May 12, 1970 G. IFE ET AL 3,511,135

VARIABLE SPEED HYDRAULIC MOTORS

Filed Oct. 22, 1968 4 Sheets-Sheet 1

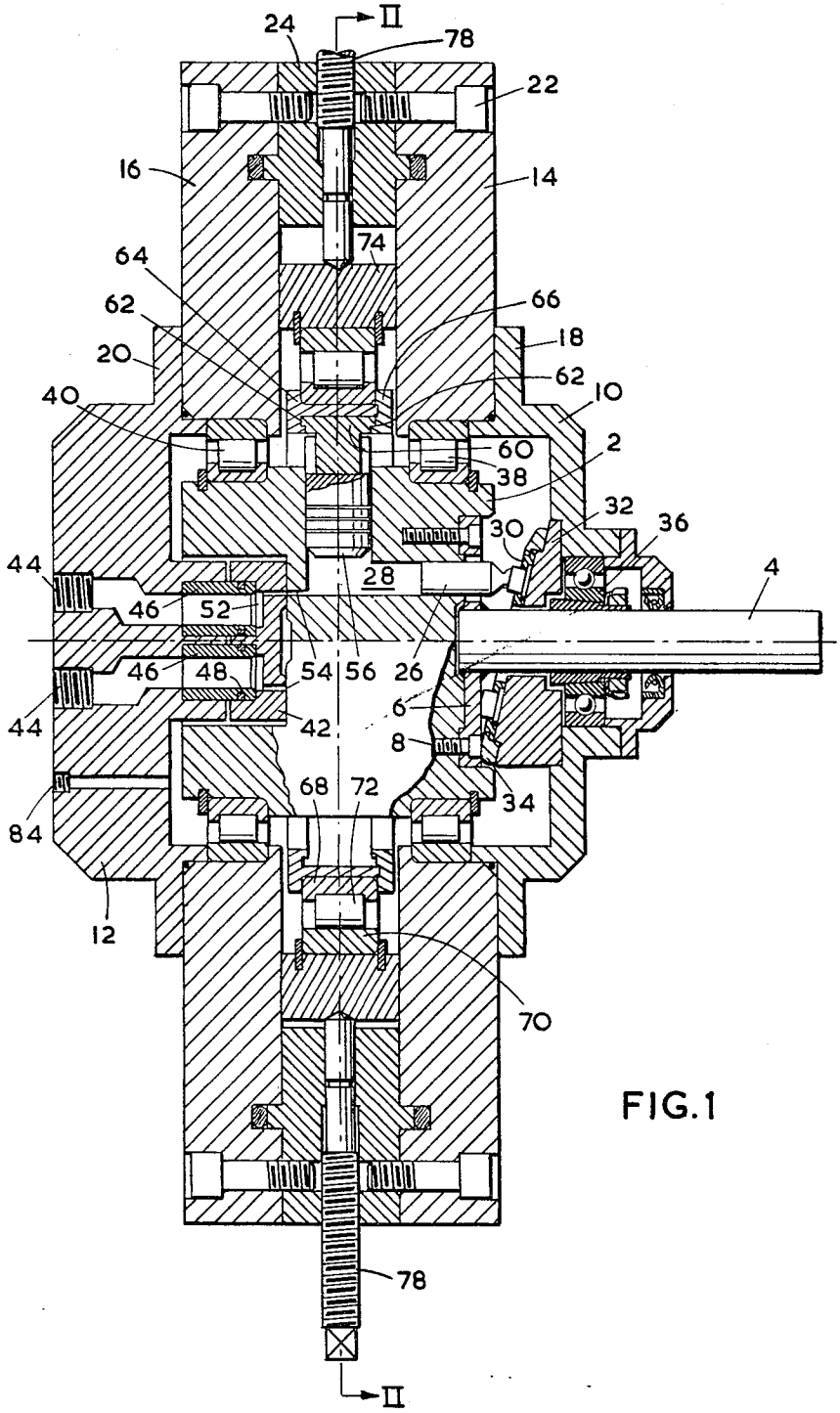


FIG.1

VARIABLE SPEED HYDRAULIC MOTORS

Filed Oct. 22, 1968 4 Sheets-Sheet 2

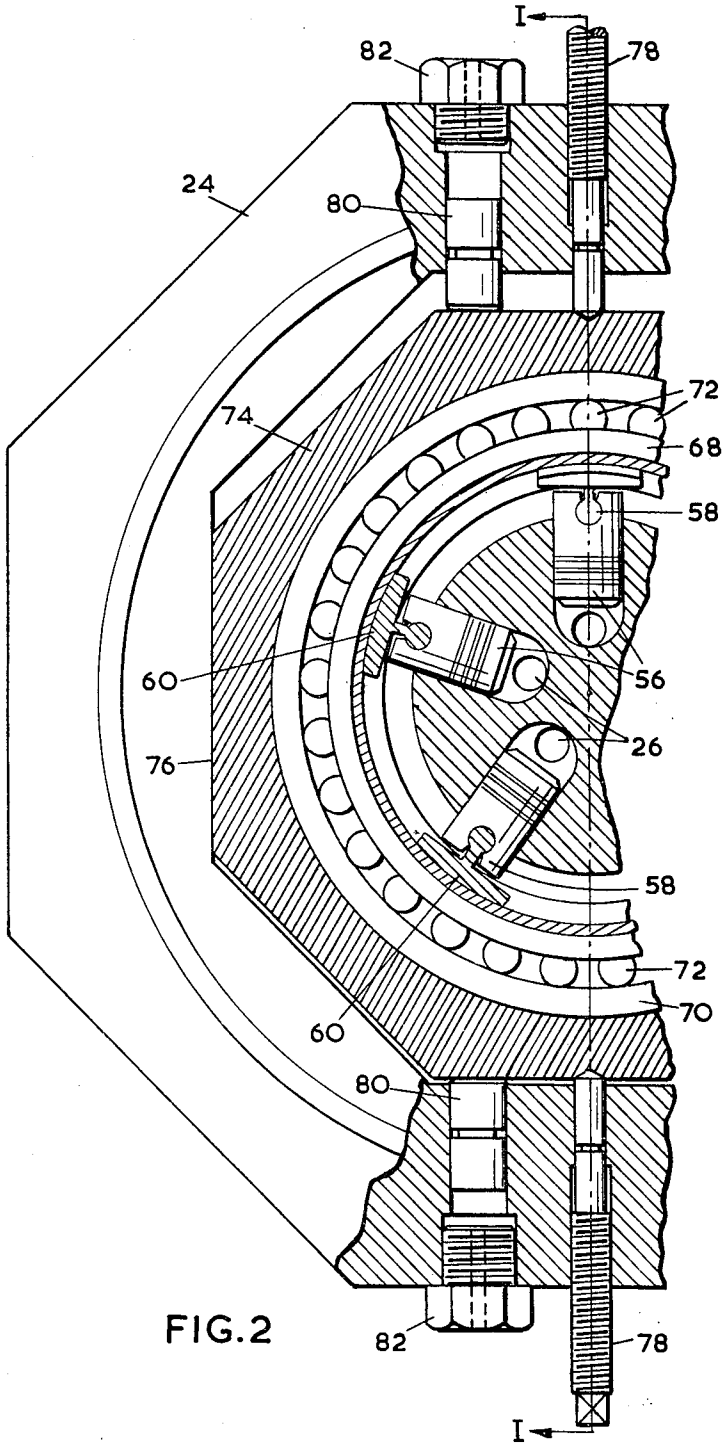


FIG.2

VARIABLE SPEED HYDRAULIC MOTORS

Filed Oct. 22, 1968 4 Sheets-Sheet 3

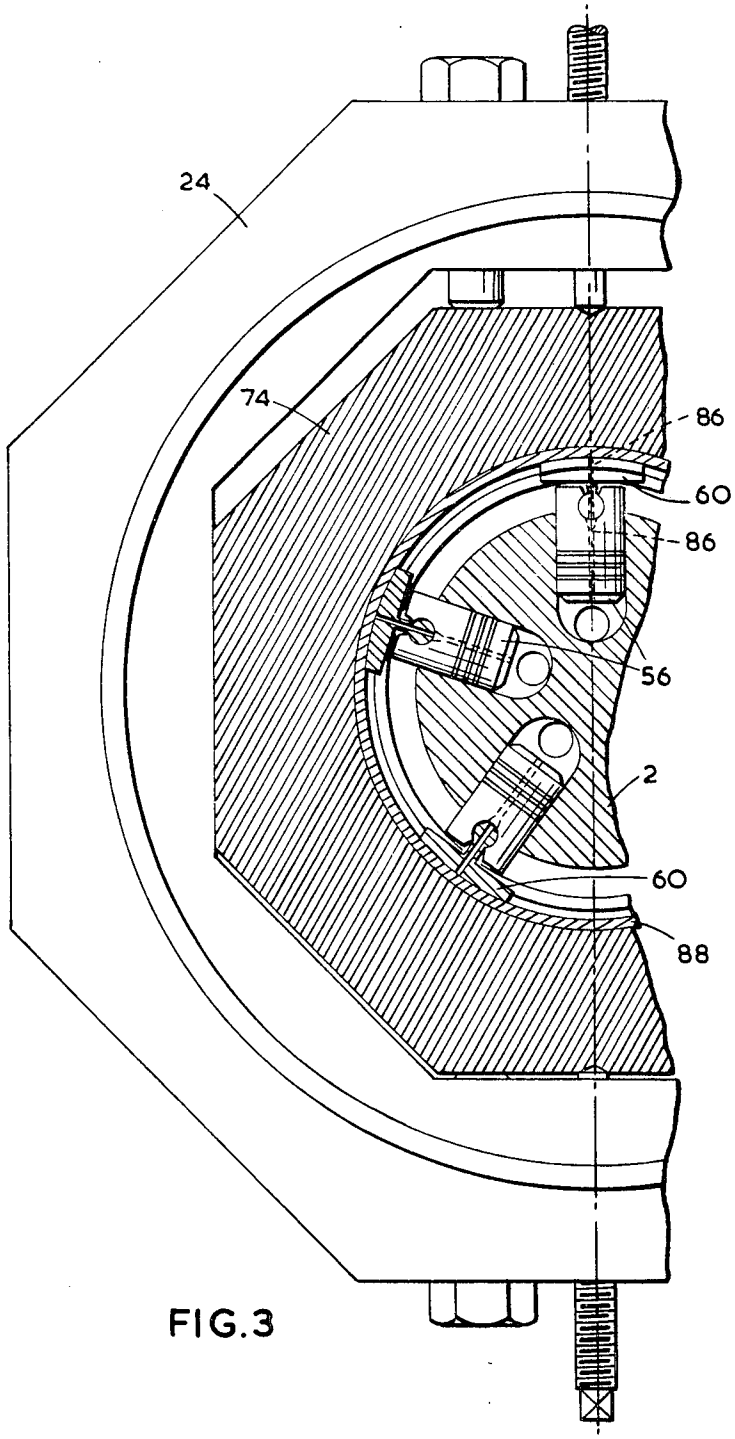


FIG.3

VARIABLE SPEED HYDRAULIC MOTORS

Filed Oct. 22, 1968 4 Sheets-Sheet 4

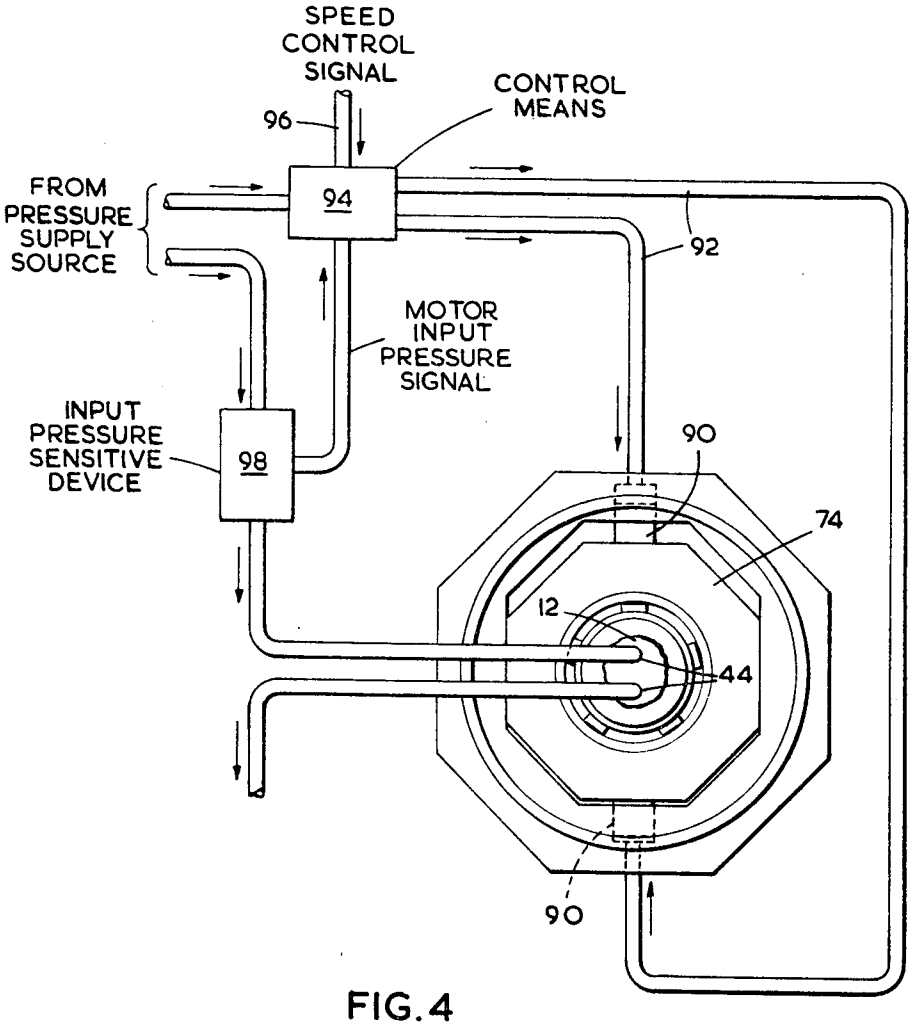


FIG. 4

United States Patent Office 3,511,135
Patented May 12, 1970

3,511,135

VARIABLE SPEED HYDRAULIC MOTORS

George Ife and John Peter Jackson, Netherton, England, assignors to The English Electric Company, Limited, London, England, a British company

Filed Oct. 22, 1968, Ser. No. 769,558
Claims priority, application Great Britain, Oct. 25, 1967, 48,494/67
Int. Cl. F01b 3/00, 15/00
