Jessie & James Trade Study

Derivation to show how mass flow rate and pressure affect injector sizing for J&J

$$\dot{m} = c_d A\sqrt{2\rho\Delta P}$$

Fuel Line (*Incompressible Fluid*)

$$\dot{m}_f = c_d A_f\sqrt{2\rho_f(P_{inj,f} - P_c)}$$

Where

$c_d = 0.7$ (square edge oriface)

$A_f = injector\ oriface\ total\ area$

$\rho_f = 810\ kg/m^3$

$P_{inj,f} = Fuel\ injector\ pressure$

$P_c = chamber\ pressure$

Oxygen Line (*Compressible Fluid*)

$$\dot{m}_o = c_d A_{i,o}\sqrt{2\rho_o(P_{inj,o} - P_c)} \qquad \rho_0 = \frac{P_{inj,o}}{R_0 T_0}$$

$$\dot{m}_o = c_d A_{i,o}\sqrt{2\left(\frac{P_{inj,o}}{R_0 T_0}\right)(P_{inj,o} - P_c)}$$

Where

$c_d = 0.7$ (square edge oriface)

$A_{i,o} = oxygen\ injector\ oriface\ total\ area$

$R_0 = 259.8\ oxygen\ gas\ constant$

$P_{inj,f} = fuel\ injector\ pressure$

$T_0 =$ oxygen temperature

$P_c = chamber\ pressure$

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Oxygen Line (*Compressible Fluid*)

$$A_i = \left(\frac{\dot{m}}{c_d}\right)\sqrt{\frac{R_0 T_0}{2Pi_{,0}\left(P_{i,o} - P_c\right)}}$$

Where

$P_{i,0}$ = oxygen injection pressure

P_d = % pressure drop

$$P_{i,o} = P_c(1 + P_d)$$

Substitute and after some algebra…

$$A_i = \frac{\dot{m}}{P_c}\left(\frac{1}{P_d{}^{1.5} c_d}\right)\sqrt{T_o R_o}$$

∴ **Keeping A_i and P_d constant $\dot{m}$ and P_d scale proportionally**

Fuel Line (*Incompressible Fluid*)

$$A_i = \left(\frac{\dot{m}}{c_d}\right)\sqrt{\left(\frac{1}{2\rho}\right)\frac{1}{\left(P_{i,f} - P_c\right)}}$$

Where

$P_{i,f}$ = fuel injection pressure

P_d = % pressure drop

$$P_{i,f} = P_c(1 + P_d)$$

Substitute and after some algebra…

$$A_i = \frac{\dot{m}}{P_c^{0.5}\, P_d^{0.5}}\left(\frac{1}{c_d}\right)\sqrt{\left(\frac{1}{2\rho}\right)}$$

∴ **Keeping A_i , double $\dot{m}$ and P_c, and the percent P_d will double**

LPL

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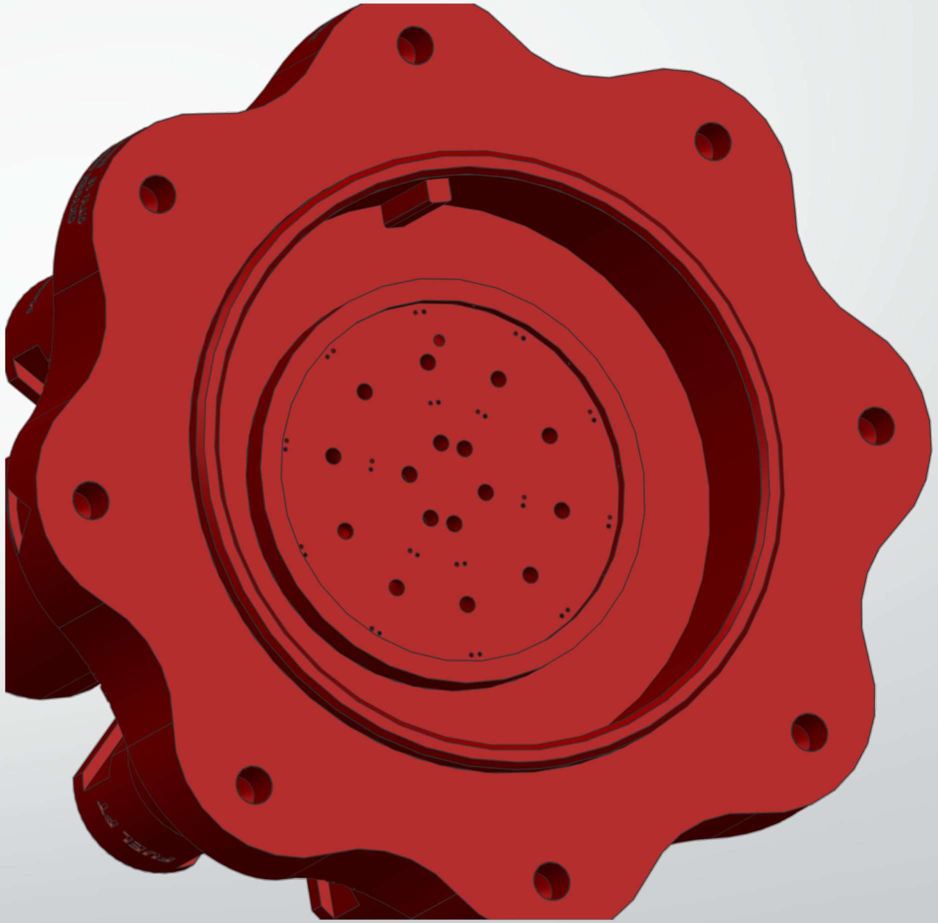
Injector Design:

Engine Injectors initial sized for a **20% pressure drop** for the **fuel & a 20% pressure drop** for **oxygen** orifices and at **50%** of Hydra **max mass flow rate** (Dual Engine Conditions)

Using the same injector for at **100%** of Hydra's **max mass flow rate** will result in a **20% pressure drop** through the **oxygen** side of the injector and a **40%** pressure drop through the **fuel** side. (Single Engine Conditions)



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