NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

October 7, 2020

MATERIALS LABORATORY FACTUAL REPORT Report No. 20-050

A. ACCIDENT INFORMATION

Place	:	Scottsbluff, Nebraska
Date	:	December 18, 2019
Vehicle	:	Cessna 525A, C-GOJG
NTSB No.	:	CEN20LA041
Investigator	:	Mitchell Gallo, ASI-CEN

B. COMPONENTS EXAMINED

Quarter-turn fastener assembly components from a right-side engine lower cowl door as follows:

1) 9 stud assemblies, grommets, and snap rings from the lower cowl door forward attachment flange;
2) 11 receptacles from the lower cowl door forward attachment flange;
3) 11 stud assemblies, grommets, snap rings, and receptacles from the lower cowl door aft attachment flange.

C. DETAILS OF THE EXAMINATION

1. Description of hardware and its operation

Quarter-turn fastener assemblies (also known as camlocks), used to secure a right-side engine lower cowl door, were received by the NTSB Materials Laboratory for examination as shown below in figure 1. The fastener system consisted of four components: a quarter-turn stud assembly, a grommet, a snap ring, and a receptacle. In the as-installed configuration, the grommets (see the exemplar in figure 2) were installed in a series of dimpled holes along the perimeter of the cowl door and secured using snap rings on the inner side of the panel. The stud assemblies (see also the exemplar in figure 2) consisted of a shank with a Phillips head at one end and cross-pin at the other. Captured between the head and the cross-pin were a spring and a spring cup. To insert the stud through the grommet, a tool was used to grab the rim of the spring cup and pull it against the underside of the stud head. One side of the cross-pin was passed through the grommet opening and the stud was tilted to pass the other side of the cross-pin through the opening. Once the tool was removed, the stud was captured in the grommet by the cross-pin on one end and the rim of the spring cup on the other end.

The receptacles (see figures 3 and 4) were installed on the backsides of forward and aft attachment flanges (parts of the engine inlet and aft firewall assemblies, respectively) with rivets. The receptacles consisted of a floating cup in a cage with a slotted hole at the bottom of the cup. In the as-installed configuration, the cross-pin was inserted through the slot and the stud was turned clockwise. As the stud was turned, each arm of the cross-pin would slide along a helical ramp that passed over a raised bump and into a detent on the backside of the receptacle. The appropriate stud length is determined by the total thickness of the panel assembly. If the stud grip length is too short, the cross-pin cannot pass over the bump. If the grip length is too long, the raised bump cannot stop the stud from rotating out of the locked position. Stud lengths come in 0.03-inch increments as indicated in table 1 below. For convenience, dash numbers will be used to refer to their respective stud lengths. The total material thickness is also given in the table below. Total material thickness is the recommended net thickness of the stack of panels sandwiched between the receptacle and the grommet. In this application, it is assumed that the top of the grommet flange is flush with the outer surface of the cowl door.

Table 1: Stud dash numbers and associated dimensional data.

Stud Dash Number	**Total Stud Length, inch**	**Total Material Thickness (with Floating Receptacles), inch**
-2	0.72	0.051 – 0.080
-3	0.75	0.081 – 0.110
-4	0.78	0.111 – 0.140
-5	0.81	0.141 – 0.170
-6	0.84	0.171 – 0.200

According to the Cessna 525A Illustrated Parts Catalog, the designated stud part number is S3412-103, which has the same stud length and total material thickness as the “-3” stud in the table above. According to a Textron Air Safety Investigator, the cowl door and attachment flanges were both nominally 0.040-inch thick panels (with additional unspecified thickness for primer and paint layers). In two locations around each flange, there were splice plates that were also nominally 0.040-inch thick.

The grommets are also available in different heights for different outer panel thicknesses. According to the Cessna 525A Illustrated Parts Catalog, the grommet part number for the lower cowl door was S2319-63, which had a specified total height between 0.183 inch and 0.191 inch.

2. Examination of accident aircraft hardware

The lower cowl door fastener assemblies from the forward and aft attachment flanges were received by the Materials Laboratory as shown in figures 1a and 1b, respectively. There were eleven receptacles but only nine stud assemblies, grommets, and snap rings. On-scene examination of the right engine revealed that the missing hardware originated from the inboard side of the engine as shown in figure 3. When viewed from the aft position looking forward, the fasteners were between the 8:00 and 9:00 positions. On scene, the fasteners were given numbers starting at the 3:00 position and proceeding clockwise, so that the missing hardware was located at positions 10 and 11, as indicated in figure 3. Of the remaining nine studs, studs 1, 3, 4, and 6 were matched with their corresponding receptacles. The other studs were not labelled and could not be associated with a receptacle. Similarly, for the aft attachment flange, only studs 1, 4, 5, 8, and 9 were matched to their corresponding receptacle.

The hardware was examined for part numbers or other identifying marks. Non were found on the receptacles. The stud heads were labelled with dash numbers and all studs were “-3” except for the studs at receptacle location 4 on both the forward and aft attachment flanges, which were “-4” studs. The length of a “-3” and “-4” stud was measured with a micrometer and each corresponded to the length given in table 1 above. According to a Textron Air Safety Investigator, the number 4 receptacles are located at a splice plate. The grommets were all labelled as “SKYBOLT HS”. According to Skybolt product information, HS-type grommets are nominally 0.197 inch in height. The height of one of the grommets was measured with a micrometer and measured 0.204 inch in height. A top-down view of a HS grommet from the accident aircraft is shown in figure 5a and a side view comparing the height with that of a S2319-63 (from the part catalog) is shown in figure 5b.

The numbers 10 and 11 receptacles were examined for any notable features, but none were found. An overview image of the two receptacles is shown in figure 4a and a side view of receptacle 10 is shown in figure 4b. The interior of the number 10 receptacle cup is shown in figure 6a and the backside of the cup is shown in figure 6b. Deformation and wear of material was observed at the edge of the slot where the cross-pin passed through the base of the cup and the ramps on the backside of the cup exhibited a rubbed appearance consistent with sliding contact. The detent regions exhibited regions with a rubbed appearance interspersed with the matte appearance of the as-manufactured cup. The vertical walls of the slotted hole adjacent to the detent were examined for any deformation or contact damage as shown in figures 7 and 8 for receptacles 10 and 11, respectively. The areas directly adjacent to the detent exhibited a matte appearance consistent with the surface finish of the as-manufactured cup. One area on each receptacle, adjacent to the cup interior, exhibited a rubbed appearance as indicated in figures 7b and 8a.

3. Additional measurements and testing

The receptacle cup backsides were measured for indications of wear of either the detent or raised bump using a laser scanner. Receptacles 10, 11, and an exemplar receptacle were scanned with a tabletop coordinate measurement machine (CMM) with a laser scanning attachment and single point precision of 0.001 inch. The exemplar and receptacle 10 were scanned in two steps and the two scans were later merged. For the first scan, the receptacle was placed bottom-side up and clamped against a flat plate which served as a reference plane. For the second scan, the clamps were removed and the areas obscured by the clamps were scanned. The two scans were then aligned, merged, and converted into a mesh, the results of which are shown in figures 9a and 9b for the exemplar and receptacle 10, respectively. The mounting flange for receptacle 11 was damaged during removal from the attachment flange and could not be clamped flat against the table so a point on the cup where the external diameter changed was used as a substitute reference plane. The scans were then used to measure (where possible) the vertical distance from the reference plane to the tip of each stop, detent, and raised bump, as indicated in figure 9a. The tip/detent and bump/detent vertical distances were then calculated. The results are shown in table 2 below and are for information purposes only. The two sides of each receptacle were arbitrarily labelled 1 and 2.

Table 2: Measured attributes on the backsides of the exemplar receptacle, receptacle 10, and receptacle 11 cups.

Receptacle / Side	Distance from reference plane to tip of stop, inch	Tip of stop to base of detent, inch	Tip of bump to base of detent, inch
Exemplar - side 1	0.552	0.111	0.025
Exemplar - side 2	0.553	0.112	0.027
Receptacle 10 - side 1	0.547	0.109	0.025
Receptacle 10 - side 2	0.549	0.111	0.022
Receptacle 11 - side 1	—	0.104	0.025
Receptacle 11 - side 2	—	0.104	0.025

The maximum and minimum distances from the tip of the stop to base of the detent were 0.112 inch and 0.104 inch, respectively; a difference of 0.008 inch. The vertical distance from the tip of the raised bump to the base of the detent measured 0.025 inch for four of the six measurements, while one side on the exemplar measured 0.027 inch and one side on receptacle 10 measured 0.022 inch.

