Thermal

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Mission Requirements

- **Thermal Stability**
  - **The Thermal Control Subsystem (TCS) Shall Provide Thermal Stability to the Spacecraft Bus So As Not to Preclude the Attitude Control Subsystem From Meeting Mission Requirements**

Derived Requirements (1 of 4)

- **Temperature**

	Operational (ºC)	Non-Operational (ºC)
– Components	0 to 40	-10 to 50
– Battery	0 to 30	0 to 30
– Thruster Valves	5 to 40	5 to 40
– RCS Components	5 to 40	5 to 40
– Structure	TBD	TBD
– Elect. Deck Gradient	TBD	TBD
– Thrust Tube Gradient	TBD	TBD
– Instrument Interface	18 to 22	TBD
– Solar Array-Shade Side	-40 to 0	-100 to 125 (TBR)
– Margins	5ºC	5ºC
– Star Cameras	-20 to 40	-30 to 50
– AKM	< 370	4 to 32
– Trim Motor	-40 to 80	-40 to 80

Derived Requirements (2 of 4)

- **Environments**
  - **Solar Flux** — **415 to 444 BTU/HR-sqft**
  - **Albedo** — **TBD**
  - **Earth IR** — **TBD**
  - **Eclipse Duration** — **71 min/Day @20 Days Max**
  - **Launch Vehicle** — **TBD**
- **Power (Preliminary)**

(Watts)	Operational	Survival	Launch
– Electronics	150	82	48
– Heaters	25	93	25

  - **Heater Design Margin**
    - **Sized for 24 Volts - Nominal Voltage Is 30 ± 6 Volts**

Derived Requirements (3 of 4)

- Materials
  - All Components/Materials Shall Have Certification/Lot Traceability
  - Environmental Testing Will Be in Accordance With NCST-TP-FM001, FAME Test Plan
  - MLI Blankets
    - Meet Requirements for Outgassing
      - TML < 1.0% CVCM < 0.1%
    - Redundantly Grounded With No Single Layer Exceeding 50 Ohms to Any Point on Structure
  - Applied Optical Surfaces
    - Metalized Tapes/OSR's Provided With Some TBD Path to Ground
  - Optical Property Variations Shall Be Minimized
  - Optical Property Degradation Shall Be Understood
- Thermal Closeout
  - Thermal Closeouts Shall Be Designed Such That No Thermal Hardware Will Adversely Affect the Operation of Any Mechanism

Derived Requirements (4 of 4)

- Instrument
  - The Thermal Conductance of the Instrument/Bus Ground Strap Shall Be Less Than TBD
  - The Thermal Conductance of the Instrument/Bus Electrical Interface Cables Shall be Less Than TBD
  - The Conductive Heat Transfer From the Star Trackers to the Instrument Shall Be ±TBD Watts
  - The Radiative Heat Transfer From the Bus to the Instrument Shall Be ± TBD Watts
  - The Conductive Heat Transfer From the Omni Antenna to the Instrument Shall Be ±TBD Watts
- Thermal Distortion
  - The Flatness of the Solar Array Panels, Sun Shade Webs and Electronics Deck Shall be Maintained Within 2.5mm Over 2m for the Life of the Mission

TCS Levied Requirements

- **Electronics Boxes**
  - **Surface Coatings Provided Shall Be High Emittance (>70%)**
  - **Mating Surfaces Shall Be Flat When Power Dissipation Exceeds 1.0 Watt/in^2**
- **Solar Panels**
  - **Solar Cell Layout Shall Be Arranged to Minimize Thermal Gradient**
  - **String Operations Management Shall Be Conducted in a Symmetrical Fashion to Minimize Temperature Differentials**
- **Heater Control**
  - **EPS Shall Provide Some Means of Varying the Power Dissipated by the Heaters As Determined by the Spacecraft or Ground Control**

Trade Studies

- Trim Tabs
  - Temperature Control vs Motor Control*
- Temperature Gradients
  - Thrust Tube Cavity Thermal Management*
  - Material Optical Property Variation
  - Battery Location/Box Layout on Electronics Deck
- Optical Properties
  - Optical Property Degradation Over Time
  - Materials for Sun Shield, Radiator, Trim Tabs Are Focus of Trade
- Heater Control
  - Ground Controlled Voltage Variation vs “Closed Loop” Proportional Control
- Solar Panel
  - Panel Deployment Angle*
  - Solar Cell Layout
  - Blanketing on Backside of Arrays

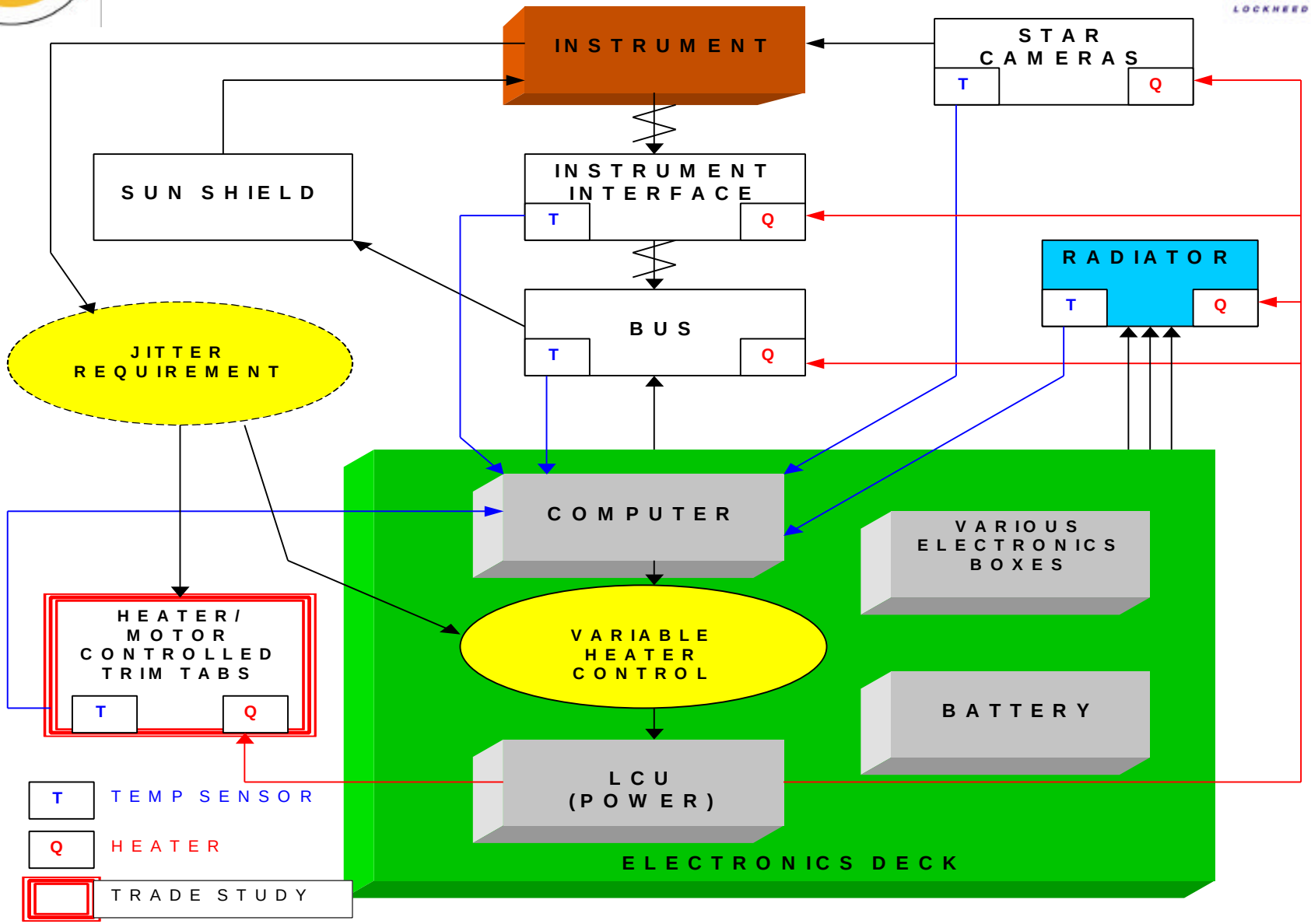
* Preliminary Results included in Backup Slides

