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THE USE OF CONTROLLABLE PITCH PROPELLER SYSTEMS BY THE POINT JUDITH FISHING FLEET-- A FEASIBILITY/ COST EFFECTIVENESS STUDY

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UNIVERSITY OF RHODE ISLAND
Kingston, Rhode Island
in partial fulfillment of the requirements for the degree of
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IN
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The current propulsion systems in use of three vessels of the fishing fleet (ranging in length from 64 to 87 feet) were examined. Then, a numerical and cost effectiveness analysis was accomplished based on a conversion of these vessels to a controllable pitch propeller system. Additionally, pay-back periods were computed based on installation of controllable pitch systems on comparable nawly built vessels.

Interviews were conducted with representatives of the controllable pitch manufacturers so that the marketing and sales philosophies could be examined. Finally, the owners of the three subject vessels were given exit interviews where the results of the study were discussed with each to determine their acceptance of such a system.

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THE USE OF CONTROLLABLE PITCH PROPELLER SYSTEMS

BY THE POINT JUDITH FISHING FLEET--

A FEASIBILITY/ COST EFFECTIVENESS STUDY

BY

DENNIS MICHAEL MILLER

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

IN

OCEAN ENGINEERING

UNIVERSITY OF RHODE ISLAND

1982

MASTER OF SCIENCE THESIS

OF

DENNIS MICHAEL MILLER

APPROVED:

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DEAN OF THE GRADUATE SCHOOL

UNIVERSITY OF RHODE ISLAND

1982

ABSTRACT

An analysis of three selected fishing vessels of the Point Judith fleet was conducted to determine the feasibility and cost effectiveness of replacing the current fixed pitch propeller systems with controllable pitch propeller systems. The optimum amount of fuel saved through conversion to a controllable pitch system was approximately 17.4 to 19 per cent for the three vessels, and the cost of the systems could be paid back through these savings in periods of less than five years. Generally, the vessel owners were interested in such systems and would like to see an actual retrofit on a fleet vessel.

The current propulsion systems in use on three vessels of the fishing fleet (ranging in length from 64 to 87 feet) were initially examined. Then, a numerical and cost effectiveness analysis was accomplished based on a conversion of these vessels to a controllable pitch propeller system. Additionally, pay-back periods were computed based on installation of controllable pitch systems on comparable newly built vessels.

First, the basic operating characteristics of the vessels of the fleet were examined. At the same time, three controllable pitch systems were selected and studied to determine their relative strengths and weaknesses. Three vessels of the fleet were then selected and information concerning their physical plants and operating

characteristics was gathered. Optimum controllable pitch propeller settings were then determined for both free running and trawling modes based on constant propulsion plant characteristics and set thrust and speed requirements. From the information obtained, fuel-savings percentages for each of the three vessels were computed. Using cost estimates from the controllable pitch companies and calculated yearly savings based on the lowered fuel consumption rates, pay-back periods were determined for each of the three vessels. These periods covered the system costs for two cases--retrofits and installation on newly constructed vessels. Interviews were conducted with representatives of the controllable pitch manufacturers so that the marketing and sales philosophies could be examined. Finally, the owners of the three subject fishing vessels were given exit interviews where the results of the study were discussed with each to determine their acceptance of such a system.

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The author wishes to thank the members of his committee, Dr. Conrad Recksiek, Dr. David Shao, and especially Dr. Tadeusz Kowalski for their invaluable assistance and advice throughout this project.

A special thanks to my wife, Pat, for her help and understanding during the course of this work.

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NOMENCLATURE

Symbol	Definition	Units
Ae	expanded area (propeller blades)	ft^2
Ao	area of propeller disk	ft^2
bhp	brake horsepower	
Bp	Taylor propeller coefficient, $n(dhp)^{.5}/(Va)^{2.5}$	
D	diameter of propeller	ft
dhp	delivered horsepower	
J	advance coefficient, Va/nD	
Kq	torque coefficient, $Q/\rho n^2 D^5$	
Kt	thrust coefficient, $T/\rho n^2 D^4$	
N	engine speed, in revolutions per minute	rpm
n	revolutions per unit time	rpm, rps
P	pitch of propeller	ft
Q	torque	ft-lbs
T	thrust of propeller	lbs
V	velocity, speed of a ship in knots	kn
Va	speed of advance of a propeller	kn
w	wake reduction fraction .8 for a single propeller vessel .88 for a twin propeller vessel	
δ	(delta) Taylor advance coefficient, nD/Va	
η_o	open water propeller efficiency	
ρ	density of water	$slugs/ft^3$

I

INTRODUCTION

The successful operation of the commercial fishing fleet of Point Judith, Rhode Island, depends on the cost effectiveness of each vessel. One cost factor which has risen significantly over the past decade is the price of fuel. This study examines the possible consequences that the use of controllable pitch propeller systems would have on the fuel consumption rates, along with the potential for acceptance that such systems would have among the local commercial fishermen.

Controllable pitch propeller systems have been operating on commercial vessels for over fifty years and have been used successfully in a wide variety of applications. Such systems offer the user the ability to maximize thrust over the range of operating speeds and provide the vessel with greatly enhanced maneuverability. Due to its effectiveness at all speeds, the controllable pitch propeller system has become particularly popular for vessels whose missions dictate that they be operated at more than one speed.

Fishing trawlers must have the capability to move from their home ports to the fishing grounds at fairly high speeds, trawl for extended periods at about three and a half knots, and then rapidly return to port to unload their catch. These operational requirements have led to the outfitting of a large number of fishing vessels with controllable pitch systems, with the Scandinavian fleets employing a large percentage of the systems.

The events of the last decade have caused a tremendous increase in the price of fuel oil and most industries have reacted by attempting to find methods of reducing their fuel consumption to cut operating expenses. Since the controllable pitch propeller system has the ability to maximize thrust at all speeds, then use of such a system should, with no decrease in thrust, lower fuel consumption rates. The Newage Company has already marketed a two pitch system for the expressed purpose of saving fuel for vessels which generally operate in two distinct modes. This study will examine both the traditional controllable pitch systems and the Newage system with the goals of determining the fuel savings which could be achieved and the potential for acceptance of such systems by an American fishing fleet.

Although much material has been written concerning controllable pitch propellers, relatively little emphasis has been placed on written results of its use on fishing vessels in the 50 to 100 foot range. Additionally, most studies stress the gains in thrust possible through use of such systems without discussing the aspect of reduced fuel consumption. As a result, much of the material was gathered from interviews, letters, and company information booklets.

II

THE VESSEL PROPULSION SYSTEM

In order to fully understand the important role of the propeller as it relates to the fishing vessel , it will be necessary to look at the basic operating characteristics of the vessel propulsion system. The elements of the propulsion system for the typical vessel of the Point Judith fleet ranging in length from 50 to 100 feet are as follows:

Diesel Engine (single or twin)

Reduction and Reverse Gears

Shafting

Propeller (single or twin)

Nozzle (if present)

Marine diesel engines are generally classified based on their shaft revolutions per minute (rpm). In the case of the vessels of the Point Judith fishing fleet , the diesel engines generate over 1000 rpm and are designated as high speed marine engines. (Henshall,1972) As the basis of the propulsion system for the fishing vessel , the engine has several key operating parameters. The power output of an engine measured at the crankshaft is known as the brake horsepower (bhp) . This is the power which has been internally generated by the engine minus a friction parameter . The name was derived from an early method of measuring the engine power by absorbing it with a brake.

Engine torque is the turning force (measured in ft-lbs) produced by an engine at the crankshaft. It is directly related to the engine power and can be found using the following formula :

$$Q = 33{,}000 * dhp / 2 * 3.1416 * N$$

where : Q = torque , ft-lb

N = engine speed , rpm

dhp = delivered horsepower

Torque becomes especially important when the thrust capabilities of a vessel's propeller are examined .

Engine manufacturers publish performance curves in order to facilitate the selection of the correct engine for a specific application . Generally , these curves detail the horsepower generated and the fuel consumption rates for given engine speeds (rpm). Curves which most manufacturers publish include the gross brake horsepower , a shaft horsepower rating which is the net power available at the output shaft (this takes the reduction of power due to gearing and systems such as the alternator and water cooling pump into account) , and a fuel consumption curve for either net shaft horsepower or for a hypothetical propeller. Most marine engines have three separate sets of ratings: pleasure boat , light duty commercial and continuous . As this study deals with fishing vessels which operate at fairly high engine load levels for extended periods of time , the continuous rating is the only one used . Generally , the engine ratings are certified to be correct within a range of five percent . For the purposes of this study , the key rating curves are the net horsepower and the fuel consumption curves . A representative performance curves chart is included as Figure 2-1.

The function of marine gearing systems is to transmit rotary motion from one shaft to another. The reduction gears transmit a different speed of rotation, while the reverse gears change the direction of rotation. Although there are many different classifications of marine gears sold by numerous manufacturers, the basic operations of these gear systems can be outlined in a fairly simple manner. With the exception of special applications such as high speed naval craft, high speed marine engines must have their operating revolutions reduced so that the propellers can efficiently move the vessel through the water. Without some method of reduction, cavitation would drastically reduce the propeller's efficiency. The operation of the reduction gears consists of the meshing of two different size gears, the smaller being called the pinion and the larger the gear. The pinion is connected to the engine's crankshaft, while the gear is connected to the propeller shaft. In a case where the surface area of the gear was six times larger than that of the pinion, the ratio of speed reduction would be 6:1, or if 1800 rpm were being generated by the engine through the crankshaft, the propeller shaft would be turning at the rate of 300 rpm.

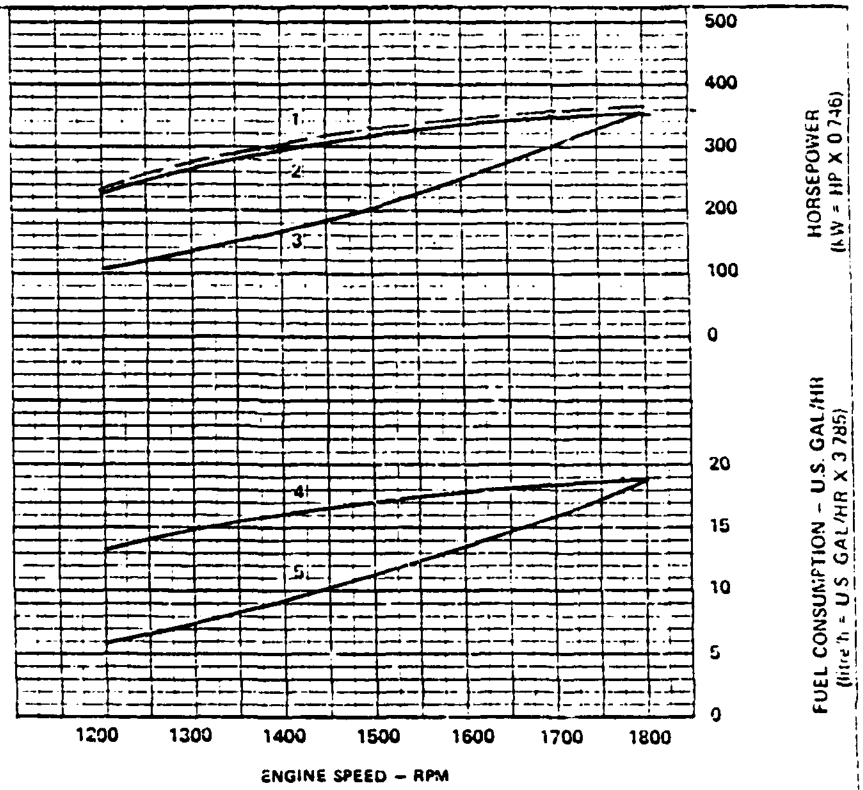
CUMMINS ENGINE COMPANY, INC.
Columbus, Indiana 47201
ENGINE PERFORMANCE CURVE

ENGINE MODEL:	CURVE NUMBER:	
KT–1150 M	C-3654-3	
ASPIRATION:	DATE	BY
Turbocharged	6/13/80	E.E.M.