Finally, the locking and unlocking torques of several studs from the forward attachment flange were measured and compared against a set of exemplar hardware. An aluminum plate was machined with through-holes for attaching an exemplar receptacle to the backside of the plate and for inserting a grommet through the topside of the plate above the receptacle cup. The plate was then milled until the total material thickness, measured from the top of the grommet to the underside of the plate, was 0.085 inch. The receptacle was then attached to the plate with machine screws. A stud was inserted through a grommet and then inserted into the hole above the receptacle cup. A torque gauge with a range of 0 lb-in to 20 lb-in and 0.1 lb-in resolution, attached to a data recorder, was then coupled to a Phillips head bit and the stud was repeatedly rotated back and forth between the locked and unlocked positions. The torque gauge/bit assembly was supported so as not to apply axial load to the stud during the measurement. The measurements are for information purposes only and the following limitations of the measurements should be noted:

1. There is no requirement for locking or unlocking torques;
2. The measurements were made on a single-piece solid plate and not a multi-panel stack;
3. Studs were selected from the accident aircraft with minimal damage but there was still some deformation of the cross-pins and spring cups;
4. The actual stack height on the accident aircraft likely differed from the test panel.

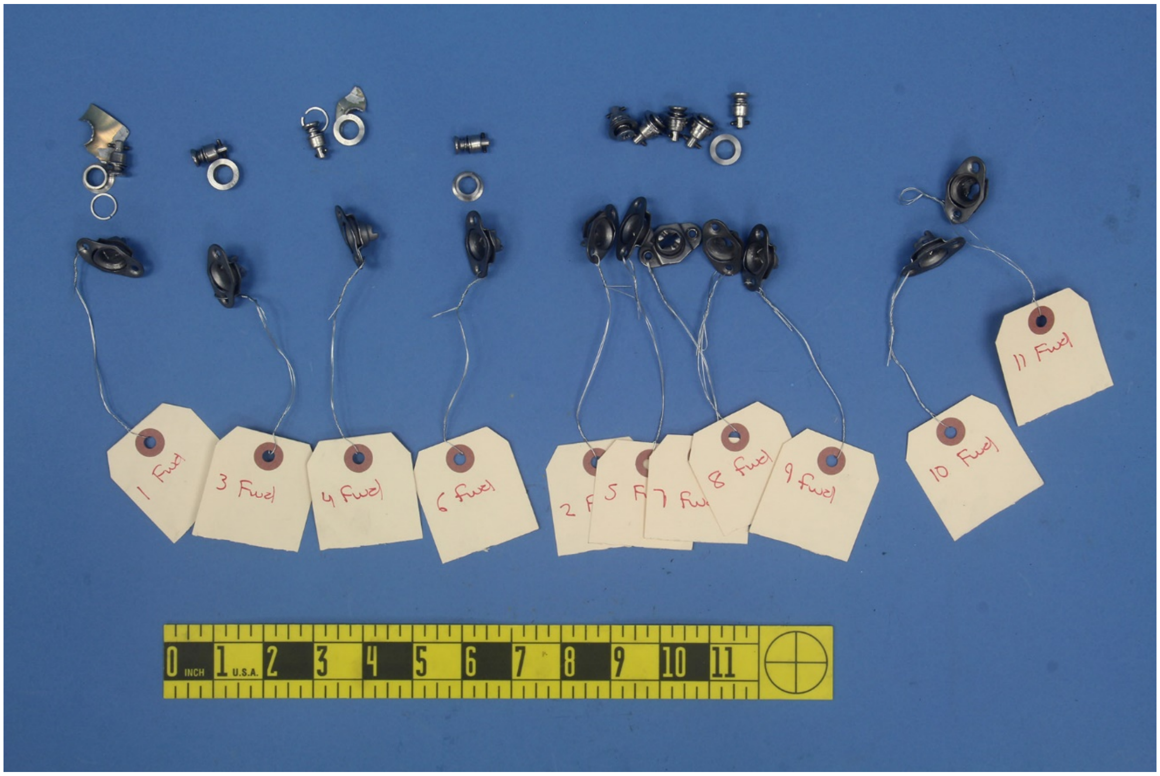
Figure 10a shows the locking and unlocking torque data for an exemplar S3412-103 stud and exemplar S2319-63 grommet. Over five cycles, the applied torque increased from 0 lb-in to a peak between 3.5 lb-in – 4.1 lb-in at which point the cross-pin crossed over the bumps into the detents and the applied torque was removed. During the unlocking phase, counterclockwise torque was applied and the torque decreased to a minimum that ranged between -4.7 lb-in to -5.2 lb-in, at which point the cross-pins popped out of the detents and the applied torque was removed. The height of the exemplar grommet was 0.186 inch, as measured with a micrometer. Figure 10b shows data from a similar test but with a 0.204-inch height "HS" grommet taken from the accident aircraft. In contrast to the GS grommet, the peak locking torques for the HS grommet were higher, starting at 12.5 lb-in and decreasing with subsequent cycles to 6.7 lb-in. The peak unlocking torques were comparatively constant after the first cycle, ranging from -6.5 lb-in to -6.8 lb-in.

Visual examination of the exemplar receptacle revealed that the HS grommet had impinged on the rim of the receptacle cup causing plastic deformation as indicated in figure 11a. Similar features were observed on the rim of receptacles 10 and 11, as shown for receptacle 10 in figure 11b.

Two "-3" studs from the accident aircraft, taken from receptacles 1 and 6 were inserted through an HS grommet and similar locking and unlocking torque measurements were taken.[1] For comparison, the data from one unlocking sequence for receptacles 1 and 6 have been extracted and time-aligned with one unlocking sequence for the exemplar stud, as shown in figure 12. Over five cycles, the peak unlocking torques for the stud from receptacle 1 ranged from -5.7 lb-in to -5.2 lb-in. Similarly, the peak unlocking torques for the stud from receptacle 6 ranged from -5.5 lb-in -5.0 lb-in. As stated above, peak unlocking torque for the exemplar stud after the first cycle ranged from -6.5 lb-in to -6.8 lb-in.

Donald Kramer, Ph.D.
Sr. Materials Engineer

[1] The torque measurement for studs from receptacles 1 and 6 were taken before the exemplar stud in figure 10b.

a)


b)


Figure 1: Images of the as-received quarter-turn fastener assemblies: a) hardware from the forward attachement flange and b) hardware from the aft attachment flange.

