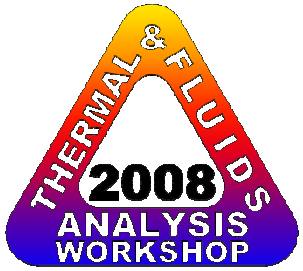

CLV Mobile Launcher Solid Rocket Motor Plume Induced Environment

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NASA Kennedy Space Center

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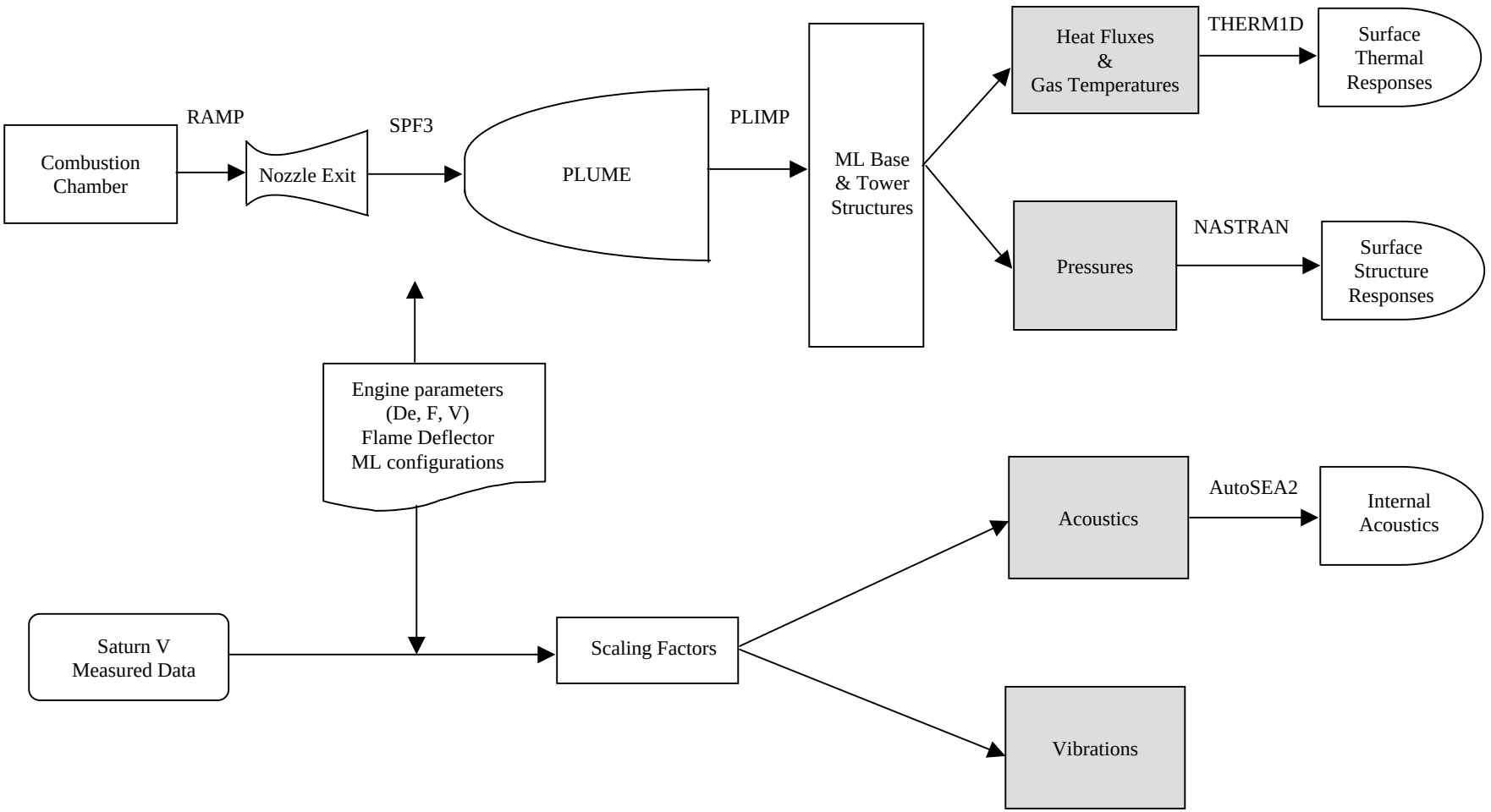
NASA Marshall Space Flight Center

Thermal & Fluids Analysis Workshop (TFAWS 2008)
San Jose State University, San Jose, CA
August 18-22, 2008

Outline

- Objectives
- Launch Induced Environment
- THERM1D
- Examples

Prediction


Combustion Chamber
RAMP
Nozzle Exit
SPF3
PLUME
PLIMP
ML Base & Tower Structures
Heat Fluxes & Gas Temperatures
THERM1D
Surface Thermal Responses
Pressures
NASTRAN
Surface Structure Responses
Engine parameters (De, F, V) Flame Deflector ML configurations
Saturn V Measured Data
Scaling Factors
Acoustics
AutoSEA2
Internal Acoustics
Vibrations