DISPLACEMENT: 1150 in^3 (18.9 litre) **NO. OF CYLINDERS:** 6
BORE: 6.25 in (159 mm) **STROKE:** 6.25 in (159 mm)

RATING: HP (kW) @ RPM 365 (272) @ 1800

MAXIMUM CONTINUOUS DUTY RATING WITH TWIN DISC MG 514



Curves shown above represent engine performance capabilities at SAE standard J816b conditions of 500 ft (15C m) altitude (29.00" Hg (736mm Hg) dry barometer), 85°F (29°C) air intake temperature, and 0.38" Hg (9.5mm Hg) water vapor pressure with No. 2 diesel fuel.

The fuel consumption curves are based on a fuel weight of 7.0 lbs. (3.2 kg) per U.S. gallon.

1. Gross Brake Horsepower.
2. Net Horsepower with Reverse Reduction Gear, Alternator and Raw Water Pump.
3. Hypothetical Propeller Power Curve (3.0 exponent).
4. Fuel Consumption for Net Shaft Horsepower.
5. Fuel Consumption for Hypothetical Propeller.

Continuous Duty Rating – This is a 24-hour continuous rating and is intended for use in applications requiring uninterrupted service at full throttle operation.

Figure 2-1

Engine Performance Curves Chart

Most small marine diesel engines are not reversible, and therefore some adaptation must be made to them to allow the vessel to go astern. This is accomplished through the addition of a reversing gear system. Generally, the reversing gear system operates through the use of a clutch off the engine crankshaft which connects to two different sets of gears, one turning clockwise and the other counterclockwise. The activation of the clutch determines which direction the propeller shaft will rotate. Many of the gearing systems in operation today combine the functions of the reduction and reverse gears into one gearbox system.

The next segment of the vessel propulsion system to be examined is the shafting. The mission of propulsion shafting is to transfer the rotative power output generated by the main engine to the propeller. In doing this , the shafting also provides support for the propeller. Shafting located inside the fishing vessel is called line shafting , while the outside section to which the propeller is secured is referred to as the propeller or tail shaft. Bearings located along the length of the shafting provide two major services: they help keep the shafting in a straight line for its entire length, and they also assist in reducing the amounts of vibration which would be present during operation of the propulsion system. The shafting system plays an important part in this study as the majority of controllable pitch propeller systems in operation today transmit pitch changes through the center of the shaft. This means that the shafting system would have to be modified or replaced during the retrofitting operation to a controllable pitch system on the vessels now in the fishing fleet.

The marine propeller is the heart of the vessel propulsion system, and as such, demands detailed investigation. The propeller is essentially a screw which rotates in the water to produce motion. The blades of the propeller act as airfoils which develop thrust by accelerating the water into a slip stream. As with airfoils, propellers are subject to losses while working in their fluid element and have only limited ranges of efficiency. Certain propeller characteristics impact heavily on the relative efficiencies of the fixed pitch propellers, so this paper will examine these as they relate to the vessels of the Point Judith fleet.

Number of blades. Generally, fishing boats in the fifty to one hundred foot range have propellers with either four or five blades. The major factor in the determination of the number of blades is the presence of vibration and its ill effects. The vessels used in this study all possess four-bladed propellers.

Propeller hub. The dimensions of the propeller hub are based on the shaft thickness, propeller blade thickness at the blade-hub interface, and structural strength considerations. Although these requirements are somewhat standard for fixed pitch propellers, they have to be increased in the case of a controllable pitch system. This increase can result in an increase in weight and a decrease in the area available for thrust generation.

Propeller diameter. This is defined as the diameter of a circle described by the tip of the propeller blades. Generally, the larger the diameter the greater the propeller's efficiency. The maximum diameter of the propeller is limited by the hull structure of the fishing vessel. The diameter of the propellers in this study averaged about five feet.

Propeller pitch. The pitch of a propeller is defined as the distance the propeller would advance during one revolution if the water acted as a solid (this means that slippage of the propeller is not taken into account). The average pitch of the propellers being studied here is about four feet.

Propeller rpm. The propeller rpm is determined by the operating rpm of the engine and the reduction gear ratio, both of which have been previously discussed. It is important to realize that the propeller rpm is only one of the factors which bears heavily upon the propeller efficiency and while decreases in the rpm toward the optimum efficiency are desirable, other operating constraints must be taken into account.

Blade-area ratio. This is defined as the ratio of the expanded area of the back of the propeller blades to the area of the propeller disk. This ratio is important since the standard propeller efficiency curves are based on a set of given blade-area ratios.

In this next part of the propeller section, the propeller efficiency curves will be examined as they relate to this study. Propeller efficiency charts provide the marine engineer with valid information concerning the performance of various types of propellers based on open water testing of models in cavitation tunnels. A representative chart has been included as Figure 2-2 so that the methods of computing efficiencies can be demonstrated. The chart illustrated was derived from a series of tests conducted by the Netherlands Ship Model Basin at *Wageningen on the B-screw series.* (von Lammeren, 1969) This chart gives open water efficiencies based on the intersection of two propeller coefficients, Bp (Taylor coefficient) and the speed ratio. Before looking directly at these two coefficients, the nomenclature used with the chart must be explained. Each chart is based on three different parameters-- the type of screw, the number of blades, and the blade area ratio of the screw. Figure 2-2 is a type B-screw propeller with four blades and a blade area ratio of .55 . The ordinate extends from .5 to 1.4, and is based on the ratio of the pitch over the diameter. The abscissa extends from 1 to 200, and is the Bp, which is expressed in terms of the equation:

$$Bp = n(dhp)^{.5} / (Va)^{2.5}$$

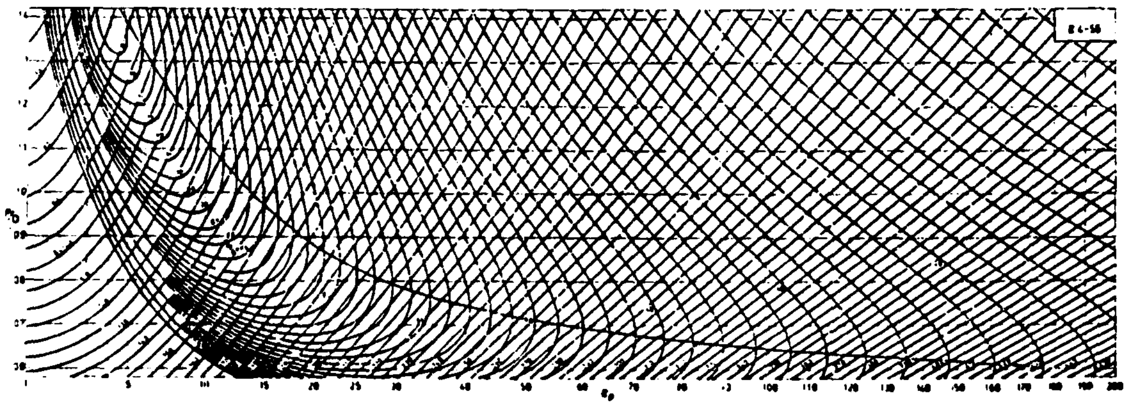


Figure 2-2

B 4-55 Screw Series Test Results

where : n=shaft rpm

dhp=delivered horsepower

Va=V(w) in knots

V=speed in knots

w=the wake fraction

The values for the wake fraction which were used in this study were .8 for a single propeller vessel and .88 for a twin propeller vessel. (Kress and Lorenz, 1970) The lines running diagonally from the lower left to the upper right represent the coefficient of the speed ratio, which is expressed by the equation:

$$\delta = n(D) / Va$$

where : n=shaft rpm

D=propeller diameter in feet

Va=V(w) in knots

The open water efficiency is plotted on the chart in a series of loops which start at the upper left corner of the chart and gradually extend to a series of lines running diagonally from the upper left to the lower right of the chart. The charts available will normally cover the free running efficiencies but must be extended to find the towing efficiencies since the loading coefficients are above 300. In this study the propeller manufacturers were contacted to determine which series of propeller efficiency charts to use. While the larger manufacturers had complete sets of charts on hand, the smaller companies seemed to rely more on their experience and less on charted data.

The last element of the propulsion system which will be discussed is the nozzle which was in use on one of the three sample vessels from the fishing fleet. The nozzle in use--a Kort accelerating nozzle (named after its German inventor) offers the operator a means of increasing the efficiency of heavily loaded propellers by producing a positive thrust. While the nozzle does not provide for any increased efficiency during free running (in fact, the added drag can reduce the efficiency), it does allow for an increase of thrust of up to 30 percent while trawling. If fuel efficiency is more important than thrust, the fuel usage can be dropped by approximately 10 percent with the presence of a nozzle if the thrust or speed is not increased. In order to achieve these savings, however; the vessel must have a type of propeller such as a Kaplan series which is specifically designed to operate inside a nozzle. One additional advantage of a nozzle system is that the propeller is offered increased protection from damage due to striking objects.

III

CONTROLLABLE PITCH PROPELLERS

Controllable Pitch Propellers (CPP) operating as an integral part of a vessel propulsion system have been in existence for over fifty years. CPP systems are now being employed on a worldwide basis, the Scandinavian countries having the best-known firms. Scandinavian fishermen have, over the years, shown an increasing acceptance of controllable pitch systems for their fishing craft. According to the Norwegian Institute of Fishery Technology Research, approximately ninety-five per cent of the Norwegian fishing fleet is equipped with some kind of CPP system. (Berg, 1981) Despite the innovative spirit of American technology , only a handful of American fishing vessels have made use of a controllable pitch propeller. This chapter will examine the following aspects of the CPP system: what it is and how it works, some examples of its use in the United States, and particulars concerning three current systems which could be used by the vessels of the Point Judith fishing fleet .

