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ORBITER DOOR CLOSURE TOOLS

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SUMMARY

Safe reentry of the Shuttle Orbiter requires that the payload bay doors be closed and securely latched. Since a malfunction in the door drive or bulkhead latch systems could make safe reentry impossible, the requirement to provide tools to manually close and secure the doors has been implemented. These tools would disconnect a disabled door or latch closure system and close and secure the doors if the normal system failed. The tools required to perform these tasks have evolved into a set that consists of a tubing cutter, a winch, a latching tool, and a bolt extractor.

Use of the tools requires that a crewmember enter the payload bay in a pressurized suit and manually complete door closure. Therefore, it is highly desirable that the tools be operable with one hand, leaving the other free for positioning and for counteracting the force required to operate the tool. Controls, handgrips, operating forces, and procedures must all be within the capabilities of a partially restrained, suited crewmember in a zero-g environment. The extravehicular-activity (EVA) door closure tools designed, developed, and tested at the Johnson Space Center meet these requirements.

INTRODUCTION

The complex payload bay door system (fig. 1) was discussed in detail at the 13th Aerospace Mechanisms Symposium in a report entitled "Space Shuttle Orbiter Payload Bay Door Mechanisms" (ref. 1). A review of that report will help to understand the need and use of the EVA tool set.

The payload bay doors are closed by a drive system that moves the doors to a designated position by two actuator systems, one on either side of the payload bay. Each system drives one 18.3-meter (60 foot) door and consists of an electromechanical actuator that drives six gear boxes interconnected by torque tubes. The gear box output is transmitted through drive linkage to the door as shown in figure 2.

The forward edges of the doors are connected to the bulkhead by latch mechanisms mounted on the doors and mating hook rollers mounted on the bulkhead (fig. 3). The latch mechanisms consist of a right-hand and a left-hand gang of four latches, one on each door, that operate sequentially. Each gang of latches is driven by an electromechanical rotary actuator. The aft edges of the doors are secured to the aft bulkhead in a manner similar to that used on the forward edge except that a fore/aft shear tie at each latch, identified as a passive roller in figure 4, is used to control the distance between the door and the bulkhead.

During normal operation, each door is closed by the door drive system to within 5.1 centimeters (2 inches) of the number 1 bulkhead latch. The ganged latches are activated and provide a zippering effect whereby the number 1 latch first engages the door and then pulls it to a position within reach of the number 2 latch. The number 2 latch continues to pull the door further closed until it is within the reach of the number 3 latch and so on until all four latches have fully closed and secured the doors.

A failure in any actuator system could require a manual operation using one or more of the tools described in this paper to complete the door closure and latching process. The basic types of failures that could occur, the causes, and the required EVA actions are described in table I.

TUBING CUTTER

In the event the door drive system fails such that the door can neither be opened or closed, the upper or lower drive tubes (fig. 2) must be disconnected from the door to allow manual door closure. Cutting these six tubes has proved to be the quickest and easiest way to accomplish this task.

Design criteria required that the cutter be operable with one hand, be installed on a tube that is attached at both ends, and be able to cut a tube that is 5.0 centimeters (1.97 inches) from an obstruction. The cutter must be able to cut a tube that ranges from 1.27 to 2.54 centimeters (0.500 to 1.000 inch) outside diameter and is made of 718 Inconel with a wall thickness of 0.16 centimeter (0.063 inch) and with a hardness from 36 to 38 RC. It must also withstand side loads introduced by a crewmember in zero-g conditions.

Designing a cutting wheel that would satisfy these requirements proved to be a real challenge. The material selected was AISI Type 0 tool steel heat-treated to 60 RC. Various cutting angles and wheel thicknesses were tried until a combination that could withstand the side loads and the cutting loads was found.

The tubing cutter (fig. 5) consists of the housing, the body that contains two fixed rollers, a spring-loaded roller, and the cutting wheel/screw ratchet assembly. The body is turned in one direction within the housing by three pawls mounted in the housing. By alining openings in the housing and the body, the tool can be installed anywhere along the tube. The tool is retained in position by a spring-loaded roller until the cutting wheel can be forced against the tube by the screw ratchet. Once a load is applied on the cutting wheel, the handle on the housing is ratcheted back and forth, causing the body to turn around the tube. After the body has made one complete revolution around the tube, the cutting wheel is again advanced against the tube with the screw ratchet. This procedure is continued until the tube has been cut.

After the tube is cut, the tool is removed from the tube and reset for the next cut by alining the openings in the housing and body, reversing the control lever, and retracting the cutting wheel with the screw ratchet until the next tube to be cut will move into position in the tool. The control lever is returned to the original position and the cutting wheel is forced against the second tube by the screw ratchet. This procedure is repeated until all six drive tubes on the affected door have been cut. The door is then ready to be manually closed by using the winch to pull the disabled door to a position where the bulkhead latching system can be actuated.

