TCC III, Fired, Full View

Philipp Schiffmann, Ph.D.
University of Michigan
2016

Acknowledgement Request for published use:

It is requested that ALL published use of the TCC engine simulation geometry and/or data be acknowledged with the following statement.

> "The study here used publicly available TCC engine data, which was created with funding by General Motors through the General Motors University of Michigan Automotive Cooperative Research Laboratory, Engine Systems Division."

This README document is an overview of the cataloged data in the Deep Blue Data work deposit "TCC-III, Fired, Full View", which is a permanent unaltered archive of the data used in Dr. Philipp Schiffmann's Ph. D. dissertation (http://hdl.handle.net/2027.42/137636) and subsequent publications , such as Philipp Schiffmann, David L. Reuss, Volker Sick, International Journal of Engine Research, 2017, DOI: 10.1177/1468087417720558.

This document includes descriptions of the following.

Engine Operating Conditions	(Slide 2),
Data Summary and File Structure	(Slides 3-9) ,
Engine Geometry	(Slides 10 – 25)
Engine Intake and Exhaust System Geometry	(Slides 26 -33).

Measured parameter locations and nomenclature are provided in the Geometry slides.

The Deep Blue Data TCC-III "Collection README.pdf" file contains references and errata, and will be updated in time.

TCC-III Fired Full View Test Conditions & File Summary

RPM	MAP	φ	Image Plane	Grid	Recorded Pressure cycles/test	Imaged cycles/test	Recorded Images imgs/test	Image Range deg. ATDCE	Crankangles between images	IMEP	COV IMEP	Data ID
1300	40	1	x =0	PIV & Com	500	375	65	35 -340 341 - 442	5 1	333	0.6%	S_2014_02_05_01
					500	375	65	35 -340 341 - 342	5 1	333	0.7%	S_2014_02_12_01
					500	375	65	35 -340 341 - 342	5 1	323	0.5%	**S_2014_02_13_02**
			y =0	PIV & Com	400	358	59	45 -340 341 - 370	5 1	343	1.9%	**S_2013_10_29_01**
					400	379	88	30 -340 341 - 365	5 1	333	0.8%	S_2013_10_31_02
					500	457	73	30 -340 341 - 365	5 2.5	333	0.7%	S_2013_11_07_03
			z=-5	PIV & Com	700	622	57	60 - 340	5	343	1.9%	S_2014_05_06_01
					700	643	57	60 - 340	5	329	0.9%	**S_2014_05_08_01**
					2000	643	59	50 - 340	5	326	1.2%	S_2014_05_13_01
			z = -30	PIV	1200	1134	49	60 - 300	5	332	1.1%	S_2014_04_01_01
					1134	1134	49	60 - 300	5	329	0.7%	**S_2014_04_03_02**
			All Transient	PIV	1400	1 - 1157	50	60 - 300	5	n.a.	n.a.	S_2014_04_16_03
			Motored SS		1400	1 - 400	50	60 - 300	5	-17	n.a.	S_2014_04_16_03_A
			Fired SS		1400	757 - 1157	50	60 - 300	5	334	0.6%	S_2014_04_16_03_B

Start of Ignition, SOIgn = 342 ATDCE which is Maximum Brake Torque, MBT, timing.

RPM – Revolutions Per Minute,
MAP – Manifold Absolute Pressure
ATDCE – degrees After Top Dead Center Exhaust, all data use this crank angle convention.
Data ID – File name used in archive directory, indicating when the data was taken S_year_month_day_test#
Files in **blue-bold** font indicate recommendations from Schiffmann's PhD dissertation.

Fired Full View: Data Summary and File Structure

Slides 3 – 9 summarize archive data-file directory structure, which contains pressure and velocity measurements acquired at multiple crank angles, during hundreds of contiguously engine cycles, at each engine-operating condition. There is one complete data set cataloged by **Test ID (bottom, Slide 2)** at each of the particle image velocimetry, **PIV, measurement planes (Slide 4)**.

Pressure data for each test is cataloged in Excel Workbooks, which contain worksheets with the following parameters.

Test Info	(pressure-data cycle number vs. imaged-data cycle numbers)
Per_Run_Summary	(test average & standard deviation)
Per_Cycle_Data	(cycle averaged pressure parameters, heat release, and spark-plasma energy and duration.)
Ensemble_Average	(cylinder volume and average pressures per crank angle)
P_IntakePlenIn (kPa)	(5 **measured pressures (Slide 5)** acquired each 0.5 crank angle degree)
P_IntkPort (kPa)	.
P_Cyl (kPa)	.
P_ExhPort (kPa)	.
P_ExhPlenOut (kPa)	

There is one Pressure file for each test, located in the **Pressure Data-File Directories (Slide 6)**. The Pressure files include parameters that were directly measured or computed as described in **Schiffmann's Dissertation (**http://hdl.handle.net/2027.42/137636**).**

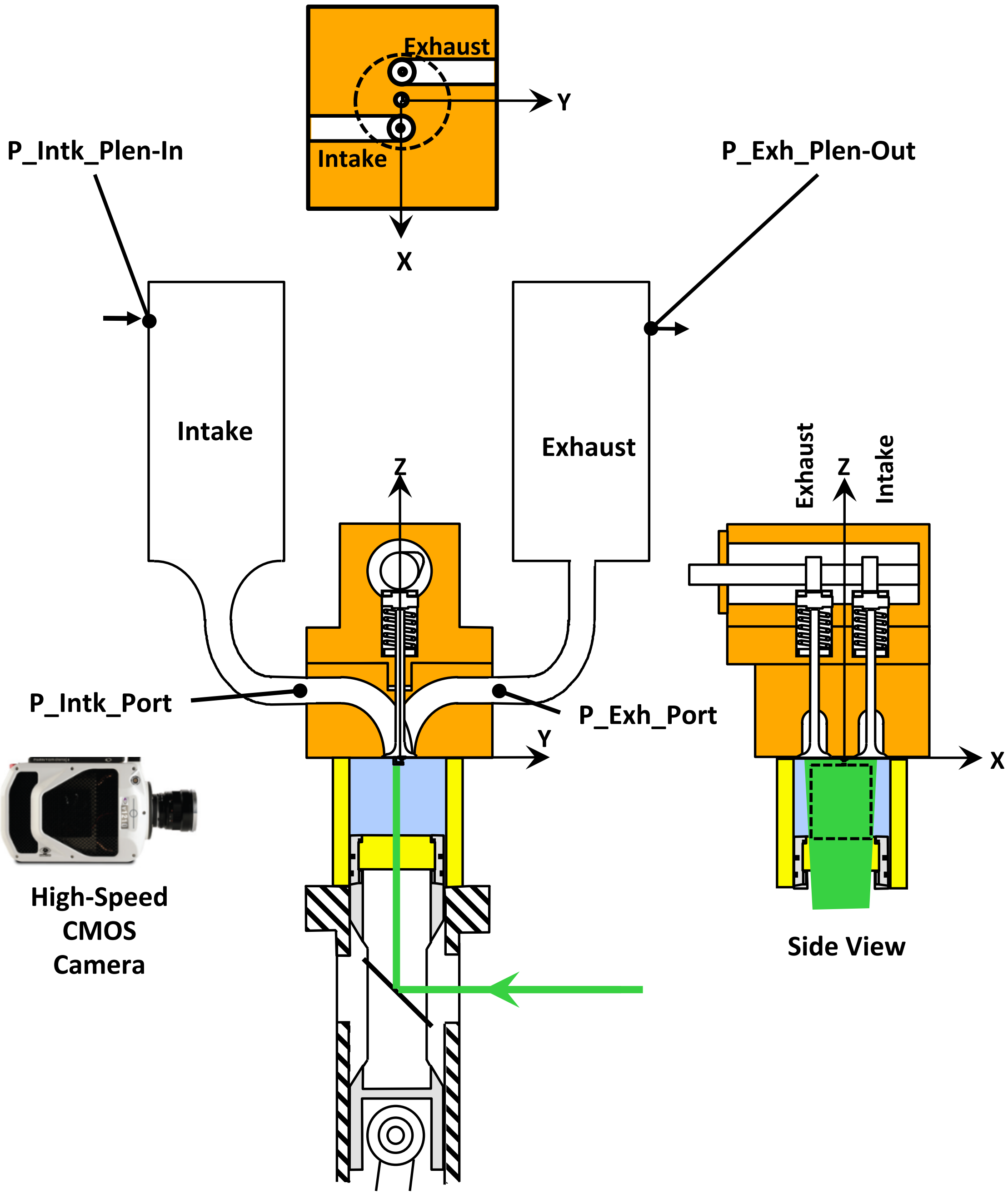
Velocity data are in text files, B000##.txt, containing the x,y,z coordinates and u,v,w velocity components of the two-component, **PIV measurement planes (Slide 4).** Each velocity file contains the velocity distribution from one image pair, taken with frame straddling. Thus, one image was taken at the beginning of the specified crank angle, and one was take Δt μs earlier (laser pulse separation), at the end of the previous crank angle.

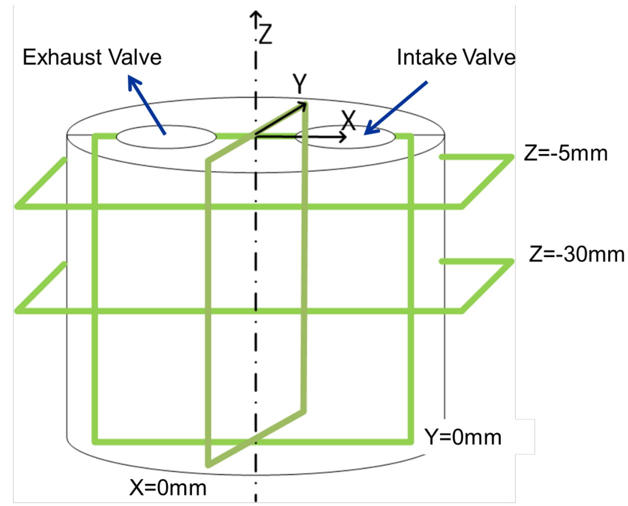
The velocity data are located in the **PIV Data-File Directories (Slide 7),** cataloged by

Test ID,	S_year_month_day_test#, e.g., S_2013_01_30_01.
PIV measurement plane,	e.g., x=0 as shown in Slide 4.
Test cycle number,	Cycle=000##
Crank angle,	B000## = crank angle ATDC, values found in **Vector_field_encoder.xls (cf. Slide 7)**

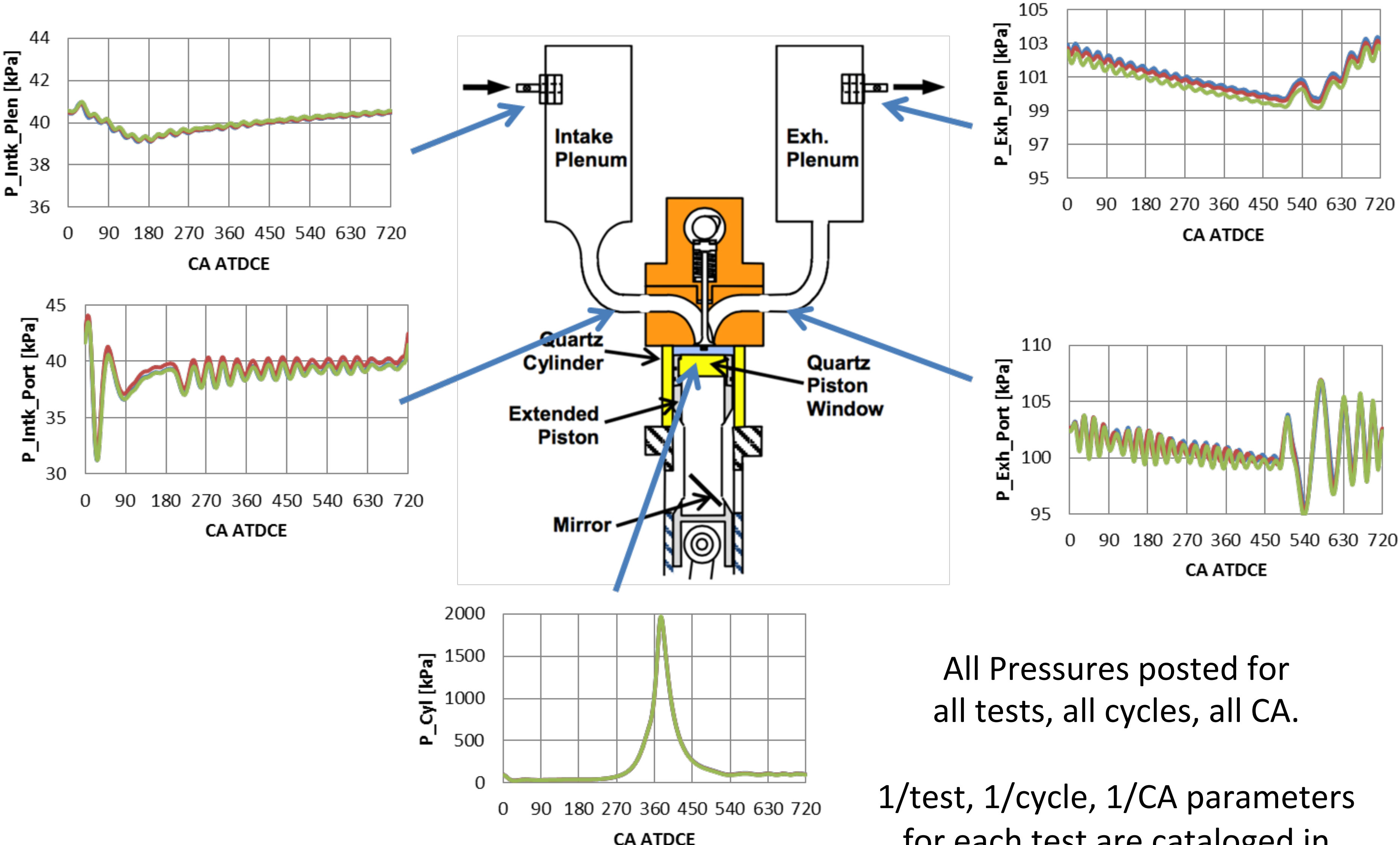
The velocity distribution are provided on the **Original Grids and a Common Grid (Slide 8)** with the **Resolution and Dynamic Range (Slide 9)**.