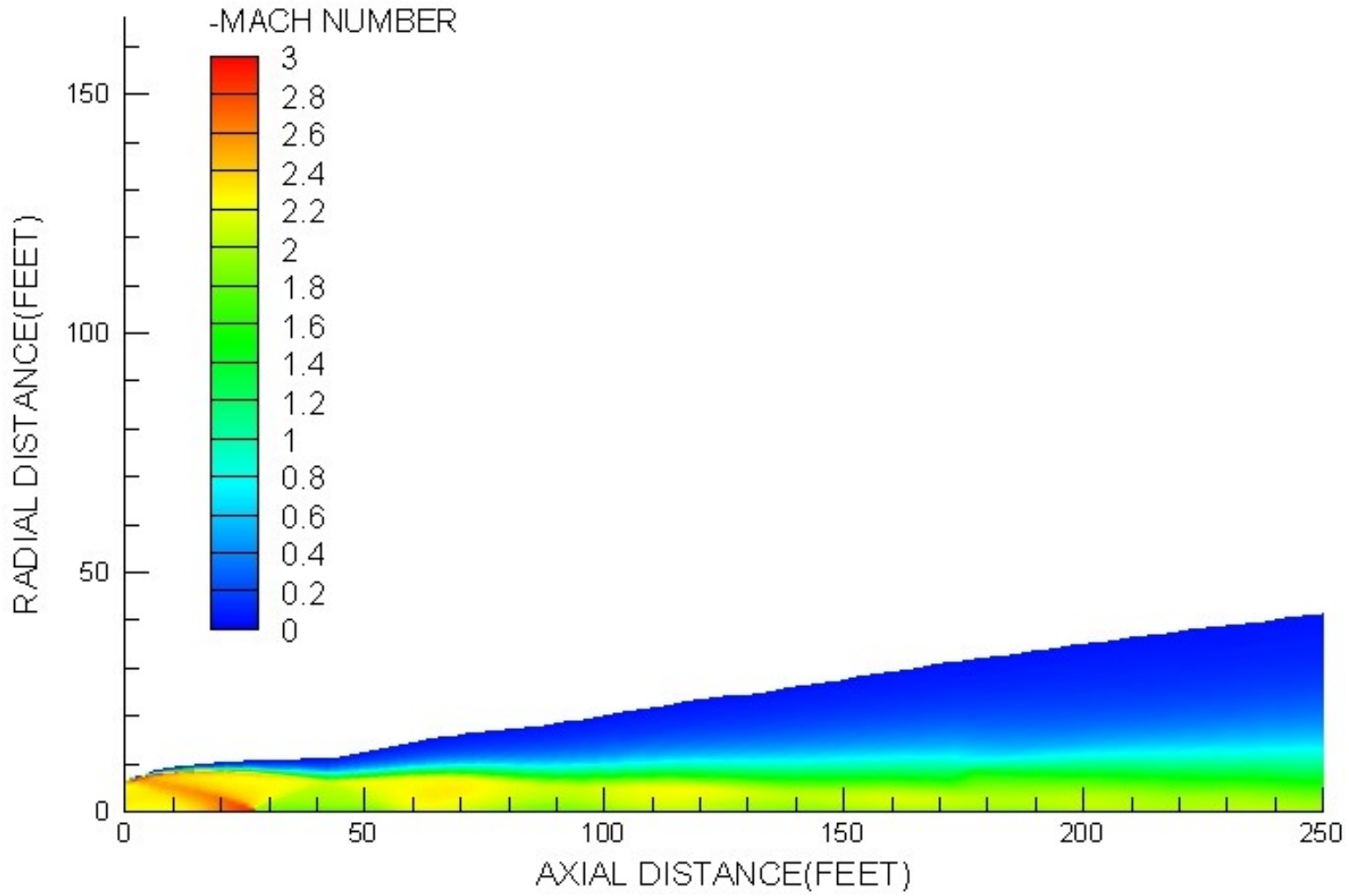
Objectives

- To ensure overall structural integrity and flight safety
- CLV ML Launch Induced Environments
  - Acoustics
  - Vibration
  - Impact Pressure
  - Heating Rates
- Follow-on analyses to determine thermal responses due to plume induced environments (THERM1D)
- Examples
  - Shuttle
  - Ares-I

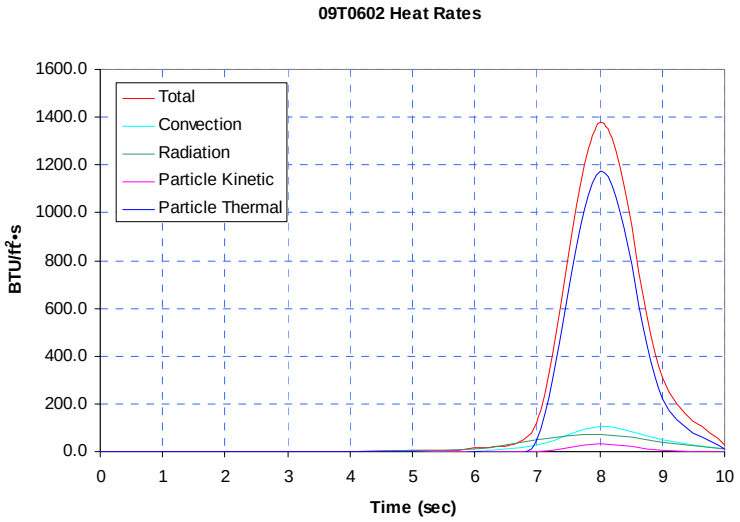
Launch-Induced Environments

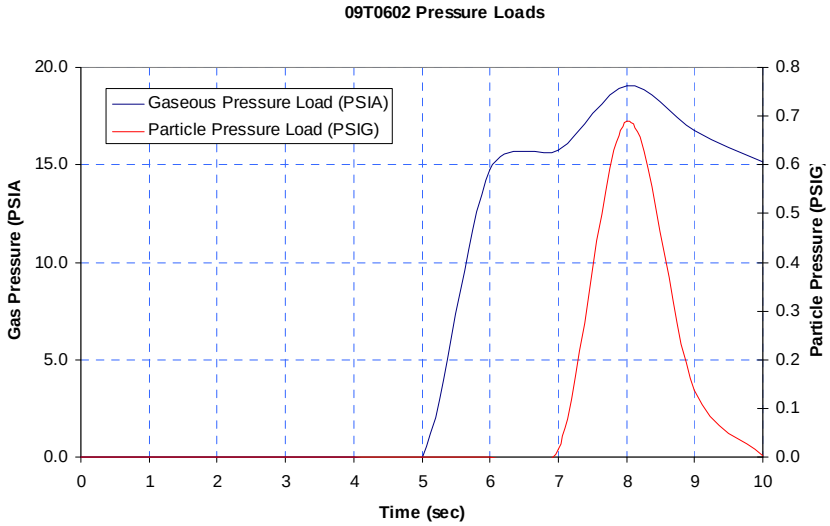
- Input conditions
  - Coordinate systems
  - Lift-off trajectories
  - ML configurations
  - RSRMV engine performance with propellant mixture provided by ATK
- Processes
  - Combustion chamber condition predicted by **CEC** at Pc=905 psia
  - Nozzle condition by **RAMP2**
  - Plume expansion by **SPF3**
  - Impingement on different structures by **PLIMP**
- Launch complex components
  - Exhaust deflectors
  - Hold-down posts, Sound Suppression Water Pipes
  - Blast shields
  - GN2 Purge Line & Heater
  - MLB deck and MLT floors and roofs
  - Elevator shaft

