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(54) **MUSCLE TRAINING AND MEASURING MACHINE.**

(57) A muscle training and measuring machine employs a servo torque amplifier having a mechanical feedback function therein. The servo torque amplifier has a high ratio of inertia to torque and fast responsiveness. Accordingly, this machine dispenses with a conventional gear train in matching the load applied to a handle and a pedal. Thus, the machine which has a multiple functional performance can be readily manufactured, and the accuracy, the characteristics and the operability of the machine can be improved. The function of the machine can also be improved by providing the direct reading of evaluated values and the automatic recording of these values.

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# S P E C I F I C A T I O N

# MUSCLE STRENGTH TRAINING AND MEASURING APPARATUS

## FIELD OF THE INVENTION

The invention relates to a muscle strength training and measuring apparatus which is applicable to the training of muscle strength as well as to the measurement thereof.

## BACKGROUND ART

The muscle strength training apparatus is used for rehabilitative exercises in order to restore muscle strength or is used for the development of muscle strength and for the increase of athletic capabilities. The fundamental functions required for the muscle strength training apparatus are to exert resistive forces against a handle, pedal or the like to which a load is applied by a person exercising or under measurement.

Such resistive forces can be attained by employing among various systems a mechanical brake system which has been widely introduced in a practical use due to its simplicity, compactness and low cost. The mechanical brake system, however, brings about some disadvantages such as for example in that (1) a torque or resistive forces can not be preset precisely and it is difficult to obtain the same torque as set previously, and (2) a brake torque varies with speed incorporated at a time.

In order to solve the above problems accompanied by the mechanical brake system, it has been proposed to apply an electrical brake technique as shown in Fig. 1 (A) to (C).

(A) A system using a permanent magnet D.C. motor

In this system, the drive shaft of a permanent magnet type motor 1 is rotated by a person exercising with the aid of such a load applying means 2 as a handle, pedal or the like through a gear train 3. In this case, the torque to be exerted upon the shaft of the motor 1 is generated in proportion to a current flowing through an armature, so that the torque is readily set by connecting a variable resistor 4 between the both terminals of the motor armature. A proper torque can only be attained with the shaft of the motor 1 rotating relatively at a high speed.

However, since the attainable movement by the exerciser of the load applying means 2 such as a handle, pedal or the like can not reach so high a speed that the gear train 3 is required for increasing the rotational speed of the motor shaft. In the operation of the motor 1 by means of the gear train 3, the total friction loss generated at the motor 1 and the gear train 3 as viewed from the load applying means 2 such as a handle or the like amounts to that multiplied by the speed increasing ratio of thus increased speed to the speed of the load applying means 2. This results in the difficulties of setting a low torque and also in the lowering of setting accuracy of the torque. Moreover, since the inertia of the motor armature is squared by the speed increasing ratio, additional large torque is required when starting and stopping the rotation of the motor 1, with a less precise setting value of the torque thus disabling this system to be applied to a practical use.

(B) and (C)

The system has been proposed in order to preclude the problems encountered with the above system (A). This system comprises a torque setting means 5 and a constant current source 6, or a servo amplifier 8 with a feedback loop of a torque detecting means 7, wherein the motor 1 is fed with a controlled current. In this case, the limitations imposed in the design of the system (A), in which the motor 1 is used for serving as a dynamo, are remarkably reduced such that a motor of a relatively small size can be operated at a low speed, and the gear ratio of the gear train 3 can also be decreased. However, since the speed during which the motor 1 operates with high efficiency is substantially higher than that to be obtained by the exerciser, it is inherent and unavoidable to be added to the load applying means 2 such as a handle, pedal or the like an additional torque proportionate to the square of the gear ratio, the additional torque being originated from an inertia of the motor armature during acceleration or deceleration at the time of starting and stopping. Accordingly, it is difficult to coincide the both torques set by the torque setting means 5 and applied by the handle or the like.

Apart from the foregoing technical problems, other functions must be taken into consideration for obtaining a versatile muscle strength training and measuring apparatus. The muscle strength and capabilities of the exerciser or the person under measurement can be estimated in accordance with not only a torque, i.e., the amount of force applied, but also a rotational speed of a handle or the like and the position thereof (i.e., rotational angle) which function as important quality parameters. One of the factors which determine the quality of the apparatus is to provide with the function capable of setting any one of the position, speed and torque at a certain value, and capable of making the other two parameters variable in accordance with the capabilities the person exercising or under measurement possesses. This means to be operative under the three functions, i.e., a constant torque (variable speed)- Isotonic Mode, a constant speed (variable torque)- Isokinetic Mode, and a constant position (variable torque)- Isometric Mode.

