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Fuel Saving Methods for the Commercial Fishing Fleet

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INTRODUCTION

The Oil Embargo of 1973 emphasized not only how oil dependant the fishing industry has become but that the days of inexpensive energy had ended. Pre-oil embargo prices, in real dollars, actually declined which made the use of diesel fuel cheaper. The price of oil did not rise quickly enough to overcome shrinking currency values. As energy became less expensive and labor more expensive a shift in the commercial fishing industry occurred. It became more energy intensive and less labor intensive via increased mechanization.[1] One would suspect that regardless of the price of fuel, a fuel intensive industry would be interested in reducing costs and therefore economize through fuel conservation.[2] This is not necessarily so. The decision to conserve or not to conserve rests upon the concept of economic advantage. The vessel owner must evaluate all alternatives and choose the one factor or combination of factors which yields the greatest return.

Oil prices have risen dramatically, but so have the price tags on new technologies, labor, vessel renovation, new construction and the cost of procuring capital for making improvements. However, one must focus on the long range picture vice the short term snap shot. This can be accomplished by looking at two aspects of the problem. First, as costs increase so does the price of fish in the market place. There is a point however where the consumer will substitute another good which is less expensive and/or perceived to be a better buy. Therefore there is a ceiling price above which the fisherman cannot sell his product. To remain competitive in the market place he must be cost conscious. Second, dollars, though expensive today, would be well spent if used to significantly reduce the dependancy upon a cost item whose price continually increases. As the price of the cost item goes up, the real dollar cost of the money borrowed goes down. Therefore it would be to the fisherman's advantage to spend on innovations that will conserve on cost items providing his operation is financially sound enough to borrow the capital required. The question is, "<u>where</u> should he place his money in order to gain the greatest economic advantage?".

This paper concentrates on fuel saving technologies and techniques. In Section One those items which are available today are addressed. Section Two outlines four areas which may be developed in the future. Observations made while researching this topic, a summary and conclusions are contained in Section Three.

SECTION I

TECHNIQUES AND TECHNOLOGY AVAILABLE TODAY

SECTION I

SLOWER SPEEDS

One method of conserving fuel in the commercial fishing industry which offers substantial fuel savings and requires neither technological innovation nor capital expenditure is merely reducing the transit speed of the vessel. To obtain maximum speed on a vessel which has a single speed transmission and a fixed propeller, the engine must be operated at the safe maximum RPM. At 100% of engine ouput, only 60% of the energy is captured and producing the work required for the speed.[3] The task is to quantify the information given into fuel economy figures.

Increased speed yields greater vessel resistance through the water. As the resistance rises more horsepower is required to maintain that speed. The graph and table in figures 1 and 2 respectively are drawn for an average 80 ft commercial fishing vessel.[4]

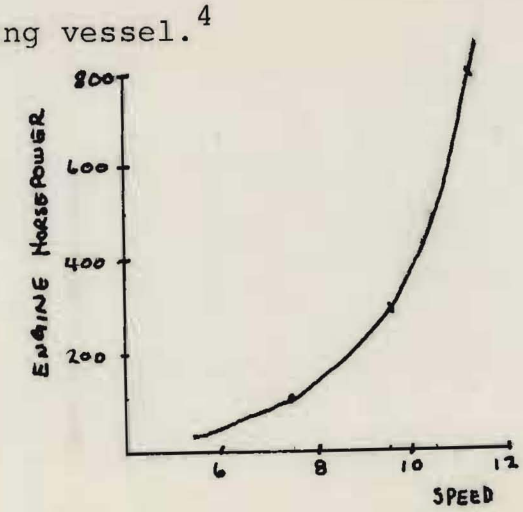

Figure 1

SPEED	H.P. REQ	SPEED INCREASE	H.P. INCREASE
7.5	100	—	—
9.5	300	2.0/127%	200/300%
10.5	500	2.0/110.5%	200/167%
11	800	.5/105%	300/160%

Figure 2

As can be gleaned from the graph and chart, a disproportional amount of horsepower is used to gain a modicum of speed. To obtain the increased speed and horsepower the engine must be operated at a higher RPM which increases the amount of fuel flowing to the engine. The speed/horsepower ratio is disproportional in the high RPM range. If the speed of the vessel is reduced by 10% during a transit, fuel consumption is reduced by 30-40%.[5]

A similar experiment was conducted on an 80 ft vessel which is not utilized for fishing. It is a twin vice single propeller vessel. Seven hundred horsepower is obtained at maximum safe RPM which yields a maximum sustained speed of 12 kts. The fuel efficiency curve and table in figures 3 and 4 below outline the data collected.[6]

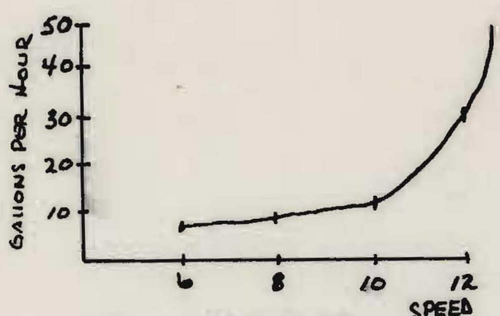

Figure 3

SPEED	GALLONS PER HR
6	8
8	10
10	13
12	31

Figure 4

From this data it can be seen that for this particular vessel a reduction of 20% from maximum speed reduces the fuel consumed in one hour by 58%. Worthy of note, in this experiment the fuel usage data reflects that for the main engine alone. Also the economy trials were conducted over a two day period, 14 April and 16 April 1981. The wind and weather conditions were nearly identical on both days. Speeds 6 kts and 10 kts were tested on 14 April, speeds 8 kts and 12 kts on 16 April.

From the information given in this section thus far, it would appear that if a vessel operator spends 30% of his total fuel for transiting, by merely slowing his vessel to one or two knots below maximum speed he will realize a fuel savings of 12-17%. However, consideration must be given to what he may sacrifice in so doing. Assuming a round trip complete with fishing effort covers a distance of 400 miles over a three day period. If his average catch is worth $20,000 (20,000 lbs @ $1.00 per lb), his fuel costs are $3,000 per trip (approx. 42 GPH average), the turn around time is 2 days per trip and the season is 44 weeks per year, a vessel with a transit speed of 14 knots could make three to four more trips per year than if he had traveled 9.5 knots. An additional $9,000-$12,000 would be spent on fuel but his income would increase $60-80,000 per year.[7] Expanding the information provided by this example, the table in figure 5 is constructed.

	14 knots	9]/2 knots
trips per year	62	58
fuel costs ($3K/trip)	$ 186,000	$ 106,000
gross income ($20K/trip)	$1,240,000	$1,160,000
net income	$1,054,000	$1,054,000

Figure 5

For the 9 1/2 knot vessel to equal the net income of the 14 knot vessel, it would have to consume 39% less fuel.** Granted, the 14 knot vessel would incurr more costs i.e., crew, maintenance, etc., for having made the four extra trips, but the 9 1/2 vessle has the opportunity to make the savings during the transit periods only. Judging from the information given earlier the 9 1/2 knot vessel would not make as much profit as does the 14 knot vessel in this case.

Slower speeds offer attractive fuel savings. In some cases it will yield an economic gain for the vessel operator yet in other instances it will not. The conclusion which must be inferred is that each vessel owner must analyze his particular situation and ascertain if slower speed savings outweigh the benefits he could enjoy by not slowing.

