CR-170894

TECHNICAL NOTE

LOCKHEED
Missiles & Space Company, Inc.
Huntsville Research & Engineering Center

SQT

Contract NAS8-32982 **Date** 11 October 1982 **Doc.** LMSC-HREC TN D867581

Title EVALUATION OF SRB PHENOLIC TPS MATERIAL MADE BY AN ALTERNATE VENDOR

FOREWORD

This report documents the tests conducted to evaluate the adequacy of SRB phenolic TPS material supplied by an alternate vendor chosen by United Space Boosters, Inc. (USBI), to replace the current phenolic TPS sections used thus far on the first four Shuttle flights. The work was performed under Contract NAS8-32982, "Solid Rocket Booster Thermal Protection System Material Development." The NASA Contracting Officer's Representative for this work is Mr. Bill Baker, EP44.

INTRODUCTION

Verification tests were conducted for the current line of phenolic TPS and are documented in a Lockheed report (Ref. 1). Similar tests were planned in this new series of runs to verify the alternate phenolic material. Since some modifications were made to the Hot Gas Facility in which the tests were performed, it was decided to recalibrate the test models used to test the alternate phenolic TPS. The phenolic TPS is applied mainly to the attach and kick rings of the SRB. Full-scale sectional models of both the attach and kick ring structure were made up with 0.0265 in. thick stainless steel thin skin covers with thermocouples on them to determine the heating rates. Such models were made up for both the forward and rear faces of the kick ring which has a different configuration on each side. The thin skins were replaced with the alternate phenolic TPS sections cut from flight hardware configuration phenolic parts as supplied by the new vendor. Two tests were performed for each configuration of the attach and kick rings and the samples were exposed

to the flow for a duration that gave a heat load equivalent to that obtained in the series of runs made for the current line of phenolic TPS as in Ref. 1.

The samples performed very well with no loss of any phenolic layers. The post-test samples looked better than those used to verify the current phenolic TPS.

TECHNICAL DISCUSSION

Figures 1 and 2 show the thin skin calibration models of the forward and aft face of the kick ring. A photograph of the attach ring calibration model is not available. Three 5-sec runs were made in the Hot Gas Facility for repeatability on each of the three models. The average cold-wall heating rates deduced from the temperature-time slopes of the responses measured by the thermocouples are shown in Figs. 3 through 5. The test samples were cut from a longer flight configuration section in case of the kick ring and from a channel shaped section of the alternate phenolic supplied by the new vendor. The models were completed using the old "Edler" small grey seal as seen in the pre- and post-test photographs of the test models in Figs. 6 through 17. The seal was lost in one attach ring test and eroded considerably in the other repeat test. However, the phenolic TPS performed excellent in all tests. In the case of the kick ring, the rear face was tested first and the same TPS was reconfigured for testing on the other face. When testing the forward face of the kick ring, the Z-section phenolic part used on the lower side of the face was from a previous, old "Edler" consignment of parts. It is seen to have lost layers in contrast to the new alternate phenolic TPS (see Figs. 14 through 17).

The test duration for each of the three types of tests was reevaluated based on heating rates measured during the new calibration runs and such that the heat loads obtained were identical to those in the verification tests performed to qualify the present phenolic TPS. The calculations and logic used to determine these run times are shown on the HGF Test Requirements log sheets shown in Figs. 18, 19 and 20.

The test samples were each instrumented with two thermocouples on the back side of the phenolic test face. Maximum temperatures indicated were in the neighborhood of 250 F except when near the end of the run temperatures shot up after the grey seals broke on the two attach ring models.

CONCLUSIONS

The alternate phenolic TPS material performed excellently, withstanding the shear and heat loads required for the SRB design trajectory. The phenolic cloth layers did not delaminate or bubble, indicating a well processed product. This alternate phenolic material performed better than the current baselined phenolic material.

Z.S. Karu

Approved

W.G. Dean, Project Engineer
Contract NAS8-32982

B. Hobson Shirley, Manager (Acting)
Systems Engineering Section

Attach: Figs. 1 through 20

REFERENCE

1. Wojciechowski, C.J., "SRB TPS Verification Test Results; Phenolic Glass on Kick Ring and ET/SRB Aft Attach Ring," LMSC-HREC TM D697991, Lockheed Missiles & Space Company, Huntsville, Ala., June 1980.