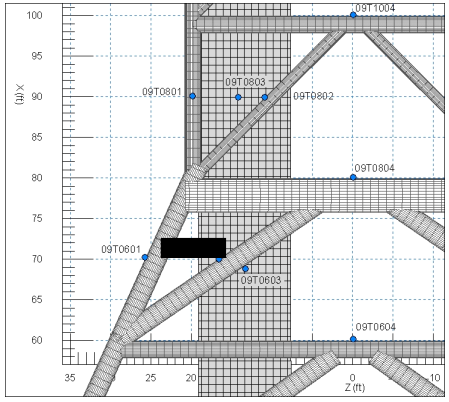
Plume Induced Environments



PLIMP







Time	*Qc*	*Qr*	*Tr*	*Mdot*	*Qpke*	*Qpte*	*Pimp*	*Pimppar*	*Qtotal*
sec	BTU/ft^2·s	BTU/ft^2·s	R	lbm/ft^2·s	BTU/ft^2·s	BTU/ft^2·s	Psia	Psig	BTU/ft^2·s
0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
5	0.0	2.9	0.0	0.00	0.0	0.0	0.0	0.0	2.9
6	1.2	12.1	804.4	0.01	0.0	0.7	14.8	0.0	14.1
7	25.9	50.4	2560.1	0.17	0.2	47.2	15.8	0.0	123.7
8	102.9	69.9	4508.2	2.21	33.2	1171.6	19.0	0.7	1377.6
9	49.8	38.3	3306.1	0.80	3.7	219.9	16.7	0.1	311.8
10	9.7	9.4	1581.8	0.05	0.0	9.0	15.2	0.0	28.1

Thermal and Pressure Predictions for Body Point 09T0602 Using a North Drift Trajectory

PLIMP

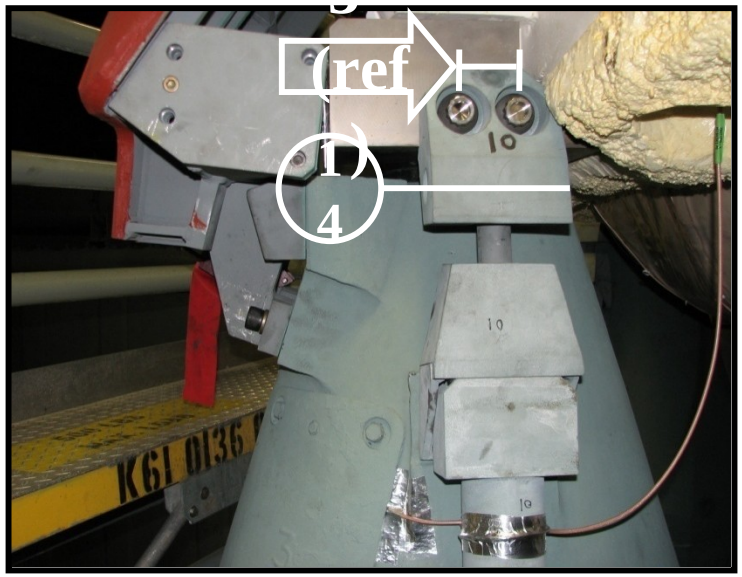
Aluminum Oxide Deposition Layer Integral

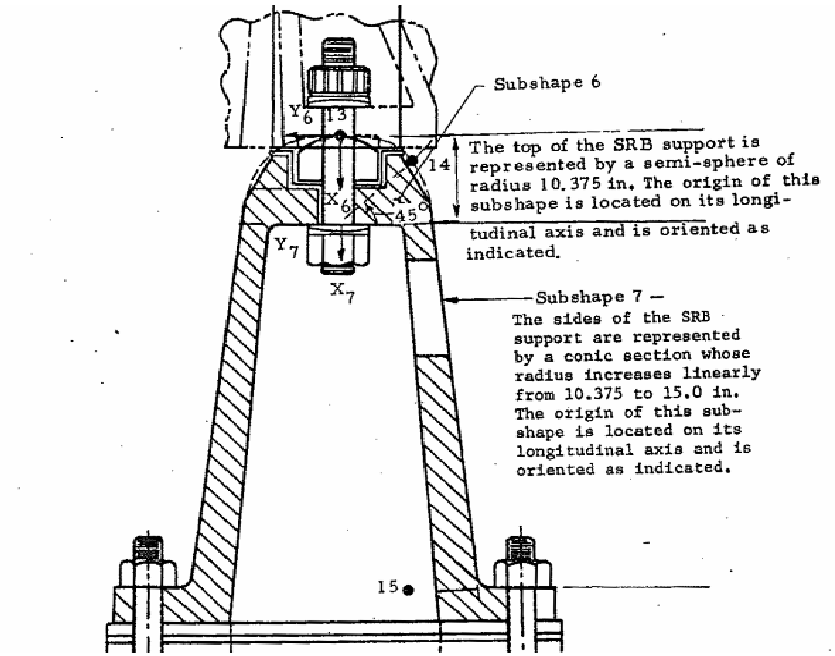
$$\Delta = \frac{\alpha}{\rho_{Al_2O_3}} \int_{t}^{t+dt} (\rho v)_W \, dt$$

Heat Rate Calculation with Aluminum Oxide Deposition

$$Q_{HW} = Q_{C_{CW}} \left[\frac{T_{o_R} - T_{WALL}}{T_{o_R} - 540^o R} \right] + \alpha (\rho v)_W (H_P - H_W)$$

