

Fabco Valve Upgrade

Model 500 4-way Solenoid Valve

Quality Issues & New Applications Drive Supplier Change

February 2013 - Move to the Fabco solenoid valve from the AllenAir solenoid valve

- Driven by:
 - Quality Issues
 - Performing 100% incoming inspection
 - 7-8% of incoming inspected valves failed for leakage
 - Valves sent back to AllenAir for leakage repair and returned to Rosemount Analytical were found to still leak
 - Failing for leakage after cold chamber cycle. These were valves that passed incoming inspection.
 - New applications required the solenoid valves be rated for Group B for Hydrogen, which the AllenAir valves were not



Validation of the Move from AllenAir to Fabco

✓ CSA Approval

- CSA approved of Fabco solenoid valve for Group B Hydrogen
- CSA certificate for use of Fabco solenoid valve in 500 GC

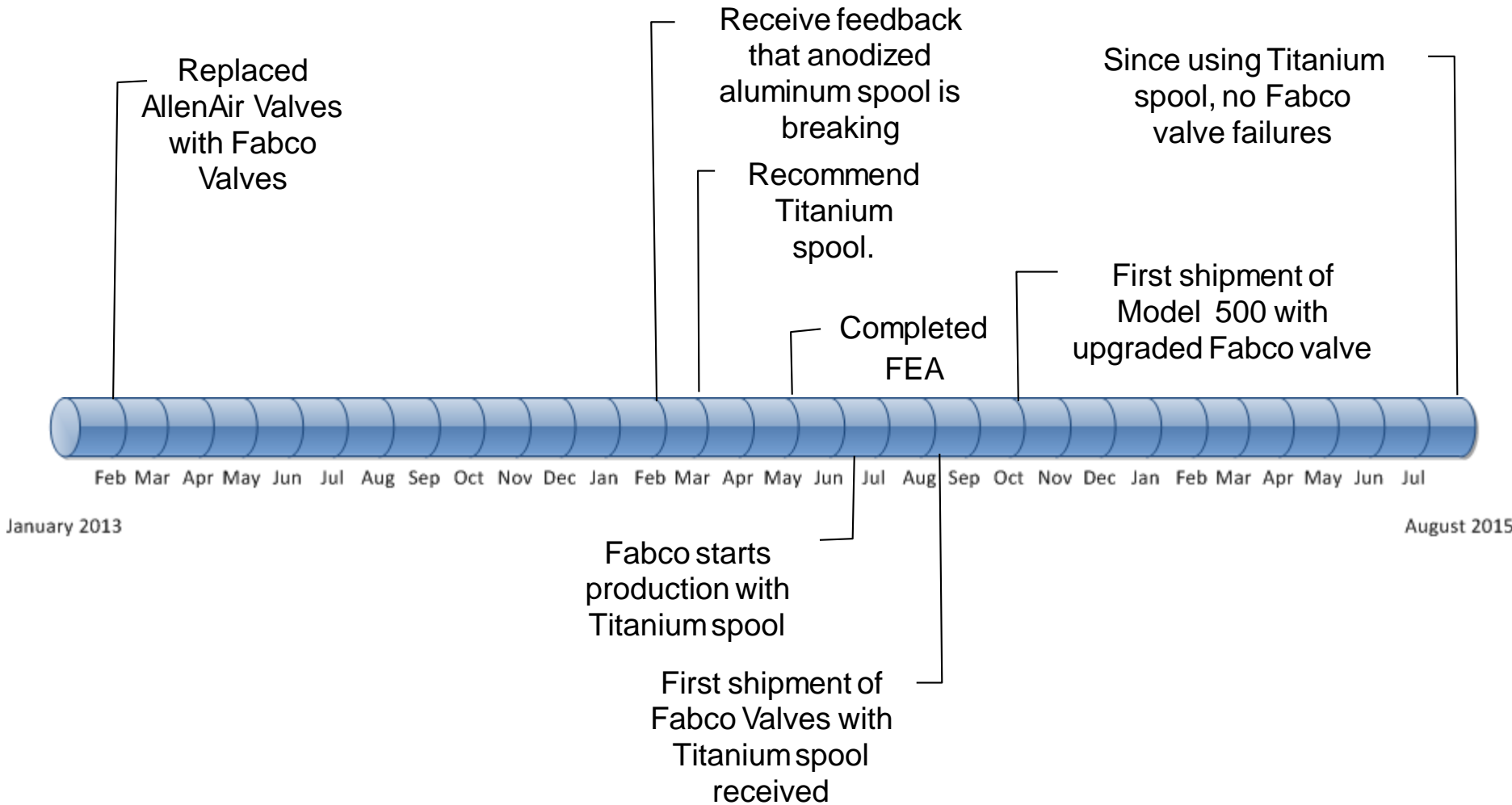
✓ Positive Test Results

- Solenoid valves were installed in several Model 500 GC and worked at -18C with no leakage
- Fabco completed 5M life cycle test on the valves, without leakage

✓ Ease of Use & Support

- Port labels were incorporated in the valve for ease of identification
- Direct compatible wiring
