THE CONCEPT FOR THE MULTI-USER SOLID FUEL APPARATUS

The current concept for the Multi-User Solid Fuel Apparatus (MSFA) insert to the Combustion Integrated Rack (CIR) is described below. The current development of MSFA is in the early conceptual stage; therefore, the concept below is subject to change during the detailed design process before the hardware is built.

The insert for the first flight of the MSFA is planned to support several solid fuel combustion experiment operating scenarios. Thin fuel testing in both quiescent and concurrent flow will be supported, as will thick fuel testing in quiescent, concurrent, and opposed flow.

The insert for the first flight will consist of a single flow tunnel, separate fuel handling systems for thin and thick fuel tests, and a radiant heater. A set of cameras will be provided by the CIR facility. In the event that these cameras do not meet the needs of the science investigation, additional cameras and/or camera accessories (e.g. filters, lenses) may be provided by MSFA as well. Each science investigation will be permitted a very limited amount of upmass allocation and volume for the additional cameras, fuels, and gases needed to run the experiments.

For tests with flow, recirculating flow was selected due to the unacceptably high number of gas bottles that would be required to run a blowdown system as well as the limited flow rate for real-time venting by the CIR. To support the different scenarios below, the fuel dispensers and radiant heater will be modular and the flow tunnel can be located at two different positions within the CIR chamber volume.

The various test scenarios that will be supported by the first flight of the MSFA insert are described in detail below.

Thin Fuel, Quiescent or Concurrent Flow

- An 8 x 8 cm flow tunnel (minimum), roughly 30 cm long, will utilize recirculating flow to provide a concurrent flow test environment. Quiescent tests could also be performed.
- A thin fuel will be located at the centerline of the tunnel, which is also the centerline of the CIR chamber.
- Fuel could remain stationary or be advanced at a rate equal to the flame spread rate so that the flame would remain stationary with respect to the diagnostic systems. An IR camera looking at the fuel edge is required for tracking the flame position in the fuel-advancing mode. This camera may also be used for science.
- Fuel could be ignited from 1 or 2 sides.
- Filtering and some by-product cleanup will be inherent to tunnel design.
- Two edge views and two surface views would be available for direct imaging for cameras/diagnostics exterior to the chamber.
- A sketch of a side view of this concept is shown in Figure 1 and a cross section view of the CIR chamber with this concept is shown in Figure 2.

