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NASA CR109452

A JETTISON FITTING FOR

MULTIPLE BALLOON SYSTEMS

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October 1969

CASE FILE
COPY

NASA-185

National Center for Atmospheric Research
Boulder, Colorado

The National Center for Atmospheric Research is
sponsored by the National Science Foundation.

PREFACE

The work reported here was done by the Scientific Balloon Facility of the National Center for Atmospheric Research (NCAR) as part of a continuing R & D effort to extend the capabilities of scientific ballooning. NCAR, operated by the University Corporation for Atmospheric Research (UCAR), a private, university controlled, nonprofit organization, sponsored and principally funded by the National Science Foundation, provided the staff time. Hardware expenditures were funded by the National Aeronautics and Space Administration through NASA contract number NASr-185. This report constitutes the final report under the NASA contract.

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SUMMARY

Requirements were determined for a balloon coupling, or transfer fitting, which allows the balloons of a multiple balloon system to be separated in flight, thereby enhancing system performance. Detail prototype design was completed and the major subassembly fabricated. The concept and design are described by reference to the design layout and photographs of the prototype hardware.

INTRODUCTION

Multiple balloon systems which consist of two or more balloons of increasing size, each connected to the next by a gas transfer passage, have up to this time been inseparably connected on the ground before inflation of the smallest balloon. During ascent as the expanding gas fills each succeedingly larger balloon the smaller balloons carry decreasing proportions of the total load. At some altitude determined by the volume and weight of the smaller balloon it is no longer buoyant, and it becomes a dead weight which the larger balloon must carry. A device allowing the smaller balloon to be jettisoned before it becomes a load on the larger balloon will increase the ultimate altitude of the flight or increase the payload capacity.

PERFORMANCE REQUIREMENTS

A device which fills the need described above must also fit in with the mode of operation of the field crew and with established flight procedures. It should not make the operation less efficient while providing the unique jettisoning feature. The device must meet at least the following specifications.

1. Allow normal transfer of gas reliably.
2. Be disconnectable reliably in flight under all possible loads from zero to maximum.
3. Allow jettisoning at a predetermined load (altitude).
4. Close the transfer passage in the larger balloon immediately and reliably when the smaller balloon is jettisoned.

5. Provide for normal valving of the larger balloon after jettisoning the smaller balloon.

One additional feature would be desirable but not mandatory:

6. Allow quick, simple, reliable attachment of the larger balloon to the base of the inflated smaller balloon just prior to launch.

7. If feature 6 is included, the device must also provide for sealing the smaller balloon to prevent air from being forced in during inflation.

CONFIGURATION

The requirements that the transfer hole be closed after jettisoning and that normal valving of the larger balloon be allowed call for a valve somewhere in the device which rules out the simplest method of transfer, the open duct. Referring to photos of the prototype hardware, where appropriate, the general solutions to each requirement follow:

1. An open duct is the simplest method of allowing transfer of gas between the two balloons. But since there must be a valve in the duct the more reliable method of opening the duct is to use the available force between the two balloons to actuate the valve. Sufficient force is always available when the valve must be open and there need be no external commands to apply the force. When the smaller balloon must be jettisoned the relative force between the two balloons has become small and the valve will close. There can be no human errors or command failures causing the valve to be actuated either open or closed

in the wrong sequence.

2. Reliable jettisoning can best be accomplished by the use of proven hardware in simple arrangements. Mechanical disconnect is accomplished with a single-point aircraft-qualified pyrotechnic separator. The separator operates under any load from zero to maximum rated load and does not depend on loading for disengagement. The fabric gas passage tube is separated either by mild detonating fuze, explosive cord or Pyrofuze.

3. If disconnecting at a pre-determined load is desired, provision is made for load-cell monitoring of the relative force between the two balloons. The load cell may be omitted if force measurement is not needed. A single point mechanical connection allows the simplest method of force measurement. Only a single load cell is required and no complicated calibration or summing of forces is required. The single connection point and the entire valve assembly are shown in the photograph, Fig. 3.

4. The transfer passage is closed immediately and simply when the smaller balloon is jettisoned by spring loading the valve to close and clamp when the external force from the smaller balloon is removed.

5. The valve closing the transfer passage remains with the larger balloon and occupies the passage in the top fitting normally occupied by the helium valve. On command it can be opened or closed in the usual way, Fig. 3.

6. A quick disconnect feature is included with the device to allow the larger balloon to be attached to the inflated (or uninflated) smaller balloon by a simple 15° twist and tightening 12 bolts. Figures

3, 6, and 8.

7. The valve which stays with the main balloon after jettisoning the smaller balloon is initially assembled to the smaller balloon. Since there is no force applied to the valve it is spring loaded in the closed position and seals the base of the smaller balloon from ambient air during inflation.

Since a single point mechanical connection is required and the valve must be actuated by the force applied at this point, several otherwise desirable types of valves are difficult to adapt to the requirement. Flapper valves, iris valves, or other types whose motion is rotary would require a more complex force transmission arrangement than the poppet valve. A poppet valve is used for simplicity since its movement is colinear with the applied force and the mechanical connection is easily arranged in the center of the valve. The poppet valve does, however, constitute a major flow obstruction during gas transfer. Since this obstruction can be minimized by proper design it is felt that the trade-off between obstruction and mechanical simplicity definitely favors the poppet valve.

Clamping pressure of the valve on its seat must be carefully controlled for reliable sealing. The larger the valve the greater the seal area with a consequent increase in required clamping force. To allow the use of lighter components and a low-force duty cycle for the actuating motor a clamping linkage is used to multiply the normal actuating force during the final portion of the closing cycle, Fig. 11.

Since the closing force is applied by a spring through the actuating linkage a special constant-force spring is used to eliminate the increasing force gradient that would be characteristic of the use of an extension spring, Fig. 12. The resulting force gradient at the poppet valve is essentially flat throughout its travel except near closing where it increases by the multiplying effect of the linkage, Fig. 1.

Duty cycle of the valve motor is kept low by driving the entire spring carrier throughout the travel range of the valve. Except for clamping, when the motor must open a gap in the spring carrier to apply full spring force to the actuating linkage, the motor operates under a light load.

Full load of the buoyant force is carried directly from the single point attachment in the center of the poppet valve outward to the balloon fitting through folding links. These load-carrying links are arranged as parallelograms to assure straight-line motion of the valve (upper links, Fig. 11). Actuating links are not subjected to the buoyant force (lower links, Fig. 11).

The portion of the assembly attached to the base of the smaller balloon serves as an attachment point for ground equipment restraining the buoyant force prior to launch. (No prototype of this assembly has been built.) It provides two inflation fittings with a plenum chamber and diffuser for inflation through the base of the balloon. A cable harness attached directly to the end fitting of the balloon carries the lift forces into the single point connection at the load cell or load separator. The fabric transfer passage is banded around the fitting.