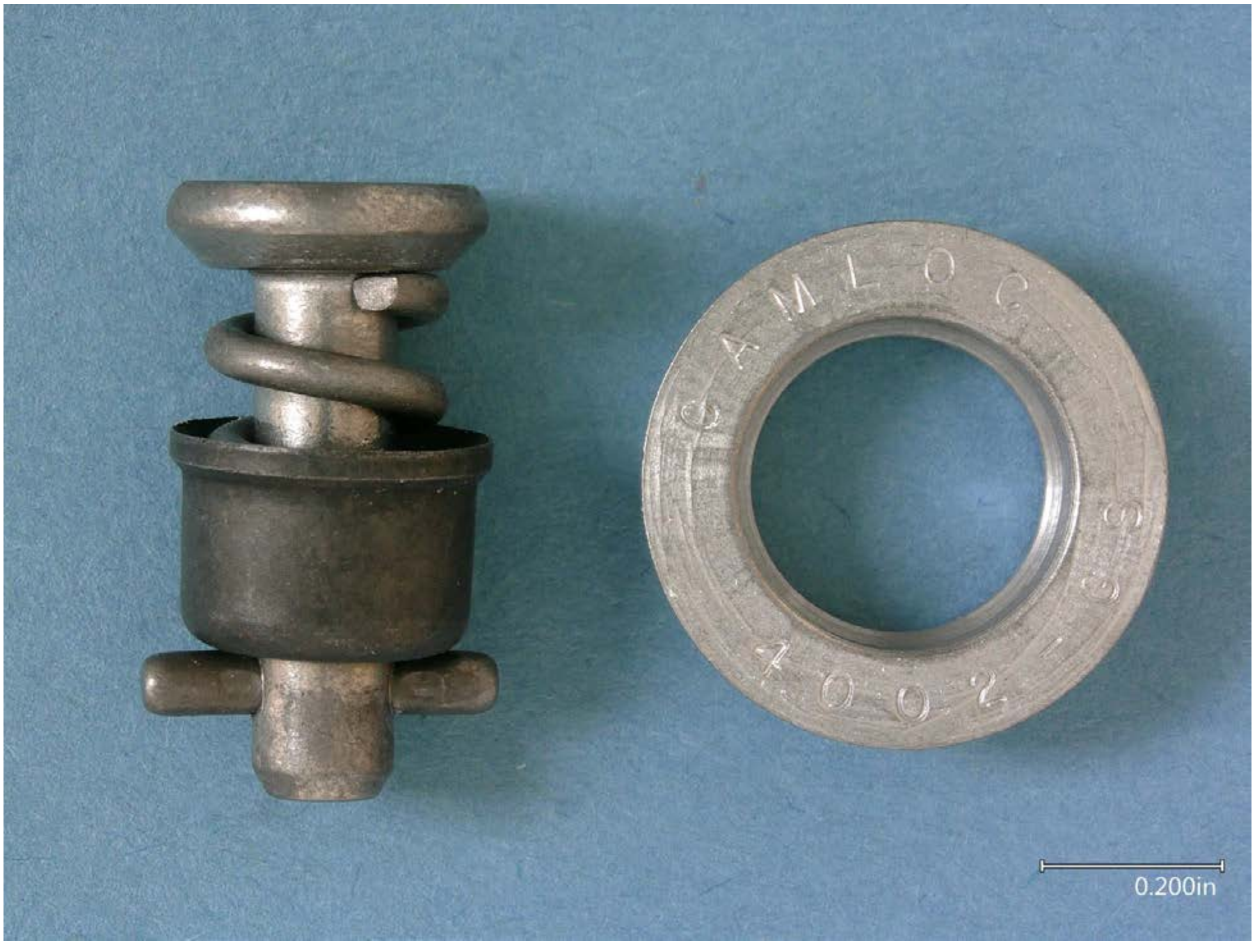


Figure 2: Image of an exemplar stud assembly and grommet.

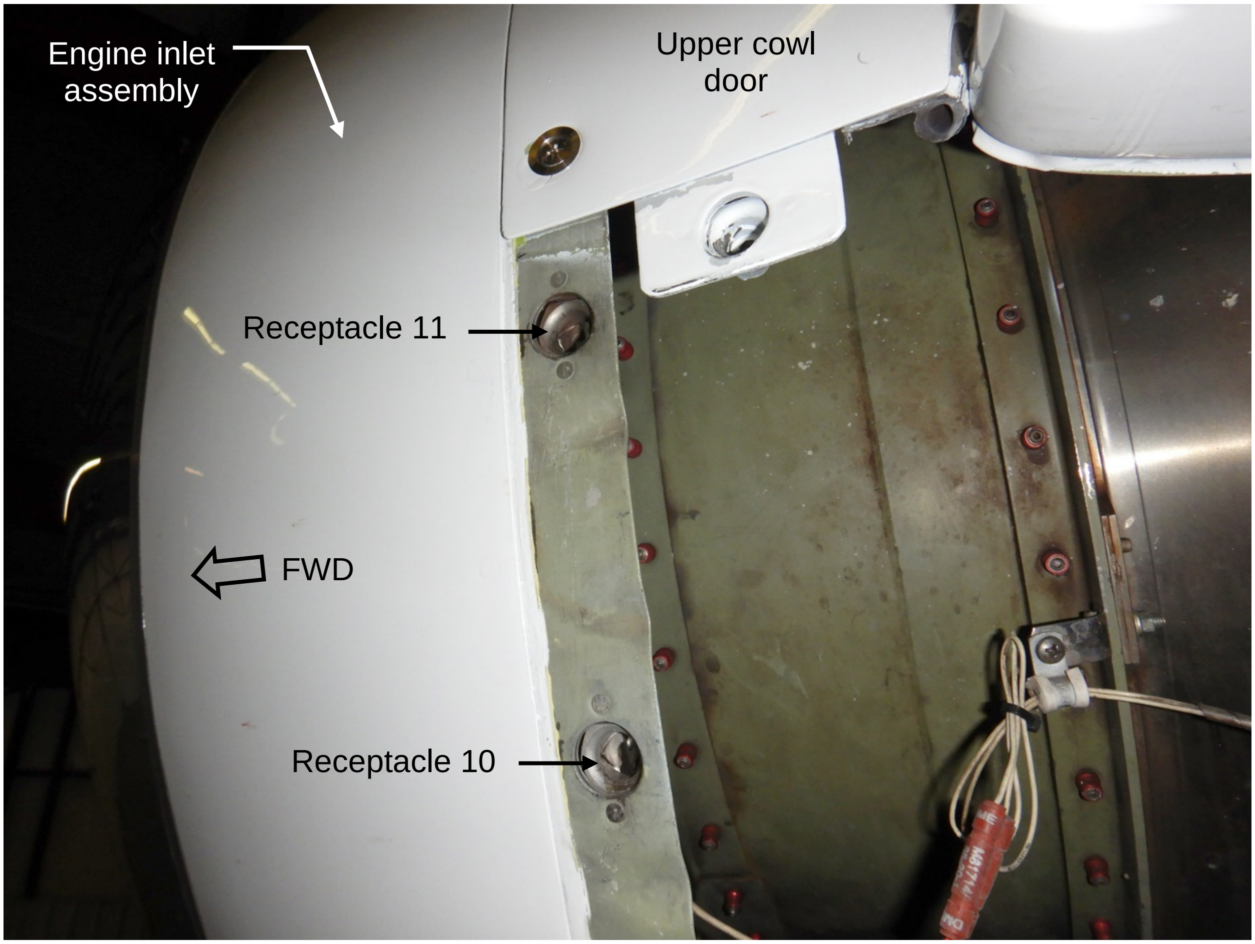
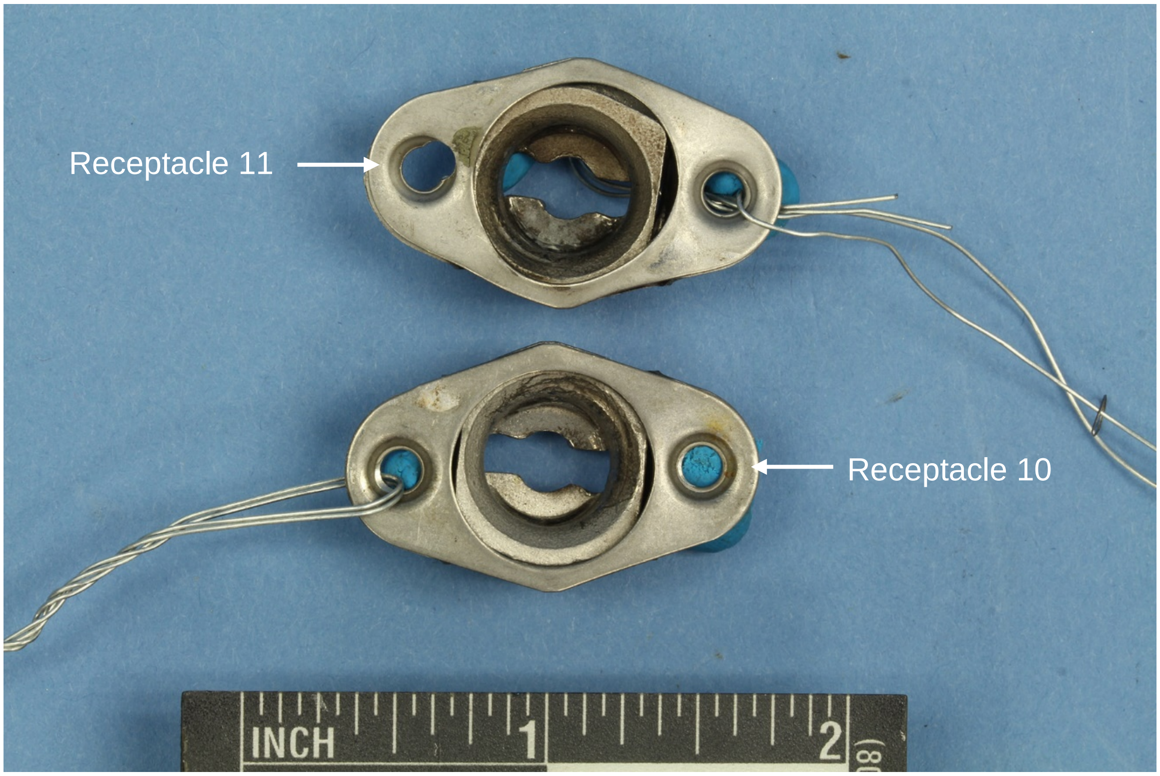
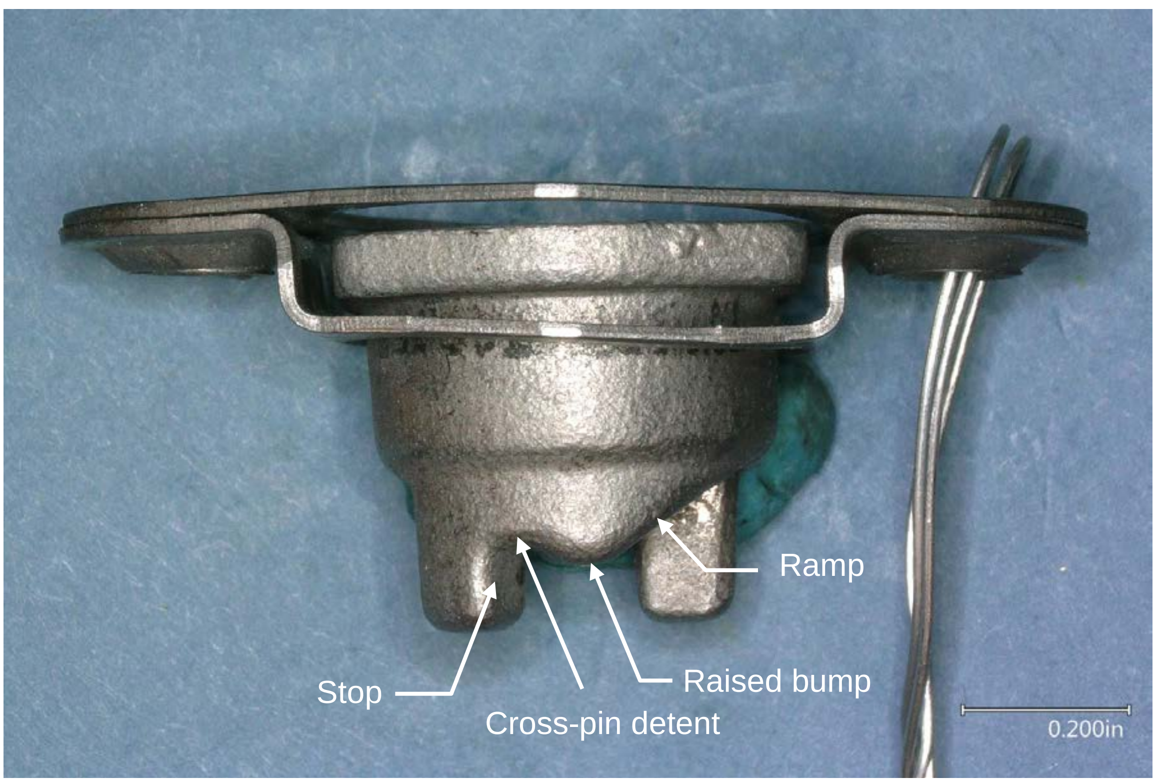