Controllable pitch propellers are so named because they have blades whose pitch can be changed while the vessel is in an operational mode. Since pitch has been defined as the distance the propeller would advance during one revolution (if the water acted as a solid) this means that a change in pitch directly impacts on the motion of the vessel through the water, all other factors remaining the same. In a small solid propeller, the blades and the hub are usually cast from the same piece , while the CPP has separate blades which are individually mounted on the hub. The pitch of the blades is changed through the use of a piston inside the shaft to the hub acting on crossheads. This piston can be activated by either hydraulic or mechanical means.

For certain types of vessels, the advantages of such a system over a solid propeller become readily apparent. Solid propellers are designed to meet the specifications of one operating condition, while CPP systems can change the propeller's pitch to adjust to a wide range of operating conditions. The fishing vessels of the Point Judith fishing fleet demonstrate such a range of operating conditions. They leave port lightly loaded , free run to the fishing sites at speeds around ten knots, trawl at speeds in the three knot range, and finally head back into port fully loaded at free running speeds.

Presently, none of the boats of the fishing fleet operating from Point Judith use the controllable pitch propeller system. There have, however; been boats from this area and from other sections of the country which have used such a system. The Narragansett was constructed by Blount Marine of Warren , Rhode Island in 1963. It was an eighty-three foot stern trawler which had a controllable pitch propeller which was designed by Luther Blount. The engine developed 380 horsepower and the propeller was sixty inches in diameter. Based on data from fifteen groundfish trips during 1964, the operating characteristics and costs of the Narragansett compared favorably with the side trawlers then in operation . (Blount, 1967) In the early 1960's, Blount Marine also converted the vessel Gosnold to a CPP system. It was also equipped with a sixty inch propeller and was used as a research vessel operating from Woods Hole. (Carlson, 1981) Although the operation of these vessels appeared to be highly successful, the local fishermen opted to stay with their fixed pitch systems and no further CPP'S were manufactured by Blount Marine. It is interesting to note that in the early 1960's, the thrust of designing a CPP system here in Rhode Island was to increase maneuverability and decrease engine operating strain.

For the following vessel, the reason for installing a CPP system is primarily for cost reduction based on fuel savings. The Golden Venture is a recently launched eighty-five foot combination trawler operating from Brookings, Oregon, which is equipped with a Newage CPP system. The vessel is driven by a 1,120 horsepower Detroit Diesel engine and the propeller has an eighty inch diameter. The Newage system (manufactured by Newage Marine Propulsion Ltd. of Shaw, England) uses a hydraulically controlled two-pitch setting which can be set for either free running or trawling. Newage claims that the vessel will have a fuel savings of at least twenty-five percent.

(Lesh, 1981) With the price of diesel fuel at about the $1.10 per gallon level currently , the need to reduce fuel usage can be easily understood.

For the purposes of this study, it was important to find several manufacturers of CPP systems whose propellers could be fitted to vessels of the Point Judith fleet in the 50 to 100 foot length range. There were several selection criteria which were used to identify prospective companies:

1. That the company was well-extablished in the CPP business.

2. That the company had business agents established in the local area so that person-to-person contacts could be utilized both for informational purposes concerning the systems and also that any equipment-related problems could be quickly identified, confronted and solved.

3. That the company had manufactured systems for fishing boats with the size range of those out of Point Judith and that it had a desire to enter the American market.

Based on a combination of these factors, three CPP manufacturing firms were selected:

1. J W Berg
   S-430 90 Ockero- Gothenburg, Sweden
   represented by: Berg Propulsion Systems, Inc.
   Essex, Connecticut

2. Karlstads Mekaniska Werkstad (KMW)

Gothenburg, Sweden

represented by: Bird- Johnson Company

Walpole, Massachusetts

3. Newage Marine Propulsion Limited

Shaw, England

represented by: M.P.E.C.O. Inc.

Harvey, Louisiana.

This study will examine how each system works and review their individual advantages and drawbacks. The information presented was gathered from interviews with company personnel and information booklets published by the subject organizations.

The J W Berg company was established in 1912 and delivered its first controllable pitch propeller in 1928. The Berg D/HM CPP system is designed to be installed in either new construction or retrofit for fishing and small commercial vessels having engine horsepower ratings up to 850 horsepower. A space of approximately 1.5 feet is needed between the marine gear output shaft and the inboard flange of the tail shaft for installation of the pitch control unit. The entire system consists of an inboard hydraulic pitch control unit that operates a pushrod within a bored tailshaft to send signals to a hub fitted with controllable pitch blades. The model D hub can be fitted with either three or four cast aluminum bronze blades. Diagrams of the pitch control unit and the propeller are included as Figures 3-1 and 3-2. The pitch control unit is an intermediate shaft which contains a pitch servo-motor in its aft end. This has a piston rod which is connected to the push-pull rod from the propeller. The forward end of the unit contains an emergency locking piston, which allows the pitch to be manually set in the ahead position in the event of an hydraulic breakdown. The propeller boss is split on the center line of the blade bearings, and is connected with six stainless steel set bolts. The crank pins (which do the actual turning of the blades) fit into rectangular trunion blocks which slide in the central cross-piece. This cross-piece is in turn attached to the end of the push-pull rod. The boss itself is filled with a water absorbant grease so that its mechanism will not be affected if sea water leaks in during its service life. To eliminate any pumping effect inside the boss during a pitch change, a plunger is attached to the aft end of the push-pull rod which is open to the sea water. There are some inherent advantages with the design of the Berg CPP system:

1. The design of the propeller hub, with the securing bolts entering the hub from the rear, allows large blade flange diameters. This gives the connection of the blades to the boss a superior strength.

2. Due to the location of the bolts, the propeller blades can be easily mounted or dismounted from inside a nozzle without having to remove the shaft or nozzle.

BERG PITCH CONTROL UNIT MODEL HM

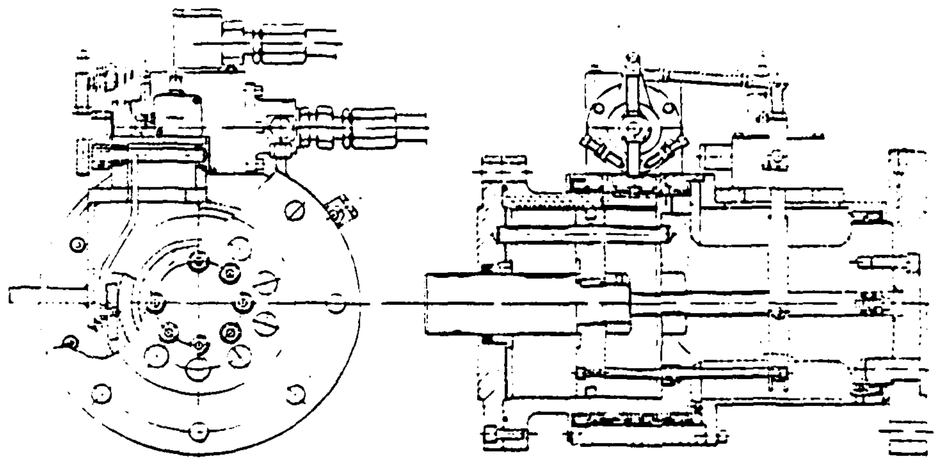


Figure 3-1

Berg Pitch Control Unit

BERG C. P. Propeller, Model D

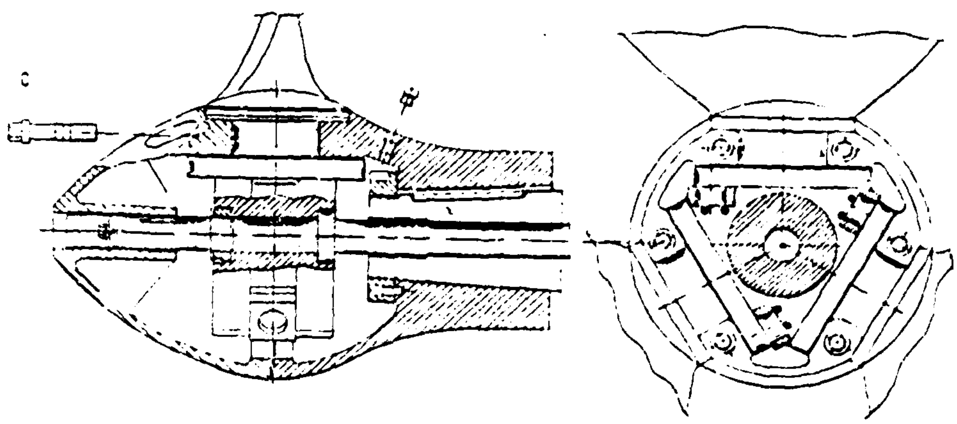


Figure 3-2

Berg Hub and Propeller

3. The boss mechanism is designed for easy mounting and dismounting and allows for replacing of moving elements without dismantling the entire boss.

4. The emergency blocking system allows operation in the ahead mode with full engine power.

The Berg system does possess some potential drawbacks which may discourage customers:

1. The fully CPP system has a very high initial cost associated with its installation.

2. In the event of a breakdown, the location of the main plant in Sweden means that there would be a longer down time associated with major parts replacement.

The Karlstads Mekaniska Werkstad in Sweden , which originally designed and manufactured water turbines, installed its first KaMeWa controllable pitch propeller in 1937 in a small coaster. The standard KaMeWa CPP system consists of the standard four-bladed propeller (with three or five blades optional), the valve rod, and a hydraulically activated oil distribution box. The hub design which would be used in the 50 to 100 foot fishing vessel range is the XF, which features screw mounting of the blades through the flange and a fail-safe mechanism which will set the blades in the ahead position in the event of an oil pressure failure. Diagrams of the hub and oil distribution box are included as Figures 3-3 and 3-4. The internal activation mechanism itself is very much like the Berg system. The oil distribution box which controls