WINCH

Two EVA winches, one mounted to each bulkhead, are provided to manually close the doors to a position where the bulkhead latching system can be actuated or the three-point latch tool can be installed.

The winch assembly (fig. 6) is made up of a housing, a reel, a ratchet handle, and a mounting adapter. The housing encloses the reel and the mechanism that turns and controls it. A rope guide assembly mounted on the housing guides the rope over a set of rollers to prevent fraying. The mounting adapter also attaches to the housing. A reel powered by a negator spring houses 7.3 meters (24 feet) of 0.95-centimeter (0.375 inch) diameter Kevlar rope with a hook attached to the free end. Load is transmitted to the reel and rope by the ratchet handle through a gear system. A ratchet control lever selects the function of the ratchet between the handle and gear system and has reverse, neutral, and engage positions. A second ratchet system controls movement of the reel; ratchet-in, ratchet-out, reel-out, and gear-release functions can be selected with its control handle. The complete winch assembly is attached to the bulkhead handrails by the adapter.

After all apparent obstructions to free door movement have been removed, the crewmember routes the rope over the number 4 hook roller and attaches the rope hook to the number 4 latch bellcrank at the tip of the door. The rope can be pulled from the winch with a 4.45-newton (1 pound) force by placing the control handle momentarily to GEAR RELEASE to release the load on the reel ratchet and then to REEL OUT, and moving the ratchet control lever to the NEUTRAL position. The rope can be extended but will not automatically retract with the controls in this position. When the crewmember returns to the winch, slack rope is automatically retracted by placing the controls to RATCHET OUT and NEUTRAL. A load of 2669 newtons (600 pounds) can be applied on the rope by placing the controls to RATCHET IN and ENGAGE and either cranking or racheting the ratchet handle. When that load is reached, a torque limiter incorporated in the handle allows it to "collapse" approximately 15°. This is verified by misalinement of indicator marks on the handle and also by feeling the handle suddenly give way. If this occurs, the crewmember finds the obstruction to door movement, removes it, and completes closing the door.

The rope can be safely extended under load by placing the controls in the RATCHET OUT and ENGAGE positions and applying a load on the ratchet handle and then releasing it. This allows the reel to back up one tooth of its ratchet. Repeating this process will extend the rope until the load has been relieved.

After the door has been fully closed by this method, the bulkhead latching system is actuated to secure the door, the rope hook is removed from the latch bellcrank, and the rope is completely retracted by placing the controls in the RATCHET OUT and NEUTRAL positions. If the bulkhead latching system works properly, the crewmember returns to the crew module.

THREE-POINT LATCH TOOL

If a gang of latches on either end of one or both doors fails to complete door closure, the door must be secured to the bulkhead by some other means. The three-point latch tool was designed for this purpose. Eight of these tools (enough to bypass two gangs of latches) will be carried on the first Orbiter flight.

Design criteria for this tool required that the tool must fit all 16 latches, must be able to be installed and close a door that is 5.1 centimeters (2 inches) open with the number 1 latch hook 37° or more from being closed, must withstand design reentry loads on the latch, must transmit these loads into the latch pivot points with similar magnitudes and directions as the latch mechanisms, and must retain itself in position while being used by the crewmember.

The three-point latch tool (fig. 7) consists of a frame of two parallel plates, a compensator that pivots in the frame and attaches to the nut, a screw turned by a ratchet, and a bellcrank. The ratchet handle hinges to conserve stowage space. The force required to retain the tool in place is supplied by a spring-loaded telescoping pivot held in the compressed position by a release catch. The trigger to release this catch is mounted on the handle, requiring that the rod that releases the catch also hinge at the same point as the handle. The catch also incorporates a means to lock the ratchet handle offset 30° on either side of the tool to aid in installing the tool. Releasing the telescoping pivot also releases the ratchet handle positioning lock; however, a position release button is provided to reposition the handle in the desired position.

The tool is installed by first straightening the handle and offsetting it to the desired side (fig. 7(a)). The hook portion of the frame is fitted on the latch hook pivot shaft (fig. 7(b)) with the frame plates straddling the latch hook, which may be in any position greater than 37° from the closed position. The frame is then rotated until it contacts the bellcrank pivot. The telescoping pivot is released (fig. 7(c)), forcing the tool bellcrank against the hook roller, and the nut forces the compensator against the bellcrank pivot. In this configuration, the tool will hold itself in position while the crewmember extends the screw by means of the ratchet until a force is exerted on the hook roller, closing and securing the door (fig. 7(d)).