Referring now to Fig. 2, a system capable of affording such three functions is shown, wherein each of the functions may be attained by selecting with a changeover switch 10 any one of a speed detecting means $9_a$, an angle detecting means $9_b$ or a torque detecting means $9_c$ provided in a feedback loop. This system is advantageous, in addition to the aforementioned, in that the evaluation of the variable parameters can be obtained with the corresponding detecting means $9_a$, $9_b$ and $9_c$ being monitored. However, in this system as well it is essential to employ a gear train 3 for matching the motor 1 with the load applying means 2 such as a handle, pedal or the like, the effects of the inertia of the motor 1 armature and the friction of the gear train 3 being unavoidable as is the same with the systems described above. Thus, the problems caused by the additional torque during the starting and stopping still exist.

The present invention has been made in consideration of the above problems. The muscle strength training apparatus according to the invention may afford the three functions and also effect a smooth matching for the brake system with the handle, pedal or the like without the introduction of a gear train therebetween, and in addition may be used for the measurement of muscle strength.

Furthermore, the muscle strength training and measuring apparatus according to the invention has made an improvement in the accuracy, quality and operation by employing various feedback loops, and can afford a direct reading of actual values and an automatic recording thereof.

## DISCLOSURE OF THE INVENTION

The present invention, therefore, utilizes a mechanical feedback hydraulic servo-torque amplification device characterized by a large torque-inertia ratio to which device a pedal, handle or the like is coupled directly. Such a mechanical feedback hydraulic servo-torque amplification device (hereinafter referred to as servo-torque amplifier) is known to the public in the name of the merchandise RSA (Rotary Servo Actuator) manufactured by Mitsubishi Kinzoku Kabushiki Kaisha. The servo-torque amplifier has a large torque-inertia ratio and need not provide a gear train between the brake system and the handle, pedal or the like so that the effects of acceleration and deceleration torque and friction torque are precluded. The response time of the servo-torque amplifier is sufficiently quick when compared with the operational speed applied by the person exercising or under measurement.

The apparatus according to the invention comprises the servo-torque amplifier whose output shaft is directly coupled to a load applying means such as a handle, pedal or the like, the input shaft of which being coupled to an electromechanical conversion means for driving the input shaft. The electromechanical conversion means comprises a direct current servo motor and a gear train, the electromechanical conversion means transmitting the rotation of the direct current servo motor to the input shaft of the servo-torque amplifier through the gear train. A servo motor driving means is connected to the direct current servo motor of the electromechanical conversion means for driving the same. The input summing point of the servo motor driving means is supplied with a desired value of any one of Isotonic, Isokinetic or Isometric mode, and the corresponding real value. The above elements of the apparatus constitute an electromechanical servo amplifier as a whole. The respective real value of each mode is selectively fed back to the input summing point by means of a mode changeover circuit, and also applied to a display device, printer, recorder or the like for the display and recording thereof.

The real value of the output of the respective Isotonic, Isometric or Isokinetic mode is detected at between the output shaft of the servo-torque amplifier, and the pedal, handle or the like, and then fed back to the input summing point of the electromechanical servo amplifier. Since the servo-torque amplifier utilized in this invention has by itself a mechanical feedback loop which causes the servo-torque amplifier to be highly stable, it should be noted here that among the real values of the outputs of the three modes, the real values of the Isometric and Isokinetic modes can be derived from the gear train of the electromechanical conversion means. The detection of position, speed and torque in each mode can be easily made by using a known potentiometer, tachogenerator, strain gauge or the like.

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 (A) to (C) and Fig. 2 are diagrams showing some examples of the muscle strength training apparatus according to the prior art, and

Fig. 3 is a schematic block diagram illustrating one of the embodiments according to this invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENT OF THE INVENTION

The contents of the invention will now be described in detail with reference to Fig. 3 of the accompanying drawings.

First, the gist of the invention is described below. The characteristic feature of the invention resides in that an electromechanical servo amplifier as a whole is constructed such that a rotary actuator 13 in combination with a control valve 12 (both the elements constitute a servo-torque amplification device or servo-torque amplifier 14 in which a mechanical feedback device 140 serves as a feedback loop from the rotary actuator 13 to the control valve 12) is controlled either by a feedback loop through a speed, angle or torque detection device $9_c$, $9_b$ or $9_c$, or by a feedback loop through a speed or angle detection device $19_a$ or $19_b$.

