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(54) **A METHOD OF CONTROLLING THE PROPULSION MACHINERY IN A SHIP HAVING A VARIABLE-PITCH PROPELLER.**

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EP-A-0 048 587
DE-A-1 531 730
SE-C- 215 146
US-A-3 069 548
US-A-3 110 348

Patent Abstracts of Japan, abstract of JP 51-139097, publ. 1976-12-01
Dissertation paper: "Minimising fuel consumption for marine machinery with a diesel engine and variable propeller," by G. Buttenschön, 1980, Sweden

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Description

The present invention relates to a method of controlling the propulsion machinery in a ship having a variable-pitch propeller, the method being carried out by using detectors for the ship's speed, fuel consumption and number of revolutions, a control equipment and operating means for separately controlling the propeller pitch and the number of revolutions.

Increasing fuel prices have compelled ships to reduce speed in order to cut down fuel consumption and thereby to compensate, to some extent, for the increased cost. However, the fuel consumption does not depend solely on the speed, but also on the weather and the state of the sea as well as on the relation between the number of revolutions and the pitch of the propeller.

The relation between the number of revolutions and the pitch usually is determined by a so-called combinator, i.e. a device by which the number of revolutions and the pitch are simultaneously actuated by means of a single operating lever. This means that the relation between the number of revolutions and the pitch has been established for each position of the operating lever already upon construction, and thus the fuel consumption cannot be optimised.

Although it is possible, if the weather conditions and the state of the sea along a planned route and also the factors referable to the ship are known, to lay down in advance suitable speeds for the different parts of the route, this method does not safely guarantee that the desired result is obtained.

Several different methods of controlling the fuel supply, the number of revolutions and the pitch are previously known. According to these methods, however, the control is effected more or less independently of the ship's speed, for which reason one cannot be sure whether an achieved cutdown in fuel consumption is the result of the control effected or whether it depends on, for example, a reduction in speed.

DE—A—1,531,750 discloses a method of optimising at different operating conditions a relation between the number of revolutions and the pitch that is preset by a combinator. This optimisation occurs under the condition that the thrust of the propeller be constant, which means that the speed may be varied during optimisation. It is therefore difficult to establish whether an optimisation has occurred.

The published European patent application EP—A—0,048,587 constituting prior art in the sense of Art 54(3) EPC and claiming priority from September 19, 1980 on the basis of a Japanese Patent Application discloses a control or adjustment of the number of revolutions and the propeller blade angle with the view to minimizing the fuel consumption at a constant speed.

The control method disclosed in said European patent application thus comprises deriving a desired horsepower corresponding to a desired speed of a ship in accordance with an actual horsepower, a detected ship speed value and a preset ship speed value; deriving a desired number of revolutions of a main engine of said ship in accordance with an engine loading function for minimum fuel consumption derived from a predetermined engine loading function for optimum propeller efficiency and a predetermined desired load characteristic function and said desired horsepower and controlling the number of revolutions of said main engine; deriving a desired fuel rack position in accordance with said desired number of revolutions and said desired horsepower; and comparing said desired fuel rack position with an actual fuel rack position and thereby controlling a propeller blade angle of said ship.

The present invention is directed to a method for maintaining a constant desired fuel consumption value per unit of length for the distance sailed, by controlling the propulsion machinery of a ship having an adjustable propeller. This method is carried out by using detectors for the ship's speed, fuel consumption and number of revolutions, a control equipment and operating means for separately controlling the propeller pitch and the number of revolutions. The control operation comprises changing the number of revolutions and the pitch by means of the control equipment and the operating means while maintaining the speed within a predetermined interval until there is obtained a combination of the number of revolutions and the pitch which gives a minimum of fuel consumption in the propulsion machinery of the ship, by measuring the speed after each change of the number of revolutions and the pitch for checking, by means of the control equipment, that the speed still lies within said interval and by measuring the fuel consumption after each such change and comparing it, by means of the control equipment, with the immediately preceding measurement of the fuel consumption, if the speed after said change was within said interval. This control in accordance with the first part of claim 1 is essentially known from a dissertation paper having the title "Minimising fuel consumption for marine machinery with a diesel engine and variable propeller". This paper was written by Gerhard Buttenschön in 1980, (Sweden), and it discloses an adaptive regulator which, starting from a given combination of the number of revolutions and the pitch, varies one or both of these until a combination giving the lowest possible fuel consumption is obtained, on the secondary condition that the speed of the ship must be constant.

The present invention has for its object to solve this problem, while at the same time keeping the fuel consumption constant at a desired level based on the distance sailed.

To achieve this object, the method according to the invention has been given the characteristic features stated in claim 1. Preferred forms of the invention are defined in claims 2 and 3.