One tool is installed on each latch in the disabled gang in the same manner, starting with number 1 and proceeding in order to the number 4 latch, closing the door at each position before proceeding to the next latch. After installing the last required three-point latch tool, the crewmember is ready to enter the crew module.

BOLT EXTRACTOR

If the actuator of a gang of bulkhead latches fails such that a latch hook prevents installation of the three-point latch tool, the gang linkage must be disconnected from the disabled actuator. The bolt extractor (fig. 8) was designed for this task.

The linkage is attached to the actuator through a clevis joint using a shoulder bolt as the connecting pin. Removal of the bolt is required to disconnect the linkage. A force can be expected to be transmitted across the joint at the time of removal.

The bolt extractor consists of an expanding frame that straddles the clevis, a socket that turns the bolt, and an extractor that pulls the bolt free after the nut is removed. To operate the tool, the nut retaining slot in the frame is fitted completely on the nut and held in place while the tool is squeezed at points A and B. This compresses the frame until the socket contacts the bolthead. With pressure still being applied at points A and B, the bolthead socket handle is turned to aline the socket with the bolthead and the tool can be fully installed on the bolthead.

The nut retainer keeps the nut from turning and also holds it against the clevis while the bolt is unscrewed. When the bolt threads have cleared the nut, the bolthead has been pushed into the socket past the extractor hooks. The bolt removal ratchet is then ratcheted back and forth to force the extractor away from the clevis and pull the bolt out. The tool will then slip off the clevis and the bolt can be removed from the socket.

Three bolt extractors will be taken on Shuttle flights, normally making it unnecessary to reset the tool for further use. The tool can be reset in flight if required, however, by holding the frame at point A and lifting up on the ratchet latches and point B simultaneously. The reset disk is turned to move the extractor and socket into position against the upper part of the frame. The same procedure is followed to remove any other bolts necessary to prepare the latch system to accept the three-point latch tool.

With the required bolts removed from the clevis joints, the latch gangs can be manually moved to rotate the latch hooks, thus allowing the three-point latch tool to be installed and door closure to be completed.

TEST PROGRAM

Each of the door closure tools has undergone a period of development and evaluation by crewmembers and NASA officials and has repeatedly been used with success in the Neutral Buoyancy Facility at the Johnson Space Center. The flight tools have been delivered and are ready for the first Shuttle flight.

CONCLUDING REMARKS

The door drive and bulkhead latch systems are reliable mechanical systems; however, like any mechanical system, they are subject to malfunctions that could cause an unsafe reentry of the Orbiter. This set of backup door closure tools provides the extra degree of safety needed for the Shuttle Program.

REFERENCE

1. McAnally, Bill M.: Space Shuttle Orbiter Payload Bay Door Mechanisms. Proceedings of the 13th Aerospace Mechanisms Symposium, NASA CP-2081, 1979, pp. 261-269.

TABLE I.- DOOR CLOSURE FAILURES

Type of failure	Cause	Action
One or both doors will not close	Door drive system failure	Attach the winch hook to the affected door and manually close the door. Actuate the bulkhead latch system.
	Door drive system failure and jam	Cut the six drive tubes on the affected door with the tubing cutter and manually close the door using the winch. Actuate the bulkhead latch system.
Bulkhead latch system fails with the latch hook greater than 37° from the closed position	Latch actuator fails or jams	Install the three-point latch tool on the end of the affected door starting with the number 1 latch. Proceed in order to the number 4 latch, closing the door at each position before proceeding to the next latch.
Bulkhead latch system fails with the latch hook less than 37° from the closed position	Latch actuator fails or jams	Remove the connector bolt from the actuator linkage with the bolt extractor. Manually backdrive the latch hooks until the three-point latch tool can be installed on the number 1 latch; proceed in order to the number 4 latch, closing the door at each position before proceeding to the next latch.

