Cassini MLI Blankets High-Temperature Exposure Tests[1]

by

Edward 1. Lin and James W. Stultz
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Abstract

The Cassini spacecraft is currently under development for a mission designed to explore Saturn and its rings, satellites and magnetosphere, The Venus-Venus-Earth-Jupiter Gravity Assist (VVEJGA) trajectory will subject the spacecraft to a 0.61 AU (Astronomical Unit) high-temperature environment at perihelion. Temperatures on some sunlit blanket surfaces at 0.61 AU can reach levels that are beyond the service capability of the conventional Mylar/Dacron net MLI (Multi-Layer Insulation). For example, the RTG (Radioisotope Thermoelectric Generator) shade temperature is predicted to be around 300°C under the combined heating of the RTG (3900 W) and 2.7 suns (i.e., at 0.61 AU) during a trajectory correction maneuver (TCM). The main engine blanket temperature can reach 360°C under plume heating in conjunction with the 0.61 AU solar illumination. The majority of the blanket surfaces, however, will experience temperatures with an upper bound 'of 25(F'C.

Temperature limits for various MLI constituents and assemblies are first reviewed and evaluated (Table 1). Based on manufacturers' information and data from past test programs, "weak links" in several blanket layups are identified. The maximum allowable temperature for Mylar/Dacron net is determined to be 220°C. A layup consisting of 20 layers of embossed Kapton with appropriate outer and inner layers was once considered to be a baseline design, because Kapton can withstand temperatures in excess of 400°C. However, the high cost of embossed Kapton relative to Mylar/Dacron net changed the baseline to the current design which includes a standard layup and a high-temperature layup. The standard layup is a hybrid which consists of an outer layer of ITO-coated second surface aluminized Kapton (SSAK) with Nomex scrim, five layers of embossed Kapton, fifteen layers of Mylar/Dacron net, and a doubly aluminized Kapton inner layer. The high-temperature layup consists of a carbon-filled (black) Kapton outer layer, twenty intermediate layers of embossed Kapton, and a doubly aluminized Kapton inner layer. The high-temperature layup is utilized at a limited number of locations, while at least 90% of the blankets are of the standard layup.

The verification of both layups' capability to meet all temperature requirements has been accomplished by a comprehensive test program which addressed their high-temperature

---

[1] The work described in this paper was carried out by the Jet Propulsion Laboratory under a contract with the National Aeronautics and Space Administration. The paper is submitted to the 3.3rd AIAA Aerospace Sciences Meeting, to be held in Reno, NV, on Jan 9-12, 1995.

survivability, effective emittance, and optical and electrical properties. This paper focuses on the high-temperature exposure tests which helped define the hybrid standard layup, and which demonstrated the adequacy of both layups in withstanding their respective thermal environments.

Two series of tests were conducted. The first employed a small bell-jar vacuum chamber, as shown in Figs. 1 and 2. The inset in Fig. 2 shows the essence of the test setup where heat was driven through the blanket from the hot plate to the cold plate. The blanket samples with instrumentation are shown in Figs. 3 and 4. Typical test results, in terms of temperature profiles across the blanket samples, are presented in Figs, 5, 6 and 7. The tests show (Fig. 5) that the standard layup is able to withstand an outer layer temperature of 250°C, with no visible damage occurring to any layer and with all layer temperatures well within the material limits. Note that the first Mylar layer is at 180°C which is 40°C below the material limit, Also, increased cold plate temperatures (i, e., hardware temperatures on the spacecraft) are seen to have little impact on Mylar vulnerability. The addition of five more Iayers of Kapton reduces the first Mylar layer temperature by 40°C (Fig. 6), a step that can be taken if extra protection is needed. For the high-temperature layup, the tests show (Fig. 7) that it is fully capable of sustaining an outer-layer temperature of 430°C; no visible damage occurred to any layer and all layer temperatures are within the material limits. The monotonic decrease of blanket layer temperatures from the hot side to the cold side is as expected in all cases.

The second series of tests employed a solar simulator, with the test article suspended inside a 3-ft-diameter vacuum chamber (Fig. 8). l'he chamber was cooled by liquid nitrogen, and the aluminum box that the blanket enclosed was controlled to different temperature levels. When exposed to a 2.7-sun illumination from the solar simulator, the temperature profiles across the blanket layers are as shown in Figs. 9 and 10. Figure 9 shows that the first Mylar layer saw a temperat ure of 130°C, substantial] y below the material limit of 220°C. The SSAK outer layer (Fig. 9) saw a temperature of 200°C, while the black Kapton (Fig. 10) saw 250°C, reflecting a difference in absorptivity /emissivity ratio between the t wo, These results corroborate with those from the bell-jar tests, and indicate that the outer layer temperatures agree reasonably with predictions.

