

1072-13858



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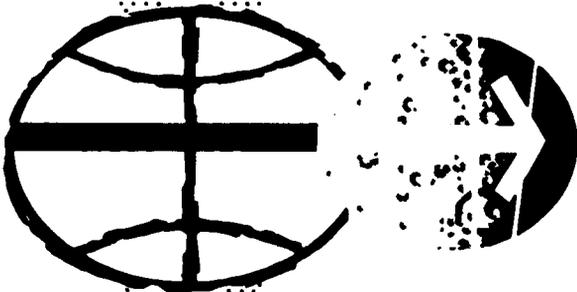
APOLLO 14 MISSION
ANOMALY REPORT NO. 1

FAILURE TO ACHIEVE DOCKING PROBE
CAPTURE LATCH ENGAGEMENT

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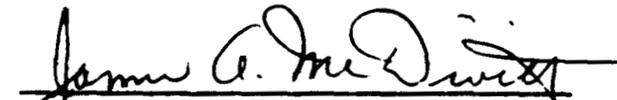
APOLLO 14 MISSION

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FAILURE TO ACHIEVE DOCKING PROBE CAPTURE LATCH ENGAGEMENT

STATEMENT

Six docking attempts were required in order to successfully achieve capture latch engagement during the transposition and docking phase following translunar injection. After docking, the probe (fig. 1) and drogue (fig. 2) were examined by the crew. Probe operation appeared normal and radial marks were noted on the drogue. During all subsequent operations, the probe operated properly.

DESCRIPTION AND SYSTEM OPERATION

During prelaunch operations of the Apollo spacecraft, the docking probe assembly is installed in the command module docking ring in the retracted and cocked configuration and is attached to the boost protective cover by a tension-tie mechanism. If a launch escape system abort of the command module is required during ascent, the docking ring is severed from the command module by an explosive charge and the docking ring and probe assembly are jettisoned with the launch escape tower and boost protective cover (fig. 3). However, for normal ascent, the docking ring is not severed. Instead, the tension-tie shear pins shear when the launch escape tower and boost protective cover are jettisoned; thus, the tension tie is pulled out of the probe head by the launch escape tower, leaving the docking ring and probe assembly intact. The tension tie is shown in figure 3. After docking has been accomplished, the probe is removed from the command module tunnel for access to the lunar module. The probe is normally jettisoned with the lunar module ascent stage. (The Apollo 14 probe was returned for failure analysis.)

The docking probe (fig. 1) is a tripod-mounted device that serves as the active portion of the docking system. The probe incorporates provisions for the initial capture of the lunar module, energy attenuation, command module/lunar module retraction, relative vehicle alignment, and undocking. The three probe support arms are made of titanium and most of the remaining structure is aluminum with a nickel-plated exterior finish to provide passive thermal control. The structural items (fig. 4) consist of the central cylinder, a piston, a collar, three pitch arms, three shock struts, and the three support arms. The primary subassemblies of the probe consist of the capture latch assembly, the actuator assembly, the capture latch release handle, the nitrogen pressure system, the ratchet-handle assembly, the extend latch/preload assembly, the shock struts, and the attenuators.



Figure 1.- Apollo 14 probe assembly.

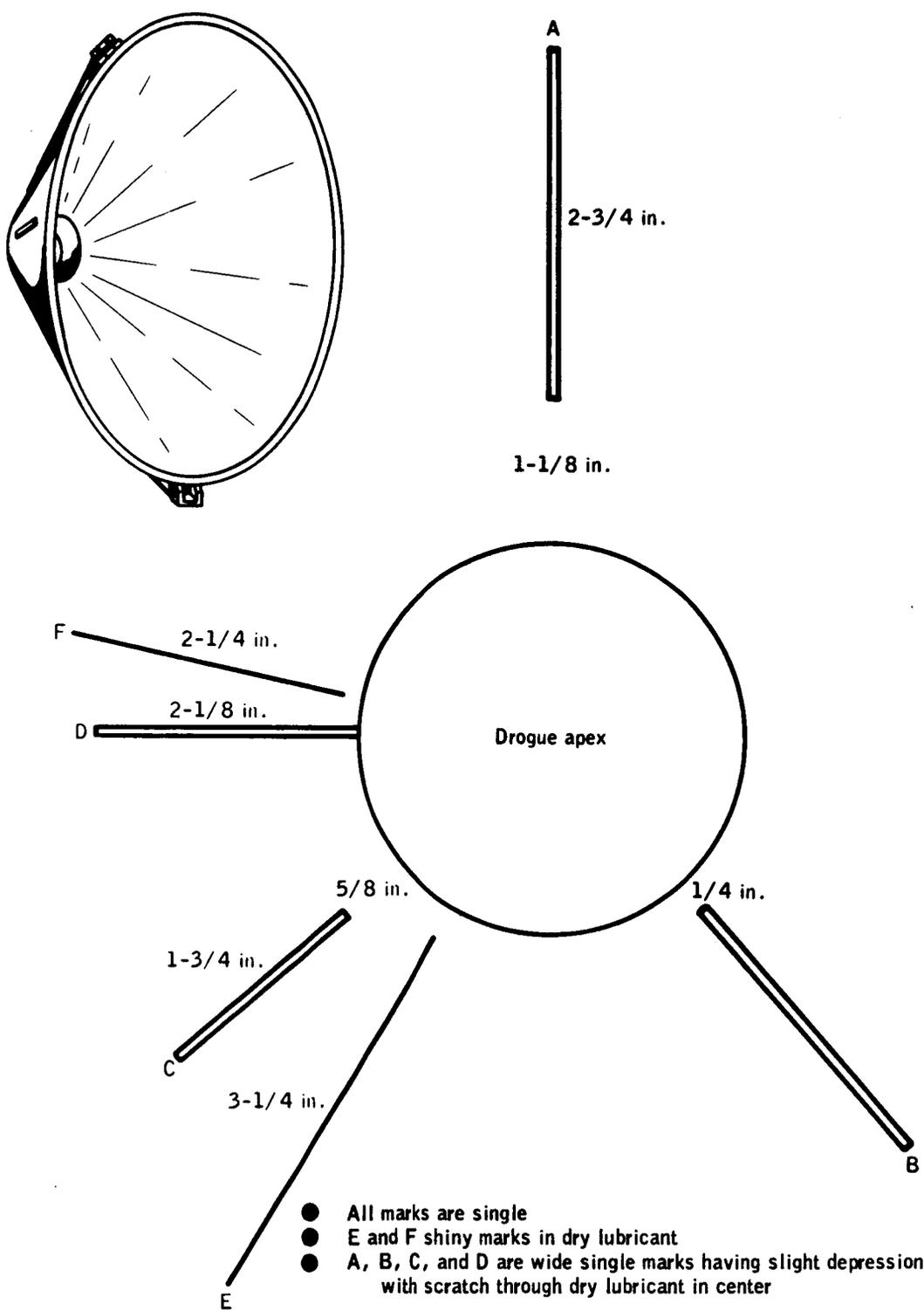


Figure 2.- Drogue assembly and location of radial marks.