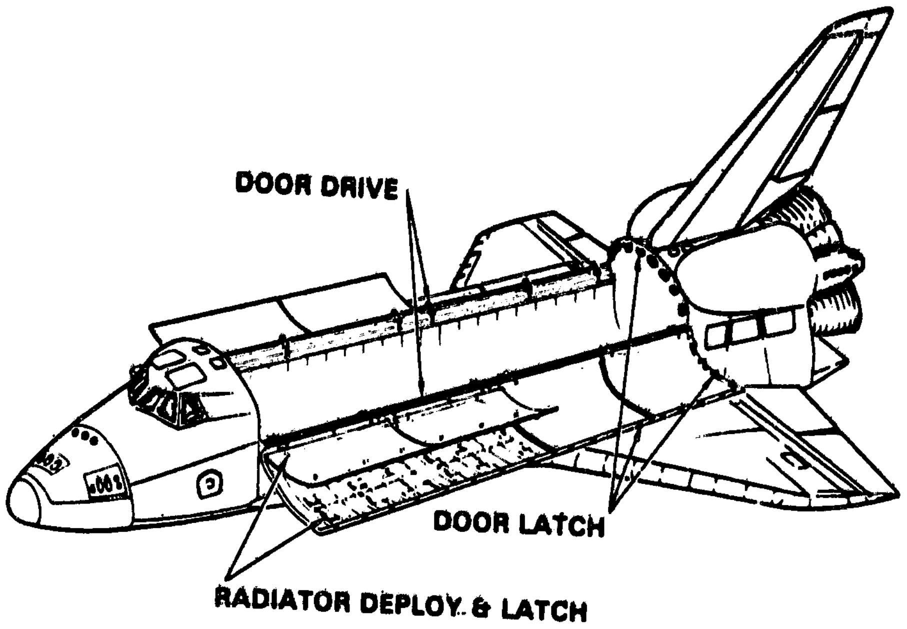

Figure 1.- Payload bay door system (from ref. 1).

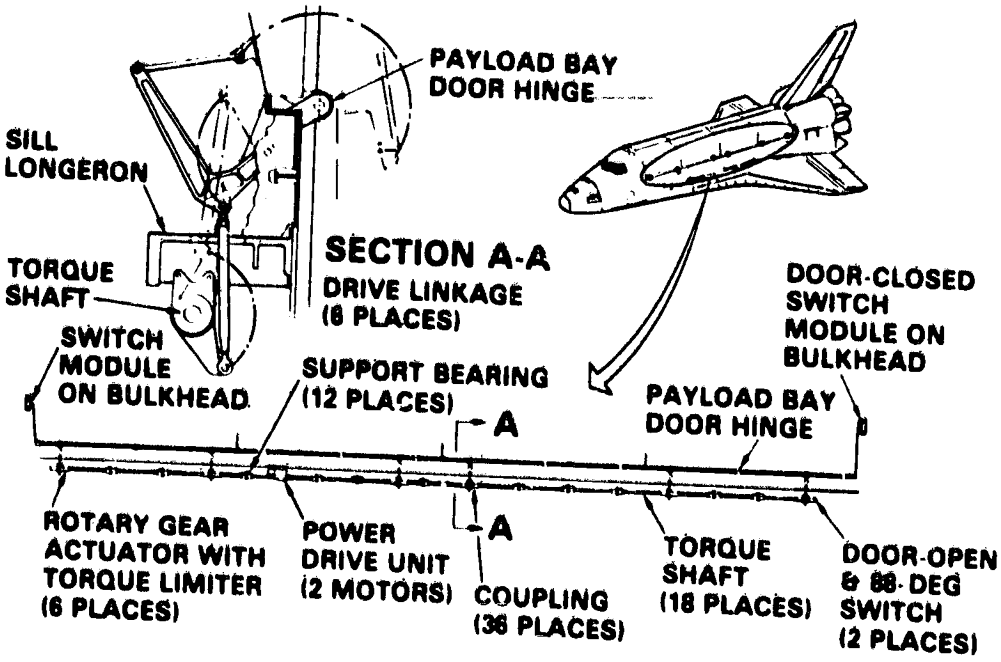

Figure 2.- Payload bay door drive system (from ref. 1).

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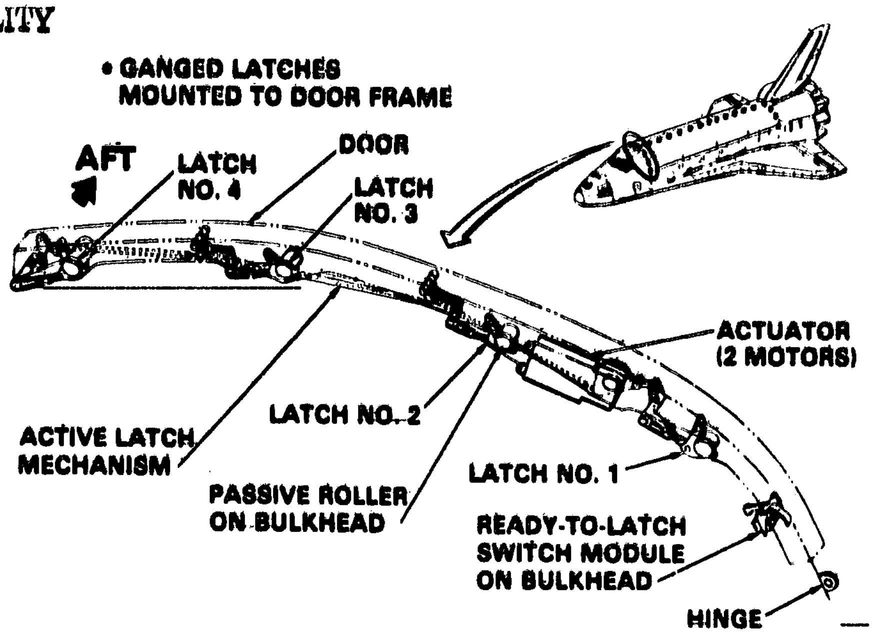


Figure 3.- Forward bulkhead circular latch system (from ref. 1).