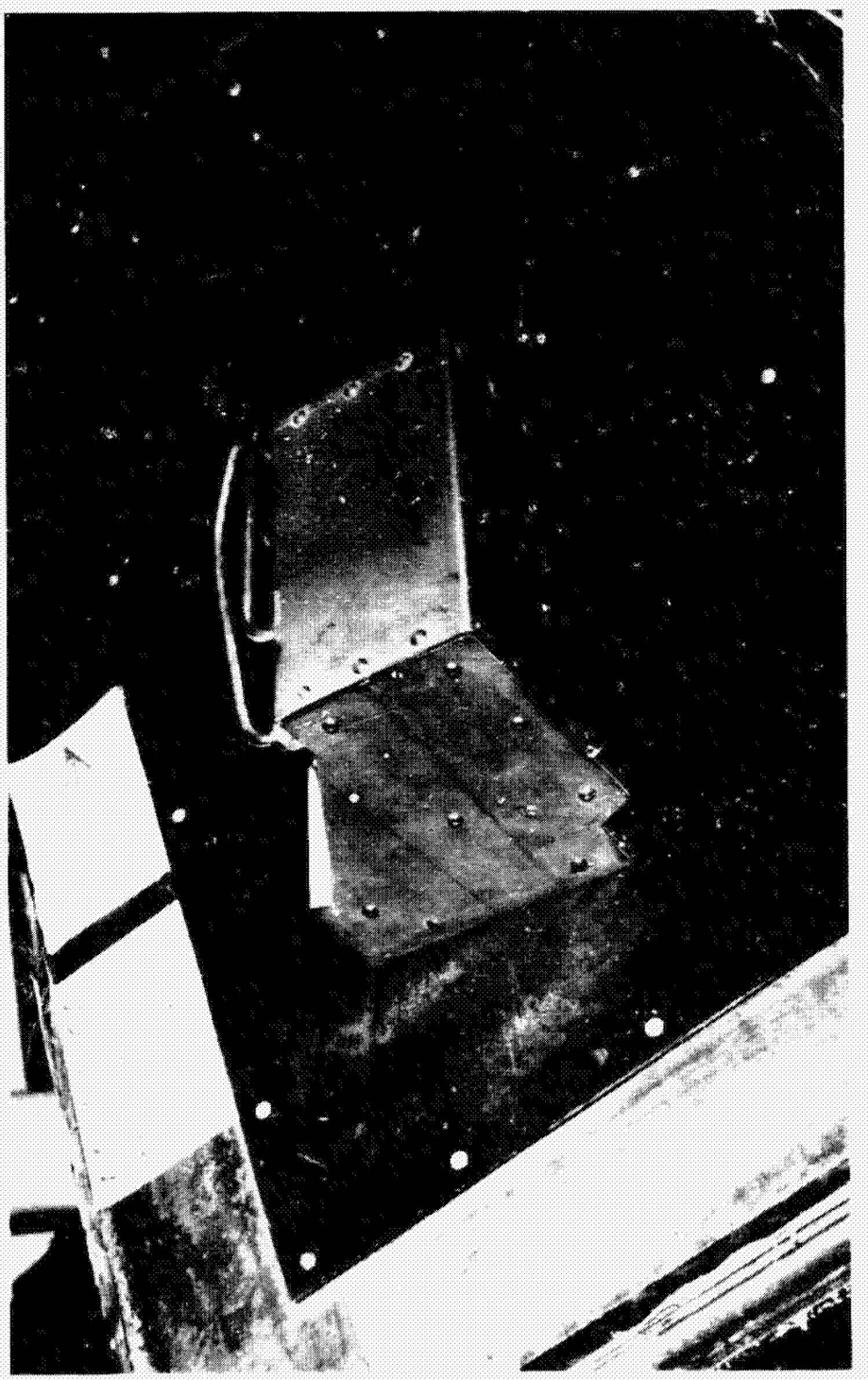

Fig. 1 - Thin Skin Thermocouple Model of Forward Face of Kick Ring at 15-deg Angle of Attack in Hot Gas Facility