** 58 trips X $3000 fuel = $174,000
$1,160,000 gross income - $1,054,000 net profit = $106,000
106,000 ÷ 174,000 = .61 1.00-.61=39%

MULTIPLE ENGINES

The multiple engine concept is not a new innovation to marine vehicles. Redundant engineering systems have long been utilized in military and civilian vessels. For many, the philosophy was "If one is good, two must be better". With respect to multiple engines, a flexibility was achieved in which, if a breakdown of one system occured, the vessel possessed a "Get Home" capability. Prior to 1973, little if any consideration was given to fuel economy as a viable reason for the increased cost of installing a second engine in a vessel.

An example of a vessel with two engines where traditionally only one is used is the 72 ton Boston Harbor Pilot Boat. The craft has two V1271 engines and is a single propeller vessel. The engines are centerlined, one aft, one forward, connected by a hydraulic compound gear. Either or both engines can supply the drive to the propeller shaft. The operator may make the engine selection from the Pilot House. During normal operations the vessel is powered by both engines. The reason for two engines is for the "Get Home" capability mentioned earlier. When operating at full power (both engines) and both generators on the line, the vessel consumes 44 gallons per hour of diesel fuel at full speed. The main engines burn 32 of this 44 gallons. With both engines supplying power, the maximum speed available is 12 knots.

If only one engine is used the maximum speed available is reduced by less than one knot. Accurate fuel consumption figures with only one engine on the line have not been computed.[8] It may not be assumed that 1/2 of the 32 gallons would be utilized per hour with only one engine on the line. With only one engine on the line, the full load is drawn on that engine making it work harder. It is expected that the engine would consume a greater amount of fuel. The question is, "How much more fuel?",

In an attempt to answer this question three vessels were used. Although identical to one another in length, displacement and hull construction, they were quite different from the Pilot Boat. The vessels are twin propeller and displace only 67 tons. Each vessel has a total of 700 rated horsepower at maximum RPM. Two vessels have four 671 diesel engines, two per shaft. The third vessel has two V-1271 diesel engines, one per shaft. The three craft had been hauled and painted within three months of one another. Even so, an underwater hull inspection was performed. The results of the inspection indicated that all three hulls were in virtually the same condition. Two days were set aside for economy trials. It was determined that the craft with V-1271's would operate at full power (both engines on the line). Of the remaining vessels, one would operate at full power while the other would operate with a split power arrangement (one 671 engine per shaft). The days chosen had nearly identical weather and wind conditions. It was decided that spees of 6 kts and 10 kts would be used on the first day and speeds of 8 kts and 12 kts on the second. Rudder movement was restricted to 5° or less. With each speed change 1/2 hour was alloted to allow all temperature and pressure readings to stabilize. Fuel readings were taken every 1/2 hour for a period of two hours. The table in Figure 6 shows the consumption rate in gallons per hour for each vessel at tested speeds.

	6 kts	8 kts	10 kts	12 kts
V-1271 Full PWR	8	10	13	31
671 Full PWR	6.5	10	14.5	32.5
671 Split PWR	5	8	11	27*

*only 11 kts could be maintained

Figure 6

At all speeds, the split power vessel consumed less fuel per hour than did the other vessels. It appears that the V-1271 full power vessel is more efficient in the upper speed range than the full power 671 vessel. Comparing the split power 671 with the full power V-1271, the former appears to be more efficient at each speed. Although the split power 671 could not sustain 12 knots, in this experiment at least, it proved to be 13% more efficient than the 671 full power.

The 72 ton Pilot Boat was built in 1971. The two twin propeller 4 engine vessel (2 engines per shaft) were built in 1972. The compound gear box for all vessels was made by General Motors Corporation. Since 1972, neither type of compound gear box has been manufactured due to a slack in demand for the product. However these types of gears are still in use and prove to be extremely reliable. On the 72 ton Pilot Boat during the third year of use a clutching problem developed but was repaired in minimal time. The gear has not faultered since.[9] In the two vessels with four engines, the gears have been in service for nine years, have never been overhauled and have accumulated over 12,000 operating hours. To date they remained casualty free.

Figure 7 is an outline of the engine rooms which house the two types of compound gears. Either gear could be used in a commercial fishing vessel.

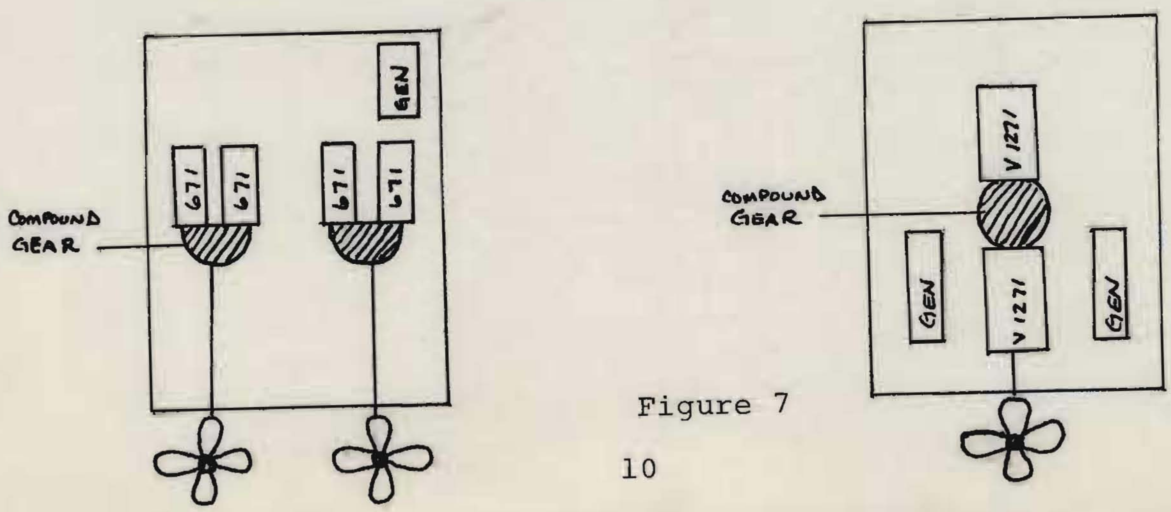

Figure 7

An 80 ft fishing vessel would require 400-500 horsepower to conduct its operations. In Figure 8 two proposed engine room arrangements are offered.