Coordinate system and image-plane labels used in file structure





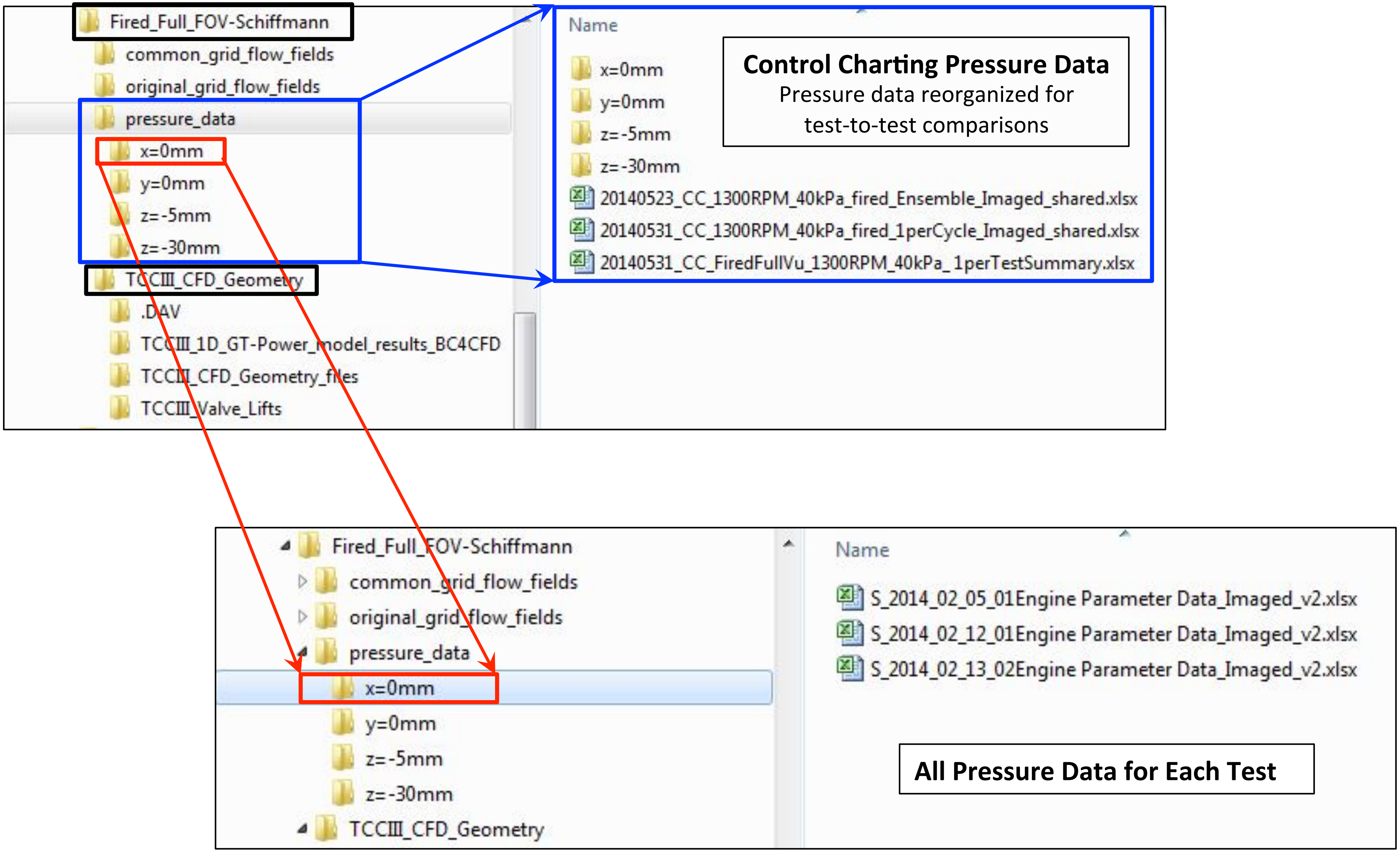
Pressure Measurement Locations, TCC-III



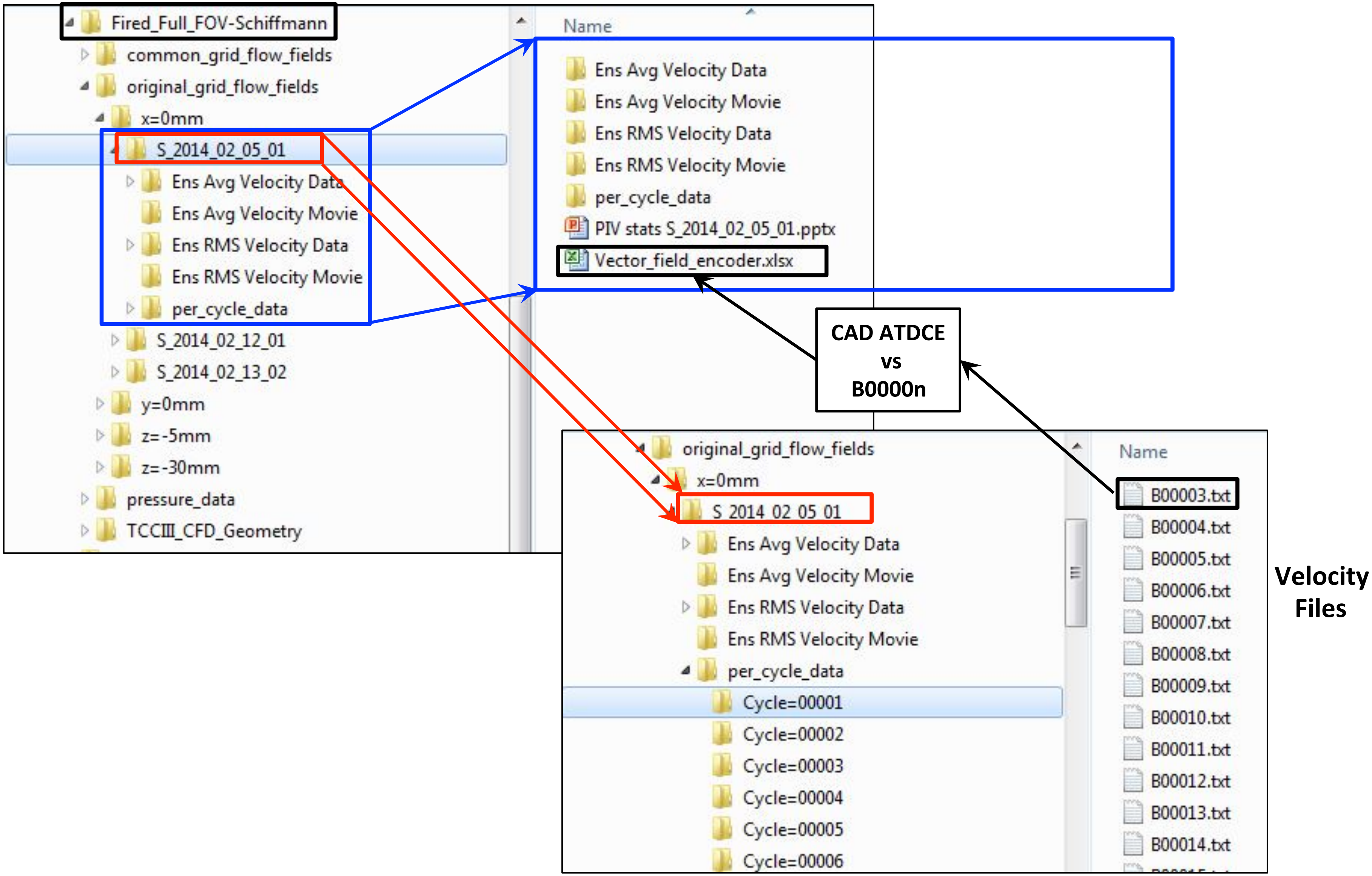
All Pressures posted for all tests, all cycles, all CA.

1/test, 1/cycle, 1/CA parameters for each test are cataloged in Microsoft Excel files.

Fired Full View: Pressure Data-File Directory Structure



Fired Full View: Pressure Data-File Directory Structure



Motored Full View: PIV FOV & Spatial Resolution

Original Grid:

The field of view (FOV) is restricted by the piston window to approximately the center 60-70mm for both vertical and horizontal cutting planes. In both the z=-5mm and z=-30mm planes the light sheet is brought into the cylinder from the positive x-direction. Thus, during intake stroke a major part of the FOV is blocked by the intake valve and its shade for the z=-5mm images. The vertical cutting planes have a FOV from piston to cylinder head with an approximate width of just below 70mm. The spatial resolution is 2.0 – 2.4mm with a vector spacing of 1 - 1.2mm.

Videos of the ensemble average flow field and ensemble RMS velocities can be found in each dataset folder, together with ensemble average data, as well as cycle resolved velocity data.

Common Grid:

For some datasets both the original PIV grid and a re-gridded version of the data is available, which was used by the author to compare flow fields of different tests and conditions. All vectors were interpolated on a common grid, of about the original grid size using a linear interpolation.

The re-gridded datasets loose one grid at edge of the FOV and at the edges of the burned gas regions. The re-gridded data sets also use interpolation to fill locally bad vectors.

Motored Full View: Velocity Resolution and Dynamic Range

The minimum and maximum resolved velocity are defined here using the criterion that PIV correlation-peak displacements, Δx_{piv}, need be limited to 0.2 pixels and 8 pixels, respectively, as described in Ref.1. A practical resolution limit of 0.2 pixels is used here, as demonstrated in Refs.2 & 3. Thus, an estimated dynamic range of 40:1 one is achieved. The laser-pulse separation, Δt, was changed throughout the cycle as described in Ref. 4, to assure that three standard deviations of the velocity distribution was 8 pixels or less. For cutting planes x=0 and y=0, within and during the intake jet, 12 pixels were allowed to better capture the lower speed flows away from the jet; this is justified by the fact that most of the jet flow is in plane for x=0 and y=0, and recursive and adaptive interrogations spots were used to capture the large velocities. Some data sets catalogued here have a file called "PIV Stats" to show the range of velocities and number of first choice vectors throughout the cycle. These plots were used to determine the Δt need at each measurement plane of each crank angle. The velocity dynamic range for any data set can be computed as follows. Since 32x32pixel interrogation spots and grid-spacing, $\Delta x)_{grid}$, of 50% overlap are used in all tests here, the resolution dynamic range can be estimated as

$$V_{min} = 0.2[2\Delta x_{grid}/32\Delta t] \quad \text{and} \quad V_{max} = 8[2\Delta x_{grid}/32\Delta t]$$

where V is m/s when Δx is in meters (from the velocity data file) and Δt in seconds from the tables below.

1300RPM40kPa fired Dt x=0mm		
CA Range (° ATDCc)		dt (µs)
-335	-335	20
-330	-330	15
-325	-320	6
-315	-310	5
-305	-300	4
-295	-240	5
-235	-230	8
-225	-215	10
-210	-205	15
-200	-195	20
-190	-180	25
-175	-135	30
-130	-65	35
-60	-17	40
-16	-11	25
-10	-5	20
-4	-2	15
-1	0	8
1	5	5

1300RPM40kPa fired Dt y=0mm		
CA Range (° ATDCc)		dt (µs)
-360	-350	100
-345	-335	60
-330	-330	40
-325	-325	10
-320	-260	5
-255	-225	10
-220	-200	15
-195	-180	20
-175	-165	25
-160	-30	30
-25	-20	40
-19	-2	25
-1	0	10
1	5	6

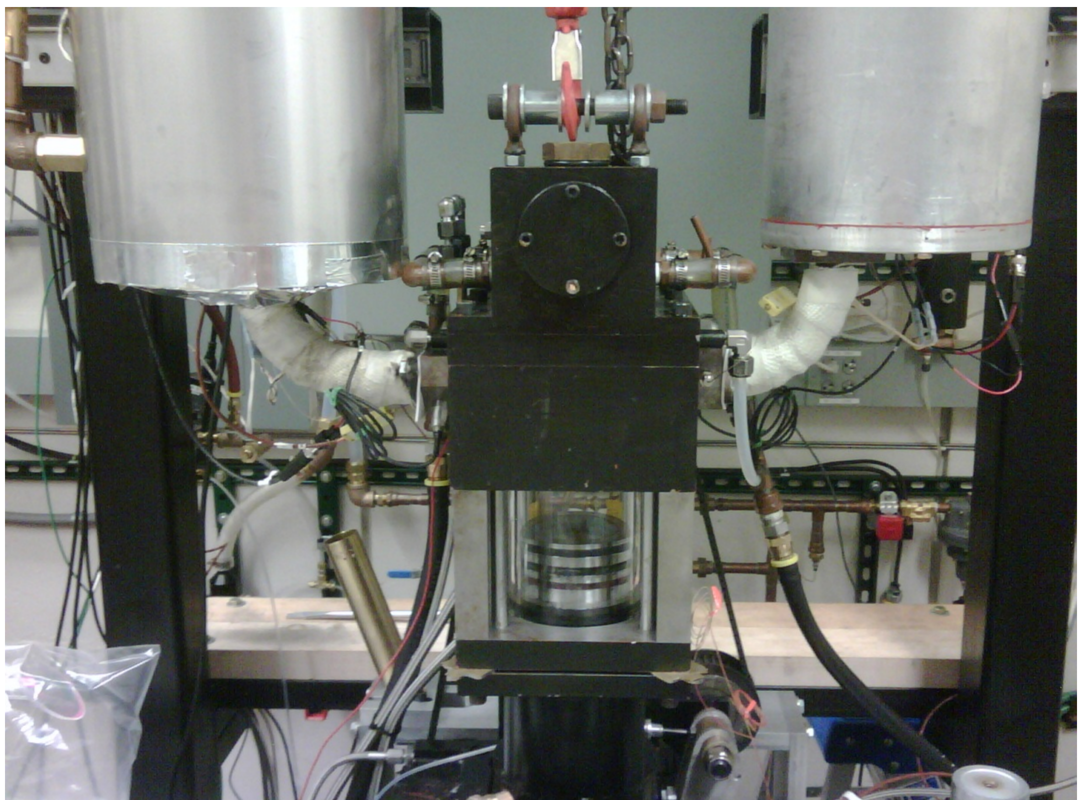
1300RPM40kPa fired Dt z=-5mm		
CA Range (° ATDCc)		dt (µs)
-360	-350	20
-345	-335	10
-330	-330	5
-325	-325	4
-320	-295	3
-290	-190	4.5
-185	-180	7
-175	-165	10
-160	-125	20
-120	-55	25
-50	-20	20
-18	-2	25
-1	0	10
1	10	5

