NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Western Pacific Region

LEFT ENGINE FUEL SELECTOR VALVE

NTSB Accident: WPR11FA002
Accident Date: October 3, 2010

This document contains 3 embedded photographs

A. ACCIDENT

Location:	Avalon, California
Date:	October 3, 2010
Aircraft:	Cessna 310, N310XX
NTSB IIC:	Michael Huhn

B. SUMMARY

The airplane and engines were examined in-situ in the two days after the accident. The right engine fuel selector valve was found set to the position corresponding to 'ON/MAIN.' The left engine fuel selector valve was found set to a position that was partially displaced (towards the 'OFF' position) from the 'ON/MAIN' position.

Since the left engine had apparently failed on takeoff, and subsequent testing of that engine revealed that the engine operated normally and was capable of developing rated takeoff power, the left engine fuel selector valve was tested to determine its functionality and flow capability at various settings. Testing revealed that the valve operated normally, and that the as-found setting position of the valve rendered it incapable of providing the necessary fuel flow rate to the engine at takeoff power.

C. FUEL SELECTOR SYSTEM DESCRIPTION

The airplane was equipped with two fuel tanks, one at the tip of each wing. Each bladder style tank had a total capacity of 51 gallons, of which 50 gallons were usable. Each fuel tank contained a cockpit-controlled boost pump. The airplane was equipped with two fuel selector valves, one for each engine. A fuel strainer was located downstream of each fuel selector valve. Each engine was equipped with an engine-driven fuel pump and a pressure carburetor.

Two separate rotary-style fuel selector controls, one for each engine, were mounted side-by-side in a recess on the cockpit floor between the two front seats. Each valve control layout was the same, with three possible setting positions, one each at the 9 o'clock (left), 6 o'clock (aft), and 3 o'clock (right) position. Those positions were respectively labeled "LEFT ON TANK," "BOTH OFF," and "RIGHT ON TANK." Setting the left selector control to "LEFT ON TANK" would provide fuel to the left engine from the left tank, while setting it to the "RIGHT ON TANK" would enable a cross-feed setting, where the left engine would feed from the right tank. The right selector valve controls and plumbing were configured the same way.

Each valve was mounted on the outboard aft wall of its respective engine nacelle. A series of mechanically linked rods, oriented transversely with respect to the airplane, coupled each selector valve control to its respective valve. Actuation of the left or right cockpit fuel selector control rotated the respective rod assembly about its longitudinal axis, which rotated the internal

valve mechanism, thereby permitting or preventing use of the various ports on the valve. This enabled selection of the tank to be used to provide fuel to each engine. There was a one-to-one ratio between the rotation of the cockpit control and the rotation of the selector valve; rotating the control 90 degrees rotated the valve 90 degrees. See below for additional details.

The manufacturer's recommended engine start and takeoff procedure was to feed each engine from its respective fuel tank. In that configuration, the left fuel selector control would point to the left, and the right selector control would point to the right. Each selector valve control would point aft when "BOTH OFF" was selected.