- Full staff of engineering support and timely response from Fabco

Timeline of Solenoid Valve



Timeline of Events

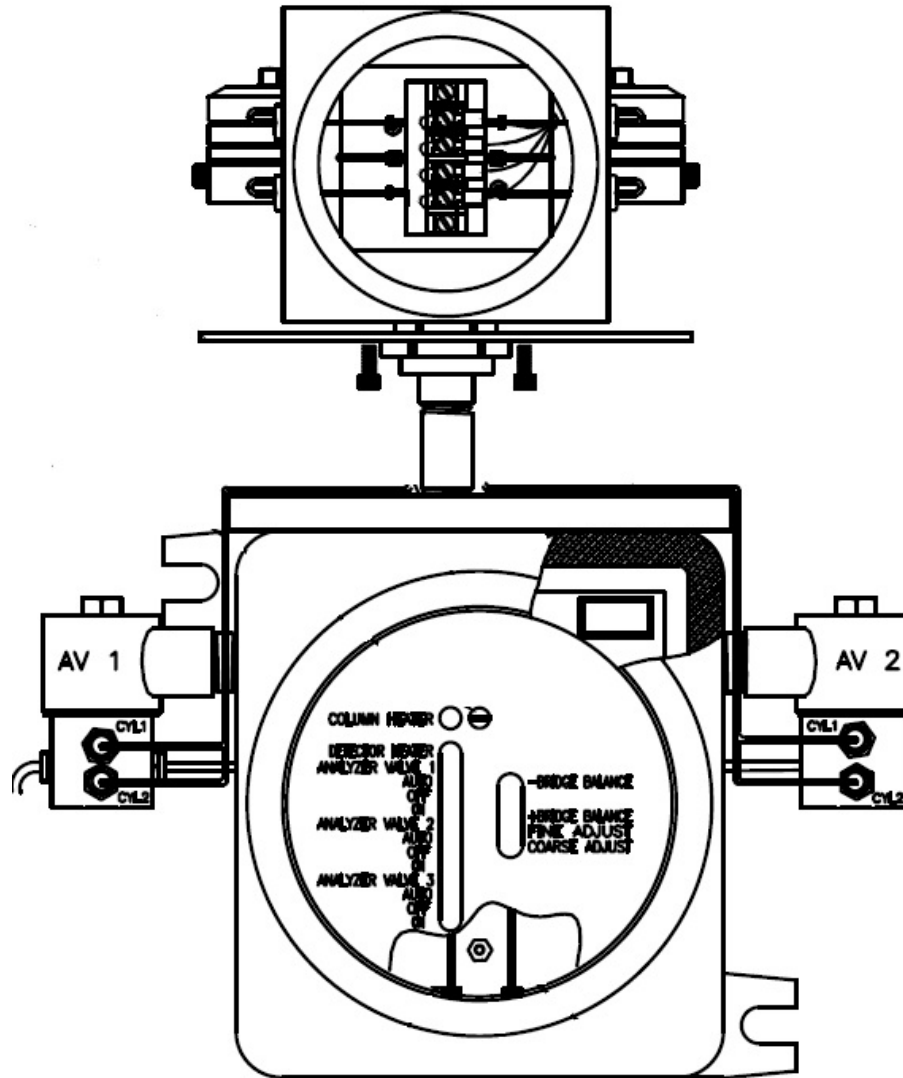
- **February 2014**: QC received first incident of broken spool from customer. Engineering immediately informed Fabco of the issue. Intermediate solution is the installation of an improved spring cap
- **March 2014**: Engineering and Quality visit Fabco to investigate root cause of broken spool. The test result shown Titanium spool has superior endurance limit five times higher than the current Aluminum spool. Titanium spool is the recommended permanent and long term solution for the broken spool.
- **May 2014**: Engineering and ACOE India completed the FEA (Finite Element Analysis) report comparing and confirmed the superior strength of Titanium spool.
- **June 2014**: Fabco implemented the Titanium spool in production
- **August 2014**: Received the first shipment of valve with Titanium spool
- **October 2014**: First shipment of the Model 500 GC with the Titanium spool solenoid valve
- **August 2015**: No reported field failures with the Fabco Titanium spool solenoid valve since implementation