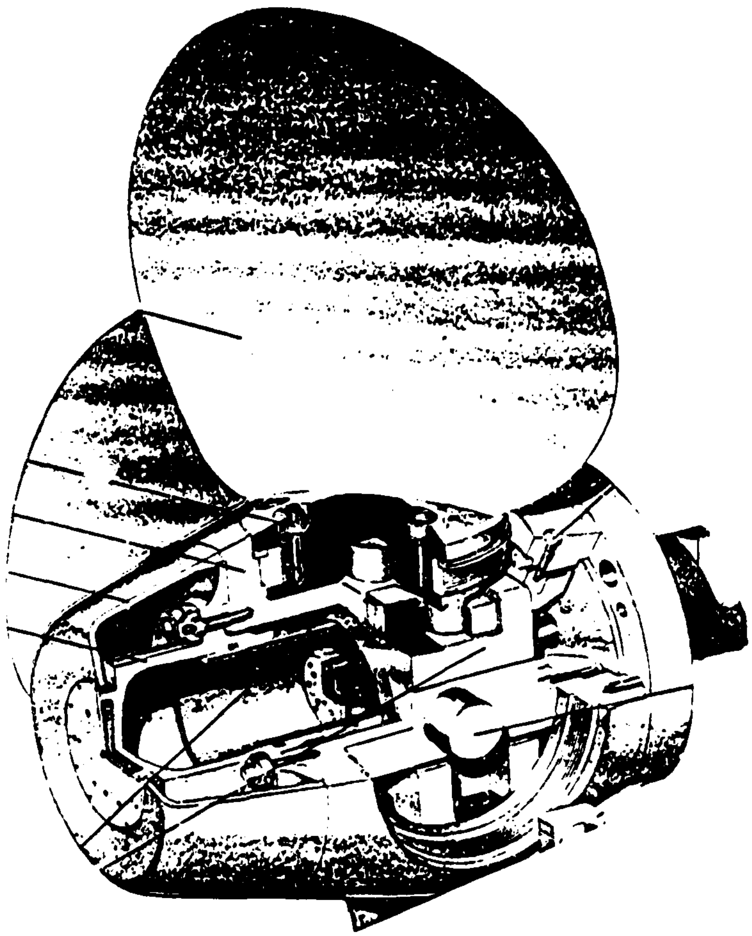


Figure 3-3

KaMeWa Hub and Propeller

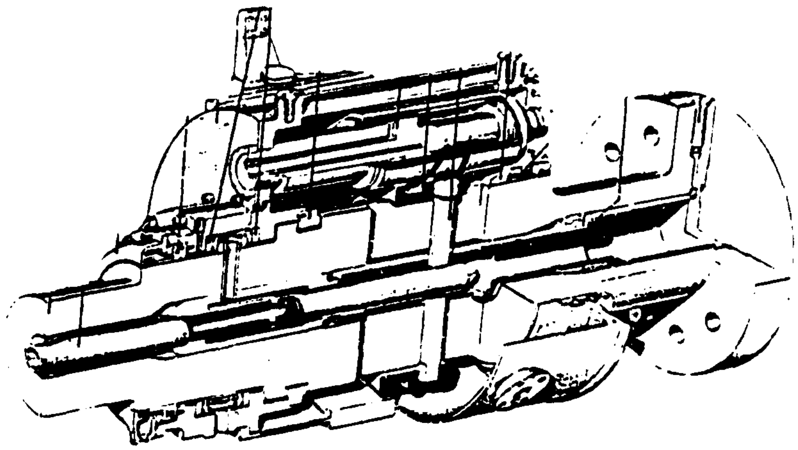


Figure 3-4

KaMeWa Pitch Control Unit

the valve rod can be placed on either the intermediate shaft or on the forward end of the gear.

The advantages of the KaMeWa system are:

1. The emergency blocking system which automatically sets the blades at the full ahead position.

2. The oil distribution box is fairly simple and can be easily located where the vessel owner feels he has greater access.

Disadvantages of the system are:

1. Being a full hydraulically-activated CPP system, its initial costs will be high.

2. The location of the main plant in Sweden means, once again, more down time in the event that major parts replacement is necessary.

The Newage Marine Propulsion company is a relative newcomer to the field of controllable pitch propulsion systems but has been included in this study based on the varied line of controllable pitch systems which it offers. It has an aggressive world-wide marketing program which has already resulted in one sale to an American fishing vessel. Like Berg and KaMeWa, Newage offers a hydraulically activated controllable pitch propeller system. Since two such systems have already been examined, it will be included in this study only for a cost comparison between the three similar systems. Newage, however; has two other controllable pitch systems which it can offer to the prospective vessel owner who does not desire, for whatever reason, to go with a full CPP system.

The most basic system which Newage has to offer is the inside mechanically adjustable propeller (IMA). The system is composed of a standard Newage adjustable pitch propeller, a hollow tailshaft through which a pitch adjustment rod passes, and a mechanical actuator. Diagrams of the hub and actuator are included as Figures 3-5 and 3-6. The actuator consists of an internal worm gear and wheel mechanism which is turned by a hand crank. In order to make a pitch adjustment, the tailshaft must be made stationary. Then, the crank handle is used to turn the adjustor (which is located on either the gearbox or intermediate shaft flange) to the desired pitch. An indicator located near the crank handle can be preset to show the most efficient pitch angles for the vessel in its various operating modes.

The advantages of this system are:

1. It is specifically designed for use on smaller vessels which have operations demanding changes in pitch for more efficiency.

2. Because of its simplicity, it costs much less than hydraulically activated systems.

The disadvantages of the IMA system are:

1. Because of the location of the crankshaft, it would be inconvenient for the vessel operator who could not control the system from the wheelhouse.

2. Since the pitch change can only be activated when

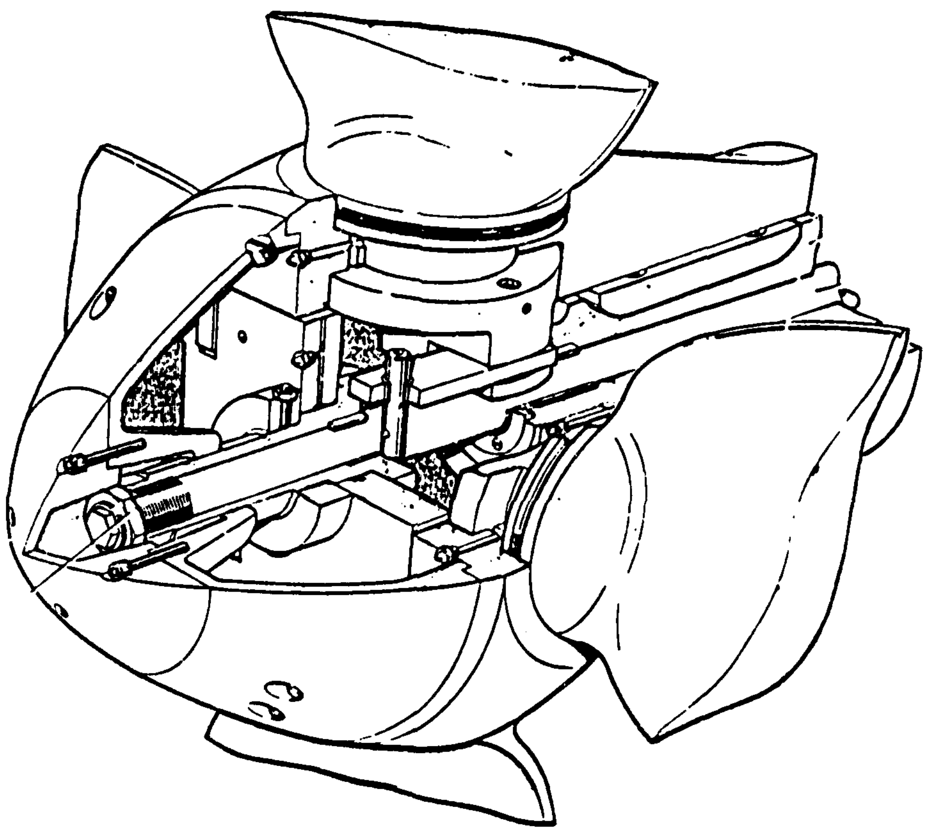
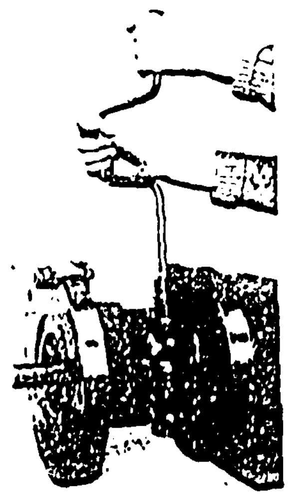
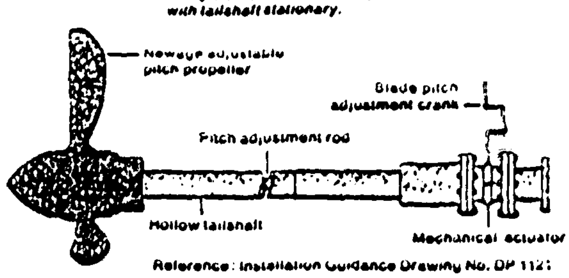


Figure 3-5
Newage Hub

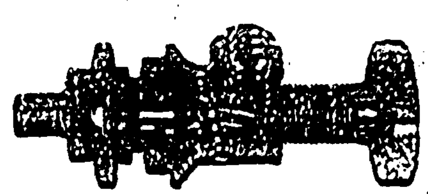


IMA propeller blade pitch is altered using a simple crank handle with tailshaft stationary.



Reference: Installation Guidance Drawing No. DP 112[illegible]

Indicator preset to show correct pitch angle.



Internal worm and wheel mechanism for the IMA actuator

Figure 3-6
Newage Mechanical Pitch Control Unit

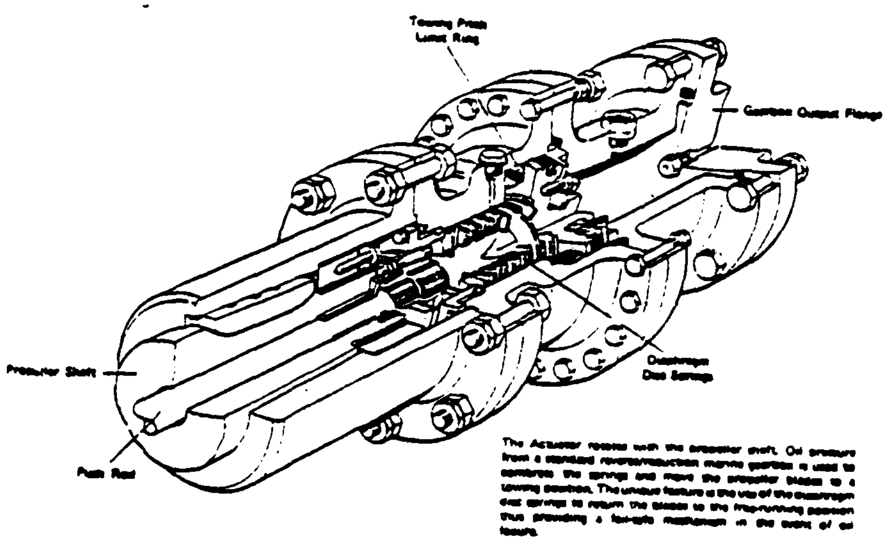
the tailshaft is stationary, the vessel must be stopped each time a pitch adjustment it to be made.

3. As the system has been designed for use on smaller vessels, it is recommended for installation on systems of 350 horsepower or less, and thus would only be available for use on vessels closer to the 50 foot range.

Newage offers another type of controllable pitch propeller system--the H2P, or hydraulically actuated 2-pitch system. The propeller hub is manufactured in standard three and four blade arrangements with the four blade hubs absorbing from 300 to 1500 brake horsepower. The hub is basically the same as the other systems, with two types of propeller blades available depending on whether the hub is to be mounted in the open or inside a nozzle. The aft end of the hub has a cap which, when removed, allows for fine tuning of the free running pitch at the time of installation at the boatyard. The hydraulic actuator is different from the others mentioned in that there are only two pitch positions allowed--one for free running and the other for trawling operations. A diagram of the actuator is included as Figure 3-7. In the event of hydraulic failure, the pitch actuator automatically returns to the full ahead position.