1. Adrian, R.J. and J. Westerweel, Particle image velocimetry. 2011: Cambridge University Press.
2. Reuss, D.L., M. Megerle, and V. Sick, Particle-image velocimetry Measurement Errors when Imaging through a Transparent Engine Cylinder. Measurement Science and Technology, 2002.
3. Megerle, M., V. Sick, and D.L. Reuss, Measurement of Digital PIV Precision using Electrooptically-Created Particle-Image Displacements. Measurement Science and Technology, 2002. 13: p. 997-1005.
4. Abraham, P.S., D.L. Reuss, and V. Sick. High-speed particle image velocimetry study of in-cylinder flows with improved dynamic range. in SAE Paper 2013-01-0542. 2013

TCC-III Engine Geometry

The Slides 10 – 25 quantify the TCC-III engine geometry, that was used to create the CFD .stl and igs files. In addition, these geometry slides define the nomenclature and locations of the pressure transducers and thermocouples cataloged in the Pressure Data Files.

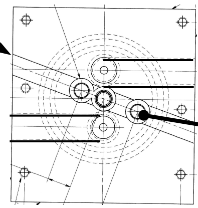
Scanned figures of original printed material are used to avoid transposition errors. The Deep Blue Data TCC-III Collection README file contains errata, which are updated as they become available.

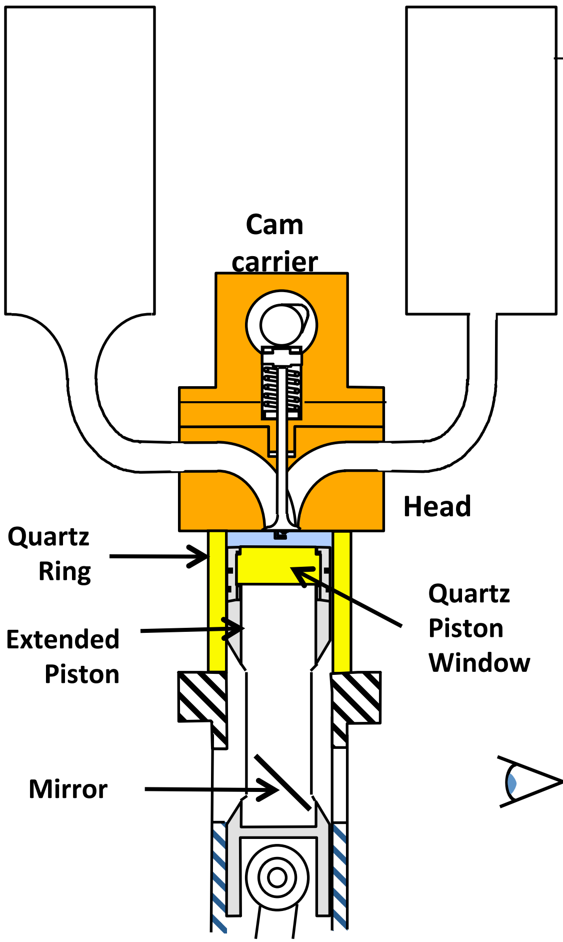


TCC-III Engine Geometry			
Bore, cm	9.20	Connecting-rod length, cm	23.1
Stroke, cm	8.60	Piston-pin offset, cm	0.0
Clearance @ TDC, cm	0.95	Conn rod offset, cm	0.0
Combustion chamber volume, cc	63.15	Exhaust Valve Closing, aTDCexh	12.8
Top-land crevice volume, cc	0.37	Intake Peak Lift, aTDCexh	114.8
Spark-plug crevice volume, cc	0.02	Intake Valve Closing, aTDCexh	240.8
TDC Volume, cc	63.54	Exhaust Valve Opening, aTDCexh	484.8
Swept volume, cc	571.7	Exhaust Peak Lift, aTDCexh	606.8
Geometric CR	10.0	Intake Valve Opening, aTDCexh	712.8
Effective (IVC) CR	8.0	Valve-seat angles, deg.	30/45/60/75
Steady-flow swirl ratio	0.4	Spark Plug	AC Delco R44LTS

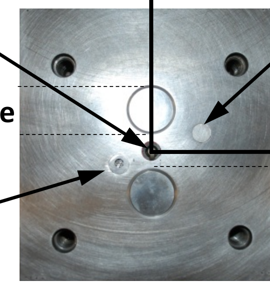
TCC-III Overview

Slot cut in the head between the "flow-box" and "cam-carrier base plate" to allow spark plug and pressure transducer

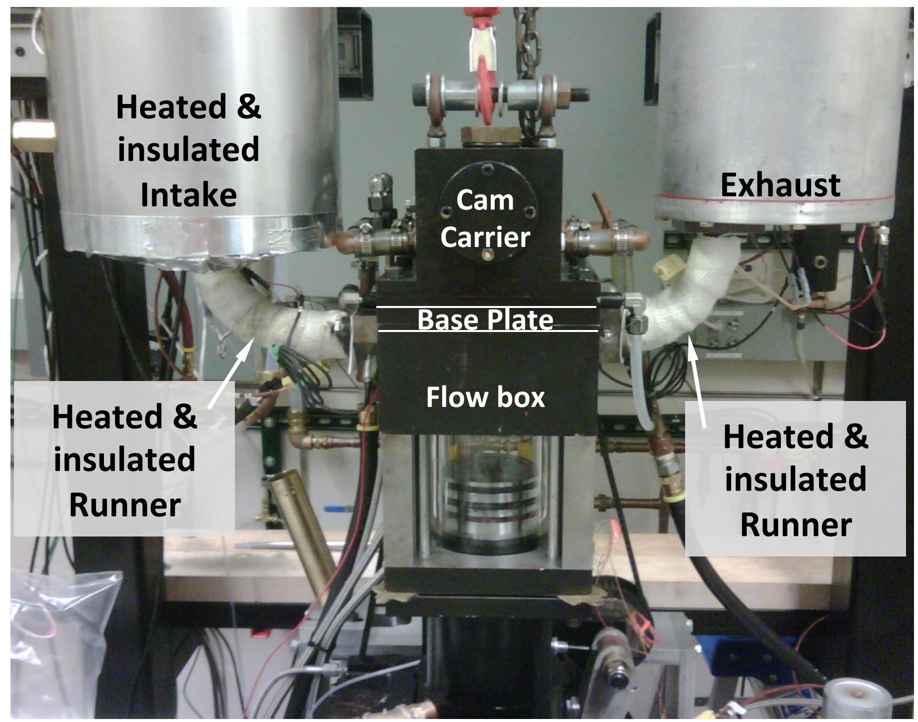




The three-piece head
"cam carrier" (cam and lifters)
"base plate" (valves & guides)
"flow box" (ports, plug, valve seats)

