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DESIGN OF MECHANISMS TO LOCK/LATCH SYSTEMS
UNDER ROTATIONAL OR TRANSLATIONAL MOTION

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ABSTRACT

Several systems in the aerospace industry undergo rotational or translational motion. These bodies/systems need to be stopped and locked/latched at the end of their path. Some examples of these systems in the aerospace industry (including launch vehicle, spacecraft, and the ground support equipment) are the Command Module Access Arm, Service Arms, Docking Module of the ASTP and the Orbiter Access Arm for the Space Shuttle (Figures 1 and 2). This paper covers two major aspects: (1) various methods of latching and (2) selection of the optimum method for latching, depending on the application and the design requirement criteria.

INTRODUCTION

Before analyzing the design aspect of these mechanisms, it is worthwhile mentioning the major functions performed by them. Because of their critical functions of latching and unlatching, the mechanisms become part of the launch critical phase. For some applications, these functions are performed after the vehicle has begun lift-off.

Four major operations need to be performed by these mechanisms:

- (1) Stopping the system
- (2) Positive locking/latching
- (3) Maintaining the system locked due to loads on the mechanism
- (4) Positive unlatch

Each of these modes of the lock mechanism has to be designed depending on the critical modes of the application involved. However, the mechanism utilized to stop the systems may or may not be an integral part of the latch assembly. A brief discussion of all these modes of operation will be presented in the following paragraphs.

MODES OF OPERATIONS

The first major function to be performed is to stop the system under rotational or translational motion. Systems can be stopped by utilizing either shock absorbers or attenuators, or even by bringing them to a hard stop. However, most systems require deceleration before being brought in contact with the stop mechanism, i.e., by coupling the system to a cam mechanism or engaging a skid plate.

The next three modes involve mainly the latching and unlatching operations. Figure 3 illustrates various options that could be set up for the three phases of the locking mechanism. Studies and analyses have to be conducted to select the best possible option, depending on the critical modes of application involved.

DEVELOPMENTAL PHASES

The processes involved in the development of a product or mechanism are highly diversified and include a wide variety of detail. However, the typical detail in all these mechanisms involves four basic factors which should always be considered:

- (1) Simplicity of design
- (2) Ease of operation
- (3) Extent of failure of the mechanism due to
 - a) System failure, i.e., failure in the power system
 - b) Component failure, i.e., failure in the linkages of the mechanism
- (4) Developmental and manufacturing cost

After developing the concepts, selection of the kinematic scheme should be outlined. The decision as to the type or types of mechanism to transmit and transform the motion from the input to the output is an important one - for it may limit the selection of the components of the mechanism, it limits the capacity of the hydraulic or pneumatic power system, and it may determine the mechanical efficiency and cost of the latch mechanism.

Three concepts for the design of locks are briefly discussed below, with reference to Figures 4 through 8.

CONCEPTUAL DESIGN

Following the selection of the kinematic scheme and the concept, further design can be incorporated. Three conceptual designs are discussed below, with calculations and equations shown for the locks utilized on the Command Module Access Arm and one which will be used on the Orbiter Access Arm.

Figures 4 and 6 illustrate the Extend Stop and Lock mechanism used on the Command module Access Arm. The main features of this mechanism are the hard stop, automatic lock with over-center latch and powered unlatch (system utilizing an hydraulic cylinder).