Issues/Concerns

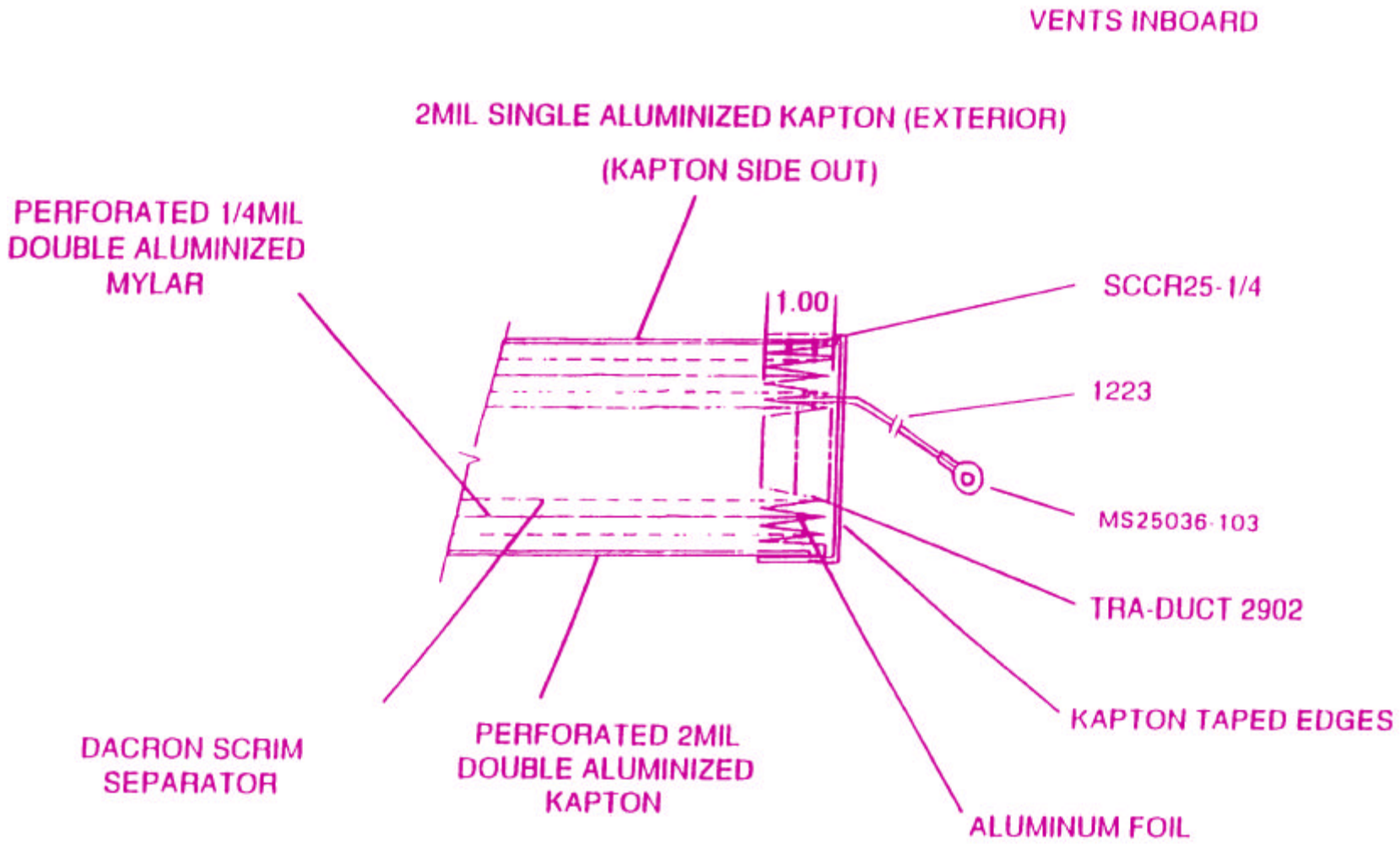
- **Optical Properties**
  - **Optical Property Degradation Over Time**
- **Heater Control**
- **Electro-Static Discharge**
- **Thrust Tube Gradient**
  - **Due to Cavity Left by AKM**