U.S. Cl. 91—483 6 Claims

ABSTRACT OF THE DISCLOSURE

This invention is concerned with a variable-speed hydraulic motor having axial and radial pistons arranged in pairs with intercommunicating cylinders. In the preferred arrangement the axial pistons co-operate with a stationary swashplate of fixed inclination, while the radial pistons co-operate with a surrounding circular eccentric cam of which the eccentricity can be varied to vary the motor speed.

This invention is concerned with variable-speed hydraulic motors having pistons of which the displacement is adjustable to vary the motor speed.

A motor according to this invention has a rotary cylinder barrel which is connected to an output shaft and which contains substantially axially extending pistons which drive the barrel by engagement with a stationary inclined swashplate, the axial pistons being housed in cylinders in the barrel each of which communicates with a radial cylinder containing a radially movable piston co-operating with a surrounding eccentric cam which causes the radial pistons to move in and out during each revolution of the cylinder barrel. The displacement of the motor (and consequently the speed) is preferably varied by varying the degree of eccentricity of the cam; alternatively it could be varied by varying the inclination of the swashplate.

The cam is preferably circular and may, for example, contain a stationary outer race which surrounds a rotary inner race engaged by the radial pistons, with balls or rollers interposed at circumferential intervals between the inner and outer races.

A motor according to this invention can be designed for optimum efficiency operation at its highest speed with the cam set at zero eccentricity, so that the cylinder barrel is driven purely by the axial pistons. Increasing the eccentricity of the cam in the appropriate direction then increases the displacement of each pair of axial and radial pistons and therefore decreases the motor speed. A motor according to this invention can be readily designed to operate at a constant flow and at a constant pressure, and can be arranged to be powered by a relatively simple and inexpensive fixed-capacity pump such as a gear pump (assuming that the pump is driven at a fixed speed).

An example of a motor according to this invention is shown in the accompanying drawings. In these drawings:

FIG. 1 is an axial section of the motor taken on the line I—I in FIG. 2;

FIG. 2 is a transverse section of the motor taken on the line II—II in FIG. 1;

FIG. 3 is a transverse section of a modified form of the motor shown in FIGS. 1 and 2; and

FIG. 4 shows diagrammatically a control arrangement for the motor or the modified form of motor.

