Caelus Feedback

Pressure Drop Calculation

To determine tank pressure, we need need to know a few things first. To begin, need to know the required pressure delivered to your injector manifold. You also need to know the mass flow required. These two quantities (for both fuel and ox), in combination with your engine contour and injector design, are what give you your thrust. To state more clearly, your thrust requirements are what *drive* these quantities. So before you calculate your tank pressure, you should already know what pressures you need and what your flow rates should be.

Without getting into injector design (look up NASA SP-8089), your injector manifold pressures will be something like this:

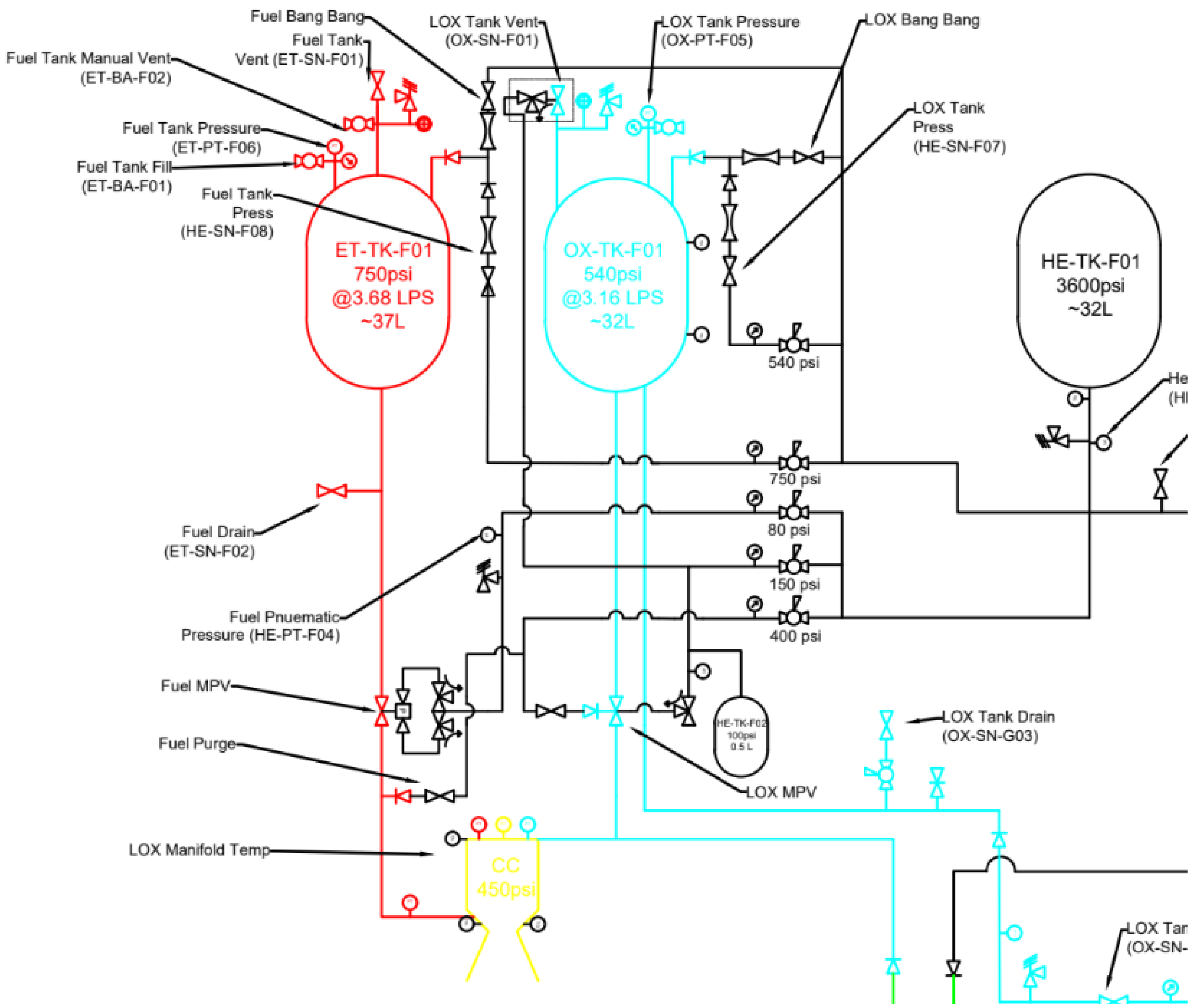
$$P_{manifold} = P_{chamber} + \Delta P$$

Where the DP term is some % of your chamber pressure (This was all figured out in the 50s and you should just use the suggested values in the NASA paper I mentioned).