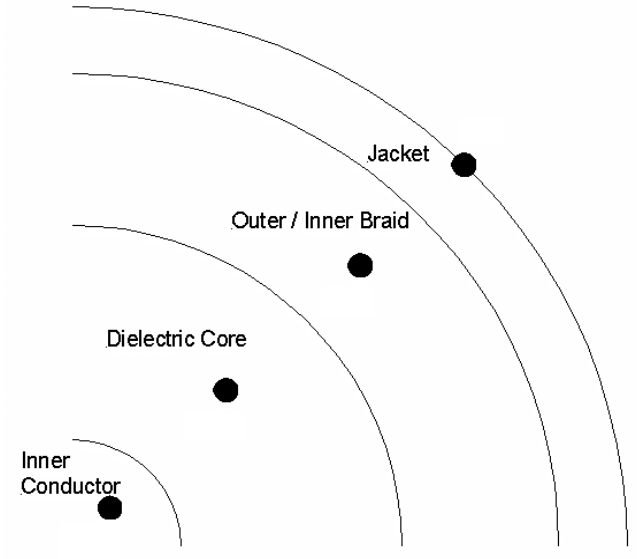
Shuttle Example

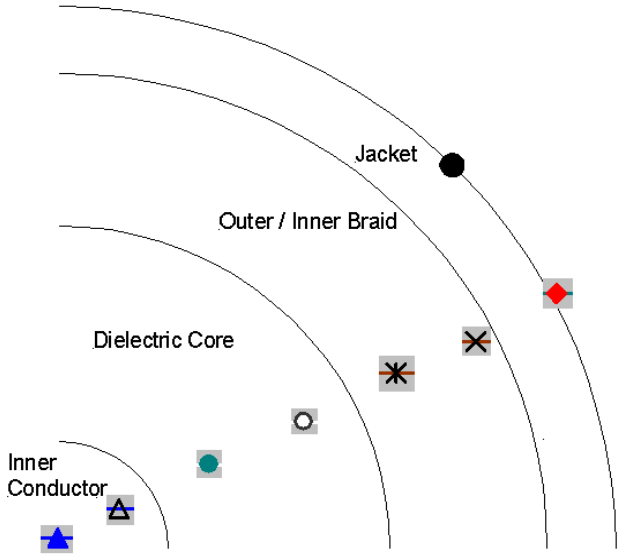




- Shuttle Range Safety Cable might have caused debris issue
  - Previous analyses did not include Al2O3 buildup