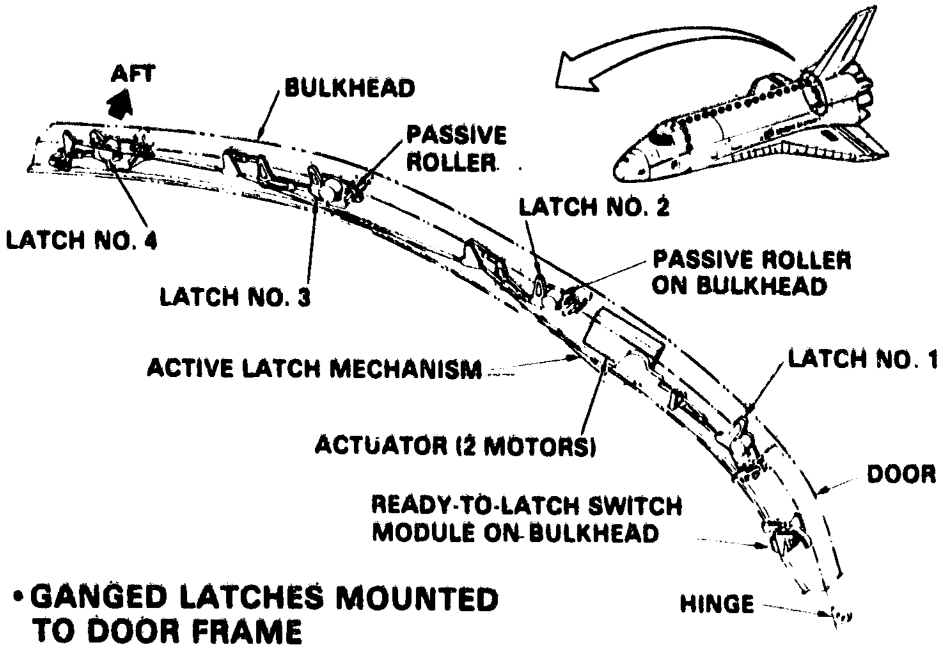


Figure 4.- Aft bulkhead circular latch system (from ref. 1).

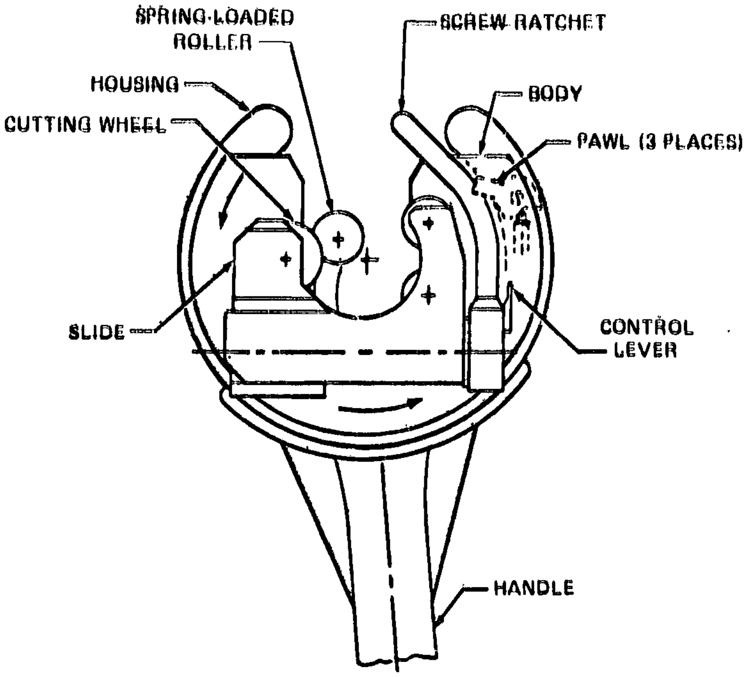


Figure 5.- Tubing cutter.

