TELEDYNE INSTRUMENTS
Hastings Instruments
A Teledyne Technologies Company

APPLICATION NOTE

HASTINGS

Thermal Spray Gas Flow Control

How to Achieve a Consistent Flame and Avoid Problems

High Velocity Oxygen Fuel (HVOF) thermal spray technology has evolved and advanced recently through the use of more sophisticated controls and design. In particular, the ignition and control of the flame has benefited from the use of actively controlled flow rates which deliver steady, consistent, and programmable flame characteristics and gas mix ratios. As opposed to volumetric flow devices like rotameters and critical orifices, thermal mass flow controllers (MFCs) are relatively unaffected by changes in pressure and temperature—which routinely occur over an operation run of a thermal spray coater. This capability in turn helps produce a higher quality, more uniform coating.

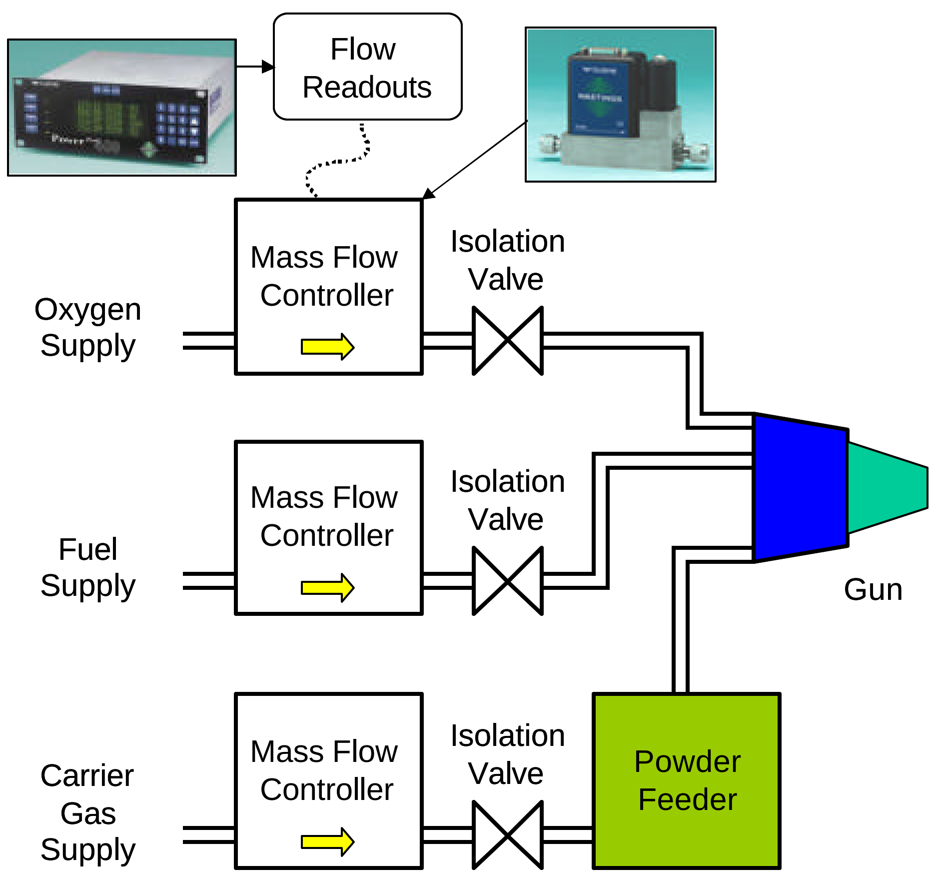
Objectives

- ✓ Provide precise, stable flow rates and oxygen/fuel mix ratios to thermal spray flame.
- ✓ Achieve controlled ignition without “popping” and “flame-out”.
- ✓ Consistent powder feed to the gun with controlled carrier gas flow.