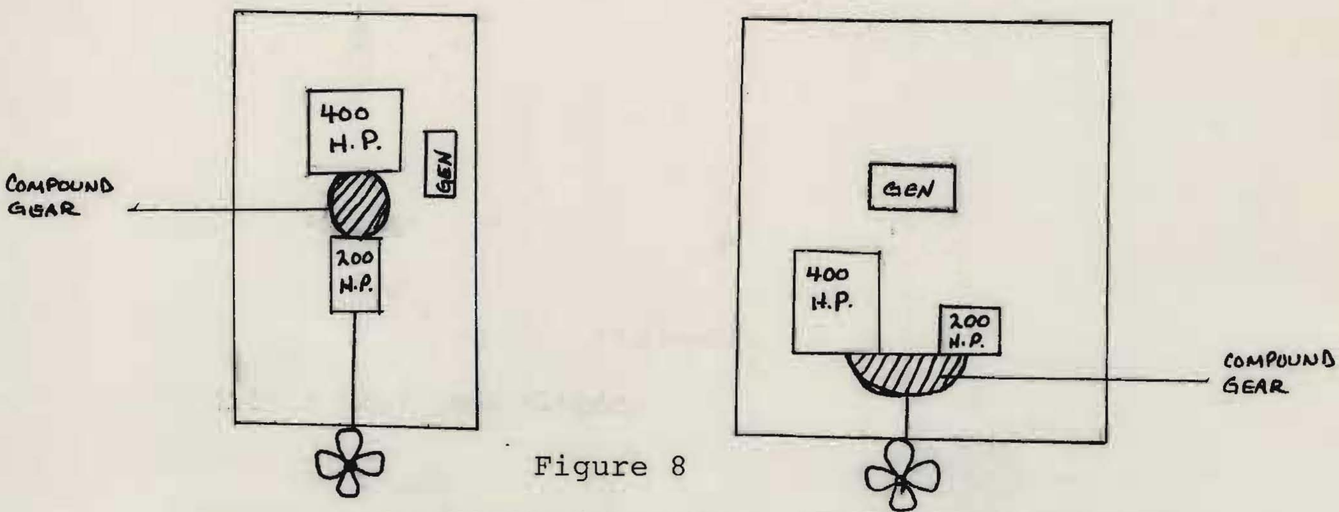

Figure 8

With a main propulsion system as picture in Figure 8, the fisherman has greater flexibility. He may have either 200 HP, 400 HP or 600HP available at his choice. Two hundred horsepower would allow for a low speed transit at speeds up to 8 knots.[10] This could be used for transits between fishing grounds when time is not critical. Four hundred horsepower would enable the vessel to maintain a transit speed of approximately 10 knots while 600 HP allows for an approximate transit speed of 11 knots.[11] With 600 HP in use, the transit speed may be reduced by 10% to 9.9 knots which will yield a fuel saving during transit of 30-40%.[12] In Figure 6 the split power vessel with 350 HP consumed 25% less fuel than the full power vessels with 700 HP at 8 knots. It is reasonable to assume that greater savings will be enjoyed by the fisherman who uses the 200 HP engine for slow speed transits than the fisherman who uses 400-500 HP to accomplish the same task.

TWO SPEED TRANSMISSION

The two speed transmission concept was developed in Europe and imported to the United States. At one half to one third of the cost of the controllable pitch (C.P.) propeller installation, the two speed transmission was designed to be a cost effective alternative to the fixed propeller and C.P. The 2 speed transmission costs roughly 20% more than a 1 speed transmission.[13]

Basically, the system houses two speeds forward and one reverse. The first gear is built for the power necessary for the trawling operation and the second or high gear is for the high speed transit phase. A fixed pitch single speed transmission is built for one of two phases: fishing/trawling or speed. In any event, it cannot be designed to operate in both phases efficiently and therefore fuel is wasted. To illustrate this point, the average vessel with a fixed pitch single speed transmission at full speed utilizes only 60-65% of the power the engine delivers yet consumes a maximum rate of fuel. By introducing a two speed transmission the engine RPM may be reduced by 20% or a smaller engine may be installed yet the vessel will maintain the same speed.[14] This is a fuel saving technique. The hard data to quantify the efficiency is being collected but is not yet available.[15]

The two speed transmission presently found on fishing vessels is used on engines of 900 horsepower and greater. To import a two speed transmission for a vessel with less horsepower could be accomplished only by individual orders at this time. This would lead to a parts support problem for repair.[16] For vessels in the 60 to 80 ft range which require 400-500 HP, this system is not readily available. Newport Shipyard, Inc. has designed a 108 ft deep freeze trawler which will use the Reintjes two speed transmission with a 1200 HP Caterpillar engine.[17]

The advantages, other than cost, of the two speed transmissions when compared to the controllable pitch system are: 1. simplicity, 2. less maintenance, 3. less vulnerable to damage. Because the controllable pitch propeller which will be addressed in detail later is a much more complicated system, it requires more parts and maintenance. When the C.P. is operating correctly, though, it is a far superior system.[18] The C.P. system is much more delicate than the two speed transmission by virtue of its position- exterior to the vessel. "Touching" bottom or entangling the fishing gear into the propeller can cause serious damage to the C.P. system.[19]

The two speed transmission is not without its drawbacks. Unlike the fixed pitch, single speed transmission or C.P. propeller, the two speed transmission can accomodate only one engine. This reduces the potential for flexibility that could be enjoyed by having multiple engines. As previously stated, the 2 speed transmission is imported for engines of 900 H.P. or greater. It would not be economically feasible to place this system in the 60 to 80 ft vessel due to the parts support problem at this time.

KORT NOZZLE

There are several mechanical theories under experimentation and in use throughout the commercial fishing realm designed to capture and use a greater percentage of the energy expended to produce work. One such mechanical theory that has received a great deal of attention of late is the Kort Nozzle. As a propeller turns, it provides thrust to move the vessel and a water flow which passes the rudder to make the vessel maneuverable. The Kort Nozzel is simply a solid circular screen placed around the propeller which vectors the lost thrust that "flies off" the propeller to a desired direction and maximizes the water flow over the rudder. Figures 9 and 10 illustrate these forces.

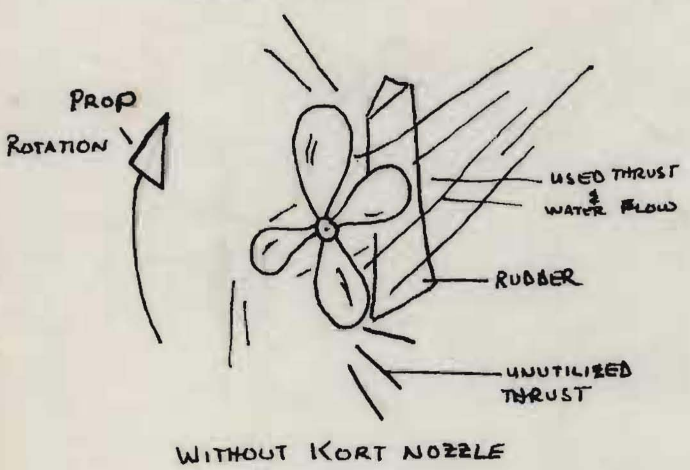

Figure 9

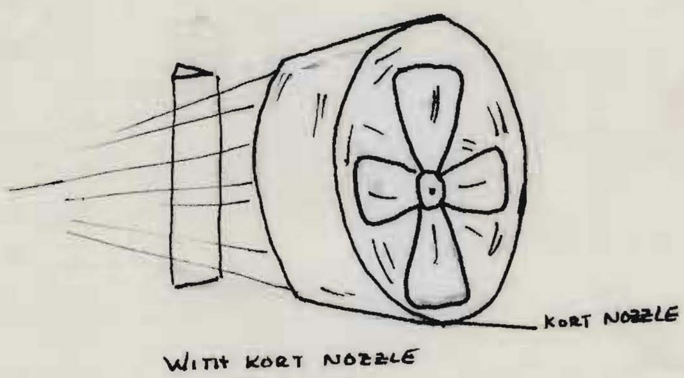

Figure 10

By vectoring the thrust that would otherwise be lost and forcing a greater volume of water past the rudder two desirable effects result. First, engine's RPM's may be reduced because it will take approximately 40% less power to provide the same amount of work.[20] Second, less rudder will be needed to maintain a course. With less rudder used, there will be less water resistance (drag) on the vessel resulting in fuel savings. Essential to the Kort Nozzle's success is the relationship between the specially designed and tuned propeller with the fitted circular screen.[21]