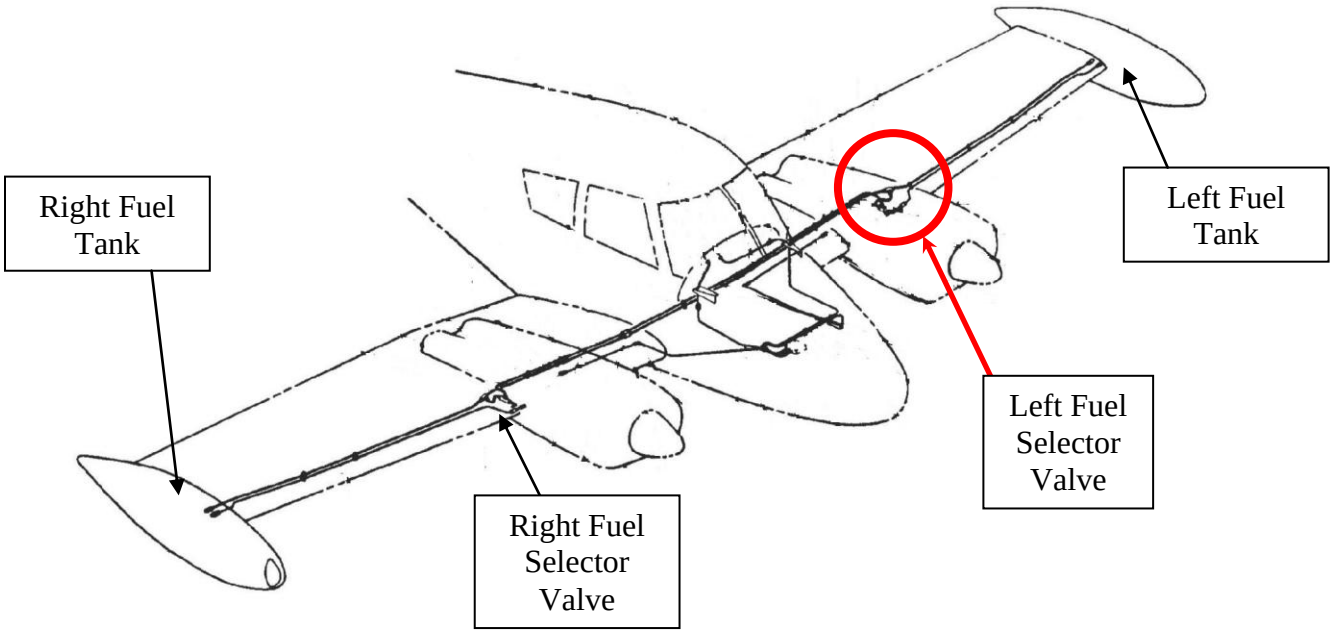

Figure 1 - Fuel System Component Layout

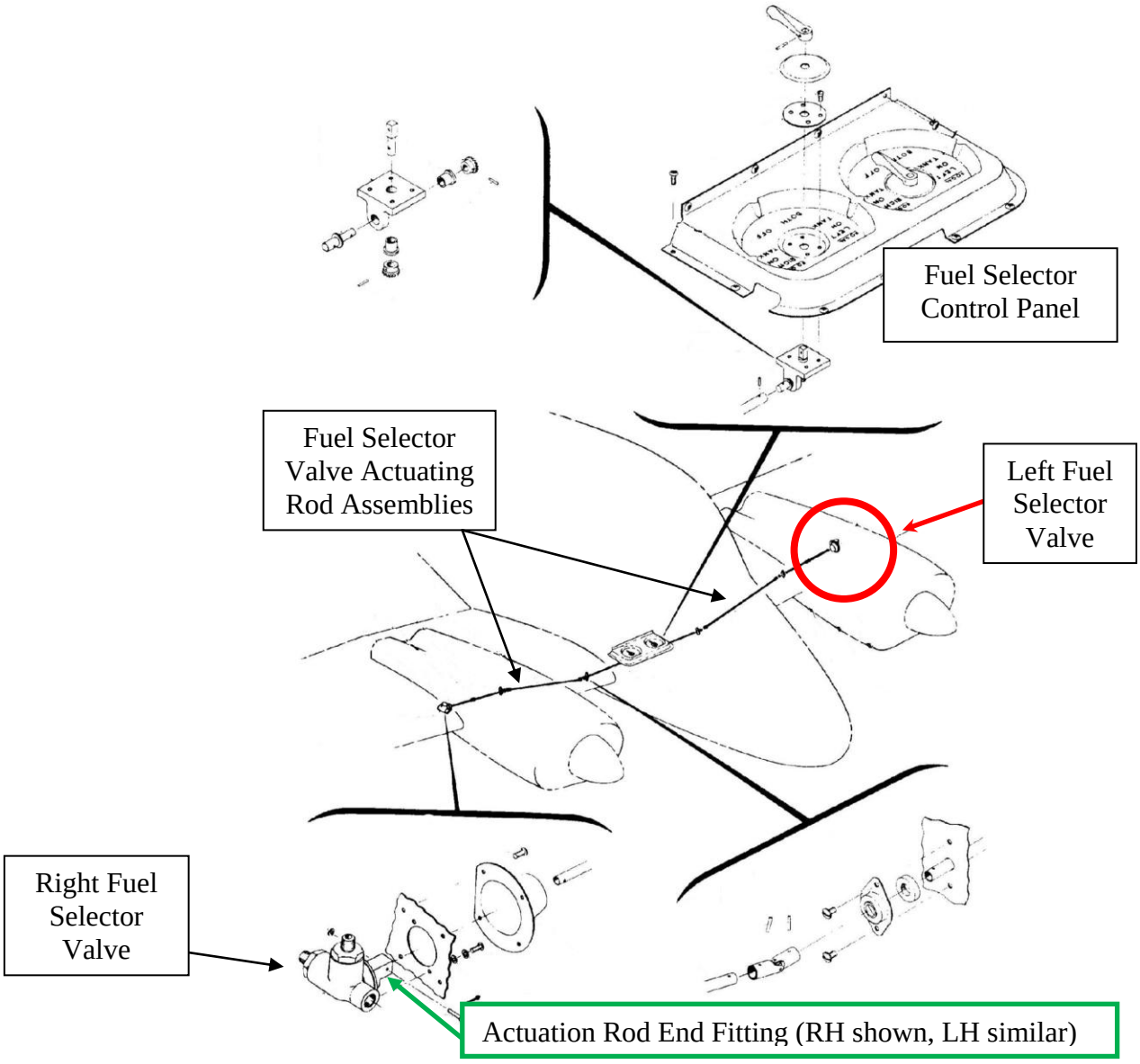

Figure 2 - Fuel Selection System Layout

D. LEFT FUEL SELECTOR VALVE DESCRIPTION

- Three ports (Arbitrarily labeled A, B, C; see below)
- Reference Orientation:
  - Actuation rod assembly runs transversely/laterally in airplane, inboard to outboard
  - The valve body is at outboard terminus of rod assembly

    - A fitting (with one flat side, and one stepped side) served as the attach linkage between the rod assembly and the valve
    - When viewed looking left/outboard, one port ('A') exits up, one ('B') exits aft, and one ('C') exits down
- Port Identification
    - 'A' = Crossfeed Line (to opposite (in this case, RH) main tank line)
    - 'B' = Main/Same Side/ Tank (in this case, LH)
    - 'C' = Engine
- When freed from the aircraft actuation assembly, the valve internal mechanism could be rotated freely in either direction (CW or CCW) an unlimited number of times
- The rod-end fitting that attached to the valve had 4 detent positions on the valve body, each 90º apart
- The 'flat' side of the actuation rod end fitting (not the stepped portion, but the side opposite to that) was used as the reference position indicator for the valve setting for this report and test