Two types of rotary actuator 13 are available, that is, a swinging type and a continuously rotating type, and both of them may be used as the rotary actuator 13. The former is mainly used for training arms (that is, in the case of applying brake effect upon a handle), and the latter is mainly used for training feet (that is, in the case of applying brake effect upon a pedal). The control valve 12 is mounted in the rotary actuator 13 the output shaft of which is caused to follow the rotation of the input shaft under the operation of the mechanical feedback device 140 with fluid pressure (oil pressure, pneumatic pressure or the like) supplied from the hydraulic resources $12_a$. The control valve 12 may be either a direct straight moving type or a rotary moving type. The rotary moving type control valve is advantageous in that it is less susceptible to worsening the performance due to contamination of the operating fluid, and it needs not provide a straight-rotary moving conversion mechanic which is necessary for a straight moving type. First of all, above all various advantages aforementioned, this invention can enjoy fairly good operational qualities, since a gear train is dispensed with between the rotary actuator 13 and the load applying means 2 such as a handle, pedal or the like, the torque-inertia ratio being large enough to eliminate the effects of acceleration, deceleration and friction torque.

In order to drive the input shaft of the control valve 12 of the servo torque amplification device 14 thus constructed, there is provided an electromechanical conversion means 16. The electromechanical conversion means 16 includes a direct current servo motor 17, a speed reduction gear train 18, and a detection means comprised of a tachogenerator (speed detector) $19_a$ and a potentiometer (position detector) $19_b$. At the preceding stage of the electromechanical conversion means 16, connected thereto is a servo motor driving means 15 the input of which serves as an input summing point of the electromechanical servo amplifier for controlling the servo system. It should be understood that the gear train 18 of the electromechanical conversion means 16 does not function to transmit power but only to transmit position (angle) signal, resulting in a lower loss than that of the other conventional system. It is more important for the invention to have no adverse effects as described above, since the gear train 18 is separated by the servo-torque amplifier 14 from the load applying means 2 such as a handle, pedal or the like.

In the electromechanical servo amplifier according to the invention, feedback signals may be supplied either as (1) any one of the detection signals (each detection signal is detected as an electrical signal from the respective detection means $9_a$, $9_b$ or $9_c$) of speed, angle and torque from the rotary actuator 13 at the output side thereof, or as (2) any one of the detection signals (each detection signal is detected as an electrical signal from the respective detection means $19_a$ and $19_b$) of speed and position from the electromechanical conversion means 16. The former servo system (1) constitutes what is called a full-closed loop, and the latter servo system (2) constitutes what is called a semi-closed loop. It is common in the case of conventional servo amplifiers to feed back real values of the output data to the input summing point of the servo motor driving means 15. However, in the present invention it is also possible without any troubles to adopt the semi-closed loop system in which real values of position or speed is detected from the reduction gear train 18, and then fed back to the summing point, because the servo-torque amplifier 14 by itself is provided with the mechanical feedback means 140. As seen from the foregoing, since either the full-closed loop or the semi-closed loop may be used for the precise control of the system, the muscle strength training apparatus according to the invention has various advantages in circuit design.

The feedback signal is fed back through the mode changeover circuit 25 to one of the input terminals of the input summing point of the servo motor driving means 15, and to the other terminal a desired value corresponding to the Isotonic, Isokinetic or Isometric mode is inputted through a setting device 23. The setting device 23 may be constructed either as an interior setting device $23_a$ which is installed on the panel of the apparatus or as an exterior setting device $23_b$ which is located remotely from the apparatus and controlled by a micro computer. The feedback signal detected by the detection means $9_a$, $9_b$, $9_c$, $19_a$ or $19_b$ may be fed through the mode changeover circuit 25 to a recording machine 21 such as a printer or recorder or to a display device 22, where the feedback signal is recorded or displayed for estimation purpose. This enables the person to have a direct reading of the estimated value and also to have an automatic recording if desired. Moreover, the person under measurement can grasp his present muscle strength capabilities and training results so that he can set a goal or hope to his rehabilitation. It may be possible to provide a protection circuit 24 adapted to display a warning on the display 22 in order to give the person under measurement or exercising a warning of danger.

The operation of the muscle strength training and measuring apparatus thus constructed will now be described.