PROTOTYPE HARDWARE

Prototype hardware was designed to fit standard end fittings in a tandem balloon system with 1,500 pounds gross lift. All load carrying members were sized for a safety factor of 10 and aircraft quality high strength fasteners were specified throughout for weight savings and reliability.

Valve sealing (gasket) pressure is 88 psi using a spring force of 45 pounds, force multiplication of 2.2 and valve sealing area of 1.13 square inches.

Valve travel is 3.0 inches when opened by either lift force or motor and minimum gas flow area is 104 sq. in. Opening and closing time is 10 seconds when motor driven.

Force-displacement characteristic of the valve is shown in Fig. 1 for both calculated and actual conditions. If opening force drops below 0.9 times the spring force of 45 pounds, the valve will close positively, preventing hunting or bouncing of the valve. This action may be used as an automatic jettisoning method to back up external command. If lift force drops low enough to close the valve, a switch can sense valve closure and actuate the jettisoning circuit while the launch balloon still has enough free lift to float free of the ascending larger balloon.

The photographs, Figs. 3 through 12, illustrate the completed prototype hardware in various stages of assembly. Only the valve assembly is completed. The inflation assembly which attaches to the base of the launch balloon has not been built but is a straightforward fabrication which should cause no difficulties. A reduced size copy of the design layout including both major assemblies is included as Fig. 2.

TESTS

Some sub-assembly tests have been completed, such as force/ displacement and general function, both by external actuation and by motor driving.

Most major testing remains to be done including gas flow/pressure drop, thermal-vacuum and flight testing.

FLIGHT HARDWARE

Scale-ups for actual flight hardware should present no problem provided the length ratios of linkages are preserved, the valve sealing pressure/clamping force is calculated and appropriate adjustments made in spring force and motor characteristics. Direct scale-up is discouraged; all pertinent stress and flow calculations should be made for each new size and load rating.

Computer programs BTOGLE and DTOGLE were developed to calculate linkage geometry and to evaluate changes in linkage length ratios. The programs and instructions for their use will be made available on request.