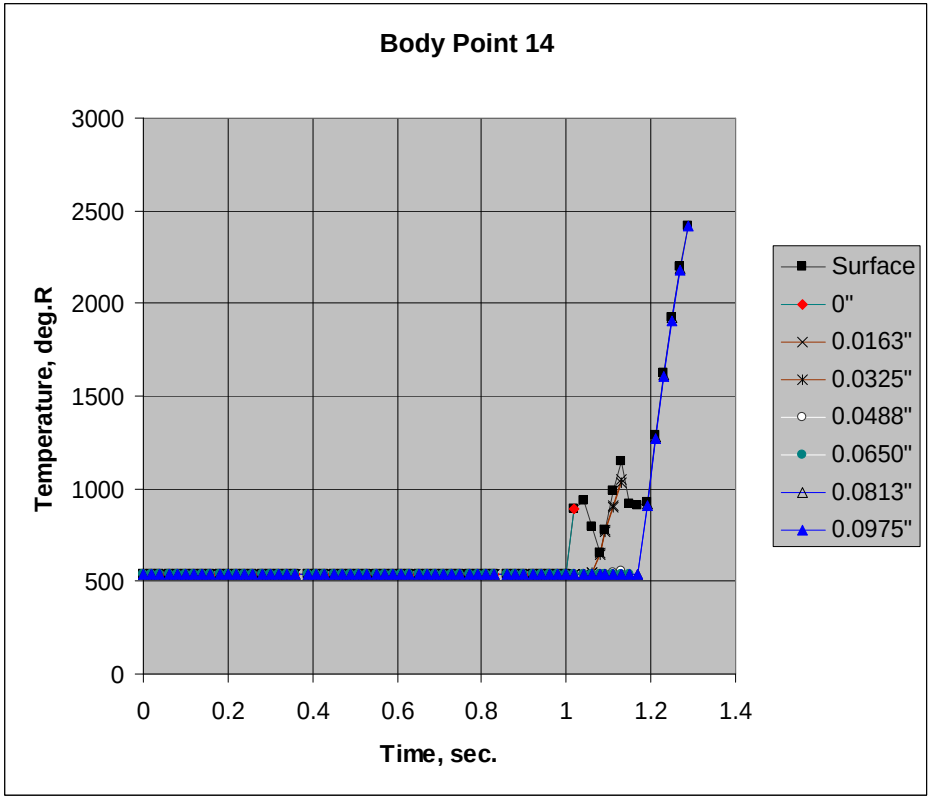
Shuttle Example

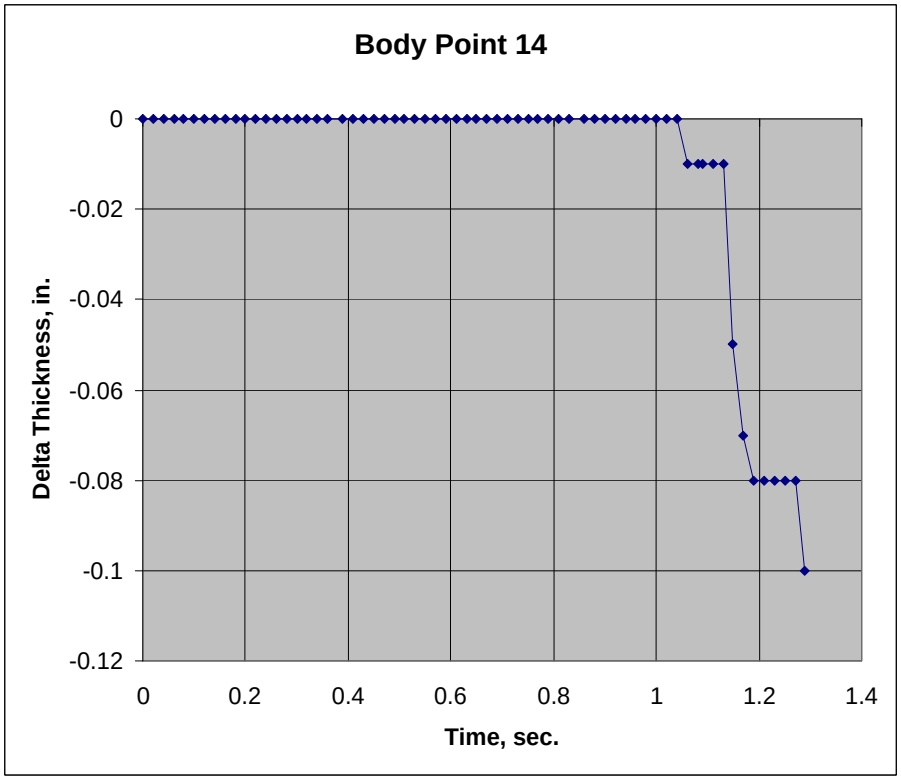




- Cable materials include layers of Teflon and Copper
  - Five inner locations identified in THERM1D

