylinder walls at the required angles. Since three sides of the cylinder are used in this method of scavenging, the ports cannot be drilled in a multi cylinder engine. This design had many advantages so a method of casting the ports into the cylinder walls was developed and because the position of the ports in a 2-cycle engine are the equivalent of the valve timing of the 4-cycle engine, their position is very critical.



CROSS SCAVENGING



LOOP SCAVENGING

By careful design of the inner exhaust tube of an outboard motor, it is possible to enhance the efficiency of both the above methods of combustion chamber scavenging. The pressures existing in the exhaust passages after combustion are used to increase the scavenging efficiency. If the exhaust tube is made exactly the right length, the pressure wave present in the exhaust passages immediately the exhaust port opens, runs down the exhaust

tube until it reaches the open end of the tube. Here it expands and is reflected back as a negative pressure wave to draw out a little extra burnt gas. So that there is a minimum amount of unburnt gas drawn from say No. 1 cylinder, the exhaust pressure wave from No. 2 cylinder is channeled so that it blocks off the exhaust port just before the port is covered by the piston. This improves both the performance and the fuel consumption of the engine.

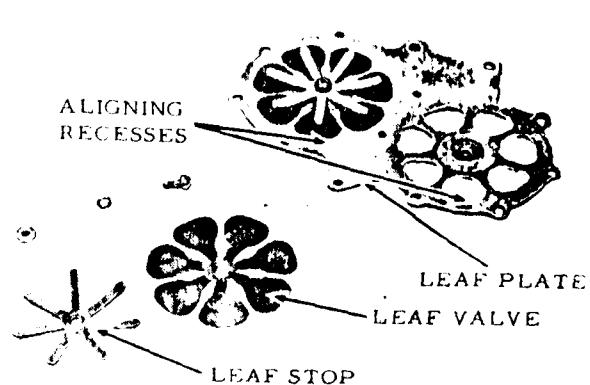
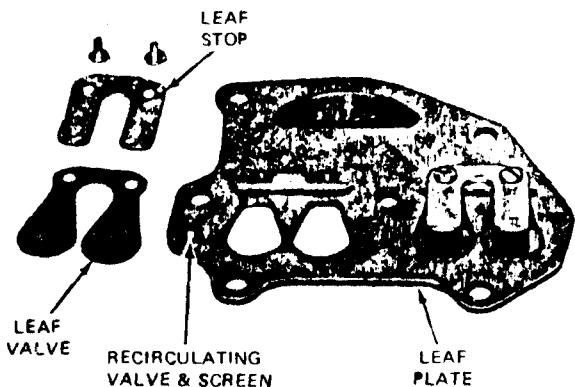
The air fuel ratio requirement of most outboard motors varies between 12:1 and 18:1. The rich mixture for idle and maximum power, the leaner mixture for maximum economy at cruising speeds.

The carburettors used to achieve this are of single or multiple-throat side-draught. Usually one carburettor or carburettor throat feeds a maximum of two cylinders and it is common on large engines to have one carburettor or carburettor throat per cylinder. This is because a high inlet velocity is important to crankcase efficiency and because a high carburettor venturi velocity is needed to obtain quick motor response. If single carburettors were fitted to large motors the venturi would be so large that fuel-air mixing would not be complete, so response would be extremely sluggish.

Some outboard carburettors have an adjustable low speed jet for smooth idling and easy starting, but the high speed jet usually has a fixed orifice.

The throttle butterfly on an outboard carburettor is synchronised with the spark advance and is usually operated by a cam on the magneto mounting plate or on larger motors, linked to the distributor base.

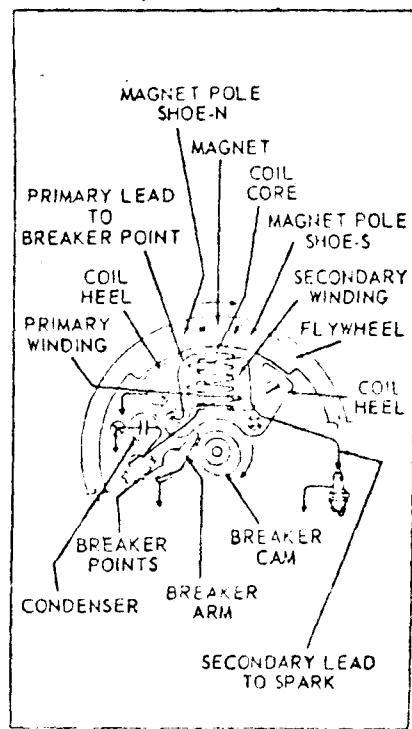
Outboard motors use leaf valves to control the introduction of the fuel-air mix into the crankcase and although they vary greatly in shape and size, all leaf valves are basically a one-way valve operated by a thin reed of steel - usually high quality Swedis- stainless steel - which is allowed to open in one direction only. When the crankcase pressure drops below atmospheric pressure, the reed opens and allows the fuel-air mixture to enter.



