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Edward Malinowski, NTSB
Via e-mail to [redacted]

June 26, 2013

Subject: ***Proposed Findings/Recommendations – Revision of 26-JUNE-2013***

Ref: NTSB ID CEN11FA193, Incident Dated 02/14/2011

Dear Mr. Malinowski,

As suggested in your transmitting e-mail of 5/23/12 containing the draft factual report, PneuDraulics would like to provide additional input and proposed findings to be drawn from the evidence produced during the investigation, and to propose safety recommendations designed to prevent future accidents.

1. Additional Input

    a. Swivel Design Authority Information

    There has been speculation by other parties to the investigation that there may have been some contribution to the damage to the swivel from the absence of anodic coating on the interior bores of some portions of the housings. PneuDraulics, as the design authority for the swivel, wants to correct this flawed misunderstanding. There is no relevance to the presence or absence of the interior anodic coating on the reliability or performance of the swivel.

    The anodic coating used on the exterior of the swivel is specified solely as an anti-corrosion feature, not as a means of countering abrasion or wear. Considering the extreme thinness of the coating as specified in the PneuDraulics technical data (between .0001" and .0002") and its resulting fragility, it would not be suitable as an anti-wear measure. Field experience shows that when properly installed and used the swivel is not subject to concerns about wear, either on the exterior or the interior.

    In the interior bores the anodic coating is a non-functional feature and its inclusion in those locations is an inconsequential artifact of the anodize process, the sole purpose of which is to provide for the anodic coating on the *outside* of the swivel assembly as an environmental anti-corrosion measure. The anodize process is performed by immersion in a tank of fluid while a current is applied – a process circumstance that obviously develops the anodic coating on all surfaces exposed to the fluid during

immersion. The coincident anodizing of the *interior* bore has no functional significance to the swivel or its performance.

As the design authority for this PneuDraulics determines the appropriate actions on various minor product characteristics, a minor characteristic being defined as one that has no appreciable effect on the weight, balance, structural strength, reliability, operational characteristics, or other characteristics affecting the airworthiness of the product. As a consequence of this, it is our determination that any products exhibiting this interior bore anodize deletion are acceptable for use, regardless of the origin of the coating-deletion.

b. Observations of Supply Chain Potential for Swivel Damage

PneuDraulics undertook a review of the potential for pre-incident swivel damage during the week of November 26, 2012, encompassing post-manufacture handling and installation at the UTAS and GAC facilities, and transportation in between those points. Participating in the review were:

(PneuDraulics) Dain Miller, Greg Burns
(UTAS) Les Sarlos, Wayne Johnston, Dan Seelal
(GAC) Tommy Tucker, Keith Nesheim, Walter Young, Doug Cameron

i. Purpose and Logistics of Trip

The trip was conducted to perform an informal process review of the portion of the supply chain from the supply of the 7438-4 swivel from PDI as received and installed by UTAS, who in turn provides the next higher assembly to GAC for installation on the aircraft. Specifically, we wanted to look for any vulnerabilities for handling damage and other physical mistreatment. Dain Miller and Greg Burns represented PDI, Les Sarlos was the main contact at UTAS, and Tommy Tucker the main contact at GAC. Mon/Wed/Fri were travel days with Tuesday spent at UTAS and Thursday at GAC.

ii. UTAS Portion (11/27/12)

The main sequence of processing reviewed on-site at the Oakville facility was receiving, stocking, kit issuance, assembly, and packaging for transportation to GAC:

Receiving – materials are received at a standard dock and offloaded from the truck, the boxes being transferred to a rolling cart for movement to the stocking area for storage. No significant potential for damage was noted.

Stocking – an automated storage and retrieval system (ASRS) is used for storage once the materials are removed from the shipping box. So long as a single layer of swivels is present in the storage tray, the clearance is adequate (6") to ensure no damage as the automated mechanism first stores them and then later retrieves them. Interview with the employee and observation at the station showed good practices used in layering parts in the storage tray, so there seemed to be no significant potential for damage at this stage.

Kit Issuance – when retrieved from the storage tray system the parts are placed into a cart dedicated to the specific kit being issued and provided with adequate dunnage for protection of parts from movement or undesirable contact with each other. Observation showed no tendencies to stack parts inappropriately in the cart, there being adequate space for the entire kit.

Assembly – The Assembly Process Specification (APS) (a graphical narrative of the process) was found to have been revised from the initial issue to revision level A on 11/26/12, the day prior to our review. Intrigued, our further digging into the circumstances of this revision showed:

> A comparison of the initial issue and revision A documents showed that additional photographs clarifying the fitting torqueing process had been added.
>
> The revision comparison also showed that the sequence of steps had been altered. The initial issue APS first installed the swivel on the column, and thereafter torqued the fittings to "170 inch-pounds" (at the swivel end farthest from the point it was attached to the column, e.g. the fulcrum for the bending moment), while the revision A document first torqued the fittings and thereafter installed the swivel on the column (cylinder). The significance of this change is that work performed in accordance with the initial APS issue would impart an unnecessary bending load across the entire unit, with the majority of the load being withstood by the tubes connecting the mounting ends to the center section, a situation that might result in detrimental damage to the swivel, especially if the documented torque limitations were not observed (note that there was no tolerance described in the document, only a nominal value, and there developed some uncertainty regarding the technician's observation of the documented process—see following).
>
> Personal interview with the technician (Mike) described as the one who normally worked this product line indicated that he did not follow the sequence required by the initial issue APS, but instead used the process

described by the revision A, and he had always done so. This left open the following questions:

> What other APS instructions were not followed by this specific technician? For example, the value of 170 inch-pounds for torqueing the fittings is an important instruction; over-torquing them could induce further damage potential as noted above. Was the value observed during performance of the task, and what tolerance was used?
>
> What do other technicians do? Do they follow the APS or not? As a side note, observation did not indicate other technicians routinely or frequently using or referring to the few terminals/workstations that were in the area.