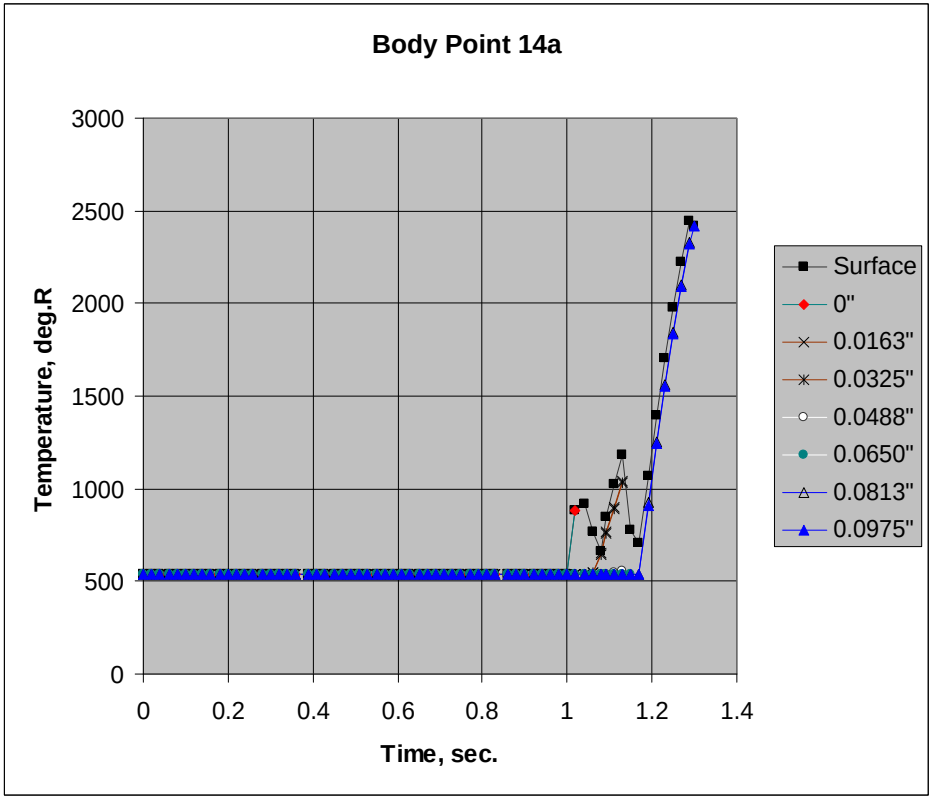
Shuttle Example

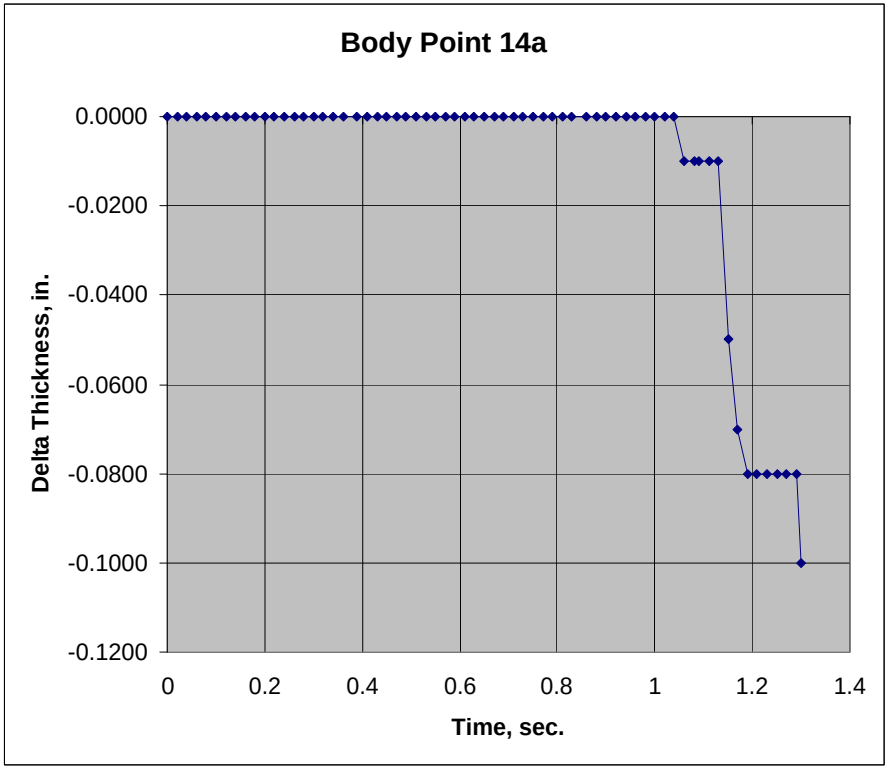




- Outer jacket starts melting at 1.02 sec
  - Complete burn-through at 1.3 sec

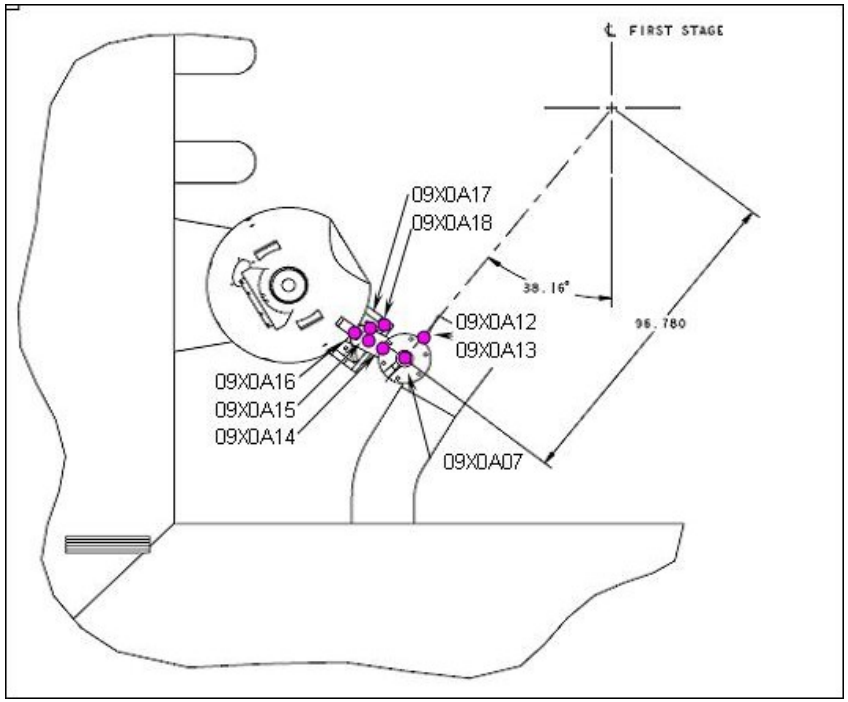
Shuttle Example

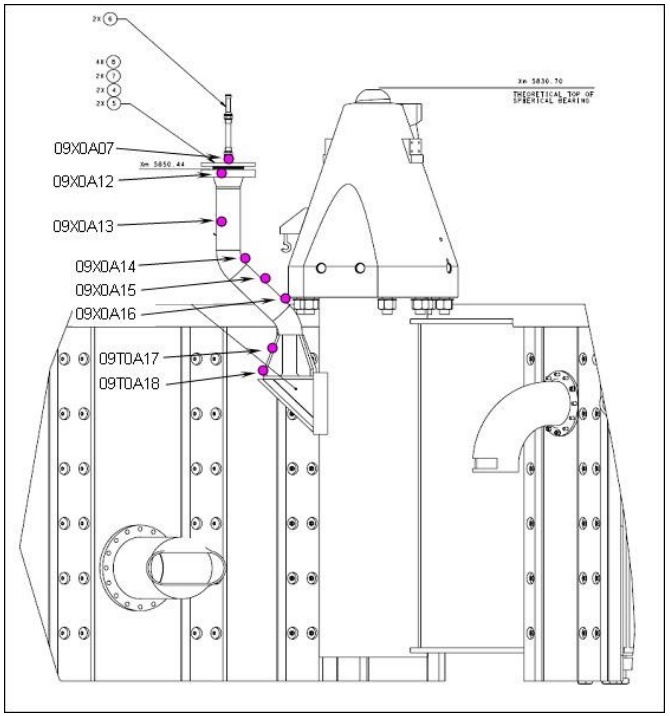




- Outer jacket starts melting at 1.02 sec
  - Complete burn-through at 1.3 sec

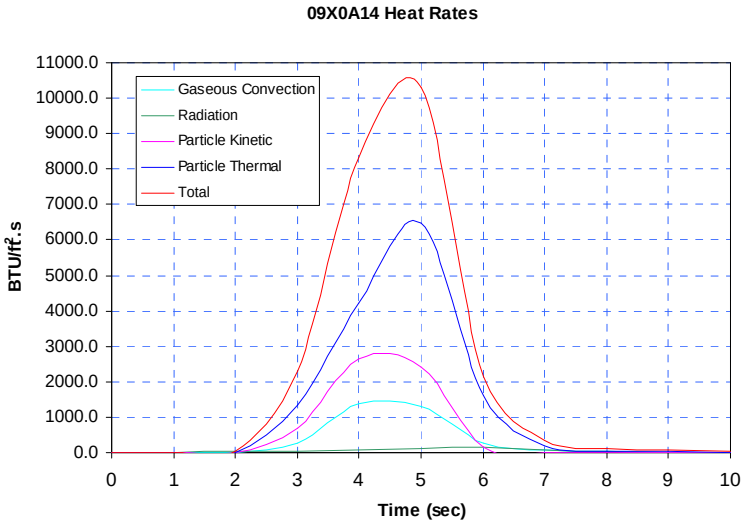
CLV Example

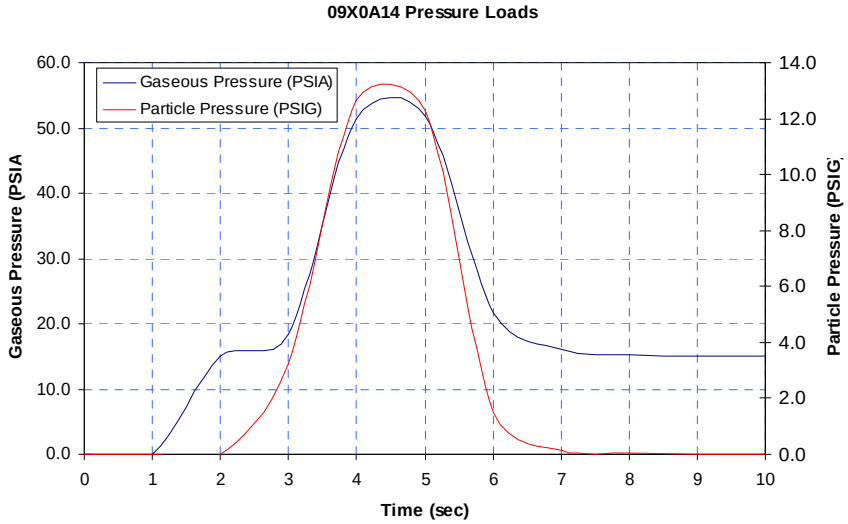




Body Point	Description	PLIMP Coordinate Frame (FT)			Launch Complex Coordinate Frame (IN)		
		X	Y	Z	X	Y	Z
09X0A07	GN2 Purge Line Top	12.50	-6.34	4.98	5850.0	-1300.1	-59.8
09X0A12	GN2 Purge Line Duct	12.13	-6.14	4.78	5854.4	-1297.6	-57.4
09X0A13	GN2 Purge Line Duct	11.27	-6.14	4.78	5864.8	-1297.6	-57.4
09X0A14	GN2 Purge Line Duct	10.32	-6.13	5.60	5876.1	-1297.5	-67.2
09X0A15	GN2 Purge Line Duct	9.84	-5.91	6.00	5882.0	-1294.9	-72.0
09X0A16	GN2 Purge Line Duct	9.29	-5.67	6.45	5888.6	-1292.1	-77.4
09X0A17	GN2 Purge Line Base	8.22	-5.66	5.64	5901.4	-1291.9	-67.7
09X0A18	GN2 Purge Line Base	7.55	-5.74	5.40	5909.4	-1292.9	-64.8