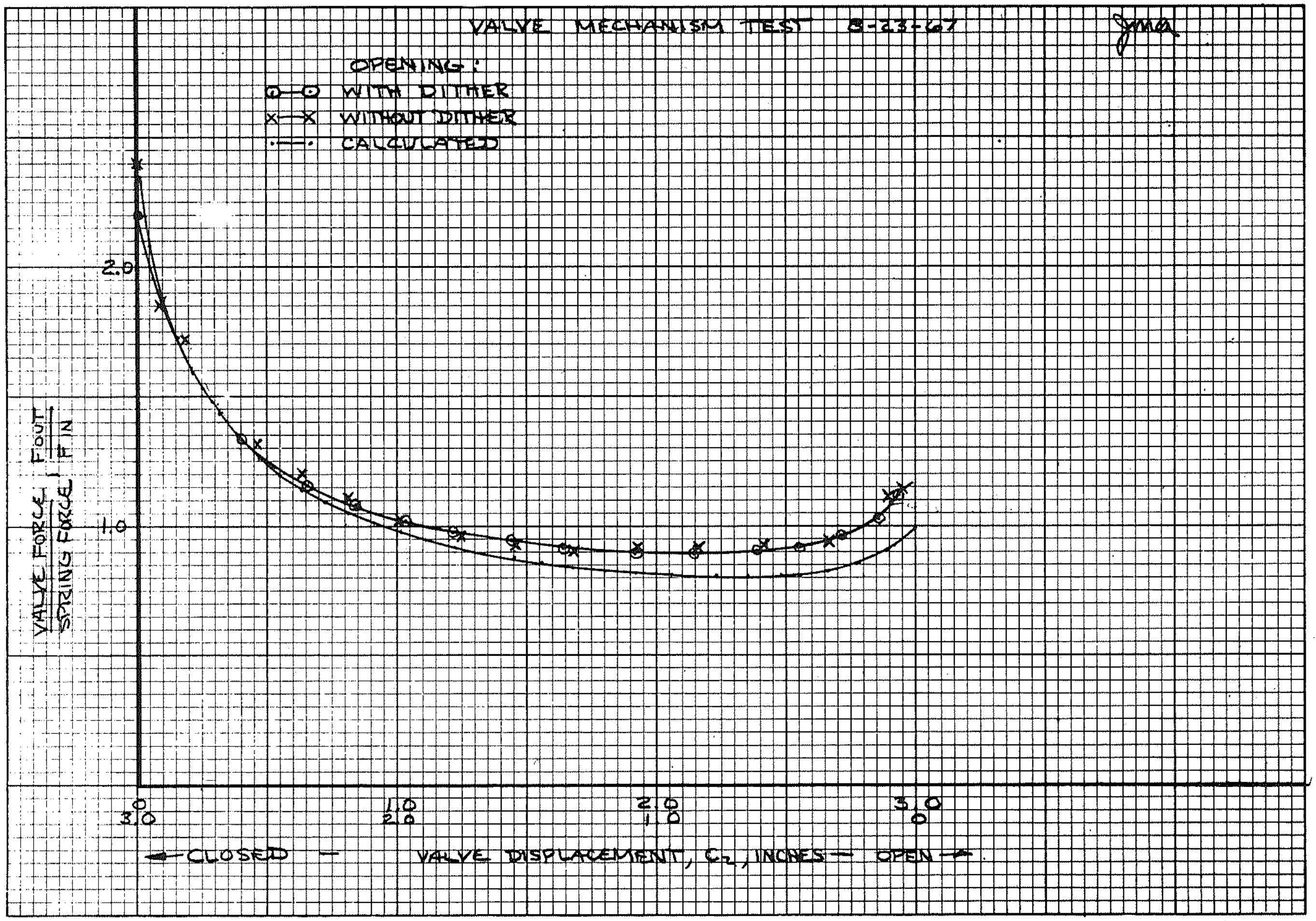

Figure 1. Valve Force vs Valve Displacement

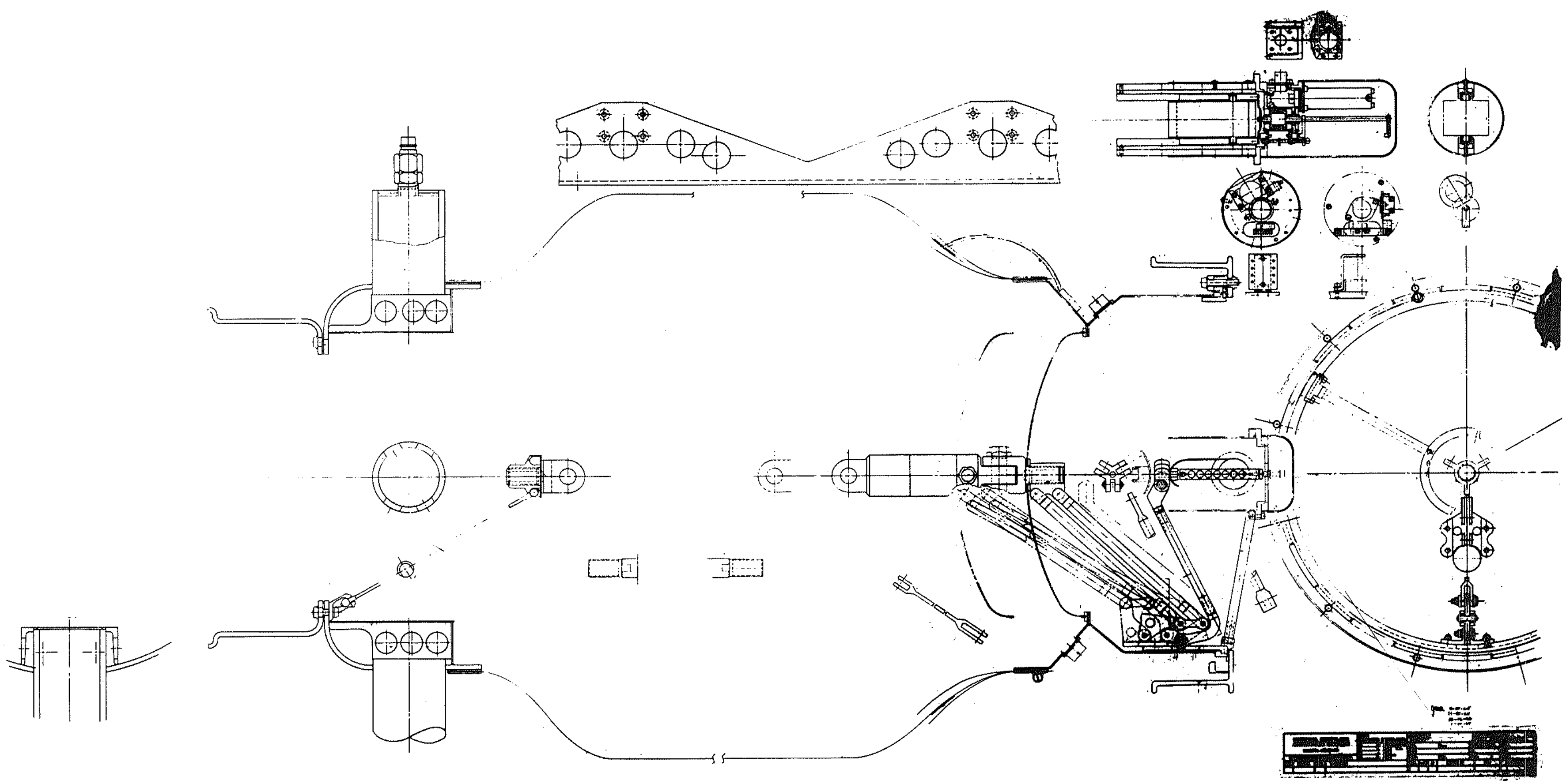

Figure 2. Design Layout