The invention will be described in more detail

below, reference being had to the accompanying drawings. Fig. 1 is a flow chart showing an embodiment of a speed control comprised by the method according to this invention. Fig. 2 is a flow chart showing how the efficiency according to the invention is made as high as possible at a previously set speed. Fig. 3 shows how the method illustrated in Figs. 1 and 2 is utilised in order to attain a substantially constant fuel consumption for the distance sailed. Fig. 4 is a diagram showing the character of the relations between the number of revolutions, the power output, the speed and the propeller pitch. Fig. 5 is a block diagram of a device for carrying the method illustrated in Figs. 1—3 into effect.

As will appear from Fig. 5, the method according to the invention requires for its execution detectors 1, 2 and 3 for the ship's speed, the fuel consumption and the number of revolutions. These detectors 1—3 may be of any suitable type, analog or digital, and are connected, via an interface unit 4, to a control equipment 5 which preferably contains a computer and supplies control signals to operating means 6 and 7 for controlling the propeller pitch and the number of revolutions of the propulsion machinery, respectively, and thus the number of revolutions of the propeller or propellers.

The control according to this invention is effected in two stages, the first of which is exemplified in Fig. 1. It implies that the ship's speed or velocity is made substantially to correspond to a predetermined desired value of the speed. More particularly, the first stage causes the actual speed of the ship to be adjusted to a desired speed interval

$$V_{desired} \pm \Delta V_{desired}.$$

Adjusting the ship's speed to the desired interval is initiated by sensing the actual speed of the ship. If this speed already lies within said interval, a direct change-over to the second stage of the method according to the invention is effected, which second stage has been designated optimization in Fig. 1. If, on the other hand, the actual speed lies outside the interval in question, a rough adjustment is first effected by utilizing empirical values recorded in a table. Thus, the number of revolutions of the propulsion machinery is decreased/increased to a value X corresponding approximately to a desired speed value according to the said table, and the pitch of the propeller blades is alternatively increased or decreased. The ship is then allowed to stabilize itself at its new speed, for example during 90 seconds, whereupon the ship's speed is measured during a measuring period of, for example 90 seconds. If the speed value now measured lies within the predetermined interval, a change-over to the second stage of the method occurs, whereas otherwise the number of revolutions is increased/decreased by a predetermined amount, for instance 15 r.p.m. for each deviation of 1 knot between the actual and the desired speed value. This change in the number of revolutions is accompanied by respectively a decrease or an increase of the propeller pitch. The measuring operation previously effected is then repeated, whereupon it is again checked whether the latest measured value lies within the predetermined interval. The procedure is repeated until it does, unless the number of revolutions before then deviates by more than a predetermined amount, for instance 15 r.p.m., from the original roughly adjusted value, in which case an alarm is given.

When a change-over to the second stage of the control method according to the invention has occurred, a flag $A_{rev.}=1$ is set, whereupon the number of revolutions is reduced by a predetermined increment, for instance 1 r.p.m., and the propeller pitch is increased by a predetermined amount. After the ship has been allowed to stabilize its motion during a suitable interval, for example 90 seconds, the ship's speed is measured, and it is checked whether this speed lies within the above-mentioned interval. If the measured speed lies outside the interval, a return to the speed adjustment of the first stage takes place, whereas, if the speed lies within the interval in question, the flat $A_{rev.}$ is set to 0, and it is checked whether a cutdown in fuel consumption has occurred owing to the immediately preceding decrease in the number of revolutions. If this is the case, the number of revolutions is further decreased, and the pitch is again increased, and the speed is again measured to check whether it lies within the said speed interval. If the speed lies outside the interval (actually, below said interval), the preceding change of the number of revolutions and the pitch is eliminated by a corresponding increase of the number of revolutions and decrease of the pitch, whereupon the number of revolutions and the pitch are locked. If, on the other hand, the speed lies within the interval, it is again checked whether the fuel consumption has been cut down by the latest change of the number of revolutions and the pitch. If this is the case, the preceding procedure is repeated, either until the number of revolutions and the pitch are locked in the manner described above, or until an increase in fuel consumption can be established. In the latter case, a second flag $B_{rev.}=1$ is set, and the number of revolutions is increased by the increment of the number of revolutions previously utilized, for instance 1 r.p.m., whereupon a further increase of the number of revolutions, preferably by the same increment, and a decrease of the propeller pitch takes place. The speed is then measured with a delay of, for example 90 seconds, and it is checked whether the measured speed value lies within the above-memtioned speed interval. If this is not the case, a return to the first stage of the method, with reviewed speed adjustment, takes place. If, on the other hand, the measured speed values lies within the speed interval in question, the flag $B_{rev.}$ is given the value 0, and it is checked whether the last increase in speed and the

decrease in pitch have caused an increase or a cutdown in fuel consumption. If a cutdown is established, the speed is again increased and the pitch is decreased, and measuring and checking whether the speed now measured lies within the speed interval in question, are repeated. If this is not the case, the latest change of the number of revolutions and the pitch is compensated for, whereupon the number of revolutions and the pitch are locked. If, on the other hand, the measured speed value lies within the speed interval in question, the fuel consumption is again checked. The loop described above is repeated a number of times until either the measured speed value lies outside the speed interval in question or until an increase in fuel consumption is established, in which case the latest change of the number of revolutions of the propulsion machinery and the propeller pitch is eliminated by reducing the number of revolutions and increasing the pitch, whereupon these are locked.

