Project NEO Specific Impulse Testing Solutions

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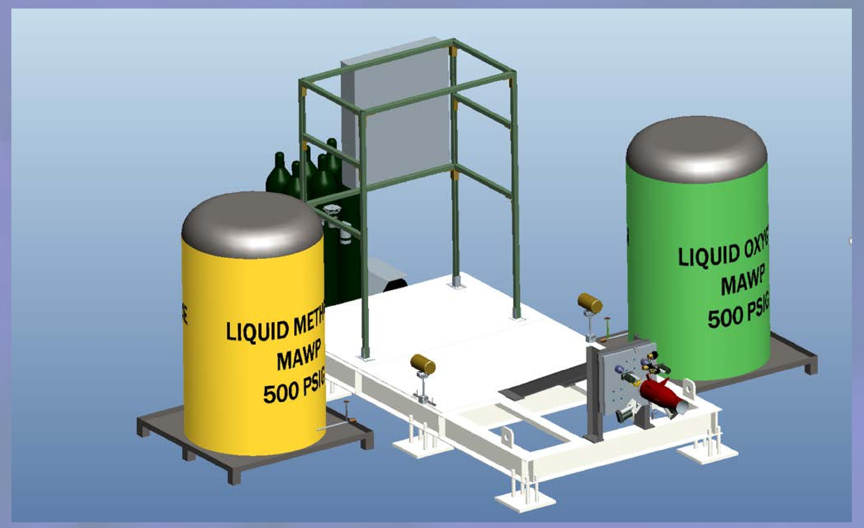
BACKGROUND

Specific impulse is the measure of efficiency for rocket propulsion, similar to miles per gallon for a car. The unit of measure for specific impulse is seconds, [s]. Specific impulse is the change in momentum per unit of propellant. A bipropellant rocket motor with a high specific impulse can provide more change in momentum than a different motor with a lower specific impulse; using the same amount of propellant.

The Neo test stand is currently configured to fire a horizontally mounted rocket motor with up to 6500 lbf thrust. Currently, the Neo test stand can measure flow of liquid propellant and oxidizer, pressures residing in the closed system up to the combustion chamber. The current configuration **does not** have the ability to provide all data needed to compute specific impulse.

OBJECTIVE

Determine three methods to outfit the NEO test fixture with instrumentation allowing for calculation of specific impulse.



METHOD #1

Determining what measuring equipment is required begins with understanding what variables are needed to solve for specific impulse. Starting with the basic equation for thrust,

$$F_{thrust} = \dot{m}V_e + (p_e - p_0)(1)$$

we find key variables the NEO test fixture cannot currently measure such as: force (F_{thrust}), pressure (p_e), and exit velocity (V_e). Neo does have flowmeters which help determine mass flow ($\dot{m}$). However, mass flow measurements are inaccurate without temperature sensors nearby to help determine the proper density (ρ) of the flow.

However, unlike the basic equation for thrust, finding specific impulse only relies on accurate measurements of Force and mass flow ($\dot{m}$)

$$I_{sp} = \frac{F_{thrust}}{\dot{m}g_o}(2)$$

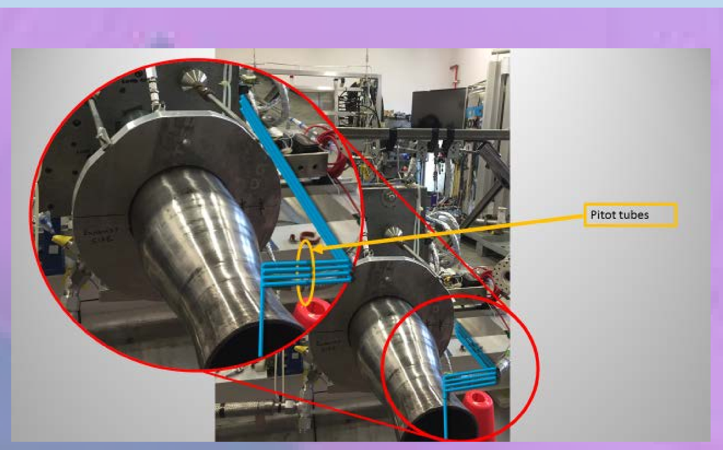
By taking mass out of the equation we need only one variable to solve for, exit velocity (V_e)

$$I_{sp} = \frac{V_e}{g_o}\ (3)$$

Using the installed Flowmeters, and solving for equation 2, load cells and thermocouples would be needed to find specific impulse. An axially mounted load cell need only have a range up to 7000 lbs. Also, we would need to include temperature sensors near the flowmeters. Including temperature sensors will provide us with more accurate mass flow calculation. Data logging equipment would need to be attached to the flowmeters and sensors to capture the data. Data could then be easily transferred to a graph displaying specific impulse as the dependent variable with many points of data.