In theory, the Kort Nozzle is an energy saver, but it is only effective at low speeds. During fishing operations, for example, a 10% to 15% savings in fuel may be realized.[22] There is conflicting information concerning the nozzle's use at higher speeds. While providing a vectored thrust for power and water flow for rudder control, the Kort Nozzle is also producing drag. Some estimate that the drag at high speeds(i.e. 9.5 to 10 kts) will offset any savings realized during the fishing operation on small (60 FT) vessels.[23] This is of little consequence to the fisherman. The Kort Nozzle was widely received due to the thrust advantage enjoyed which aids in better towing ability.[24] In spite of the drag problem, many will claim that the nozzle is an overall fuel saver.[25] It does not work at high speeds such as those used for transit but rather concentrates upon the fishing operations.[26]

Using the Icelandic fishing fleet as a bench mark, 70% of the fuel used on the commercial fishing vessel is consumed during the fishing operation.[27] Simple arithmetic would indicate that 7% to 10.5% of all fuel used could be conserved by installing a Kort Nozzle. It is recommended that figures from the industry be solicited to determine to what extent, if any, the increase drag effects overall fuel economy. Only one article sited indicates that the total economy of the Kort Nozzle is offset by the drag problem at transit speeds.[28] All other readings and interviews indicate that the high speed drag effect on fuel use is negligable. The cost of installing a Kort Nozzle system in an 80 ft vessel is $10,000 or less.[29] A payback period could be determined depending upon vessel utilization.

One other short note on propellers. The manufacturing process of this essential unit is not as exacting as it should be. The angle of pitch and diameter of the blades has a guaranteed accuracy of only 20% of the design specifications when received from the factory. On a 20 inch propeller, two of the four blades could be out of calibration from one another by 2 inches. This would certainly lead to fuel inefficiency.[30] It is recommended that during a normal hauling of a vessel that the propeller be scupulously checked, polished and balanced.

CONTROLLABLE PITCH PROPELLERS

Controllable Pitch (C.P.) Propellers are not new to the fishing industry.[31] The introduction of the Controllable Pitch Propeller was not made to conserve fuel but rather, like the Kort Nozzle, to increase the amount of thrust available in order to enhance towing ability.[32]

There are two ways to use the controllable pitch propeller. First, the main engine may be operated at a given RPM. To increase the amount of thrust or speed, whichever is desired, the blades of the propeller are adjusted to an angle which yields the desired output. The second means of using the C.P. is adjusting both the engine RPM and the angle of the propeller blades so that the desired thrust or speed may be obtained. Both means are employed. The first requires a larger volume of fuel although it is the easier method for operating the system. The second will save fuel but more adustments of RPM and propeller pitch make the system more complicated.

A comparison of the two methods may be made on the graph in figure 11.[33]

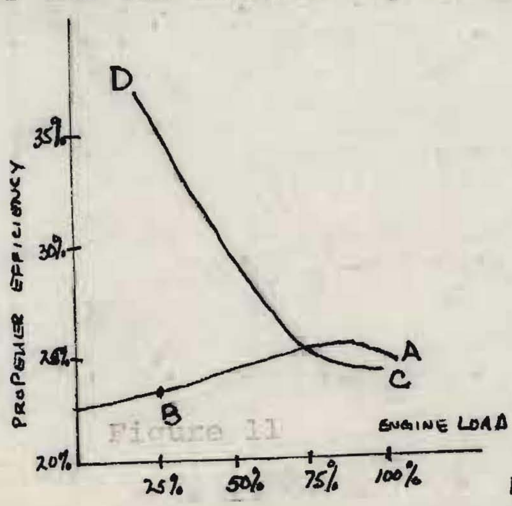

FIGURE 11

"Properly used, the C.P. Propeller is an asset in fuel conservation, improper use may turn into a heavy liability. The best fuel consumption is obtained by maintaining design pitch, and keeping the engine loaded for maximum fuel efficiency. When reducing vessel speed this should be done by reducing RPM, not by reducing the pitch. Reducing the load to 25% by constant RPM from A to B gives poor fuel consumption. Reduction along the constant pitch line DC gives a much better result...to achieve maximum performance is a matter of education and instrumentation. Savings potential from 0-15%, depending on present practice".[34] The graph in Figure 12 shows the fuel consumption differential by choosing either reduced RPM or reduced propeller pitch to obtain the speed desired on a 155 ft vessel.[35]

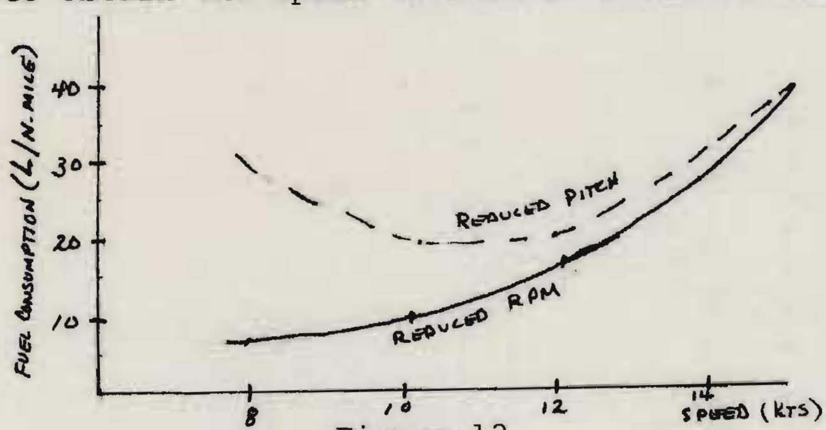

Figure 12

For those vessels with controllable pitch propellers already installed, a modification of the method in which the system is employed may result in a fuel savings of up ot 15%. It will require thorough testing of the system with various propeller pitch/RPM combinations and graphing the fuel efficiency curves to determine the most advantageous use of the system for each vessel. This is considered to be a worth while effort.

For vessels in which a controllable pitch propeller has not yet been installed, a greater fuel savings is projected. Reports of up to 30% savings of fuel have been claimed due to this conversion.[36] There are two types of systems that could be employed on an 80 ft vessel: Hydralic (cost $200,000) or Mechanical(cost $100,000). If there existed a demand for 50 or more systems the cost could be reduced to $150,00 for the Hydralic and $75,000 for the Mechanical. The original cost for a fixed pitch system is roughly $50,000.[37] It has been estimated that the system could pay for itself after one to two years of use.[38] This of course is dependant upon the proper use of the system and upon a high utilization factor of the vessel.

NAVIGATION AND FISH FINDING EQUIPMENT

In the course of researching potential fuel savings in the fishing industry, one area repeatedly mentioned was the need for better navigation and fish finding equipment. It is intuitively obvious that if speed is not increased, a true course is maintained, the catch is brought aboard in less time and the transit time from and to the port is reduced, fuel will be saved. There are several systems on the market the fisherman may purchase. All of the advertisements do not attempt to quantify the savings. There are too many variables involved. First, how efficient is the vessel in its present state? Second, what is the fish population in the area? Third, how far must the vessel travel?