Figure 3: Image of the right engine inboard side showing the missing lower cowl door and the missing studs two of which were in the inlet flange and were numbered 10 and 11.



a)



b)

Figure 4: a) Image of receptacles 10 and 11, each showing the cup into which the stud and spring cup are inserted and b) side view image of receptacle 10 showing the raised bump, cross-pin detent, and stop.

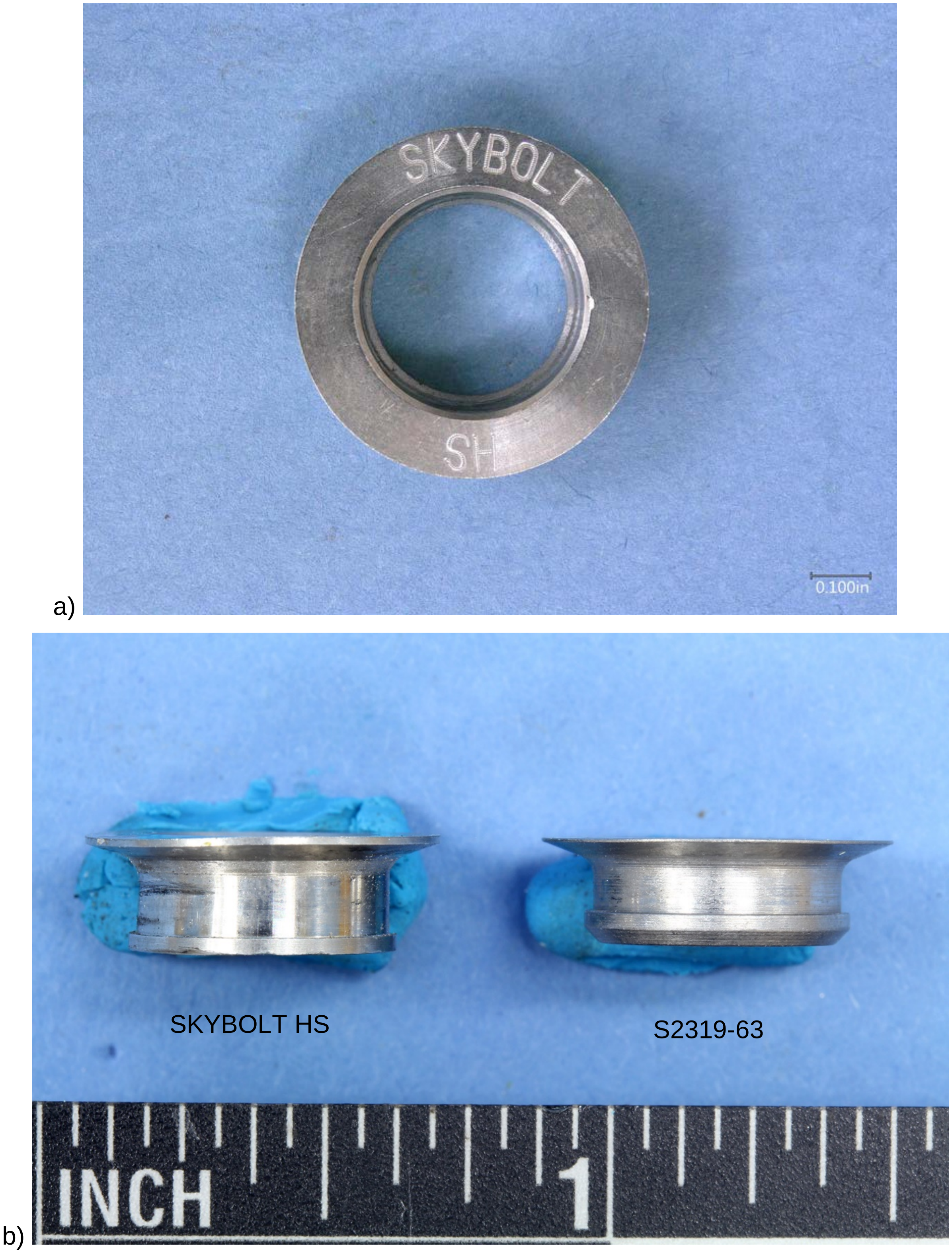
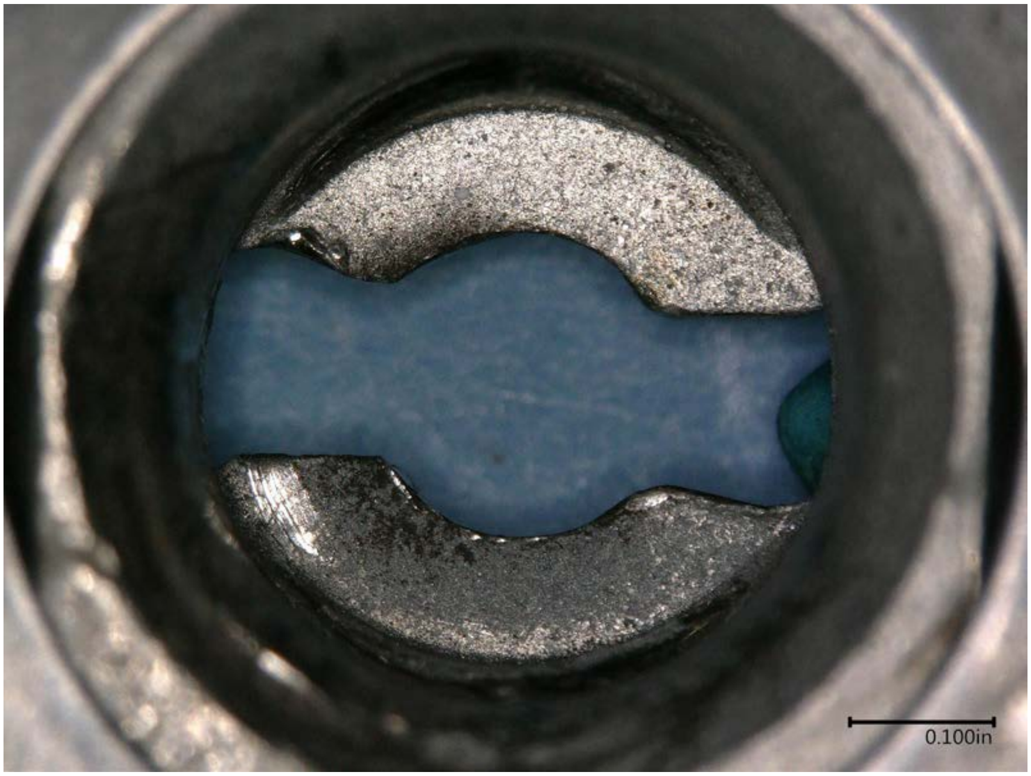