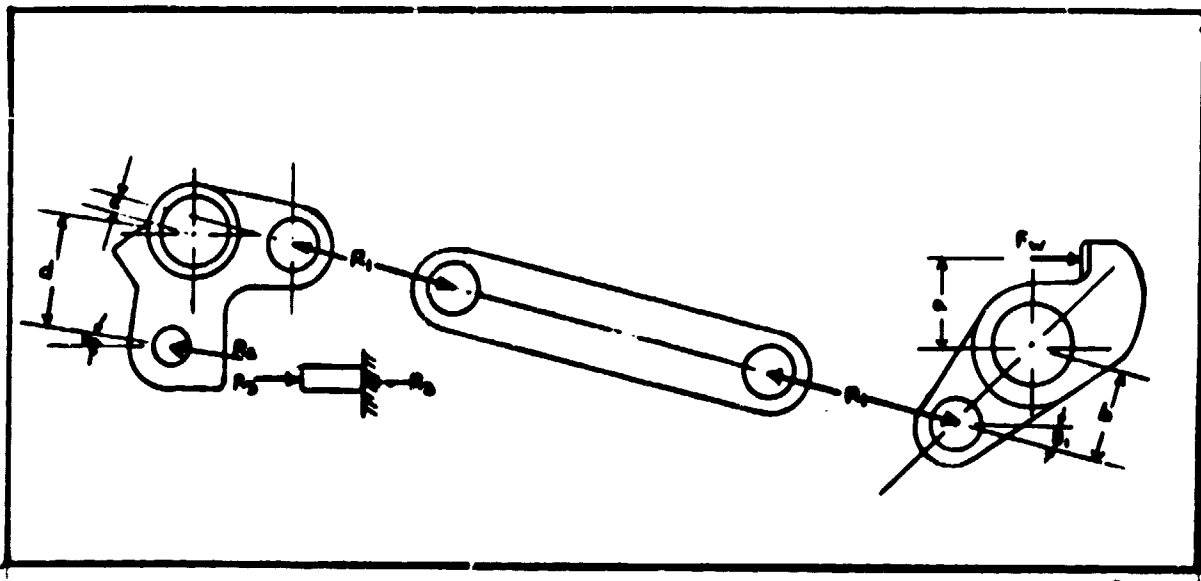


EXHIBIT A

The free body diagram of the latch mechanism is shown in Exhibit A above. Once the links are in the locked position, the kinematic scheme is so arranged that the links over-center. This prevents the system from unlatching when a load is applied from the system (i.e., the arm) onto the latch. The power required to unlatch depends on the geometry of the links. Load on the latch (when the arm is locked) is transmitted into the base block of the latch weldment. This load on the base block could be determined by using the following equation:

$$R_3 = \frac{F_w \times a \times c}{b \times d} \cdot \cos \theta_2$$

where

F_w - load on the latch

R_3 - load on the base block

θ_2 - angle made by the actuator with the base block

a, b, c & d - geometric lengths on links

Figures 5 and 7 illustrate the latches used to hold the Apollo arms in the retracted condition. The main feature of this latch is the remote latching with a positive locking system (accomplished by holding the cam up against latch weldment). The arm is decelerated by riding it over a skid plate with the final impact absorbed by two shock absorbers. The cam roller principle for unlatching does not link the hydraulic/pneumatic power to the latch. This system can have a manual override for use in the event of system power failure. However, the force required to unlatch this mechanism is greater than that required by the Extend Stop and Lock mechanism (assuming that the forces on the latch for both the mechanisms are the same). This is due to the fact that the remote latch mechanism, shown in Figure 7, retracts towards the load and not away from it.

Figure 8 illustrates the lock mechanism to be used on the Orbiter Access Arm. The main features for this lock are hard stop, remote lock with over-center latch and powered unlatch (system utilizing pneumatic cylinder).

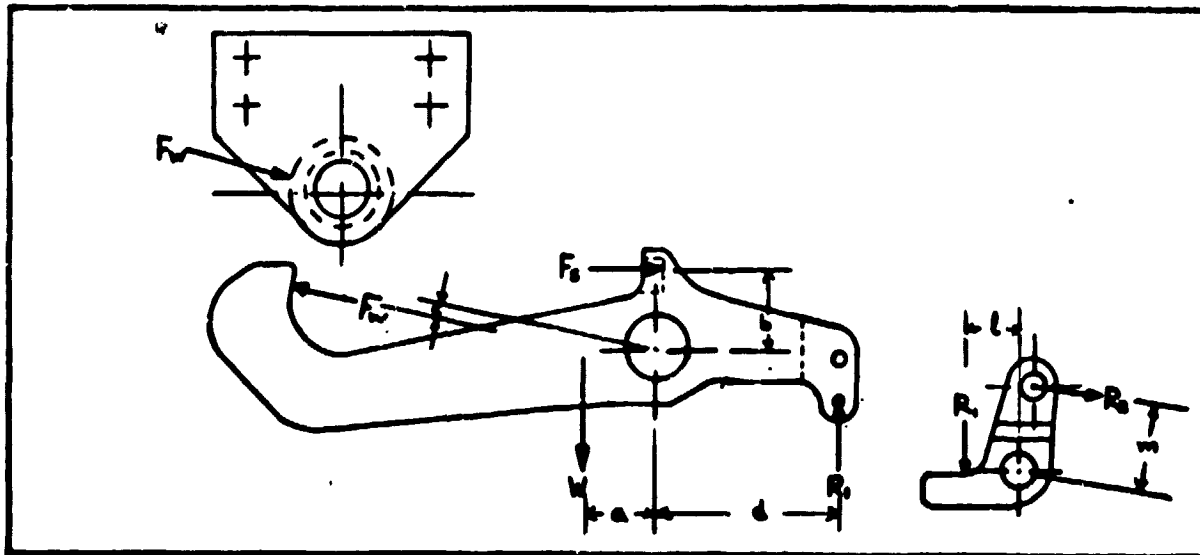


EXHIBIT B

Exhibit B illustrates the free body diagram of the latch mechanism. The cam roller arrangement gives the mechanism the ability to have a manual override, which can be used in the event