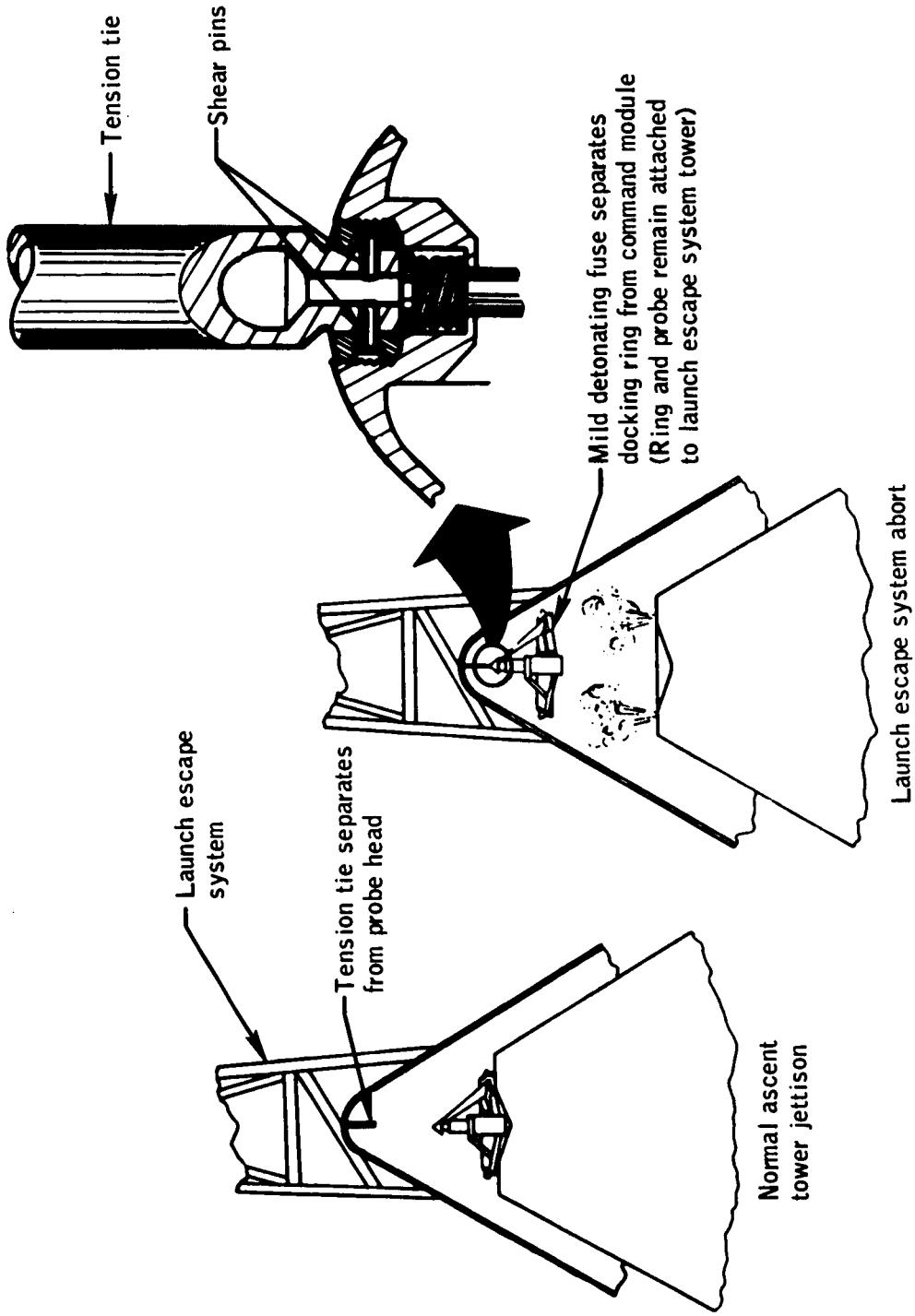


Figure 3.- Tension tie operation.

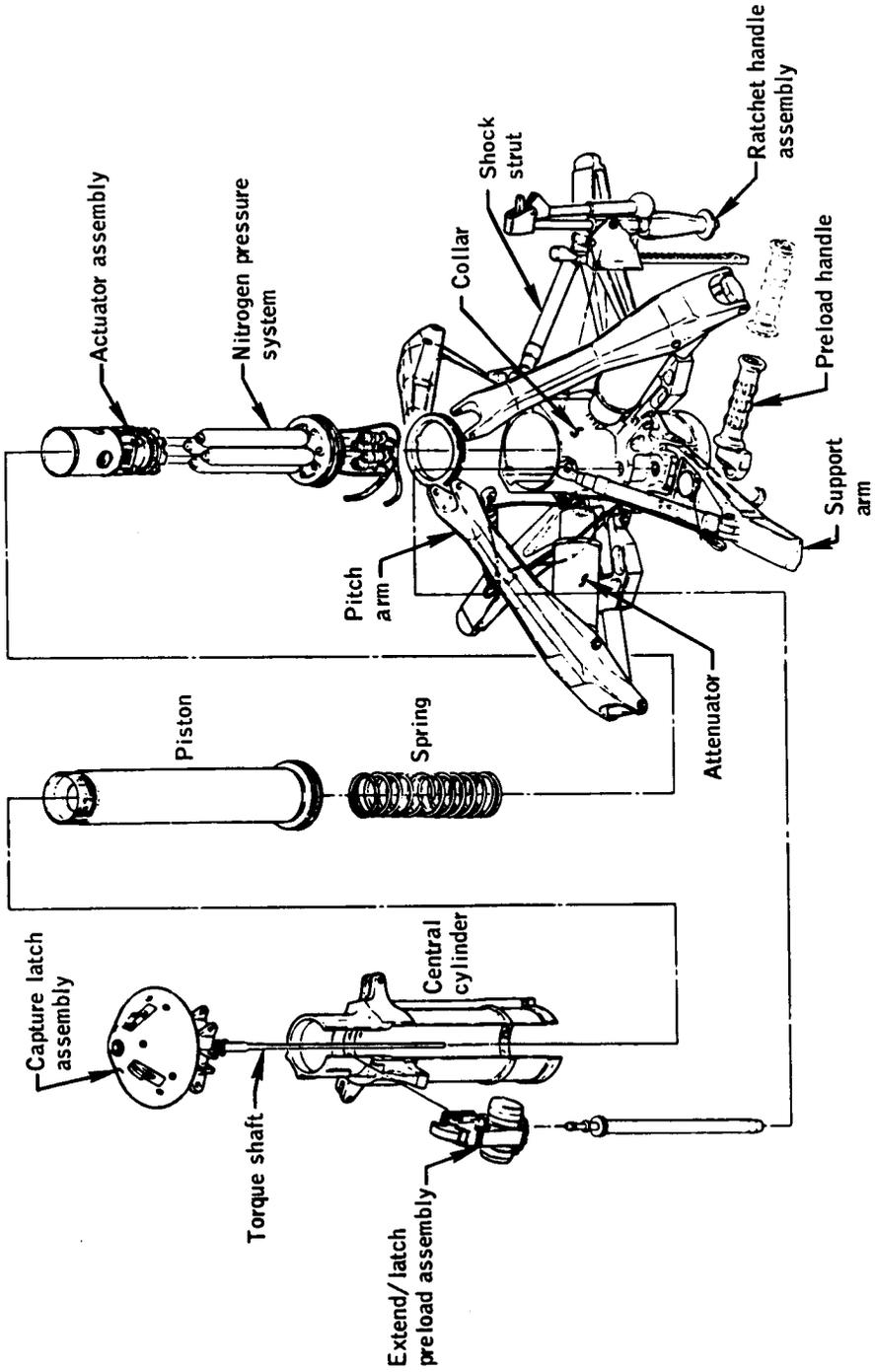


Figure 4.- Structural items of probe assembly.

The probe capture latch assembly (fig. 5) is contained within the probe head and is used for achieving the initial coupling between the command module and lunar module. Figure 6 shows the probe latches locked to a test tool in the same manner as they lock to the drogue. The capture latch assembly consists of three latch hooks (fig. 7) which are pin mounted in the probe head and spring loaded such that the hook protrudes beyond the surface of the probe head. Opposite each of the latch-hook pivot points is a two-piece toggle link (fig. 5) that connects the latch hook to a fixed point on the probe head.

Locking and releasing of the latch hook is determined by the axial position of a single, symmetrical spider (fig. 8) which is spring loaded to the full forward (locked) position (fig. 5). In this position, a roller on the spider (fig. 7) rests beneath each of the latch-hook toggle links such that the latch hooks cannot be depressed. To unlock the latch hooks, the spider must be moved aft and retained until subsequent latch lock is required (fig. 9).

