Modulating Float Valve Analysis

In an effort to create the best possible modulating float valves (MFVs), Fluidtrol Process Technologies, Inc., analyzed its MFV's performance and material characteristics using Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA). CFD revealed accelerating flow streams around the disc, alleviating any concerns about pressure drop. Fluidtrol's modulating float valve also excelled when it can to analysis of the adjusted flow rate for surge tank level, the force and moment balance of float arm, and the material strength of the disc, which showed less than ¼" deflection at the tips when subjected to a differential pressure of 40 psi.

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DESCRIPTION

Modulating float valves are designed to regulate the flow of water in a pool recirculation system. When surges from the gutter drain spikes levels in the surge tank (or surge pit), the modulating float valve (MFV) closes, limiting the return of water coming from the main drain. This allows surge flows from the pool gutter system to be dampened. The following analysis was performed to determine Fluidtrol's modulating float valve's performance and material characteristics.

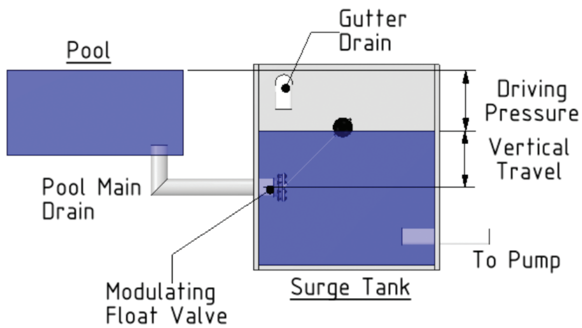

FIGURE 1.
The modulating float valve (MFV) maintains the balance between the pool level and the surge tank level. When surges from the gutter system occur, the MFV will close and restore balance between the pool and the surge tank level.

The Fluidtrol modulating float valve was analyzed to characterize its:

- Pressure drop
- Adjusted flow rate for surge tank level
- Force and moment balance of float arm
- Material strength of disc

FIGURE 2.
Fluidtrol's modulating float valve was analyzed for performance and strength.

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PRESSURE DROP

The pressure drop of the MFV was modeled using Computational Fluid Dynamics (CFD). The induced forces and moments due to the flow resistance were captured in each simulation. The mesh for the valve, shown below, was refined to capture features less than 1/32”. The following figures demonstrate the valve at a 30° angle (float arm is at 75° because of 45° offset).

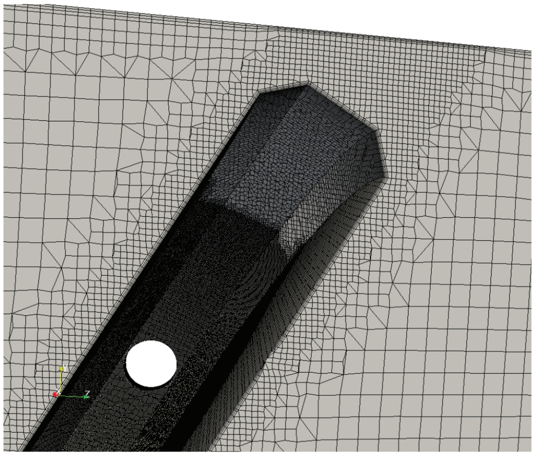

FIGURE 3.
The CFD model was detailed enough to consider wall effects and fine geometry.

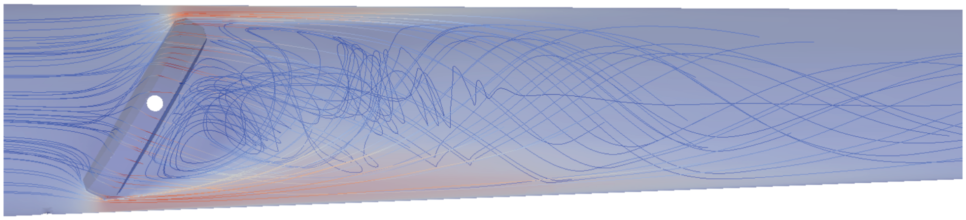

FIGURE 4.
The CFD analysis shows the direction of flow (streamlines) and the velocity (red is faster than blue).

