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CENTRAL INTELLIGENCE AGENCY

INFORMATION REPORT

REPORT

COUNTRY	USSR	DATE DISTR.	7 DEC 1954
SUBJECT	Variable-Pitch Propellors (VRSh)	NO. OF PAGES	4
PLACE ACQUIRED		NO. OF ENCLS. (LISTED BELOW)	
DATE ACQUIRED		SUPPLEMENT TO REPORT NO.	
DATE OF INFORMATION			

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1. In contrast to screw propellors having blades fixed in one position, the variable-pitch propellor has blades which can be turned on their axes, thus changing the pitch of the propellor.

2. The mechanism that controls the turning of the blades is located in the hollow propellor hub. This mechanism is connected with a motor in the engine room by means of a control running thru the hollow propellor shaft. The pitch can be changed either from the engine room or directly from the bridge.

3. A changeable-pitch propellor has the following basic advantages:

   (A) The main engine of the ship can be set at a certain number of revolutions per minute while the stress on the engine can be regulated by means of the variable-pitch propellor;

   (B) With the variable-pitch propellor it is not necessary to reverse the main engine. In the case of steam turbine engines it is not necessary to have a special reverse turbine;

   (C) The ship may be put into reverse directly from the bridge, thus reducing the time needed for this operation.

4. Regulated-pitch propellors are still not in wide use in the merchant fleet of the USSR. However, they are being put into use on ships having a dual work routine ie, tugs (which must operate sometimes pulling or pushing other craft and sometimes without pulling anything), icebreakers, fishing trawlers and minesweepers. These propellors are also being introduced on ships that require good maneuverability such as ferry boats, shallow-draft passenger ships, etc. The River Fleet is carrying on most of the experimentation in the use of variable-pitch propellors.

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5. It must be noted that a whole series of other measures is also being carried out in the field of increasing the effectiveness of screw propellors, again mostly in the River Fleet. For example, experiments are being made with counter-propellors, pressure on the screw, and tunnel by-passes through the hull of the ship. The use of these devices can increase the efficiency of an engine from 10 to 30%.

6. The theoretical basis of the variable-pitch propellor (VMSh) can be described as follows:

(A) External Characteristics of the Engines. The external characteristics are one of the aspects of speed characteristics. In this respect the effective power of the engine is the function of the independent variable, which here will be the number of revolutions of the engine, ie, Ne= f(n). The external characteristics of the operational capacities of engines are represented by a series of curves which have areas located beneath them. These areas give the geometrical place of all operational capacities for given numbers of revolutions. Depending on the requirements imposed by navigational conditions of a given ship in operation, the following aspects of external characteristics may be used: (see figure #1 below)

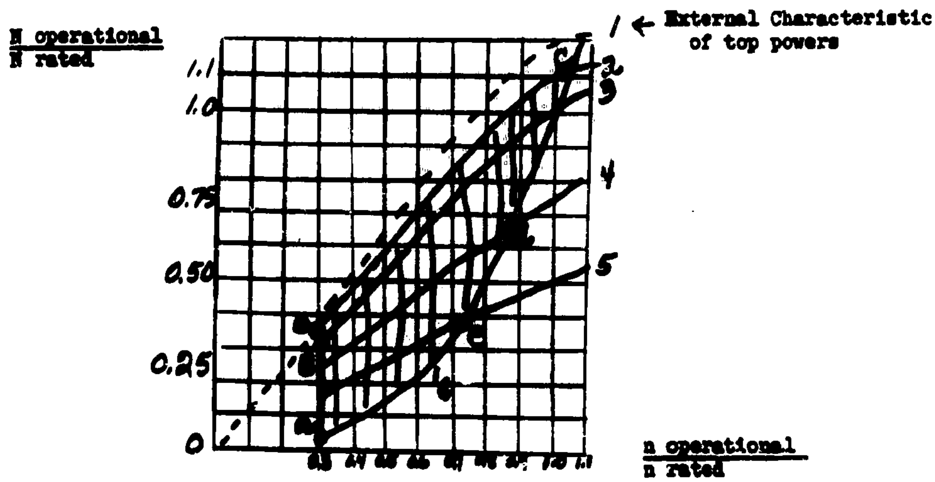


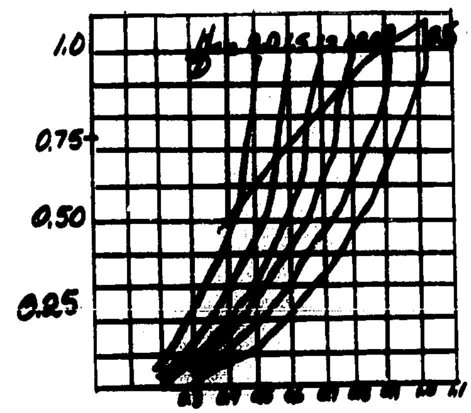
Figure 1. Characteristics of Ship Engines

(1) The period of greatest operational capacity (curve 2) is a limited time, not more than one-three hours;
(2) Full capacity (curve 3) usually corresponds with the "rated" capacity (guaranteed by the engine manufacturer for specified conditions) and is accomplished in operation over an unlimited period of time;
(3) Partial capacity (curves 4-5) is accomplished during reduced feeding of fuel in the working cycle.