Packaging – We observed the packaging process beginning with a reusable box (cycled between UTAS and GAC for repeat use). The strapping arrangement used to hoist the completed landing gear (LG) from the work jig and place it into the box seemed appropriate and used a robust point well removed from the swivel and the LG center of gravity (so that it hung in a predictable and controllable fashion while maneuvering the LG into the shipping box. Transfer to the truck (dedicated solely to shipments to GAC) allow only a single layer (no double stacking). There did not seem to be any significant damage potential at the boxing/transportation stage.

iii. GAC Portion (11/29/12)

Unfortunately, despite the trip having been planned for several weeks, no provisions or advanced planning had been made to accommodate the stated purpose of observing the performance of work throughout the GAC value stream. However, we were able to walk the process, interview various employees, and through a stroke of luck (and the floor technician's initiative) able to observe some of the preliminary work operations just prior to the LG installation into the aircraft. The main sequence of processing reviewed on-site at the Savannah facility was receiving, stocking, pre-assembly (wheel installation), and assembly (into aircraft):

Receiving – The boxed LG comes on a dedicated truck, and the LG is offloaded to a receiving area. The accompanying paperwork is reviewed and the box lid is temporarily removed for visual confirmation of LG identity and freedom from damage, and the lid reattached thereafter. The boxed LG is then transferred as-is to the floor location adjacent to where it will next be worked and ultimately installed on the aircraft. (I want to differentiate the 550 from

the 450 process. The 450 has that added step and location where it essentially get worked and then worked again at installation.).

Stocking – stocking is done on the line as inventory levels are minimal.

Pre-Assembly – (Note: LG's designated for the 450 line require this step; LG's for the 550 come in with wheels/tires already installed.) We did not observe this process as no provisions had been made to have product at this state during our visit. Though busy with other tasks, the technician did give us a brief verbal overview of how he performs this process. He uses a strapping/hoist protocol very similar to that used by UTAS and described in 2e to remove the LG from the box and install it on a work jig. During the installation of the LG onto the work jig the technician also installs the wheels/tires. I was unable to get a clear picture of all the work tasks involved (equipment, etc.), but did note there seemed to be no detailed formal written instructions guiding the technician in the performance of the task.

Assembly – We did not observe this process as no provisions had been made to have product at this state during our visit. There was, however, a LG in a box, and the technician took it upon himself to suggest we observe his preparatory operations for installation on the aircraft. Oddly, roughly the last 20% of the UTAS assembly process is undone by GAC in order to enable the installation. Significantly, the drag brace and trunnion-arm are removed from the LG, the relevance of interest being the consequent additional vulnerability to incidental damage to the swivel thereby being enabled by the removal of structure that (prior to removal) posed a triangle of protection around the swivel. In other words, the swivel is greatly exposed to damage hazards once these surrounding features are taken off of the LG. The technician helpfully described the installation process and the remaining components that went into the front nose-wheel landing gear bay after the installation of the LG, but because the timing of that installation hadn't been coordinated with our visit we were unable to informally assess what additional hazards may be presented by other remaining component installations or use of equipment/tools for those tasks.

iv. Conclusions/Recommendations

As recommended by PDI over two years ago, and as confirmed by the observations at UTAS regarding hazardous works tasks and the potential gap between documented/undocumented work tasks/sequences and actual practices (item 2dii), a more substantive supply chain process review is recommended (extending from supply of component to delivery of aircraft, the fabrication of the component itself already having been subjected to

multiple extensive reviews and audits), and GAC seems to be in the best position to conduct or coordinate that.

2. Proposed Findings

On the basis of the acceptance of the swivel during its outbound testing at time of shipment from PneuDraulics, the confirmation of post-accident deformation (visually evident torsional loading of the swivel tubes and the .03" misalignment), the absence of any implicating evidence relating to the as-manufactured condition of the swivel, and coupled with the observation that previous incidents of swivel damage were associated with shipment or installation faults and had resulted in similar tube fractures and swivel deformation, PneuDraulics believes it's reasonable to conclude that the root cause of the incident was installation/handling damage subsequent to the shipment of the swivel from PneuDraulics, and that this conclusion should be stated explicitly within the report.

3. Proposed Safety Recommendations

After a review of the Gulfstream GV-SP hydraulic system architecture, it seems that a fundamental improvement to the hydraulic system on the Nose Wheel section of the aircraft would be the addition of a velocity or volumetric hydraulic fuse. This component is designed to minimize the loss of hydraulic fluid in the event of a line break downstream of such a device. In fact, the GV-SP does have hydraulic volumetric fuses as part of the main landing gear brake system to protect against hydraulic system pressure loss should a similar incident happen in the main landing gear area.

PneuDraulics appreciates the opportunity to participate in the review of the incident and the report of the facts as reflected in the draft reports provided; please let me know if there are any other contributions we can offer.

Sincerely,

[redacted]

Greg Burns
Director of Quality

Cc: Dain Miller
Michael Schober
Gerry Loftis