You should be using some sort of combustor calculator (such as RPA which is free and very good). This will give you the mass flow of each propellant. So now we know both propellant flow rate and pressure.

Example

Here is a snippit of a recent P&ID from our hotfire.



Lets focus on the red line (fuel). This line is fairly simple component wise. The only component is the main fuel valve. Our flow rate is about 1 gal/sec of fuel (I can't remember the exact flow right now). Every component has a dimensionless factor called a Flow Coefficient which is defined as:

$$C_v = \dot{Q}\sqrt{SG/\Delta P}$$

Where Q_dot is the volume flow rate in Gallons/Minute. SG is the specific gravity (Density of working fluid/density of water). DP is the pressure drop through the component (in psi). Cv is usually provided with commercial valves (although sometimes it is not and you'll have to do waterflow tests and calculate it yourself).

Lets assume our fuel MPV (main propellant valve) has a Cv of 10 (this is much higher than you'll need). We get then that the DP across the valve is 28.8 psi. Note that this is independent of the static pressure in the line.

For our design, we need about 15% of the chamber pressure in DP across the injector. This means the fuel manifold needs to be at:

$$P_{manifold} = 1.15 P_c = 518 psi$$

If we add our DP from the fuel valve, we get 547 psi. There is an additional pressure loss due to our cooling, so I'll add another 75 psi for that, bringing the total to 621 psi.

621 is definitely different from 750. Where does that remaining P requirement come from? Two things, one of which is specific to our design. Essentially our fuel manifold causes lots of losses, so there is significant compensation we needed to do in terms of tank pressure. We purposefully made the tanks MUCH stronger than they need to be for testing purposes so this didnt cause much of a problem.

The last thing that you'll have to look out for is pressure losses in the tubing/fittings . You can use an online calculator to figure this out: http://www.pressure-drop.com/Online-Calculator/

Note that the one I linked above is pretty glitchy, and I wouldn't use many of its advanced features, but for doing basic straight tube/bends its fine.