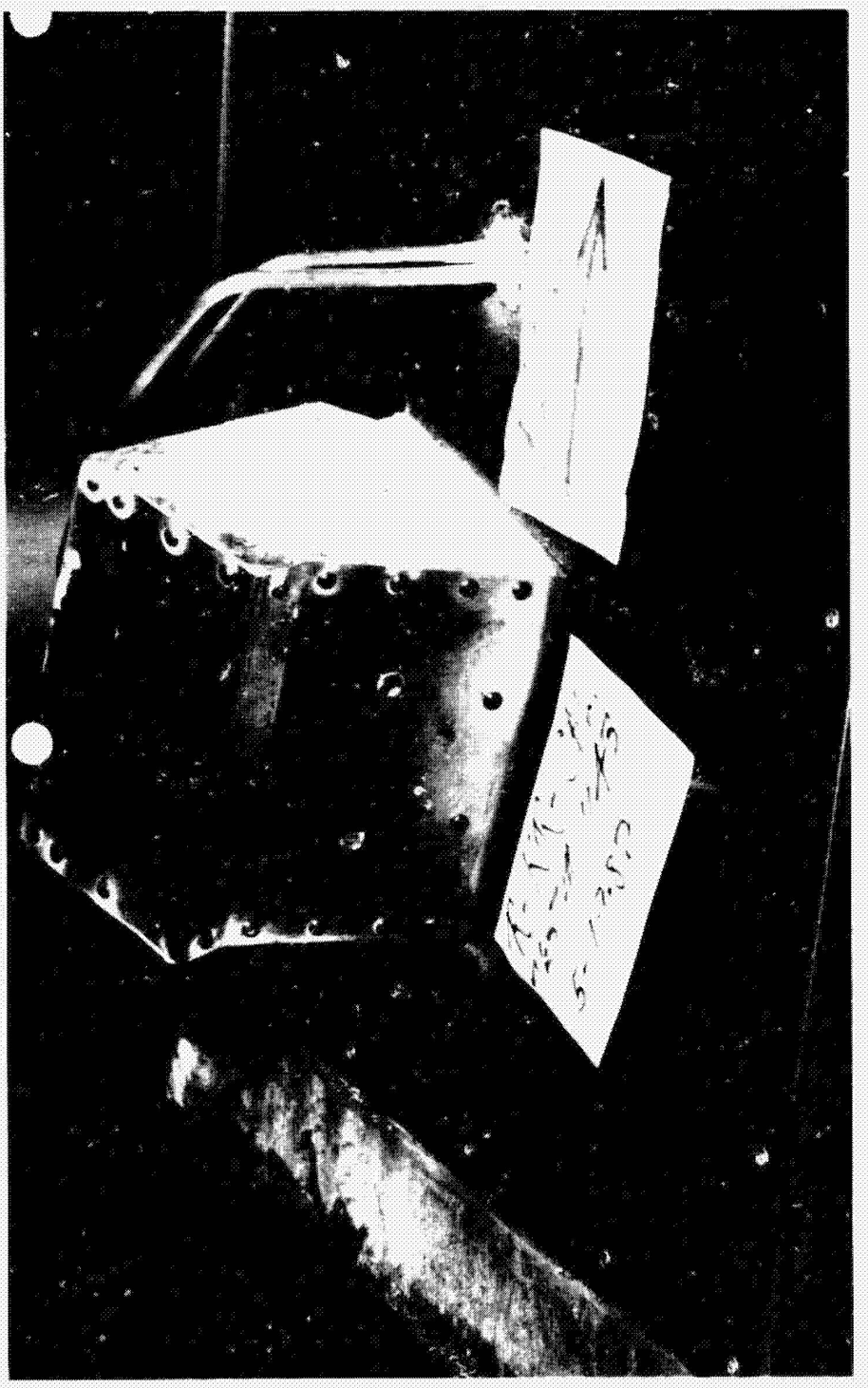

Fig. 2 - Thin Skin Thermocouple Model of Rear Face of Kick Ring at 15-deg Angle of Attack in Hot Gas Facility