Figure 5: a) Top-down image of a SKYBOLT HS grommet from the accident aircraft and b) side view image of the HS grommet along with a S2319-63 grommet as called out by the parts catalog.

a)


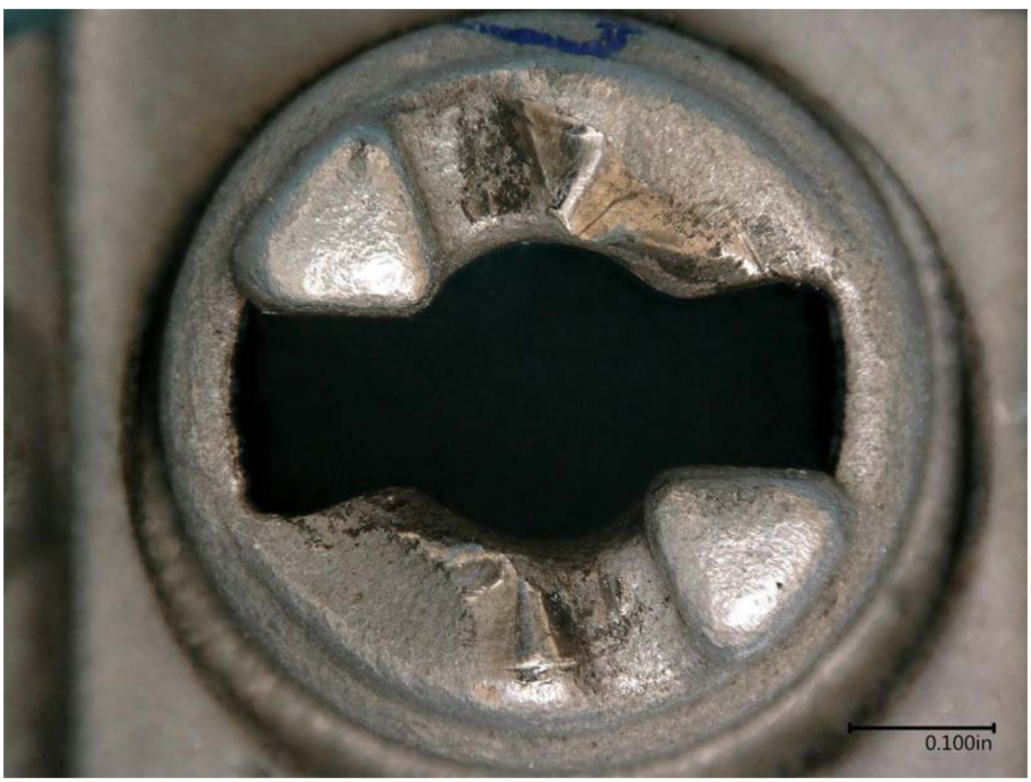
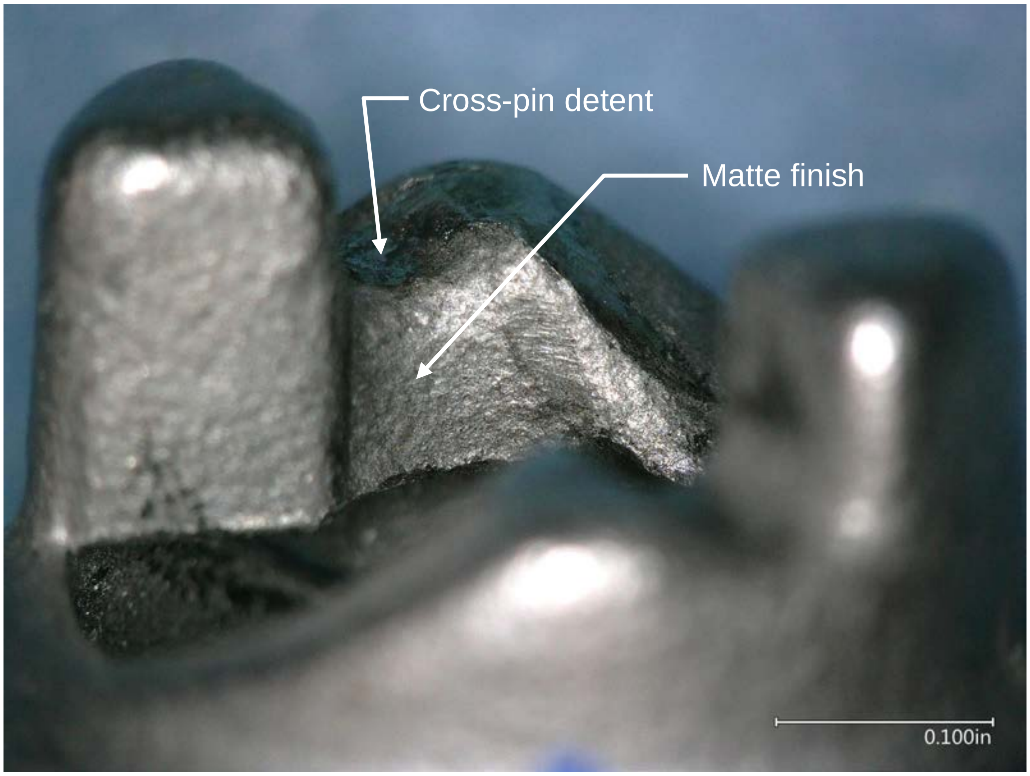
b)


Figure 6: Higher magnification views of the receptacle cup for receptacle 10: a) cup side into which the stud and spring cup are inserted and b) backside with the ramp, raised bump, and detent that engage the cross-pin on the stud.

a) 