The CFD simulation produced flow streams that illustrate the acceleration around the disc and vortex behind the disc. Note the flow streams are not parallel for several pipe diameters downstream of the valve. This demonstrates the general rule of thumb that 10 pipe diameters are required for flow streams to normalize. When installing directly in-line with a suction pump, designers should consider the pump inlet flow stream requirements.

Additionally, designers should be aware of the localized low pressure at the edges of the disc. Air bubbles can become trapped behind the disc if the downstream piping has a downward gradient. If not purged, the air bubbles may collect and be sucked into the pump. This can be avoided if the MFV is installed upstream of a surge tank or with an air trap prior to the pump.

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The pressure on the disc surface shown to the left validates the general assumption that the upstream pressure applies equally on the upstream disc surface, and that the downstream pressure applies evenly on the downstream disc surface.

There are some localized pressure drops around the leading edges of the disc. The valve should not pose a cavitation issue as the lowest localized pressure is 0.07 psi below the valve outlet pressure. This is not enough suction to flash water if the pump is operating atmospheric pressure.

The pressure drop between the inlet and outlet at various flow rates was simulated for different valve angles. Tabulating this data allowed for the calculation of the flow coefficient, Cv, for each valve size. The Cv allows designers to estimate the flowrate at their operating pressures. The Cv value is the flowrate at 1 psi pressure drop.

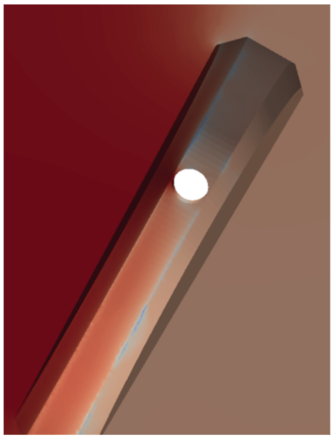


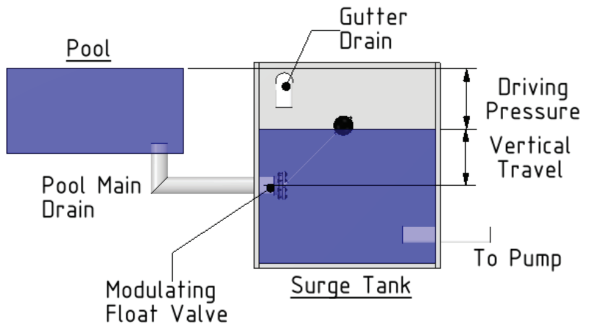
FIGURE 5.
The pressure drop across the disc.

$$Flow\ (gpm) = C_v\sqrt{\Delta P\ (psi)}$$

		Closed ← % Open → Open				
		11%	33%	56%	78%	100%
Valve Size	4"	46	80	171	316	497
	6"	72	166	396	875	1,510
	8"	102	291	714	1,619	3,005
	10"	142	459	1,163	2,833	5,571
	12"	180	656	1,757	4,049	7,440
	14"	208	790	2,117	5,021	9,492
	16"	241	1,020	2,806	6,772	13,031

FIGURE 6.
The Cv for various valve positions allows designers to estimate the flow for any pressure drop.

ADJUSTED FLOWRATE FOR SURGE TANK LEVEL



The Flow coefficient value, Cv, calculates the flowrate for a given differential pressure. However, the differential pressure in a surge tank system changes because the level in the surge tank will raise and lower. The driving differential pressure is the difference between the pool surface and surge tank surface, and the MFV should be the largest flow resistance in the system. The graph below shows the flowrate at various float positions from the valve centerline. We assumed the centerline of the valve is 3 feet below the surface of the pool and placed a vertical line where velocities are approximately 3 fps.