Backup

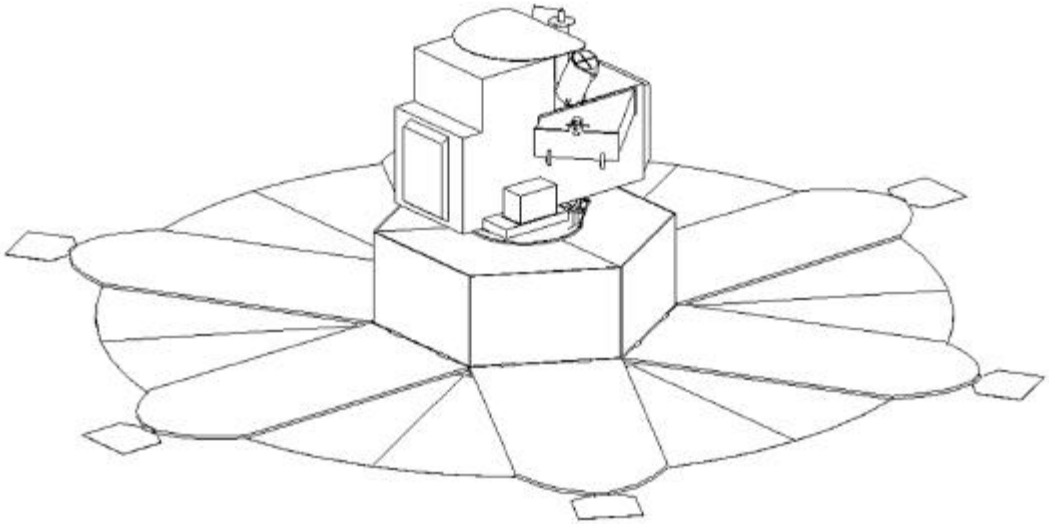
TCS Block Diagram

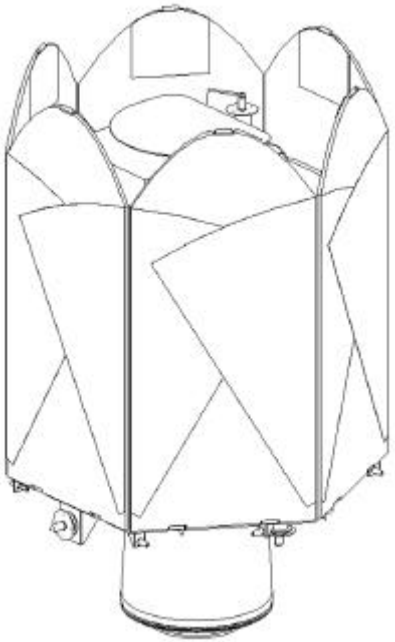


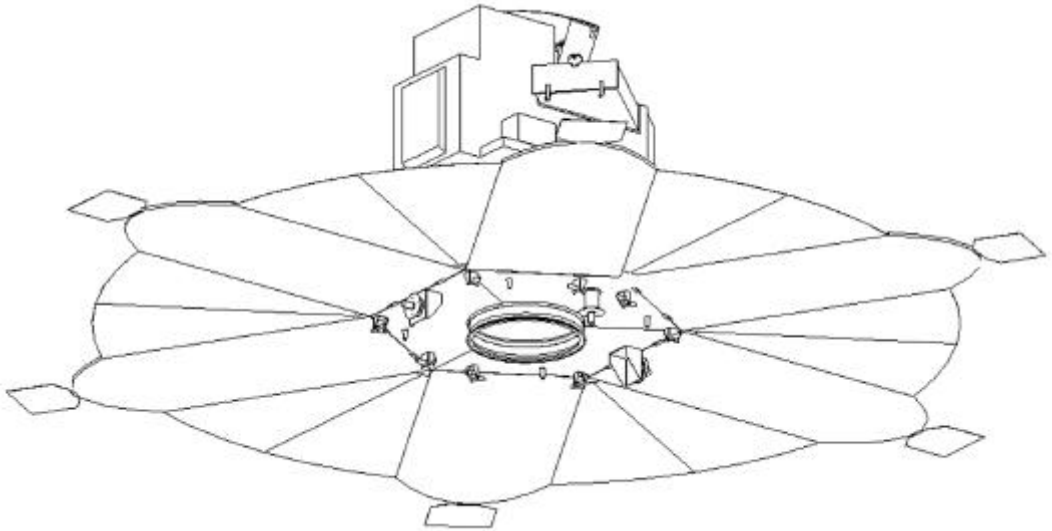
MLI Blanket Design



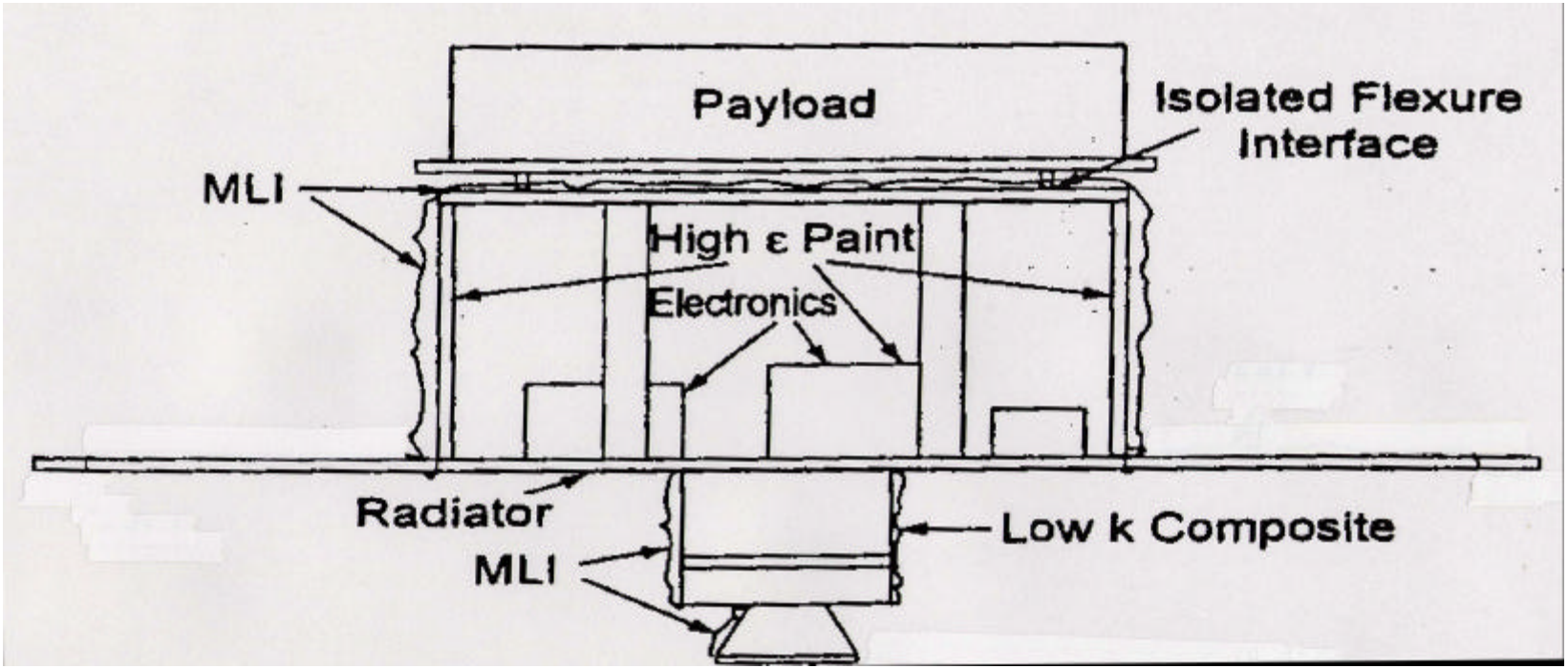
Preliminary Design







Current Baseline/Approach

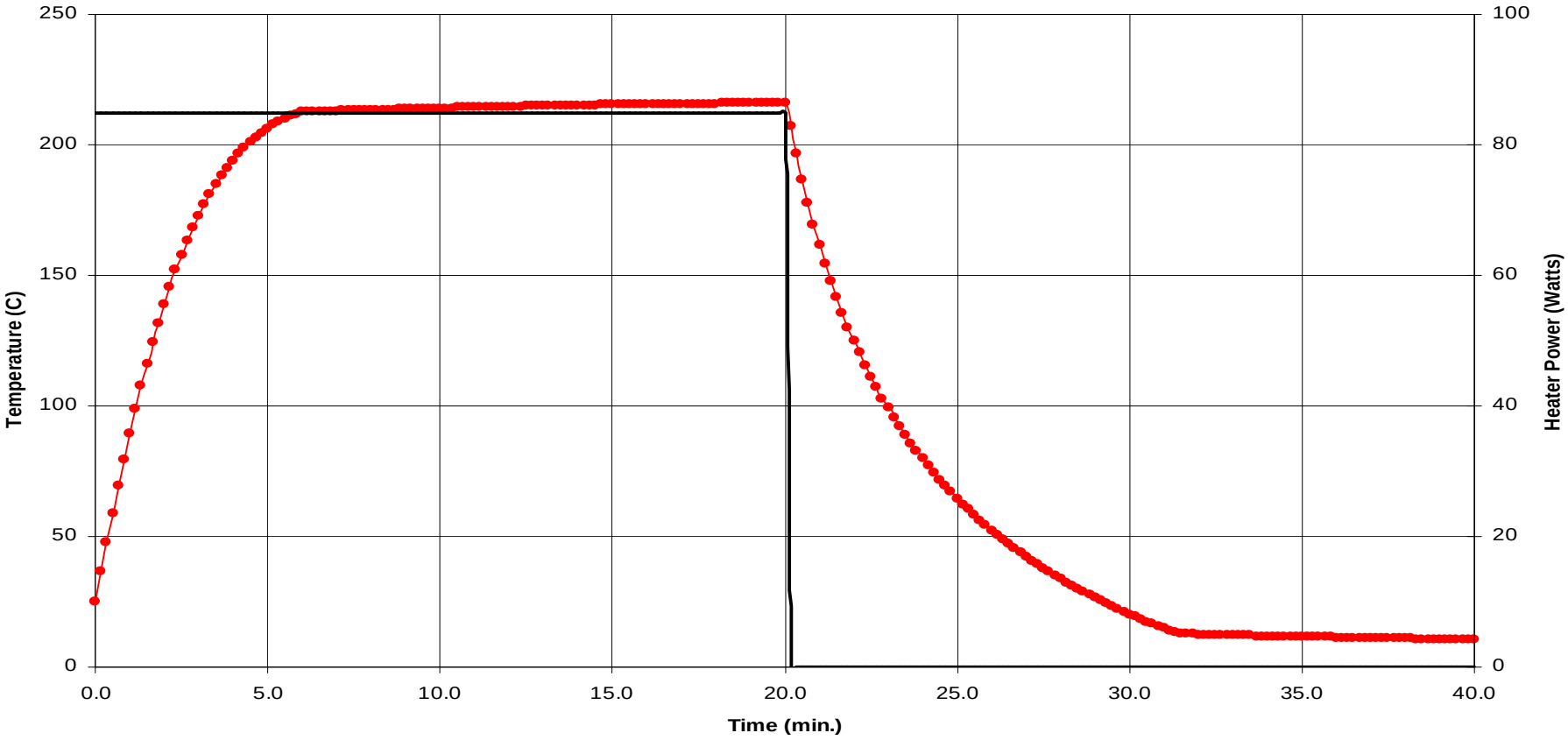


Trade Studies Preliminary Results

Trim Tab Heater Trade

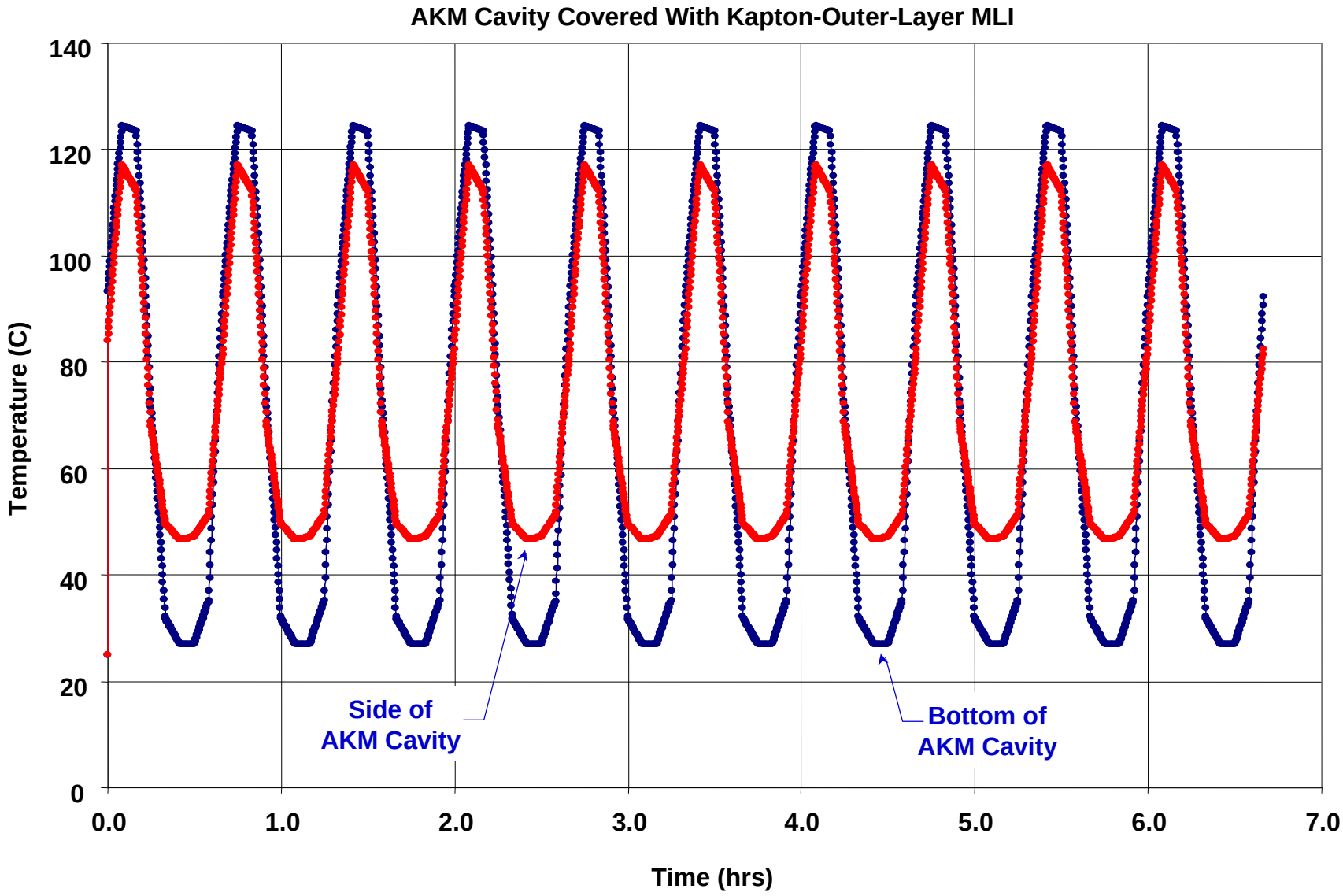
Case Study	Radiator	S/C Shear Panel	S/A Sun Side	S/A Shade Side	Beta Cloth Sun Shield	Trim Tab Heater Power	Trim Tab Sun Side	Trim Tab Shade Side
1. MLI on Shade Side of S/A Black Trim Tabs Without MLI on Shade Side	-17C	-100C/-140C	92C	-109C	-14C	250W	250C/50C	250C/50C
2. No MLI on Shade Side of S/A Black Trim Tabs Without MLI on Shade Side	-17C	-56C/-68C	41C	40C	-13C	270W	258C/58C	258C/58C
3. No MLI on Shade Side of S/A Black Trim Tabs With MLI on Shade Side	-17C	-59C/-69C	41C	40C	-13C	170W	298C/98C	-35C/-113C
4. Same As Case 2 But With Silver Teflon Trim Tabs	-17C	-51C/-68C	41C	40C	-13C	165W	209C/9C	209C/9C
5. Same As Case 3 But With Silver Teflon Trim Tabs	-17C	-53C/-69C	41C	40C	-13C	85W	210C/10C	-60C/-137C