It will be appreciated that the above described method affords a combination of the number of revolutions and the pitch which provides for minimum fuel consumption in the propulsion machinery for speeds within the speed interval in question. In some cases, it may be desirable to maintain the fuel consumption constant at a desired level per unit of length for the distance sailed. An embodiment of the method according to the present invention, by which this desideratum is realized, is shown in Fig. 3. In accordance with what is shown in Fig. 3, there is calculated, in a first step, a suitable speed value according to the formula

$$V=V_{actual}\cdot\left(\frac{B_{desired}}{B_{actual}}\right)^{0.5}$$

in which B is the fuel consumption per unit of length for the distance sailed. In a second step, the speed control illustrated in Fig. 1 is carried out on the basis of the calculated speed value. It is then checked whether the actual fuel consumption lies within an interval containing the desired value of the fuel consumption, for instance $B_{desired}\pm 1\%$. If this is the case, the fuel consumption is optimized by effecting the control as illustrated in the flow chart according to Fig. 2. If, on the other hand, the fuel consumption lies outside the interval in question, a suitable speed value is again calculated in accordance with the above formula, whereupon the procedure is repeated until the number of revolutions and the pitch are locked as shown in the chart according to Fig. 2.

It appears from the diagram shown in Fig. 4 that the power output depends upon the number of revolutions and the pitch. However, the above described mechanized method ensures that the minimum fuel consumption for a given desired speed is attained. A corresponding manual control by means of instruments indicating the speed, the fuel consumption, the pitch and the number of revolutions is not possible in actual practice because the control requires constant supervision and attention which can only be effected by automatic means.

As has been mentioned above, the detectors 1, 2 and 3 for the ship's speed, fuel consumption and number of revolutions, respectively, may be of any suitable type. However, the detector 3 for the number of revolutions preferably is an inductive detector and may comprise soft iron gears mounted around the periphery of the shaft, the revolutions of which are to be measured, and an inductive transducer which is so mounted that it detects the passage of the gears and, thus, the number of revolutions of the shaft. Such revolution detectors are available from Verkon Electronics AB, Sweden. The fuel consumption detector 2 may be a flow-meter of the type utilizing ultrasonic pulses. Such a flow-meter is available under the designation EMUF from Danfoss A/S, Denmark.

The operating means 6 and 7 may consist of electropneumatic transducers, for instance of the type 346 018 from Wabco Westinghouse.

Claims

1. A method for maintaining, by controlling the propulsion machinery of a ship having an adjustable propeller, a constant desired fuel consumption value per unit of length for the distance sailed, said method being carried out by using detectors (1, 2, 3) for the ship's speed, fuel consumption and number of revolutions, a control equipment (5) and operating means (6, 7) for separately controlling the propeller pitch and the number of revolutions, said controlling comprising changing the number of revolutions and the pitch by means of said control equipment (5) and said operating means (6, 7) while maintaining the speed within a predetermined interval until there is obtained a combination of the number of revolutions and the pitch which gives a minimum of fuel consumption in the propulsion machinery of the ship, by measuring the speed after each change of the number of revolutions and the pitch for checking, by means of said control equipment, that the speed still lies within said interval, and by measuring the fuel consumption after each such change and comparing it, by means of said control equipment, with the immediately preceding measurement of the fuel consumption, if the speed after said change was within said interval, characterised in that the ship's speed is first adjusted, by means of said control equipment (5) and said operating means (6, 7), to a value within said predetermined interval containing a desired value of the speed which is selected on the basis of the desired fuel consumption value per unit of length for the distance sailed, by changing the number of revolutions of the propulsion machinery of the ship and the pitch of the propeller, that minimization of the fuel consumption is effected after said speed adjustment, that it is checked, after said

minimization of the fuel consumption, whether the fuel consumption lies within a predetermined second interval containing the desired fuel consumption value, and that a new desired value is calculated for a further speed adjustment, if the fuel consumption, after said minimization of the fuel consumption, lies outside said second interval.

2. Method as claimed in claim 1, characterised in that further changes in the number of revolutions are made, by means of said control equipment (5) and said means (7) for operating the number of revolutions, in the same direction as the preceding change, if this change implied a cutdown in fuel consumption, until either an increase in fuel consumption is recorded or the speed lies outside said interval.