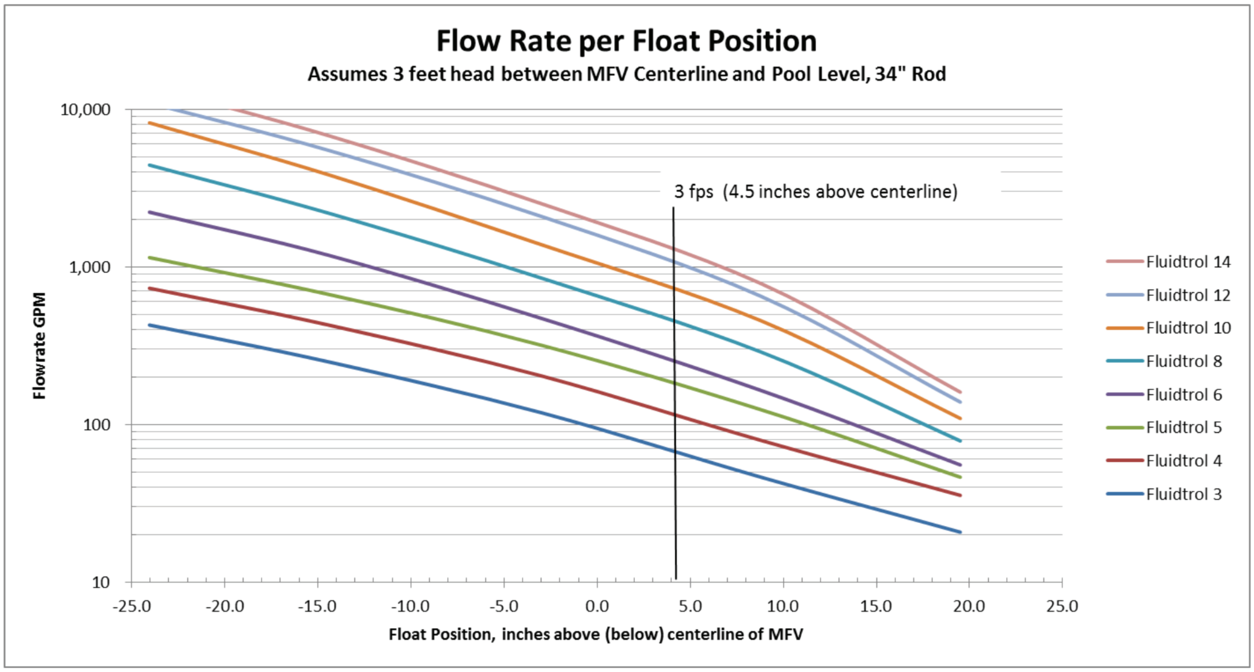


FIGURE 7.
Flowrate at various float positions.

FORCE AND MOMENT BALANCE ON FLOAT ARM

The valve positions itself by using the buoyant force of the float. For the valve to operate, the float must overpower all the other moments (torque). The moments on the axis include the moment induced by fluid flow, the moment of stem and float arm weight, and the friction opposing change. During our simulations, the moment due to fluid flow was captured and graphed below. The largest moment was less than 17 ft-lbs and the largest force on the axis was less than 260 lbf. These forces and moments were modeled at maximum expected flowrates for the size 16” valve.