of system power failure. Another distinguishing characteristic of this type of kinematic scheme is that the force required to unlatch this mechanism is comparatively smaller than that required by the Extend Stop and Lock mechanism (Figure 6). The force required to unlatch can be determined by the following equation:

$$R_2 = \frac{F_w \times c + F_s \times b - W \times a}{d} \cdot \frac{l}{m}$$

where

R_2 - force required to unlatch

F_w - load on the latch

F_s - spring load on the latch

W - latch weight

a, b, c, d, l & m - geometric lengths on links

CONCLUDING REMARKS

In conclusion, one may realize that more than a cursory investigation is useful for final mechanism selection. Proper definition of requirements, with effective trade studies performed, would further aid in developing or selecting the right concept for a particular application. Furthermore, because of the complexity of detail design that arises, consideration should be given to whether the mechanism can be manufactured with minimum expense, can be assembled efficiently, and can be serviced and repaired easily.

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3. General Criteria for Design of New Equipment and Facilities to be Utilized at Kennedy Space Center, Rev. 1, AP-863, John F. Kennedy Space Center, KSC, Florida, February 2, 1973.
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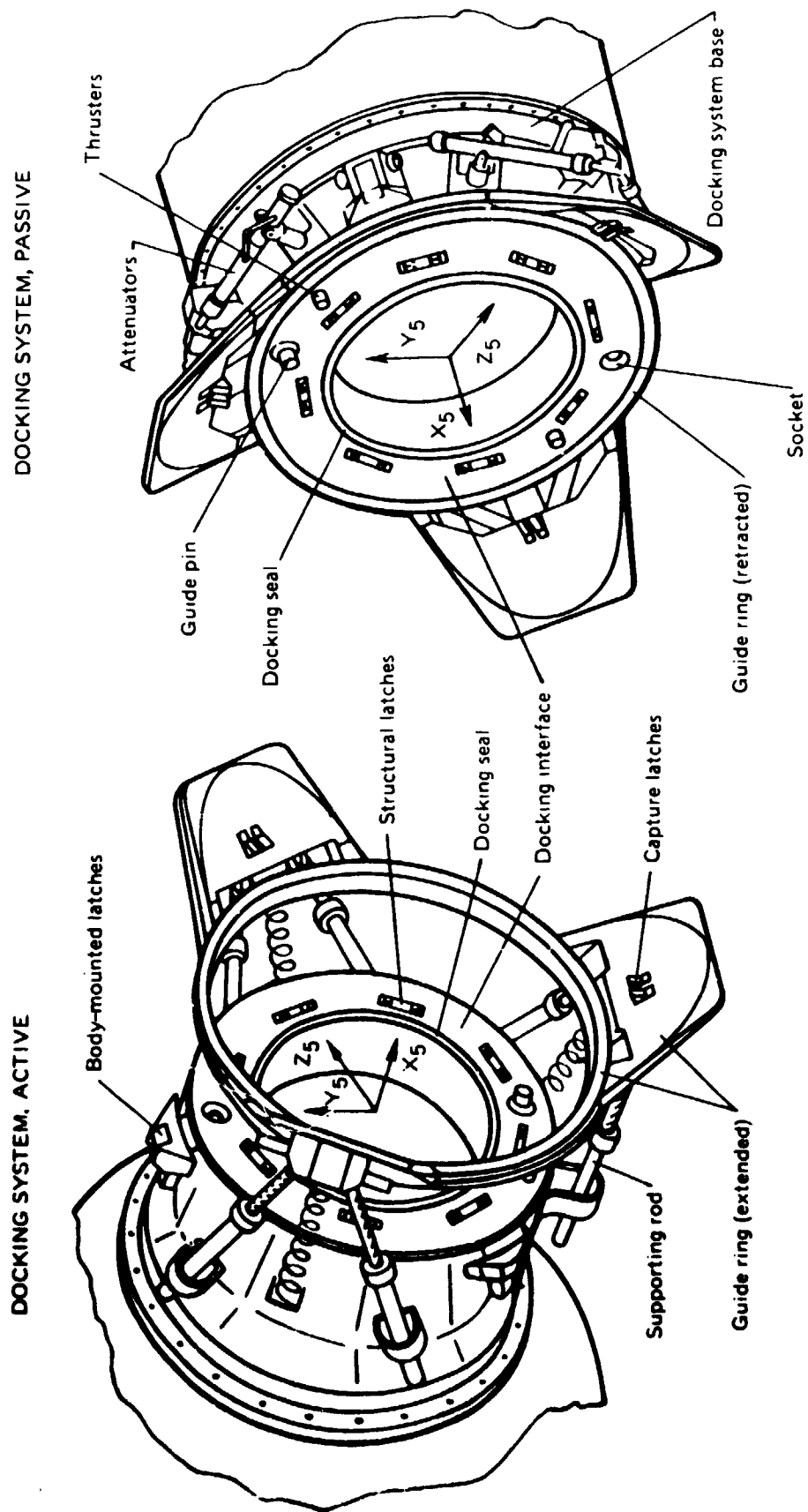


Figure 1. Docking System---ASTP.