First, upon selecting with the mode changeover circuit 25 any one of the modes, i.e., position (angle), speed and torque (force), a desired value as a control signal for the particular mode is then fed to the input summing point of the servo motor driving means 15 from either the interior setting device $23_a$ or exterior setting device $23_b$. The servo-torque amplifier operates to reach an equilibrium condition such that the desired values of the setting device ($23_a$, $23_b$) equals to that of the selected mode from either the detection means $9_a$, $9_b$ and $9_c$ at the output shaft of the rotary actuator 13 or the detection means $19_a$ and $19_b$ of the gear train. Since the operational response of the servo-torque amplifier is sufficiently quicker than the movement applied by the person under measurement to the load applying means 2 such as a handle, pedal or the like, the servo-torque amplifier can hold the desired value at any time. Further, the actual value of each mode is displayed on the display device 22 or is recorded on the recording machine 21, so that the actual value can be monitored with high accuracy thus providing a muscle strength training apparatus as well as a muscle strength measuring apparatus.

## APPLICABILITY TO INDUSTRIES

As described above, the muscle strength training and measuring apparatus according to the invention uses a servo-torque amplifier having by itself a mechanical feedback with a large inertia-torque ratio and a quick response, so that a gear train can be dispensed with for matching with a pedal or handle to which a load is applied. Accordingly, it is easy to manufacture such a muscle strength training and measuring apparatus having various functions therein, and a remarkable improvement is made upon the accuracy and operation. Moreover, a direct reading and automatic recording of the actual value is readily available. The muscle strength training and measuring apparatus according to the invention can function as a multi-functional apparatus for use in Isotonic, Isokinetic or Isometric mode.

CLAIMS

1. A muscle strength training and measuring apparatus which comprises:

a servo-torque amplifier comprising a control valve having an input shaft and an actuator having an output shaft, said servo-torque amplifier having therein a mechanical feedback which controls the moving of said input shaft;

an electromechanical conversion means for driving said input shaft of the servo-torque amplifier;

an electric amplifier means connected at the preceding stage of said electromechanical conversion means and having a summing point to which a desired value and an actual value for controlling the whole servo system is applied; and

a means for applying load from the person exercising or under measurement, such as a handle, pedal or the like, said load applying means being coupled to said output shaft of the actuator.

2. A muscle strength training and measuring apparatus as defined in claim 1, wherein said electromechanical conversion means comprises a gear train connected to said input shaft of the control valve and a servo motor which drives said gear train, and wherein said electric amplifier means is a servo motor driving means which drives said servo motor.

3. A muscle strength training and measuring apparatus as

defined in claim 1 or claim 2, wherein a real value to be inputted to the summing point of said electric amplifier means is any one of signal values of torque, speed and angle at said servo system.

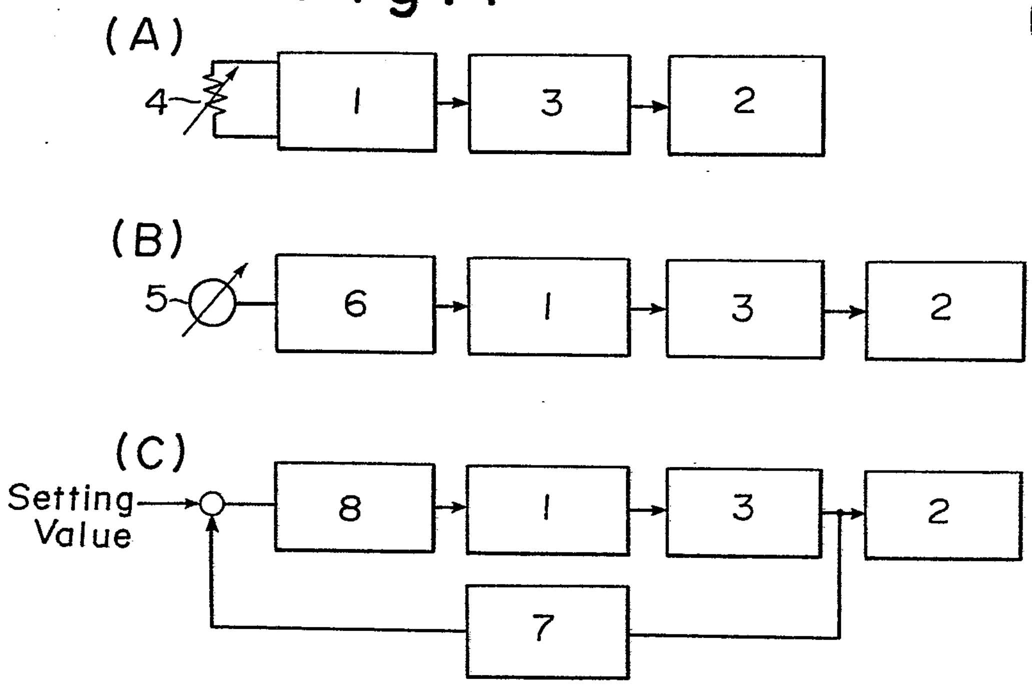
4. A muscle strength training and measuring apparatus as defined in claim 3, wherein a real value to be inputted to the summing point of said electric amplifier means is any one of signal values of torque, speed and angle at the output shaft of the actuator of said servo system.