Upgrade Support to Titanium spool Fabco Valves

- Created a Model 500 Fabco Solenoid Valve Field Upgrade Kit, 2-4-5001-999 as an easier alternative to replacing the valve, 2-4-5000-218
 - Kit includes:
 - Replacement components
 - Grease lube
 - New label
 - Detailed instructions with photographs of every step
- Created a [YouTube](#) video showing the step-step process of performing the upgrade
- Issued Product Notice requesting customers upgrade their old style Fabco valves (ones with yellow anodized aluminum spools) with the kit

Drawings & FEA Analysis

Locations of Solenoid Valves – AV1 & AV2



FEA Analysis of Titanium Spool

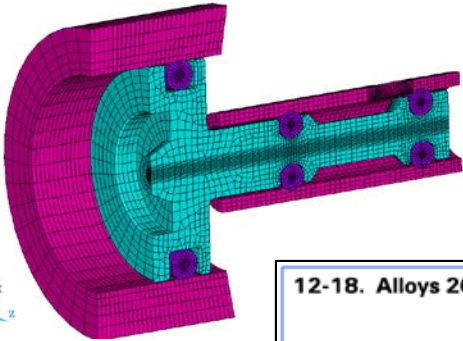
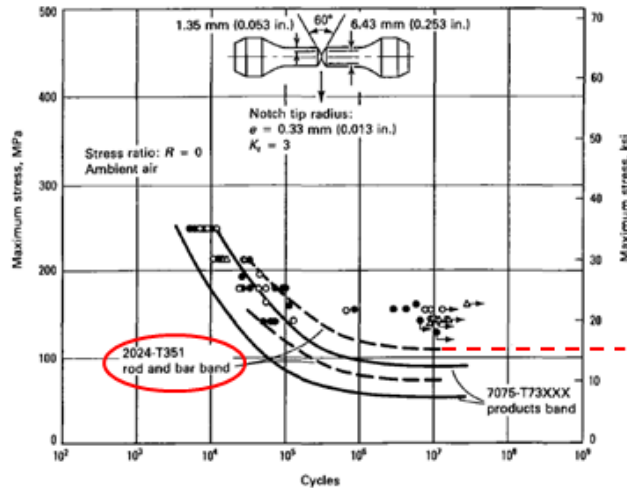


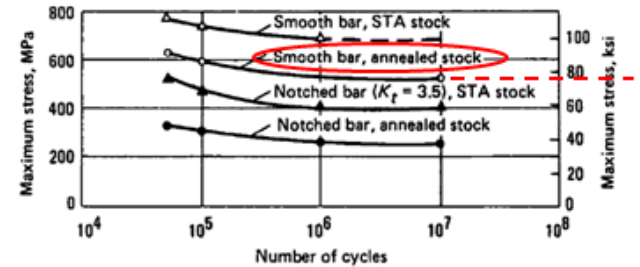
Figure 1 shown Titanium alloy material has superior endurance limit five times higher than Aluminium alloy.

12-18. Alloys 2024-T351 and 7075-T73XXX: Comparison of P/M Extrusions and Rod



Aluminum → Endurance limit, 15 Ksi

17-17. Ti-6Al-4V: Effect of Condition and Notches on Fatigue Characteristics



S-N curves for titanium alloy Ti-6Al-4V (rotating beam) showing effects of STA (solution treated and aged) versus annealed conditions, and effect of notches.