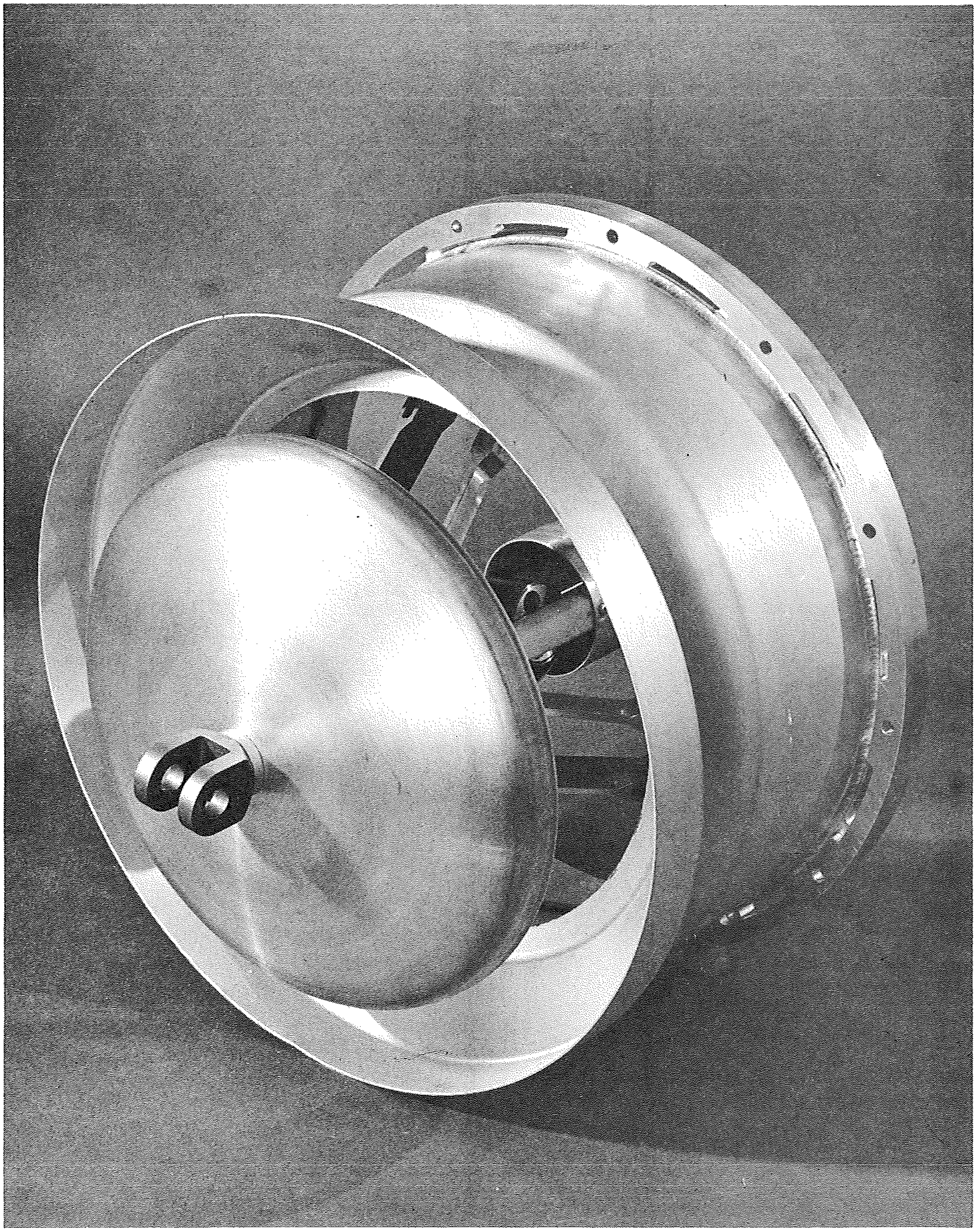

Figure 3. Valve Assembly with Valve Open

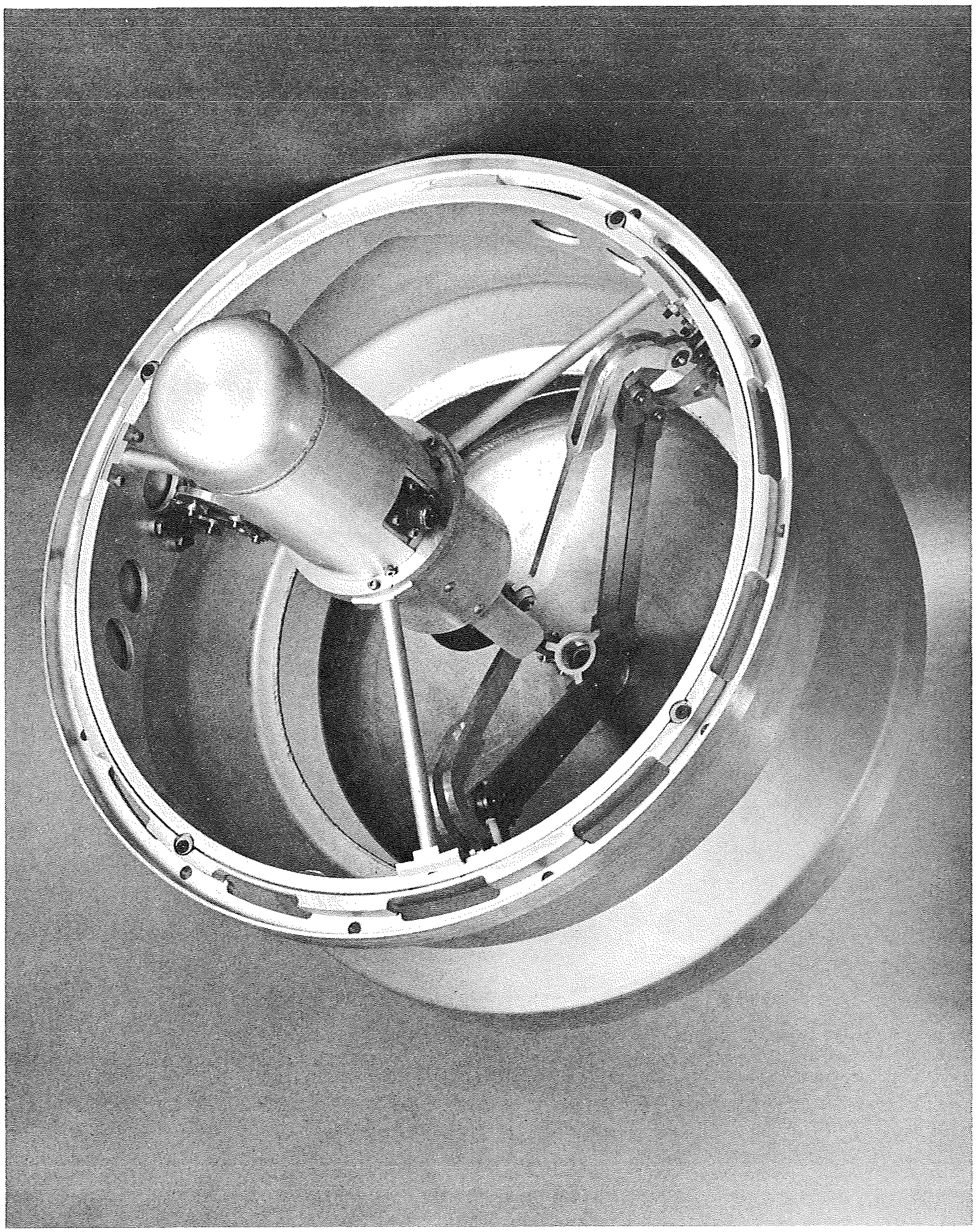

Figure 4. Valve Assembly Viewed from Below