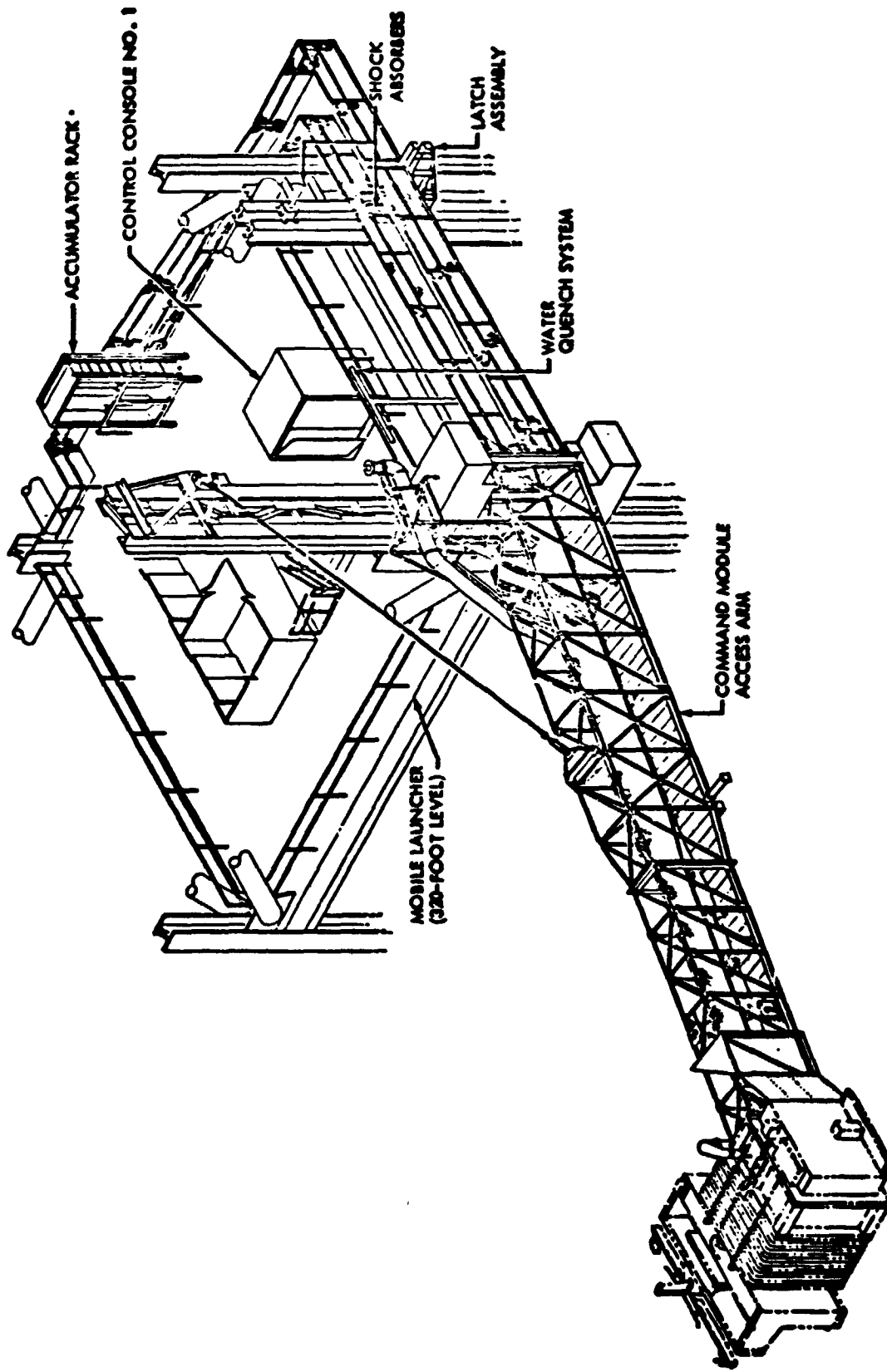


Figure 2. Command Module Access Arm System.