This system has certain distinct advantages over the other systems:

1. Because there are only two set pitches, the mechanism itself is much simpler.



NEWAGE HYDRAULIC ACTUATOR

Figure 3-7

Newage Pitch Control Unit

2. The push-button controls allow for operation in only one of two pitches, equating to the most economical operating pitch modes for the specific vessel. This precludes the operators of the vessel from making constant pitch changes which may, in reality, be detrimental to the overall system efficiency.

3. In the case of a retrofit, the inservice shaft can usually be bored to provide access for the control rod, a much less expensive proposition than having to replace the entire shaft.

The disadvantages of this system are:

1. The fact that there are only two ahead pitch settings means that, unlike the other CPP systems, this type needs to be operated in conjunction with a reverse reduction gear.

2. Since this system has only the two pitch settings, it neglects the fact that maximum fuel efficiency can be gained from altering the pitch for a variety of conditions, such as the difference between free running empty and free running fully loaded.

3. With both this and the IMA systems, major replacement would have to be sent from England in the event of equipment breakdown here in the United States.

IV

NUMERICAL COMPARISON

After having looked at the characteristics of the vessels of the Point Judith fishing fleet in general and having examined the individual CPP propulsion systems, it is now time to actually compare the fixed versus CPP systems. For the purposes of this study, three vessels of the fishing fleet were examined, each having a propeller which was manufactured by a different company.

Before any vessel owners were contacted, a questionnaire was designed which could either be sent in the mail or used during interviews. A copy of this questionnaire is included as Appendix A. Along with gathering basic vessel dimensions, it asked for information on the engine, reduction gear ratio and propeller data. It also requested information on the name and location of the builder, so that follow-up could be done on any technical data which the owner might not have known. Additionally, the questionnaire covered trawling and free running speeds, rpm, fuel consumption data and a ratio describing time spent trawling versus free running.

In order to speed up the process of finding vessel owners who would be willing to provide the necessary data, contact was made with Mr. Leonard Stasiukiewicz, one of the managers of the Point Judith Fisherman's CO-OP. Based on his information and several visits to the port at Galilee, specific data were gathered concerning three fishing vessels not more than five years old. Fairly new vessels were used as this insured that current data concerning the propellers and engines could be easily obtained. The three vessels which were used in the study were the:

1. Friesland

   owned by William and Thomas Dykstra

2. Suzanne Beth

   owned by Jack Wescott

3. Brian & Brent

   owned by Bruce Loftes

The information which was obtained from each vessel owner is listed in Appendix B.

Additional work was needed to insure that the information could be converted into a usable form. First, the engine manufacturers were contacted to get copies of the engine performance curves. Both the Cummins and Detroit Diesel Allison companies sent ratings curves, the former covering the continuous duty rating and the latter listing the entire spectrum of performance. Next, the propeller manufacturers were contacted to verify the information obtained concerning the pitch and diameter of the propellers and to obtain data on the propeller efficiency. Of the three propeller manufacturers contacted, only Columbian was able to provide information concerning the efficiency of the propellers in question. This was in the form of a propeller efficiency chart which took into account the effect of the Kaplan-style blades operating inside a Type 19A nozzle.

Based on the information which had been obtained from both the vessel owners and the manufacturers, the relative propeller efficiencies could now be obtained from the efficiency charts. Since two of the manufacturers did not provide charts, the Wageningen B-screw series was used for the propellers of the Friesland and the Brian & Brent. The Taylor coefficient and speed ratio for each vessel in the free running condition were then calculated and plotted on the efficiency charts. As a check, their intersection will correspond with the P/D ratio of the propeller. From that intersection, the efficiency of the propeller can then be obtained from the same chart. The efficiency charts used only covered a range of Bp's from 1 to 200, while the Bp range for the vessels while trawling was 300 and greater. As a result, the curves were expanded using the coefficients Kt (thrust) and Kq (torque) as calculated through the polynomials given by van Lammeren et al, (1969) for B-series propellers. The polynomials for Kt and Kq are expressed in terms of the disk-area ratio, the pitch-to-diameter ratio, and the advance coefficient, J, which is the inverse of the earlier-defined speed ratio:

$$Kt = C_{x,y,z} \; (Ae / Ao)^{x} \quad (P / D)^{y} \quad (J)^{z}$$

$$Kq = D_{x,y,z} \; (Ae / Ao)^{x} \quad (P / D)^{y} \quad (J)^{z}$$

The coeffieients Cx,y,z and Dx,y,z depend on the number of propeller blades and are given in the reference. Using the previously defined coefficients, the open-water efficiency, η_o, can be expressed in terms of the propeller parameters:

$$\eta_o = 101.27 * J / 2 * 3.1416 * Kt / Kq$$

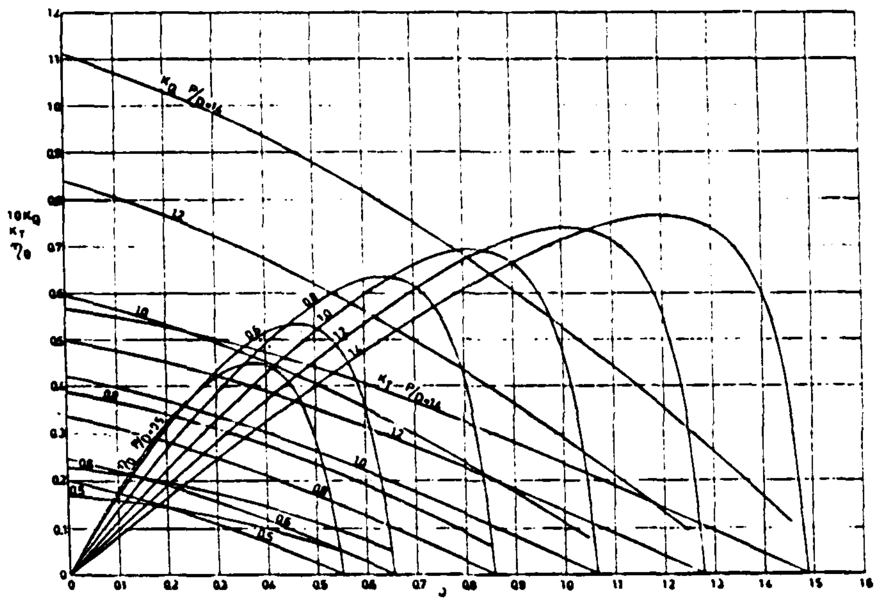
In addition to their Taylor coefficient and speed ratio charts for the B-screw series,the open-water test results were also published in the form of charts which related the advance coefficient,propeller efficiency,and the torque and thrust coefficients. A sample showing this presentation of test results is included as Figure 4-1. Using the given information, the efficiencies for the three vessels for both free running and trawling are as follows:

Propeller Efficiencies

Vessel	Free Running	Trawling
Suzanne Beth	52.5	34
Friesland	51.5	24.5
Brian & Brent	50-51	28.3

Of the three vessels, the Friesland's pitch/diameter ratio most closely corresponded with the ratio given by the propeller manufacturer. In order to bring the data for the Suzanne Beth in line with the given pitch/diameter ratio, the vessel speed was reduced by 1.5 knots. Even with a similar reduction of 1.0 knot for the data of the Brian & Brent, the indicated pitch/diameter was still too high. As a result, the free running efficiency for this vessel could only be approximated from the chart.

With these efficiencies determined, the next step was to examine possible changes which could be made if the



(van Lammeren, 1969)

Figure 4-1

B 4-55 Screw Series Test Results

vessel were fitted with some type of CPP system. With each of the three vessels, the original engine characteristics, reduction gear ratio, and propeller diameter were maintained. These possible changes depended on the type of system which would replace the fixed pitch system. For replacement with a Newage system, reductions in fuel consumption based on a maintenance of previous thrust levels were examined, while for replacement with a fully CPP system, increases in free running speeds and trawling thrust levels were explored. This was accomplished by first determining the current operating values of both thrust and torque for the fixed pitch systems. Then, the rpm and P/D parameters were changed so that for the 2-pitch system the rpm were minimized and for the fully CPP system the thrust was maximized. The maximum torque which can be generated is based on the equation:

$$Qmax = 33{,}000 * dhp / 2 * 3.1416 * N$$

Care was taken during the changing process to insure that the maximum torque limitation was not violated.

Under current operating conditions, the <u>Friesland's</u> propeller generates approximately 8,500 pounds of thrust while free running and 10,600 pounds of thrust while trawling. The maximum allowable torque which can be generated is approximately 6,800 foot-pounds. In the case of replacement with a Newage system, a reduction of 300 rpm to a free running rpm of 1600 with a corresponding change of the pitch over diameter ratio to .95 produces the same thrust within acceptable torque limits for a decrease in fuel consumption from 28 to 18 gallons per hour, or a 36 per per cent drop. For trawling, a decrease of 50 rpm to a rate of 1600 rpm at a pitch over diameter ratio of .83 will generate the same amount of thrust with a reduction in fuel usage from 20 to 18 gallons per hour, or a 10 per cent drop. These savings in fuel can be related to reductions in operating costs per hour of $2.21 for trawling and $11.05 for free running, with the cost of diesel fuel at $1.105 per gallon. Since the time spent in free running and trawling for the Friesland is approximately 1:2.5, the overall drop in fuel consumption is 17.4 per cent resulting in a hourly savings of $4.73 as averaged over the entire trip. When replacement of the current fixed pitch system with a fully CPP system is accomplished, the emphasis can change to proposed increases in vessel speed and thrust. For free running at 1800 rpm (the engine manufacturer's recommended maximum for continuous working conditions) with a P/D ratio of .88, the thrust will increase by approximately 950 pounds for an increase in speed through the water of a little more than one knot for a slight decrease in fuel consumption. While trawling, an increase in thrust of about 1,100 pounds can be achieved at a P/D ratio of .73. However, to achieve this increase the rpm needs to be raised to 1800, increasing the fuel consumption by 30 per cent, from 20 to 26 gallons per hour at a cost of $6.63 per hour. In both the trawling and free running modes, the maximum allowable rpm is listed as 1800, while 1900 rpm is given as the current operating condition. The rpm has been held at 1800 for the controllable pitch systems as this is the manufacturer's recommended maximum for continuous operating conditions for the KT 1150 engine in use. A chart presenting some of these results is included in Appendix C.

With its fixed pitch system, the Brian & Brent generates approximately 6,770 pounds of thrust while free running and 7,450 pounds of thrust while trawling. If this were replaced with a 2-pitch system and the maximum torque constraints were not violated, a reduction of 300 rpm to a free running rpm of 1500 with a corresponding change of the pitch over diameter ratio to 1.1 produces the same thrust for a decrease in fuel consumption of approximately 39 per cent. In the trawling mode a decrease of 50 rpm with a new pitch over diameter ratio of .85 will generate the same thrust with a 9 per cent drop in fuel consumption. These fuel savings can be related to reductions in operating costs per hour of $1.21 for trawling and $8.06 for free running. Based on a ratio of free running to trawling of 1:2, the overall drop in fuel consumption is 19 per cent resulting in an hourly savings of approximately $5.77 when averaged over an entire trip. In the case of replacement of the current system with a fully CPP system, significant gains in thrust can be accomplished. For a free running rpm of 1800 with a pitch over diameter ratio of .93, the thrust will increase by over one thousand pounds resulting in an increase in vessel speed of approximately 18 per cent with no increase in fuel consumption. In the trawling mode, an increase in the rpm to 1800 coupled with a change in the pitch over diameter ratio to .78 will increase the available thrust about 29 per cent. In order to do this, however, the fuel consumption would have to be increased by approximately 52 per cent. A chart with the results of these calculations is provided in Appendix C.