3. Method as claimed in claim 1 or 2, characterised in that the first change in the number of revolutions, after the speed adjustment, is a reduction in the number of revolutions.

Patentansprüche

1. Verfahren zum Aufrechterhalten, durch Einregelung der Antriebsmaschine eines Schiffs mit verstellbarem Propeller, eines konstanten, erwünschten Kraftstoffverbrauchswertes pro Längeneinheit für die zurückgelegte Distanz, welches Verfahren unter Ausnutzung von Detektoren (1, 2, 3) für die Schiffsgeschwindigkeit, den Kraftstoffverbrauch und die Drehzahl, einer Regelausrüstung (5) und Betätigungsgliedern (6, 7) zur separaten Einregelung der Propellersteigung und der Drehzahl ausgeführt wird, und wobei die genannte Einregelung die Änderung der Drehzahl und der Steigung mittels der genannten Regelausrüstung (5) und der genannten Betätigungsglieder (6, 7) umfasst, während die Geschwindigkeit innerhalb eines vorbestimmten Intervalls aufrechterhalten wird, bis eine Kombination der Drehzahl und der Steigung erhalten wird, die in der Antriebsmaschine des Schiffs einen Mindestkraftstoffverbrauch ergibt, durch Messen der Geschwindigkeit nach jeder Änderung der Drehzahl und der Steigung, um mittels der genannten Regelausrüstung zu kontrollieren, dass die Geschwindigkeit noch innerhalb des genannten Intervalls liegt, sowie durch Messen des Kraftstoffverbrauchs nach jeder solchen Änderung und durch einem mittels der genannten Regelausrüstung ausgeführten Vergleich des Kraftstoffverbrauchs mit der unmittelbar vorhergehenden Messung des Kraftstoffverbrauchs, falls die Geschwindigkeit nach der genannten Änderung innerhalb des genannten Intervalls lv, dadurch gekennzeichnet, dass die Schiffsgeschwindigkeit zuerst mittelst der genannten Regelausrüstung (5) und der genannten Betätigungsglieder (6, 7) auf einen Wert innerhalb des genannten, vorbestimmten Intervalls eingeregelt wird, das einen erwünschten Wert der Geschwindigkeit umfasst, welcher auf Basis des erwünschten Kraftstoffverbrauchswertes pro Längeneinheit der zurückgelegten Distanz gewählt wird, durch Änderung der Drehzahl der Antriebsmaschine des Schiffs und der Propellersteigung, dass nach der genannten Geschwindigkeitseinregelung der Kraftstoffverbrauch minimiert wird, dass nach der genannten Minimierung des Kraftstoffverbrauchs kontrolliert wird, ob der Kraftstoffverbrauch innerhalb eines vorbestimmten, zweiten Intervalls liegt, welches den erwünschten Kraftstoffverbrauchswert enthält, und dass ein neuer erwünschter Wert für eine weitere Geschwindigkeitseinregelung berechnet wird, falls der Kraftstoffverbrauch nach der genannten Minimierung ausserhalb des genannten zweiten Intervalls liegt.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, dass mittels der genannten Regelausrüstung (5) und der genannten Glieder (7) zur Betätigung der Drehzahl weitere Änderungen der Drehzahl in derselben Richtung wie die vorhergehende Änderung vorgenommen werden, falls diese Änderung eine Reduzierung des Kraftstoffverbrauchs bedeutete, bis entweder eine Ehöhung des Kraftstoffverbrauchs registriert wird oder die Geschwindigkeit ausserhalb des genannten Intervalls liegt.

3. Verfahren nach Anspruch 1 oder 2, dadurch gekennzeichnet, dass die erste Änderung der Drehzahl nach der Geschwindigkeitsänderung eine Herabsetzung der Drehzahl ist.