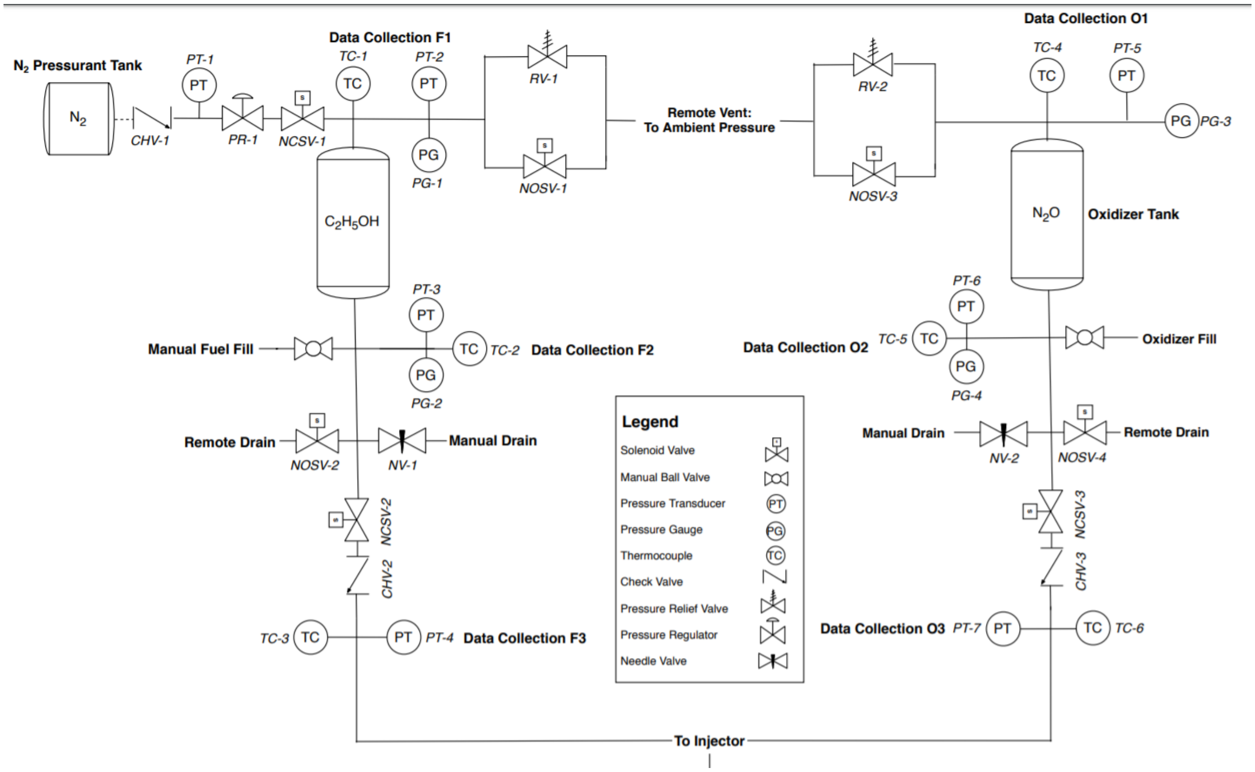
Blowdown specific details

In a blow down system, your tank pressure is not constant. This means it is impossible to get a constant chamber pressure and propellant flow rate (your thrust will change). So the approach I'd suggest is to take

Plumbing

P&ID

This looks really good conceptually and is neatly organized. Good work.



There isn't much I'd suggest changing but here are a few things for you to think about:

- You have check valves in your main propellant lines. What does this do for you? The typical answer I hear people give is that it will "prevent flashback" however, this is not really the case. For a flashback to occur you need two things: A flammable mixture, and a low pressure gradient in the direction of the flow. Your injector is designed to avoid this by the aforementioned DP across the face. This check valve is going to drive up your tank pressure requirements without any real benefit.
- Its good that you have relief valves. Can they dump the entire upstream pressure? For example, lets assume PR-1 failed open (Its a very real possibility, I've seen it happen). Will the resulting flow rate be dumped sufficiently by your RV in order to prevent overpressure of the line?
- What are you going to do with your Fuel TC data?

- Where are you getting the Normally open solenoids, and is your plan to keep them closed continuously during hotfire and propellant loading?
- I notice you have manual fill valves. What will actually push the fuel into the tank?
- N2O cavitates a LOT. Don't be surprised if you don't get the flow rate you thought you would. You'll have to probably figure this out experimentally.
- What fluids will you use for your cold flow? How will those compare to your intended fluids? How will you modify yoursetup to account for the lack of chamber pressure?

Vendor List

Name	Tags
McMaster Carr	Everything, No seriously, Tubing Stock
Swagelok	Compression Fittings, Filters, Manual Valves, Tubing Tools
Ebay	Fittings, Metal, Valves
Jegs	AN/JIC Fittings, Solenoid Valves
STC Valve	Pnuematic Valves
Peter Paul	Manual Valves

General Advice

- Things tend to take about 2x the amount of time you expect. If you think about the case where you work super hard non-stop, and how much time it will take to make something happen, it will probably take 2x that amount. This is not because you aren't trying, but the problem is you don't know what you don't know. I'd venture to say that if this is your first real independent engineering project, it will take 3x what you think. Not trying to be a negative nancy, and you should absolutely push yourself to meet insane deadlines, but don't bet your project on it.

- Team culture is as important as the technical stuff. If you have a group of headstrong, dedicated folk who don't give up when the going get tough, you'll be a lot better off.
- Safety is huge. You should be a little paranoid about things going wrong. This isn't to say you should be afraid of your system, but you need to respect it as the danger that it is. Always be thinking about how things could go wrong and what you can do to prevent it. If you cant prevent it, what will you do when something goes wrong? You need solid answers to these things because when shit hits the fan, you're not gonna be able to think up new responses.
    - On a related note, hardware is just that, hardware. If it catches on fire or explodes, let it burn. Don't risk yourself to save it, it just isn't worth it.
- Engineers tend to be people who don't like dealing with "human" problems. Examples include, administration giving you trouble, or not being able to raise enough money. Often times people say to themselves "There's nothing I can do to change this." But I'd ask yourself, are you trying as hard to solve these problems as you are to solve the technical problems? At the end of the day, it doesn't matter what the form of the problem is, if it prevents progress, it deserves the same amount of dedication.

Please feel free to reach out for more advice. In the future, if you take time to put together slides and prepare questions, I can give more useful feedback. Good luck!