Both the standard and high-temperature layups have been demonstrated to be capable of withstanding all Cassini mission thermal environments with considerable margins. The paper will provide further details on the layup design, test setups, test procedures, other related results, and pertinent interpretations. These results on embossed Kapton and hybrid Ml .1's should be of general applicability, and not merely valid within the Cassini context.

TABLE 1. TEMPERATURE LIMITS FOR CASSINI MULTILAYER INSULATION BLANKET CONSTITUENTS AND ASSEMBLES

Constituent	Melting Point(C)	Zero Strength Temperature(C)	Field Service Temperature (C)
Kapton film	None*	815*	-269 to +400*
Mylar film	250'	248"	-60 to +1 50'
Teflon film	327*	31 o*	
Dacron net	256"	245*	
Nomex net/scrim	427*		
Glass scrim	>400		
Adhesive			
3P			Max. 200-260 #
Acrylic			Max. 120 #
Silicone			Max. 150 #

Assembly .*	Allowable Temperature Range (C) Continuous	Intermittent
1. Embossed Kapton layers + ITO-coated SSAK w/3P bonded Nomex scrim outerlayer	-184 to +149 @	-184 to +260 @
2. Embossed Kapton layers + black Kapton w/3P bonded Nomex scrim outerlayer	-184 to +149 @	-184 to +260 @
3. Mylar/Dacron net layers + ITO-coated SSAK w/3P bonded Nomex scrim outerlayer	-251 to +121 @	Max. 220$
4. Mylar/Dacron net layers + black Kapton w/3P bonded Nomex scrim outerlayer	-251:0 +121 @	Max. 220$
5. Embossed Kapton layers + Carbon filled 1.0 mil Kapton w/VDA outerlayer	-251 to +288@	-251 to +399@

Notes:

.Du Pent technical information bulletin

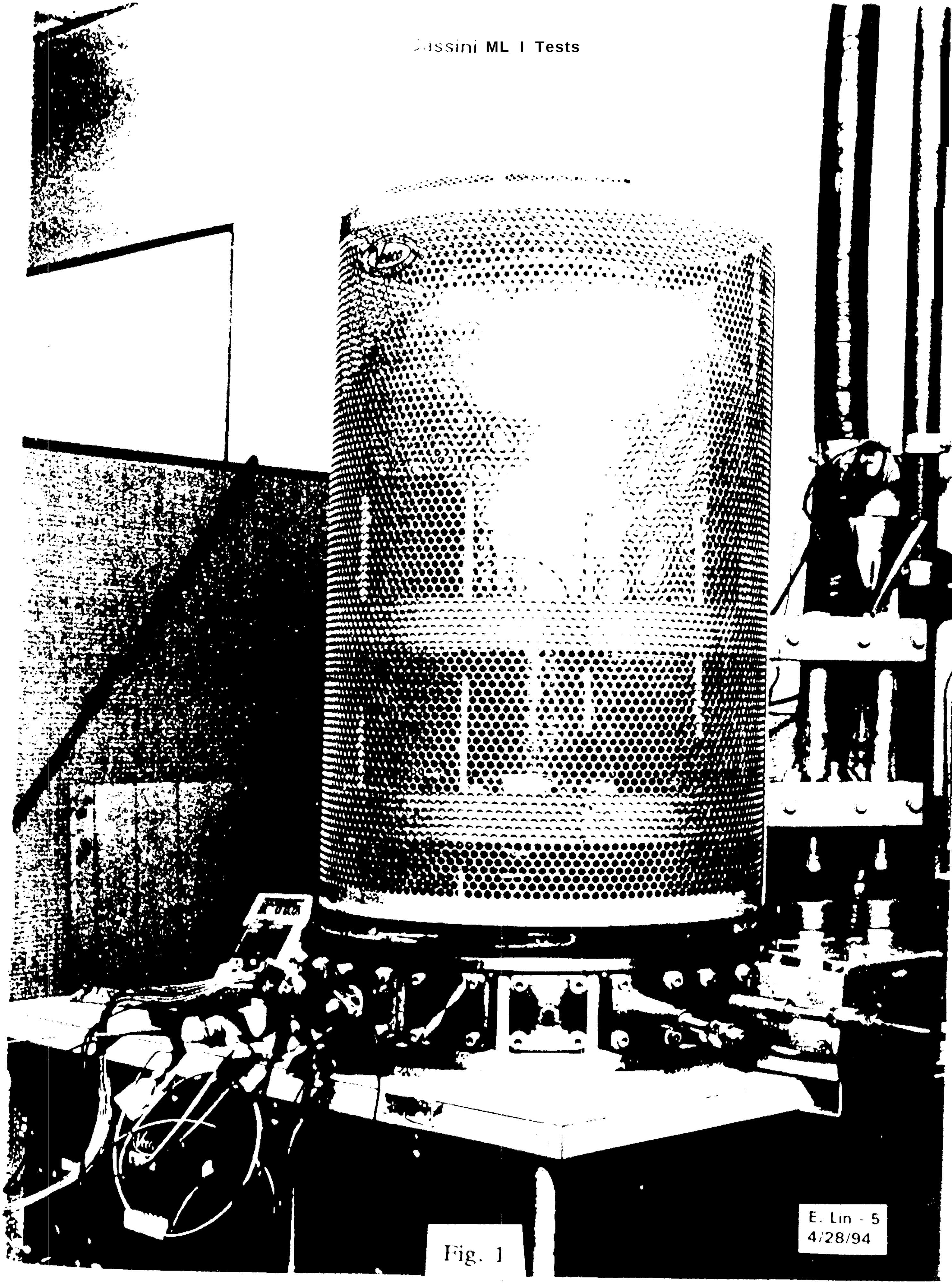
Sheldahl product information, P. Ellingboe, private communication