LEAF VALVE ACTION - The ports of the leaf valve and how they operate.

Although a half-daisy box assembly is shown here, all leaf valves, regardless of configuration, function alike.

Magneto - Magneto ignition is used on most outboard motors up to about 40 h.p. The magneto is usually mounted under the flywheel and for a 2-cylinder engine consists of the following components: A mounting plate, commonly called an armature plate, on which the components are mounted; one ignition coil per cylinder; one condenser per cylinder; and one set of primary breaker points per cylinder operated by a Cam on the Crankshaft. Permanent magnets are cast into the rim of the flywheel which revolves around the armature plate and as the poles of the magnets pass the heels of the coils a magnetic field is built up about the coil causing a current to flow through the primary winding. The breaker points, when closed, complete the primary circuit and collapsing the current. The condenser is connected across the points to prevent arcing and burning of the points and helps to bring the collapsing primary current down to zero very rapidly. The rapidly collapsing current in the primary windings permits an abrupt change in the direction of the magnetic flow in the core of the coil. This abrupt change induces in the fine secondary windings of the coil, a flow of extremely high voltage current which is carried through a high tension lead to the spark plug.



THE TYPICAL FLYWHEEL MAGNETO SYSTEM

Capacitor Discharge Ignition - Larger horsepower engines generally employ battery ignition systems, one reason being that a battery is needed for lights, accessories and electric starting.

Within recent years this battery ignition has largely been replaced by fully transistorised capacitor discharge ignition systems which are of high initial cost, but which offer significant advantages in reliability, reduced fuel consumption, reduced maintenance and trouble free operation.

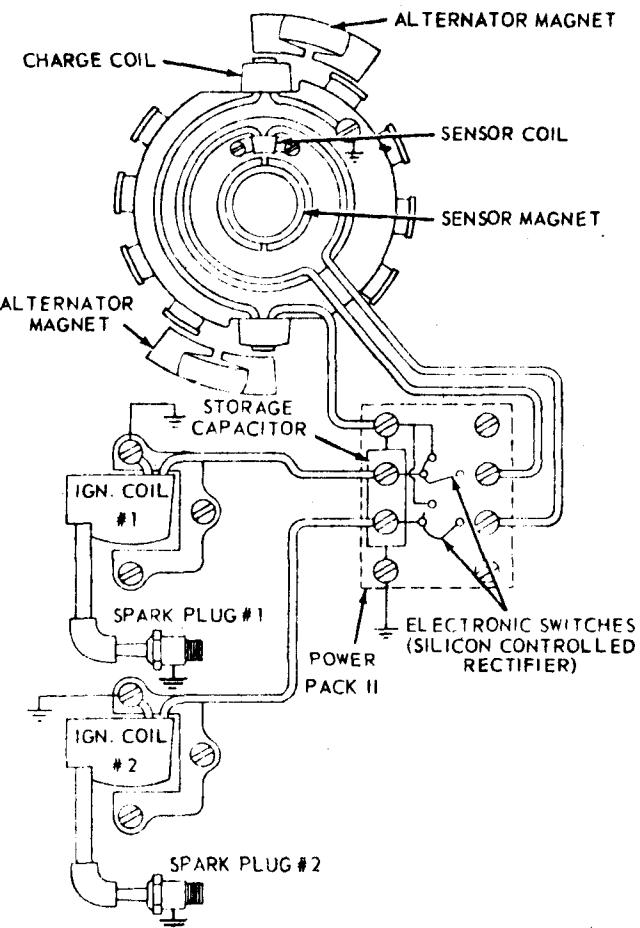
In the CD ignition systems, the discharge from a capacitor is used to produce the spark which ignites the fuel charge.

The discharge from the capacitor is directed to the primary winding of a pulse transformer which is similar to a normal ignition coil. The problem is to cause the capacitor to discharge so that the high tension spark occurs at the optimum point in the engine cycle. The silicon controlled rectifier (S.C.R.) which acts as an electronic switch, is placed in the circuit between the capacitor and the pulse transformer.