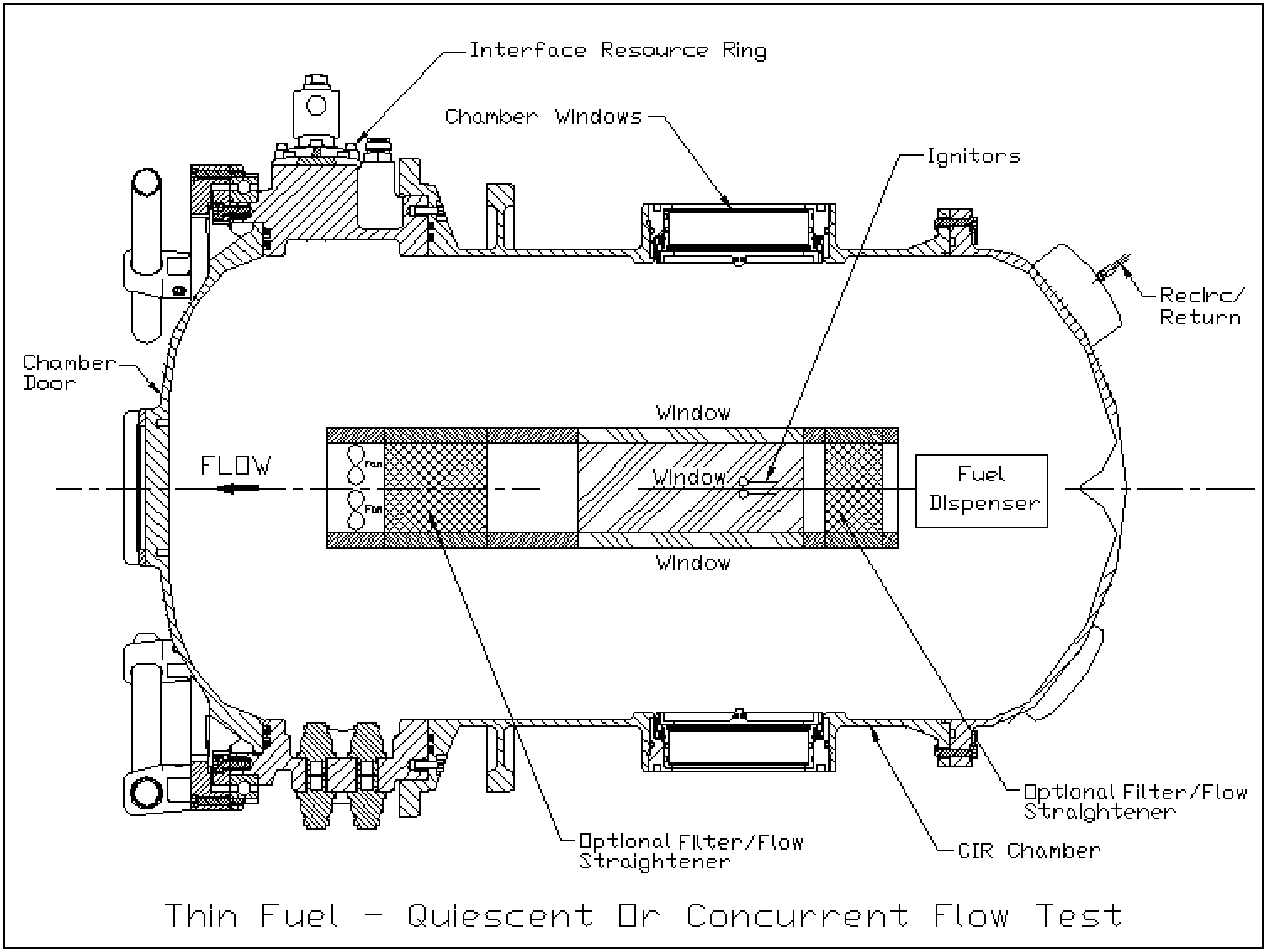

Figure 1. CIR chamber with MSFA insert configured for thin fuels

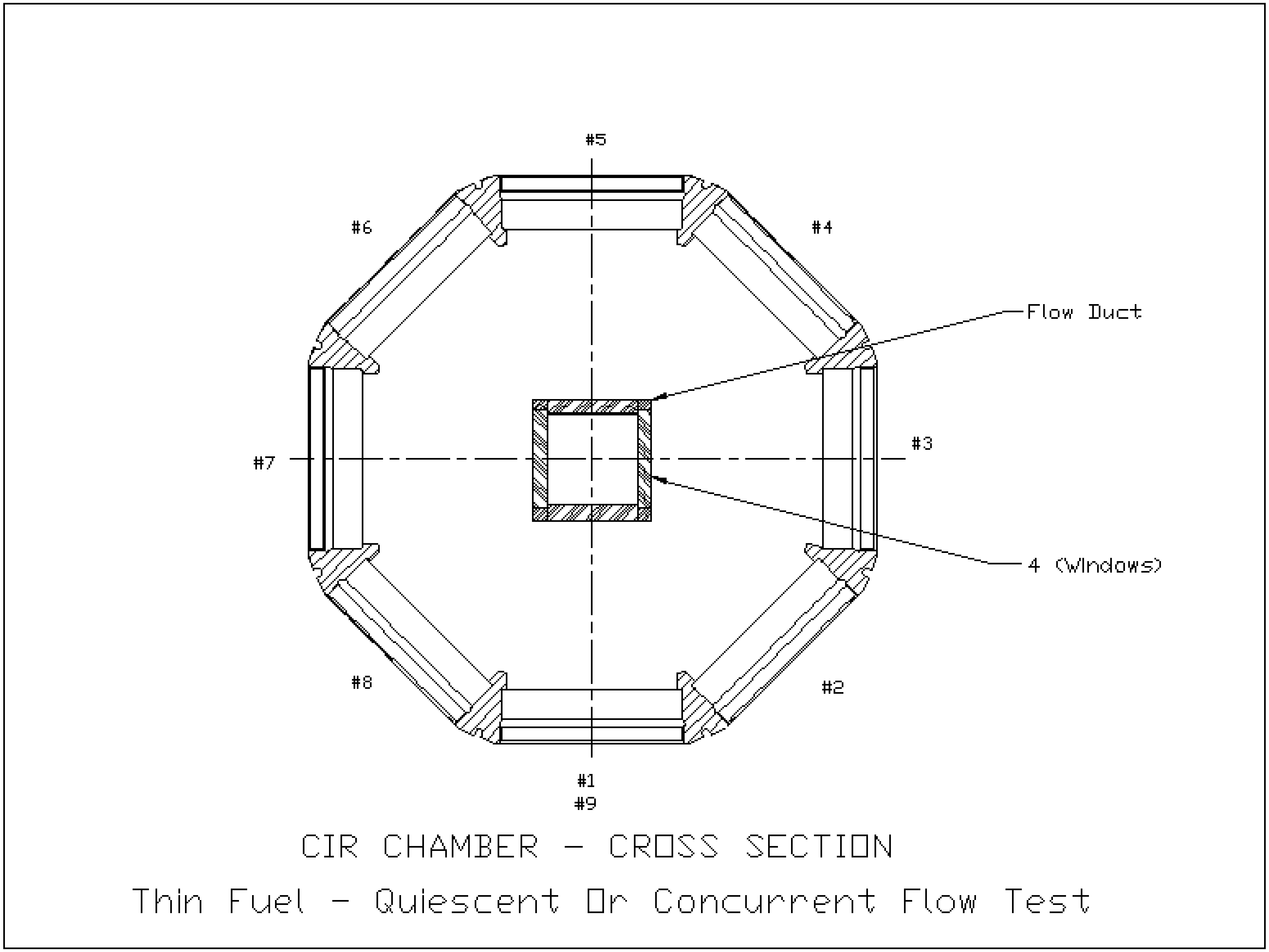

Figure 2. Cross Section of CIR chamber with MSFA insert configured for thin fuel

Thick Fuel, Concurrent or Opposed Flow

- An 8 x 8 cm flow tunnel (minimum), roughly 30 cm long, will utilize recirculating flow to provide 1-directional flow.
- Ignition could occur at either end of the fuel sample allowing for concurrent or opposed flow testing.
- The surface of a thick fuel would be flush with the bottom of the tunnel. That surface would be located at the centerline of the CIR chamber.
- A multiple fuel mechanism would move samples in and out of the tunnel.
- A radiant heater would be available to preheat the fuel surface and/or remain on during the combustion event.
- Filtering and some by-product cleanup will be inherent to tunnel design.
- Two edge views and two top surface views from a 45 degree angle, with the radiant heater in place, would be available for direct imaging for cameras/diagnostics exterior to the chamber. With no radiant heater in place, a direct surface view would be available as well.
- A sketch of a side view of this concept is shown in Figure 3 and a cross section view of the CIR chamber with this concept is shown in Figure 4.