Nonetheless, there have been technological innovations for navigation and fish finding equipment in recent years which save fuel. Automatic steering connected to LORAN C does keep the vessel on a true course. The introduction of sophisticated sonar techniques for finding the fish which allows the fisherman to search 360^{o} for the potential catch, determine the size of the school and the depth of water the school is located has reduced the time of the "hunt".

Of course the decision to purchase the new and improved equipment is one which must be analyzed with regards to a particular vessel. It has been claimed that the use of automatic steering with a LORAN C interface has saved one vessel owner 1 hour for every 24 hours in transit.[39] The steering system receives an input from LORAN which is cross checked with the plot so that tract integrity is maintained.[40] Using the 1 hour in 24 hour savings mentioned, it is assumed that a vessel makes a 10 day trip and uses 8000 gallons of diesel fuel.[41] A further assumption, 70% of the fuel is used for the fishing effort and 30% for transit, although the transit is only 23.4% of the time underway.[42] By applying the combination of all of figures, 5,600 gallons are used for fishing and 2,400 for a 2.34 day transit. A further assumption, the fuel during the transit is used at a constant rate per hour. With these assumptions applied, the owner of this theoretical vessel may determine the cost effectiveness of placing a new system on his vessel. During the transit phase he bursn 42.65 gallons per hour and saves 2.34 hours for a total fuel savings of 99.8 gallons of diesel fuel per 10 day fishing trip.

One of the sophisticated navigation systems on the market is CETCE Benmar's Course Keeper 210 with LORAN C interface. Other than the LORAN C set, this system con- of three components: 1. 210 Control Power Unit ($1390), 2. Course Keeper 210 ($1697), 3. Auto Track ($1495)[43] Most vessels already have a suitable power unit and autopilot;[44] however, given the worse case, it is assumed that this vessel requires all three components. The cost of the system, $4882.00, will be paid by fuel savings on the forty-sixth trip if fuel prices remain constant at $1.10 per gallon.

In the final analysis, a vessel may save on its fuel by introducing more advanced technology to the craft. It is a savings that would have to be computed by each vessel. The decision to buy or not to buy is based upon an economic advantage that a particular vessel will enjoy, a decision which cannot be made for the entire commercial fishing industry.

HEAVY FUELS

Heavy fuel is petroleum which has not been refined as much as Marine Diesel fuel and is distinguishable by its very thick viscosity. While interviewing many people including shipyard engineers, naval architects and vessel operators, heavy fuels is singled out as a possible fuel saver in the fishing fleet. Although it is not altogether certain what heavy fuels can or cannot do in this area, the widespread assumption is that this source of energy for the commercial fisherman's vessel will cost less, yield a higher profit margin for the fisherman, reduce the gallons per hour consumption and is therefore worthy of further study.

The savings, it is perceived, is due to the price of this substance. Surely the price for heavier fuel has neither kept pace nor has it approached the cost per ton of the higher priced Marine Diesel oil. For example, 1500 sec redwood (a typical heavy fuel) is normally 40%-50% cheaper than Marine Diesel.[45] The graph below depicts the cost differential in Europe from January to July 1979.[46]

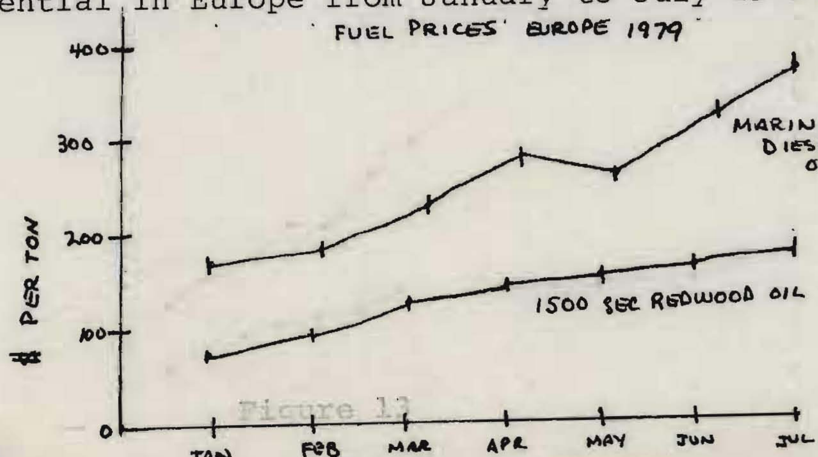

FIGURE 13

What makes heavy oil attractive is the price differential that it presently enjoys. Certainly, this structure could change drastically if the demand for heavy oil sharply increases. In order to use the heavy oil, heaters must be installed in the fuel tanks to heat the substance to transform it from a "molasses-like" state to a fluid state. Additionally, this substance must be mixed with diesel oil in an emulsifier before it can be used. This mixture must be burned in a "Slow Diesel" engine at 750 RPM's or less.[47]

In the past, heavy oil was used. Three problems existed which ushered in the use of the higher speed diesel engine: 1. High maintenance costs,[48] 2. Heating the oil in cold latitudes,[49] 3. High sulphur content which causes corrosion.[50] Technology has, for the most part, overcome the heating and sulphur problems.[51]

The problem with heavy oil is that even though there is a potential savings of up to25%, the increased maintenance cost is expected to off-set fuel savings.[52] Also, the purchase price of the low speed diesel engine has risen dramatically. Even in a vessel that is being constructed, medium and high speed diesels are the only engines considered for main propulsion.[53] Considering the maintenance costs that will be incurred and the price of the engine, in addition to the installation of all the auxilliary equipment required, the use of heavy fuels will probably not be reinstituted in the commercial fishing fleet.

SECTION II

FUTURE TECHNOLOGY

SECTION II

SAIL ASSISTANCE

Although there is little hard data that can be used to compare this with other systems, sail assistance is being used on some commercial fishing vessels and should be addressed. Using "Wind Power" via sail assistance to the main propulsion system is a concept that is receiving greater attention from private industry and many governments worldwide. However, the emphasis on this system is focused on the feasibility of its use onboard the commercial carrier (30,000 DWT and greater) vice the commercial fishing vessel.[54] There are many unique systems that are in the research and development stage at this time; Square Rig, Fore and Aft Rig, Aerofoils, Magnus Effect Devices, Wind Turbines, Airborne Sails (Kites).[55] These systems do not appear to hold much promise at this time for the 150 DWT and smaller fishing vessel.

There is one type of sail that is in use which does hold some promise for the commercial fisherman - a steadying sail. This system is used while the fixed gear vessel is conducting its fishing operation. The sail aids in keeping the vessel into the wind. By reducing the need for constant shifts in engine speed (clutching) and reducing the rudder action necessary to hold a true course, fuel is conserved.

However, the sail may only be used under certain conditions and therefore cannot be counted upon as a consistant fuel saver.[56] Also, there are no hard figures available to measure the cost effectiveness of this system. As mentioned previously, private industry and government institutions are concentrating their research and development for sail assistance on commercial carriers. Relatively little effort is being placed upon wind power for use aboard the smaller commercial fishing vessel.

As the price of fuel continues to rise, there may be a wider employment of this system. However, it is felt that sail assistance for fishing vessels will develop at a slower pace than will other fuel savings methods. If development of a viable sail method does occur, it will probably be a by-product from the research underway for use on commercial carriers.