Trade Studies Preliminary Results

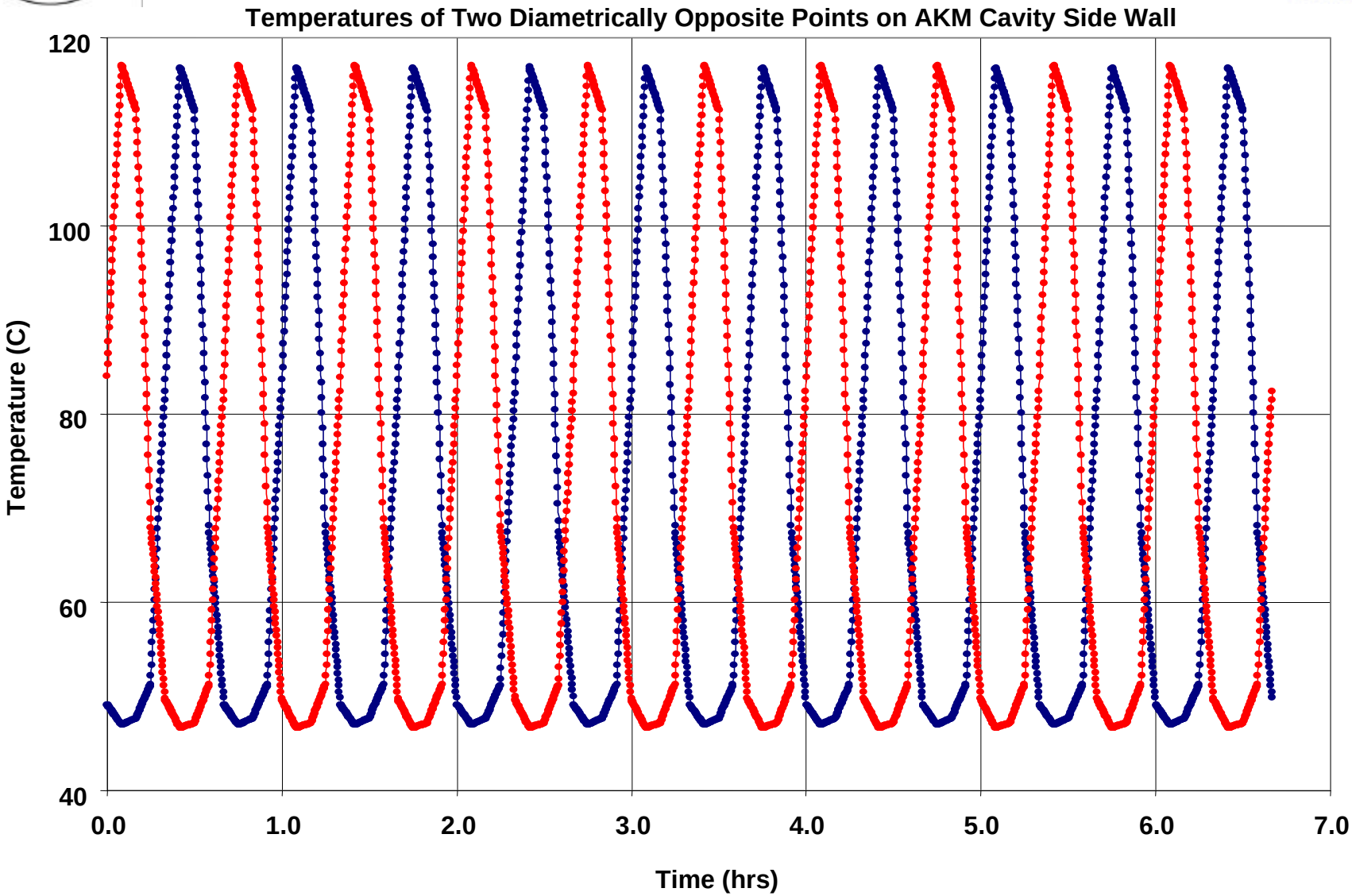


Trim Tab Temperature / Power

AKM Cavity Temperatures



AKM Cavity



AKM Cavity Covered With Kapton-Outer-Layer MLI

Trade Studies Preliminary Results

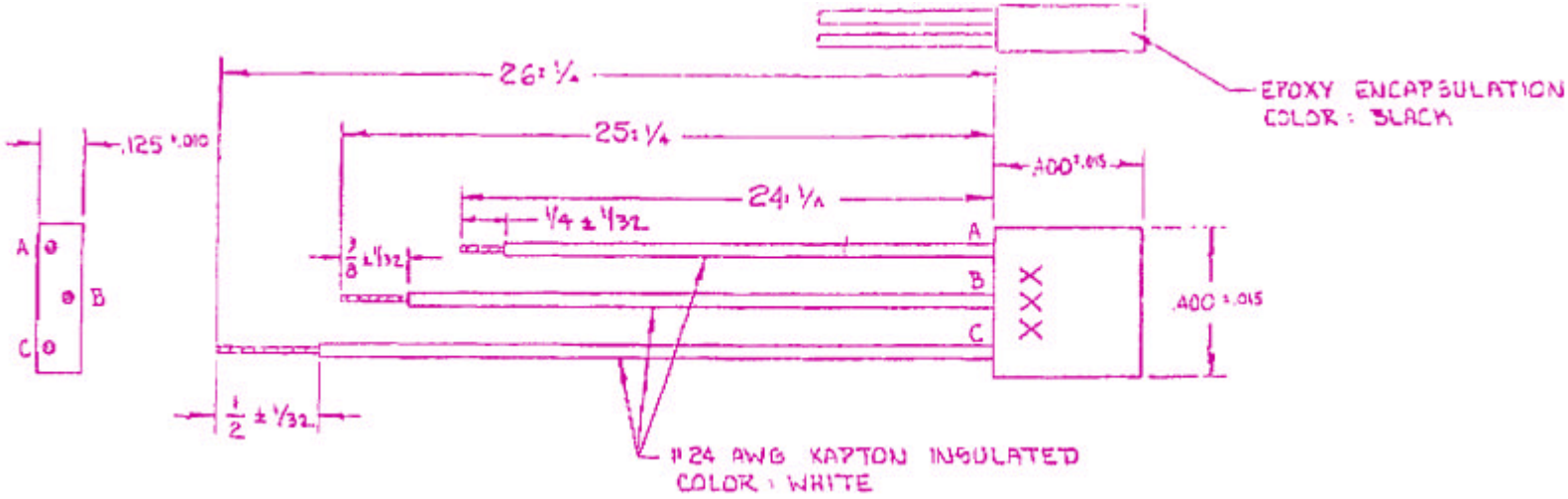
Panel Deployment Angle

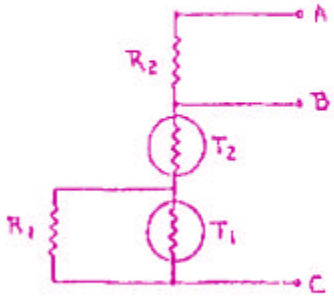
Case Study	AKM Cavity Bottom	AKM Cavity Side	S/C Shear Panel	S/A Sun Side	S/A Shade Side	Beta Cloth Sun Shield	Trim Tab Heater Power	Trim Tab Sun Side	Trim Tab Shade Side
1. Filename = FAME07.INP									
Solar Cells Cover 25% of S/A	+123/+28	+116/+47	-102.5/-72.4	-20.1/-19.7	-20.7/-20.3	-11.4/-11	80W	-15/+209	-153/-63
Silver Teflon on Shade Side of S/A	(see Note 1)	(see Note 1)	(see Note 1)	(see Note 1)	(see Note 1)	(see Note 1)		(see Note 2)	(see Note 2)
Silver Teflon Trim Tabs with MLI on Shade Side									
Kapton Outer-Layer MLI Covers AKM Cavity									
S/A Pitch Angle = 0 Deg.									
2. Filename = FAME05.INP									
Solar Cells Cover 25% of S/A	+123/+28	+117/+47	-98/-86.4	-22.0/-16.2	-22.6/-16.7	-18.3/-4.2	80W	-15/+209	-152/-63
Silver Teflon on Shade Side of S/A	(see Note 1)	(see Note 1)	(see Note 1)	(see Note 1)	(see Note 1)	(see Note 1)		(see Note 2)	(see Note 2)