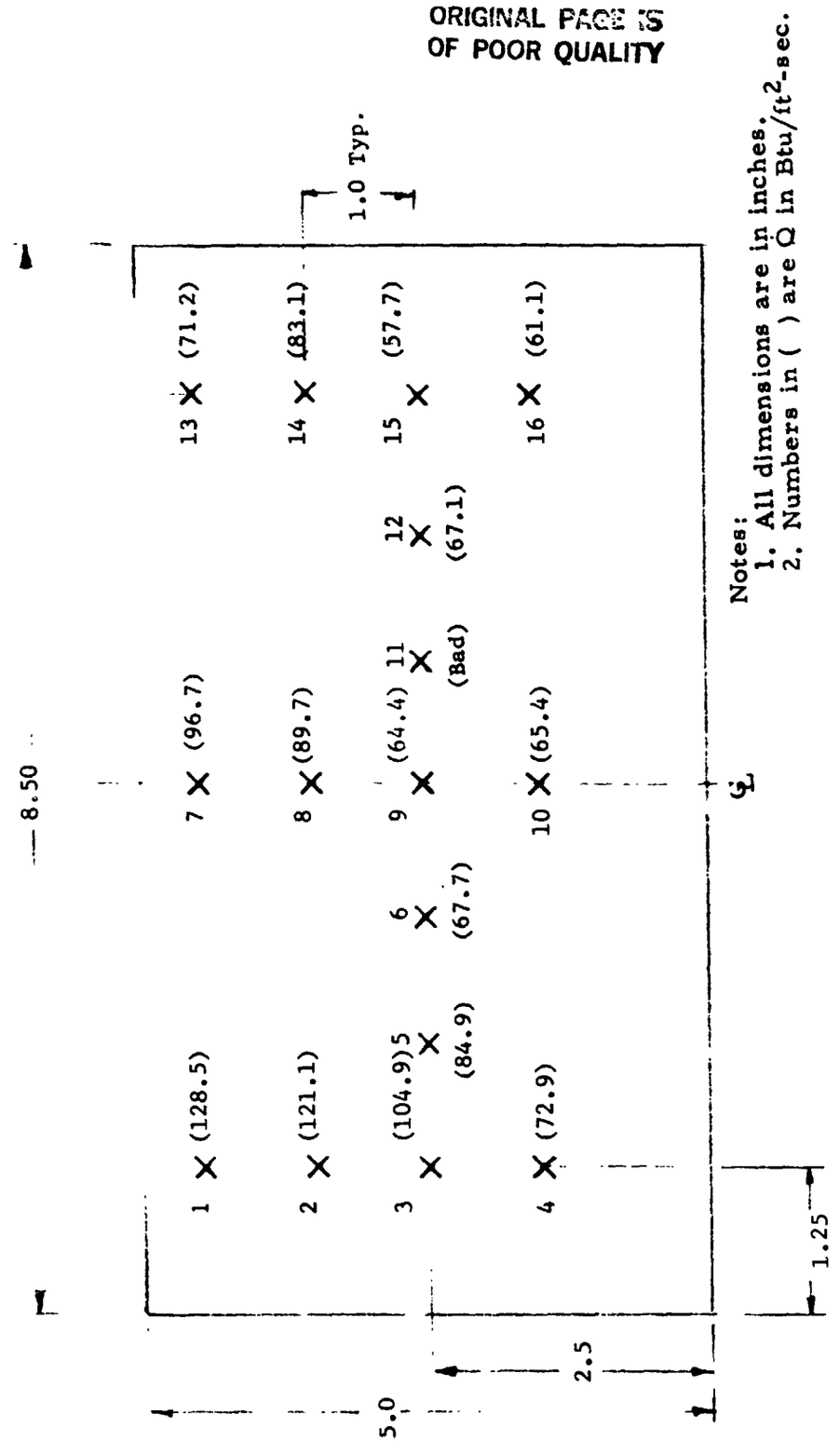

Fig. 3a - Front View of Attach Ring Thin Skin Thermocouple Cal Model Showing Measured Heating Rates (Run 1139)

