HIRDLS

TC-OXF-265

High Resolution Dynamics Limb Sounder

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Subject/Title: Black Body Heater Thermal Response

Contents:

Contains viewgraphs presented on 21 July 2000 at the IFC Preship Review. The material has been updated slightly, but the results and numerical details are unchanged. The viewgraphs show the modeled and actual thermal response of the IFC when operating the heater at full power.

Key Words: IFC thermal SAIL TSS heater

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Basic IFC thermal design was undertaken by Bob Watkins using numerous Mathcad analyses of individual components.

The design was later verified by J. Barnett using computer simulation with a single model which included all relevant parameters. The remainder of this presentation relates to this simulation.

IFC Thermal Computer Simulation Model

- 15 mass nodes
- 15 conductive links (including cabling)
- 10 radiation nodes (in cavity and cavity/shield/outer)
- Heater on one node (0.98 W at full power)
- 8 temperature sensors on 3 nodes (base, wall, outer)
- 0.768 s time step

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Requirements on temperature rise:

SP-HIR-044, C. L. Hepplewhite, 02-Nov 99

'In-Flight Calibrator Subsystem Specification Document'

3.2.1.1.2.1 Cavity Brightness Temperature

The expected normal operational temperature range for the black body cavity is between 278 K [+5 C] and 298 K [+25 C]. Additionally, the IFC, in conjunction with commands from the IPU, shall be capable of controlling the IFCBB cavity temperature to 318 Kelvin [+45 C] (ITS §4.6.7.1) in vacuum. This is for occasional mirror emissivity calibration purposes.

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IFC Thermal mass nodes

1) heater and top of cylinder on inside assembly
2) disk with aperture on inside assembly
3) next node down from (1) on inner cylindrical baffle including flange
4) next node down on inner cylindrical baffle
5) bottom node on inner cylindrical baffle
6) base cone - this is only part that is directly viewed by the radiometer
7) base cone screws
8) screws on inner baffle flange securing to outer support and radiation shield
9) radiation shield - top flange and top of cylinder
10) radiation shield – remainder of cylinder and bottom
11) top section of Ti support cylinder (just flange)
12) middle section of Ti support cylinder (thin shell with holes)
13) bottom section of Ti support cylinder (just flange)
14) outer case, (thermally coupled to optical bench), prescribed
15) outer radiation environment as seen by IFC aperture, prescribed

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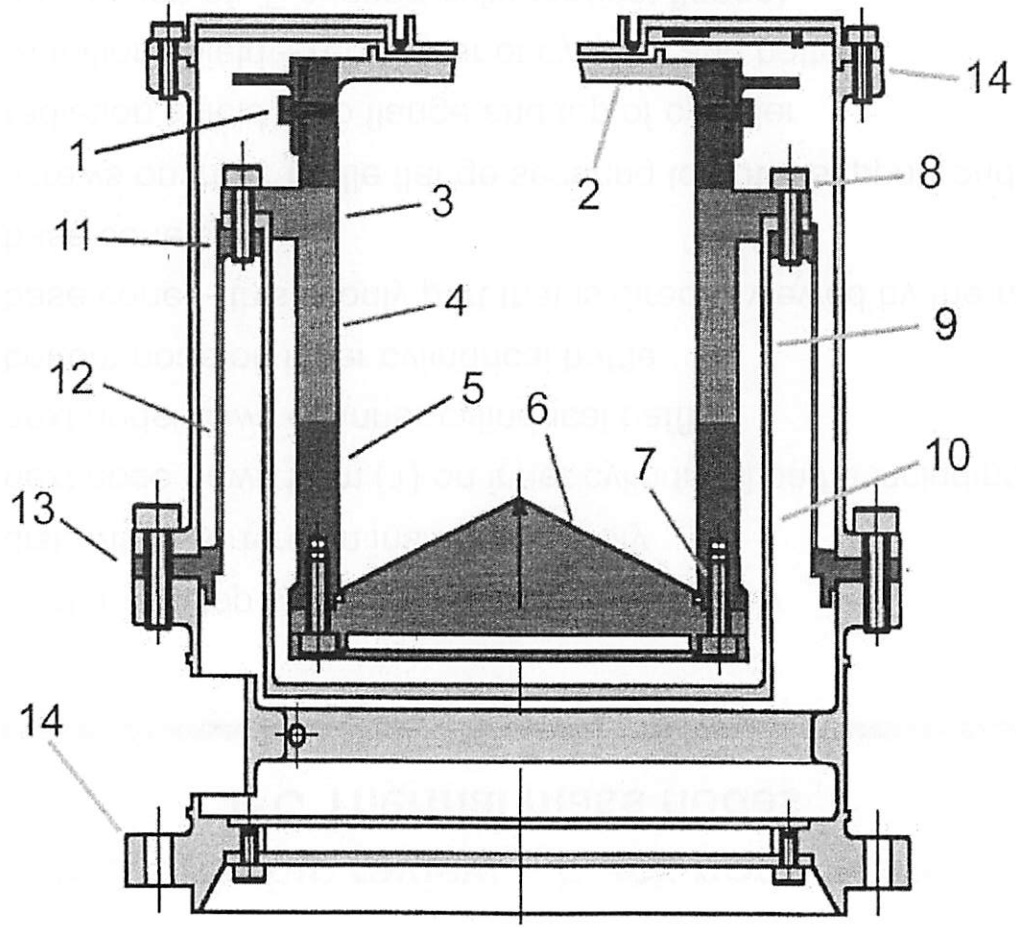
Cross section through middle of IFC showing node numbers