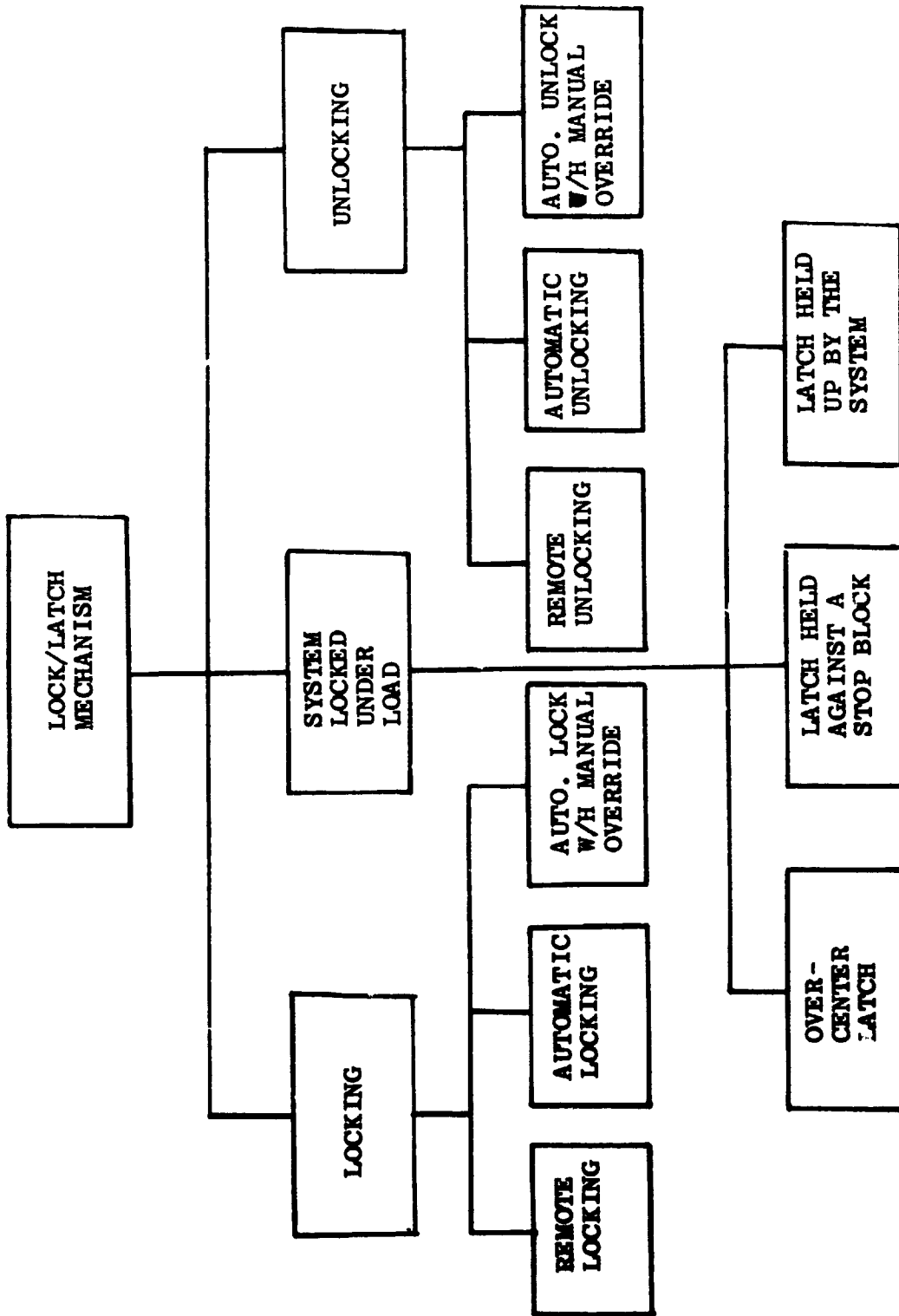


Figure 3. Locking System Tree Diagram.

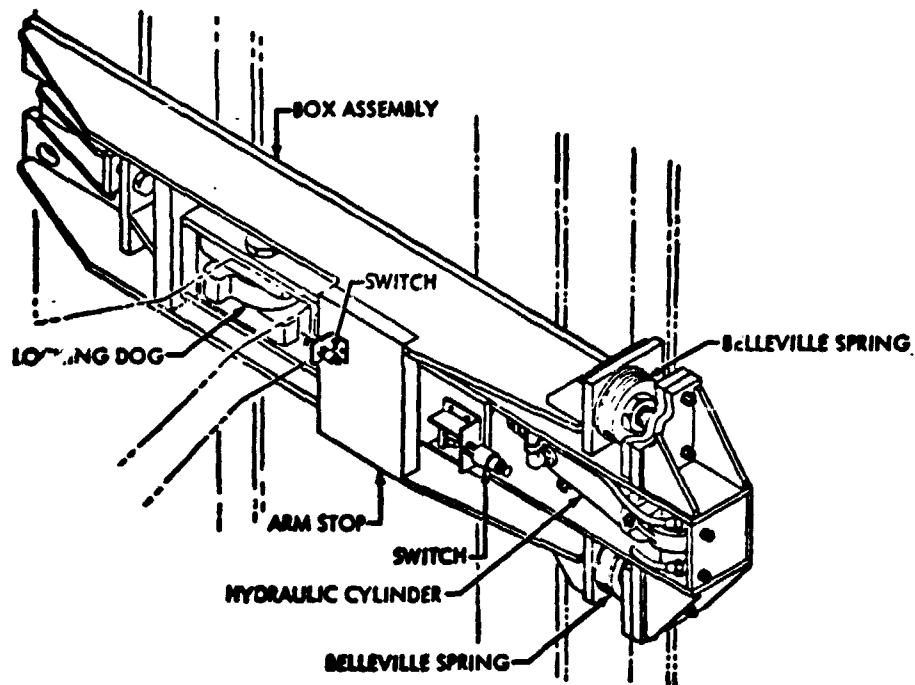


Figure 4. Arm Extend Lock.