@ Sheldahl Red Book, Rev. 7/89

.S IOM 3547-GLL-87-O02, C. Cagle, 1/12/87; IOM 3547-GLL-82-134, T. W. Irwin, 9/30/82.

“” The limiting constituents are: Assemblies 1 & 2- the 3P adhesive; Assemblies 3 & 4- Mylar/Dacron net; Assembly 5- the outerlayer

Cassini ML I Tests



E. Lin - 5
4/28/94

Fig. 1


Cassini MLI Tests
Heated Plate
MLI
Water-cooled Plate
E. Lin - 5A
4/28/94

Fig. 2

Fig. 3

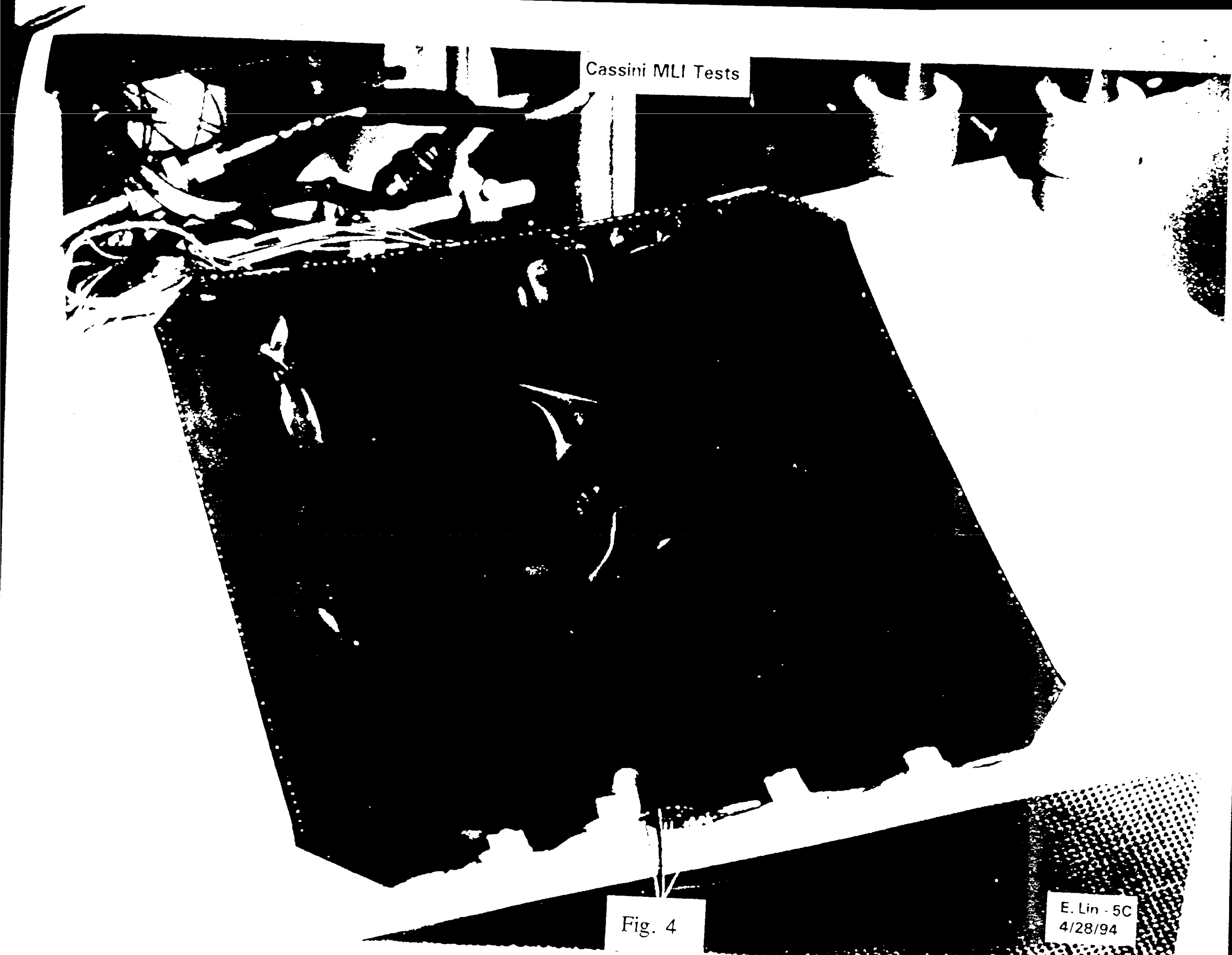


Fig. 4

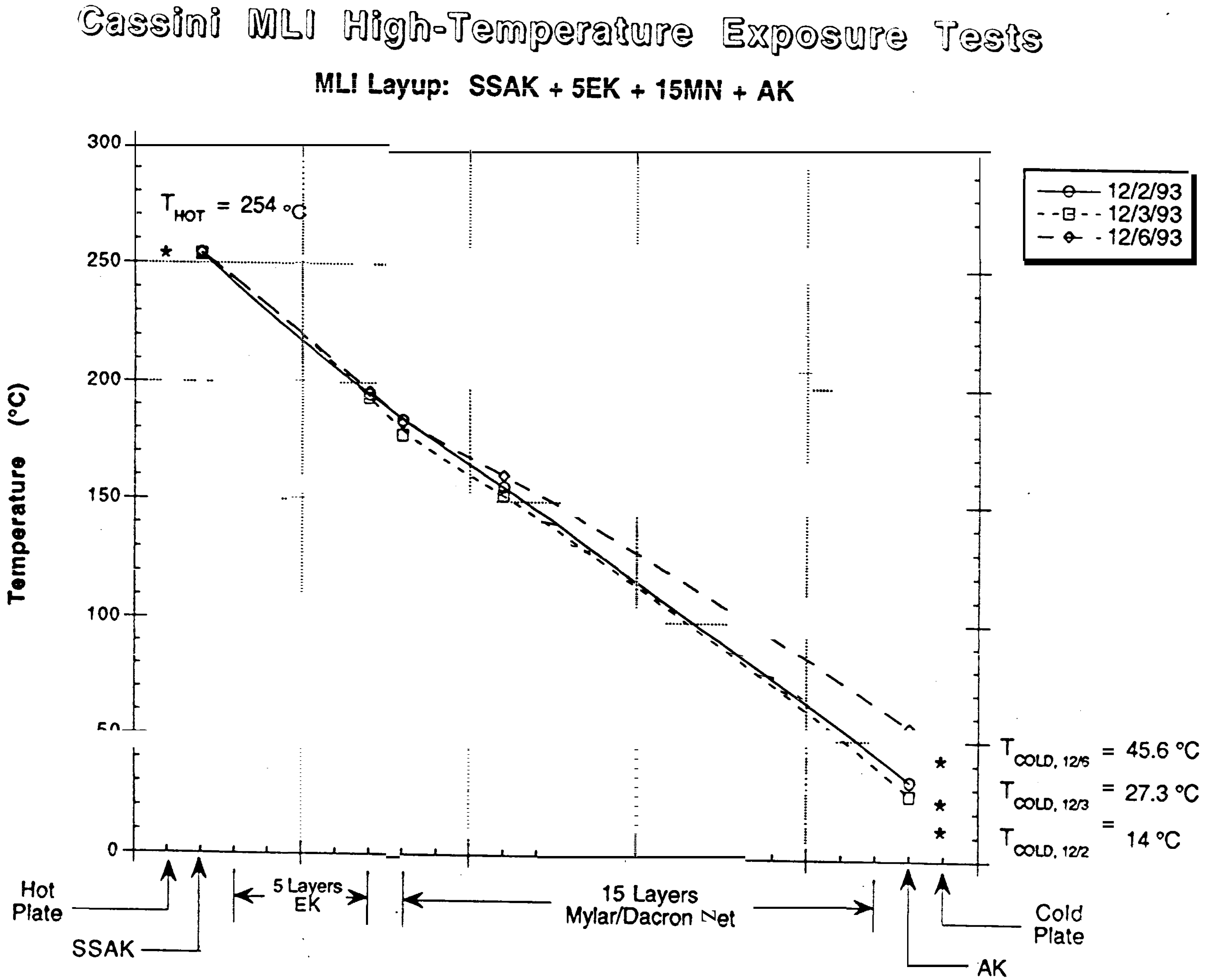


Fig. 5

E. Lin - 6
4/28/94