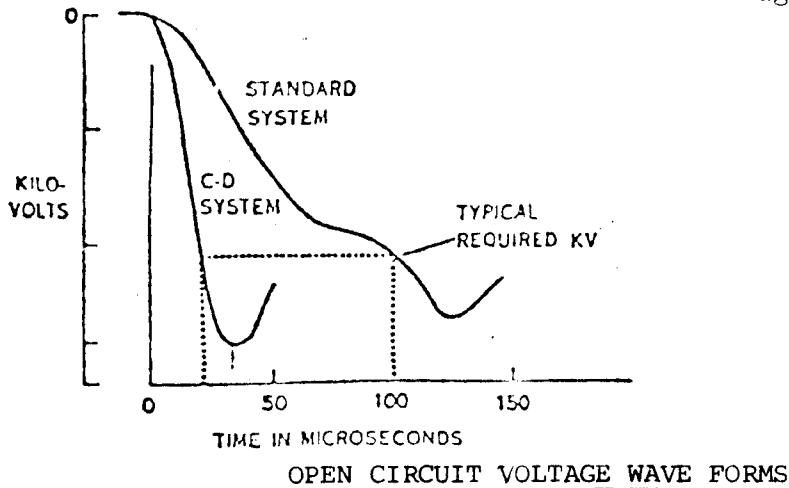
The tremendous advantage of C.D. ignition is that voltage rise time of high tension spark ranges from .2 of 1 to 10 micro seconds

(depending on system) compared with the 100 to 150 micro seconds normal for conventional ignition systems. The spark plug reaches full voltage so quickly that it literally does not have time to leak away through poor insulation, wet ignition leads, salt deposits and foul plugs which would cause a breakdown in normal ignition systems. The spark is so fast and so intense that it blasts away deposits on the spark plug.

With C.D. ignition, plug fouling problems have become a thing of the past.



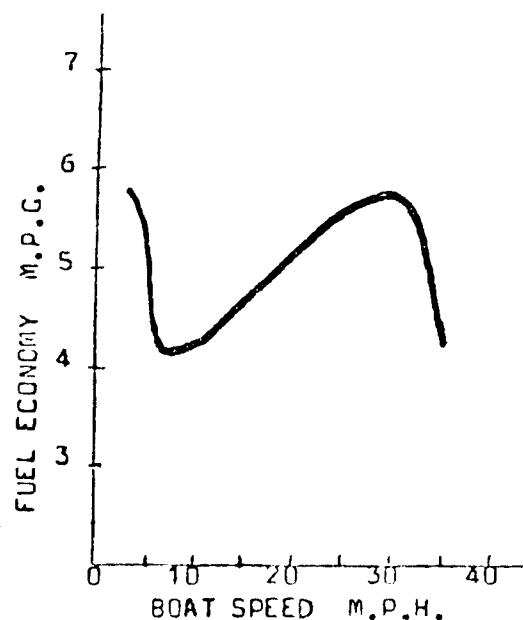
TYPICAL C.D. IGNITION SYSTEM



For an internal combustion engine to operate at maximum efficiency, all the fuel vapour charge should be burnt while the piston is at top dead centre. Since the volume of the fuel charge is constant and the speed at which the fuel ignites varies little, greater degree of advance must be allowed for proper ignition as piston speeds increase with higher rpm's.

On 2-stroke outboard engines the timing requirement is from $13^\circ - 20^\circ$ after top dead centre at idle and $30^\circ - 35^\circ$ before top dead centre at full spark advance. This is achieved by allowing either the armature plate in the magneto system or the distributor base in the C.D. system to rotate relative to the cam or rotor on the crankshaft. As previously mentioned the throttle butterfly is synchronised with the spark timing. The first one-third of engine speed is achieved by spark advance only, with no opening of the throttle butterfly; the second one-third by advancing the spark to its maximum, with very little butterfly opening; and the top one-third by complete throttle opening. This means that the outboarder can use full power to get his boat up on the plane

then back off the accelerator to a point where he has maximum spark advance but very little throttle opening. Under these conditions he can enjoy a good turn of speed with a relatively low fuel consumption. A typical fuel consumption curve for a high H.P. outboard motor is shown opposite.



FUEL CONSUMPTION CURVE FOR LARGE H.P. OUTBOARD

2-cycle outboard motors have always been lubricated by mixing oil with the gasoline. The petrol-oil ratio recommended for nearly all sophisticated outboard motors on the market today is 50 - 1.