ENGINE INNOVATION

The diesel engine, unlike the gasoline engine, operates on a simple concept. Air is placed in a cylinder and compressed by a piston which produces heat. A fine mist of fuel is added and an explosion occurs driving the piston through a power stroke. The gasoline engine operation depends upon precise timing between spark, carboration (fuel air mixture) and high RPM. As proven by an optional engine in the 1981 Cadillac, a gasoline engine may have the number of working cylinders reduced as the requirement for power is reduced. The V-8 engine in this automobile becomes a V-6 or V-4 which maintains a given speed. If additional power is required, the "Free Riding" cylinders, in pairs, become working cylinders once again. By reducing the number of working cylinders fuel is saved. The question which is addressed in this section is "Can this concept be applied to the diesel engine?". Before addressing this question, it is necessary to understand, in more precise terms, how the diesel engine works.

The diesel engine has a blower which forces air into the cylinder through air ports. As the unidirectional air rushes in, it forces exhaust gases out of the cylinder through exhaust ports and provides the cylinder with fresh air for combustion. This occurs as the top of the piston uncovers each respective air and exhaust port. The cylinder now houses fresh air which is compressed. The exhaust ports at this point have been closed by the piston's continued upward movement. Shortly before the piston reaches the apex of its travel, fuel is sprayed into the cylinder by a fuel injector. The intense heat caused by compressing the air ignites the fuel immediately causing combustion which forces the piston downward. The downward movement of the piston is the power stroke.[57]

To apply the reduced cylinder concept, a V-16 diesel engine will be used. Figure 14 is a side view of the V-16 with the modifications that would be required.

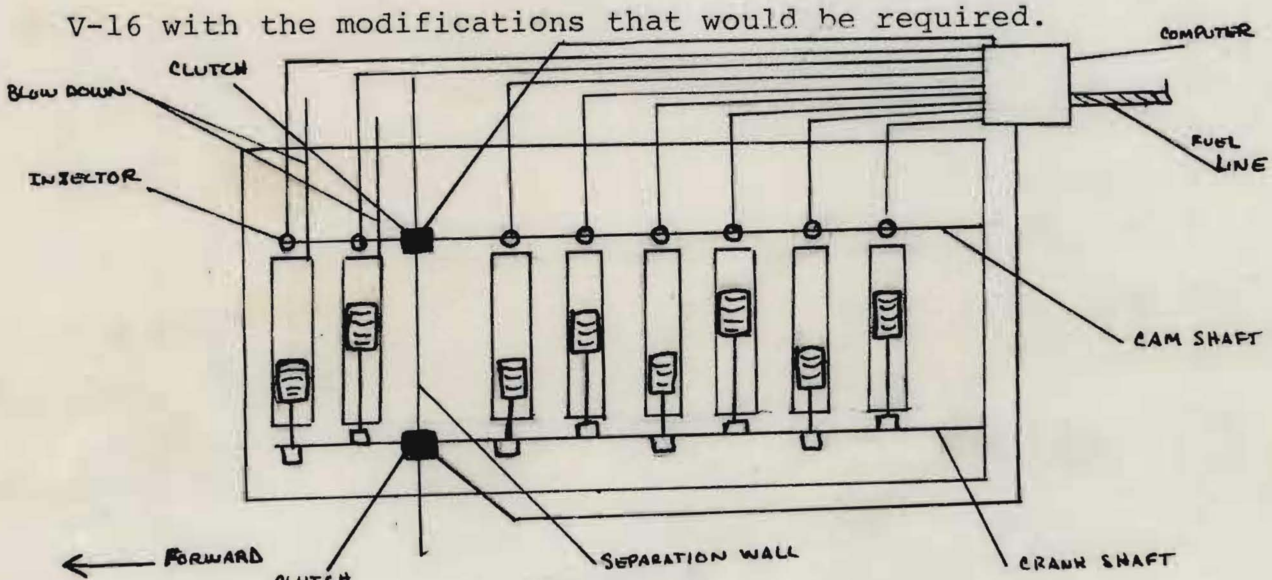

Figure 14

Because this is a side view, only 8 of the 16 cylinders can be seen. Also, a cam shaft is located above each side of the "V" for a total of 2. The object of this engine is to introduce the capability of securing 4 of the cylinders when the power requirement has been reduced, i.e. during the transit phase and therefore conserve fuel. At the operator's discretion, a selection lever in the pilot house is turned to the reduced power position. This sends a signal to the computer which disengages the three clutches (2 cam shaft, 1 crank shaft). Once the cam shaft for the forward 4 cylinders is disconnected, the fuel flow will stop. With the crank shaft disconnected via the clutch, the forward cylinders will not be forced to continue their up and down movement. Simultaneously, the blow downs are opened to allow any compressed air to escape. The computer "Re-times" the fuel input to the 12 working cylinders and the engine is now at reduced power. To return to full power, the engine is placed at idle and the select lever is shifted to the full power position. The process is reversed, the engine is "Re-timed" for 16 cylinder use and now has full power available.

There are two critical points to the operation of this engine. First the alignment of the three shafts when returning to full power allows for nearly zero tolerance from perfect alignment. The engine must be throttled very low prior to engagement of the clutches to ascertain the alignment and prevent damages to the shaft. Second, the computerized "Re-timing" of the engine must be accomplished with extreme accuracy. If the engine is not in proper time, at best, it will run inefficiently or worse, not run at all. It must be kept in mind that the 4 cylinders that are secured must be in the proper firing order in the engine or the concept will not work.

The advantages of this engine are: 1. The vessel will have nearly the same flexibility as a vessel with 2 engines, 2. The space allocated for the engine may be reduced freeing valuable space for other uses, 3. Significant fuel savings of up to 20% may be achieved during the reduced power phase.

The technology for the complete system is not presently available. Having discussed this system with several marine engineers, shipbuilders and one naval architect, the conclusion unanimously drawn is that theoretically, this or a similar system could be developed; however, there is not agreement on the extent of the potential fuel economy. Given the state of the art today, all preferred continued development of fuel saving techniques with single or dual engine vessels. The shaft alignment and timing factors mentioned earlier could eventually be eliminated with research and development but it was not felt that the resources will be allocated to this or a like project. Furthermore, each questioned: 1. The maintenance that would be involved, 2. The reliability of such an engine and

3. The cost effectiveness of the engine.

The unfavorable aspects mentioned cannot be addressed nor quantified at this point in time. The conclusion drawn from the information available is that theoretically, a diesel engine with the capability of reducing the number of working cylinders is feasible; however, a practical use for this concept in a marine environment is seriously questionable. Given other alternatives that have the potential for fuel savings and are available with today's technology, one would be better off by applying his resources towards other fuel saving techniquies and technologies.