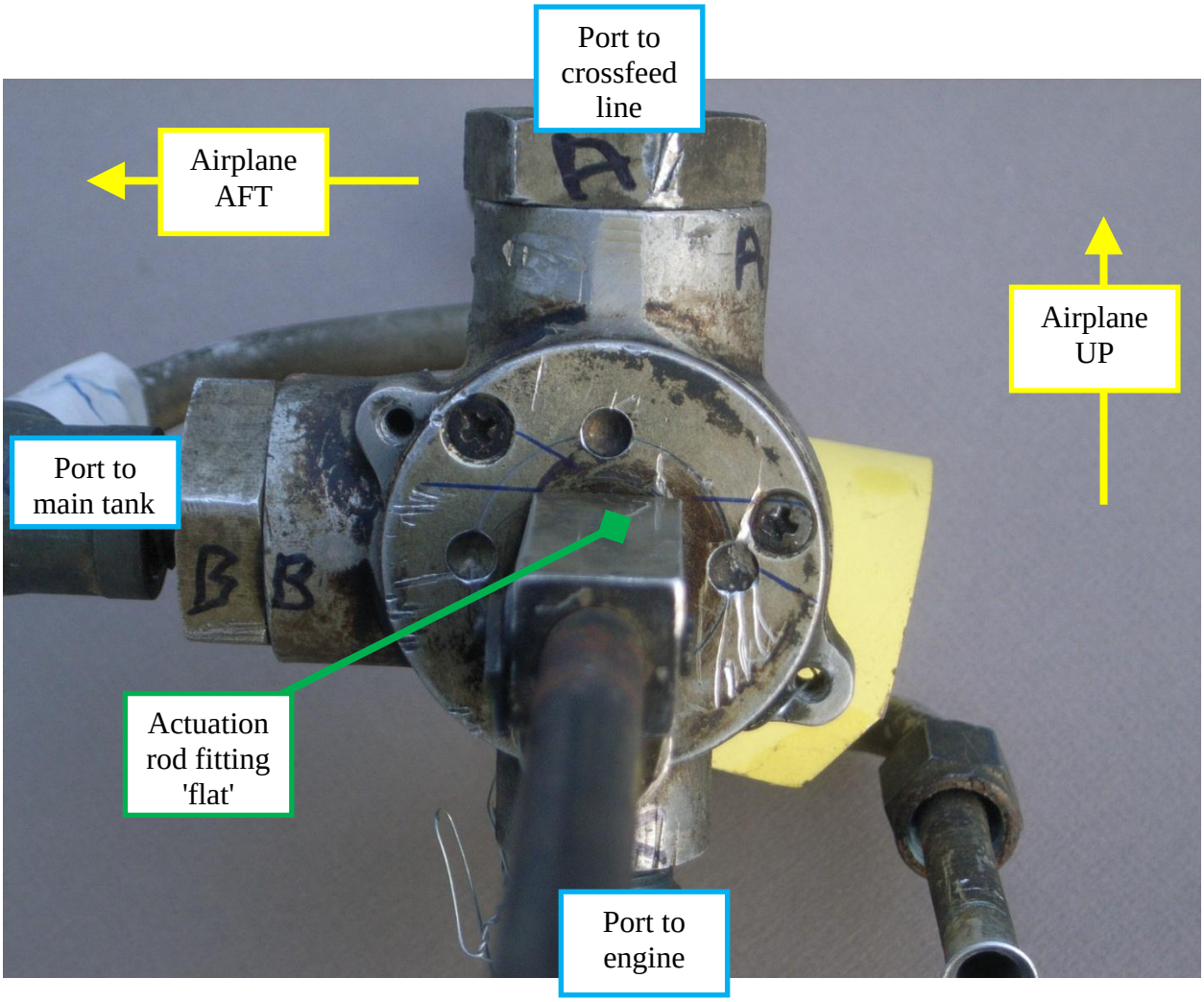

Figure 3 - Valve with Actuation Rod Fitting 'Flat' Oriented Up (View looking left/outboard)

