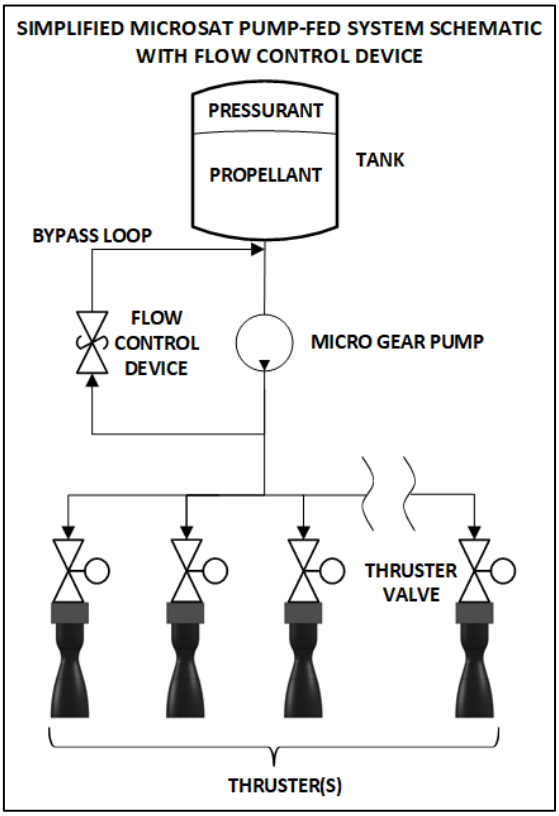
Operational Considerations for Micropump-fed Propulsion Systems

About micropump-fed systems

- An electric positive displacement micro gear pump feeds the thrusters at high pressure from a low-pressure tank.
- Typical tank pressures range from a few psi to tens of psia.
- Thruster inlet pressure can be as high as practical, typ. 300-450 psia.



Key control features

- RPM can be modulated to control flow rate.
- Pump outlet pressure/thruster inlet pressure is driven by thruster demands (number ON and size) as well as any other flow control device characteristics that may be present.
- **Feed-system control approaches:**
  1. **Direct feed, i.e., no bypass:** controlled by pump motor controller) pump is turned ON (almost) simultaneously with thruster(s) and RPM set depending on number of thrusters operating.
  2. **Flow control device (FCD):**
     - Pressure regulation with large bypass return flow through an orifice.
       - Example: NASA Lunar Flashlight propulsion system[1]
     - Pressure regulation with low or no bypass return flow through a flow control device (solenoid valve or mechanical device such as pressure-relief valve or back-pressure regulator – see schematic) while the pump remains ON while pulsing thrusters.
     - Flight Works has developed a pressure regulator type FCD that minimizes the amount of bypass needed.
  3. An accumulator can be used in combination with any of these options.
- Preferred control approach: Flow control device:
  - Allows small bypass with near constant thruster inlet pressure.
  - Can be designed to operate satisfactorily over a range of RPM to provide adequate flow rate to one or multiple thrusters, i.e., if a single thruster is going to be fired, the pump RPM can be reduced thus minimizing power consumption.

Life, reliability, and particulate generation

Pump life and reliability are system dependent including operational pressure/flow/temperature profile, system filtration, recirculation levels, etc. Pumps for propulsion applications can typically be used for high tens of hours at full pressure. In general, an inlet filter should be used to avoid any FOD ingestion which could result in pump lock (min. 25 microns). Also, as a gear pump, there are internal components in contact with one another which generates extremely fine particulates. This particulate generation should be well below the specified cleanliness requirements.[2] For example, at 25 hours of operations, Ref. 2 predicts one (x1) particle between 5-15 microns, which is small when compared to the total number of particles allowed (for example, Level 100 per IEST-STD-CC1246 allows thirty (x30) particles between 5-15 microns for the pump's wetted area).

[1] Huggins, G., Talaski, A., Lightsey, E.G., Andrews, D., Cavender, D., Diaz, C., McQueen, D., Williams, H., Baker, J., and Kowalkowski, M., "Development of a CubeSat-Scale Green Monopropellant Propulsion System for NASA's Lunar Flashlight Mission," AIAA-2021-1976, AIAA SciTech Forum, VIRTUAL EVENT (Jan 2021)

[2] NSWC-11 "HANDBOOK OF RELIABILITY PREDICTION PROCEDURES FOR MECHANICAL EQUIPMENT"