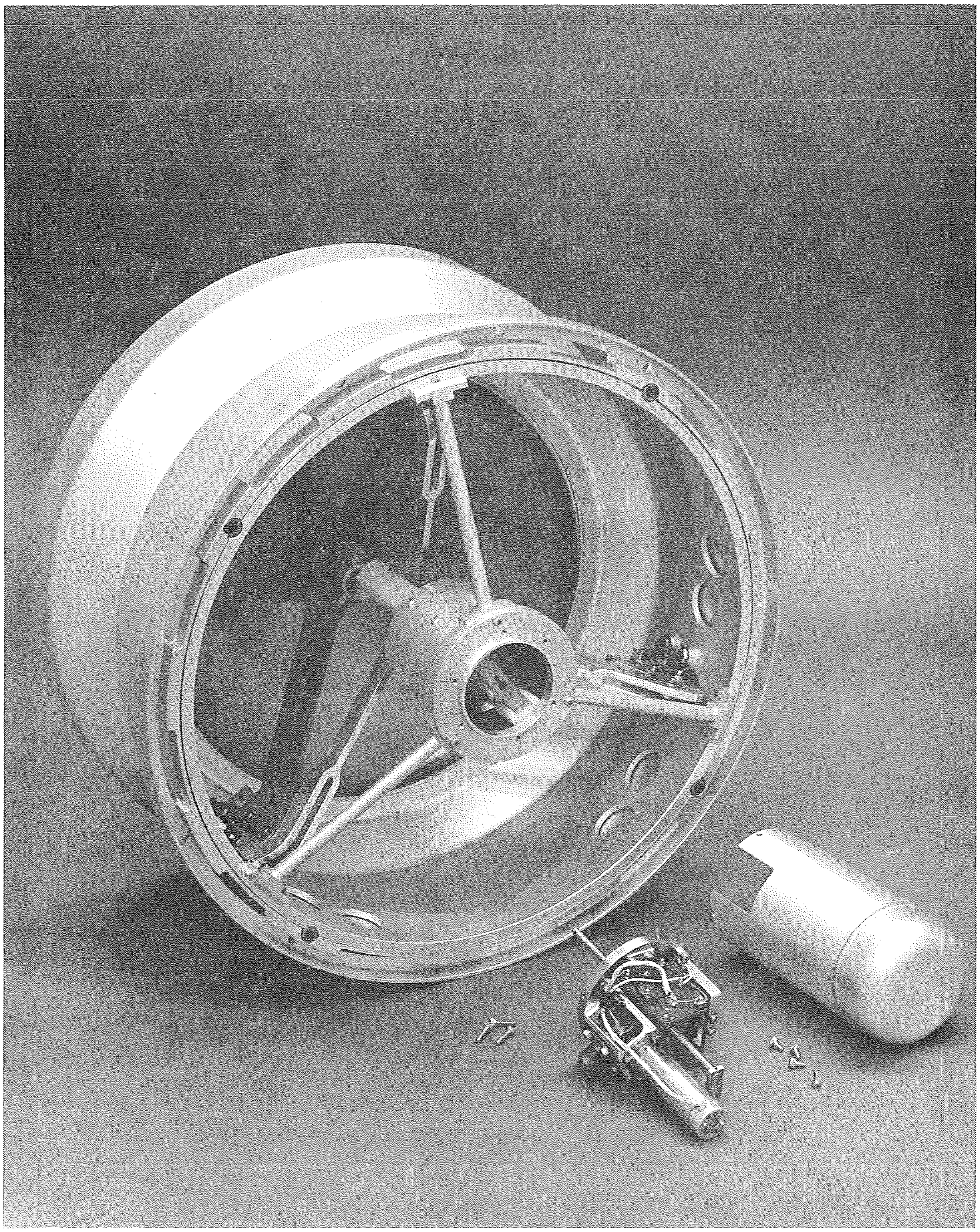

Figure 5. Disassembly of Motor Drive Unit

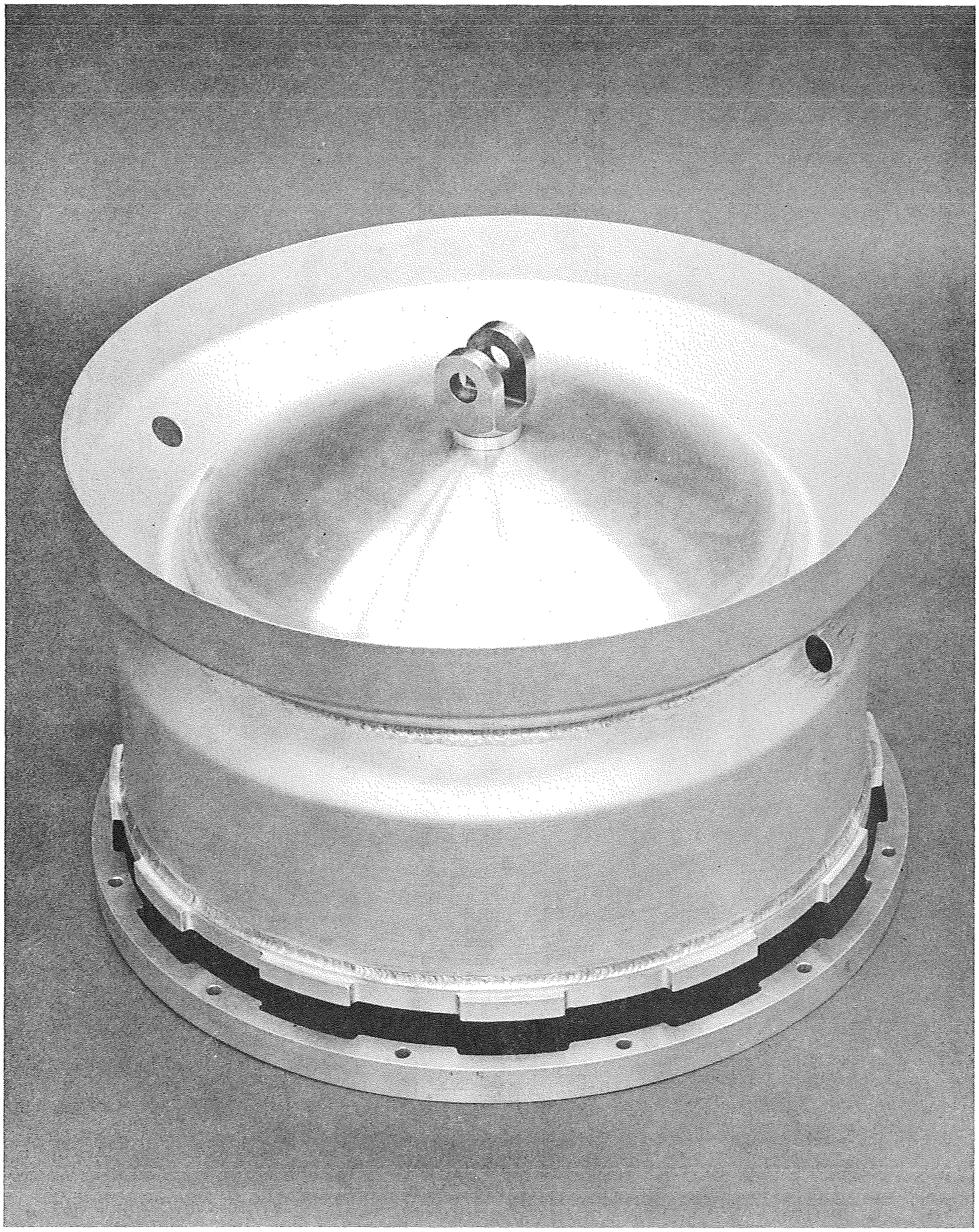

Figure 6. Housing and Quick Attachment Flanges