Revendications

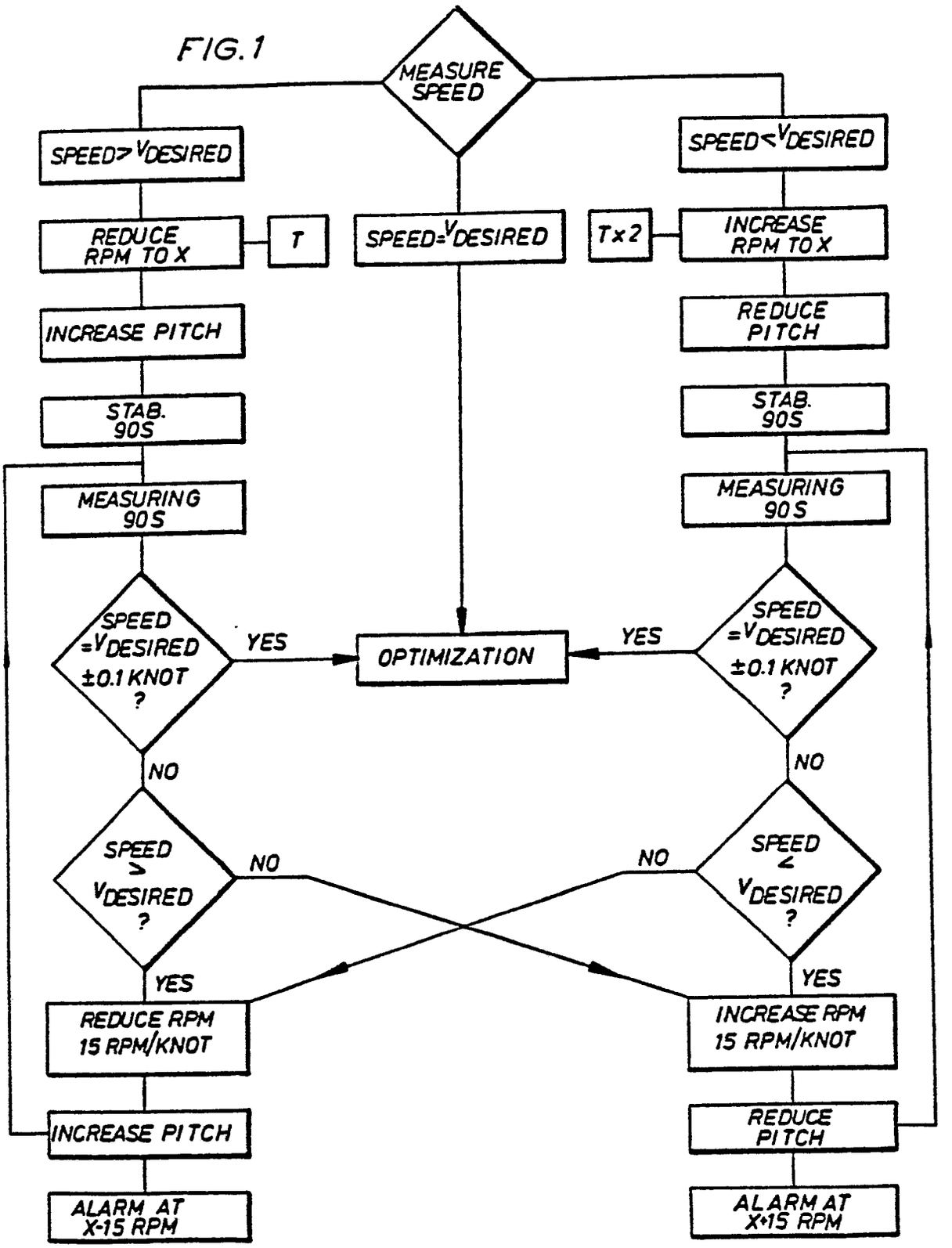
1. Procédé pour maintenir, en commandant les moyens mécaniques de propulsion d'un navire doté d'une hélice réglable, à une valeur constante désirée la consommation de combustible par unité de longueur de la distance parcourue, ce procédé étant mis en oeuvre en utilisant des détecteurs (1, 2, 3) pour la vitesse de navire, la consommation de combustible et le nombre de tours, un équipment de commande (5) et des moyens opérateurs (6, 7) pour commander séparément le pas d'hélice et le nombre de tours, cette action de commande comprenant le changement du nombre de tours et le changement du pas au moyen dudit équipment de commande (5) et desdits moyens opérateurs (6, 7) tout en maintenant la vitesse à l'intérieur d'un intervalle prédéterminé jusqu'à l'obtention d'une combinaison du nombre de tours et du pas donnant un minimum de consommation de combustible dans les moyens mécaniques de propulsion de navire, cela en mesurant la vitesse après chaque changement du nombre de tours et le pas, pour contrôler au moyen dudit équipement de commande que la vitesse se trouve encore dans ledit intervalle, et en mesurant la consommation de combustible après chaque tel changement et en la comparant, au moyen dudit équipement de commande, à la mesure de consommation de combustible immédiatement précédente, si la vitesse après ledit changement était à l'intérieur dudit intervalle, caractérisé en ce que la vitesse du navire est d'abord ajustée, au moyen dudit équipement de commande (5) et

desdits moyens opérateurs (6, 7), à une valeur comprise dans ledit intervalle prédéterminé contenant une valeur désirée de la vitesse qui est choisie sur la base de la valeur de consommation de combustible désirée par unité de longueur de distance parcourue, cet adjustement étant effectué en changeant le nombre de tours des moyens mécaniques de propulsion du navire et en changeant le pas d'hélice, en ce que la minimisation de la consommation de combustible est réalisée après ledit adjustement de vitesse, en ce qu'un contrôle est effectué après ladite minimisation de la consommation de combustible, pour examiner si la consommation de combustible se situe à l'intérieur d'un deuxième intervalle prédéterminé contenant la valeur de consommation de combustible désirée, et en ce qu'une nouvelle valeur désirée est calculée pour un autre ajustement de vitesse, cela si la consommation de combustible, après ladite minimisation de consommation, se situe en dehors dudit deuxième intervalle.