Nomenclature	Part no	Manufacture	Qty	U/P	T/P
Load cell	LCF450	Futek	1	$800	$800
Thermocouple	HGQSS-316G-12	Omega	2	$33	$66

METHOD #2



Using method 1 along with more equipment can provide more data that method 1, and an analytical solution for exit velocity. Knowing exit velocity allows us to use equation 3 which provides a second method to find specific impulse. Using a second equation to find specific impulse will let us double check, or use a statistical method to verify our specific impulse.

The only equipment needed for this method is a combination of the equipment from method 1, tubing, and pressure transducers. The tubing allows for the pressure transducers to be located at some distance away from the heat of the exhaust. Knowing the exit pressure (p_e) allows us to use equation 1. Solving equation 1 for exit velocity (V_e) gives us specific impulse by use of equation 3. Also, using method 1 we can solve for equation 2.

The tubing can be configured in various ways from 1 tube located in the center of the exit area, or a series of tubes placed along the radius of the exit area from the center to the outer diameter. Figure 1 shows a possible configuration.

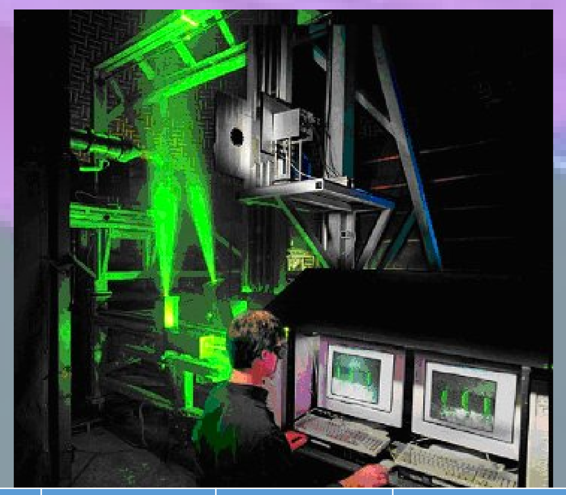
Although, the only measurement needed will be the center pressure. The tubes may all be connected a short distance away from the plume to allow for easy replacement when damaged. However, the pressure transducers should remain and last for a normal lifespan, saving money.

Nomenclature	Part no	Manufacture	Qty	U/P	T/P
Load cell	LCF450	Futek	1	$800	$800
Thermocouple	HGQSS-316G-12	Omega	2	$33	$66
Pressure Transducer	PX119	Omega	1-4	$99	$99-$396

METHOD #3

Solving for equation 3 requires measuring velocity at the nozzle exit, exit velocity (V_e). We can do this using a Laser Doppler Velocimetry system. This is an expensive method and requires equipment not currently part of the NEO test stand. This method along with the previous two methods could provide a "Cadillac" test stand capable of highly accurate, highly repeatable, and a highly data dense method to find specific impulse.

The LDV method involves two converging laser beams focused at a small volume within the exhaust flow on the exit plane. The reflected frequencies, from particles in the flow making contact with the converging beams' interference frequency, are computed in software and exit velocity is derived with known equations.



Nomenclature	Part no	Manufacture	Qty	U/P	T/P
Powersight	LCF450	TFI	1	~$100000	~$100000
Load cell	LCF450	Futek	1	$800	$800
Thermocouple	HGQSS-316G-12	Omega	2	$33	$66
Pressure Transducer	PX119	Omega	1-4	$99	$99-$396
Computerscales DXI Dual Load Cell	Jegs 44172652	Computer scales	2	$2195	$4390

CONCLUSION

Options provided give Project Manager a choice on accuracy, repeatability, and expense.

REFERENCES

PARTICLE STREAK VELOCIMETRY OF SUPERSONIC NOZZLE FLOWS

1 J. D. Willits, T. L. Pourpoint, Particale Streak Velocimetry of Supersonic Nozzle Flows, JANNAF Propulsion Meeting; 63rd; 16-20 May 2016; Newport News, VA; United States,

2 Hofer, R.R., Jankovsky, R.S., "The influence of current density and magnetic field topography in optimizing the performance, divergence, and plasma oscillations of high specific impulse Hall thrusters," IEPC–2003–142, 28th International Electric Propulsion Conference, Toulouse, France, March 17–21, 2003.