WASTE HEAT

Fuel is consumed at a surprisingly high rate for the production of electrical power for small vessels. Fuel usage for a 2 cylinder 30 KW generator or a 3 cylinder 50 KW generator at 1800 RPM is at a rate of 1.5 and 2.3 gallons per hour respectfully.[58] In a fishing vessel several combinations for main propulsion may be found including the use of heavy fuels burning engines. However, three or possibly more light diesel fuel using generators are required to produce the electrical power. The generators burn diesel fuel which in some vessels nearly doubles the fuel bill.[59] Other fishing vessels generate their electrical power from a power take off connection from the main engines. Although this is efficient at high speeds, the main engine would have to be operated at a higher RPM at lower speeds in order to produce the constant AC power requirement of the vessel.[60] While pier side, the less efficient main engine is continually running to maintain the electrical load where shore connections cannot be provided. It is estimated that the fuel used for the Norwegian trawler to produce electrical power amounts to 15% of the total fuel bill per year.[61] Using figures sited for the separate 30 KW and 50 KW generators and comparing the vessel's used for the multiple engine experiment an average of 10%

of the total fuel used for these vessels per hour was dedicated to electrical power generation.[62]

During the course of transit and fishing operations in the Norwegian fleet, an estimated 60-70% of the energy burned in the fishing vessel disappears through stack exhaust and cooling water.[63] The thermal efficiency of the diesel and gasoline engine is approximately 30-35%.[64] Approximately 1/3 of the converted energy is lost up the stack or in the cooling water, 1/3 is used for cooling and 1/3 of the energy is used to accomplish 100% of the work.[65] If the thermal efficiency of the fishing vessel could be improved two fold the fuel efficiency of the vessel would increase by 100%.[66]

Two areas in which waste heat can be utilized to promote the efficiency of the fishing vessel are: 1. Utilize the waste heat to produce the electrical power necessary for the vessel's operation, 2. Utilize the thermal differential in such a way to satisfy the heating, cooling and refrigeration requirements of the vessel. For the production of the total electrical power requirements of the vessel, theoretically, it is feasible. Although waste heat boilers and turbogenerators are not new to the marine environment, more research and development would be required. In order to place such a system on a relatively small craft, known technology would have to be modified. Physical reduction in size and mechanical simplification of this system is necessary in order to ensure that the cargo area would not be sacrificed and that the new system could be maintained in an open ocean environment. As far as using the waste heat for heating, cooling and refrigeration, the development would require a design modification to present day technology.

At best, the use of waste heat is an interesting prospect that requires significant study and development. Cost effectiveness data and data concerning the viability of this system's employment are yet to be ascertained. A waste heat to power conversion may be a method used on vessels in the future, but the development appears more to be in the long range future than on the horizon.

SYNTHETIC FUELS

As the price of petroleum increases, replacement and renewable sources of energy are sought. This is evident with the development of the distilled and natural alternative energy sources. There are several present day technologies available to convert gasoline and diesel engines into propane and methane gas burning users. However, placing these systems on a commercial fishing vessel is not feasible at this time due to two distinct problems: 1. Lack of storage capacity aboard the vessel and 2. Inability to safeguard the vessel from accidental gas leaks and explosion.[67] Even if these problems could be overcome, the presence of these gases in mass aboard a vessel would require more stringent safety inspections and thorough preventative maintenance. Therefore, it is felt that these types of fuels will probably not be used on a U.S. commercial fishing vessel in neither the near nor mid-range future.

There is one other alternative which is being developed which may eventually be used in the commercial fishing industry - Aquahol. Aquahol is a 50% mixture of water with 50% ethanol or methanol alcohol. M & W Gear of Gibson City, Illinois is currently manufacturing a conversion kit that enables small (125-380 HP) diesel engines to operate efficiently on an Aquahol-Diesel oil fuel mixture. M & W Gear claims that this mixture can reduce the use of diesel fuel by 30%.[68] The system works by injecting the mixture into the air stream. The alcohol cools the air, making the air denser which leads to a more powerful and cleaner explosion. This aids in the maintenance of the engine because the cylinder sleeves, pistons and valves will remain cleaner and therefore last longer.[69]

It is also reported this mixture delivers more horsepower while using less fuel. Under the conditions of a controlled experiment, an IHC 986 diesel tractor was first allowed to run without any modifications to the engine. Horsepower and torque readings were taken using a dynamometer and the engine was operated to produce 125 H.P. The engine consumed 8.5 gallons per hour of diesel fuel. The same engine was equipped with the M & W Gear Conversion Kit. When the Aquahol mixture was injected into the turbocharger, the engine had to be throttled down in order to produce 125 H.P. The converted engine consumed 8.0 gallons of Aquahol/ Diesel mixture per hour - 1 gallon alcohol, 1 gallon water, 6 gallons diesel fuel mixture. The following points are important and should be noted: 1.The amount of liquid fuel consumed was .5 gallons less per hour, 2. The power of the engine was increased, 3. The amount of diesel fuel used was reduced from 8.5 to 6.0 gallons per hour, a considerable savings of diesel fuel.[70]

A fourth point-the cost of this form of alcohol is only 43¢ per gallon. Unlike that used for gasohol for gasoline engines, the alcohol for this system need only be processed for the first state. The alcohol in gasohol requires a second refinement which increases the cost per gallon to $1.60, nearly quadrupling the price of this propellant.[71]

With the prices of the quantities known, an estimated savings that could accrue via aquahol use may be ascertained. The average stern trawler in this area has 12,000 to 15,000 gallon fuel capacity.[72] During a fishing trip, the trawl will leave the Point Judith/New Bedford area and transit to the Georges Bank area, fish and transit to a port to offload his catch and return to his original port. If this trip takes approximately 10 working days, the vessel will consume 8000 gallons of diesel fuel.[73] Assuming that: 1. Twelve trips are made per year, 2. 8000 gallons of diesel fuel is used per trip and 3. The price of diesel fuel averages $1.00 per gallon, the trawler will use 96,000 gallons of fuel at a cost of $96,000 per year. Assuming M & W Gear's estimate that 30% of the diesel fuel is saved using a 50% solution of Aquahol 50% fresh water mixture, at 43¢ per gallon the cost of Aquahol would be $12,384 resulting in a savings of $16,416 per year or, the cost of fuel was reduced by 17%. If the results of the IHC 986 experiment are applied to the 96,000 gallons of diesel fuel the following table may be constructed:

Diesel Fuel	96,000 gal @ $1.gal	$96,000	67,680 gal @ $1/gal	$67,680
Water	0 gal $.05/gal	-0-	11,280 gal $.05/gal*	564
Alcohol	0 gal $.43/gal	-0-	11,280 gal $.43/gal	4,850.00
Total	Gallons Fuel 96,000	$96,000	Gallons mixture 90,240***	73,094.40

*Assumption of %.05/gallon for fresh water as a nominal charge.

**The Aquahol mixture reduced the total amount of fluid used by approximately 6%.

Comparing $96,000 to $73,094.40, the results of the experiment indicate a fuel cost savings factor of 24%. Applying the more conservative figure of 17% fuel cost savings would lead one to conclude that the system is extremely cost effective. The present price of the M & W Conversion Kit is less that $1,000.[74]

There are, however, a few drawbacks to this system. First M & W Gear has not as yet developed a conversion kit for marine use.[75] Second, distribution centers for Aquahol have not yet been established. Third, there is no known market analysis available to indicate the extent of the demand for this system. It is felt that the potential for such a system is tremendous. If the conversion for marine use can be developed with only a moderate increase in price, a reasonable facsimile of the efficiency already outlined is maintained and the potential market can be convinced that the figures are accurate, the private sector of the economy will eventually promote this system.

SECTION III

CLOSING REMARKS

SECTION III

OBSERVATIONS

The research involved with this paper begain in December 1980. Naval engineers and architects, shipbuilders, vessel operators, fisherman and equipment manufacturers were interviewed. Several articles, brochures and trade journals were reviewed. From all of this, two observations have been made.