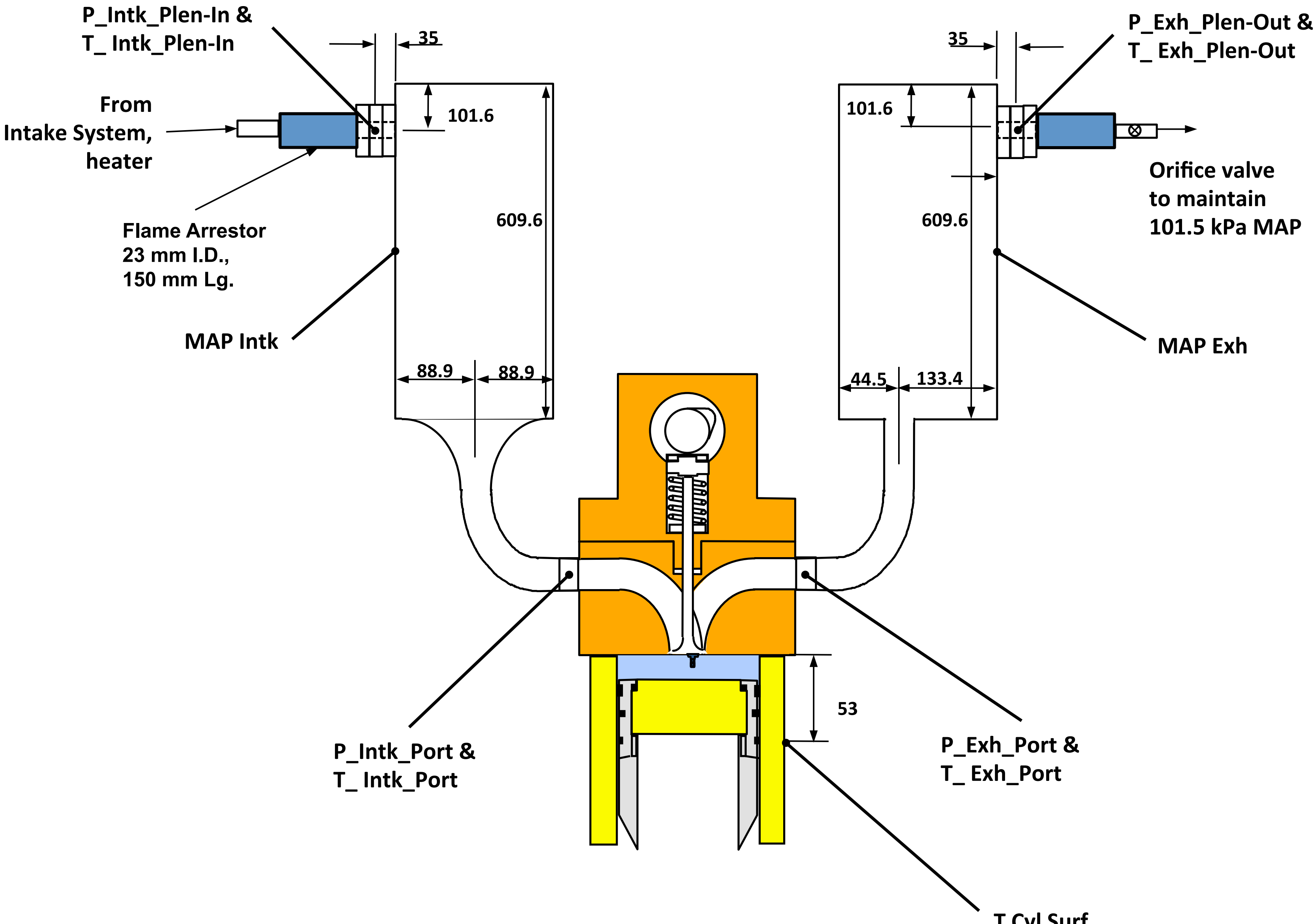


Orthogonal (bottom) View

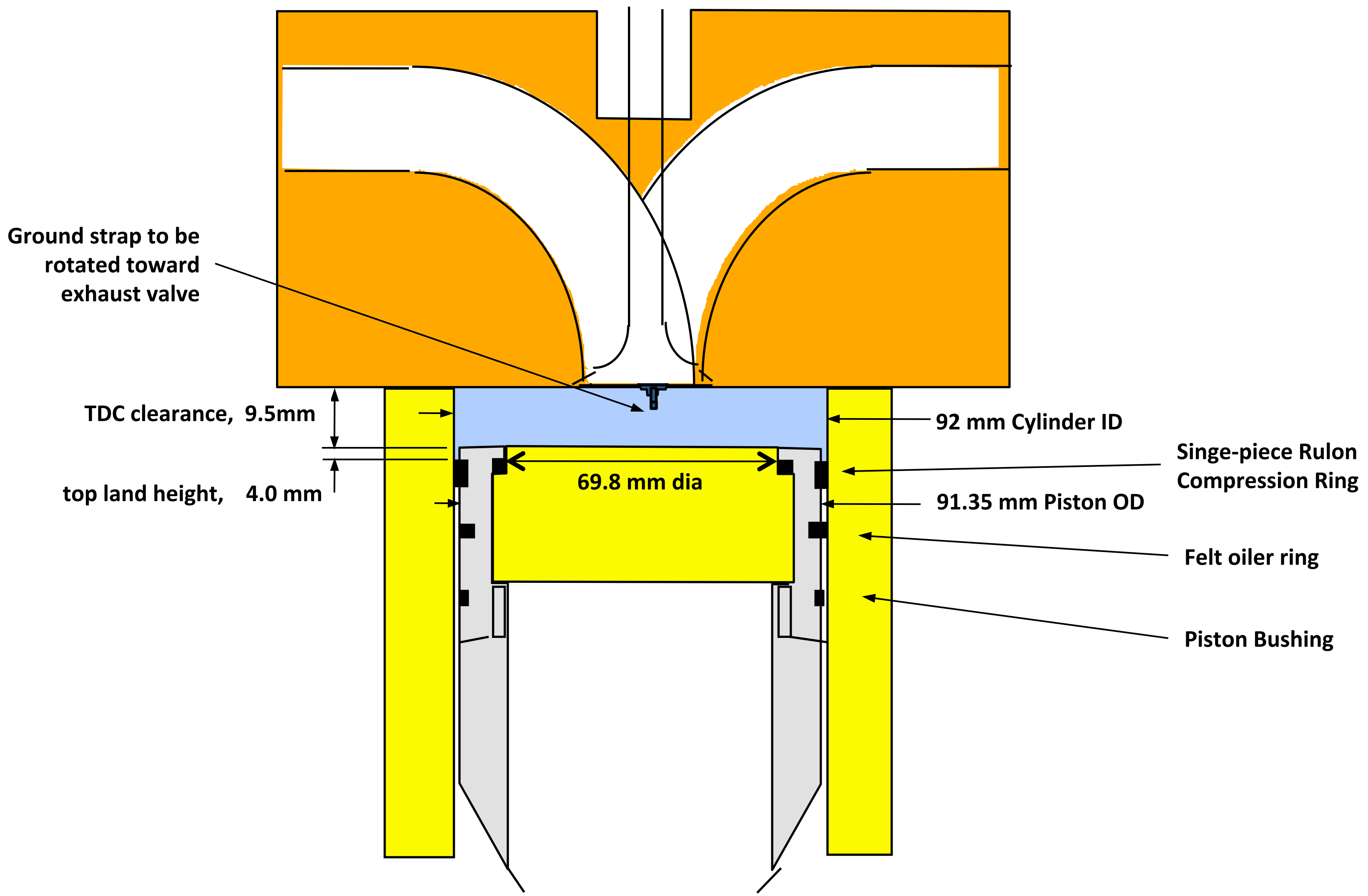


Plenum Interior Dimensions & Measurement Locations

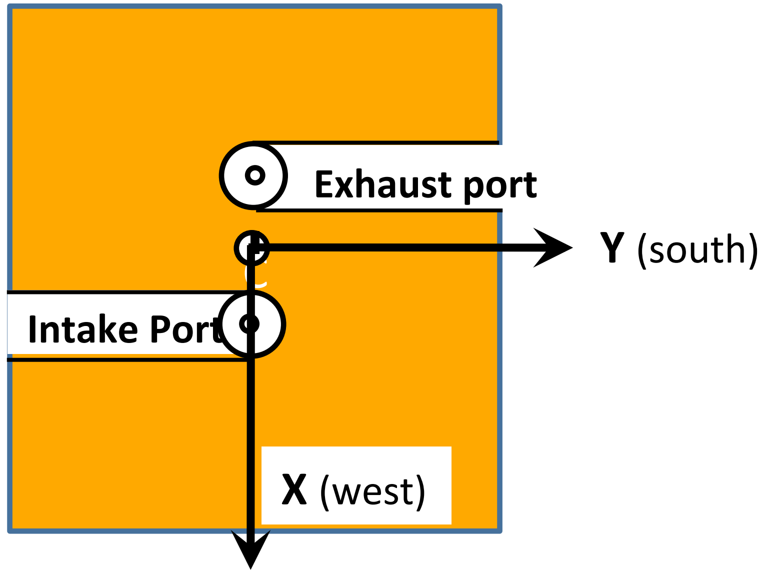
Dimensions in mm



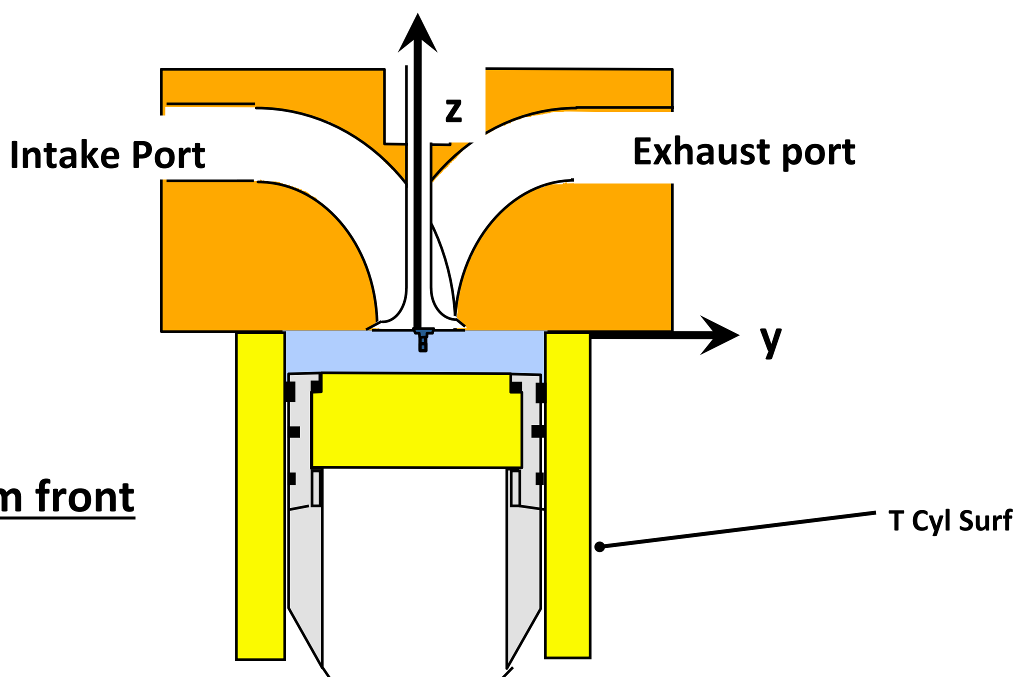
Combustion Chamber



Coordinates



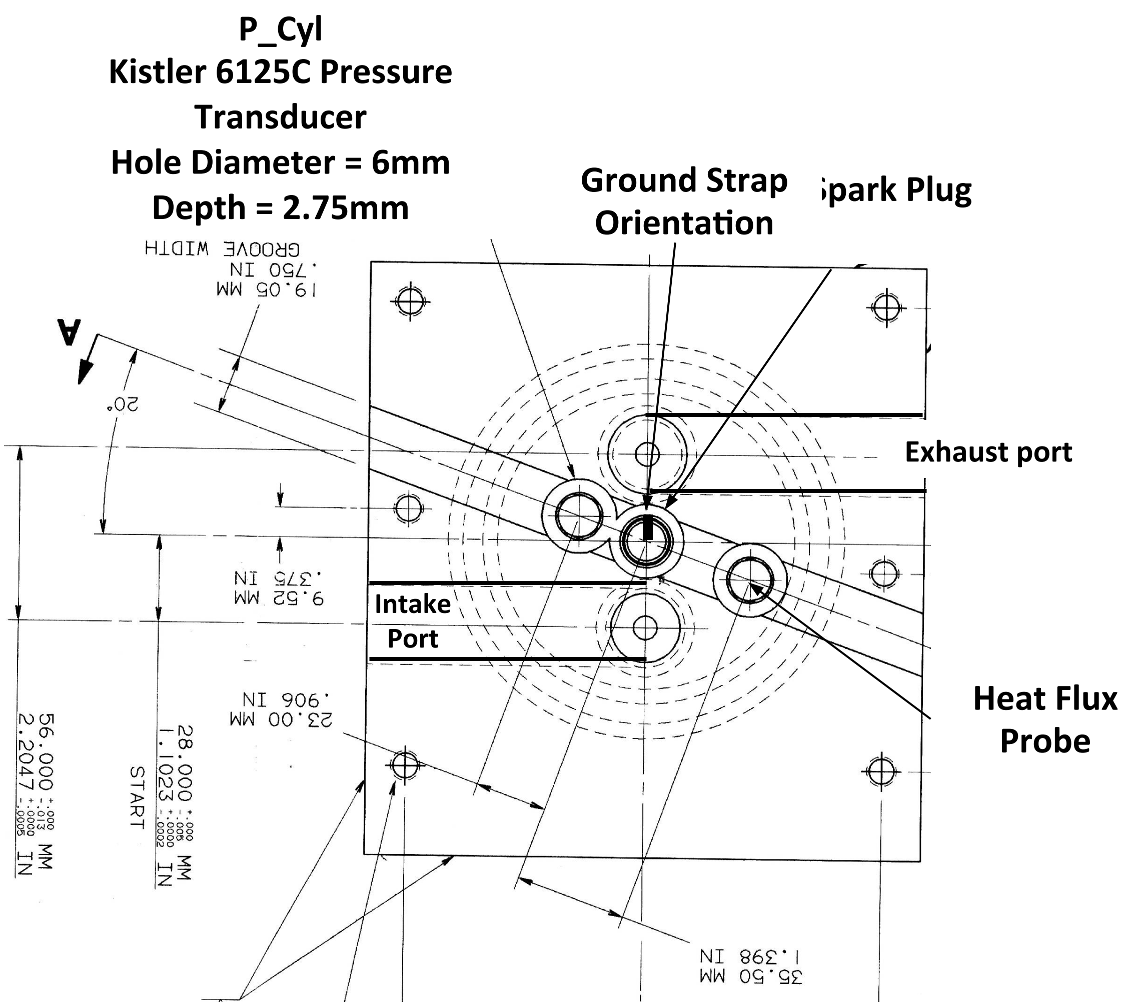
View from above



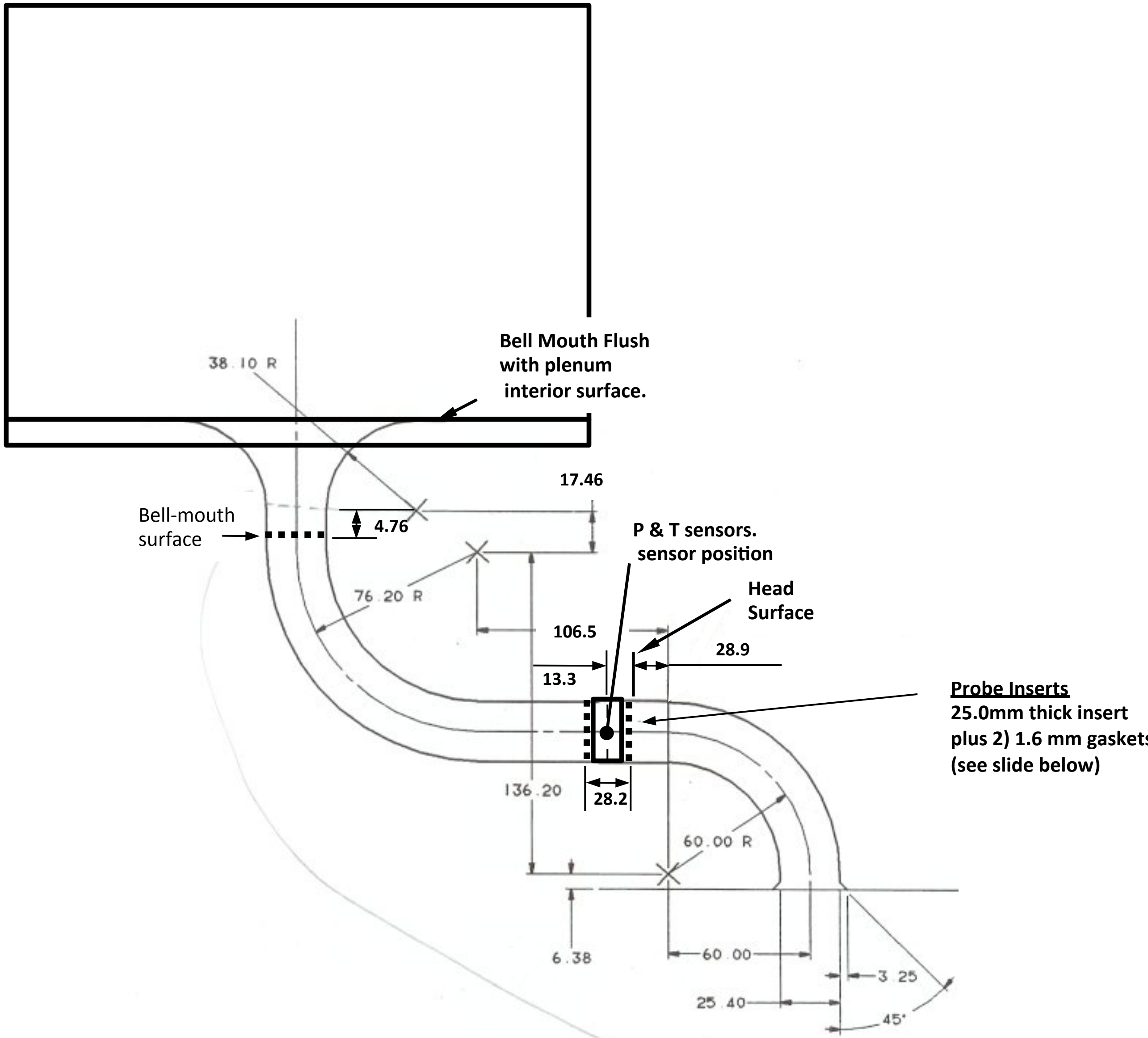
View from front

Head

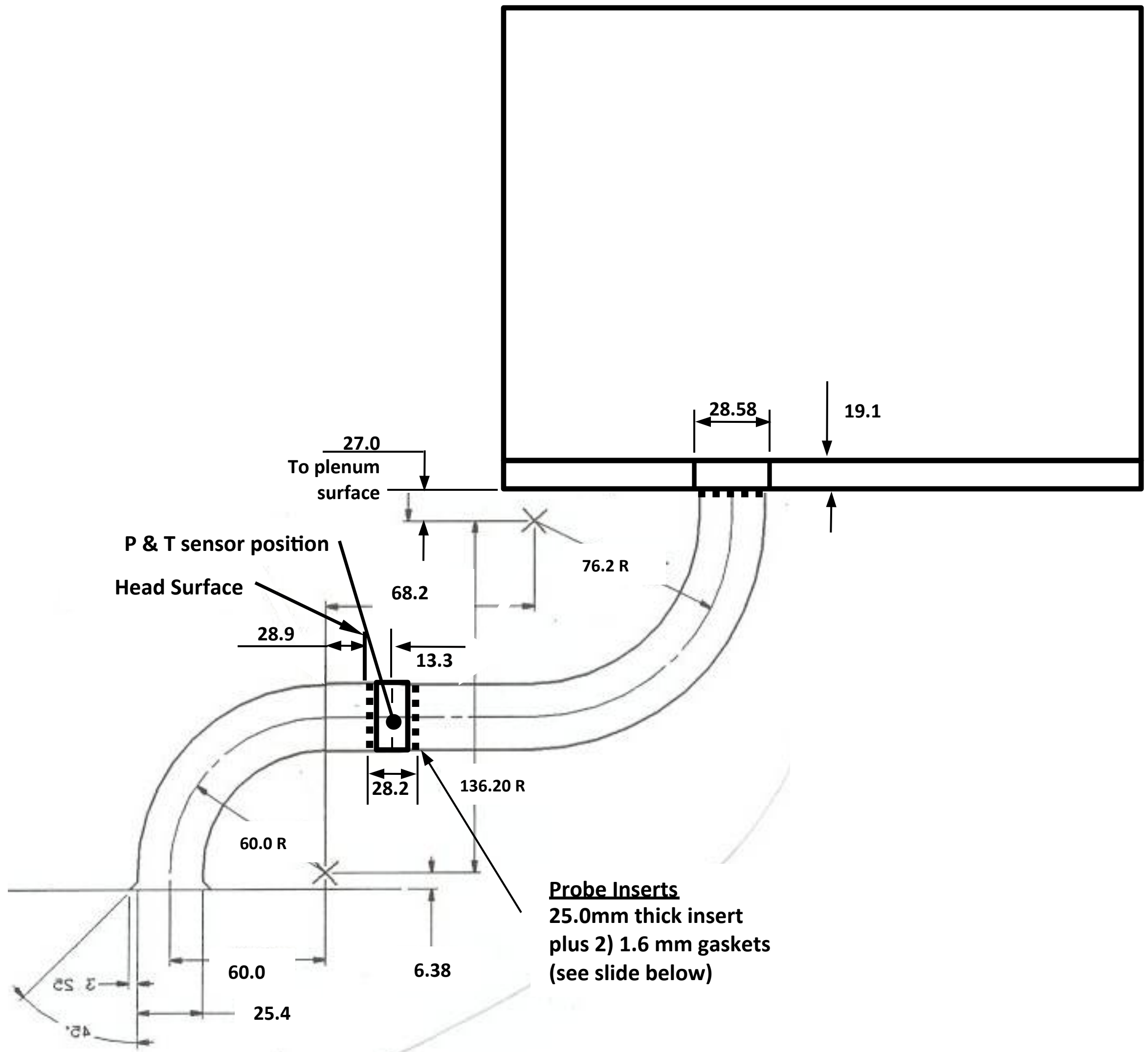
Top View



Intake Runner and Port



Exhaust Runner and Port



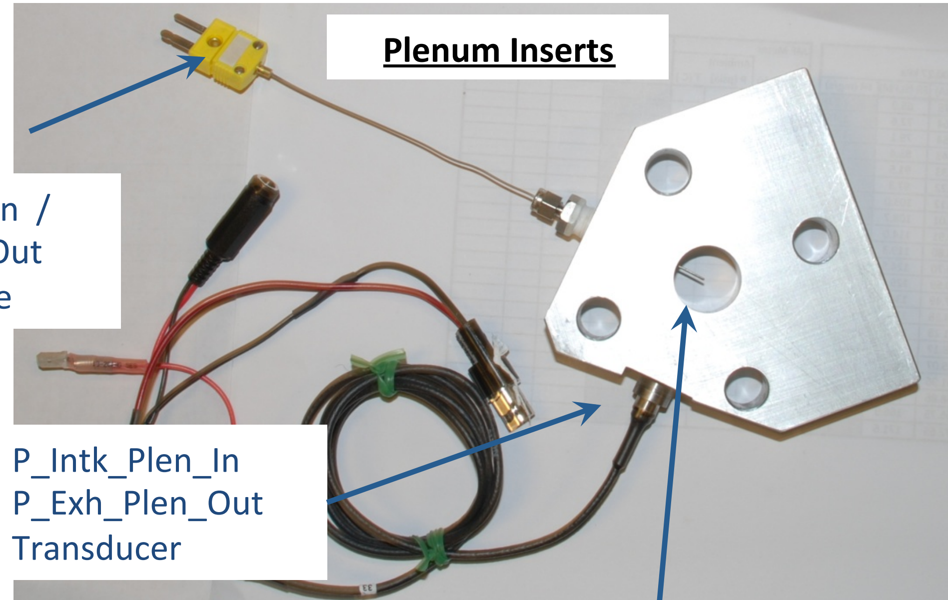
Intake and Exhaust Probe Inserts