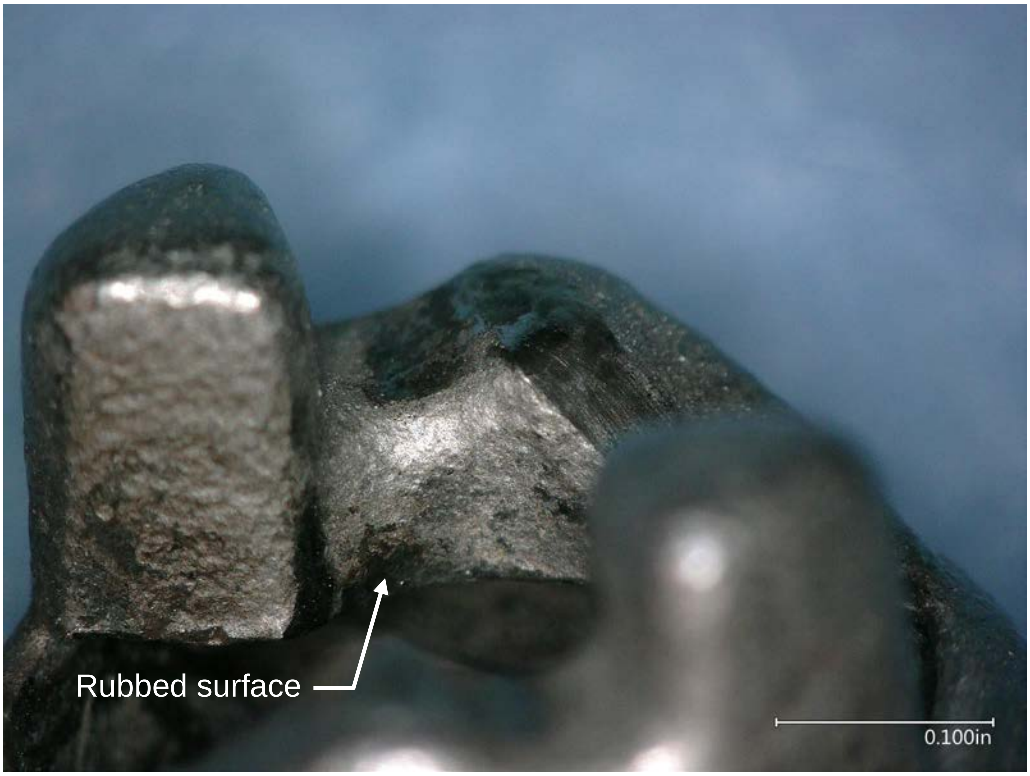
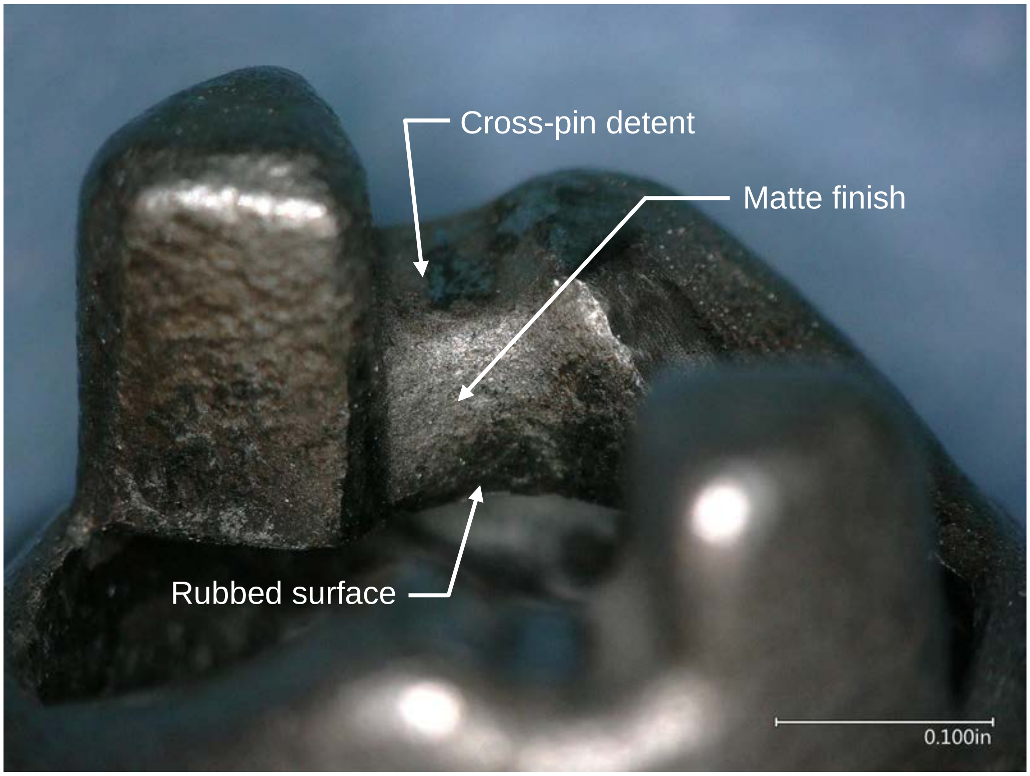
b) 

Figure 7: Images of the slotted hole on receptacle: a) one detent region and b) the second detent region.

a)


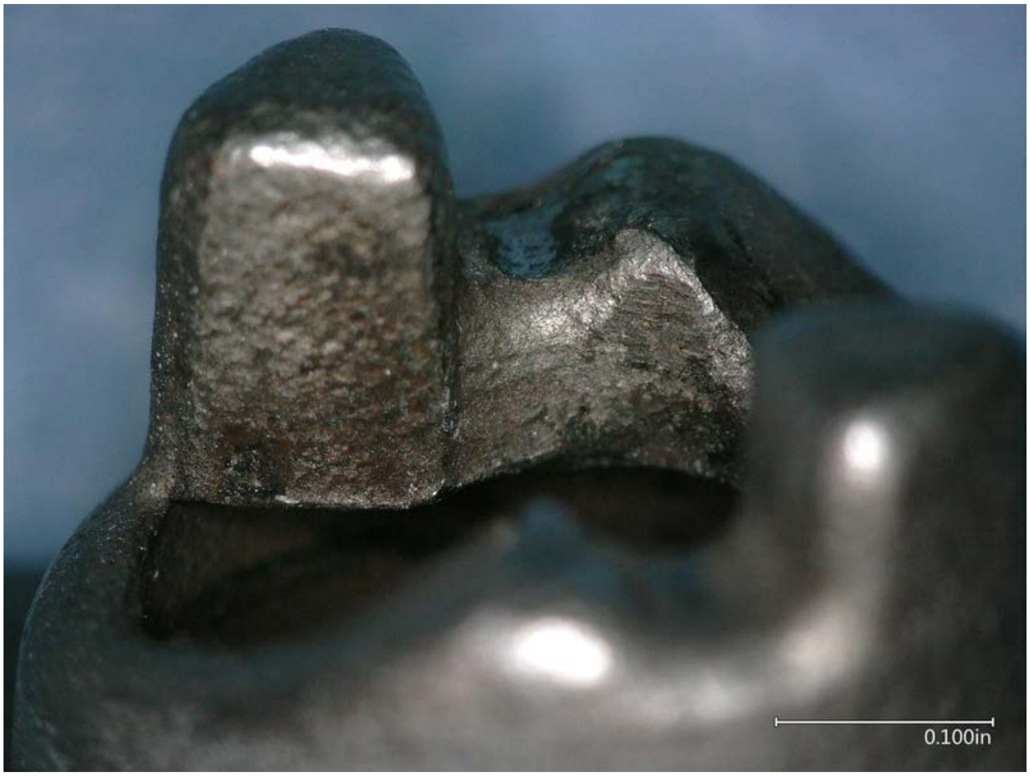
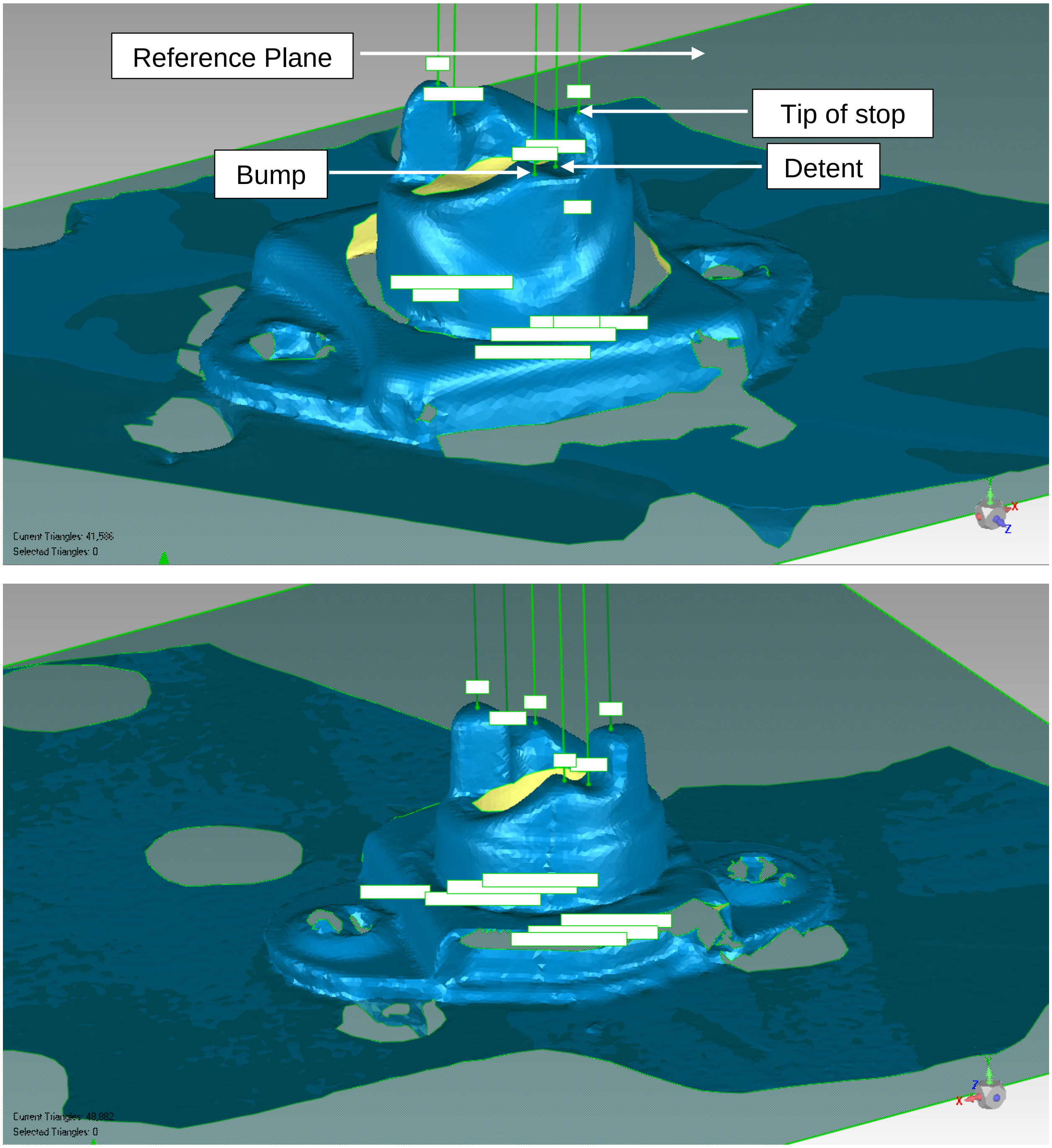
b)