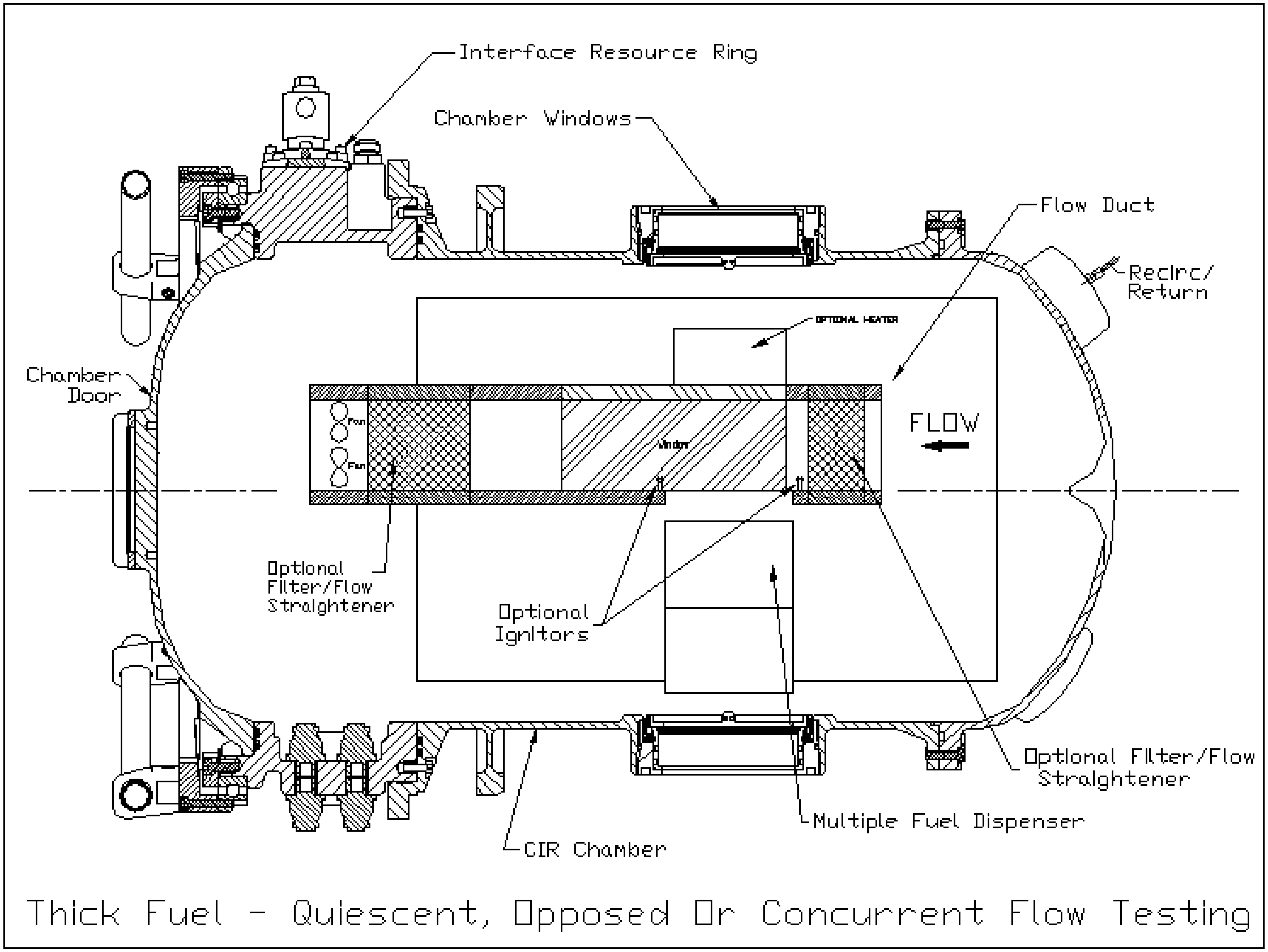

Figure 3. CIR chamber with MSFA insert configured for thick fuels

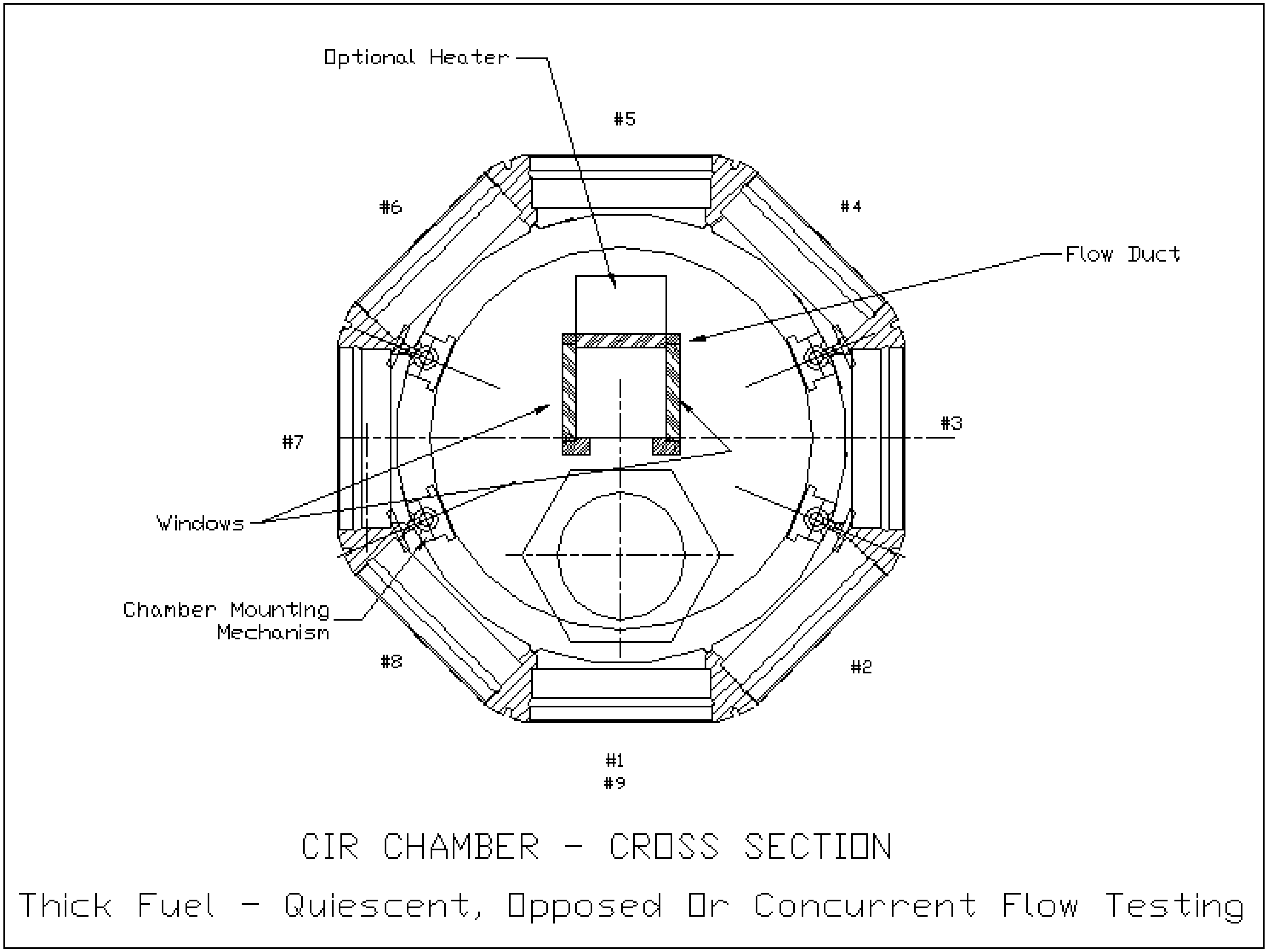

Figure 4. Cross section of CIR chamber with MSFA insert configured for thick fuels

Thick Fuel, Quiescent

- An 8 x 8 cm flow tunnel (minimum), roughly 30 cm long could have the top and two side windows removed and operate with no flow.
- The surface of a thick fuel would be flush with the bottom of the tunnel. That surface would be located at the centerline of the CIR chamber.
- A multiple fuel mechanism would move samples in and out of the tunnel.
- A radiant heater would be available to preheat the fuel surface and/or remain on during the combustion event.
- Two edge views and two top surface views from a 45 degree angle, with the radiant heater in place, would be available for direct views for cameras/diagnostics exterior to the chamber. With no radiant heater in place, a direct surface view would be available as well.
- This set-up would look exactly like Figures 3 and 4 except the tunnel windows would be removed.

Below is a table listing the capabilities that the first flight of the MSFA insert is expected to support.

MSFA 1ST FLIGHT CAPABILITIES SUMMARY

CAPABILITY	*MSFA CONCEPT*	*NOTES*