For pressure transducers and thermocouples

TCC-II Kulite Transducers shown in photo

Replaced by Kistler transducers in TCC-III

Plenum Inserts

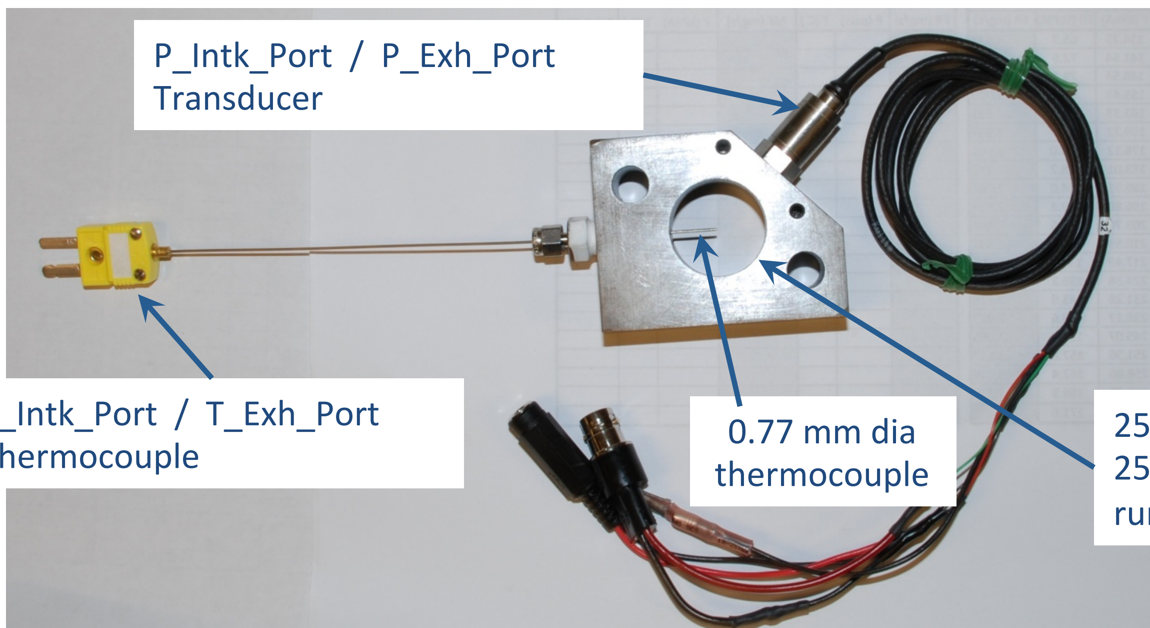


T_Intk_Plen_In / T_Exh_Plen_Out Thermocouple

P_Intk_Plen_In
P_Exh_Plen_Out
Transducer

25.4 mm thick insert
19.1 mm holes to match plenum outlet-pipe I.D.

Runner/port Inserts



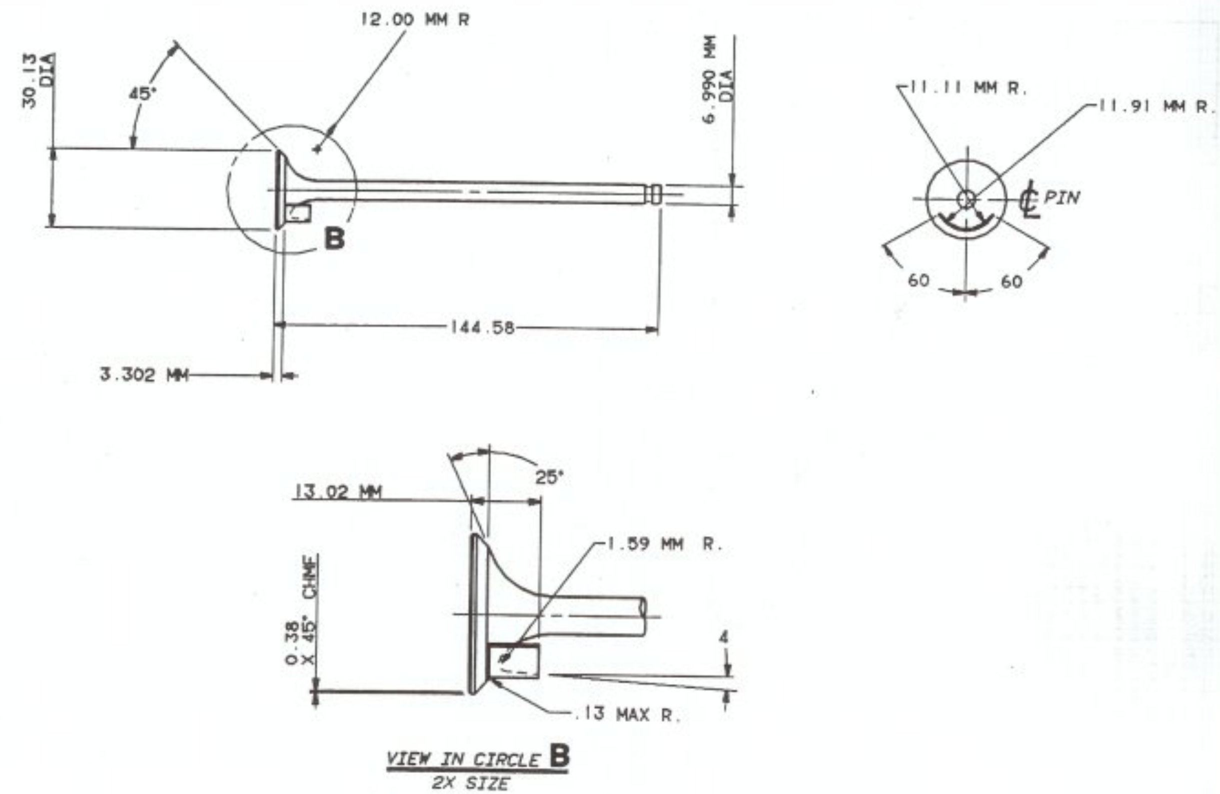
P_Intk_Port / P_Exh_Port Transducer

T_Intk_Port / T_Exh_Port Thermocouple

0.77 mm dia thermocouple

25.4 mm thick insert
25.4 mm holes to match runner and port diameters.