Until recently, the emphasis had been on marine design to manufacture equipment that would "catch more fish". The attitude and image projected today is "catch more fish and save fuel". In the future it may change to "save fuel and catch more fish". This is perhaps a minor point, but nonetheless an indication of where the industry had placed its research and development effort and where it focuses its attention today. There are several reasons which lead one to believe that saving fuel has become more important to the fisherman. First, some fishermen have reported that the cost of fuel for 1978 represented 2% of gross sales but in 1979 it had jumpted to 8%.[76] Another report states that it is as high as 12%.[77] It is expected that fuel prices will continue to increase faster than the price per pound the fisherman receives for his catch. Second, the fisherman is not petitioning the government for a fuel subsidy with the vigor he has demonstrated in the past. Instead he looks to the federal government as a protector of the area he has traditionally worked and as the equalizer who should limit the entry of the foreign catch on his market.

Third, as one casually leafs through the trade journals he sees that in recent months more space is dedicated to fuel saving techniques and equipment. Fourth, there has been a subtle change in advertising techniques, whereby fuel savings at least receives second billing to increased catch for the equipment advertised. Fifth, at fish expo's, time is dedicated to discussion on fuel management. Sixth, new technology is being discussed by the R & D sector, i.e., Aqualhol, waste heat. Seventh, academia is placing more emphasis on fuel consumption problems. By combining these seven factors it becomes apparent that the problem is receiving the attention it deserves.

A second observation made during the course of research is that is is extremely difficult to obtain accurate information. This is partly due to a lack of data base. For example, to ask "What will system "X" do to save fuel?" where "X" is not employed on a vessel leads to mere speculation. In order to obtain the data base one must compare two like vessels; one with "X" and one without "X". With limited resources it is difficult to construct scenarious that will prove or disapprove theories. A second reason contributing to the difficulty of obtaining accurate information is that there is a good portion of misinformation passed from one individual to another or found in print. Usually the misinformation is forwarded unintentionally. Nonetheless, it exists and the researcher must cross check the data wherever possible to ensure accuracy.

SUMMARY

-Fuel Prices-Fuel prices are rising. Although there may be brief periods of stable prices, in the long run, the trend of rising fuel prices is expected to continue. The price the consumer pays for fish is also rising. There is a price for fish above which the consumer will opt to purchase a substitue good (i.e. beef, vegetables) rather than spend his income on fish. If the cost of fuel rises faster than the income derived from selling the fish, in a competitive market the fisherman's profit margin declines. It would therefore be in his best interest to reduce his dependance upon the rising cost item.

-Slower Transit Speeds-If the vessel operator normally transits at maximum speed, by reducing his speed by 10% he may save 30-40% of the fuel consumed during transits. Each vessle operator must weigh the economic advantages and disadvantages of the slower speed in order to determine wherther or not to slow his vessel.

-Multiple Engines-If two engines are installed in a vessel, the operator will have better flexibility than with only one engine. Additionally, he will be able to conserve fuel. During slow speed transits when time is not a critical function the operator may chose the use of a smaller engine with less horsepower. The amount saved depends upon how the operator chooses to employ the engines and upon a transit to fishing ratio.

-Two Speed Transmission-Two speed transmissions are imported from Europe and can be fitted to engines of 900 horsepower or larger. During the transit phase engine RPM may be reduced by 20% with no loss of speed. Comparing the 20% reduction with the section on slower speed, 30-40% of the fuel used during the transit phase may be conserved over a vessel with a fixed pitch single speed transmission. There are indications that fuel may be saved with a two speed transmission during fishing operations; however, there is no quantitative information available to confirm this point. The two speed transmission may only be installed in single engine vessels.

-Kort Nozzle-The Kort Nozzle is a very popular item that is being retrofitted on vessels in service and on vessels under construction. It allows for greater "Pull" power during the fishing phase. A savings of 10-15% of the fuel used during the fishing phase has been reported. The Kort Nozzle is not effective at spees of 9.5 kts and greater.

-Controllable Pitch Propellers-When the RPM is adjusted for the speed desired and is combined with a test proven economical propeller pitch angle, the controllable pitch propeller system is very efficient. Savings over an improperly used C.P. System are reported to be as high as 15%. Vessels which convert from a single speed transmission with a fixed pitch propeller to a C.P. System may use 30% less fuel. The C.P. System may be designed for a single or multiple engine vessel.

-Navigation and Fish Finding Equipment-Although hard data confirming fuel savings is not available, it is reasonable to assume that if one arrived at the potential catch sooner, lands the catch quicker and returns to port in less time without increasing speed, fuel will be conserved. Most fishing vessels are equipped with sophisticated navigation and fish finding equipment. The pros and cons of purchasing newer technology would be a decision that each vessel operator must make for his particular vessel.

-Heavy Fuels-Heavy fuels are 40-50% cheaper than light fuels but cannot be used in high speed diesel engines. To convert to the use of heavy fuels the vessel owner would have to change to a more expensive engine, install heaters in the fuel tanks, emulsifiers to mix diesel fuel with the heavy fuel and more fuel oil purifiers and strainers. The maintenance costs would rise and may overcome the potential savings.

-Sail Assistance-Sail assistance for fishing vessels is not receiving a great deal of attention. The research and development assets are concentrated on sail assistance for commercial carriers. Perhaps "spin-off" benefits may accrue from the R&D dedicated to the commercial carrier but development for the fishing vessel will be slow.

-Engine Innovation-Theoretically, the reduced cylinder concept used in the gasoline engine may be applied to the diesel engine; however, the technology for such a system does not presently exist. A diesel engine with a reduced cylinder capability will be extremely complex and may prove to be a maintenance nightmare. Also, such an engine will be costly and estimated fuel savings is purely speculative at this time.

-Waste Heat-Sixty to seventy percent of the energy burned during the transit phase is lost through the exhaust stacks and cooling water. If the thermal efficiency of a vessel could be doubled the full efficiency of the vessel would be improved by 100%. For future development, waste heat systems are considered well worth the research and development time and funding.

-Synthetic Fuels-The development of an aquahol system for marine use appears to be quite attractive. Such a system may save the fisherman 17-24% of his fuel costs.

CONCLUSIONS

The fishing vessel must be looked upon as a single unit and not as a collection of systems. By that, it is meant that to improve the efficiency of the vessel, the owner must consider all of the systems and technologies available and employ the combination of factors that will ultimately achieve a fuel saving, cost effective unit. He must plan his overhauls and modifications well in advance. For example, should he choose to retrofit his vessel with multiple engines, controllable pitch propeller and Kort Nozzle, his last purchase should be the Kort Nozzle. Though the Kort Nozzle offers immediate savings at the lowest price, the price of the nozzle is doubled if he must purchase a second system for the controllable pitch propeller. Certainly the cost of borrowing money is high, but doubling the price of a system through double purchases for short term savings is not cost effective.

There are systems available to the fisherman that will economize his unit. However, there is a need for a "trusted party" who has the ability to collect, analyze and disseminate accurate and unbiased information. Whether or not the "trusted party" should be a function of the government, the industry or some other organization in the public or private sector is a question worthy of debate and will not be addressed in this paper. The point is, there exists a need for credible authority that has the capability of correcting misinformation and has the fisherman's confidence.

Footnotes

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2. IBID., page 6.

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17. Interview with Herman HENDRICKSON, Newport Shipyard, Inc., Newport, RI.

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35. "Fishing Vessel Speed and Fuel Economy", by Torbjorn DIGERNES and Anders ENDEL, Ices-Engineering Working Group, Reykjavik, May 1980.

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39. Letter from Capt. J. BORDIA, Claw's Inc., to Lucy SLONE, 3 March 1980.

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