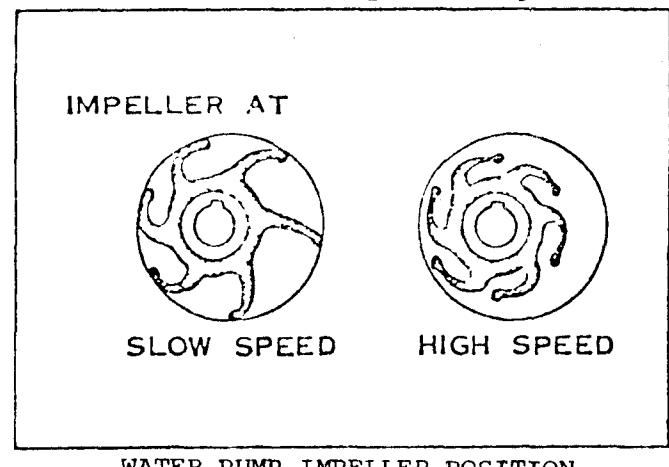
Outboard designers have paid a great deal of attention to designing for optimum lubrication to give us the reliable outboard that we have today - but meantime the oil companies have not been idle. A few years ago oil companies realised that with 4-cycle engine development heading in one direction and 2-cycle outboard development heading in another direction, that it would not be long before the automotive oil generally available would not be suitable for water-cooled 2-stroke outboards. So they set to work and evolved an oil designed specifically for use in outboard motors.

This "outboard" oil is a carefully blended mixture of bright stock and neutral basics with ash-free detergent dispersant additives which prevent the accumulation of deposits on the piston crown, the cylinder head and particularly around the piston rings. Because deposits do not build up the prime cause of pre-ignition and plug fouling is removed.

Outboard oil is not suitable for use in 4-cycle engines and 4-cycle engine oils are not suitable for use in outboard motors.

Because they are usually used where there are large quantities of water at a fairly even temperature, most outboard motors are water-cooled. Also because the cooling water is maintained at a fairly low temperature, most outboards are thermostatically controlled cooling systems. The cooling water is circulated through the exhaust covers, around the cylinder sleeves, through the cylinder head, through the thermostat, then either discharged or returned to the pump. The pump is driven directly by the driveshaft and is mounted as low as possible to facilitate priming. The pump consists of a neoprene rubber impeller and an offset pump housing. Because the housing is offset the impeller blades flex as they rotate, thus varying the space between them. The pump inlet port, located in the stainless steel plate which forms the lower part of the pump housing, is open to the blades when the space between them is increasing. The pump outlet port in the impeller housing is open to the blades when the space between them is decreasing.

Thus, at low speed the impeller works as a displacement pump. At higher speeds, when water resistance keeps the blades from flexing and the pump acts as a circulator, enough water is provided by the forward motion of the motor through the water. The pump design is capable of passing solids, sand, etc. through the pump without damage.



WATER PUMP IMPELLER POSITION

Outboard motors as previously mentioned are made almost entirely of diecast aluminium and because of the economic advantages of using this type of material and process, special attention has been given to the composition of alloys that will withstand corrosion under extremely hostile conditions. One of the best alloys is an 11% silicon alloy with copper content below 0.6%.

The internal water passages of the powerhead are specially treated with a high-solids varnish which is applied under vacuum and subsequently baked to resist the high salt atmosphere present inside the passages after the motor has been switched off. Special paints have been developed for outboard application and are subjected to extreme exposure and salt spray acceptance tests. The method of application on some motors is to heat thick paint to spraying viscosity while spraying takes place, which allows a heavier coat to be applied without sags or runs. When subsequently baked THE COATING IS DENSER BECAUSE LESS SOLVENTS NEEDS TO BE EVAPORATED OUT.

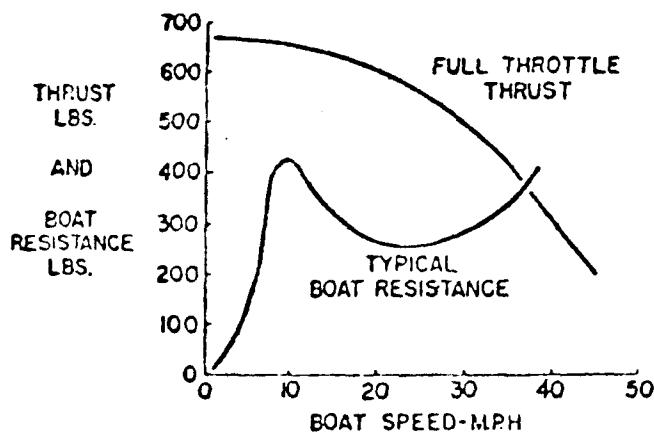
The propeller of an outboard motor performs somewhat the same function as the gear box of a motor car. A propeller which is too low in pitch gives exceptional acceleration, low top speed and excessively high engine rpm. A propeller which is too high in pitch gives poor acceleration, low top speed and low motor rpm, because the motor is overloaded. The correct propeller is one that allows the motor to reach its maximum break horsepower rpm and this will give good acceleration because of the flat torque curve of an outboard motor and optimum top speed.