Spider retention and release is achieved by triggers located within each of the latch hooks. When the spider is moved aft of the spring-loaded triggers and released, pins located on the outer tip of the spider (fig. 9) bear against the back face of the trigger and thereby prevent forward travel of the spider. To release the spider, all three triggers must be depressed simultaneously since any one of the triggers will retain the spider in the aft position. The spider can be moved from the forward to the aft position by manually depressing the plunger in the probe head or by rotating the torque shaft. The torque shaft has two rollers which ride in helical slots in a cam (figs. 9 and 10). The cam is attached to the spider with a tension link. When the torque shaft is rotated by either manually actuating the capture latch release handle or by powering the torque motors in the actuator assembly (fig. 11), the rollers turn in the cam slots and force the cam and the spider aft (fig. 9). When power is removed from the torque motors, the torsion spring on the torque shaft rotates the shaft back and allows the spider to move forward until cocked, i.e., the spider pins ride against the back of the triggers.

The actuator assembly (fig. 11) consists of two tandem-mounted dc torque motors, 16 switches, and required electrical circuitry, all located within the probe cylinder. The motor output is such that single-motor operation provides sufficient torque to unlock the capture latches. The drogue (fig. 2), a truncated cone structure that is installed in the lunar module tunnel, and serves as a guide and receiver for the probe head.

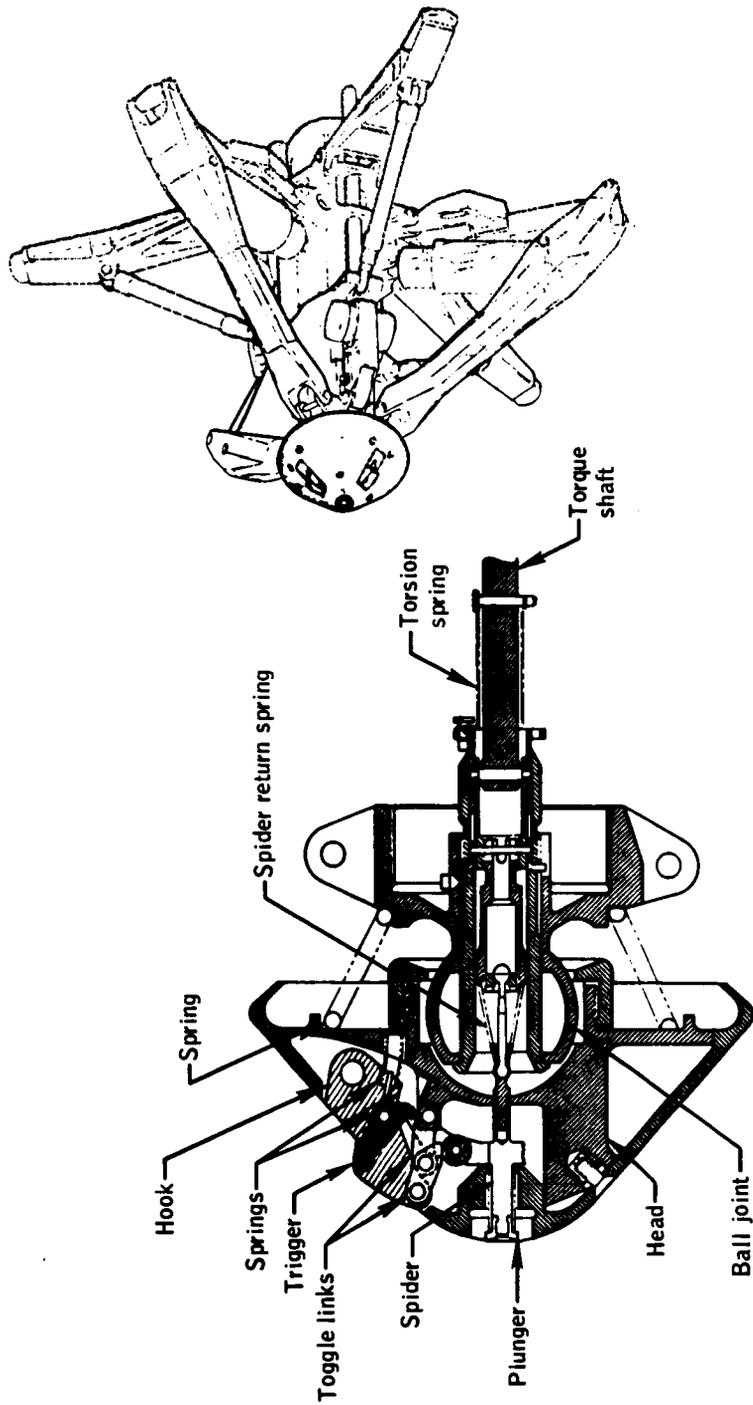


Figure 5.- Probe capture latch assembly shown in locked position.

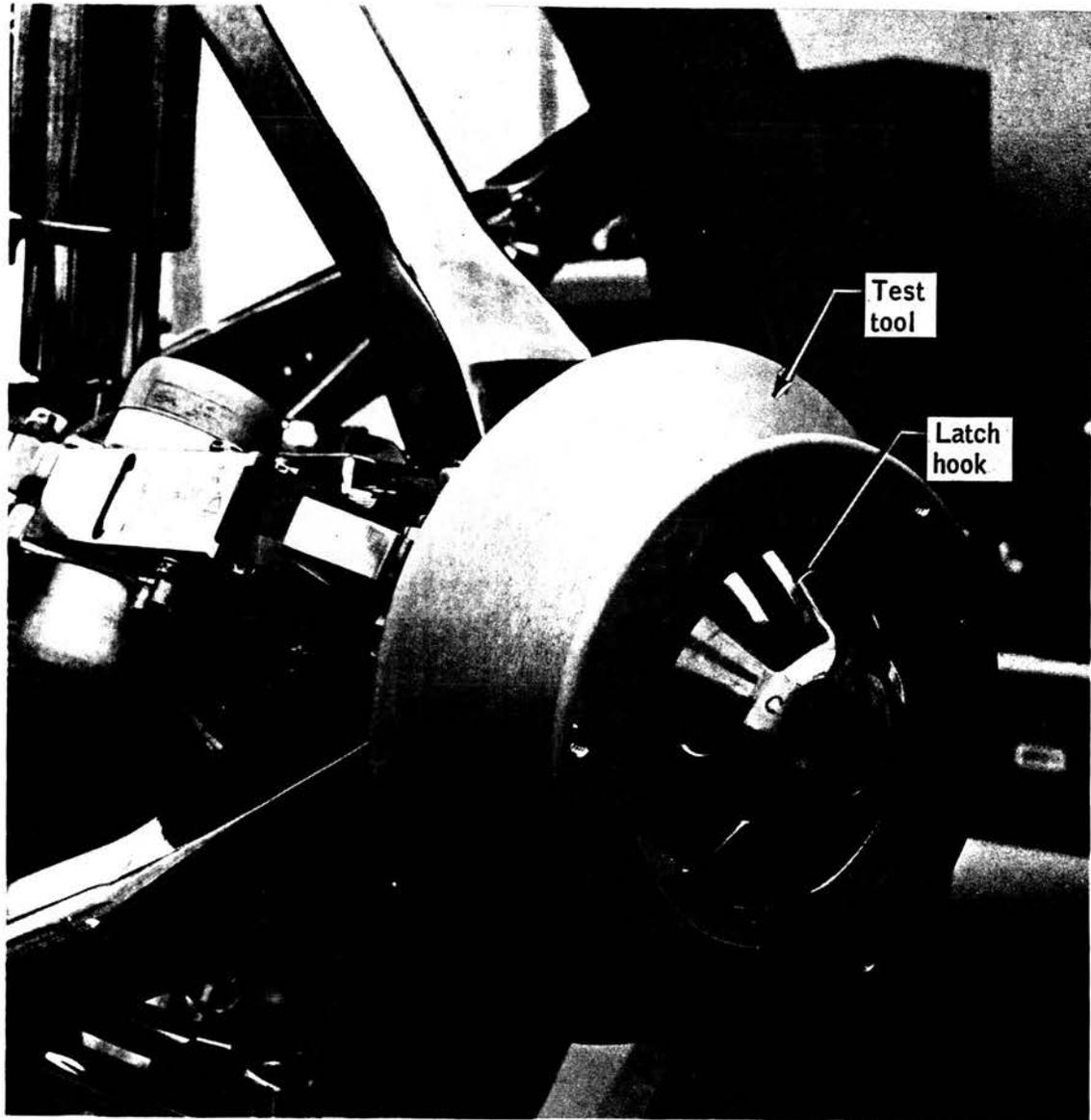


Figure 6.- Probe latched to test tool.