Cassini MLI High-Temperature Exposure Tests

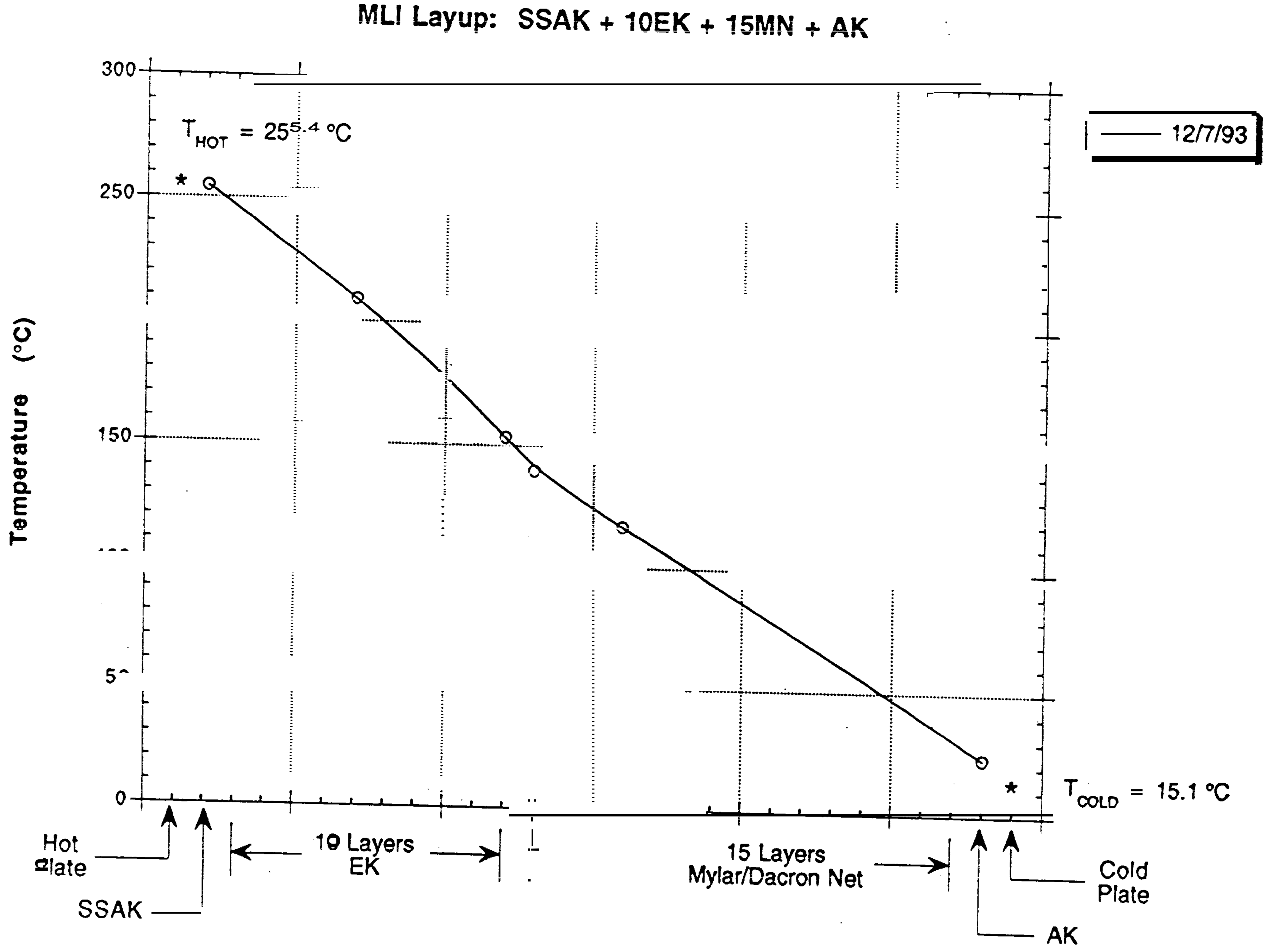


Fig. 6

Cassini MLI High-Temperature Exposure Tests

MLI Layup: BK + 20EK + AK

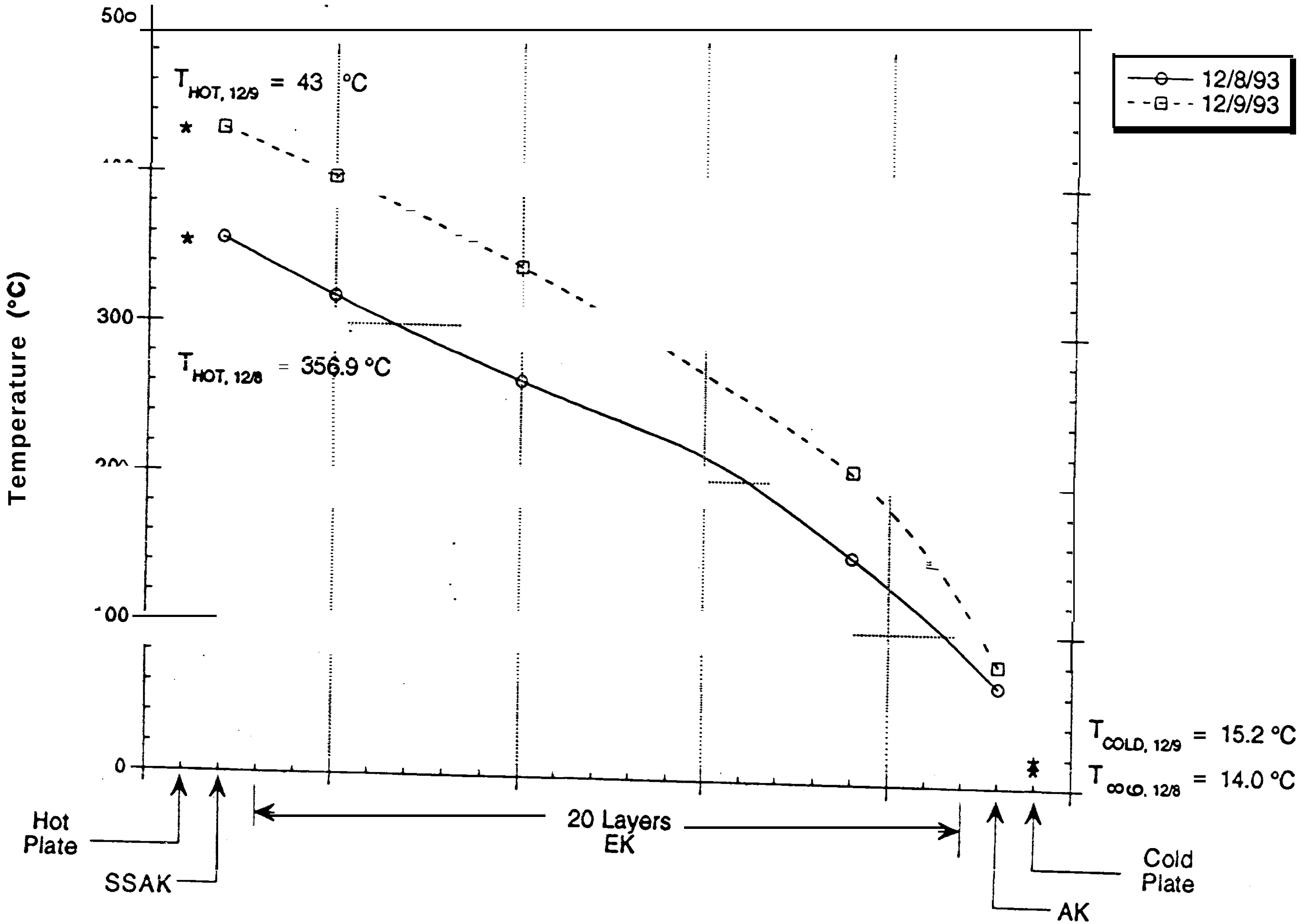