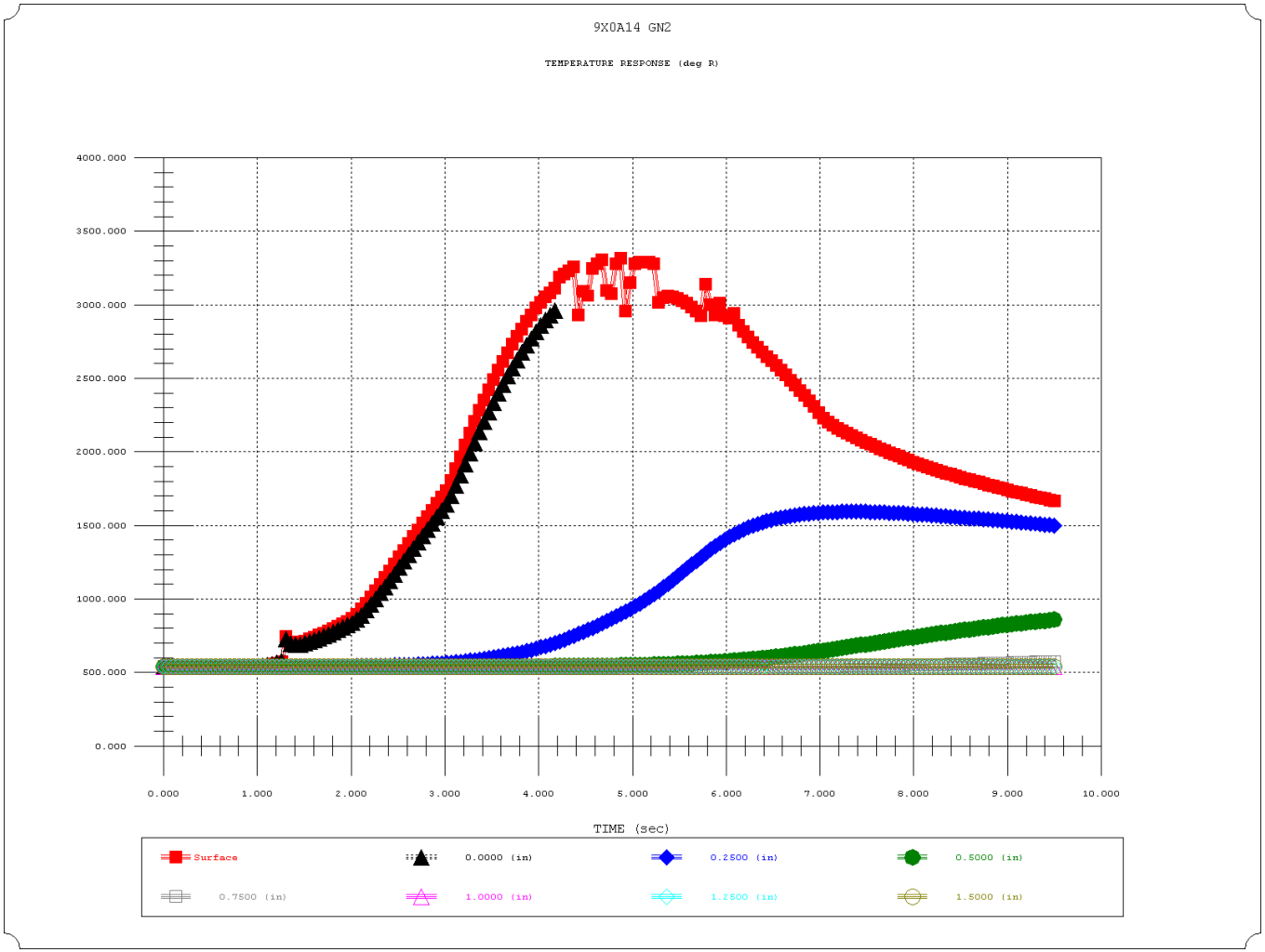
CLV Example



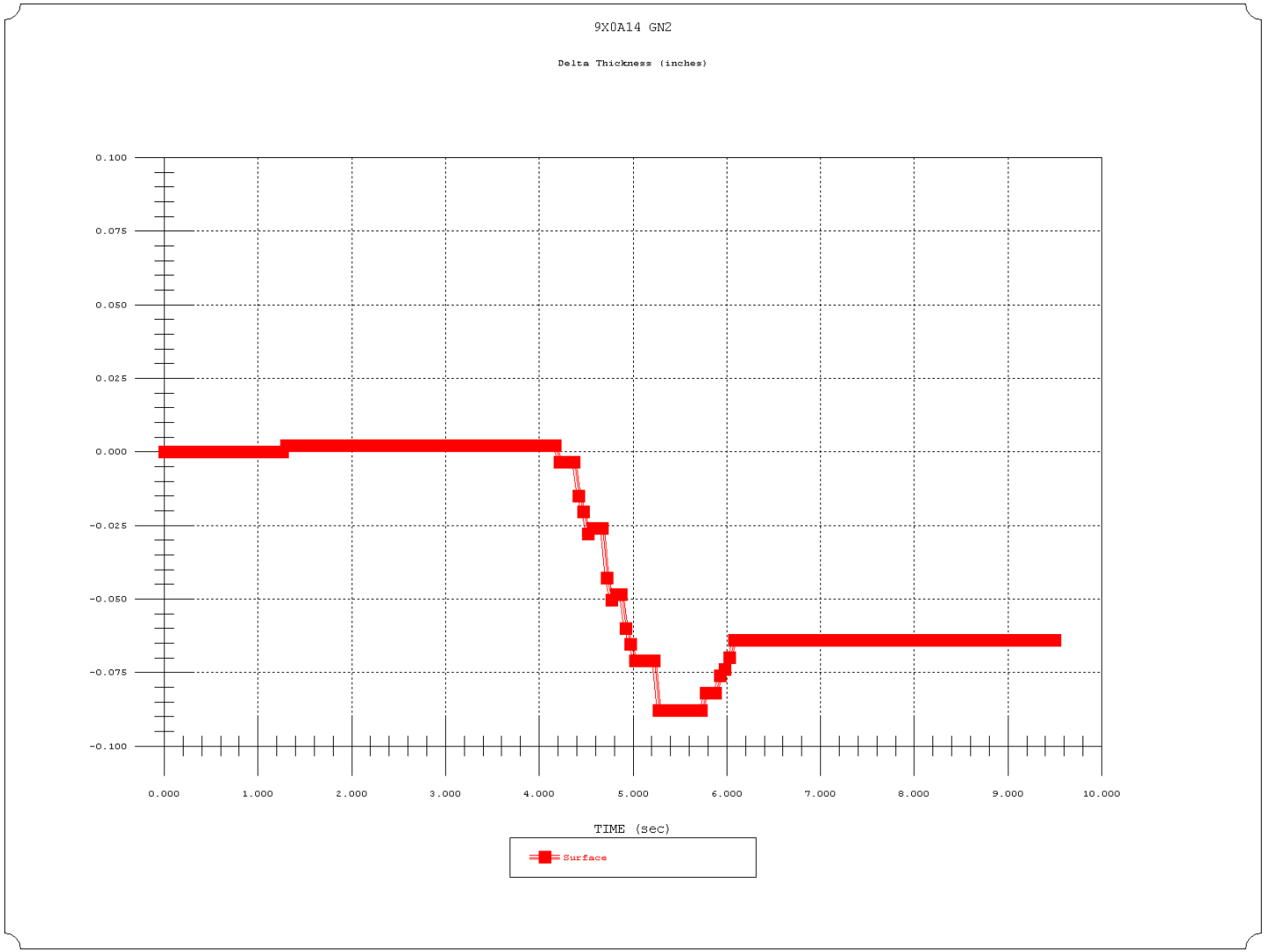


Time	*Qc*	*Qr*	*Tr*	*Mdot*	*Qpke*	*Qpte*	*Pimp*	*Pimppar*	*Qtotal*
sec	BTU/ft^2·s	BTU/ft^2·s	R	lbm/ft^2·s	BTU/ft^2·s	BTU/ft^2·s	Psia	Psig	BTU/ft^2·s
0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
2	8.8	31.0	1305.4	0.00	0.0	0.0	15.1	0.0	39.8
3	252.6	41.8	5414.1	2.76	687.4	1322.6	18.4	3.2	2304.3
4	1384.2	81.7	6035.0	8.90	2643.8	4199.2	51.3	12.7	8308.9
5	1284.6	126.0	6042.2	9.12	2422.7	6477.8	51.7	12.3	10311.1
6	255.7	146.8	5394.4	2.33	145.9	1603.9	21.6	1.5	2152.3
7	70.0	60.2	3386.7	0.55	5.8	197.5	16.0	0.1	333.5
8	29.6	36.6	2235.7	0.23	0.8	55.7	15.3	0.0	122.7
9	16.5	19.1	1712.5	0.13	0.2	23.3	15.1	0.0	59.0
10	10.5	2.3	1422.5	0.08	0.1	11.7	15.0	0.0	24.5

CLV Example


9X0A14 GN2
TEMPERATURE RESPONSE (deg R)
4000.000
3500.000
3000.000
2500.000
2000.000
1500.000
1000.000
500.000
0.000
0.000
1.000
2.000
3.000
4.000
5.000
6.000
7.000
8.000
9.000
10.000
TIME (sec)
Surface
0.0000 (in)
0.2500 (in)
0.5000 (in)
0.7500 (in)
1.0000 (in)
1.2500 (in)
1.5000 (in)

CLV Example


9X0A14 GN2
Delta Thickness (inches)
0.100
0.075
0.050
0.025
0.000
-0.025
-0.050
-0.075
-0.100
0.000
1.000
2.000
3.000
4.000
5.000
6.000
7.000
8.000
9.000
10.000
TIME (sec)
Surface

CLV Example

- Outer surface reached melting temperature
- Layers at 0.25” and below never reach melting point

SRM Plume Induced Environments Killed This NASA Money Saving Idea