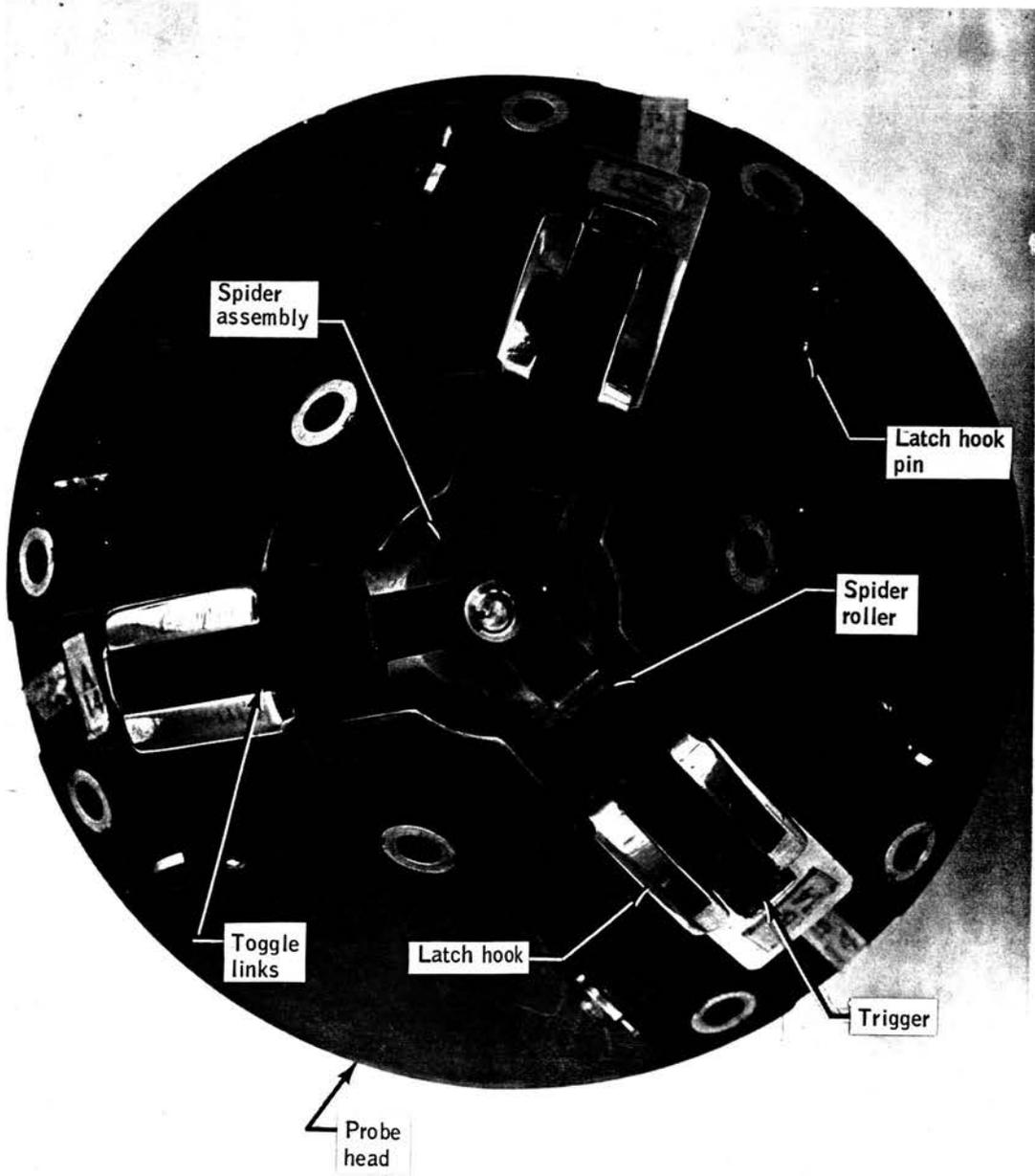


Figure 7.- Capture latch assembly.

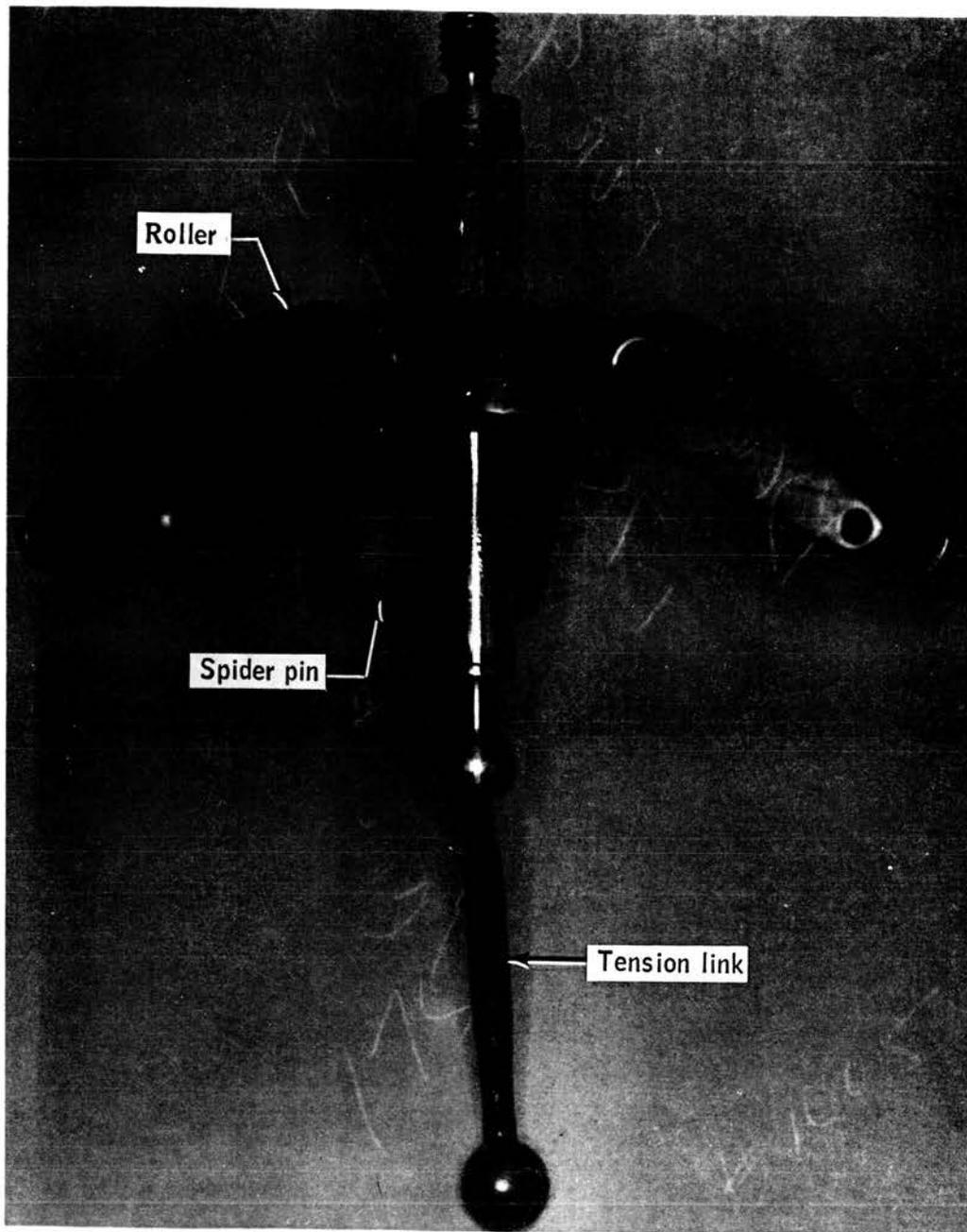


Figure 8.- Spider assembly.