Silver Teflon Trim Tabs with MLI on Shade Side									
Kapton Outer-Layer MLI Covers AKM Cavity									
S/A Pitch Angle = 5 Deg.									
3. Filename = FAME04.INP									
Solar Cells Cover 25% of S/A	+123/+28	+116/+48	-94.2/-86.8	-24.8/-14.8	-25.3/-15.4	-24/+0.5	80W	-15/+209	-148/-63
Silver Teflon on Shade Side of S/A	(see Note 1)	(see Note 1)	(see Note 1)	(see Note 1)	(see Note 1)	(see Note 1)		(see Note 2)	(see Note 2)
Silver Teflon Trim Tabs with MLI on Shade Side									
Kapton Outer-Layer MLI Covers AKM Cavity									
S/A Pitch Angle = 10 Deg.									
4. Filename = FAME06.INP									
Solar Cells Cover 25% of S/A	+123/+29	+117/+47	-92/-79	-27.4/-12	-27.9/-12.7	-39.5/+4.2	80W	-15/+209	-147/-63
Silver Teflon on Shade Side of S/A	(see Note 1)	(see Note 1)	(see Note 1)	(see Note 1)	(see Note 1)	(see Note 1)		(see Note 2)	(see Note 2)
Silver Teflon Trim Tabs with MLI on Shade Side									
Kapton Outer-Layer MLI Covers AKM Cavity									
S/A Pitch Angle = 15 Deg.									

Note 1: first number is maximum temperature for the indicated location.
second nember is minimum temperature on the diametrically opposite panel.

Note 2: first number is temperature when trim tab heater is ON
second number is temperature when trim tab heater is OFF