(B) Characteristics of the Screw Propellor. The characteristics of the screw according to revolutions per minute (curve 6) is the basic aspect of the characteristic of the marine engine as the engine is connected directly to the screw. The power capacity of the engine in this characteristic should be equal to the power absorbed by the screw in the entire range of number of revolutions. The required power of the screw is figured out mathematically or by means of towed model tests in a model basin. Usually the required power can be figured closely enough for practical purposes by the following method: Given a constant displacement of the ship, the power absorbed by a constant-pitch screw is proportionate to the cube of the number of revolutions of the engine (or the speed of the ship). True, in some cases the law of the changing of power absorbed by the screw varies significantly from the cubic parabola, coming closer to the square parabola and in special cases even coming directly under the square parabola. Besides, it might even be that the law of the changing of power differs considerably from the cubic parabola, coming close to the external characteristic of the engine. Thus the zone of possible operational capacities of a ship engine (depending upon the ship and type of engine) lies between the external characteristic of the greater operating power (curve 2) and the screw characteristic (curve 6). When the engine works directly on the screw, the ship's engine, as can be seen by the diagram, develops tremendous power reserves (as shown by areas a, b, c, cdea) which cannot be used in the operation. The engine in this case has only one rated working condition that is, at the point where the screw characteristic intersects the external characteristic of the full loan (point c). In all remaining working conditions a considerable underloading of the engine takes place, all of which is reflected unfavourably on the economic indices of the engine while working at reduced speeds and also on the working stability of the engine itself.

(c) Engines With Variable-Pitch Propellors. The adoption of the variable-pitch screw opens up broad possibilities for the use of all potential engine power, that is, of work on the external characteristic under more economical conditions in all ranges of working numbers of revolutions. In figure 2, the two curves $Ne=f(\frac{H}{D}, n)$ (the dependence of the effective power on the pitch relationships between the screw "H" and the number of revolutions "n") represent the curves of power which must be transmitted to the screw in the various pitch relationships $\frac{H}{D}$ and in the various numbers of revolutions.

$\frac{N \text{ operational}}{N \text{ rated}}$



$\frac{n \text{ operational}}{n \text{ rated}}$

Figure 2. Power curves with different $\frac{H}{D}$ and $\frac{n \text{ operational}}{n \text{ rated}}$

7. As can be seen from the curves in figure 2, with the increase in the relationship $\frac{H}{D}$ the required power for one and the same number of revolutions quickly grows, the power curves get longer and the screw gets "heavier." The coefficient of useful action of the screw, as a rule, increases somewhat with the increase of the pitch relationship with the exception of the zones of few revolutions and of large relationships $\frac{H}{D}$. With the variable-pitch screw it is possible to achieve the optimum number of combinations H and P, thus getting minimum fuel consumption and a maximum coefficient of useful action of the screw - a situation it is impossible to attain with a fixed-pitch screw. The general expression for minimum fuel consumption for one mile of travel is:

$$G\ \text{mile} = K \frac{1}{(\eta i)} \cdot \frac{1}{(\eta m)} \cdot \frac{1}{(\eta p)}\ \text{KG per mile}$$

From this expression it is obvious that G mile will be less, the greater the product of the useful action coefficients: the indicated-ηi, the mechanical-ηm, and the propulsion-ηp. Thus, the use of the variable-pitch screw makes possible to:

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(A) Operate on the external characteristic instead of on the screw characteristic that is, to utilize all the power resources of the engine;

(B) Provide for the joint functioning of the screw and engine to insure engine operation under maximum economy and screw operation under maximum efficiency;

(C) Increase the ship's speed, if necessary, and at the same time reduce the revolutions of the screw;

(D) Increase the economy of operation with partial loads and reduced screw revolutions;

(E) Reverse the direction of the ship by means of the propeller alone. This allows simpler engine construction and makes it easier to put the ship into reverse quickly.

8. It is necessary to note that, for the most economical use of the variable-pitch screw, a regulation of the distribution elements of the engine involved must be made. These include: Angle of advancement, injection pressure, angle of valve overlap, exhaust and supercharge pressure, amount of exhaust air, etc. This regulation would allow operation under optimum conditions of distribution and regulation not only in the nominal regime but also in all zones of power and screw revolutions. Under actual ship conditions, for convenience of operation the connections between the regulation of the pitch relationship and the optimum regulation of the engine should be made automatic.

9. The theoretical bases of reverse on the variable-pitch propeller are described in detail in an article written by a candidate of technical sciences /Fnu/ [illegible] (a worker in the Central Scientific Research Institute of the Merchant Fleet) which was published in the journal "Morskoy Flot", No 10, [redacted] 50X1-HUM

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