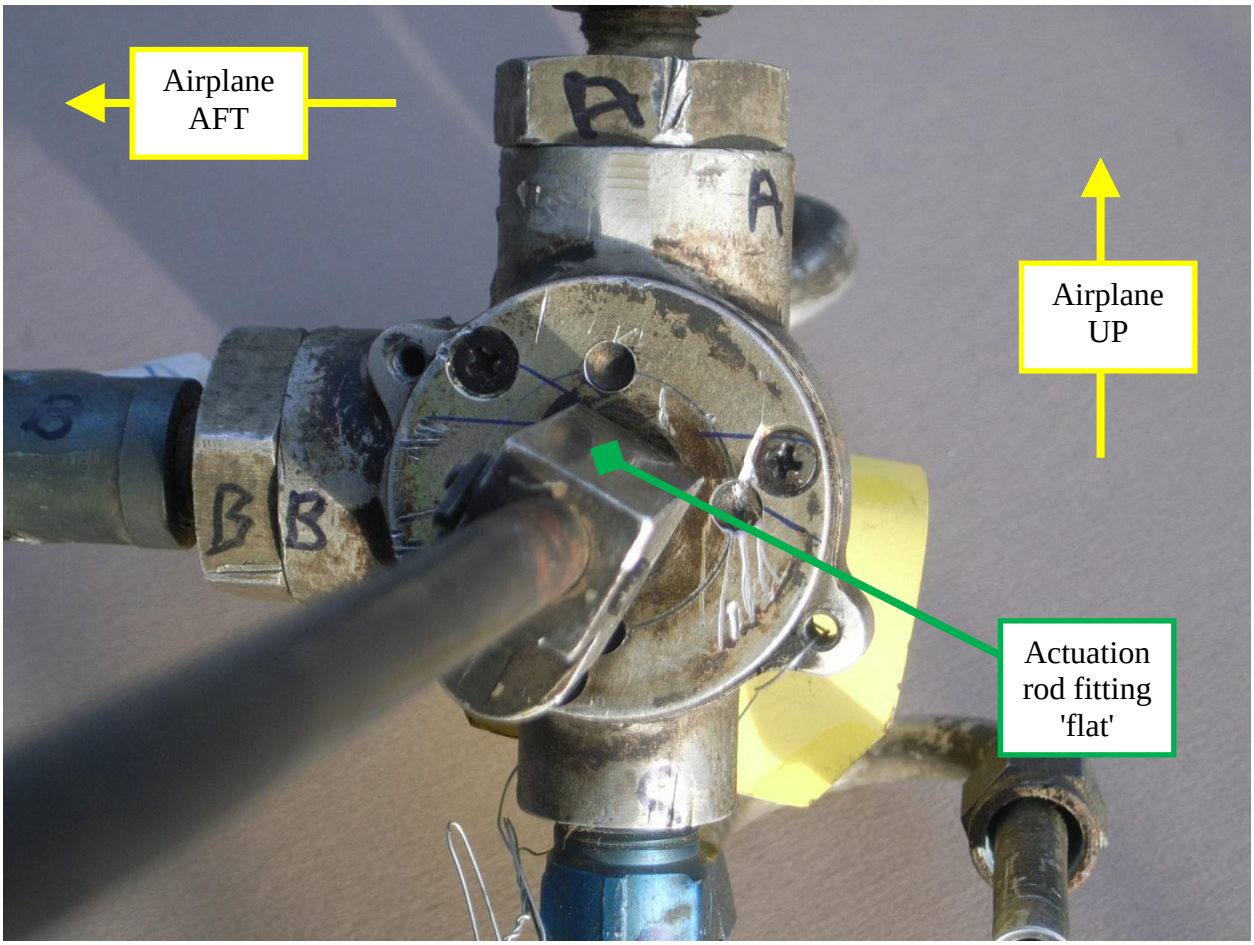

Figure 4 - Valve with Actuation Fitting in As-Found Position (View looking left/outboard)

E. VALVE FUNCTIONALITY

- Low pressure air was used to determine the which passageways/ports were opened or closed as a function of the actuation rod fitting 'flat' position/orientation (as below, and also shown on diagram)

Flat orientation and passageway/port status

Flat Orientation	**Passageway Status**		
	A - B	**A - C**	**B - C**
Up	closed	closed	closed
Right/Fwd	closed	closed	open
Down	open	open	open
Left/Aft	closed	open	closed

Flat orientation correlated with cockpit selector position

Flat Orientation	**Cockpit Selection**	**Passageway Status**		
		Opp - Main	**Opp - Eng**	**Main - Eng**
Up	OFF	closed	closed	closed
Right/Fwd	MAIN/ Same Side Tank	closed	closed	open
Down	Not Available	open	open	open
Left/Aft	Opposite Tank	closed	open	closed