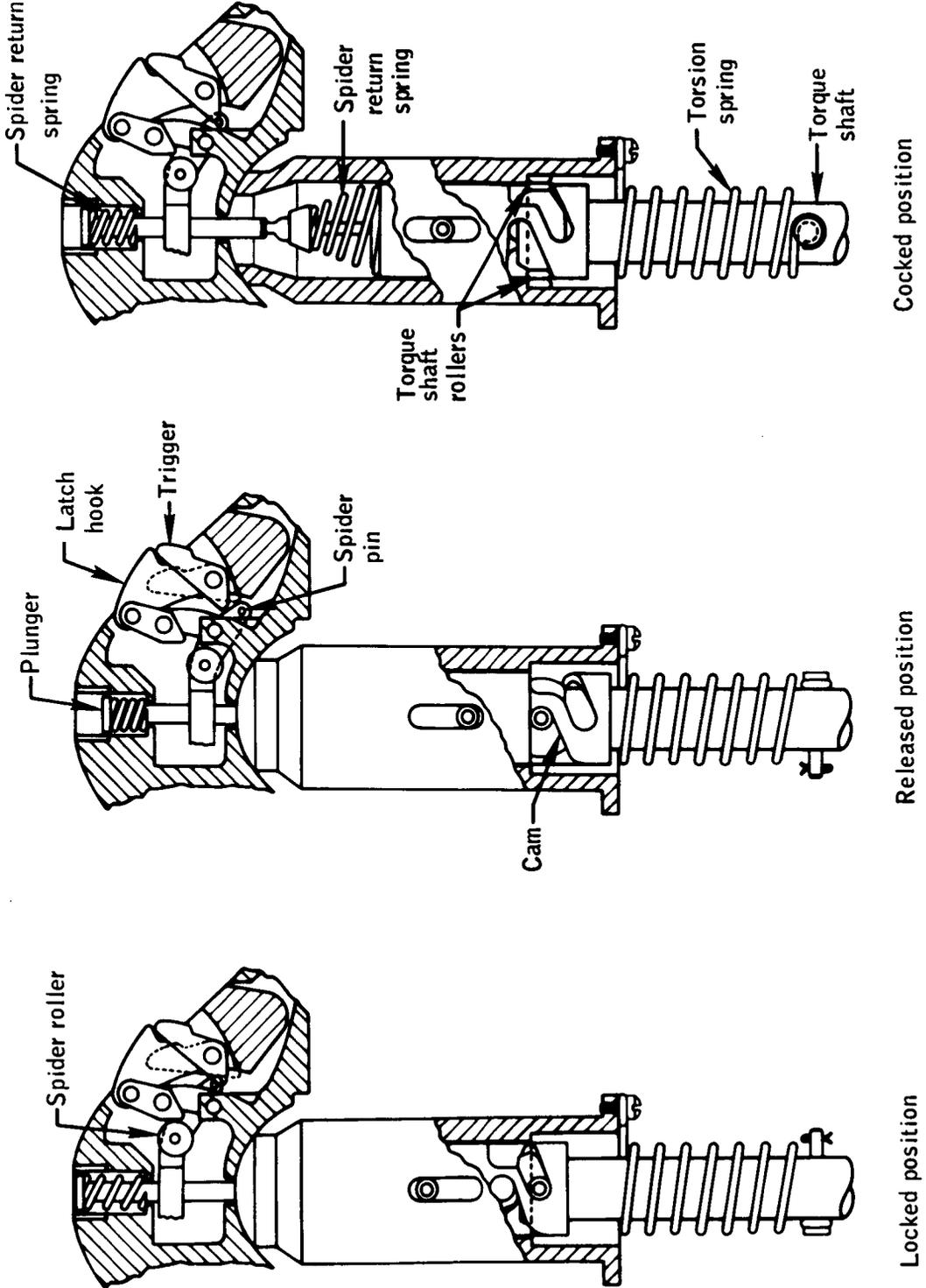


Figure 9.- Relationship of probe latch and cam mechanisms.

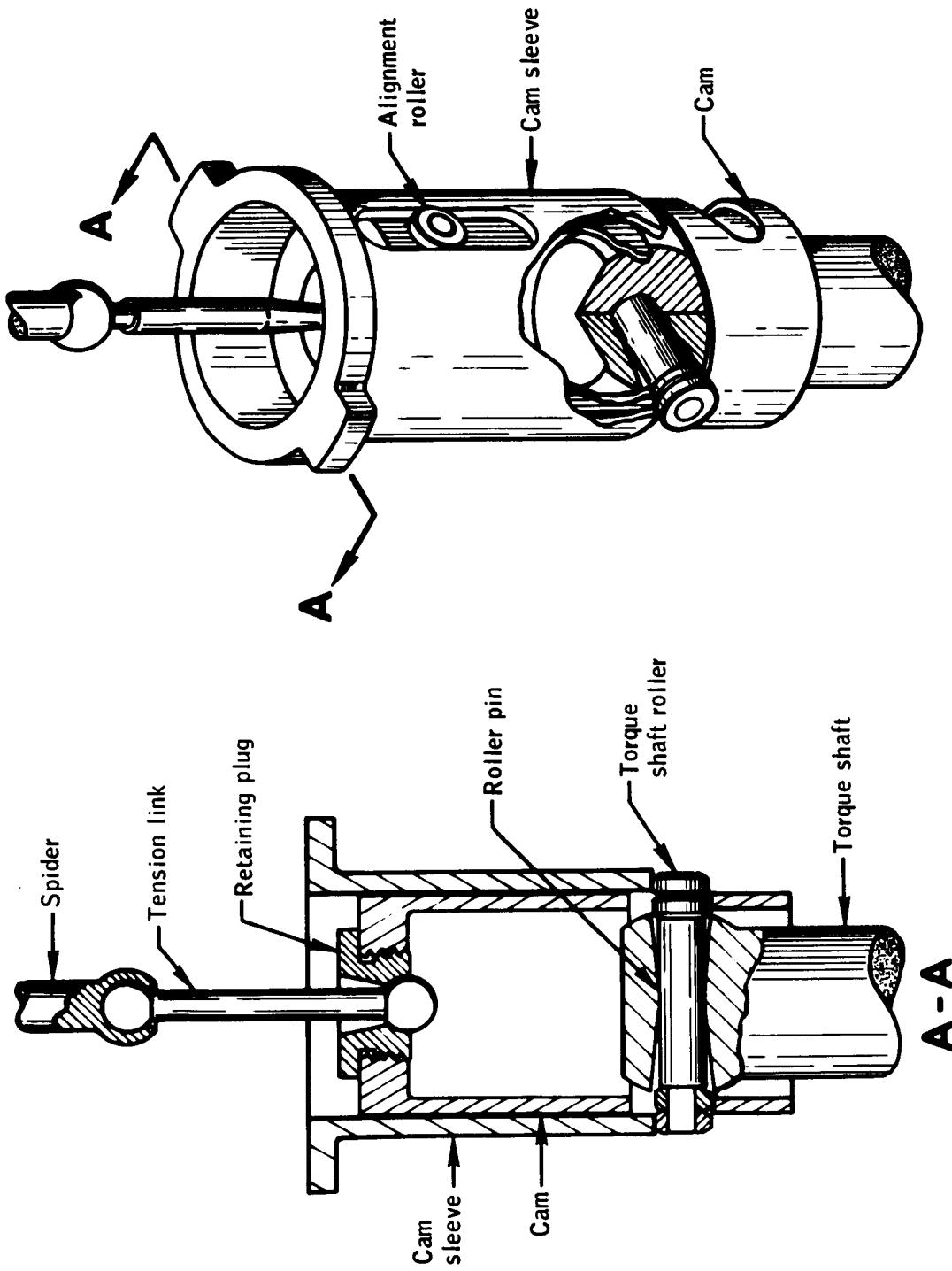


Figure 10.- Cam actuating mechanism.