Node 15 - radiation scene



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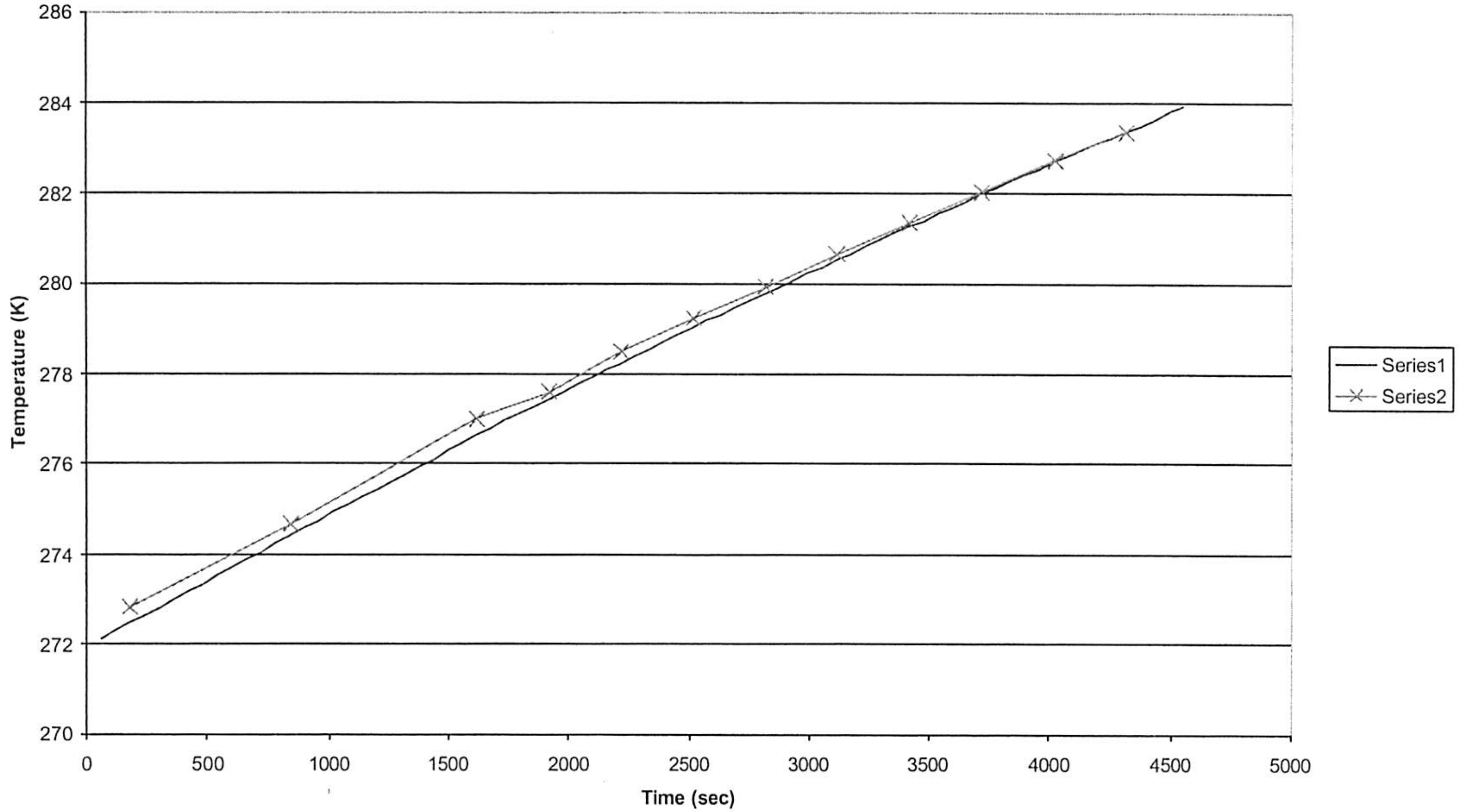
Maximum dT/dt test