F. BACKGROUND and TEST INFORMATION

- The left engine failed on takeoff, but was successfully run at full power in a test cell after the accident
- The left selector valve was found on-scene in a position between two detent positions
    - The flat was approximately 30º CW (towards the MAIN position) of 'Up' (which is the fuel OFF position)
    - A line was drawn on the valve to replicate the position as found, for reference purposes, to enable positioning for the test
- Takeoff conditions
    - O-470M engine
    - 2,600 rpm
    - 1,600 feet msl
    - Temperature 17º C (~63º F)
    - Altimeter setting 29.99 inches Hg

Estimated O-470-M Fuel Flow Values					
	70 degs F			60 degs F	
	PPH	GPH		PPH	GPH
Lean	128	21.3		129	21.5
Rich	138	23		139	23.2

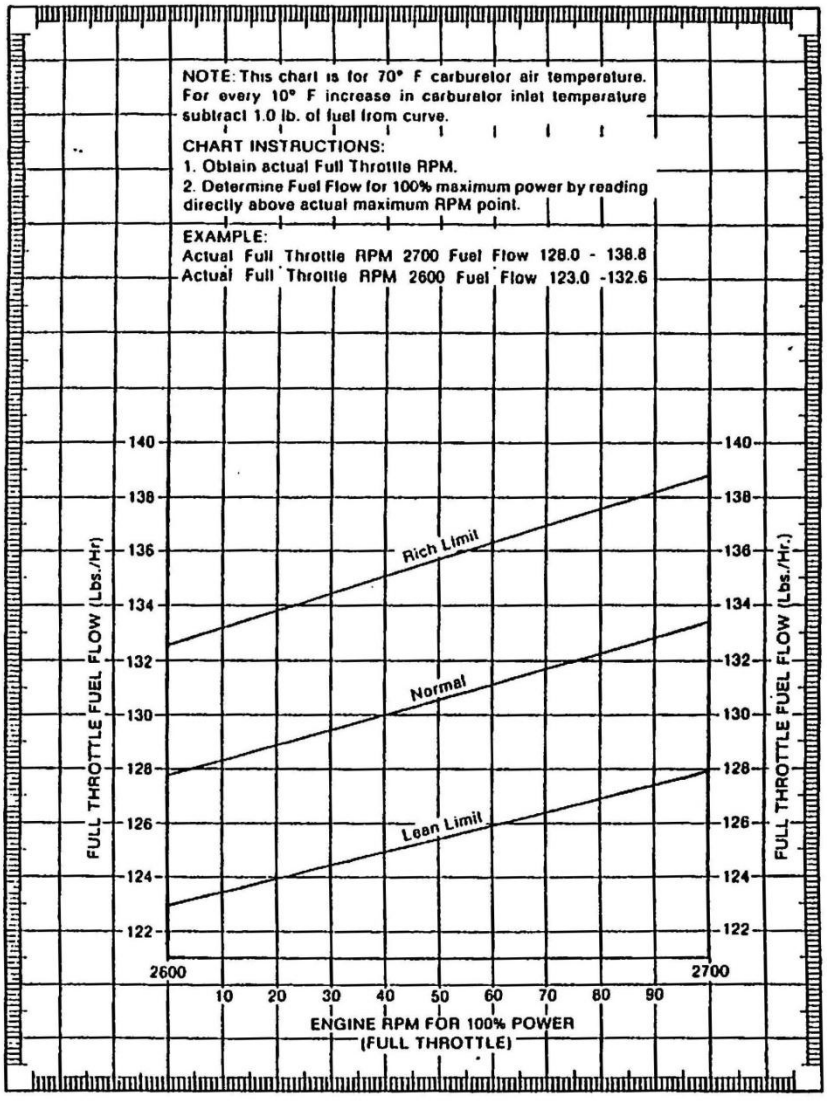

Figure 5 - TCM Engine Fuel Flow Chart

- Per Cessna and TCM information
  - Nominal fuel pressure 9 to 11 psi
  - Maximum potential fuel flow rate approximately 24 gph
- A parametric test study was designed and performed to determine the valve flow capability
- The test goal was to determine the fuel flow capability of the valve as a function of valve position
- Test values:
  - Fluid input pressures 5, 10, and 15 psi
  - Fluid input to side /Main/'B' port
  - Fluid output from bottom/Engine/'C' port
  - Valve 'flat' angles (degrees CW from straight up, which is 0º)
  - Test fluid specific gravity 0.768