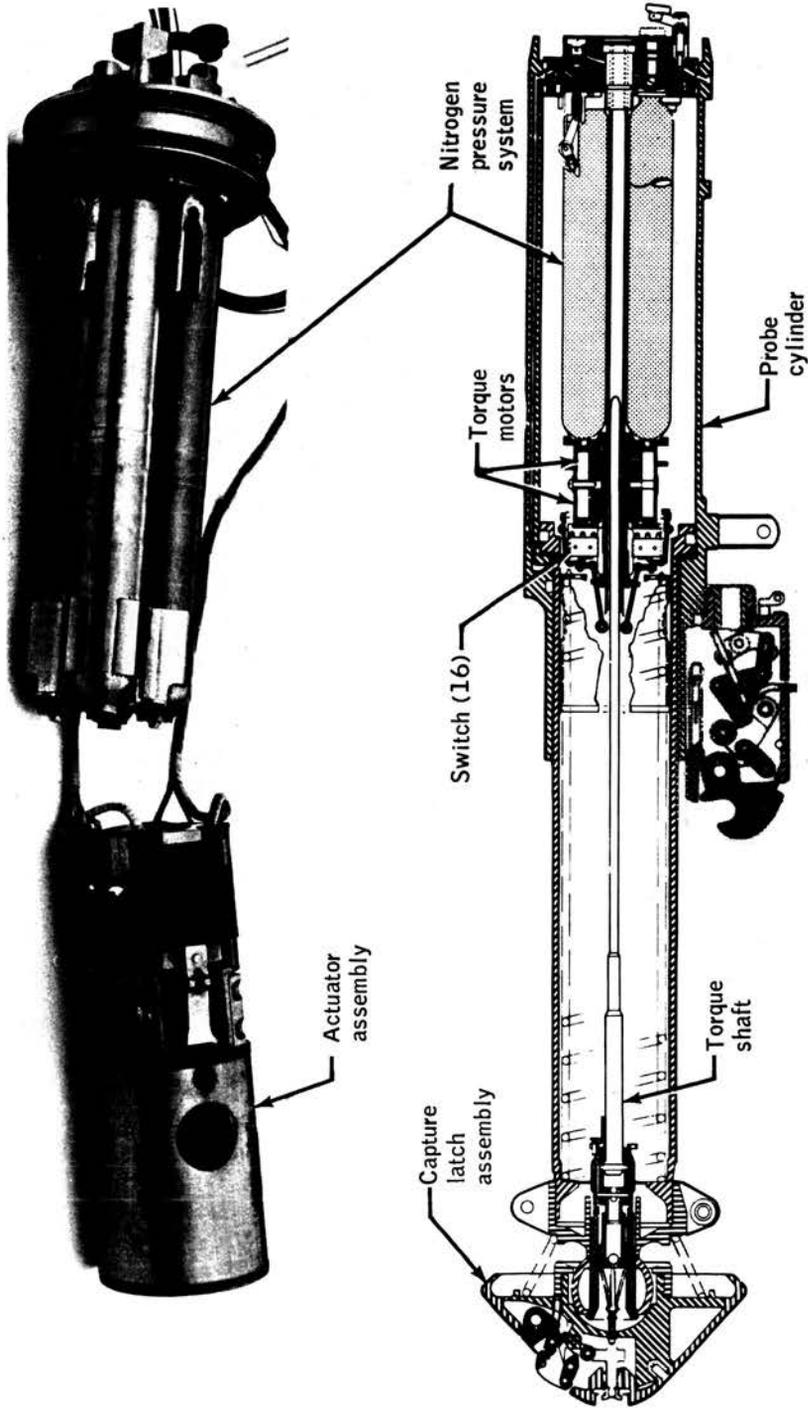


Figure 11.- Cutaway of probe assembly in extended and cocked position.

DISCUSSION

Data indicate that probe-to-drogue contact conditions were normal for all docking attempts, and capture should have been achieved for the five unsuccessful attempts (table I). The capture latch assembly must not have been in the locked configuration during the first five attempts based on the following:

1. The probe status talkback displays functioned properly before and after the unsuccessful attempts, thus indicating proper switch operation and power to the talkback circuits. The talkback displays always indicated that the capture latches were in the cocked position during the unsuccessful attempts (fig. 9). (Note that no electrical power is required to capture the drogue, because the system is cocked prior to flight and the capture operation is strictly mechanical and triggered by the drogue.)

2. The marks on the drogue noticed by the crew (fig. 2) indicate that capture latch hooks were cocked as they should have been during the docking attempts. This confirms the talkback indications at the time of the docking maneuver. Also, after the flight, a drogue that had been used in dynamic testing with multiple marks, scratches, dents, and tears in the face sheet skin was examined by the Command Module Pilot. The marks chosen by him to be most like those on the Apollo 14 drogue were caused by the capture latch hooks while operating normally (cocked position).

Since the latches were cocked, the problem was most likely caused by failure of the capture latch spider to reach the forward locked position.

A number of possible causes for preventing the capture latch spider from extending to the locked position were ruled out. A summary of these possible causes follows:

1. The tension-tie shear pin remnants re-entered the capture latch assembly during launch escape tower jettison. Tests show that the pin-remnant trajectories were such that the remnants would not re-enter the head.

2. As a result of rain on launch day, water could have entered the probe head and frozen during the launch phase. This could cause the mechanism to bind. A maximum of 30 grams of ice could have formed; however, this amount would sublime within 15 minutes, well before the docking event which occurred about 3 1/2 hours after launch.

TABLE I.- RELATED DATA AND FILM INVESTIGATION RESULTS

Docking attempt	Contact, hr:min:sec	^a Estimated velocity, ft/sec	Contact position, clock-oriented	^b Socket contact time, seconds	+X thrusting after contact, seconds	^a Comments
1A	3:13:53.7	0.1	11:00	1.55	None	1. No thruster activity 2. Contact moderately close to apex
1B	3:14:01.5	^c 0.14 max	9:00	1.65	None	Contact close to apex
1C	3:14:04.45	^c 0.14 max	4:30	1.4	0.55	Contact close to apex
1D	3:14:09.0	^c 0.29 max	4:00	2.35	1.95	Contact close to apex
2	3:14:43.7	0.4 to 0.5	8:30	1.7	None	Contact close to apex
3	3:16:43.4	0.4	7:00	2.45	None	Contact close to apex
4	3:23:41.7	0.4 to 0.5	3:00	6.5	6.2	Contact close to apex
5	4:32:29.3	0.25	6:00	2.9	None	Contact close to apex
6	4:56:44.9	0.2	7:00	In and hard docked	14.3	1. Contact moderately close to apex 2. Retract cycle began 6.9 seconds after contact 3. Initial latch triggered 11.8 seconds after contact

^aSystem is designed to capture with closing velocities between 0.1 and 1.0 ft/sec and with initial probe contact within 12 inches of the center of the drogue. These criteria were met on all docking attempts.

^bThe maximum capture-latch response time is 80 milliseconds.

^cEstimated velocity from X-thruster activity time. These are maximums with some velocity being used to null out small separation velocity. Other velocities were estimated by film interpretation.

3. Extreme temperature effects could have caused the mechanism to bind. The temperature within the probe body was between 95° and 100°F at the time of the problem. The returned probe operated properly from +50°F to +145°F.

4. A tolerance buildup in the latch mechanism combined with a normal thermal gradient between the parts caused binding. Analysis of the worst-case tolerance buildups, including thermal gradients and detailed inspection and measurement of the probe components, showed no interference.

Two possible causes remain that could prevent the capture latch spider from moving properly.

The first possibility is that of a side load being introduced into the torque shaft (fig. 12) by the torsion spring or by other means; this may cause the ball end of the torque shaft to bind against the cam. This failure occurred on another probe during acceptance tests and it was possible to demonstrate this same failure on the Apollo 14 probe by applying a side load, but the failure did not occur consistently.

The second possibility is that some small foreign material may have been lodged in the probe in a manner that prevented operation of the mechanism. Burrs from an unknown source were discovered in the bore of the tension-tie plug (fig. 13). A foreign particle might have been lodged between the plunger and the plug and may have caused the problem.

During disassembly of the probe, 12 contaminant particles were found. Three materials foreign to the probe were: Iron oxide, double-back tape, and cadmium particles. The largest of the 12 particles was 0.060-inch long. Of the particles which were large enough to cause mechanical interference none were strong enough to restrict the operations of the mechanism.