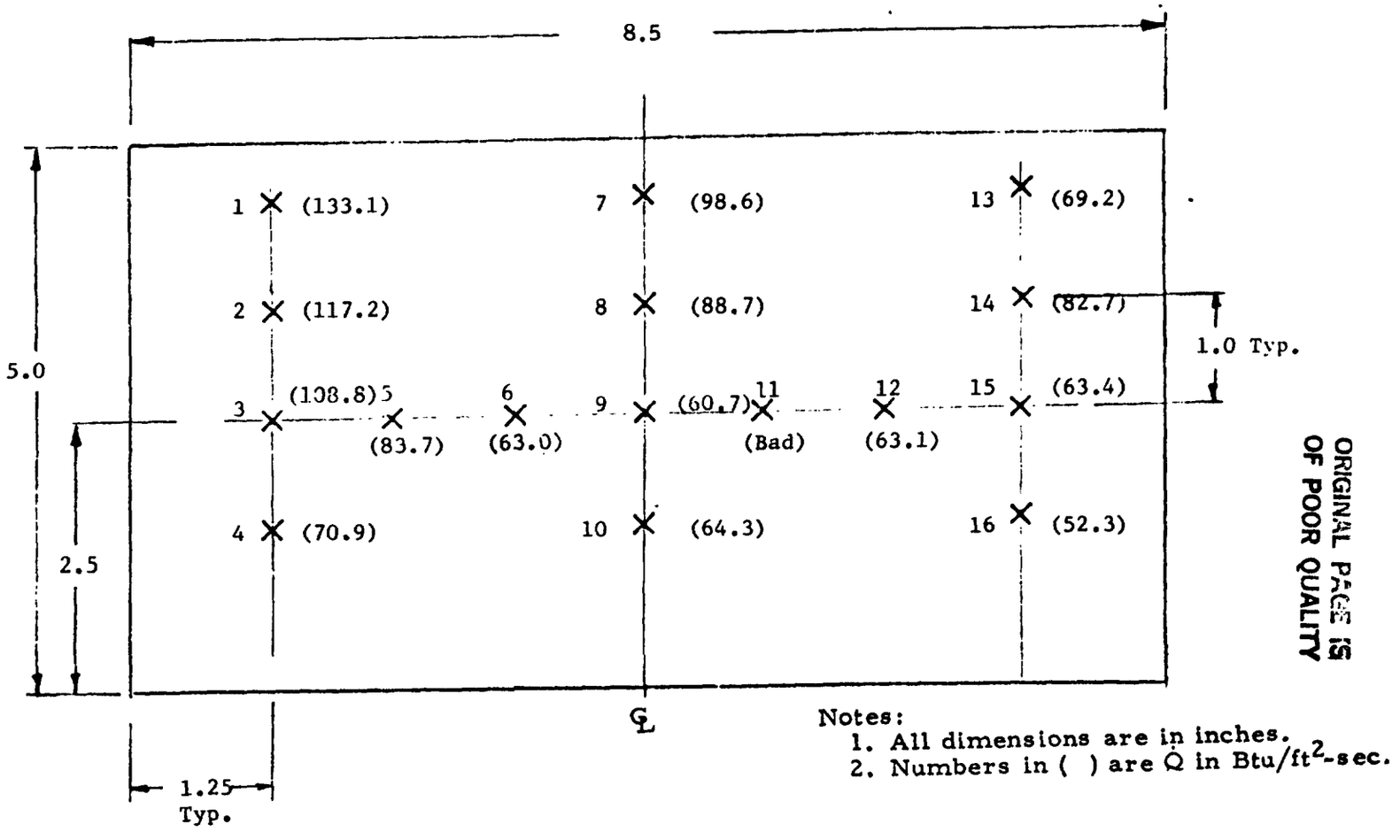

Fig. 3b - Front View of Attach Ring Thin Skin Thermocouple Cal Model Showing Heating Rates (Run 1140)