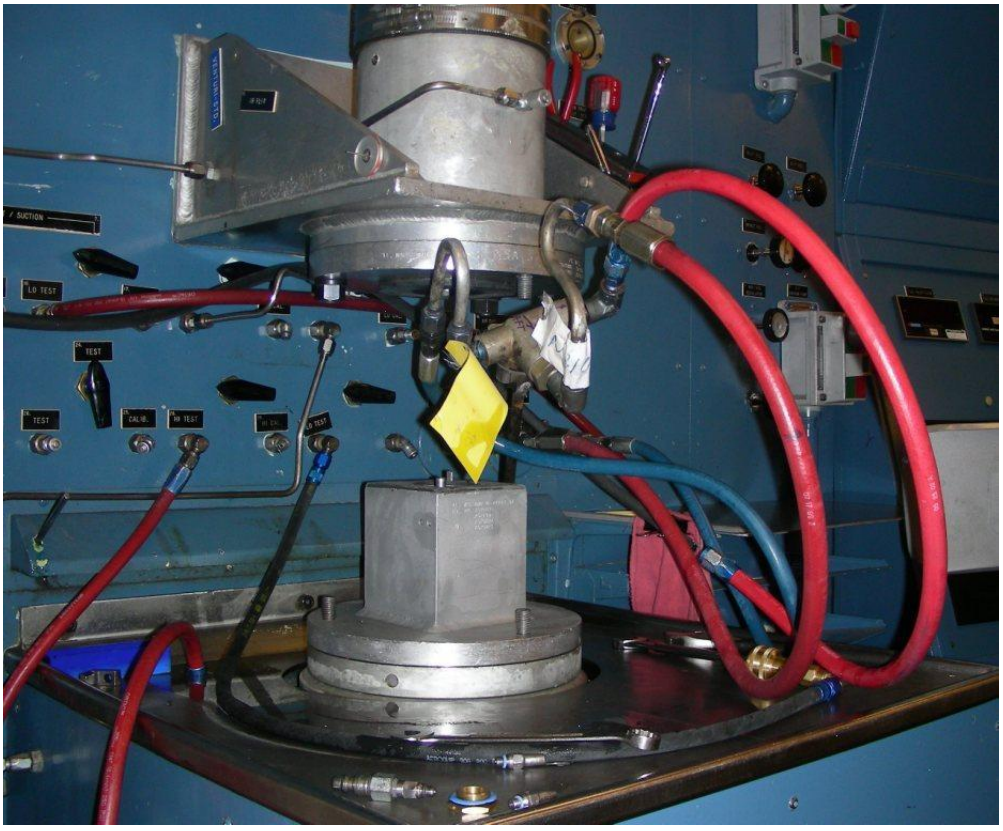

Figure 6 - Valve in Test Fixture

Test Results: Test fluid flow rates in pounds per hour (pph) and gallons per hour (gph)

VALVE FLAT ANGLE	**FLOW RATE (test fluid, pph and gph)**					
	Input: 5 psi		**Input: 10 psi**		**Input: 15 psi**	
	OUTPUT: PPH	**OUTPUT: GPH**	**OUTPUT: PPH**	**OUTPUT: GPH**	**OUTPUT: PPH**	**OUTPUT: GPH**
15°	0	0	0	0	0	0
30° (as found)	2	0.3	2.6	0.4	0.3	0.05
45°	202	32	322	50	416	65
60°	230	36	368	58	475	74
90° ('ON')	230	36	369	58	478	75