Thermistor





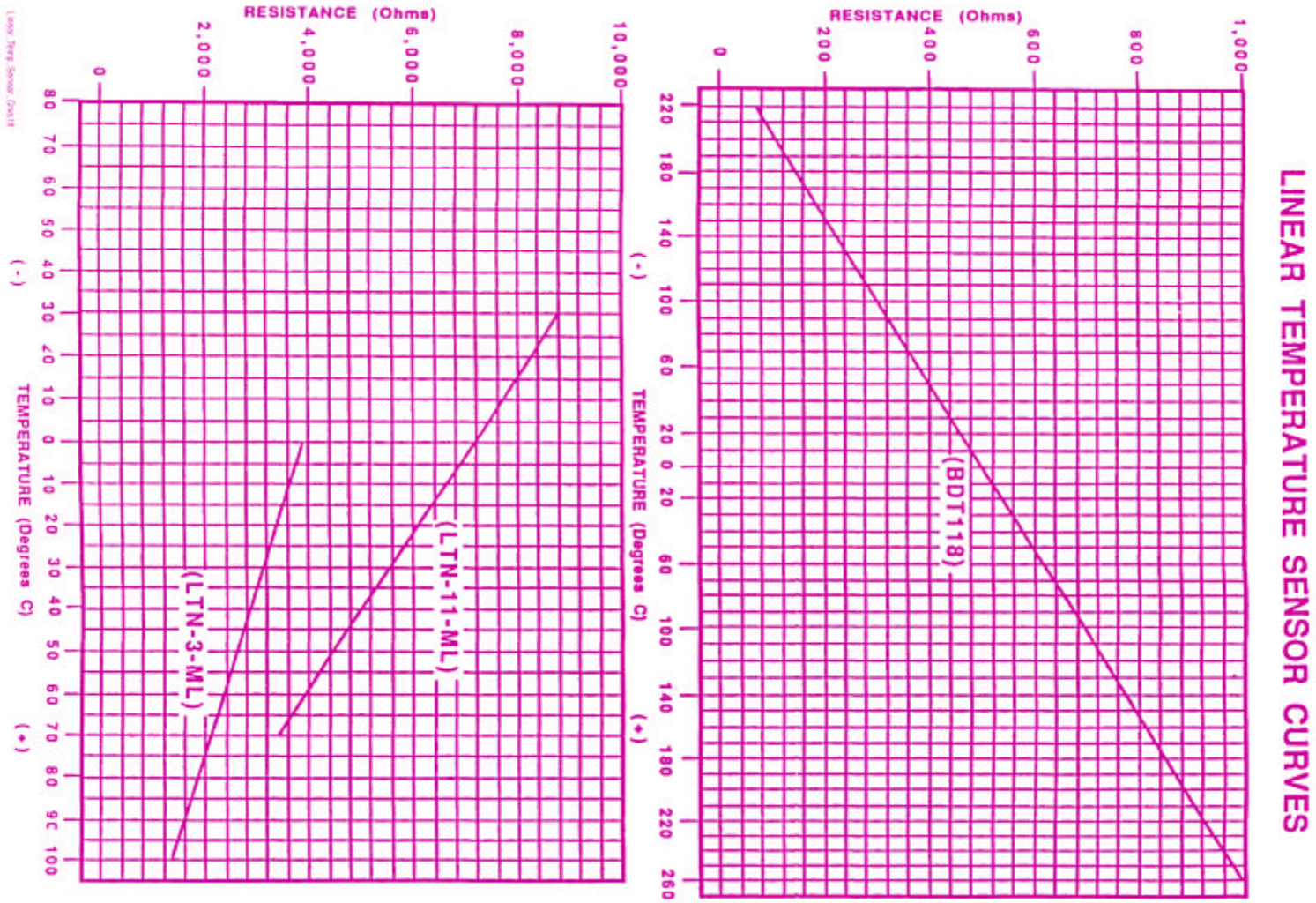
NOTES

1. R_o @ 25°C = 5649 Ω ± 1.5°C
2. MAX TEMP = 125°C
3. R_1 = 10,000 Ω
4. R_2 = 9530 Ω

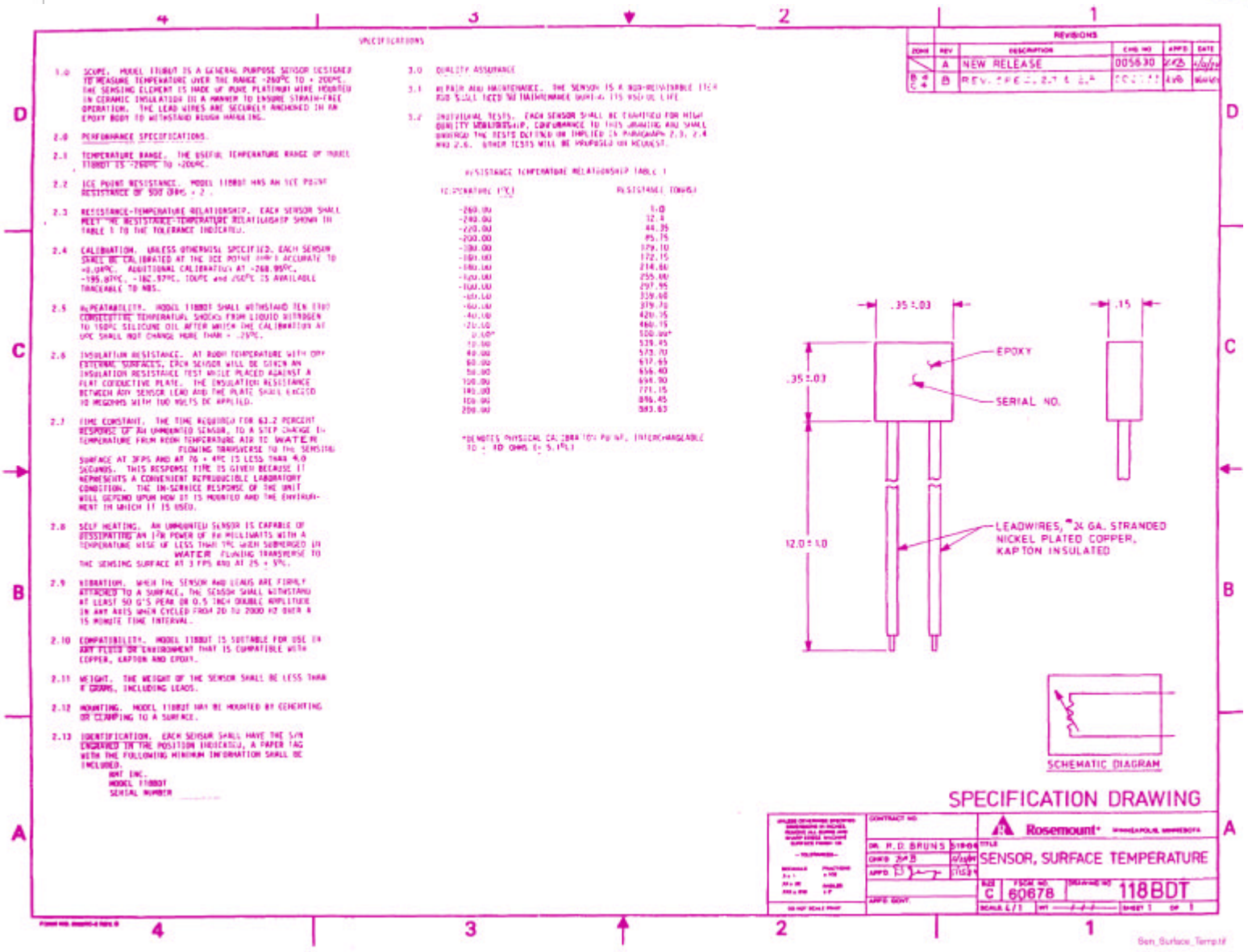
FORMERLY LTN-11 ML

TOLERANCES: UNLESS OTHERWISE NOTED, ALL DIMENSIONS ARE IN INCHES AND TOLERANCES ARE AS SHOWN HEREIN. FRACTIONS = ± 1/64; DECIMALS: .XX = .01, .XXX = .005; ANGLES = ± 0°30'	DRAWN CEM	10-28-88	FENWAL ELECTRONICS, A DIVISION OF KIDDE, INC., FRAMINGHAM, MASS. 01701
	CHECKED		
	APPD.	10-31-88	TITLE: THERMISTOR PROBE ASS'Y OUTLINE
	MFG.		
THIS INFORMATION IS THE PROPERTY OF FENWAL ELECTRONICS AND IS SUBMITTED IN CONFIDENCE AND IS NOT TO BE DISCLOSED OR UTILIZED WITHOUT WRITTEN PERMISSION.			
MATERIAL	FINISH: ✓	PLATING	
SHEET 1 OF 1	SCALE —	SIZE B	DWG. NO. 534-31A604-562 REV:

Thermistor Curves



RTD



SPECIFICATIONS

1.0 SCOPE. MODEL 118BDT IS A GENERAL PURPOSE SENSOR DESIGNED TO MEASURE TEMPERATURE OVER THE RANGE -260°C TO + 200°C. THE SENSING ELEMENT IS MADE OF PURE PLATINUM WIRE MOUNTED IN CERAMIC INSULATION IN A MANNER TO ENSURE STRAIN-FREE OPERATION. THE LEAD WIRES ARE SECURELY ANCHORED IN AN EPOXY BODY TO WITHSTAND ROUGH HANDLING.