The motor includes a cylinder barrel **2** which is connected to an output shaft **4** via a circular plate **6** which is welded to the shaft and is secured to the cylinder barrel by bolts **8**. The cylinder barrel is housed within a

casing defined by end parts **10** and **12** secured to approximately octagonal plates **14** and **16** respectively by bolts (not shown) passing through flanges **18** and **20**, the plates **14** and **16** being secured by bolts **22** to opposite sides of a further octagonal plate **24**.

Five circumferentially spaced axial pistons **26** are slidably housed in cylinders **28** in the cylinder barrel and each terminates at its outer end in a part-spherical part engaging a slipper **30** which in turn bears on a fixed inclined swashplate **32**; the slippers are held against the swashplate by a ring **34**. It will be appreciated that the pistons **26** co-operate with the swashplate **32** to drive the cylinder barrel **2** in the manner of a conventional swashplate motor.

The shaft **4** is carried by a ball bearing **36** in the housing end part **10**, while the cylinder barrel itself is mounted within roller bearings **38** and **40** within the octagonal plates **14** and **16**. The bearing **38** may, however, be omitted.

Hydraulic fluid is delivered to and from the cylinders **28** via a stationary valve plate **42** which bears against the cylinder barrel, being held firmly in contact with the cylinder barrel by fluid pressure. The valve plate communicates with external inlet and outlet ports **44** via short metal sleeves **46** each of which engages with one end in the valve plate and with its other end in the end part **12** of the motor casing. Each sleeve **46** is a tight fit in the casing part **12** but is a clearance fit in the valve plate so that the valve plate can move universally to a slight degree with respect to the sleeves **46**; this enables the valve plate to remain in firm contact with the cylinder barrel. O-rings **48** maintain a seal between the sleeves **46** and the valve plate.

The valve plate **42** delivers hydraulic fluid to and from the cylinders **28** through two kidney-shaped ports **50** and **52** which are mirror images of one another on opposite sides of a central plate passing through the pump axis. The ports **50** and **52** communicate with the cylinders **28** through narrow passageways **54**, of which there is one for each cylinder.

There may be two inlet sleeves **46** in parallel and two outlet sleeves.

In circumferential alignment with each cylinder **28** there is a radial cylinder containing a radial piston **56**. Each piston **56** is pivoted to a slipper **60** by means of a part-cylindrical projection **58** on the slipper (see FIG. 2) which seats in a corresponding part-cylindrical recess in the end of the piston. Each slipper has flanges **62** on opposite sides (see FIG. 1) by which it is trapped in a composite ring formed by ring parts **64** and **66** which are secured together by screws (not shown). The flanges also project laterally as viewed in FIG. 2. The ring parts **64** and **66** lie immediately within an inner race **68** which is surrounded by an outer race **70** with interposed trapped rollers **72**. The outer race **70** remains stationary while the inner race **68** rotates with the cylinder barrel **2**. Slight circumferential sliding of each slipper with respect to the inner race **68** must occur during use, and to assist this movement the convex outer surfaces of each slipper may have a coating, for example of silver, to reduce the coefficient of friction.

The outer race **70** is housed within a cam member **74** which has a circular interior and an octagonal exterior as shown in FIG. 2. Two opposite facets **76** of the octagonal exterior serve as guide faces co-operating with corresponding facets of the inner surface of the plate **24**. The facets **76** ensure that the cam member **74** can move only in the direction of the section line I—I shown in FIG. 2.

In use, in order to obtain the maximum speed, the cam member **74** is set by means of locating screw-threaded

spindles **78** at zero eccentricity, that is to say with the inner surface of the cam member coaxial with the cylinder barrel, so that no reciprocation of the radial pistons takes place, the motor displacement then being provided purely by the axial pistons **26**. In order to reduce the motor speed, the cam member **74** is moved in an upward direction so that the action of the cam on the radial pistons is to move each radial piston radially outwards as its corresponding axial piston moves axially out of the cylinder barrel. The speed reduces as the degree of eccentricity of the cam member **74** increases. A motor according to this invention can readily be arranged to have a speed rato (i.e. a ratio of maximum to minimum speed) of up to 10:1 this facilitates use in various applications, for example various machine carriage or tool drives, and coiler drives, for which the drum speed may need to change considerably as winding progresses in order to keep substantially constant the speed or tension of the material being wound.