Propellers rely entirely on slip to do their work, slip being the difference between the theoretical advance (pitch times rpm) and the actual advance of the boat. As the propeller slips through the water it accelerates a certain volume of water rearwards, then uses this reaction to drive the boat forward. Large displacement hulls, because of their high resistance, to movement require

a lot of slip, 50% to 60%, to get the required reaction to drive the boat forward. Planing hulls, which have a comparatively small resistance operate at a low slip of 10% to 20%, very fast hydroplanes which have even less resistance operate at 5% to 6% propeller slip.

The two main variables in the design or in the selection of the propeller are pitch, of which there is a large range for each horsepower outboard and diameter, over which the outboarder has little choice. The choice of diameter by the manufacturer is a compromise between the very large diameter which would be most suitable due to high theoretical efficiency produced under very low-speed, high-thrust conditions, and small diameter which would be far more efficient as higher boat speeds where skin friction losses become very significant.

The main reason for the outboarder having very little choice in the selection of propeller diameter is that the gearcase design limits the propeller diameter by the distance between the propeller shaft centre line and the under-side of the anti-cavitation plate, so gearcase design is also a matter for compromise. The propeller size must be considered, the gear ratio must be considered because of the size of the gears to be encased and length must be considered to give the optimum length-to-diameter (slenderness) ratio.



BOAT RESISTANCE OF TYPICAL 17FT.

BOAT WITH FOUR PASSENGER LOAD. FULL THROTTLE THRUST CURVE IS NET DRIVING THRUST OF AN 80 HP ENGINE USING A 10 in. DIAMETER x 10 in. PITCH PROPELLER.

Once the gear ratio and the inside dimension of the gearcase have been set the biggest problem facing designers is to find an outside shape which will give the least drag and the highest possible speed for the horsepower of the outboard for which it is being designed without cavitation taking place. Cavitation occurs when the pressure on the surface of the object becomes equal to the vapour pressure of the liquid in which the object is immersed.

Since computers are now available to designers for calculations an interesting method has been developed to evaluate gearcase design. A prototype gearcase is made up and tiny holes drilled all over the surface. Mounted internally in the gearcase and connected to each one of these drilled holes is a small pitot-tube. These pitot-tubes are connected to a multihead recorder. The gearcase is mounted behind a test boat which is driven through the water at varying speeds and the pressures at each one of the drilled holes is recorded. By analysing the results on a computer the gearcase design can be modified and perfected. Using this technique, significant design improvements have been achieved in the last few years.

Summary

The two stroke (cycle) water cooled outboard motor being specifically designed for constant and continuous power output is also an economical propulsion unit for small fishing craft.

By using either single or dual installations of engines from 6 h.p. upwards high power to weight ratio is available for efficient motivation from the dug out type canoes which are in constant use in Papua New Guinea up to units employed as landing barges by major defence forces.

In areas where roads are rare or inaccessible, the outboard motor because of its portability can be serviced readily.

The very application in that the motor "clamps" onto the boat affords a greater range of selectivity of power source and by correct propeller selection smaller horsepower motors can be employed.

The nett result of this exercise would be lower initial investment and lower operating costs. Whilst the engineering of the outboard motor is very sophisticated the actual product has been painstakingly kept simple so as to permit simple and cheap servicing in the very many applications that the range of models are applied to on a world basis.

A relatively low level of technical skill is all that is required to provide these engines with normal maintenance and service.

The use of light weight low cost boats and outboard motors would presumably provide employment for a large number of people and the follow on must therefore be increased in cash returns from the fishing resources spread over a wider area than if bigger and more technically oriented fishing vessels were used.

Through distributors, service skill can be acquired, and to this end, Outboard Marine Australia are prepared to contribute the necessary requirements such as training aids, service manuals, etc.

We feel we are in a position to offer assistance in expanding and developing a satisfactory fleet of reliable and economical fishing boats suitable for both inshore and offshore operations.