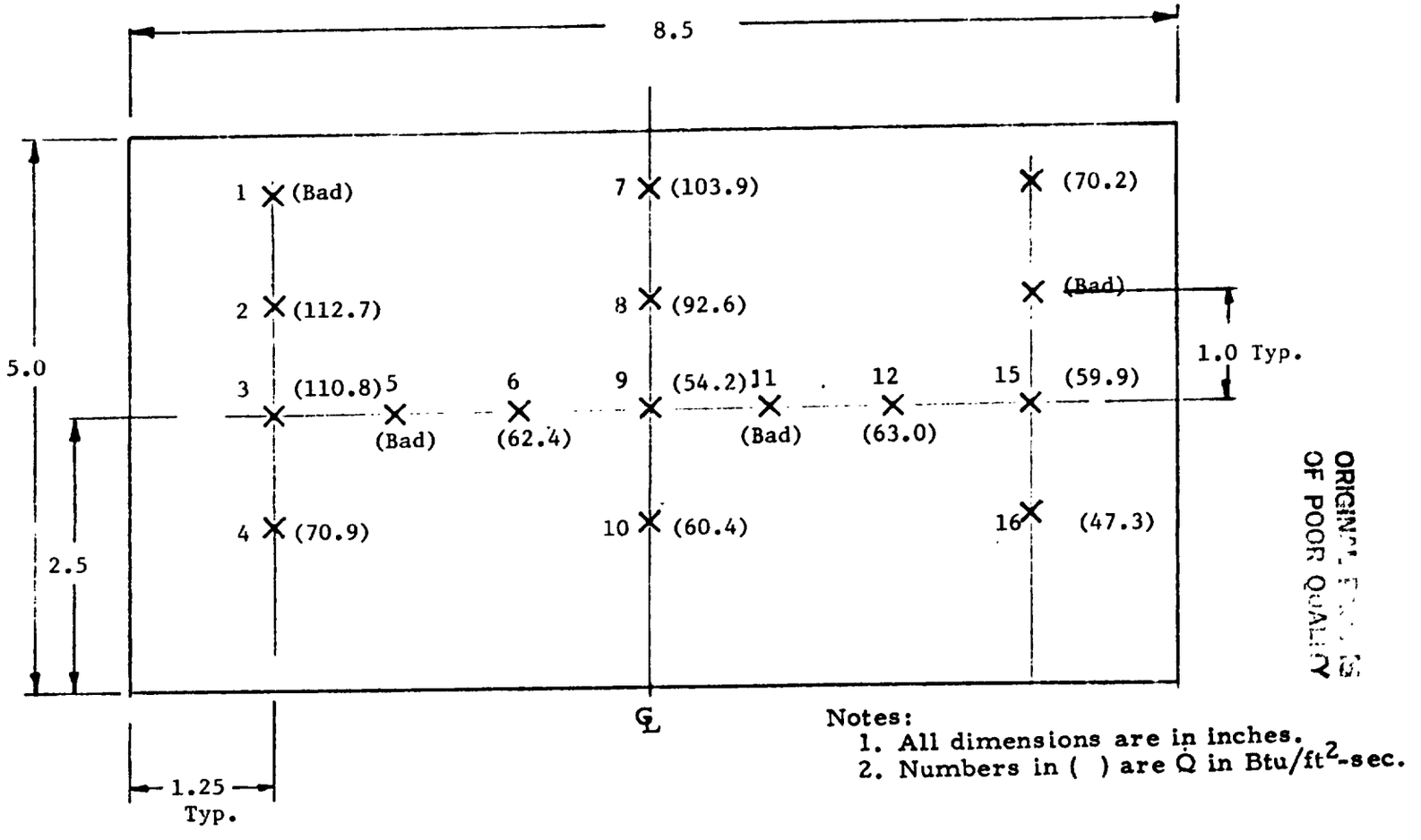

Fig. 3c - Front View of Attach Ring Thin Skin Thermocouple Cal Model Showing Heating Rates (Run 1141)