Method

Most HVOF thermal spray systems use three flow control instruments, one each to control the oxygen, fuel, and a powder carrier gas. The flame characteristics are determined primarily by the oxygen and fuel flows but also depend on the gun design and are affected somewhat by the carrier gas flow. Precision and repeatability in the flame characteristics such as temperature, distribution and stoichiometry require that each flow be controlled to well within a few percent.* Flow measurement and control based on rotameter or critical orifice devices cannot routinely achieve these levels due to inherent inaccuracies and the variations that occur as a result of pressure and temperature changes. The figure shows a preferred arrangement for proper flow control to achieve the desired performance of a modern thermal spray system.

To allow control of the total flow while ensuring a constant oxy/fuel mix ratio, a “master/slave” approach is implemented.



This can be accomplished directly between the MFCs (see Hastings HFC 303 Users Manual Section 2.7.4), or more conveniently using the power supply/readout functionality (see Hastings PowerPod 400 Users Manual Section 10.7). In either case, a flow set point is delivered to the master flow controller, while a ratio set point is automatically delivered to the slave flow controller. In this way, the total flow and the mix ratio can each be tuned and controlled independently.

Igniting the flame presents problems characterized by “popping” or more severe cases of explosive ignition and flame-out. These scenarios are related the start-up of the oxygen and fuel gas flows. Usually, problems are the result of (1) incorrect sequencing of the isolation valves and flow set points or, (2) differences between the response times of the MFCs. The sequencing problems usually occur when the isolation valves (downstream of each MFC) are used to stop the flow while leaving the set points applied to the MFCs. This does stop the flow; however the MFCs naturally respond to this situation by opening their internal control valves to maximum position (since the flow set point is still applied). When flow is reinitiated by opening the isolation valves, the MFCs are still in the wide open mode and the gases suddenly flush through the gun at very high rates until the controllers can respond. To solve problems like this and those related to response time differences, a typical sequence for isolation valve operation and MFC set points follows:

- The initial condition is MFC set points = 0, Isolation valves closed.
- Open isolation valves.
- Command total flow set point (maintaining ratio) from 0 to 20% of desired flow
- Wait 2 seconds for settling then ignite flame.
- Ramp total flow set point to desired flow (either in 20% increments for 2 seconds each or as a continuous ramp for a total of 8 seconds).

Depending on the details of the system and related instrumentation, variations on this baseline sequence may be needed to provide optimal results. Alternatively, the flows can be bypassed to a pilot light and run at a basal rate while the torch is off.

Similarly, the carrier gas isolation valve and flow set point should follow a similar sequence to avoid a sudden burst that may cause a flame-out.

Instrumentation Choice

To provide accurate and stable flow control the HFC 303 Mass Flow Controller is recommended for this application due to its fast response (<2 seconds), high accuracy (better than 1%) and insensitivity to ambient temperature and pressure. The HFC 303 can be factory calibrated for any of the fuel gases, inert carrier gases, or oxygen. When converting a system from volumetric flow devices to mass flow devices, the units of flow are converted from the ambient (room temperature) condition to standard condition reference. This means that the volumetric flow values at 20°C are multiplied by 0.932 to give the standard version of that same unit. For example, if the oxygen flow had been controlled by a volumetric flow device at 650 lpm (liters per minute), the standard flow rate is 606 slm (standard liters per minute). If operating at high altitude, a local pressure adjustment which had been applied to the volumetric flow device is no longer necessary. This conversion to mass flow using standard flow units eliminates the need to make further corrections for local pressure and temperature changes.

The PowerPod THPS-400 is the recommended multi-channel power supply and control unit for the oxygen, fuel, and powder carrier gas MFCs. This electronic unit has the master-slave functionality between two or more channels; has flow totalizer capability on each channel; and can communicate via RS-232, RS-485, or Ethernet to provide additional functions. With four available channels, the THPS-400 can also operate an alternate fuel or carrier gas to provide further process flexibility.

Producing more uniform, higher quality coatings requires better control of flame characteristics and powder delivery. Mass flow control of the oxygen, fuel, and powder carrier gas ensures you are getting the most consistent performance from your system.

For Information on all Teledyne Hastings Vacuum Measurement and Mass Flow Instruments, visit our website:

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