CONCLUSION

The failure to achieve capture-latch engagement has been narrowed to either foreign material restricting the normal function of the capture latch mechanism or jamming of the translation cam.

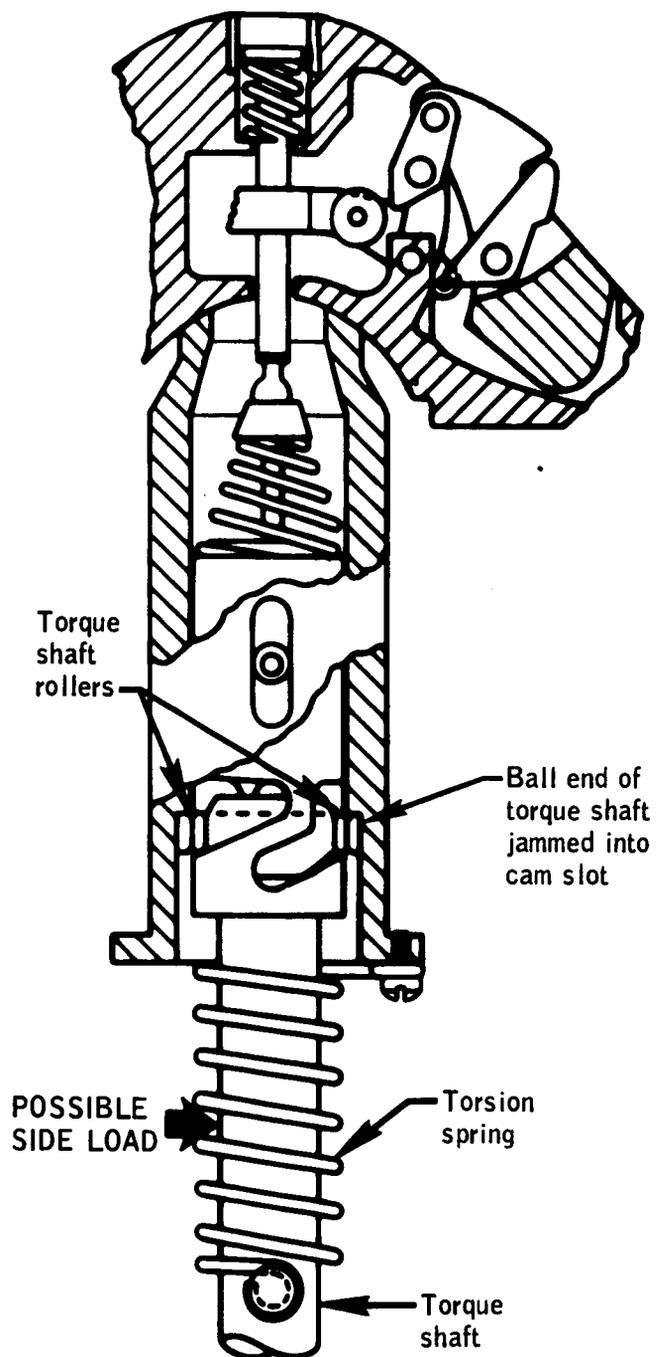


Figure 12.- Side load reaction on torque shaft operation.

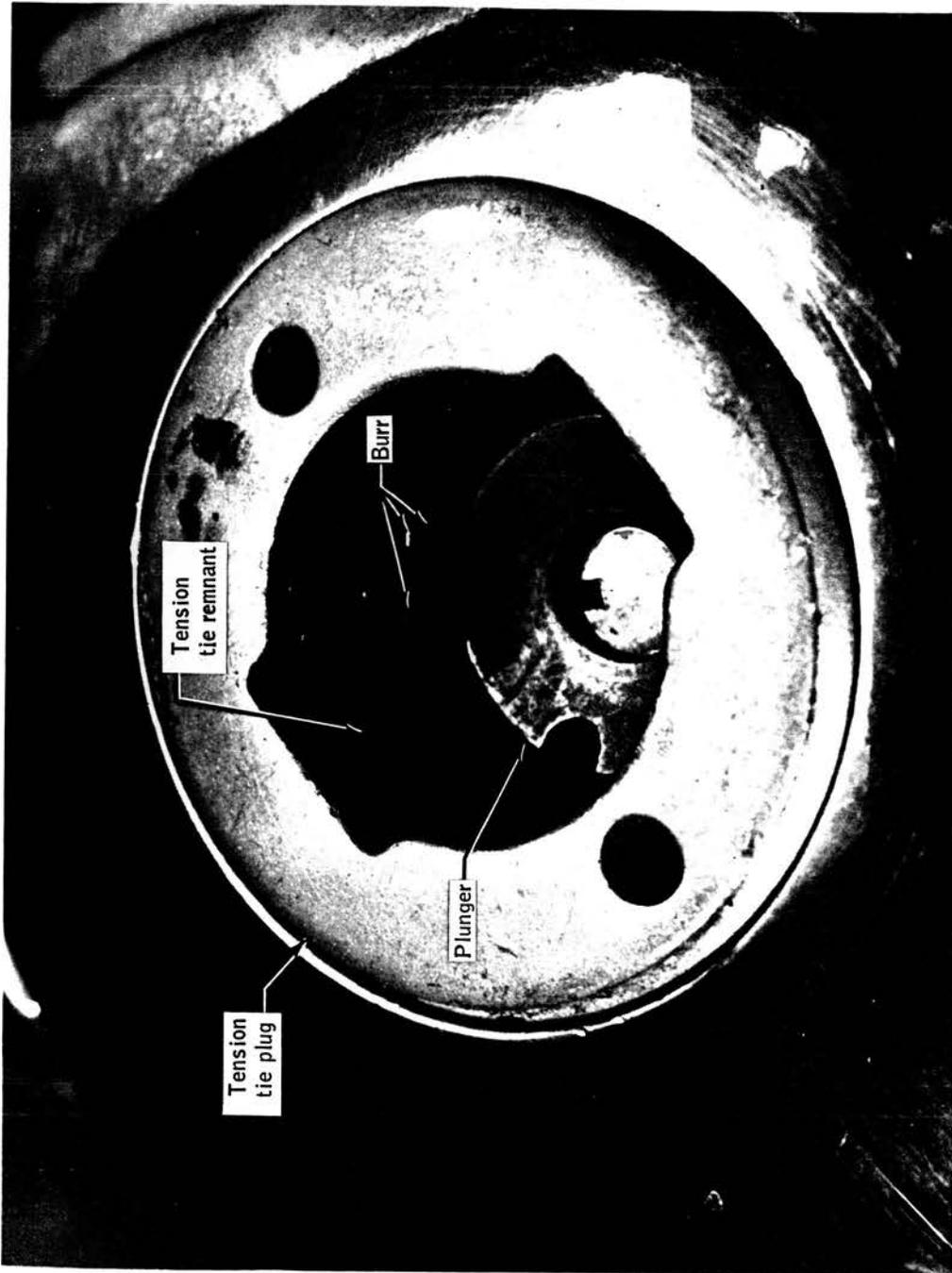


Figure 13.- Scratches and burrs adjacent to capture latch plunger.

CORRECTIVE ACTION

The following changes have been made to prevent the introduction of foreign material into the probe mechanism:

1. A removable cover was provided for the probe head. The cover will be installed at the completion of acceptance testing and remain in place until the tension-tie assembly is installed at the launch complex. It will be removed only when the probe is being tested.
2. Cleanliness requirements for all ground support equipment mating with the probe have been implemented.
3. Use of cleaners or primers when potting the tension tie nut during installation has been prohibited.
4. Shear pin remnants in the tension tie have been safety wired, and the potting holding the shear pins in place has been removed (fig. 14).

The following changes have been completed to minimize the possibility of a translation cam malfunction:

1. The probe translation-cam assembly (fig. 15) was modified to eliminate possible binding of the cam and spider.
 - a. The diameter of the ball machined on the forward end of the torque shaft was reduced.
 - b. The roller pin surface was machined to allow a rocking motion between the roller pin and hole in torque shaft.
 - c. A spherical surface was provided on the roller ends and roller pin ends for improved clearance.
 - d. An alignment bushing was added to insure proper torque shaft alignment.
2. A requirement was added to test the probe in the horizontal as well as vertical position during the capture latch timing test of the acceptance testing.
3. Capture latch timing tests were added just prior to the countdown demonstration test for the latest possible verification of latch operation in the spacecraft checkout flow.