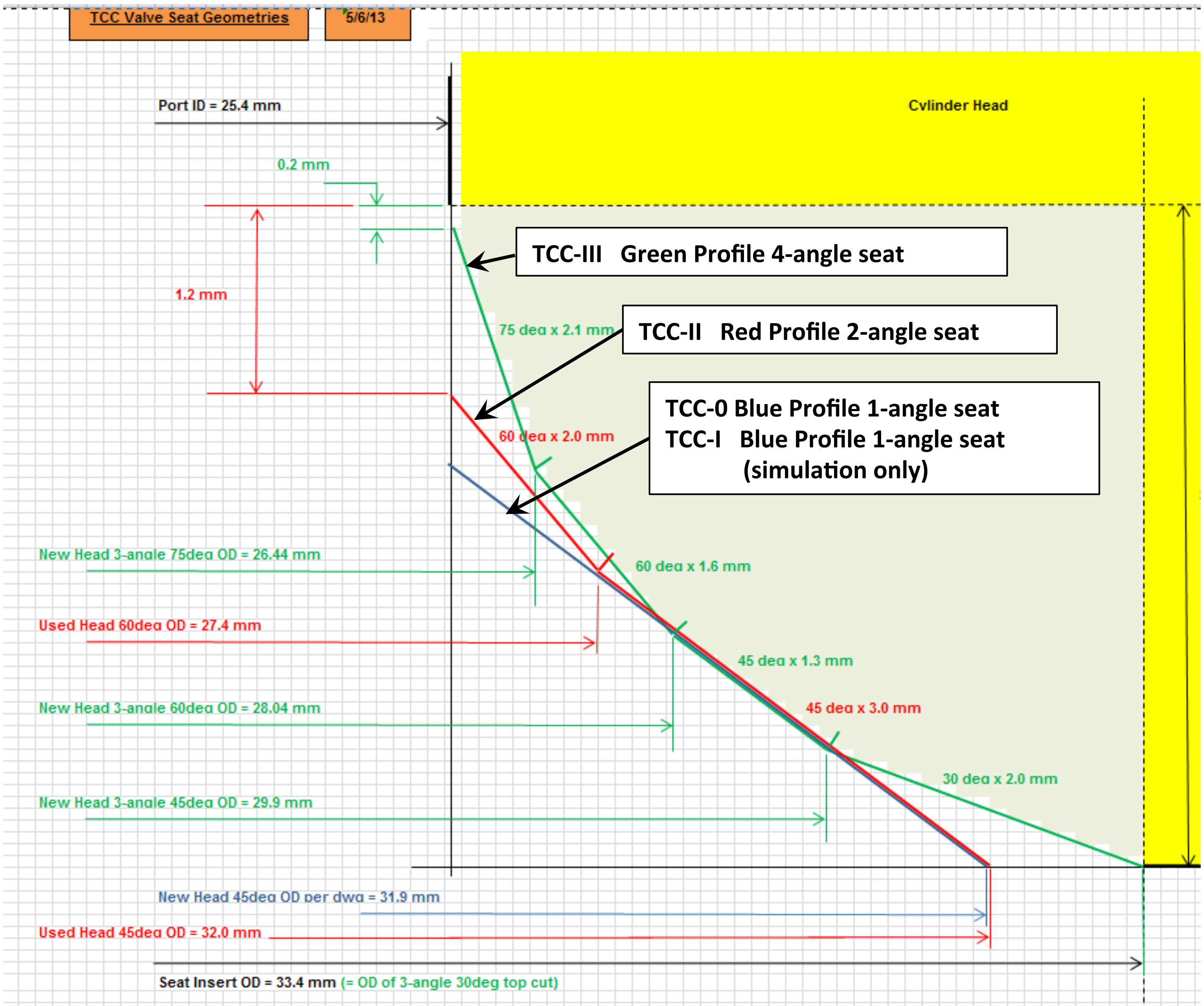
TCC-0 single-angle Valves



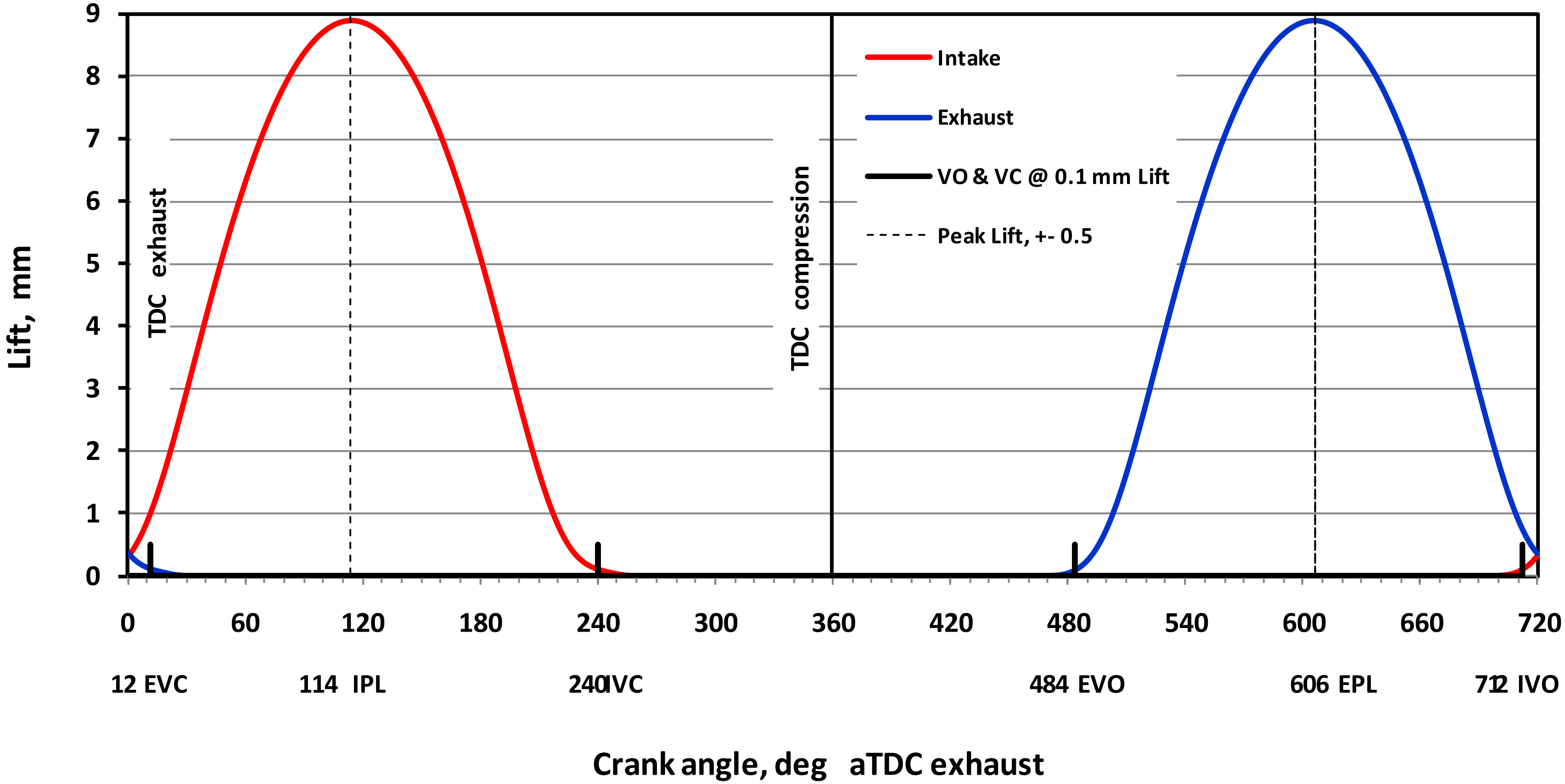
Unshrouded intake valve and exhaust valve are the same but with no shroud.

Figure 3 Details of the TCC-engine shrouded intake valve.

TCC Valve Seat Anthology



Nominal Cam Timing



Cam Profile

Original used for grinding cams

F-252

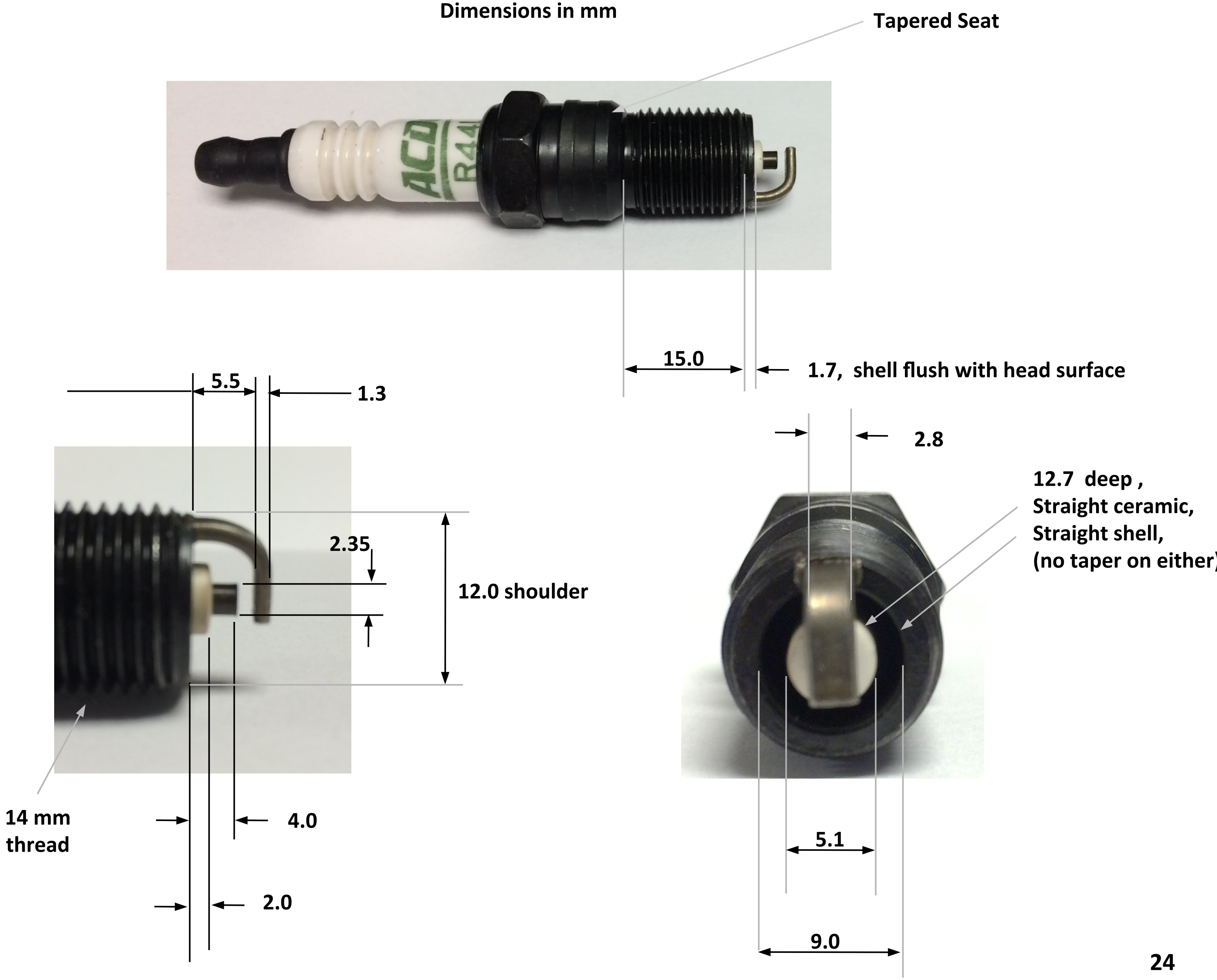
CAM CONTOUR DATA

ANGLE	OPENING	CLOSING	ANGLE	OPENING	CLOSING	
0	8.8900	8.8900	40	3.4591	3.4647	
1	8.8864	8.8864	41	3.2182	3.2246	
2	8.8758	8.8758	42	2.9780	2.9853	
3	8.8580	8.8580	43	2.7397	2.7481	
4	8.8331	8.8331	44	2.5045	2.5141	
5	8.8011	8.8011	45	2.2736	2.2846	
6	8.7620	8.7620	46	2.0485	2.0610	
7	8.7158	8.7158	47	1.8306	1.8448	
8	8.6625	8.6625	48	1.6212	1.6374	
9	8.6021	8.6021	49	1.4218	1.4402	
10	8.5346	8.5346	50	1.2337	1.2547	
11	8.4600	8.4600	51	1.0582	1.0820	
12	8.3783	8.3783	52	0.8963	0.9233	
13	8.2896	8.2896	53	0.7490	0.7793	
14	8.1939	8.1939	54	0.6167	0.6508	
15	8.0911	8.0911	55	0.4997	0.5379	
16	7.9813	7.9813	56	0.3979	0.4404	
17	7.8646	7.8646	57	0.3109	0.3578	TDC
18	7.7409	7.7409	58	0.2379	0.2892	
19	7.6102	7.6102	59	0.1776	0.2331	
20	7.4727	7.4728	60	0.1290	0.1882	
21	7.3284	7.3286	61	0.0904	0.1525	open
22	7.1772	7.1775	62	0.0605	0.1242	
23	7.0194	7.0197	63	0.0381	0.1016	closed
24	6.8548	6.8552	64	0.0220	0.0830	
25	6.6837	6.6842	65	0.0113	0.0669	
26	6.5061	6.5067	66	0.0047	0.0522	
27	6.3222	6.3229	67	0.0014	0.0384	
28	6.1320	6.1329	68	0.0002	0.0259	
29	5.9357	5.9367	69	0.0000	0.0153	
30	5.7335	5.7347	70		0.0074	
31	5.5256	5.5271	71		0.0025	
32	5.3123	5.3140	72		0.0006	
33	5.0939	5.0959	73		0.0000	
34	4.8707	4.8730				
35	4.6431	4.6458				
36	4.4116	4.4148				
37	4.1768	4.1805				
38	3.9393	3.9435				
39	3.6998	3.7046				

Spark Plug

AC Delco R44LTS

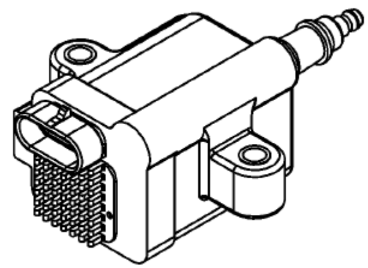
Dimensions in mm



HIGH OUTPUT IGBT COIL 30-2853

The model **30-2853 HO IGBT Coil** is specially designed for racing applications and does not require a CDI or external Igniter to function. This is a very high energy coil so you must take special attention to the quality of the connections. Make sure to apply a liberal amount of dielectric grease to the connector terminals and the tip and body of the spark plugs. Failure to do this may cause arcs to the cylinder head and cause a misfire.

The 30-2853 Kit Contains:
1 High Output IGBT Coil
1 Mating Connector & 6 Contacts



SPECIFICATIONS:

Output (no load):	40kV minimum
Output (50pF load):	40kV +/- 10%
Output Energy:	103 mJ +/- 7%
Peak Secondary Current:	102 mA +/- 10%
Arc Duration:	2.9mS +/- 10%
Turns Ratio	71:1
Maximum Current:	19 Amps
Maximum Battery Voltage:	17 Volts
Base Dwell:	3.0 mS
Max Continuous Dwell:	9 mS but don't exceed 40% duty cycle
Max Intermittent Dwell:	80% duty cycle, 5 seconds maximum
Mating Connector:	Packard/Delphi 12162825 "Pull to Seat"
Mating Contacts:	Packard/Delphi 12124075 "Pull to Seat"
High Tension Wire Terminal:	HEI "spark plug top" Style

PINOUT:
A: Coil Trigger (0-5V signal)
B: Coil Trigger (Ref Ground)
C: Ground to Cylinder Head
D: Battery Ground
E: Battery Positive (Relay or switched ignition)

IMPORTANT!
The contacts are "Pull to Seat" meaning you must feed the wire through the connector housing BEFORE you crimp on the contacts. The wire is then pulled back into the housing and the contact locks in place. The contact cannot be inserted or removed from the rear (wire side entry) of the housing

DWELL:
When setting the dwell the following guidelines should be used:

- Target a base dwell time of 3mS and *only* increase it when needed due to high cylinder pressures.
- The maximum individual coil dwell "ON" time must not exceed 9mS at any time, regardless of engine RPM. Exceeding this time will cause the coil to overheat and fail.
- For continuous duty the maximum "ON" time must remain below 40% duty (on 40% of the time, off 60% of the time). Exceeding this will cause the coil to overheat and fail.
- For short bursts, the coil dwell can go as high as 80% "ON" duty but these forays need to be short (under 5 seconds or so) and cannot be frequent.