Fig. 7

E. Lin - 7
4/28/94

Cassini MLI Tests

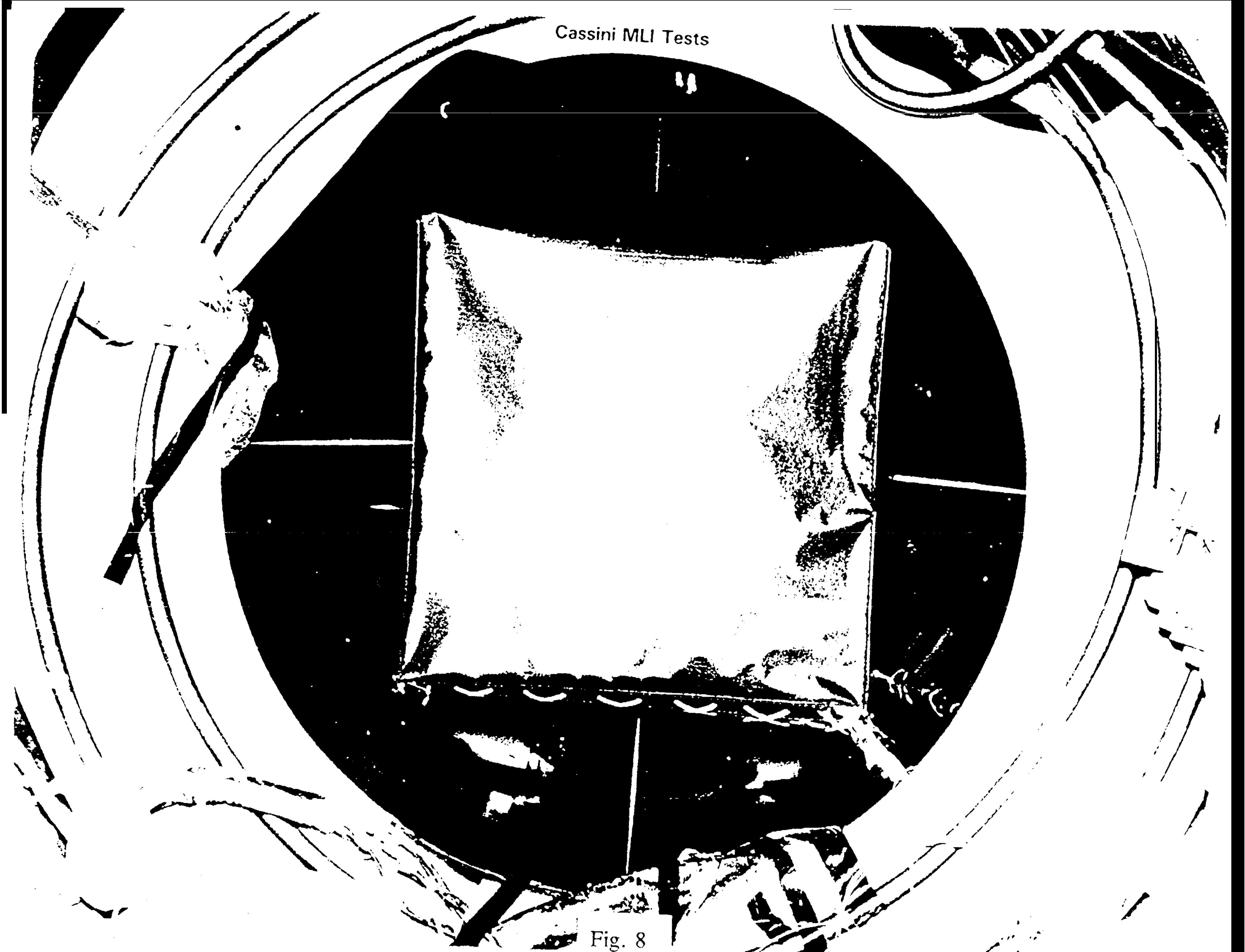


Fig. 8

Cassini MLI Tests: Phases 4a, 4b, and 4c