Simulation of full power heater test in vacuum; ambient 264 K; inner assembly starts at 272 K.
Curve 1 (black) is model. Curve 2 (purple) is measured.

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Maximum modelled temperature

The following results are for a simulation of full heater power in vacuum; ambient 264 K; inner assembly starts at 272 K.

They show the maximum possible expected temperature (although this will take more than half a day to achieve) and corresponding steady-state heat flows. This temperature is 312 K (for the cone and inner baffle) implying a temperature rise of 48 K.

The actual maximum temperature is not yet available, but a calculation based on the observed gradient change with time in the previous figure leads to a prediction of 306 K, i.e. a rise of 42 K (7 K standard deviation).

They are also relevant for normal operating conditions where the IFC will be operating a few degrees above ambient. If this is taken to correspond to 10% of the rise obtained here, then the resulting temperature gradients and heat flows will be close to 10% of those shown here.

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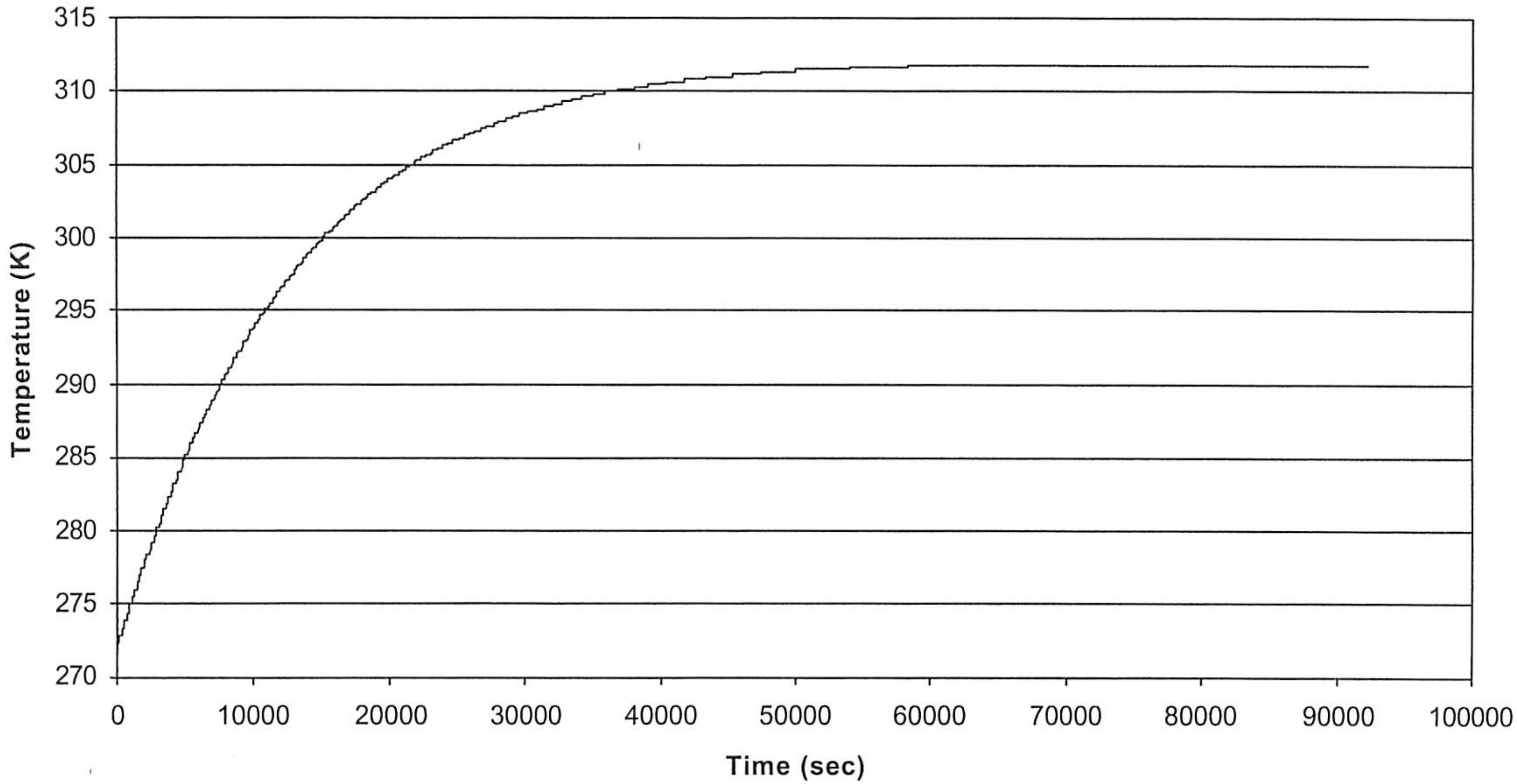
Maximum modelled temperature