Titanium → Endurance limit, 75 Ksi

Atlas of Fatigue Curves Copyright© ASM International® 1986

Figure 1: S-N Curve for Aluminum & Titanium Alloy

Configuration of Broken Aluminum Spool

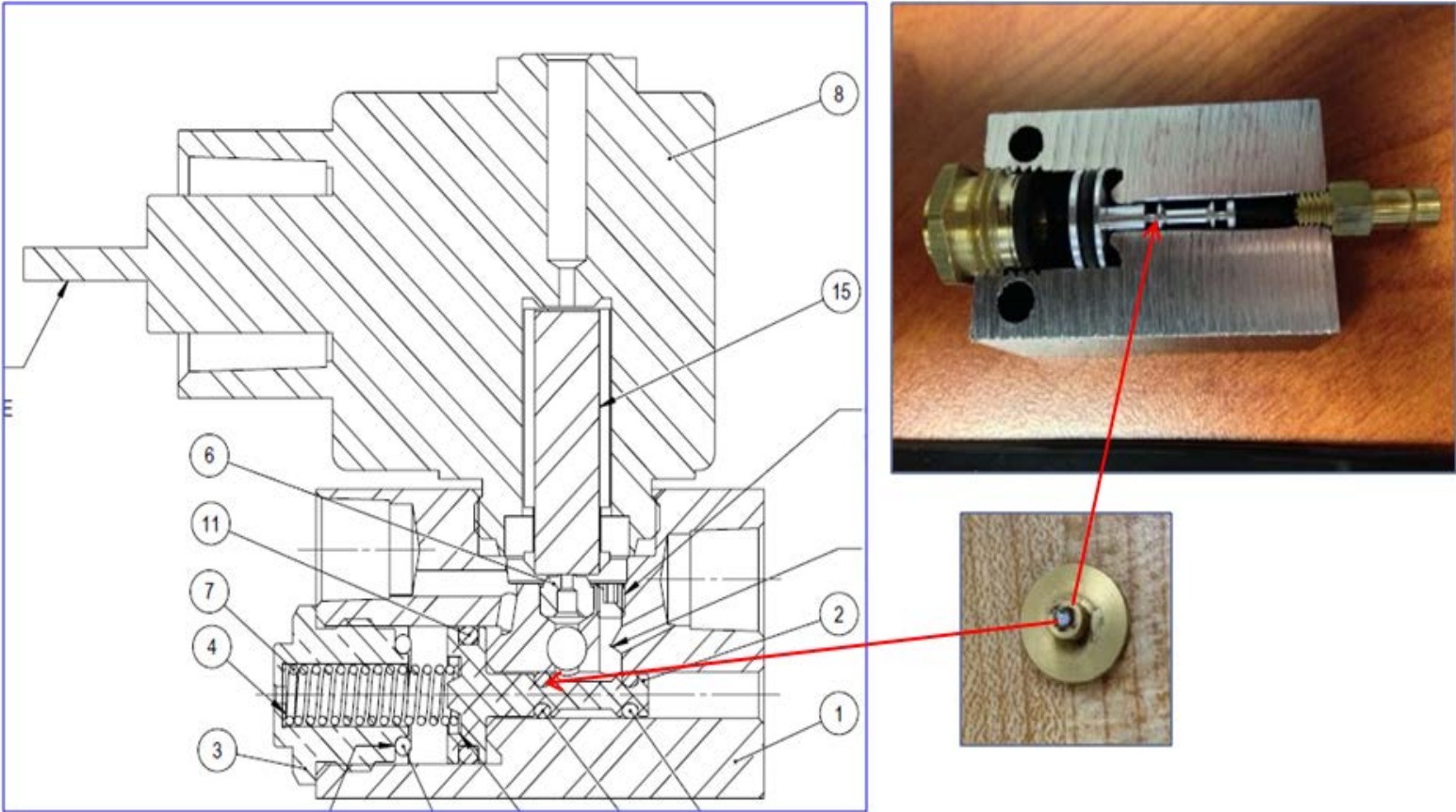


Figure 2 : Spool actual failure photograph, failed @ middle groove