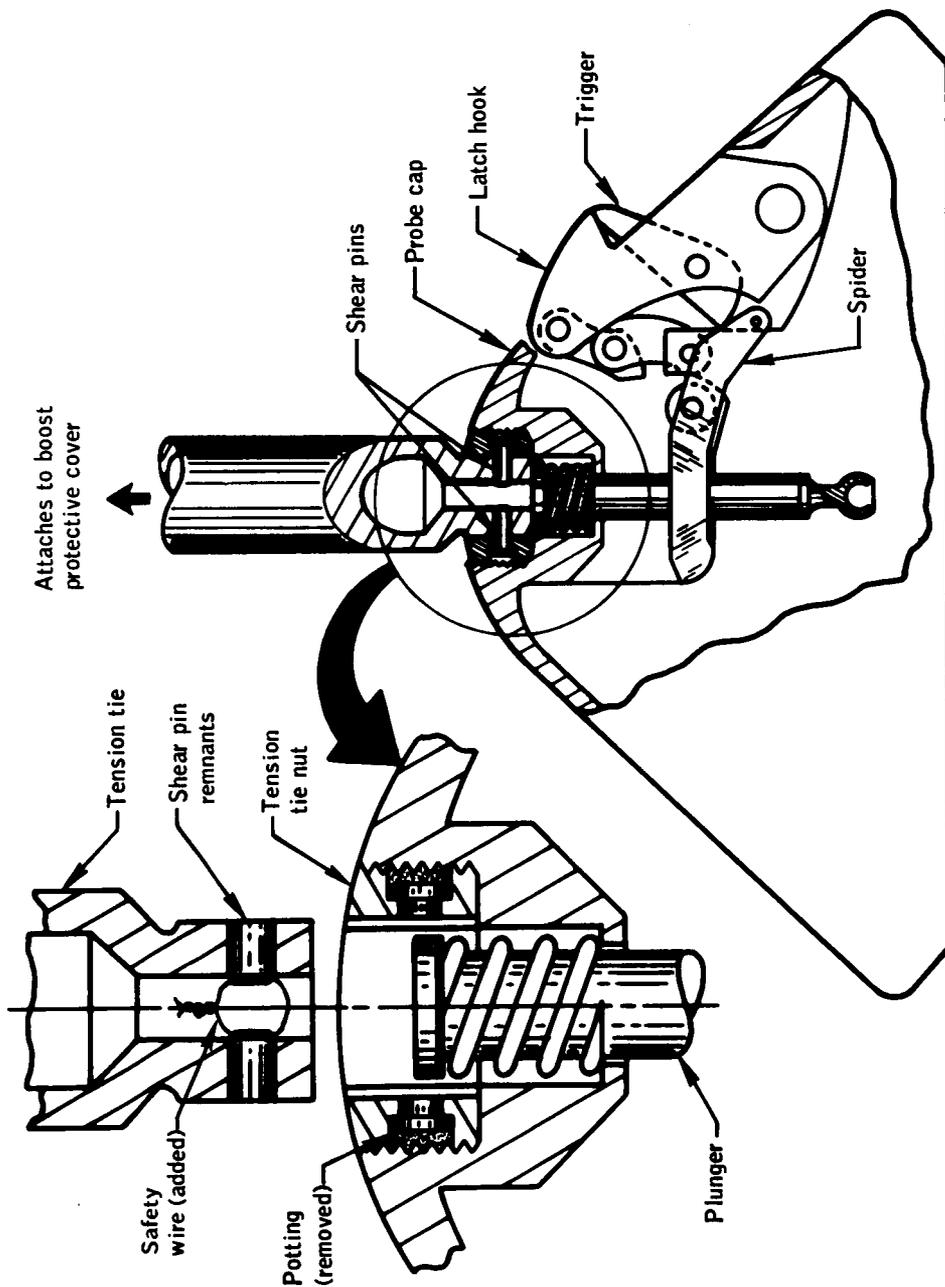
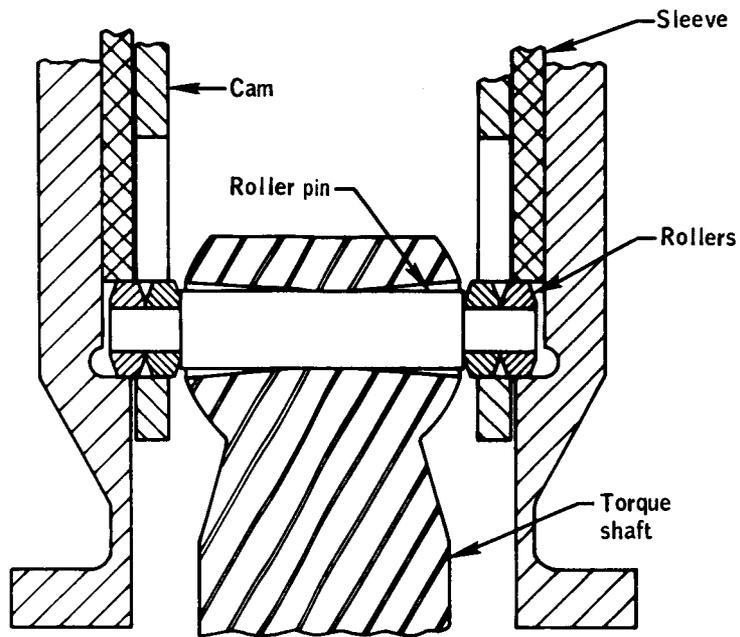
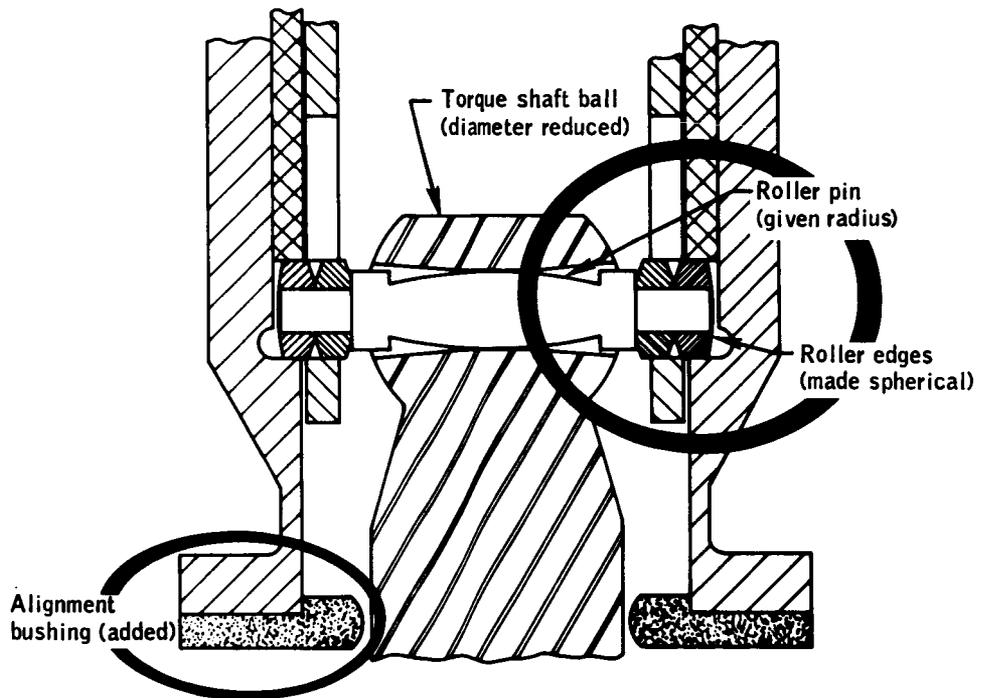


Figure 14. - Probe-tension tie changes.



(a) Apollo 14 cam assembly.



(b) Apollo 15 and subsequent cam assembly.

Figure 15.- Cam assembly modifications.