2.0 PERFORMANCE SPECIFICATIONS.

2.1 TEMPERATURE RANGE. THE USEFUL TEMPERATURE RANGE OF MODEL 118BDT IS -260°C TO +200°C.

2.2 ICE POINT RESISTANCE. MODEL 118BDT HAS AN ICE POINT RESISTANCE OF 500 OHMS ± .2 .

2.3 RESISTANCE-TEMPERATURE RELATIONSHIP. EACH SENSOR SHALL MEET THE RESISTANCE-TEMPERATURE RELATIONSHIP SHOWN IN TABLE 1 TO THE TOLERANCE INDICATED.

2.4 CALIBRATION. UNLESS OTHERWISE SPECIFIED, EACH SENSOR SHALL BE CALIBRATED AT THE ICE POINT AND IS ACCURATE TO ±0.04°C. ADDITIONAL CALIBRATION AT -268.95°C, -195.81°C, -182.97°C, 100°C and 200°C IS AVAILABLE TRACEABLE TO NBS.

2.5 REPEATABILITY. MODEL 118BDT SHALL WITHSTAND TEN (10) CONSECUTIVE TEMPERATURE SHOCKS FROM LIQUID NITROGEN TO 150°C SILICONE OIL AFTER WHICH THE CALIBRATION AT 0°C SHALL NOT CHANGE MORE THAN ± .25°C.

2.6 INSULATION RESISTANCE. AT ROOM TEMPERATURE WITH DRY EXTERNAL SURFACES, EACH SENSOR WILL BE GIVEN AN INSULATION RESISTANCE TEST WHILE PLACED AGAINST A FLAT CONDUCTIVE PLATE. THE INSULATION RESISTANCE BETWEEN ANY SENSOR LEAD AND THE PLATE SHALL EXCEED 10 MEGOHMS WITH 100 VOLTS DC APPLIED.

2.7 TIME CONSTANT. THE TIME REQUIRED FOR 63.2 PERCENT RESPONSE OF AN UNMOUNTED SENSOR, TO A STEP CHANGE IN TEMPERATURE FROM ROOM TEMPERATURE AIR TO WATER FLOWING TRANSVERSE TO THE SENSING SURFACE AT 3FPS AND AT 70 ± 4°C IS LESS THAN 4.0 SECONDS. THIS RESPONSE TIME IS GIVEN BECAUSE IT REPRESENTS A CONVENIENT REPRODUCIBLE LABORATORY CONDITION. THE IN-SERVICE RESPONSE OF THE UNIT WILL DEPEND UPON HOW IT IS MOUNTED AND THE ENVIRONMENT IN WHICH IT IS USED.

2.8 SELF HEATING. AN UNMOUNTED SENSOR IS CAPABLE OF DISSIPATING AN 1PR POWER OF 80 MILLIWATTS WITH A TEMPERATURE RISE OF LESS THAN 1°C WHEN SUBMERGED IN WATER FLOWING TRANSVERSE TO THE SENSING SURFACE AT 3 FPS AND AT 25 ± 5°C.

2.9 VIBRATION. WHEN THE SENSOR AND LEADS ARE FIRMLY ATTACHED TO A SURFACE, THE SENSOR SHALL WITHSTAND AT LEAST 50 G'S PEAK OR 0.5 INCH DOUBLE AMPLITUDE IN ANY AXIS WHEN CYCLED FROM 20 TO 2000 HZ OVER A 15 MINUTE TIME INTERVAL.

2.10 COMPATIBILITY. MODEL 118BDT IS SUITABLE FOR USE IN ANY FLUID OR ENVIRONMENT THAT IS COMPATIBLE WITH COPPER, KAPTON AND EPOXY.

2.11 WEIGHT. THE WEIGHT OF THE SENSOR SHALL BE LESS THAN 8 GRAMS, INCLUDING LEADS.

2.12 MOUNTING. MODEL 118BDT MAY BE MOUNTED BY CEMENTING OR CLAMPING TO A SURFACE.

2.13 IDENTIFICATION. EACH SENSOR SHALL HAVE THE S/N ENGRAVED IN THE POSITION INDICATED, A PAPER TAG WITH THE FOLLOWING MINIMUM INFORMATION SHALL BE INCLUDED.
RMT INC.
MODEL 118BDT
SERIAL NUMBER _____

3.0 QUALITY ASSURANCE

3.1 REPAIR AND MAINTENANCE. THE SENSOR IS A NON-REPAIRABLE ITEM AND SHALL NEED NO MAINTENANCE DURING ITS USEFUL LIFE.

3.2 INDIVIDUAL TESTS. EACH SENSOR SHALL BE CERTIFIED FOR HIGH QUALITY WORKMANSHIP, CONFORMANCE TO THIS DRAWING AND SHALL WITHSTAND THE TESTS DEFINED OR IMPLIED IN PARAGRAPH 2.3, 2.4 AND 2.6. OTHER TESTS WILL BE PERFORMED ON REQUEST.

RESISTANCE TEMPERATURE RELATIONSHIP TABLE 1

TEMPERATURE (°C)	RESISTANCE (OHMS)
-260.00	5.0
-240.00	12.4
-220.00	44.35
-200.00	85.75
-180.00	129.10
-160.00	172.15
-140.00	214.60
-120.00	255.80
-100.00	297.55
-80.00	339.60
-60.00	379.70
-40.00	420.35
-20.00	460.15
0.00*	500.00*
10.00	539.45
40.00	573.70
60.00	617.65
80.00	656.40
100.00	698.90
140.00	771.15
160.00	896.45
200.00	980.83

*DENOTES PHYSICAL CALIBRATION POINT, INTERCHANGEABLE TO ± 40 OHMS (± 5.1°C)

.35 ±.03
.15
EPOXY
SERIAL NO.
.35 ±.03
12.0 ± 1.0
LEADWIRES, #24 GA. STRANDED NICKEL PLATED COPPER, KAPTON INSULATED

SCHEMATIC DIAGRAM

REVISIONS

ZONE	REV	DESCRIPTION	CHG NO	APPD	DATE
	A	NEW RELEASE	005630	[illegible]	[illegible]
[illegible]	B	REV. SPEC. 2.7 & 2.8	[illegible]	[illegible]	[illegible]

SPECIFICATION DRAWING

Rosemount MINNEAPOLIS, MINNESOTA

DR. R.D. BRUNS 5-19-94
CHKD [illegible]
APPD [illegible]
APPR. GOVT.

TITLE: SENSOR, SURFACE TEMPERATURE

SIZE C | FSCM NO. 60678 | DRAWING NO. 118BDT

SCALE 2/1 | WT [illegible] | SHEET 1 OF 1

Sen_Surface_Temp.tif