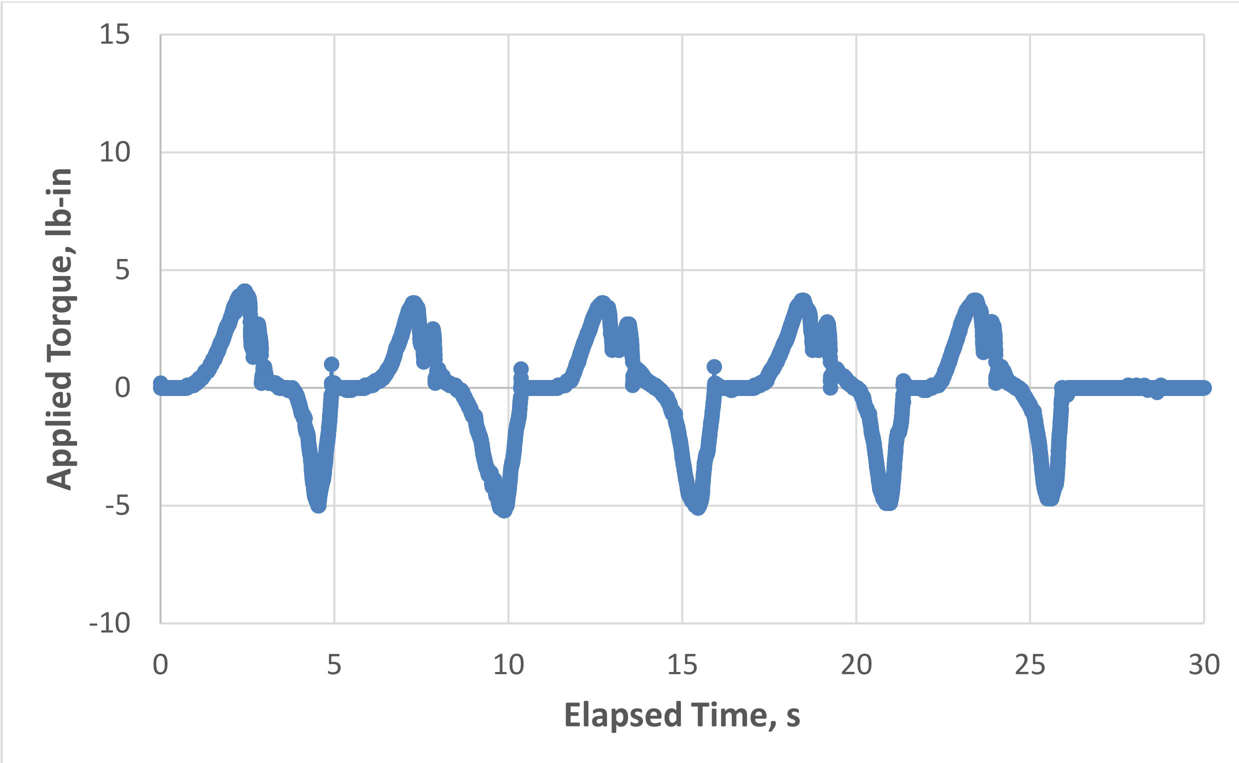
Figure 8: Images of the slotted hole on receptacle 11: a) one detent region and b) the second detent region.



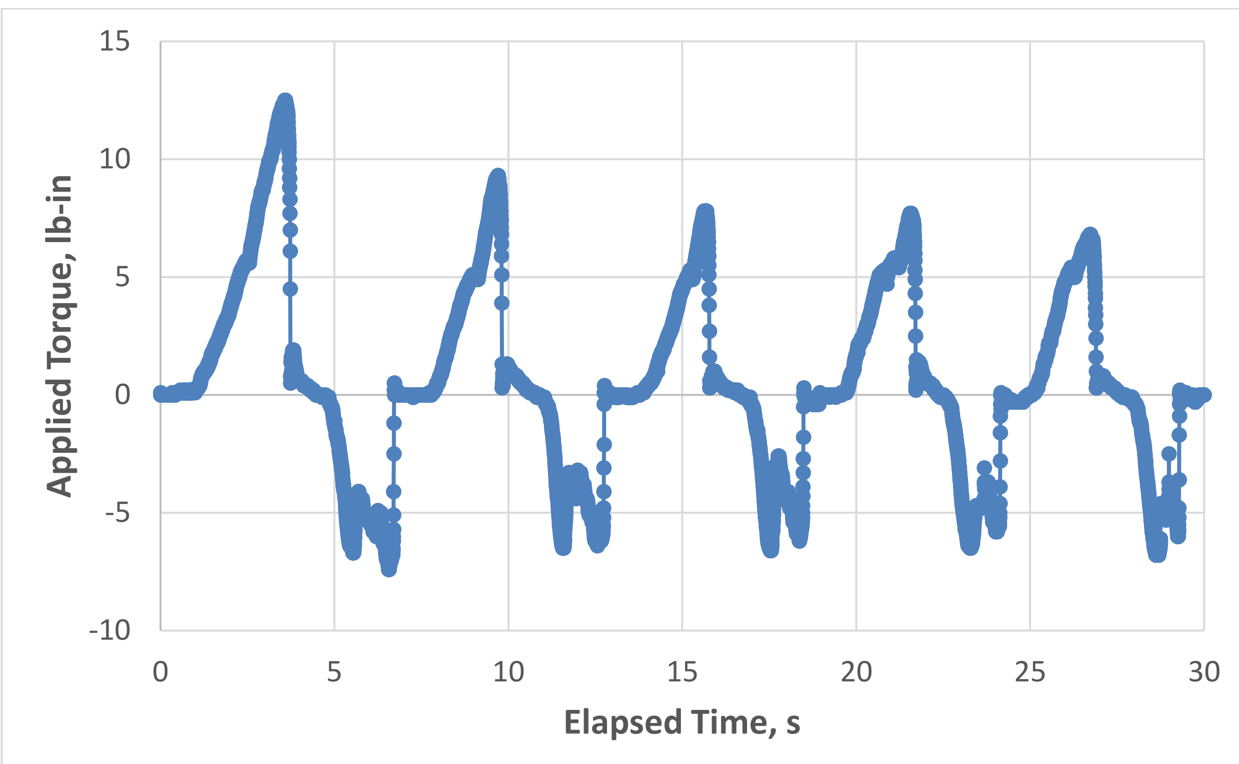
a)

b)

Figure 9: 3D laser scan surface meshes used to measure the vertical distance from the flat face of the receptacle (coincident with the reference plane) to the tip end of the stop, the detent, and the tip of the raised bump: a) scan of an exemplar receptacle and b) scan of receptacle 10.