2. Procédé selon revendication 1, caractérisé en ce que d'autres changements du nombre de tours sont effectués, au moyen dudit équipement de commande (5) et desdits moyens opérateurs (7) agissant sur le nombre de tours, ces autres changement étant effectués dans le même sens que le changement précédent si celui-ci impliquait une diminution de consommation de combustible, jusqu'à ce qu'une augmentation de consommation de combustible soit décelée, ou que la vitesse ne soit pas comprise dans ledit intervalle.

3. Procédé selon revendication 1 ou 2, caractérisé en ce que le premier changement du nombre de tours, après l'ajustement de vitesse, est une diminution du nombre de tours.

FIG.1


MEASURE SPEED
SPEED > VDESIRED
SPEED = VDESIRED
SPEED < VDESIRED
REDUCE RPM TO X
T
T x 2
INCREASE RPM TO X
INCREASE PITCH
REDUCE PITCH
STAB. 90S
STAB. 90S
MEASURING 90S
MEASURING 90S
SPEED = VDESIRED ±0.1 KNOT ?
YES
OPTIMIZATION
YES
SPEED = VDESIRED ±0.1 KNOT ?
NO
NO
SPEED > VDESIRED ?
NO
NO
SPEED < VDESIRED ?
YES
YES
REDUCE RPM 15 RPM/KNOT
INCREASE RPM 15 RPM/KNOT
INCREASE PITCH
REDUCE PITCH
ALARM AT X-15 RPM
ALARM AT X+15 RPM