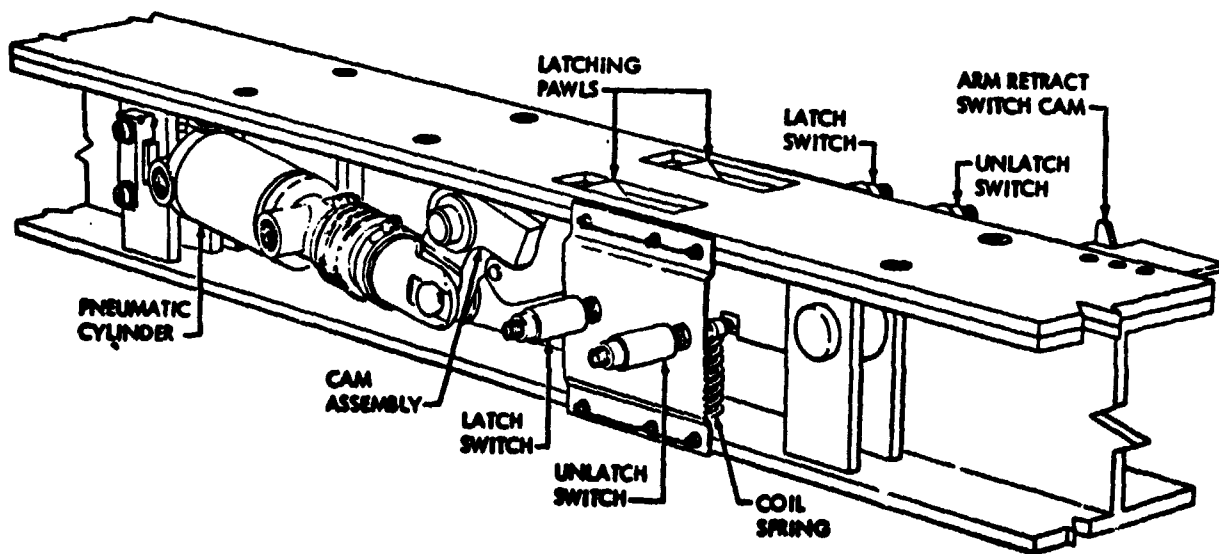


Figure 5. Arm Latch Assembly.