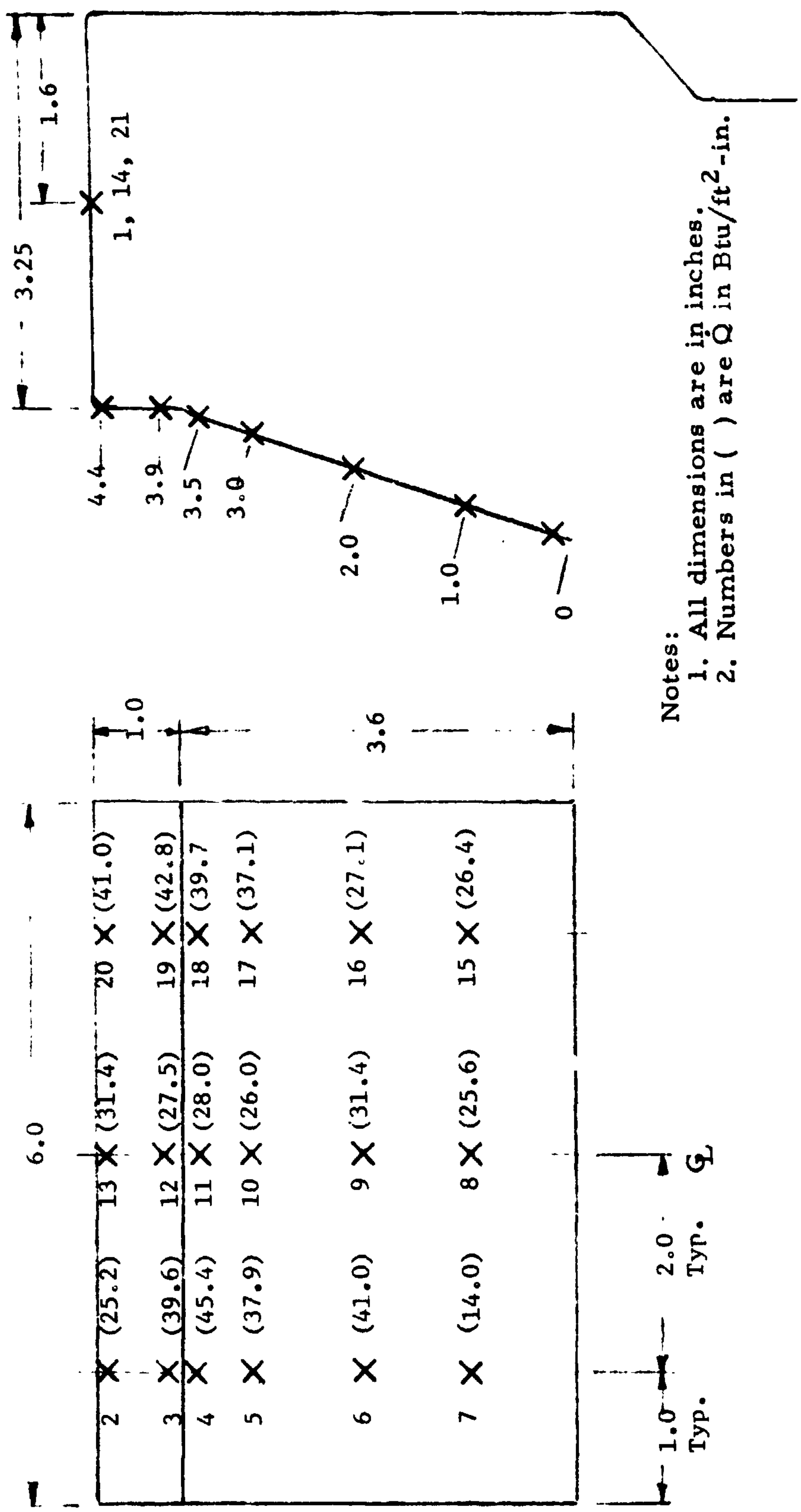

Fig. 4a - Front and Side View of Kick Ring Rear Face Thin Skin Thermocouple Cal Model Showing Measured Heating Rates (Run 1143)

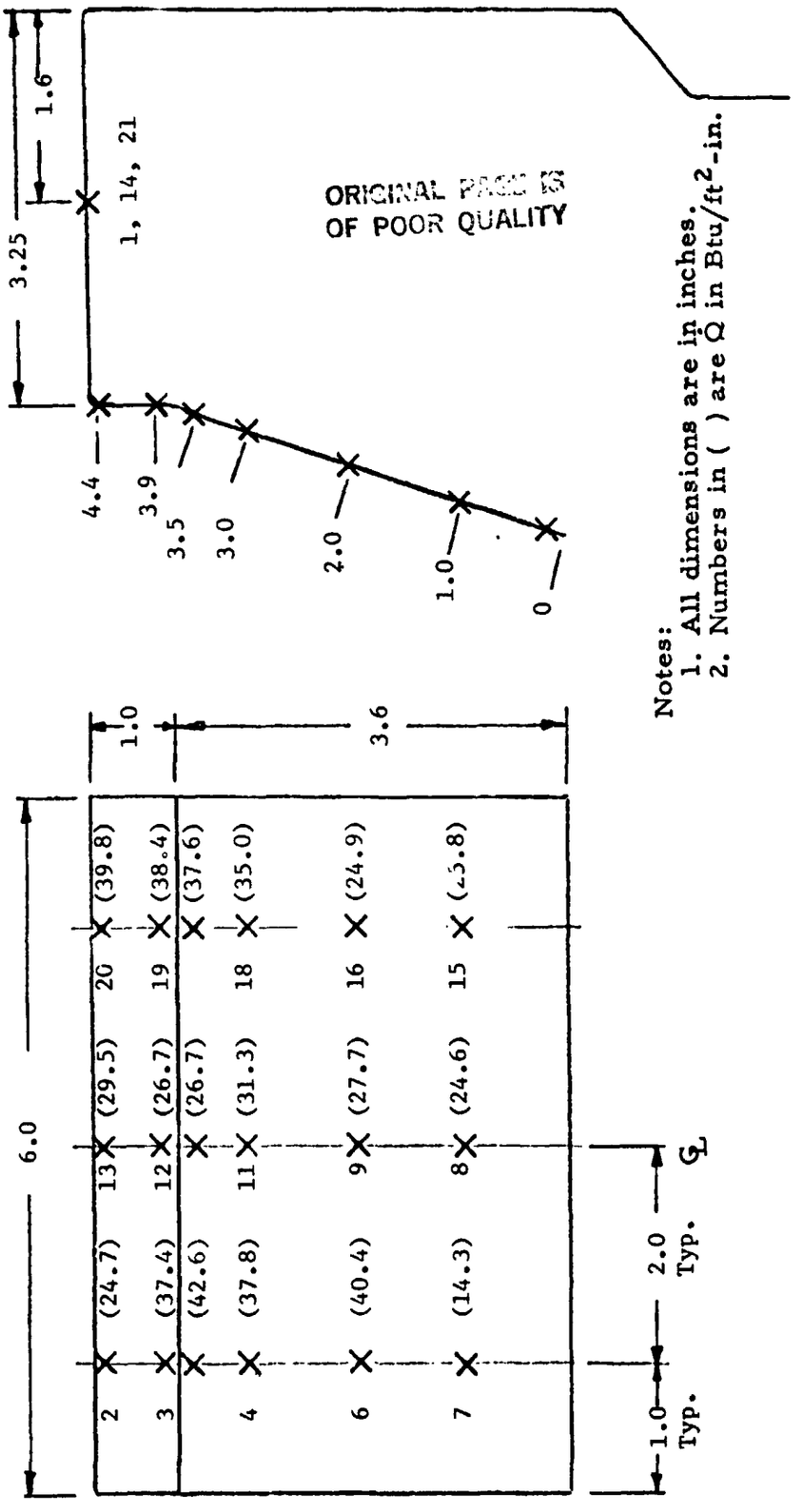

Fig. 4b - Front and Side View of Kick Ring Rear Face Thin Skin Thermocouple Cal Model Showing Measured Heating Rates (Run 1144)