Simulation of full power heater test in vacuum; ambient 264 K; inner assembly starts at 272 K.
Gradients fitted from test data imply limiting maximum temperature of 306 K +/-7 (1 sigma).

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Maximum modelled temperature

Conditions: vacuum; ambient 264 K; heater power 100% (0.98 W);
Run to equilibrium (120000 maf=25.6 hours).

Mass node temperatures (K):

1)	heater and top of cylinder on inside assembly	311.944
2)	disk with aperture on inside assembly	311.910
3)	next node down on inner baffle incl flange	311.894
4)	next node down on inner baffle	311.885
5)	bottom node on inner baffle	311.884
6)	base cone	311.881
7)	base screws	311.884
8)	screws on inner baffle flange	311.894
9)	radiation shield - top flange	311.741
10)	radiation shield - cylinder+bottom	311.451
11)	top section of Ti cylinder (flange)	311.571
12)	middle section of Ti cylinder (thin shell)	287.838
13)	bottom section of Ti cylinder (flange)	264.117
14)	outer case, prescribed	264.000
15)	outer radiation environment, prescribed	264.000

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Maximum modelled temperature - conduction

node 1	node 2	heat flow W	temp difference K
1	2	0.1874	0.3378E-01
1	3	0.5618	0.4947E-01
2	3	0.9717	0.1569E-01
3	4	0.0571	0.9216E-02
4	5	0.0090	0.1465E-02
5	6	0.0070	0.2899E-02
5	7	0.0000	0.0000E+00
3	8	0.0000	0.0000E+00
3	9	0.6015	0.1533E+00
9	10	0.1789	0.2904E+00
9	11	0.4222	0.1700E+00
11	12	0.4220	0.2373E+02
12	13	0.4218	0.2372E+02
13	14	0.4216	0.1167E+00
1	14	0.2301	0.4794E+02

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Maximum modelled temperature - radiation

mass node	net flow away (W)	
15	-0.5312E-01	outer radiation environment, prescribed
2	0.4362E-03	disk with aperture on inside assembly
6	0.6213E-02	base cone
4	0.4647E-01	intermediate node on inner baffle
5	0.1928E-02	bottom node on inner baffle
10	-0.1928E-02	radiation shield - cylinder+bottom
10	0.1804E+00	radiation shield - cylinder+bottom
14	-0.1804E+00	outer case, prescribed
2	0.8972E-01	disk with aperture on inside assembly
14	-0.8972E-01	outer case, prescribed

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SAIL IFC control task

IFC is controlled from SAIL task which will also control the IFC mirror and two other optical bench heaters.

Task reads IFC temperature sensor telemetry each minor frame (0.768 s) and performs calibration to temperature in K; each of the 8 sensors has individual coefficients. One of the 3 available cavity sensors is selected on command for temperature control. Temperatures updated at 30 s intervals (cycle within BEU).

Task sends heater level commands (0-255) every major frame (0.768 s).

Currently use dither between adjacent levels with cycle of 4 frames to obtain fractional levels (other powers of two can be programmed; 16 was used originally).

Heater power (0.98 W max) assumed proportional to level squared.

Task can command constant power or constant temperature, using PI control.
PI coefficients determined with software simulator; verified during test and on-orbit.

See documents:

'Proposed Scheme for IFC and OBA Heater Control`, SP-OXF-195, J.G.Whitney, 17 July 1998

'IFC Heater Control Algorithm` TC-OXF-210, J.J.Barnett, 8 March 1999.

'SAIL IFC and TSS temperature control task`, SW-OXF-236, J.J.Barnett, 21 March 2000.