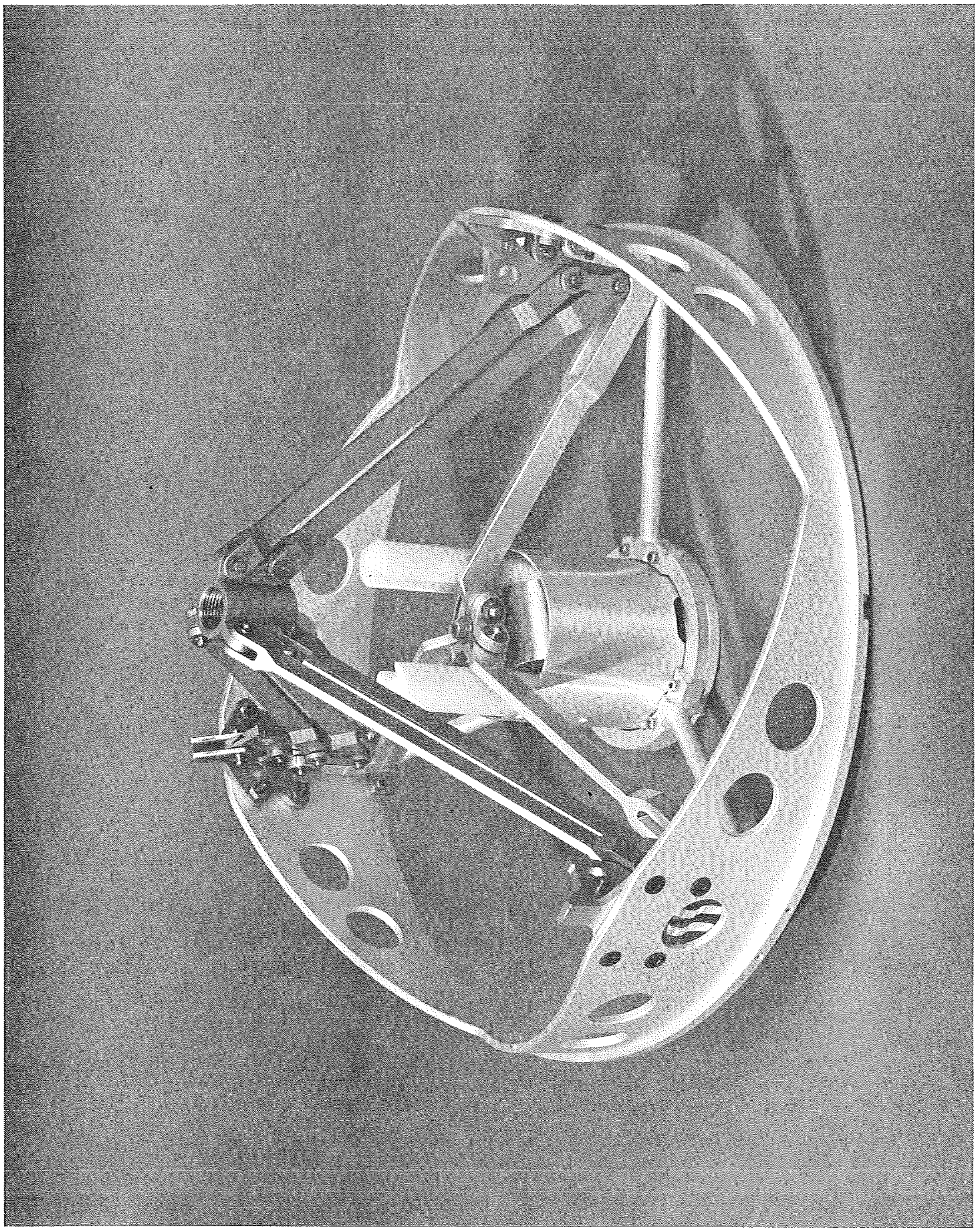

Figure 7. Linkages and Load Ring

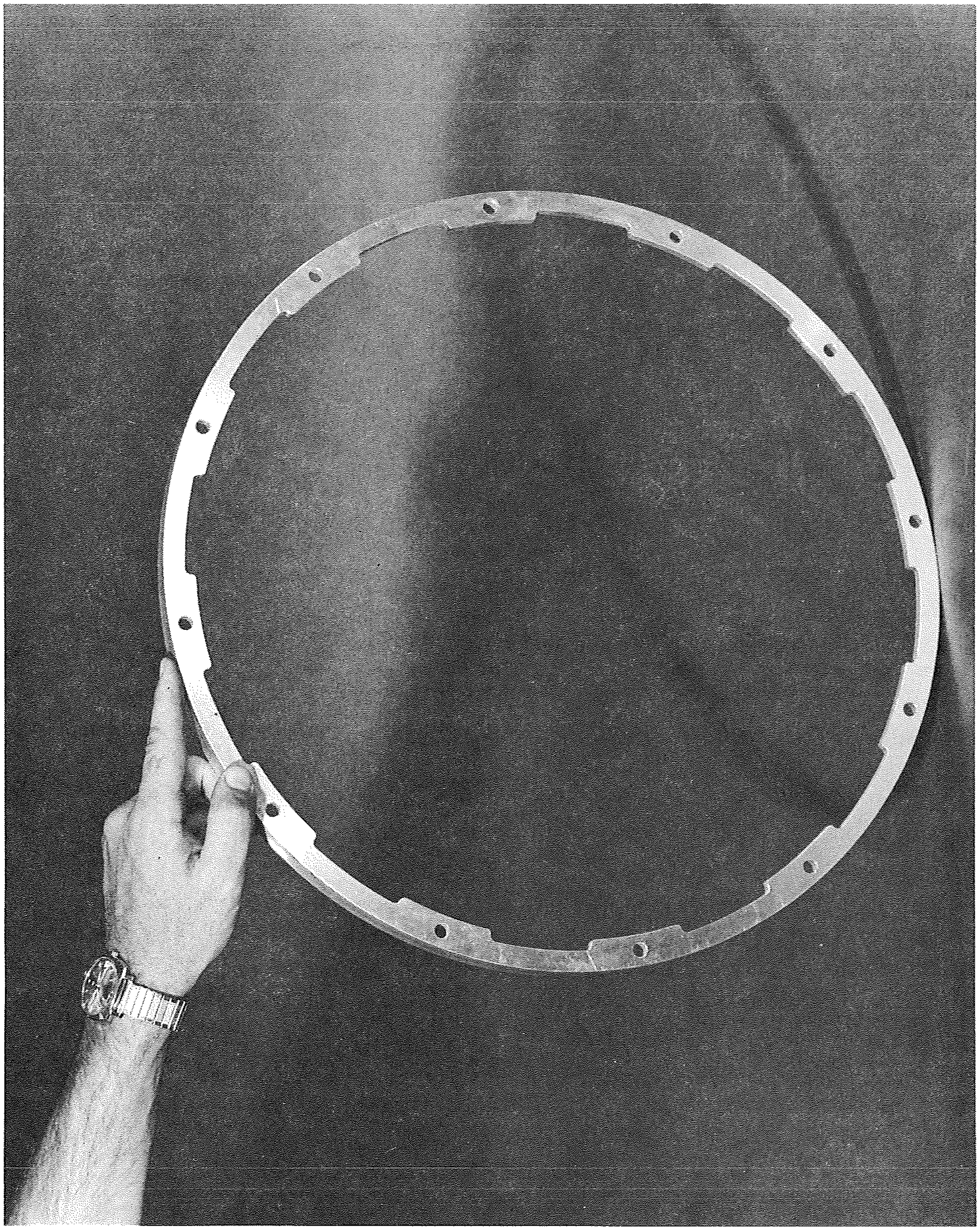

Figure 8. Quick Attachment Flange