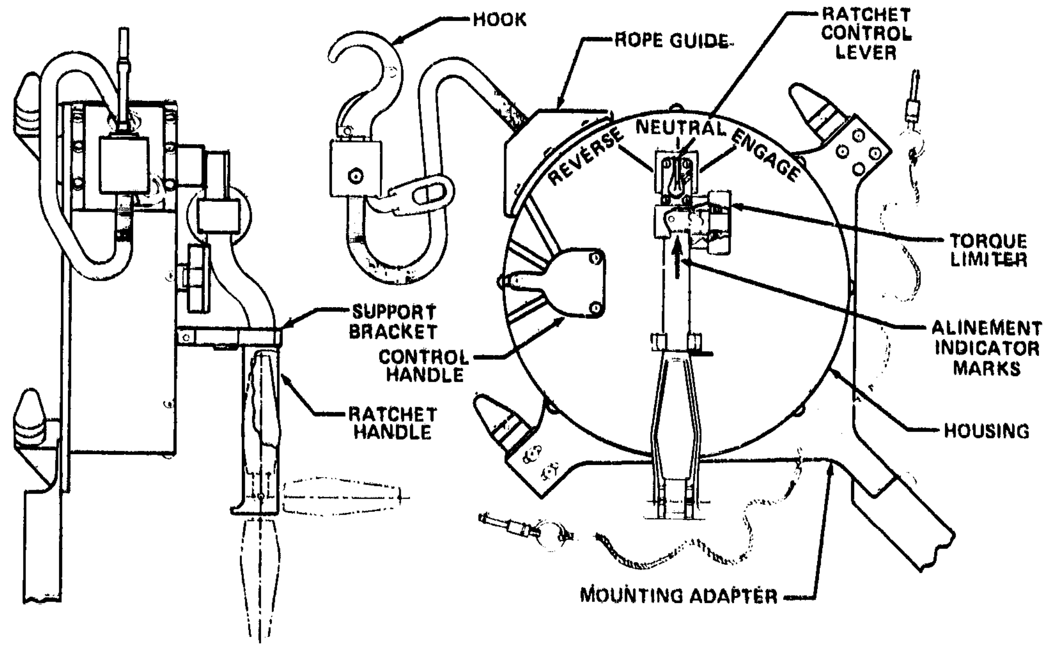
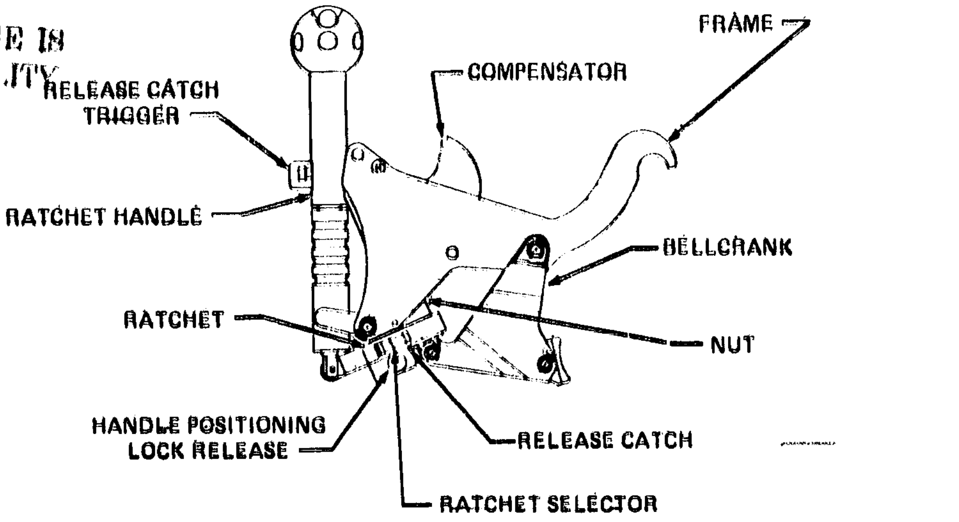
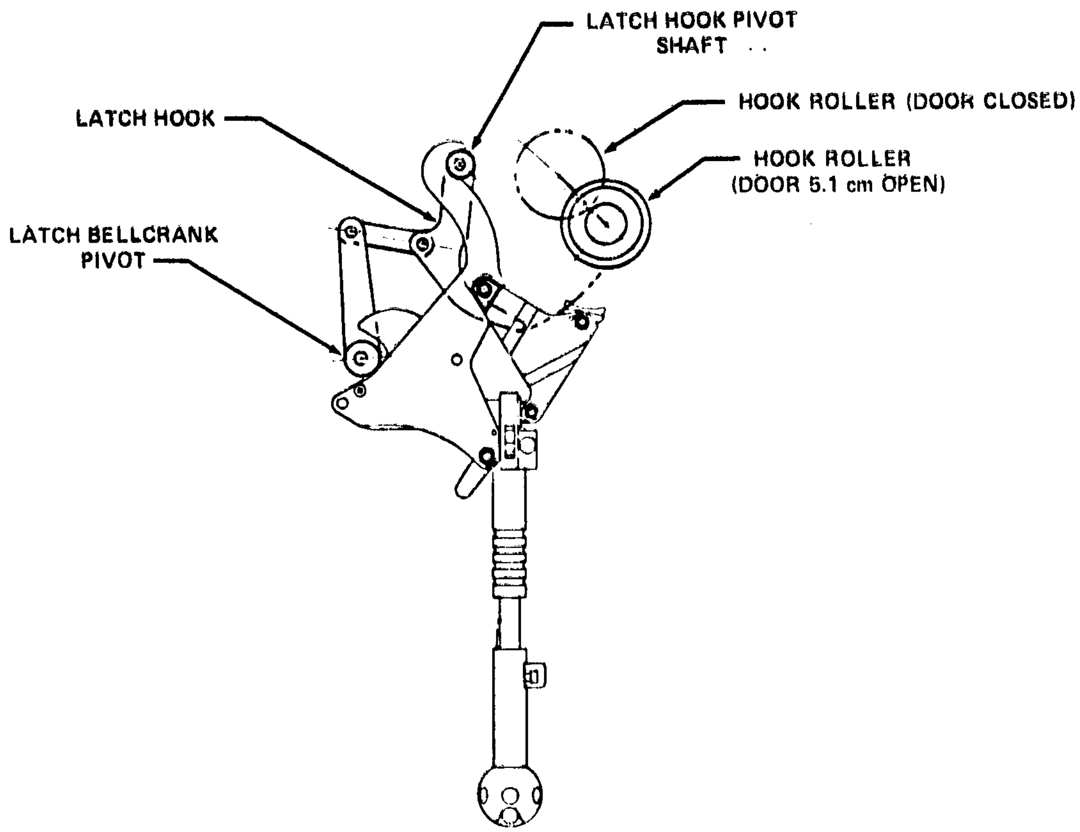