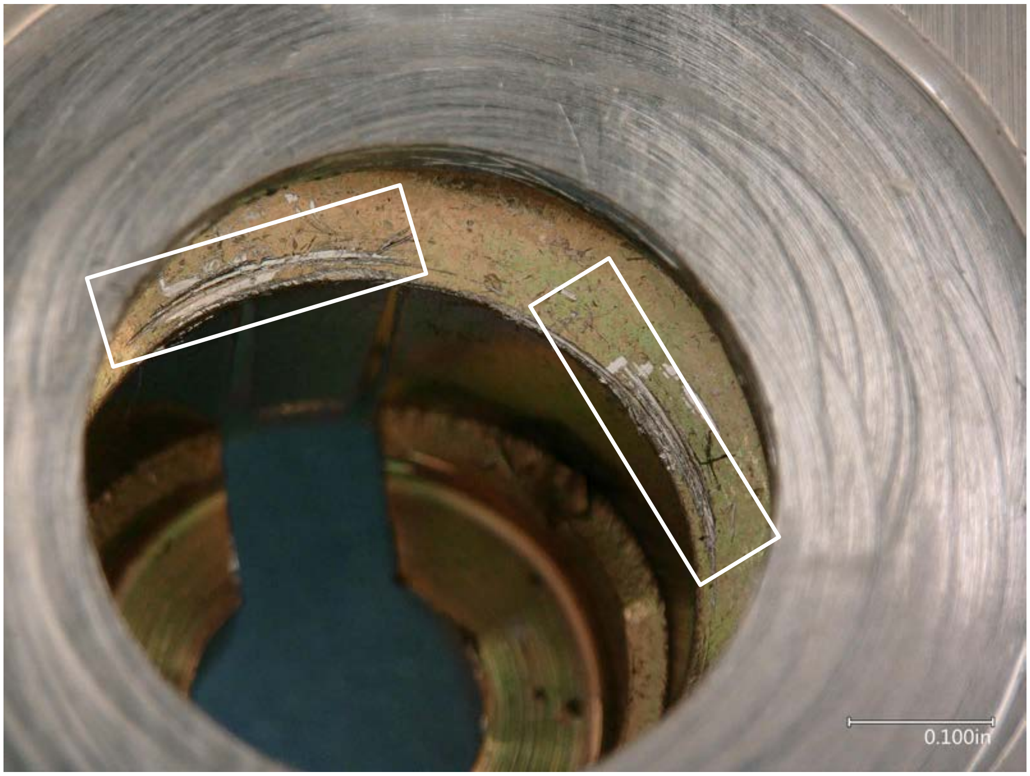


a)

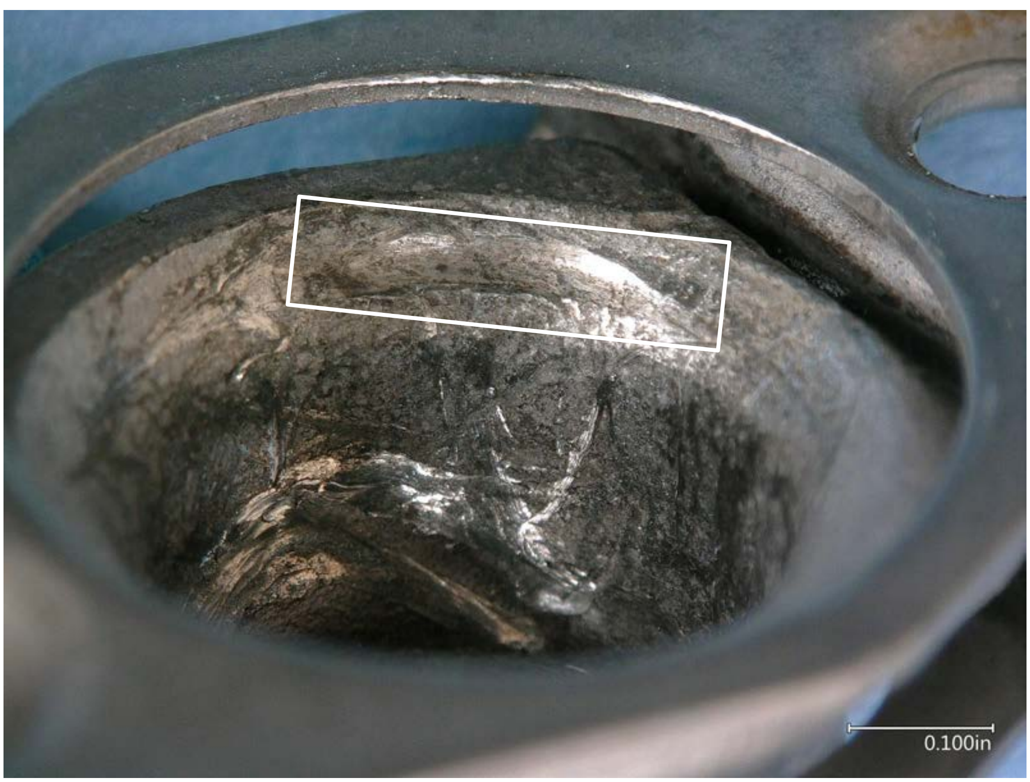


b)

Figure 10: Locking and unlocking torque curves for an exemplar “-3” stud (0.72 inch in length) and exemplar receptacle mounted to a plate with an effective thickness of 0.085 inch: a) locking and unlocking torque with a “GS”-type grommet and b) locking and unlocking with a “HS”-type grommet.



a)



b)

Figure 11: Images of receptacle cups showing contact damage on the cup: a) exemplar receptacle after locking and unlocking with an "HS"-type grommet and b) receptacle 10 as received.

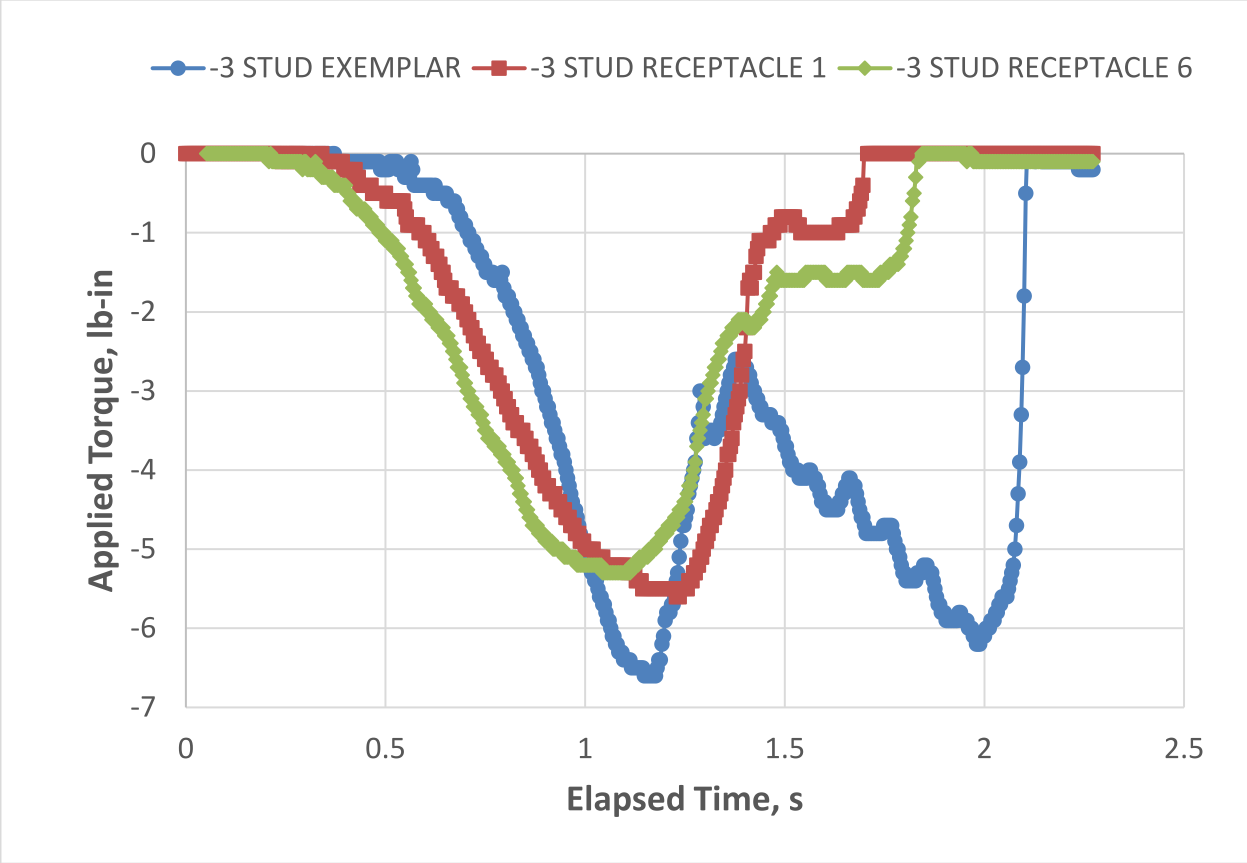


Figure 12: Single unlocking curves extracted from the locking/unlocking data and time aligned for the exemplar stud and studs from forward attachment flange receptacles 1 and 6.