The calculations for the Suzanne Beth were slightly different based on the fact that there were two complete propulsion systems in this fishing vessel and the systems were also equipped with nozzles. Results of testing with the Kaplan style 4-55 screw series in nozzle type 19A have been published in the same style format as for the Wageningen series (van Manen, 1963). Unfortunately, the scales used for the thrust and torque coefficients are smaller than those used for the B-series tests and it is much more difficult to precisely pinpoint accurate values for the coefficients. The results both in this section and in Appendix C for this vessel will be for each individual propeller. With its current system, the Suzanne Beth's individual propellers generate approximately 7,790 pounds of thrust while free running and 9,630 pounds of thrust while trawling. If the present type nozzles and propellers were retained and a two pitch system were installed so the maximum torque constraints were not violated, the free running rpm could be reduced by 200 rpm and the trawling rpm could be reduced by 100 rpm. Based on pitch over diameter ratio changes for free running to 1.03 and trawling to .94, fuel savings of 28 per cent and 15 per cent, respectively, could be achieved. These savings would equate to a cost savings of approximately $7.29 when averaged over the entire trip. In the case of replacement of the current system with a fully CPP system, the trawling pitch over diameter ratio would remain at about .90 and the free running ratio would be approximately .96. For these changes, coupled with maximum rpm at both modes, the vessel speed could be increased by approximately 9 per cent in the free running mode and the vessel could gain approximately 20 per cent more thrust for trawling operations. This could be accomplished with no increase in fuel use for free running, and with an increase in fuel use of about 17.5 per cent in the trawling mode.

Overall, the calculations indicate that there are substantial benefits to be derived from the installation of some type of controllable pitch system. In the case of replacement with a 2-pitch system, the average fuel savings per trip is approximately 19 per cent for each of the three vessels. (See Figure 4-2) Switching to a fully CPP system would give each of the three vessels substantial increases in thrust which can be translated to increased free running speed and greater net pulling ability, but these come with some increases in fuel consumption. It is important to

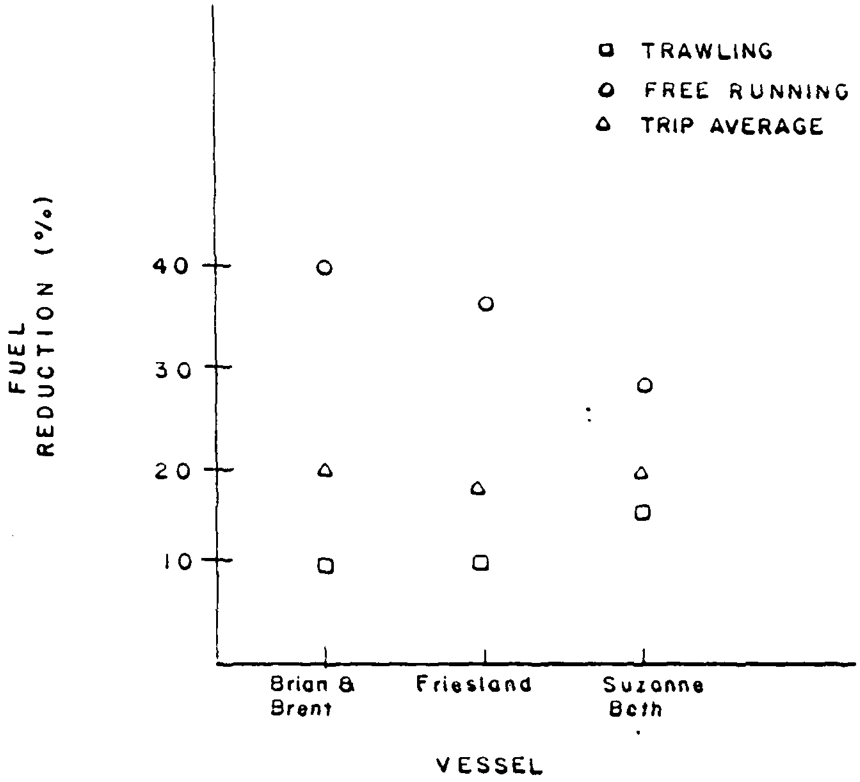


Figure 4-2
Fuel Usage Reduction Chart

remember that the fully CPP systems have the capacity to operate at the most fuel-efficient settings as well as those which would generate the greatest thrust. Whether these increases for the 2-pitch and fully CPP systems will offset their higher purchase prices will be examined in the next section of this study.

V

ECONOMIC ANALYSIS

After having accomplished a numerical comparison of the different types of propeller systems currently available in the previous section, it is now important to procede with an economic analysis of the same systems. Operating within the current economic conditions, it would be impossible to recommend a change to some type of controllable pitch system if such a change were not cost effective. Important questions which must be answered deal with the pay-back period of the initial investment for a retrofit system and the expected savings over the life of the vessel. Although the vessel's fuel consumption is the most important cost factor, other variables, such as down time, operating expenses, and equipment reliability will also be examined.

The initial part of the economic analysis was accomplished in the previous section, as a figure representing the cost savings per hour for each fishing trip was arrived at based on the amount of fuel saved during the two different modes of fishing operation. Input from the surveys concerning the ratio of free running time to trawling time was also used in the computation of the hourly cost savings figure. A listing of these per hour savings follows:

Suzanne Beth $7.29

Brian & Brent	$5.77
Friesland	$4.73

Note that these figures were arrived at through use of the fuel consumption curves for the typical propeller on the engine manufacturer's ratings and were not the ones obtained from the survey of the vessel owners. The Suzanne Beth's savings are the highest based on the vessel's two engines, while the savings for the Brian & Brent are proportionally greater than for the first vessel based on its higher ratio of free running to trawling time. It is interesting to note that all three vessels, independent of the type or number of engines, had about the same percentage of fuel savings--from 17.4 to 19 per cent.

The next step in this study is to take the average hourly cost savings and to relate them to the average savings per year for the subject fishing vessels. Based on a survey done by the Woods Hole Oceanographic Institution, the average number of days fished per year for a fishing vessel from the New England fleets is 181 days, with the larger vessels spending more time at sea (Peterson and Smith, 1979). Since the sample population was 43, with 4 vessels from Point Judith answering this particular question, the overall fleet average (181 days) compares favorably with the Point Judith average (177 days). The owners of the three sample fishing vessels were then asked for an average number of hours in each fishing day which were spent in either of the two operational modes. The responses from the three owners are listed below:

Suzanne Beth	18 hours per day
Brian & Brent	15 hours per day
Friesland	16 hours per day

Using the combined inputs of the hourly savings, average number of fishing days per year and the average hours per day spent in an operational mode, the yearly savings for each vessel can be approximated by:

(hourly savings) * (operational hours per day) * (181)

These calculations yield:

	Average Yearly Savings
Suzanne Beth	$23,750
Brian & Brent	$15,665
Friesland	$13,698

These projected savings will now be compared with the cost of a retrofitting operation which would entail replacing the current fixed pitch system of the vessels with a CPP system. This entailed getting some cost estimates from the controllable pitch propeller companies for their systems. Additionally, cost estimates were requested from the manufacturers for the fixed pitch propellers which are now in use on the vessels. Instead of getting three separate cost quotations for each of the three fishing vessels, a hypothetical vessel was given to each of the three manufacturers as a candidate for a retrofit operation. This fishing vessel was named Miss Lee (after the author's daughter) and had the following general characteristics:

Miss Lee

Southern built, Southern rig, Single chine, Flat stern

Length 85 feet

Beam 23 feet

Draft 10 feet

Engine: Detroit Diesel 16V-71 700 HP

with the engine producing 455 continuous SHP at 1800 RPM

Reduction gear ratio 5:1

4-bladed propeller with a diameter of approximately 60 inches

Desired speeds: Free Running: 9.5 knots

Trawling: 3.5 knots

Shaft length of about 25 feet with an original diameter of 4.5 inches.

The cost estimates, which do not include figures for installation, are listed in Appendix D.

Based on these estimates, pay-back periods can now be calculated for the three fishing vessels. These calculations will be based on comparisons between the Newage 2-pitch system and the fully CPP system of J W Berg. The retrofit estimates do not contain any increased costs based on lost fishing time or getting the vessel pulled out of the water, as it is assumed that this job could be accomplished during a scheduled maintenance period. For this reason, the retrofit costs for the Newage system will be based on the acquisition of a new shaft, as the boring process for the present shaft could impose a costly delay which would extend the vessel down time beyond that normally scheduled. The KaMeWa system was dropped from the economic analysis at this point based on the following factors:

1. Taking into account the different wheel sizes in the estimations, the Berg system is several times less expensive than the KaMeWa system.

2. The delivery time for the Berg system is approximately four months less than that for the KaMeWa. Additionally, it should be noted at this time that the cost savings analysis will be done based on a similar usage of the 2-pitch and fully CPP systems. In reality, the cost savings for the 2-pitch system would be greater than those of the fully CPP based on the former's enforced fuel saving characteristics.

The economic comparisons will be done for each vessel based on two different conditions:

1. That a retrofit job has been accomplished and the entire cost of the new system must be regained before the change begins to pay for itself.

2. That the system has been installed on a new vessel. This means that the acquisition cost can be based on the difference between the fixed pitch cost and the controllable pitch cost and the pay-back time will be

shortened.

This economic analysis does not take into account the costs of borrowing funds to finance the conversion process or any increases or drops in the price of fuel oil. Over the long run, these two factors, whose exact trends would be highly speculative at best, could be expected to act to cancel themselves out.

Based on its lower ratio of free running time to trawling time, the Brian & Brent has the smallest pay-back periods. If a new system were retrofitted on the vessel, the 2-pitch type would pay for itself in 2.25 years, while the more expensive fully CPP system would be paid for in 3.2 years. If a controllable pitch system were installed on a new vessel, the pay-back period for the added cost of the system itself would be less if the cost of the fixed pitch system were subtracted from the cost of the new system. In the case of the Brian & Brent, the period for a 2-pitch system goes to 1.45 years and for a fully CPP the time goes to 2.32 years.

Even though the hourly savings for the Suzanne Beth are the highest of the three vessels, the pay-back periods will be greater because of its twin-engine installation. In the case of a retrofit, the 2-pitch type would pay for itself in 3 years, while the fully CPP would take 4.2 years before it was paid for. If installation of the systems in a similar-type new vessel is considered, the 2-pitch and fully CPP systems would pay for themselves in 1.9 and 3.65

years, respectively.