5. A muscle strength training and measuring apparatus as defined in claim 3, wherein a real value to be inputted to the summing point of said electric amplifier means is any one of signal values of speed and angle detected from said electromechanical conversion means of the servo system.

6. A muscle strength training and measuring apparatus as defined in claim 1 or claim 2, wherein said real value is inputted to said summing point of the electric amplifier means selectively through a mode changeover circuit.

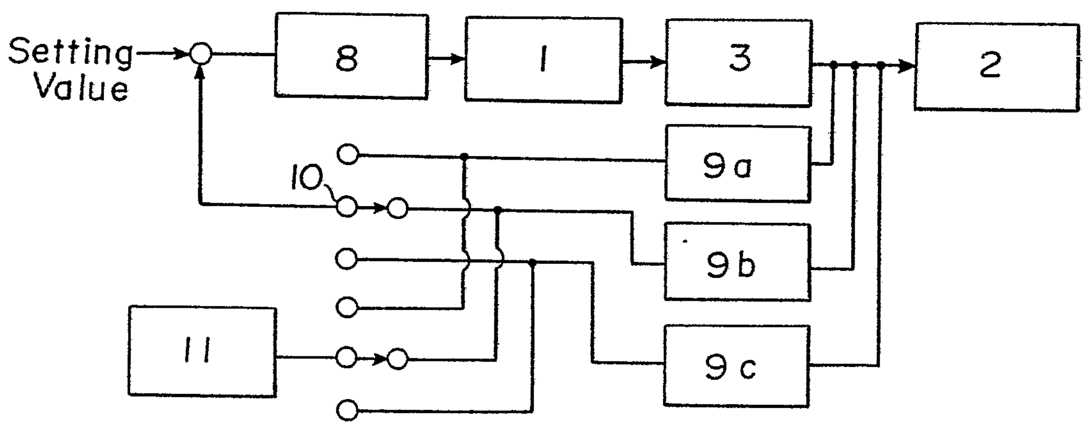
7. A muscle strength training and measuring apparatus as defined in claim 1 or claim 2, further comprising a display device or a recording machine for displaying and recording said real value.