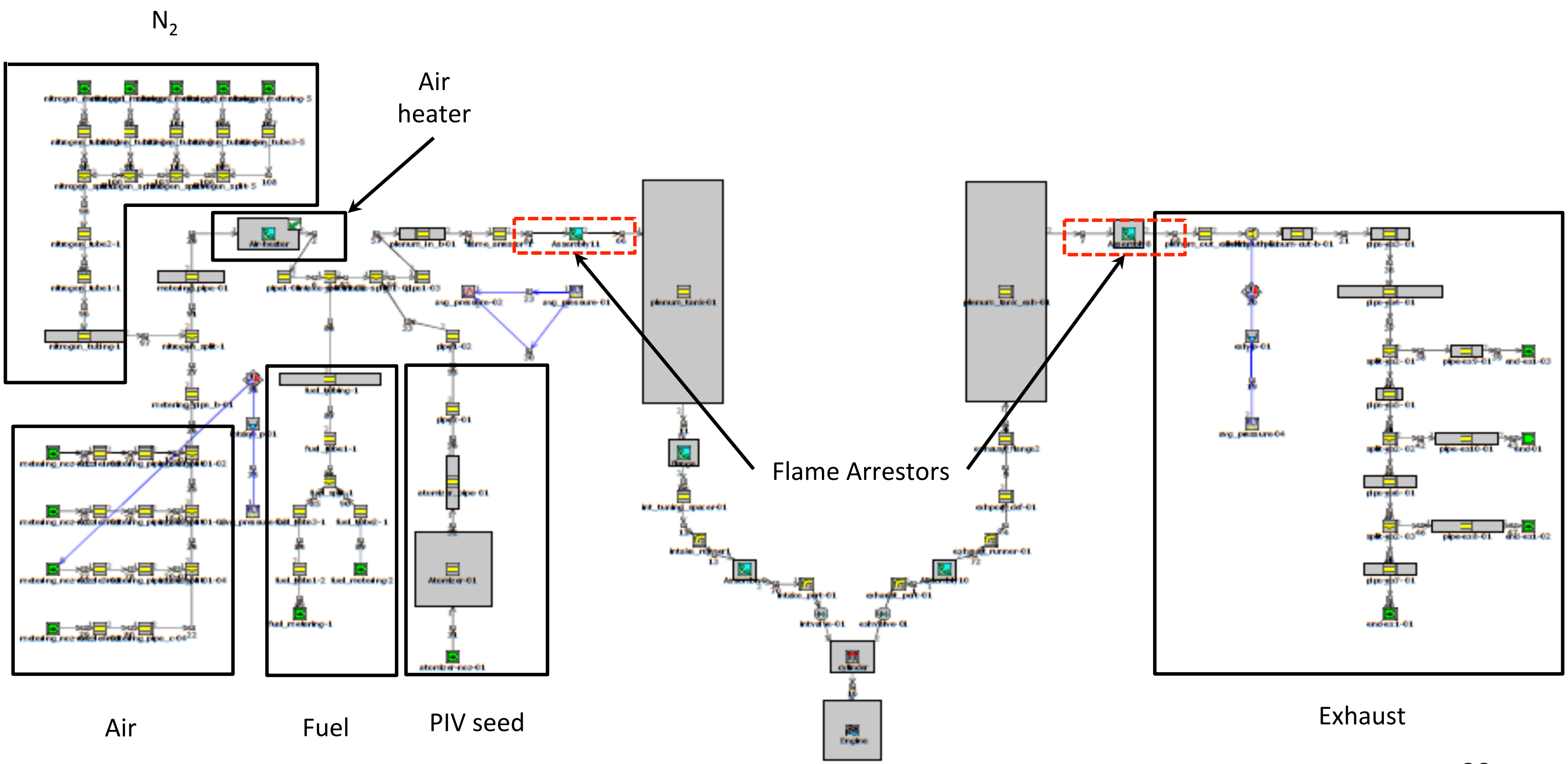
For technical assistance, contact AEM Tech support at emstech@aempower.com

ADVANCED ENGINE MANAGEMENT INC. HTTP://WWW.AEMELECTRONICS.COM
This product is legal in California for racing vehicles only and should never be used on public highways.
Advanced Engine Management, 2205 126th Street Unit A Hawthorne, CA. 90250, Phone: (310) 484-2322
Instruction Part Number: 10-2853, © 2011 Advanced Engine Management, Inc.

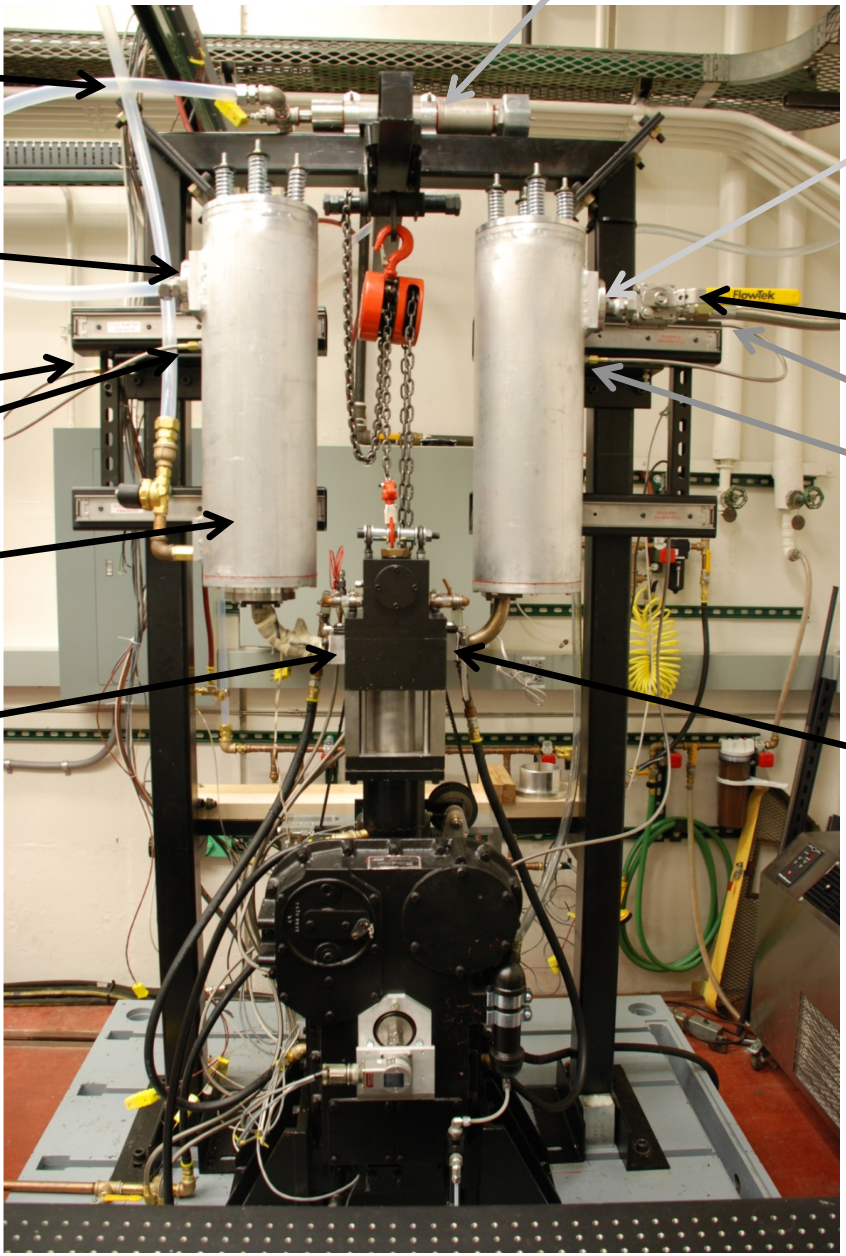
TCC-III GT-Power Summary of Intake and Exhaust Systems

Slides 26 - 33 provide detailed information on the intake and exhaust system geometries. This was used to create the GTPower 1-D model .gtm and .gdx files (located in the TCC-III_Geometry directory shown in Slide 6). In addition, the geometry slides define the nomenclature and locations of the pressure transducers and thermocouples cataloged in the Pressure Data Files.

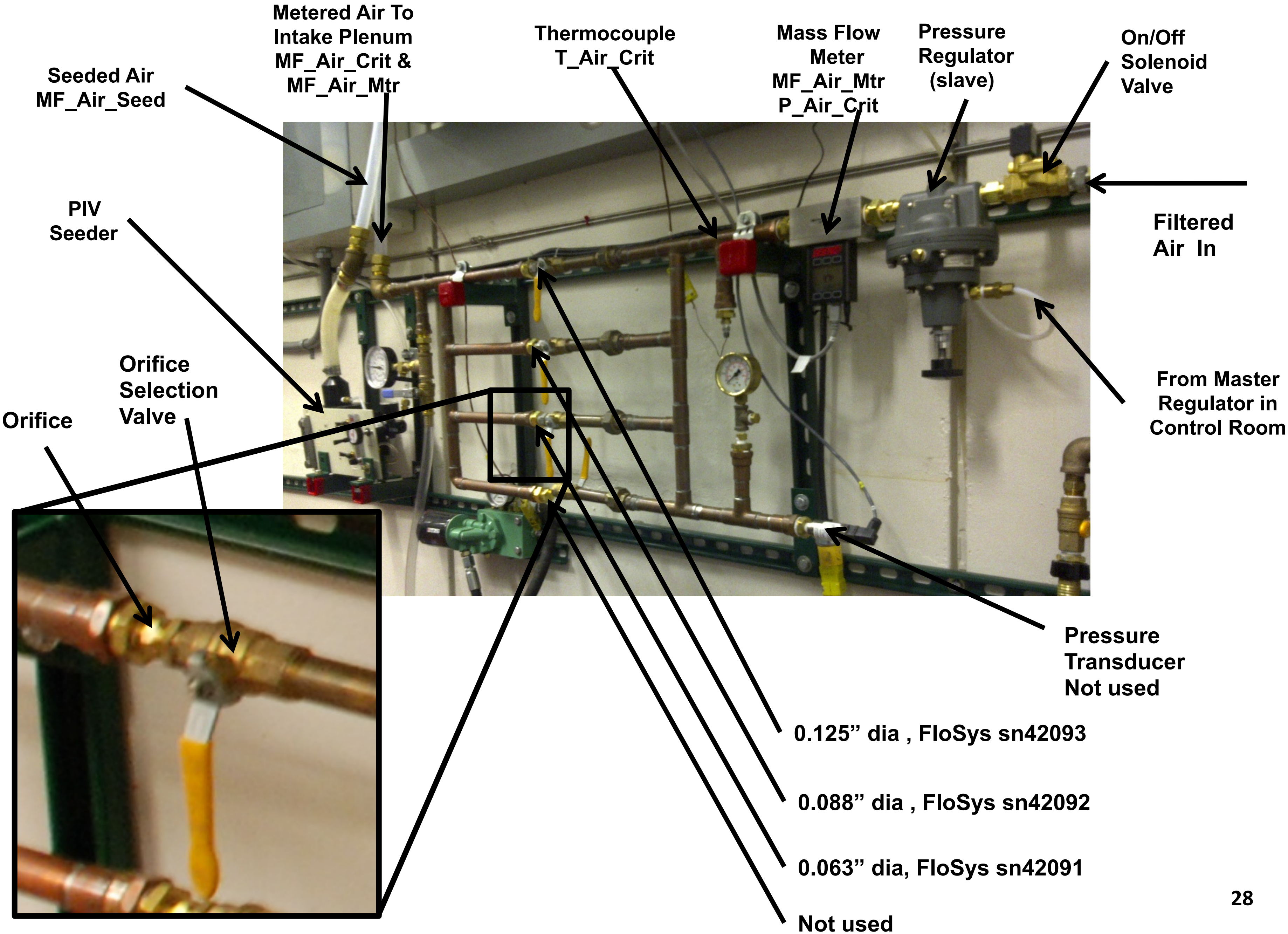
Scanned figures of original printed material are used to avoid transposition errors. The Deep Blue Data TCC-III Collection README file contains errata, which are updated as they become available.