The Friesland has pay-back periods which are fairly consistent with the previously mentioned vessels. Based on a retrofit, the Newage system would be paid for in 2.6 years, while the fully CPP installation would take 3.65 years to pay off. If the pay-back costs are figured for an installation in a newly constructed vessel, the time for the 2-pitch and fully CPP systems would drop to 1.65 and 2.7 years.

For all three fishing vessels, therefore, the costs of the conversion to or newly installing one of the two types of controllable pitch systems could be paid for in less than five years. Since the typical fishing vessel (barring an accident) can productively operate for periods of up to twenty years, it is evident that the installation of a system which would save up to 19 per cent of the fuel costs would have a drastic impact upon the profit margin of the vessel over its fishing lifetime.

Although the fuel consumption factor is definately the key cost factor, there are other factors which will have an impact on the long-range cost of the system. Day-to-day operating expenses for the controllable pitch systems as compared to the fixed pitch systems should be fairly comparable. In actuality, the propulsion system will probably fare better with a controllable pitch system as the operator will not be able to place undue strains upon the engine. In the case of the Newage system, the selector buttons do not allow for any high-speed operation, while the fully CPP systems allow the operator to change the pitch so that the engine will not become overloaded.

Equipment reliability is a primary concern for the fisherman, since he needs to keep his vessel in the water in order to make a living. Basically, it is safe to say that the more complicated system will be less mechanically reliable than the current fixed pitch propeller system. However, the large proportion of Scandinavian fishermen who have used and continue to use the controllable pitch systems demonstrate the fact that the system is indeed workable. Additionally, the controllable pitch system manufacturers have done their best to insure that if the most vulnerable part of the system, the hydraulics, does break down, then the system will continue to be usable but only in the free running propeller setting.

In the event that part of the controllable pitch system suffers a breakdown, the cost factors dealing with parts replacement must be looked at. First, the parts of the controllable pitch systems are more expensive than those of the conventional fixed pitch system. The replacement cost of two damaged controllable pitch blades equals the cost of a new fixed pitch wheel. With the controllable pitch system, the vessel owner is forced to deal with one firm, and therefore cannot shop around for replacement parts as he could with the present system. This allows the controllable pitch companies to charge what the market will bear once their systems have been installed in a vessel. The second factor concerning replacement parts is the delivery time for these parts. Although the controllable pitch companies make it abundantly clear in their sales and information booklets that the replacement time for parts is competative with the present replacement time, the overseas link is definitely further and seems more susceptible to holdups than the present system. Additionally, under the present system, if one manufacturer tells a vessel owner that he will have to wait too long for a given replacement part, the owner can go to another manufacturer. With a controllable pitch system, the vessel owner will have to live with the company's dictated replacement period and the costly down time that could be associated with it.

All of these cost factors are secondary to the savings which would be generated through use of the controllable pitch system and should be viewed in such a light. While they are important to consider before making a final decision, they do not, in themselves, present sufficient cause not to make the change.

VI

MANUFACTURER'S DESIGN AND SALES PHILOSOPHY

After having obtained the numerical results of the consequences of either staying with a fixed pitch system or converting to one of the CPP systems, it is now important to examine more closely the intentions of the propeller manufacturers. During the course of this study, contacts were made with the representatives of the manufacturers through correspondence, telephone conversations and interviews. While the emphasis during these conversations was on the methodology of propeller manufacturing, the philosophical approach of the company concerning propeller design and sales has an equally important impact on the consumer. (A complete list of all company personnel contacted during the surveys is included as Appendix E)

With a fixed pitch propeller system, the manufacturers must make the most of their key selling points :

1. Cost- Without exception, the economics for initial investment favor a low-cost system.

2. Simplicity- The fixed pitch system does not rely on hydraulics or necessitate changing modes while in operation.

3. Availability of replacement parts- When a fixed pitch system is damaged, there are companies located throughout the United States which can be relied upon to

furnish replacement equipment upon request.

4. Tradition- American fishing fleets have, through the years, relied upon and been faithfully served by the manufacturers of fixed pitch systems.

Even with these advantages, the three fixed pitch companies contacted in this survey worked to insure that the propeller they furnished for each vessel was chosen to best comply with the given operating conditions. In the case of fixed pitch propellers for fishing vessels, the propeller uniformly recommended was a compromise-- one which did not allow for the most efficient or maximum free running conditions, but one which would generate sufficient thrust in the trawling mode to be considered effective. For a fixed pitch system, this is the most effective design which can be used by a fishing vessel which has a fairly low time ratio (1 to 2.5) for operating in the free running and trawling modes. The only time that such a compromise propeller would not be the most effective would be cases of either very high or very low time ratios--in which case a design closer to pure free running or trawling would probably be called for.

While the manufacturers of the CPP systems both stress that their systems offer distinct advantages over the fixed pitch propellers, they vary their sales emphasis based on the type of propeller they build. The manufacturers of the Newage two-pitch system base their sales approach on the cost effectiveness of their propellers because of the reduced fuel consumption rates. Newage sales representatives cite observations of the manner in which Scandinavian vessel operators actually used their fully controllable pitch systems. Rather than using the system over the entire range of pitches during a trip, they referred to two pitch settings they had marked as a result of years of operational experience. These settings closely resembled the settings arrived at by the Newage experts--those which gave maximum fuel efficiency at free running and trawling speeds. Situations which , at first glance , may require two different pitch settings might be just as well served by a single setting. Free running empty to the fishing grounds and free running back in with a catch, for example, may be very similar loading conditions for the fishing vessel. The weight of the catch would, in reality, be taking the place of the fuel and fresh water which has been consumed and the ice which has melted during the trip. Why then, the representatives considered, pay more for a fully controllable pitch system when all that was really needed was a cheaper and more simple two-pitch system? The Newage engineers found that they could get a reduction of 25 per cent in fuel usage as a direct result of converting from a fixed pitch system to their own. Based on this projection, they can offer their customers an estimated pay-back period after which the vessel owners will save money as a result of switching to the Newage system. In the case of the installation of a

Newage system on a newly built vessel, the savings can be even greater as no funds have to be spent on the initial fixed pitch system and the operating span of the vessel will be longer than on a conversion.

On the other hand, the fully controllable pitch propeller companies gear their sales efforts towards a totally different emphasis. They speak of the greater flexibility the vessel operators have with a fully CPP system in that they can choose their own operational mode. A decrease of fuel consumption does not really enter into the picture, as they claim that fuel savings will probably not exceed the 5 per cent level. However, they stress that their systems allow the vessels to free run out to the fishing grounds and return faster than with a conventionaal system and that this means there will be more time available for trawling. They also cite the fact that in the trawling mode, their systems will deliver more thrust so that the vessels can handle greater catches. The maneuverability of the fully CPP system is also a fine selling point since this is the only system which can reverse the ship's direction without engaging the gearing system. Additionally, the vessel's stopping ability is greatly enhanced through use of a fully CPP system.

All of the CPP companies realize that getting firmly seated in the American market will take a great deal of time and energy. They know that American owners and operators will want to see their systems in actual operation here so that they will be able to judge for themselves the worthiness of their systems. The manufacturers also realize that the present business and economic climate effectively deters many fishing vessel owners from investing in CPP systems at this time. In the mean time, they continue to take advantage of other openings in the fishing vessel market, especially in the developing fleets of African and South American countries. With the new vessels being built in this region, there is no tradition to hold the local fishing populace to the fixed pitch system and the cost increase of a CPP versus fixed pitch systems is relatively small when compared to the initial investment for a fully equipped vessel. So, while making sales in other markets, the CPP companies will bide their time here in the United States and wait for the American fishing industry to catch up to the world.

VII

ATTITUDES OF VESSEL OWNERS

Obtaining numerical results was one aspect of this study--just as it was important to look at the intentions of the manufacturers, it is also important to examine the impact of the study, if any, upon the owners of the sample fishing vessels. Exit interviews with these owners were crucial to determine the acceptability of the systems which were compared during the study.

The owner (Loftes, 1982) of the Brian & Brent realizes that the controllable pitch systems are the systems of the future for fishing vessels. He would like to see a test of either system done on a fishing vessel in this area, but would rather such a test was done on one of the working vessels of the fleet, rather than on a research type vessel. Given the choice, he would prefer a 2-pitch system over a fully controllable pitch system based on its assured fuel-saving ability and on the lower acquisition costs. Because his vessel is smaller than the others surveyed, his fishing opportunities are more limited than the larger vessels. This leads to his primary reservation concerning the controllable pitch systems, the high cost of the initial investment. The present economic outlook severly impacts upon his ability to invest in such a system at this time. Other fears he has of such a system concern the parts availability and increased shipping time based on the foreign manufacture of the systems, and increased maintenance costs. Because virtually all parts of the system are more expensive, repairs on any particular failed item would be higher than for a similar item of a fixed pitch system. Overall, he would like to see such a system in operation and would like to have such a system on his own vessel.

The owner (Wescott, 1982) of the Suzanne Beth is satisfied with his present set-up of twin propellers in nozzles and is not currently interested in the controllable pitch systems. He would, however, like to see such a system tried out in this local area so that real world results could be obtained based on an actual conversion. The tests would mean more to him if they were accomplished on a vessel of the Point Judith fleet rather than on a research vessel. Major draw-backs he sees with the new systems are the potential for extended lay-up time during installation and the higher costs associated with major parts replacement. Given the choice between a 2-pitch system and a fully CPP system, he would go with the fully CPP system based on the fact that he would have more flexibility with the fully CPP. His fishing philosophy is that he goes for the fish that are bringing the best prices at the CO-OP. With the first come, first unload system that the CO-OP has, a thirty minute difference on entering the port may mean the difference of being the tenth or twentieth vessel in line. Since position in line determines if your vessel is unloaded that day, coming in faster can bring greater profits for the crew because of the day's high prices. The fully CPP system allows the vessel operator to make the decision to increase free running speed, while the operator of a vessel equipped with a 2-pitch system does not have that flexibility. He realizes that the price of fuel is the overriding control factor for the entire situation and that he would have to sacrifice his flexibility in order to achieve savings if the price of fuel drastically increased. For this reason, he would like to see a controllable pitch system tested at this time.