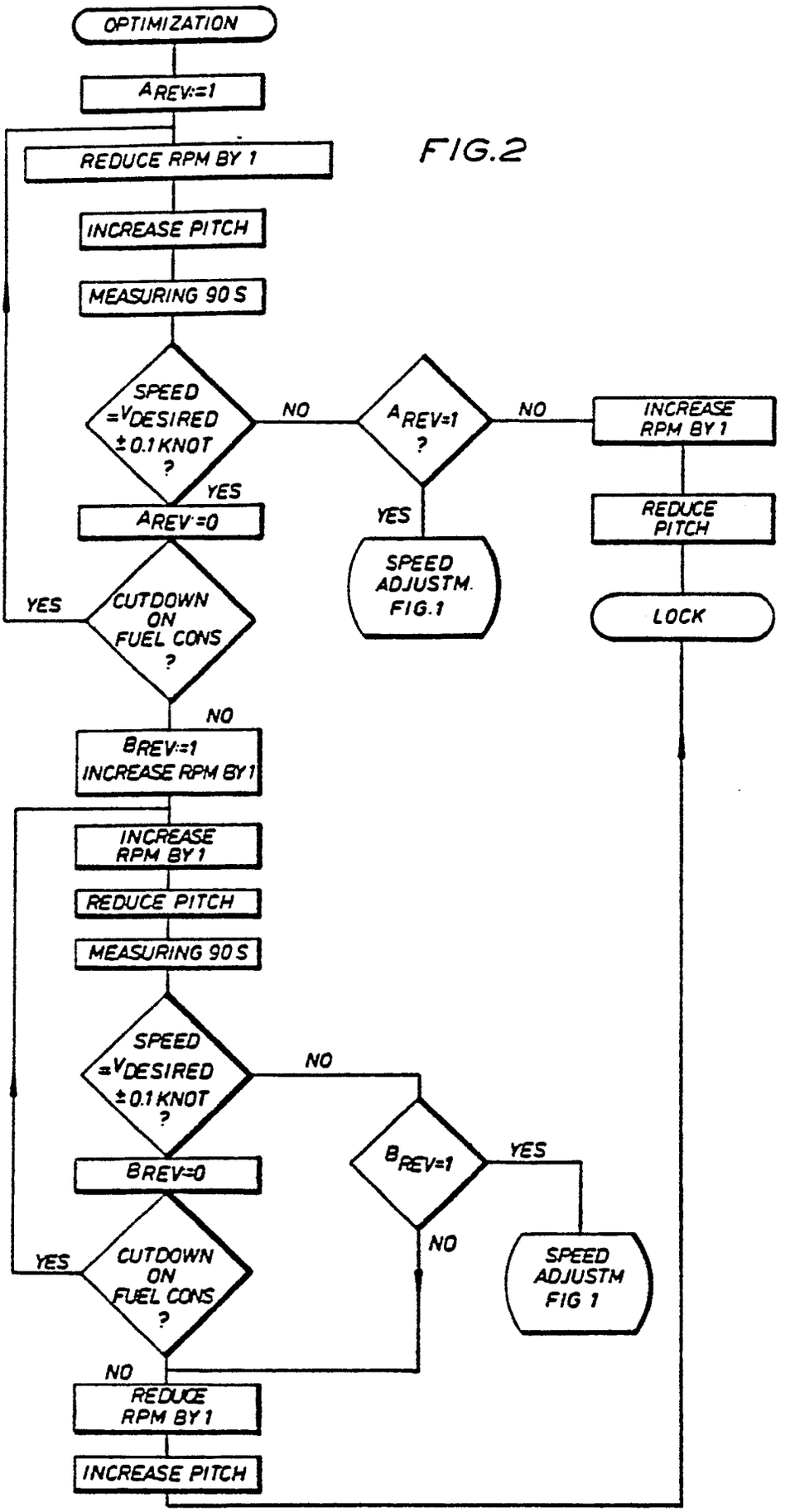

OPTIMIZATION
AREV:=1
REDUCE RPM BY 1
INCREASE PITCH
MEASURING 90 S
SPEED =VDESIRED ±0.1 KNOT ?
NO
AREV=1 ?
NO
INCREASE RPM BY 1
YES
AREV:=0
YES
SPEED ADJUSTM. FIG.1
REDUCE PITCH
LOCK
YES
CUTDOWN ON FUEL CONS ?
NO
BREV:=1 INCREASE RPM BY 1
INCREASE RPM BY 1
REDUCE PITCH
MEASURING 90 S
SPEED =VDESIRED ±0.1 KNOT ?
NO
BREV=1
YES
BREV=0
YES
CUTDOWN ON FUEL CONS ?
NO
SPEED ADJUSTM FIG 1
NO
REDUCE RPM BY 1
INCREASE PITCH

FIG.2

FIG.3

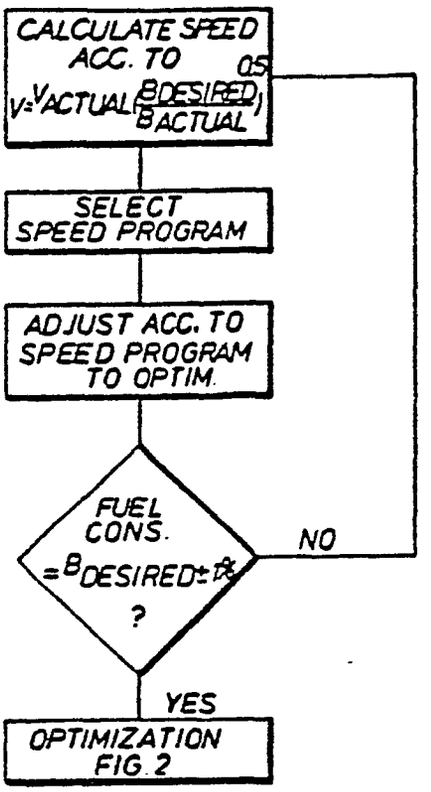
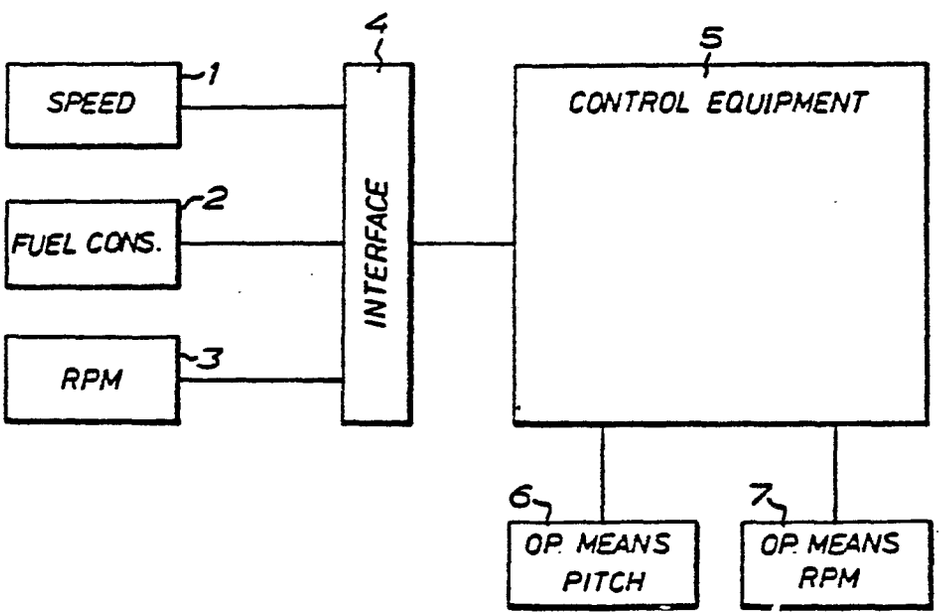