MLI-A Temperature Profile across Solar-Illuminated Layers

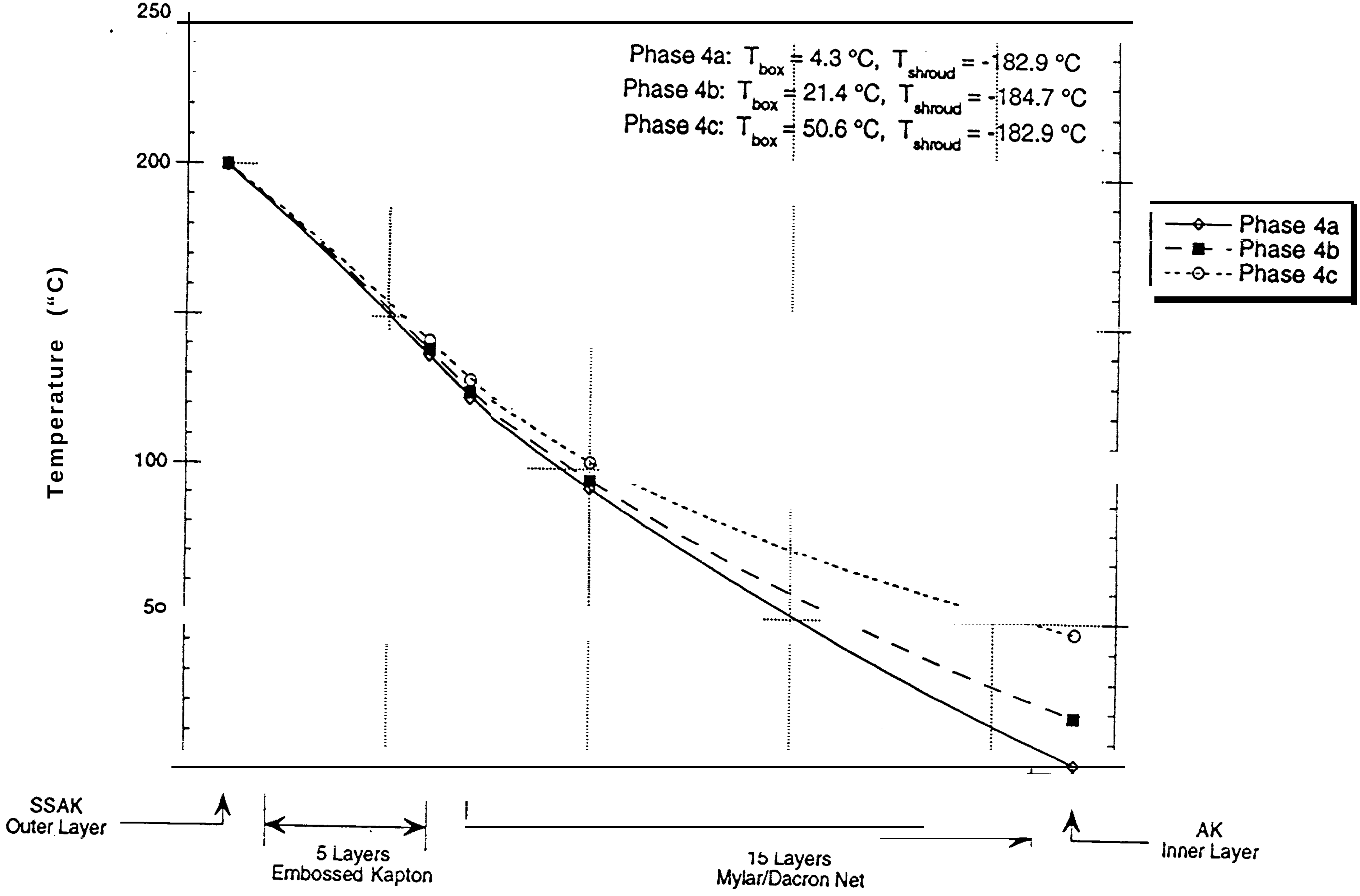


Fig 9

E. Lin - 16
4/28/94

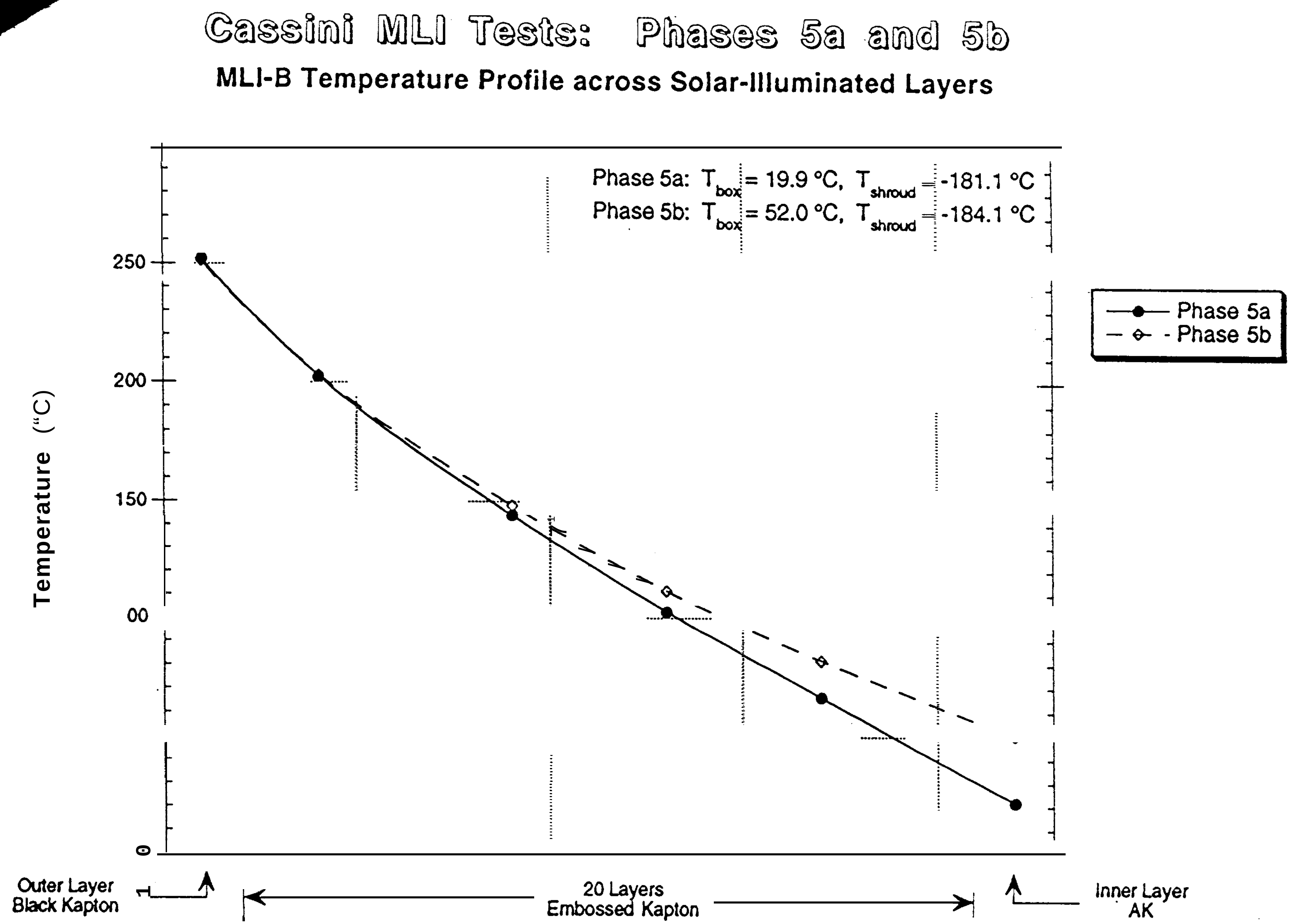


Fig. 10

E. Lin - 17
4/28/94