Test Duration	600+ seconds	Recirculation should allow for adequate times given adequate gas resources.
Velocity Range	0 - 20 cm/sec	Recirculation will allow for adequate velocity
Flow Direction	quiescent, opposed, or concurrent	Concurrent or quiescent with thin fuels. Quiescent, opposed, or concurrent with thick fuels. All flow will be in a single direction.
Pressure Range	0.5 - 5.0 atm	Limited by CIR capability and gas resources.
Tunnel Cross Section	~ 8 x 8 cm - minimum	Will make as large as possible
Tunnel Length	~ 30 cm	Will make as long as possible. Requires waiver from CIR to occupy chamber end caps
Sample Width	up to 7 cm (based on 8 x 8 cm tunnel)	Dependent on final tunnel cross section
Sample Length	up to 10 cm for thick fuels	Continuous feed for thin fuels. Thick related to final tunnel length
Sample Thickness	~ 12.5 mm for thick fuels	Thin fuel may need to be rollable
Sample Material	Limited by cleanliness	Will have to be assessed for “clean” burning and ability to scrub by-products
No. of Burning Sides	Thick - 1, Thin - 2	
Ignition Method	Hot Wire	Can provide 1- or 2-sided ignition
Ignition Location	Can accommodate PI needs	Probable multiple locations to support various test scenarios

MSFA 1ST FLIGHT CAPABILITIES SUMMARY (cont.)