Figure 6.- Winch.

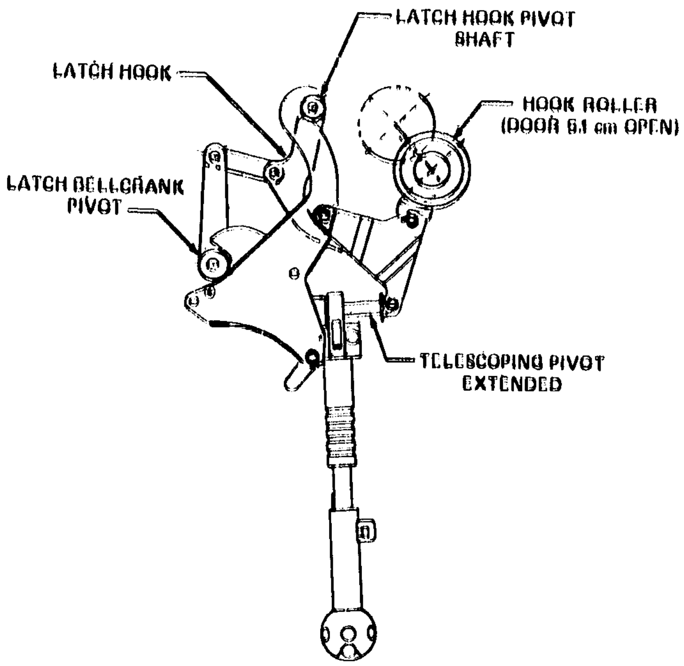


(a) Stowed.

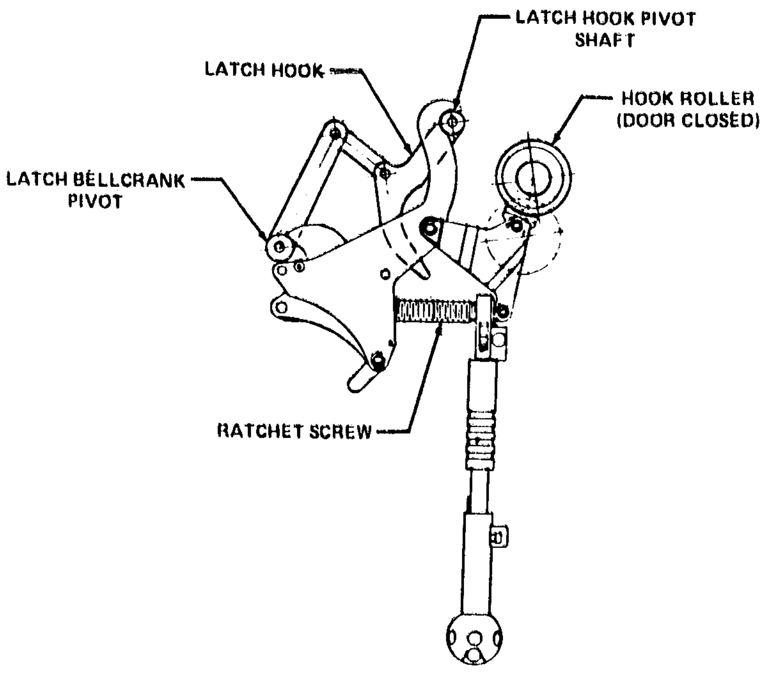


(b) Installed.