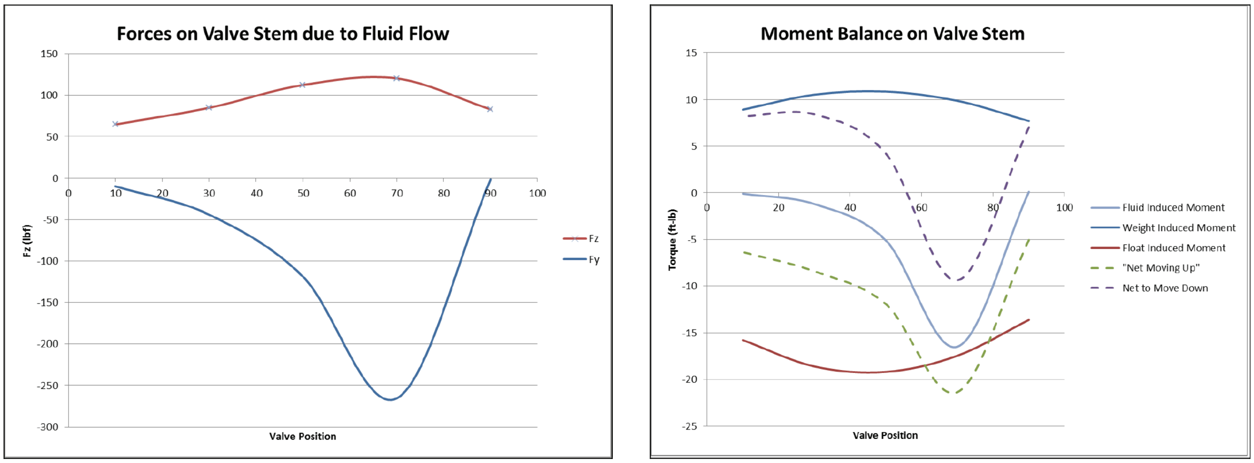


FIGURE 8.
Moment and forces on valve stem due to fluid flow at expected flowrates at 3 feet of head. The moment and forces are much lower at fully open because the disc cross section is much smaller than the partially closed valve.

At higher velocities, the larger valves may have an issue sticking closed. The valve will be “stuck” around 60° because the fluid flow induced moments will overpower the weight at high velocities. This can be visualized in the “moment balance on valve stem” graph with the dashed purple line. When the line dips below 0, the valve will resist opening any further.
To avoid this, a larger valve should be chosen or the valve operated with less driving pressure.

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MATERIAL STRENGTH OF THE DISC

The forces on the disc were analyzed using Finite Element Analysis (FEA) to determine if the material strength is adequate. The disc below is the size 14” MFV with a differential pressure of 40 psi. The left picture shows the material stress (red is greater stress) and the right picture shows deflection (red is greater deflection).

The size 14” disc was chosen because has a large diameter and is expected to have the most significant stress. The highest level of material stress occurs at the surface near the center of the disc. The upstream side is in tension and the downstream side is compressed.
This scenario produced a localized stress of 7 MPa. The disc material polypropylene is more than adequate with a tensile strength of 20 MPa. The expected differential pressure in normal pool surge tank operation is less than 5 psi. The additional thickness will increase longevity and reduce disc deformation.

Deformation occurs as the material bends under pressure. Excessive deformation may reduce the life of the valve and limit the MFV’s ability to regulate flow. The expected deformation at 40 psi differential pressure is shown in the picture on the right. We anticipate less than a ¼” deflection at the tips of the disc at these extreme conditions. During typical pool operation, no significant deformation is expected.

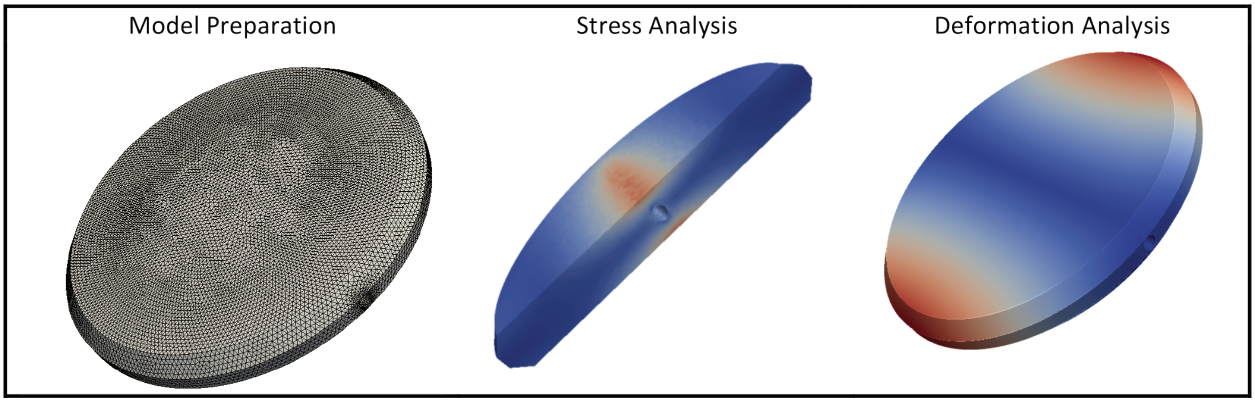

FIGURE 9.
Mechanical stress was modeled using Finite Element Analysis. The “finite elements” are shown on the left and the stress is calculated at each element node (shown in the center). The stress will cause strain and deform each element as shown on the right. We analyzed both stress and deformation to verify that the design is adequate.