A co-owner (Dykstra, 1982) of the Friesland likes the basic idea as it relates to fuel savings and had discussed installation of a Newage system while his present vessel was under construction. He would like to see a retrofit operation tested but would rather the operation were carried out on one of the fleet boats than on an URI-associated research vessel. The current price of fuel does not impact on him that much as the cost of the fuel is paid by crew share at the end of each trip. This way, each of the crew is involved in paying for the fuel used. If he invested in a CPP system, then he as vessel owner would be bearing the costs and would only see a small proportion of the return. If the price of fuel goes too high and other vessels in the fleet start using these systems, he realizes that he would have to convert in order to be able to attract a good crew to his vessel, as crew members on a CPP equipped fishing vessel would have smaller shares taken out of their pay for fuel costs. Given a choice between a 2-pitch and fully CPP system, he would go with the Newage system. Instead of using the maximum fuel saving settings, however, he would sacrifice the trawling savings of approximately 10 per cent for an increase in thrust at the current fuel consumption rates. By doing this he feels that he would be able to catch more fish and increase his economic gains in that manner. As for the other factors which would influence his decision, he likes to rely on the simplicity of the current fixed pitch system. Equipment down time is lost money to him and so the prospect of having to wait for overseas parts replacement does not sit with him well at all. Currently, he is able to switch companies if one cannot get him a part fast enough. With a controllable pitch system, he would be dependent upon that single company for the replacement parts he needed. He would like to see such a system in operation and feels that this would have a great impact on whether he would install such a system on the Friesland.

Even though each of the interviewed fishermen had some reservations concerning the use of controllable pitch systems, they seriously discussed it and considered it a viable option. They realize that fuel prices are probably going up in the future, and that conversion to this type of system can reduce fuel consumption by a sizeable amount.

All of the owners felt that having a chance to view the system in operation and getting feedback from the vessel owner who had used it would be a key to their acceptance of such a system. They see the time for testing the system is now, before they are forced into making a decision based just on the manufacturer's claims.

VIII

DISCUSSION

In reviewing this study, it is important to remember that the figures used have been extracted from several different sources, including commercial ones. The ability to convert these results to those which are applicable to the real world can be just as important. All three fishing vessel owners said that their actual fuel consumption figures were less than those identified on the manufacturer's curves. As a result, the pay-back periods are, in reality, extended beyond those which have been cited. Even use of the consumption figures supplied by the owners themselves still results in pay-back periods of less than five years for all of the vessels.

As previously noted in the numerical comparison section between the fixed pitch and controllable pitch systems, the information supplied by the vessel owners did not exactly fit the propeller efficiency charts and, in one case, the operating RPM given for the vessel exceeded the recommended RPM for continuous operating conditions. Additionally, it is important to realize that the information supplied by the engine manufacturers for their engines was certified to be correct within a margin of error (generally 5 per cent). With an engine that is rated at 355 shp at 1800 RPM, this can mean an allowable error of as much as 17 shp. In all cases, the values given by the engine manufacturers and the pitch over diameter ratios supplied by the propeller companies were used for both the numerical and cost analysis.

As in any other independent occupation, the fishing vessel owners interviewed in this study had their own ideas concerning the acceptability of the controllable pitch systems and even differed on the choice of controllable pitch system they would probably employ. Had the survey of owners been expanded to include ten vessels, their differences would still have been much more apparent than any similarities. This should not cloud the fact that they were all interested in the systems and expressed a desire to see such a system tested and results of a retrofit published. Rather than being content to stick with their current modes of operation, they realistically approached the task of examining methods of reducing fuel consumption. They place a high value on their own flexibility, but realize that the rising cost of fuel may place limits upon the flexibility which cannot be ignored if they are to successfully compete in the fishing industry.

Real-world testing of a retrofit controllable pitch propeller system can be accomplished in the near future through the use of currently available assets from the local area. Comparison testing, such as was done with U. S. Navy Tugboats after the Second World War, can yield bountiful results based on realistic operating conditions. (Rupp, 1948). Likely candidates for such testing would be either one of the vessels of the fishing fleet or the Gloria Michelle, one of the fishing research vessels which is associated with the University. The characteristics of the Gloria Michelle are listed in Appendix F.

Whether or not they are immediately accepted by the fishermen of the Point Judith fleet, controllable pitch systems constitute a growing proportion of the propulsion systems which are currently being fitted on the fishing vessels of the world. In a recent article concerning European fishing trends, more than half of the vessels mentioned were equipped with some type of controllable pitch system. (Noel, 1982). A controlled comparison of the fixed pitch and controllable pitch systems in operation would provide a needed service to the local fishing community.

IX

RECOMMENDATIONS

This study has determined that it would indeed be economically feasible for the vessels of the Point Judith fishing fleet to use some type of controllable pitch system. The next logical step is for comparison testing to be accomplished on a fishing vessel both before and after a retrofit. For the purposes of such a test, the use of one of the fishing research vessels associated with the University would be acceptable. The testing process should consist of a one year period of recording current operating conditions, to include metering fuel consumption rates, engine speed and vessel speed. Then, after a retrofit with a controllable pitch system, another one year period of recording the same information should take place.

Based on the economic considerations of this study, the recommended choice of controllable pitch system which is to be installed is the Newage 2-pitch system. Primary reasons for this are the lower acquisition costs for the system, its relative simplicity as compared with a fully CPP system and the enforced fuel-saving ability of the system.

Although the data collection would be more difficult, the retrofit operation should be done to one of the vessels of the Point Judith fleet for the following reasons:

1. The testing would be more likely to be done under

actual operating conditions and in all types of weather.

2. The Point Judith fishermen would have more of a daily opportunity to see the system in actual operation.

3. The fishermen would have an easier time relating to the results of the test as they already are aware of the operating characteristics of the retrofit vessel.

The price of fuel is not likely to remain at this present level for long--the sooner a testing program were initiated the more opportunity the vessel owners of Point Judith would have to make a realistic examination of the use of controllable pitch systems.

APPENDIX A

Vessel Data

Name: Year built:

Owner:

Owner's address and telephone number :

Type of vessel

Length:

Beam:

Draught:

Tonnage: Net:

Gross:

Engine data

Make:

Model:

Maximum RPM:

Reduction gear ratio:

Propeller data

Make:

Number of blades:

Pitch:

Diameter:

If a nozzle system is used, please list the make and inside diameter:

Name, address and phone number of builder:

Note: If all of the propeller information is not available, I will contact the builder.

Trawling data: Average speed:

Average RPM:

Travelling data: Average speed:

Average RPM:

A rough ratio of time spent per trip between trawling and travelling. For example, 2 hours trawling to every 1 hour of travelling:

If available, fuel consumption data:

The main purpose of this study will be to examine the availability and cost effectiveness of controllable pitch propeller systems in fishing craft.

Please send the completed surveys to:

Dennis M. Miller

Department of Ocean Engineering

University of Rhode Island

Kingston, RI 02881

If there are any questions, feel free to call me at 789-7124. Thanks for the time and information. If you want the results of this study, please indicate below:

APPENDIX B

Suzanne Beth

Built 1980 , steel stern trawler

Dimensions:

Length 82 feet

Beam 23.2 feet

Draft 11.8 feet

Engine characteristics:

2 ea. Cummins KT 1150 365 HP

Maximum RPM = 1800

Gear ratio 5.16 : 1

Propeller characteristics:

Columbian 4 blade Kaplans w/type 19A Nozzle

Pitch 51.5 inches

Diameter 57 inches

Operating characteristics:

Free running:

Speed 9.3 knots

1800 RPM

Trawling:

Speed 3.8 knots

1700 RPM

Ratio of free running time to trawling time 1 : 2.5

Friesland

Built 1978 , wood stern trawler

Dimensions:

Length 87 feet

Beam 24 feet

Draft 10 feet

Engine characteristics:

Detroit Diesel Marine 16V-71 700 HP

Maximum RPM 2300

Gear ratio 5:1

Propeller characteristics:

Doran-Alabama 4 blade

Pitch 46 inches

Diameter 60 inches

Operating characteristics:

Free running:

Speed 10 knots

1900 RPM

Trawling:

Speed 3.5 knots

1650 RPM

Ratio of free running time to trawling time 1 : 2.5

<u>Brian & Brent</u>

Built 1978 , wood stern trawler

Dimensions:

- Length 64 feet
- Beam 19.5 feet
- Draft 8 feet

Engine characteristics:

- Cummins KT 1150 365 HP
- Maximum RPM = 1800

Gear ratio 6:1

Propeller characteristics:

- Ellis 4 blade
- Pitch 50 inches
- Diameter 62 inches

Operating characteristics:

- Free running:
  - Speed 9.5 knots
  - 1600 RPM
- Trawling:
  - Speed 3.4 knots
  - 1550 RPM

Ratio of free running time to trawling time 1 : 2

Appendix C

Suzanne Beth

	Fixed Pitch	2 Pitch	CPP
Free Running:			
P/D	.90	1.03	.96
RPM	1800	1600	1800
GPH	18.8	13.5	18.8
Speed			+9 %
Fuel		-28 %	
Trawling:			
P/D	.90	.94	.90
RPM	1700	1600	1800
GPH	16.0	13.5	18.8
Thrust			+20 %
Fuel		-15 %	+17.5 %

Friesland

	Fixed Pitch	2 Pitch	CPP
Free Running:			
P/D	.77	.95	.87
RPM	1900	1600	1800
GPH	28	18	26
Speed			+10 %
Fuel		-36 %	-7 %
Trawling:			
P/D	.77	.83	.73
RPM	1650	1600	1800
GPH	20	18	26
Thrust			+10 %
Fuel		-10 %	+30 %

Brian & Brent

	Fixed Pitch	2 Pitch	CPP
Free Running:			
P/D	.81	1.1	.93
RPM	1800	1500	1800
GPH	18.8	11.5	18.8
Speed			+18 %
Fuel		-39 %	
Trawling:			
P/D	.81	.85	.78
RPM	1550	1500	1800
GPH	12.4	11.3	18.8
Thrust			+29 %
Fuel		-9 %	+52 %

Appendix D

List of Estimates

Propeller Prices:

Columbian Bronze Corporation
Freeport, New York
$6187 list with a 25% discount
for a cost of $4,640

Doran-Alabama Propeller Co.
Mobile, Alabama
$5645 list with a 40% discount
for a cost of $3,387

Ellis Propeller Co., Inc.
Jacksonville, Florida
cost of $5,143

Shafting and Bearings:

Essex Machine Works
Essex, Connecticut
cost of approximately $8,000

Controllable Pitch System Prices:

J W Berg

cost of approximately $49,800

KaWeMa

cost of approximately $300,000

NOTE: This is a quoted price for a 72-inch propeller.

Newage

cost of approximately $35,250

NOTE: For a retrofit operation, the present shaft can be bored and reused and this will reduce the cost to approximately $33,250

APPENDIX E

List of Company Representatives

Bird-Johnson Co.

Robert A. Casey, II

Michael G. McGurl

Columbian Bronze Corporation

James Burns

Peter Lapp

Doran-Alabama Propeller Co.

James Elliott

Ellis Propeller Company

Buddy Ellis

Essex Machine Works

Keith Strickland

J W Berg

Claes Elfström

N. P. E. C. O. , Inc.

Kenneth Robbins

APPENDIX F

<u>Gloria Michelle</u>

Steel-hulled, Southern built Stern Trawler

Dimensions:

Length 65 feet

Beam 20 feet

Draft 9.5 feet

Engine characteristics:

Cat D343 Turbocharged

365 maximum continuous shp at 1800 RPM

Gear ratio 6:1

Propeller characteristics:

Manufacturer: unknown

Number of blades: 4

Pitch: unknown

Diameter: approximately 62 inches

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