Figure 7.- Three-point latch tool.



(c) Retained by telescoping pivot.



(d) Expanded - door closed and secured.

Figure 7.- Concluded.

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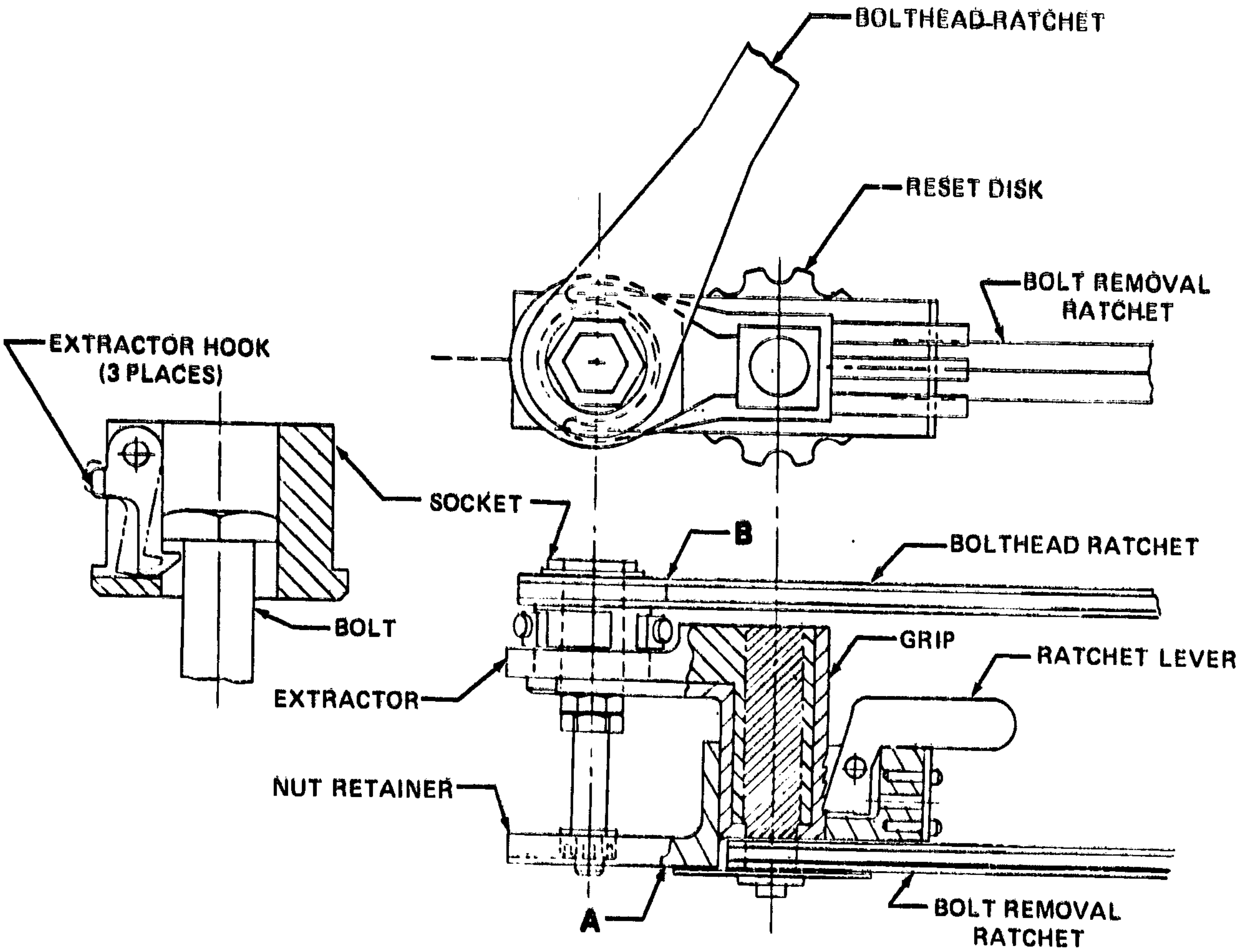

Figure 8.- Bolt extractor.