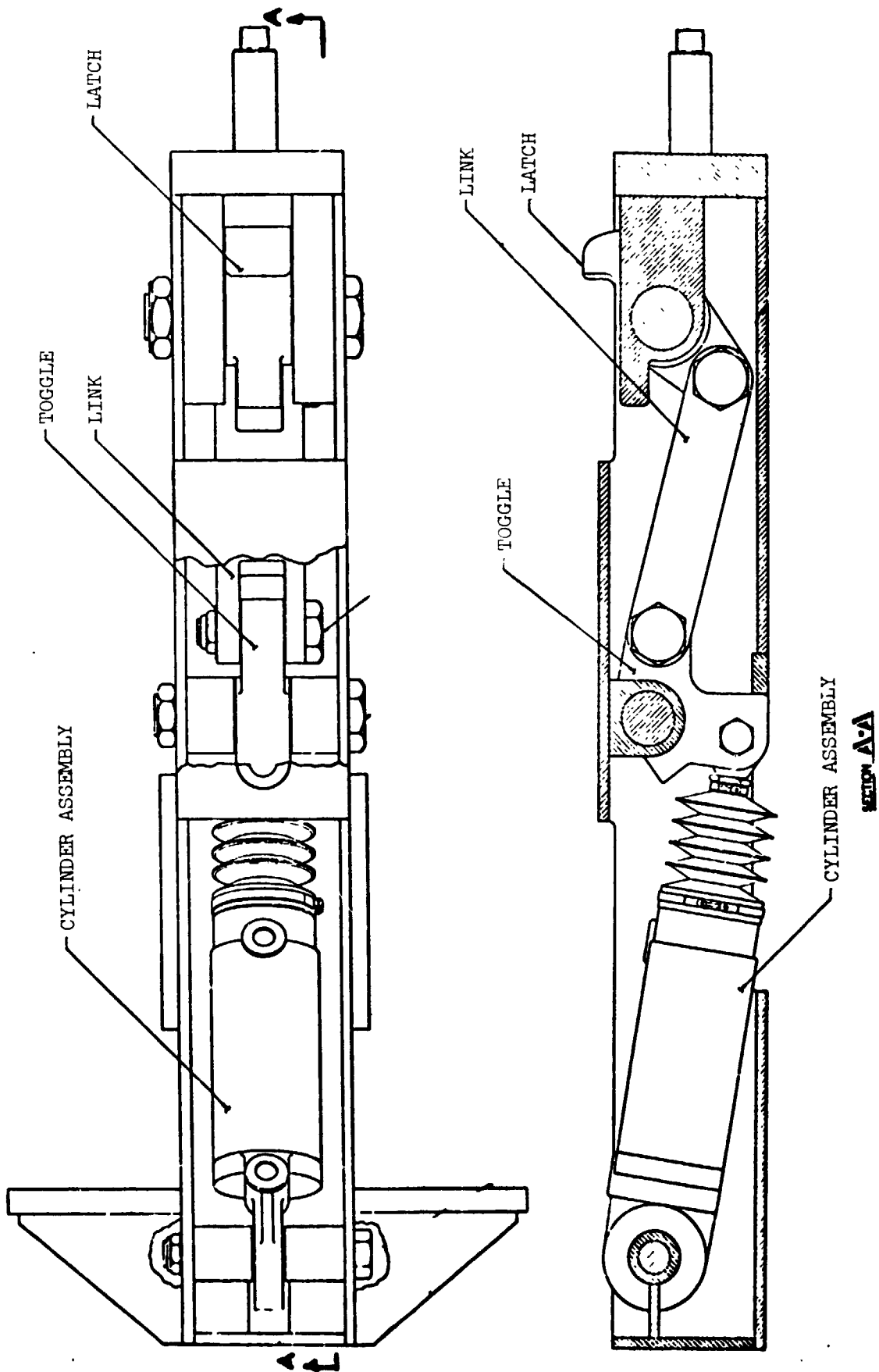


Figure 6. Arm Extend Lock.

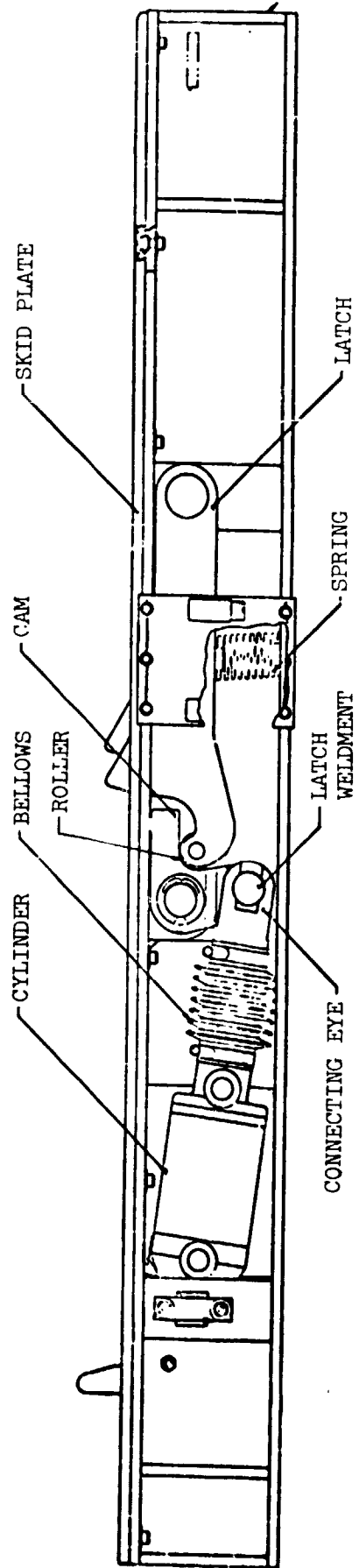
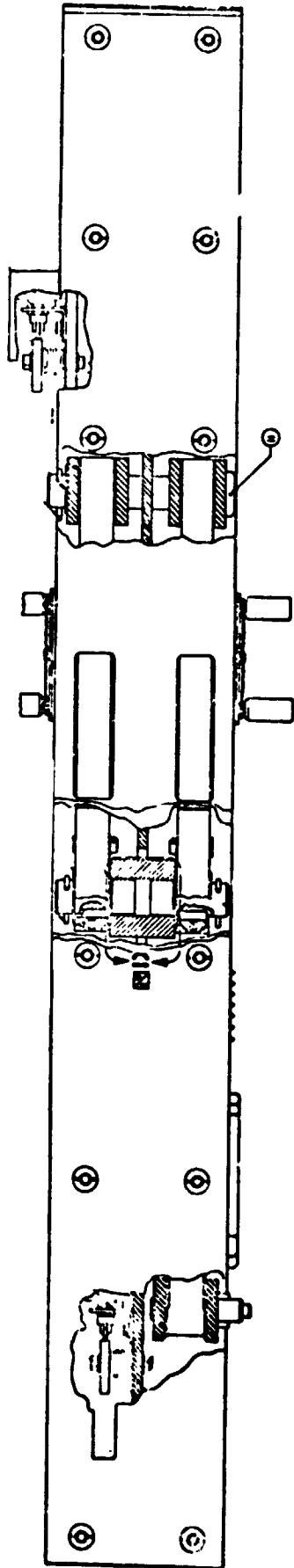