CAPABILITY	***MSFA CONCEPT***	***NOTES***
Thermocouples	~ 12 Can be negotiated	
Radiometers	~ 6 Can be negotiated	
Internal Camera	None planned	May be possible to add if there is room
O_2 Sensor	Will provide quantity required for science and to control O_2	
Hydrocarbon Sensors	TBD	Need to investigate what is available/needed
Oxygen Variation Limit	TBD	Will depend on O_2 sensor, FOMA, and EVP capability
O_2 Concentration Range	10 - 30%	CIR can only vent $\leq$30%. Flow tests limited to 30% O_2. Quiescent tests could go higher.
Camera Views	see Figures 2 and 4	
No. of Samples	limited to upmass restrictions	
Internal Lighting	Fuel surface	
Extinguisher	Turn off flow or purge with N_2	No mechanical extinguisher planned
Windows	Tunnel will have camera compatible windows	Anticipate replaceable windows that can accommodate visible, IR and/or UV cameras
Cameras	Cameras offered by CIR	MSFA will add filter wheels or special lenses as needed. May provide camera(s).
Other	Radiant Heater Panel	Up to 900 W power

CIR Camera Location Constraints

- Diagnostics and associated hardware are mounted to Universal Mounting Locations (UML's). 9 UML's are available; 8 are at windows.
- CIR imagers are supported by Image Processing Packages (IPP's); 1 IPP can support 2 imagers; 2 IPP's available, thus limiting CIR to 4 imagers. (IPP's compete with cameras for UML's)
- IPP's can only be located in non-corner UML's. They also can't be located at the 12 o'clock widow position (UML).
- CIR allows for PI provided box(es) at available UML locations to support non-CIR HW.

A typical arrangement might be:

2 IPP's
4 Imagers
1 Illumination package.
2 PI supplied packages, 1 at the non-window location

CIR Cameras

A listing of the cameras that the CIR facility is currently planning to provide and their capabilities is listed in Table 1.

Table 1. Combustion Diagnostics Capabilities

Package	Application	Pixels	FOV (mm)	Resol. (lp/mm)	Bit Depth (bits)	Run Time (min)	Frame Rate (fps)	Spectrum (nm)	Sensitivity	Features
HiBMs	Soot Volume Fraction Soot Temp. Shadowgraph	1024 or Bin 2x2	80 & 50 dia. Telecentric	5 & 10	12	20 @ 15fps	15	650 – 1050	N/A 1200K-2000K 0.8K/mm	Auto-iris
HFR/HR	High Frame Rate High Resolution	512 1024	10 sq. (37 total) Telecentric	12 @ 50% mod. 20 @ 50% mod.	8	20 @ 110fps or 30 fps	110 30	450 – 750	600 lux	Centroid Tracking Auto-focus Event Trigger
Color	Configuration Verification	512	58-350 sq. zoom	4.4 - 0.7	24	27 @ 30 fps	30	400 – 1050	2 lux	Auto-iris Auto-focus
Low Light Level	OH Emissions CH Emissions	1024	48-212 sq. zoom	12.1 - 2.4	8	20 @ 30 fps	30	280 – 700	6x10E-9 ft-candle	Auto-iris Auto-focus
Low Light Level	H_2O Emissions	1024	48-212 sq. zoom	12.1 - 2.4	8	20 @ 30 fps	30	500 – 875	4.4xE-9 ft-candle	Auto-iris Auto-focus
Mid-IR	Absorption Lines Temperature	320 x 244	183 x 138	0.9	12	20 @ 60 fps	60	1000 – 5000	-10C to 1500C	Auto-focus
llumination	Calibration Bkgrnd Illum. Interferometry	N/A	80 dia. Collimated	N/A	N/A	N/A	N/A	3000K 675	5mW output	Light Source Selectable