CALCULATE SPEED ACC. TO
V=V ACTUAL (β DESIRED / β ACTUAL)
OS
SELECT SPEED PROGRAM
ADJUST ACC. TO SPEED PROGRAM TO OPTIM.
FUEL CONS. = β DESIRED ± Δ ?
NO
YES
OPTIMIZATION FIG. 2

FIG.5


4
5
SPEED
1
FUEL CONS.
2
RPM
3
INTERFACE
CONTROL EQUIPMENT
6
7
OP. MEANS PITCH
OP. MEANS RPM

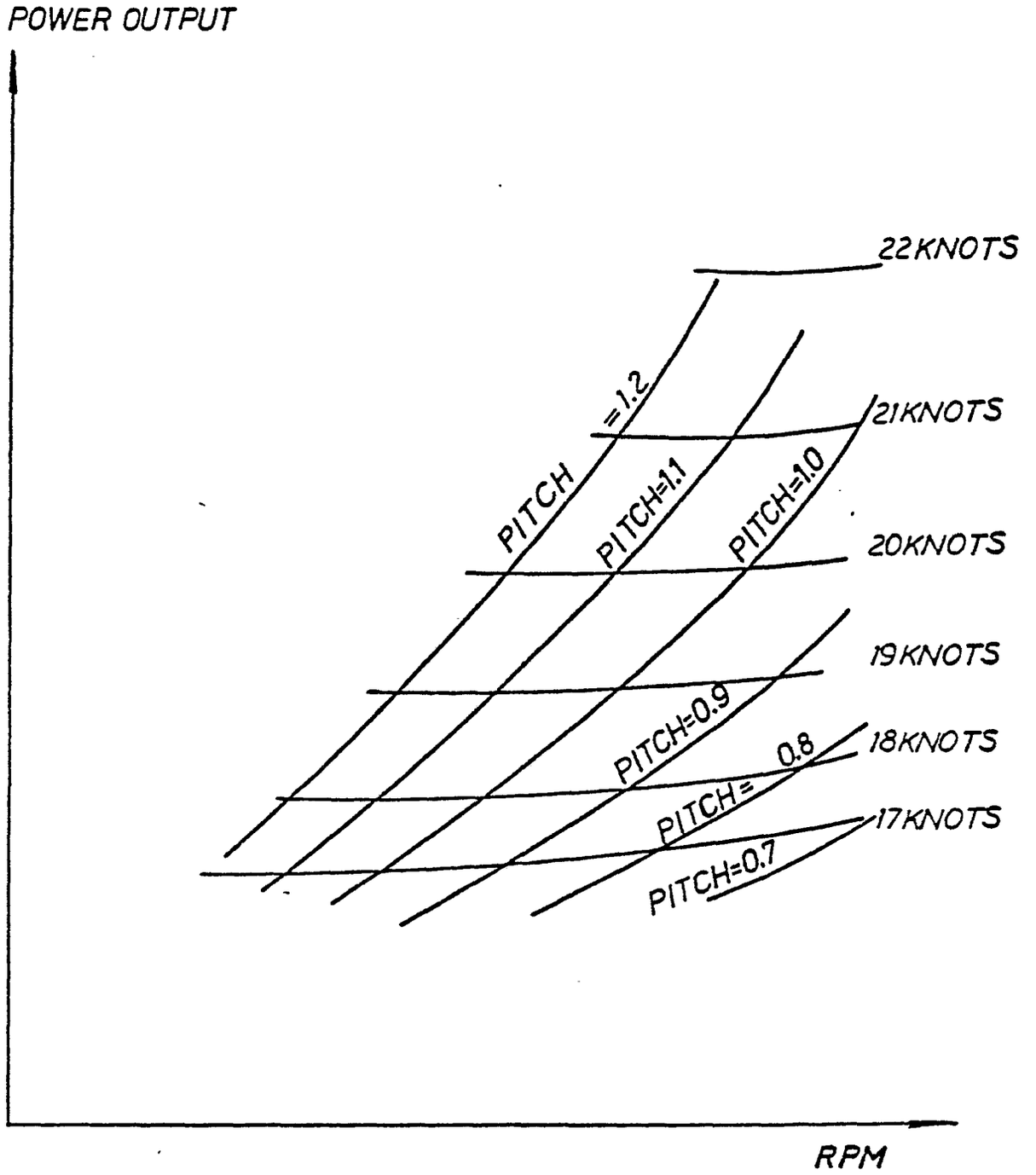

POWER OUTPUT
22KNOTS
21KNOTS
20KNOTS
19KNOTS
18KNOTS
17KNOTS
PITCH =1.2
PITCH=1.1
PITCH=1.0
PITCH=0.9
PITCH= 0.8
PITCH=0.7
RPM

FIG. 4