It will be appreciated that the degree of eccentricity of the cam member **74** is varied by screwing in one of the spindles **78** and screwing out the other. As an alternative, the cam member position may be controlled by means of oppositely disposed pistons **80**, of which there are two on each side on opposite sides of the spindles **78**, by supplying controlled high-pressure hydraulic fluid to the pistons through unions **82**; in this way the motor speed can be made subject to remote control, the spindles **78** being screwed out so as to be inoperative.

Lubricating oil for the cylinder barrel bearings is injected through a port **84**.

Various modifications of the motor are possible. For example, as shown in the FIG. 3 the outer bearing faces of the slippers **60** may be arranged as hydrostatic bearings, for example with oil directed to the bearing interface through bores **86** extending through the pistons **56** and slippers **60**; in other words the oil supply for the hydrostatic bearing surfaces is obtained from the cylinders containing the pistons **56**. In this case the roller bearing constituted by the races **68** and **70** and rollers **72** are omitted, and the slippers bear directly on the inner cylindrical surface of a lining sleeve **88** in the cam member **74**.

The cam eccentricity may be controlled purely hydraulically, for example as shown in FIG. 4 by means of two pistons **90** (like the pistons **80** but larger) lying diametrically on opposite sides of the cam **74**. In this case the hydraulic circuit **92** controlling the cam pistons **90** may include means **94** for overriding the control signal (supplied at **96**) in the event of the motor failing to start in a high-speed setting (that is to say, with the cam **74** set at zero eccentricity or nearly so), so as to move the cam and thus provide an increased starting torque. For example, the means **94** for controlling the pressure of fluid supplied to the cam pistons **90** may be subject to control by means of a device **98** sensitive to the pressure of the driving fluid at the motor input **44**; in the absence of the pressure drop which occurs when the driving fluid is flowing through the motor, the fluid pressure would be at the full supply value, and the arrangement is such

that the presence of the full supply pressure in say a servo-valve constituting the means **94** overrides the control signal (supplied at **96**) to the cam pistons and moves the cam upwards as viewed in the drawings.

We claim:

1. A variable-speed hydraulic motor comprising an output shaft; a rotary cylinder barrel connected to the output shaft; means defining a plurality of circumferentially spaced axial cylinders in the cylinder barrel; a plurality of axial pistons which are slidable in the axial cylinders and project out of one end of the cylinder barrel; an inclined swashplate engageable with the axial pistons to cause each axial piston to move into and out of the cylinder barrel during each revolution of the cylinder barrel; means defining a plurality of radial cylinders in the cylinder barrel, each communicating with one of the axial cylinders and each containing a radial piston which projects radially out of the cylinder barrel; an eccentric cam which surrounds the cylinder barrel and causes each radial piston to move in and out in phase with the associated axial piston; means for delivering hydraulic fluid to and from the cylinders; and means for varying the stroke performed during each revolution by at least one of the two sets of pistons.

2. A motor according to claim **1** in which the stroke of the radial pistons is variable by varying the degree of eccentricity of the cam.

3. A motor according to claim **2** in which the degree of eccentricity of the cam is controlled by hydraulic control pistons bearing on opposite sides of the cam, the cam being laterally movable under the control of the hydraulic control pistons.

4. A motor according to any of claims **1** to **3** in which hydraulic fluid for powering the motor is fed to and from the cylinders through a stationary valve plate at one end of the cylinder barrel.

5. A motor according to claim **2** or claim **3** in which the cam surrounding the cylinder barrel is circular and contains a stationary outer race which surrounds a rotary inner race engaged by the radial pistons, with balls or rollers interposed at circumferential intervals between the inner and outer races.

6. A motor according to claim **1** in which the radial pistons have slippers at their outer ends through which they slidably engage the cam, the outer bearing surfaces of the slippers being formed as hydrostatic bearings.

References Cited

UNITED STATES PATENTS

1,987,781	1/1935	Maw	91—205
2,678,536	5/1954	Morgan	91—175
2,989,005	6/1961	Gardineer	91—205
3,081,708	3/1963	Nyman et al.	91—205

PAUL E. MASLOUSKY, Primary Examiner

U.S. Cl. X.R.

91—176, 245, 497, 499