Figure 7. Arm Latch Assembly.

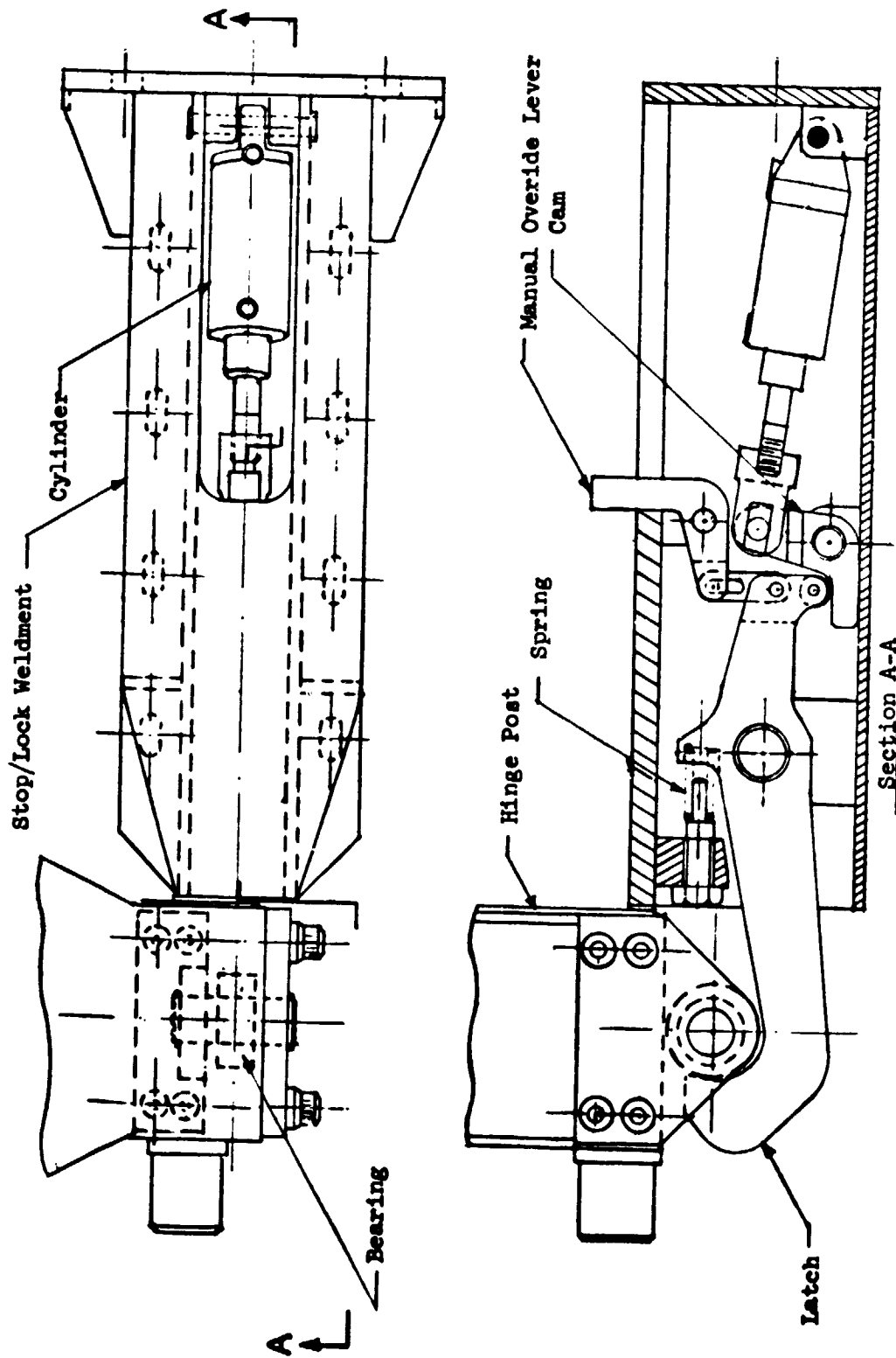


Figure 8. Stop/Lock Assembly For The Orbiter Access Arm.