# Fig. 1



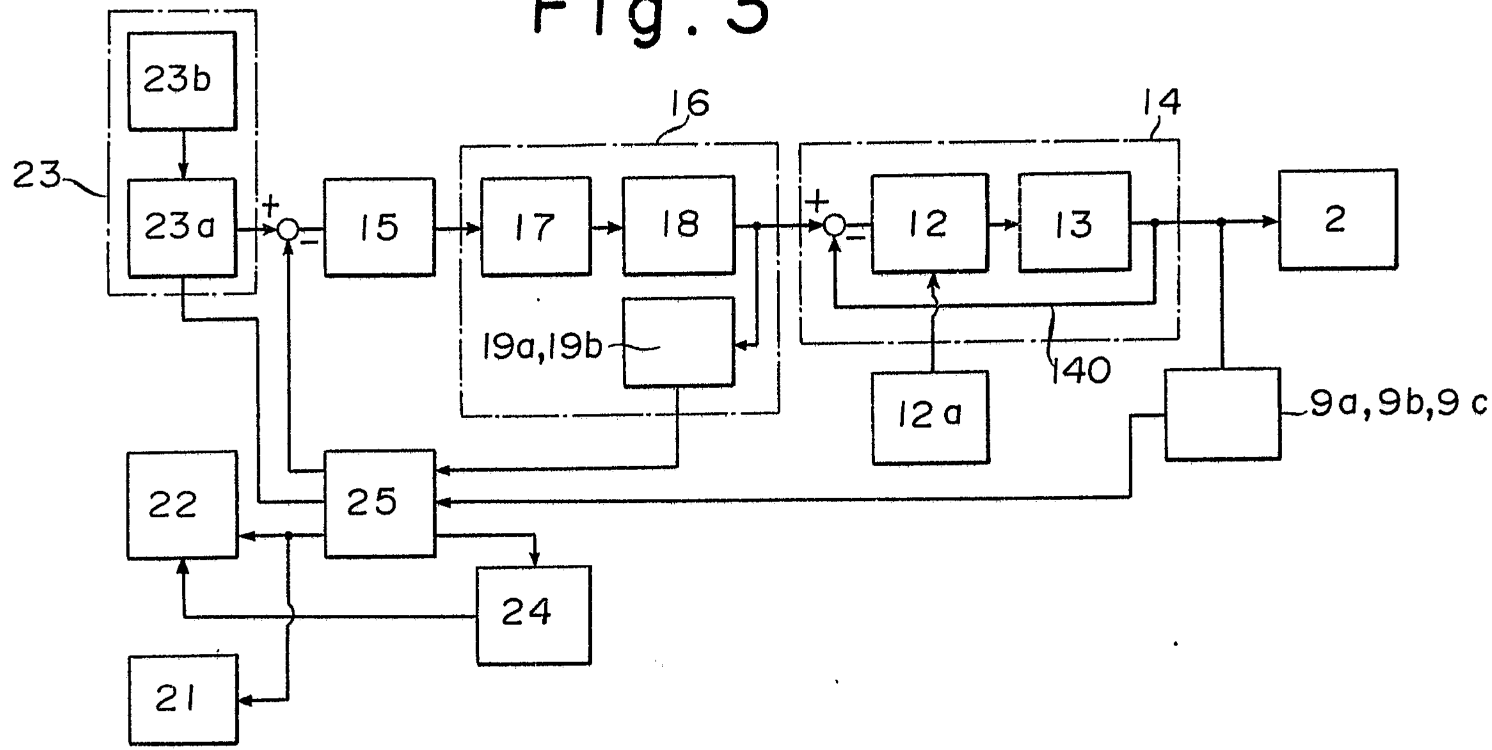

1 Permanent Magnet Type D.C. Motor
2 Handle, Pedal, etc.
3 Gear Train
4 Variable Resistor
5 Torque Setting Means
6 Constant Current Source
7 Torque Detecting Means
8 Servo Amplifier

# Fig. 2




9a Speed Detecting Means
9b Angle Detecting Means
9c Torque Detecting Means
11 Monitor

Fig. 3




21 Printer or Recorder
22 Display device
23a Interior Setting Device
23b Exterior Setting Device
24 Protection Circuit
25 Mode Changeover Circuit

2 Handle, Pedal, etc.
9a,9b,9c Detecting Means
12a Hydraulic Resources
12 Control Valve
13 Rotary Actuator
15 Servo Motor Driving Means
17 Direct Current Servo Motor
18 Gear Train
19a,19b Detecting Means

# INTERNATIONAL SEARCH REPORT

International Application No PCT/JP81/00116

0060302

**I. CLASSIFICATION OF SUBJECT MATTER** (if several classification symbols apply, indicate all)

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl$^3$ A63B23/04, A63B21/24, A63B21/00

**II. FIELDS SEARCHED**

Minimum Documentation Searched [4]

| Classification System | Classification Symbols |
|---|---|
| I P C | A63B23/04, A63B21/24, A63B21/00 |

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

Jitsuyo Shinan Koho

Kokai Jitsuyo Shinan Koho 1971 - 1980

**III. DOCUMENTS CONSIDERED TO BE RELEVANT** [14]

| Category * | Citation of Document, [16] with indication, where appropriate, of the relevant passages [17] | Relevant to Claim No. [18] |
|---|---|---|
| X | JP, A, 54-143349, 1979-11-8 | 1 - 7 |
| X | JP, A, 50-127733, 1975-10-8 | 1 - 7 |
| X | JP, A, 50-65333, 1975-6-3 | 2 - 6 |
| A | JP, A, 48-68328, 1973-9-18 | 1 |
| A | JP, U, 52-106355, 1977-8-12 | 7 |
| A | JP, A, 48-30535, 1973-4-21 | 1 |

* Special categories of cited documents: [15]

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"P" document published prior to the international filing date but on or after the priority date claimed

"T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention

"X" document of particular relevance

**IV. CERTIFICATION**

| Date of the Actual Completion of the International Search [2] | Date of Mailing of this International Search Report [2] |
|---|---|
| August 24, 1981 (24.08.81) | September 14, 1981 (14.09.81) |
| **International Searching Authority [1]** | **Signature of Authorized Officer [20]** |
| Japanese Patent Office | |