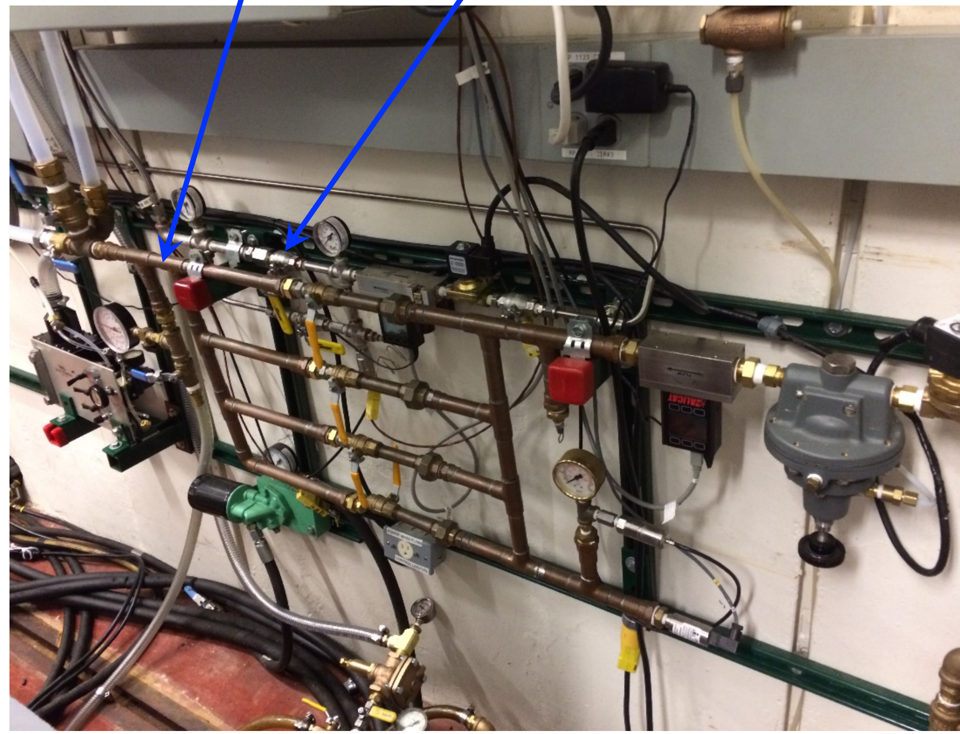
TCC-II Engine & Systems



TCC-II Critical Flow Metering System, Air only



TCC-III Critical Flow Fuel Metering Systems, Air + Fuel



Air Heater

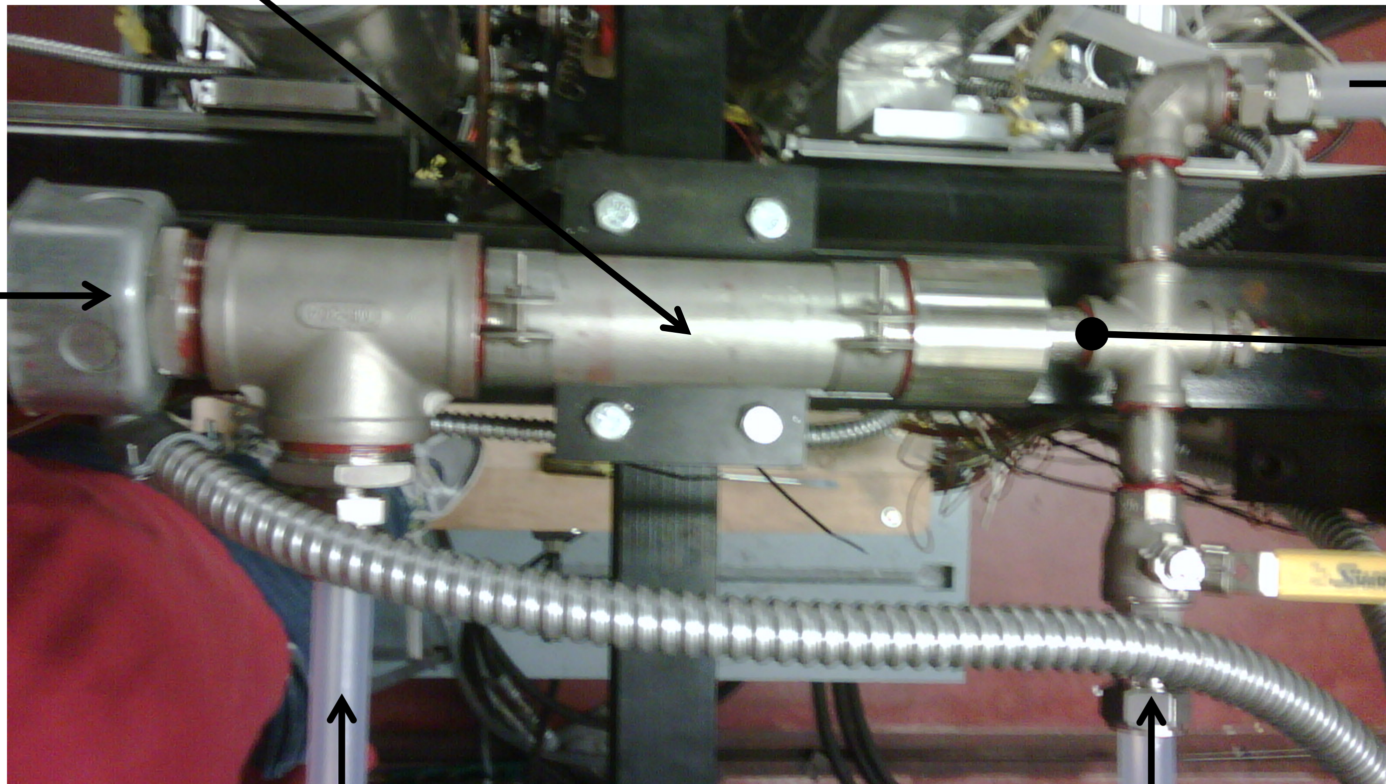
5.1 cm I.D., 34 cm Lg.

Insulation not shown

Immersion Heater

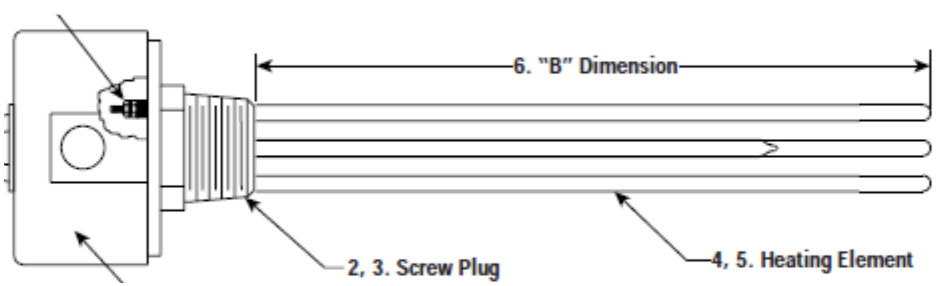
To Plenum Inlet
MF_Air_Tot

T_Air_Heater

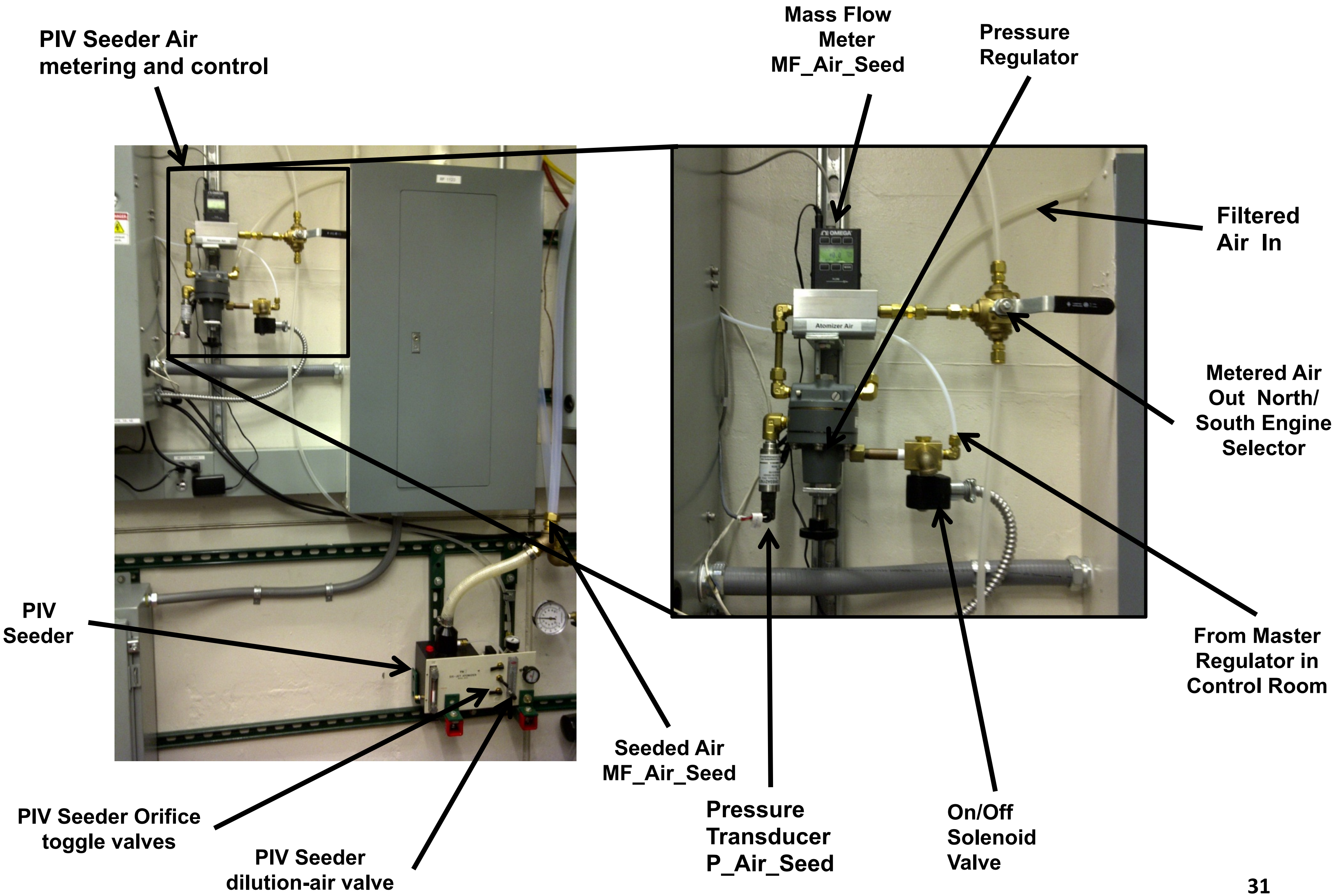


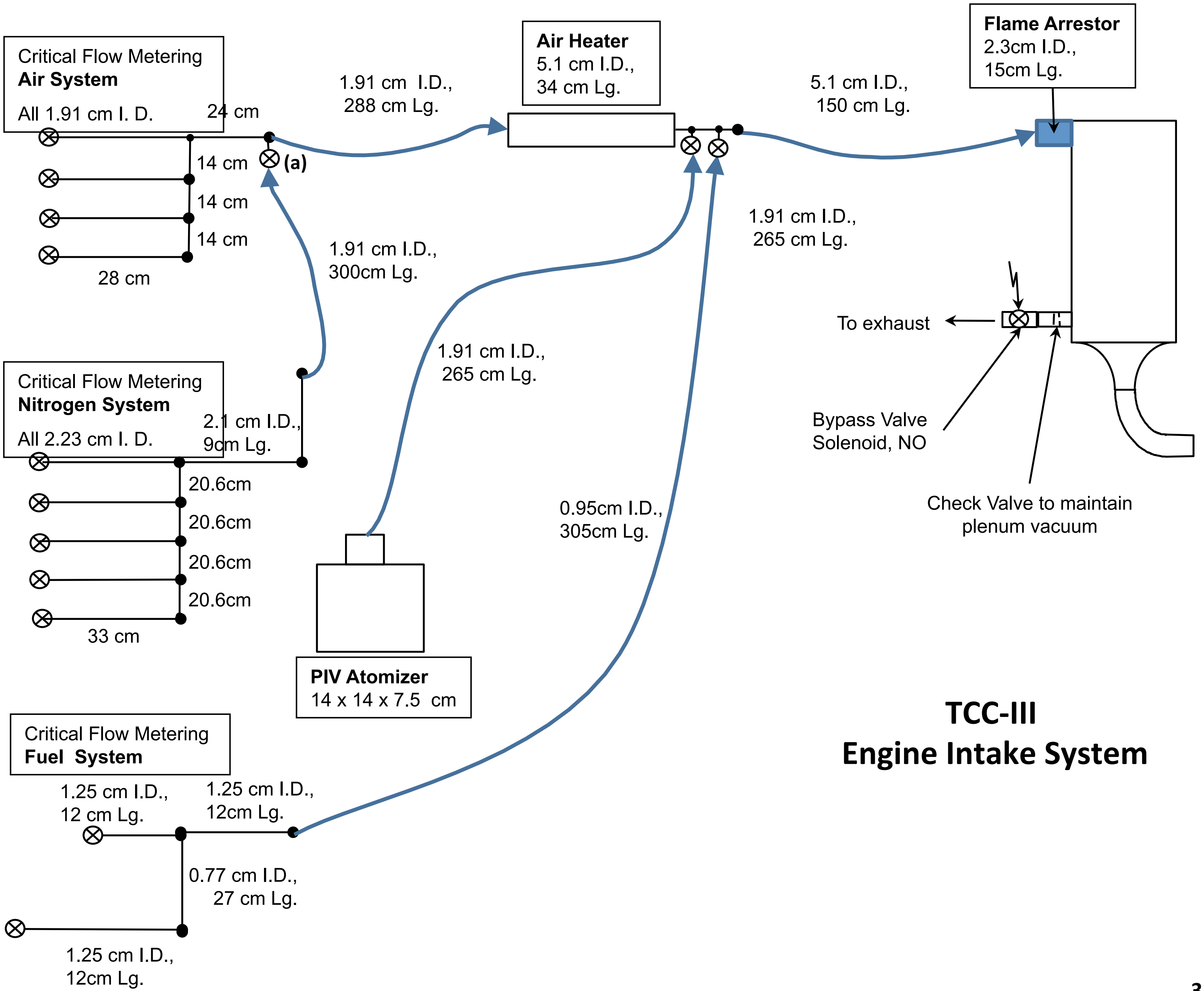
Metered Air From
Critical Flow Metering System
MF_Air_Crit, T≅ ambient

Metered Air From
PIV Atomizer
MF_Air_Seed, T≅ ambient



Seeder Flow-Metering System,





TCC-III
Engine Intake System

TCC-III Engine Exhaust System