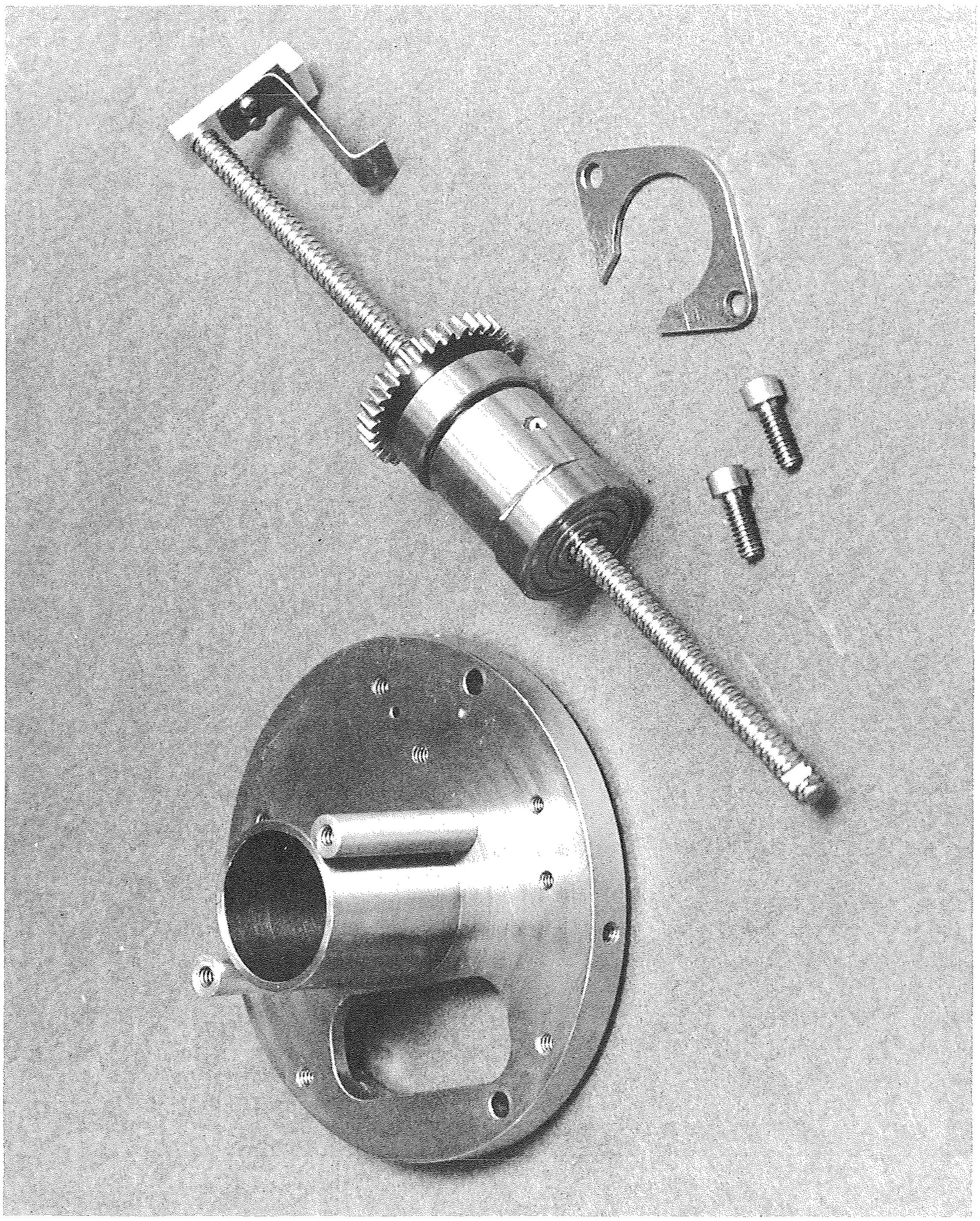

Figure 9. Ball Screw Drive Cartridge

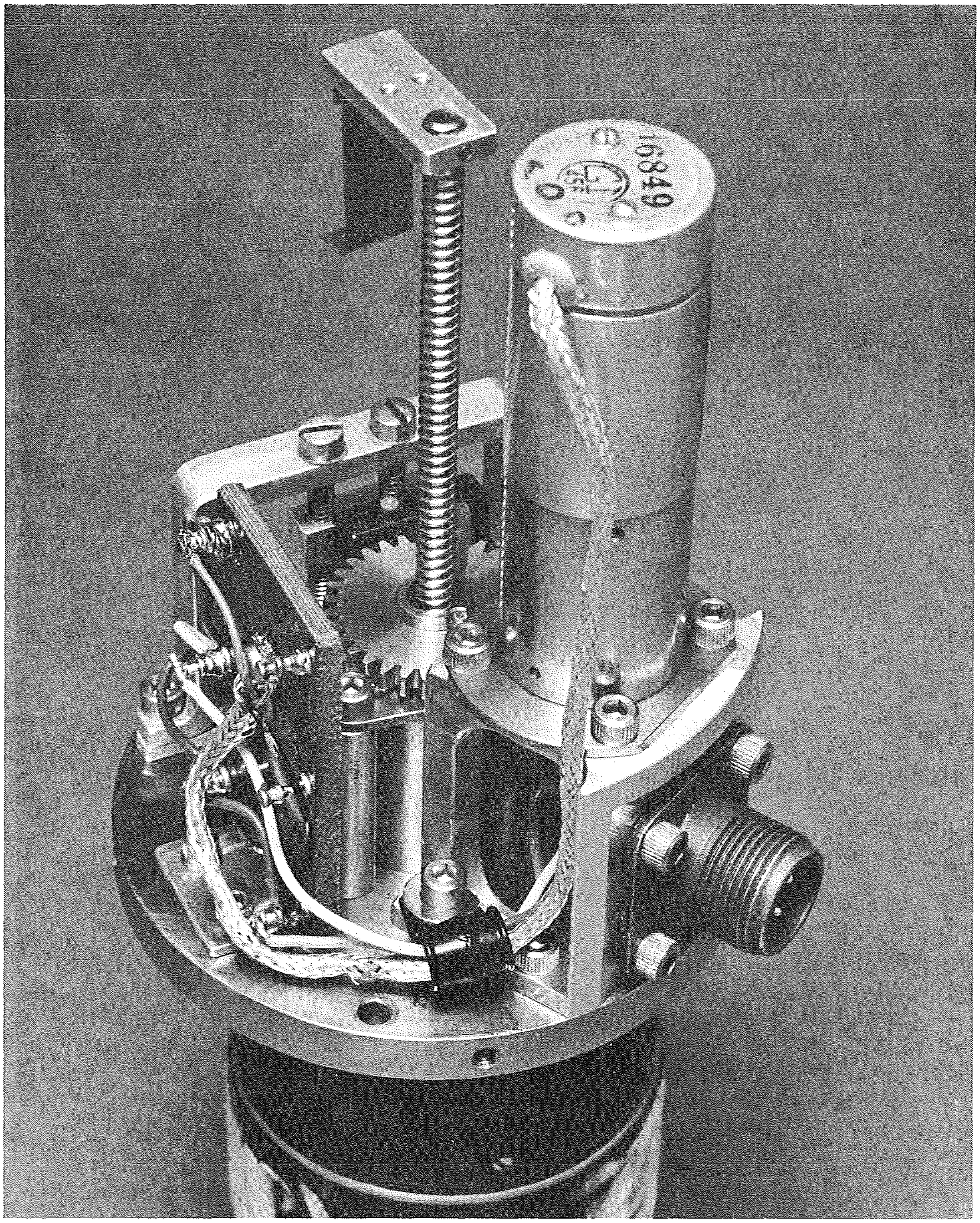

Figure 10. Motor Drive Unit

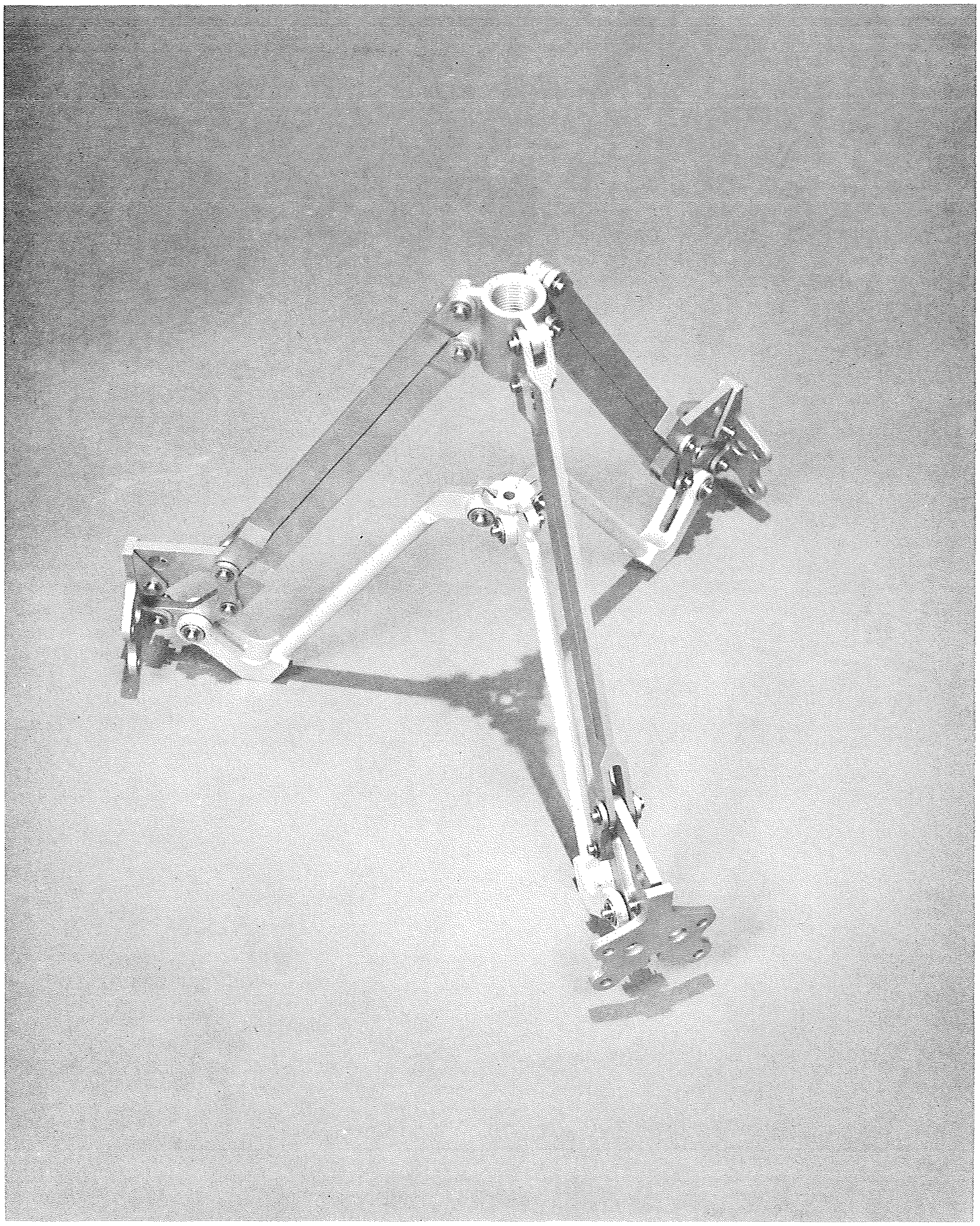

Figure 11. Load and Actuating Linkages

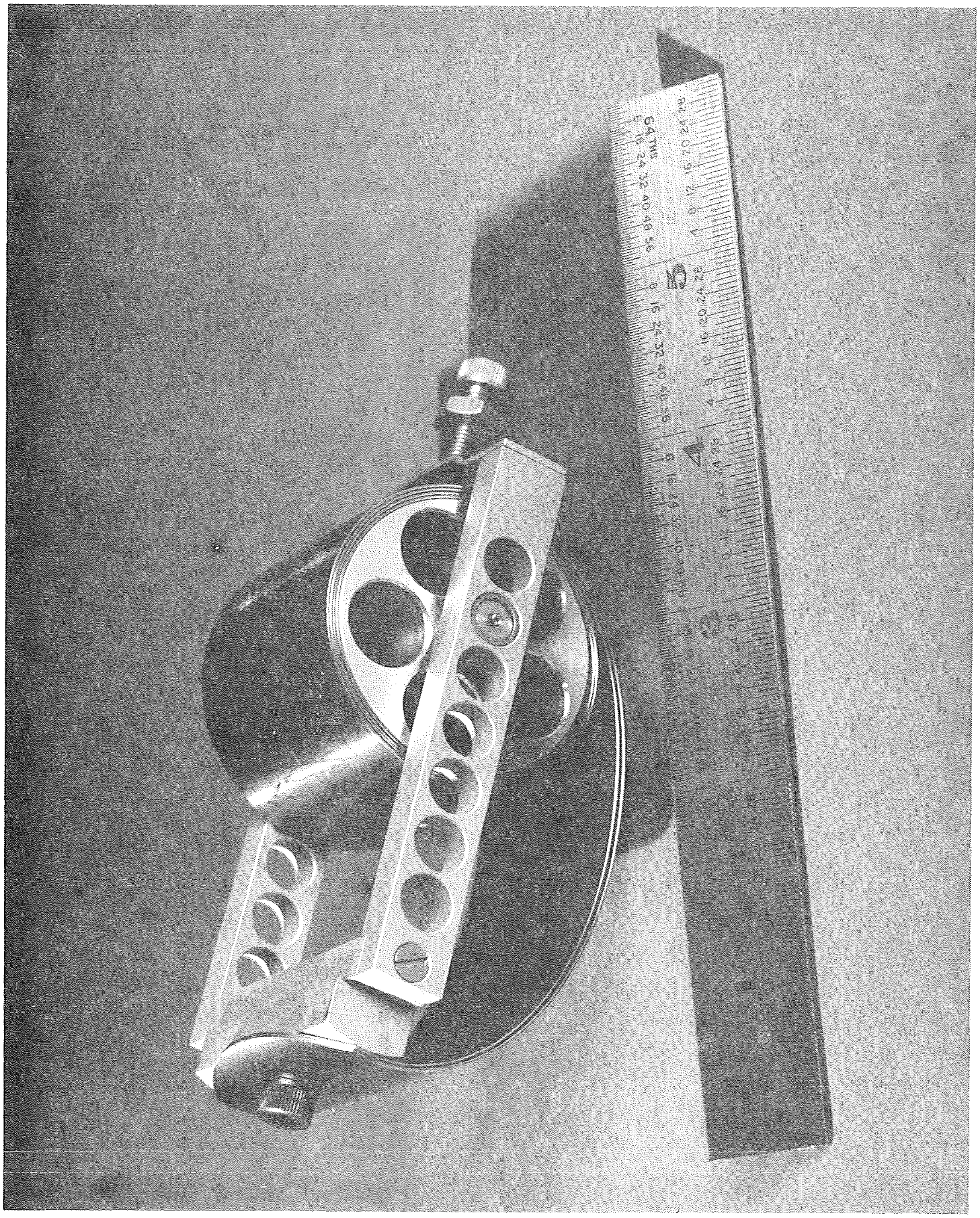

Figure 12. Constant Force Valve Spring