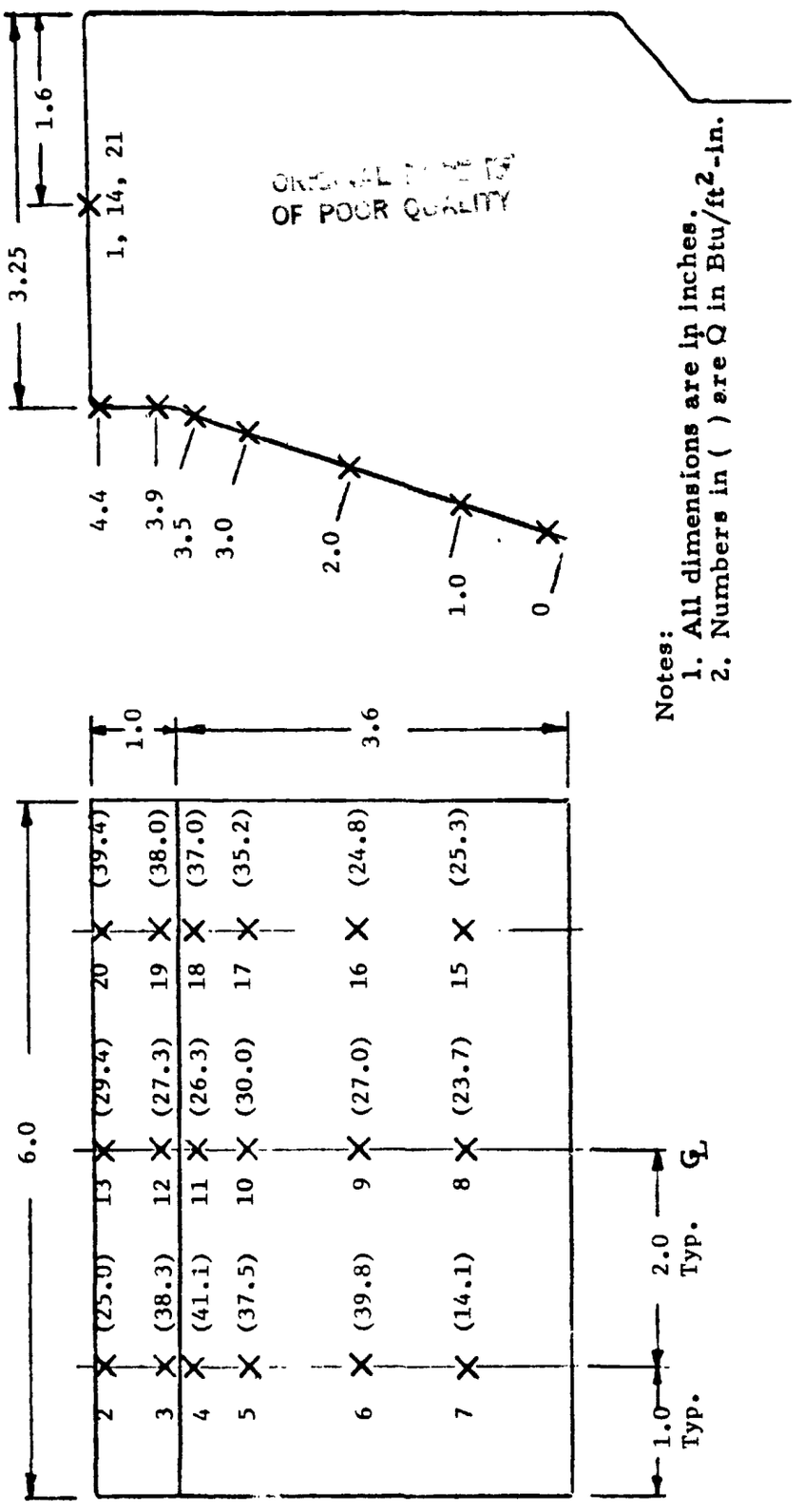

Fig. 4c - Front and Side View of Kick Ring Rear Face Thin Skin Thermocouple Cal Mod Showing Measured Heating Rates (Run 1145)

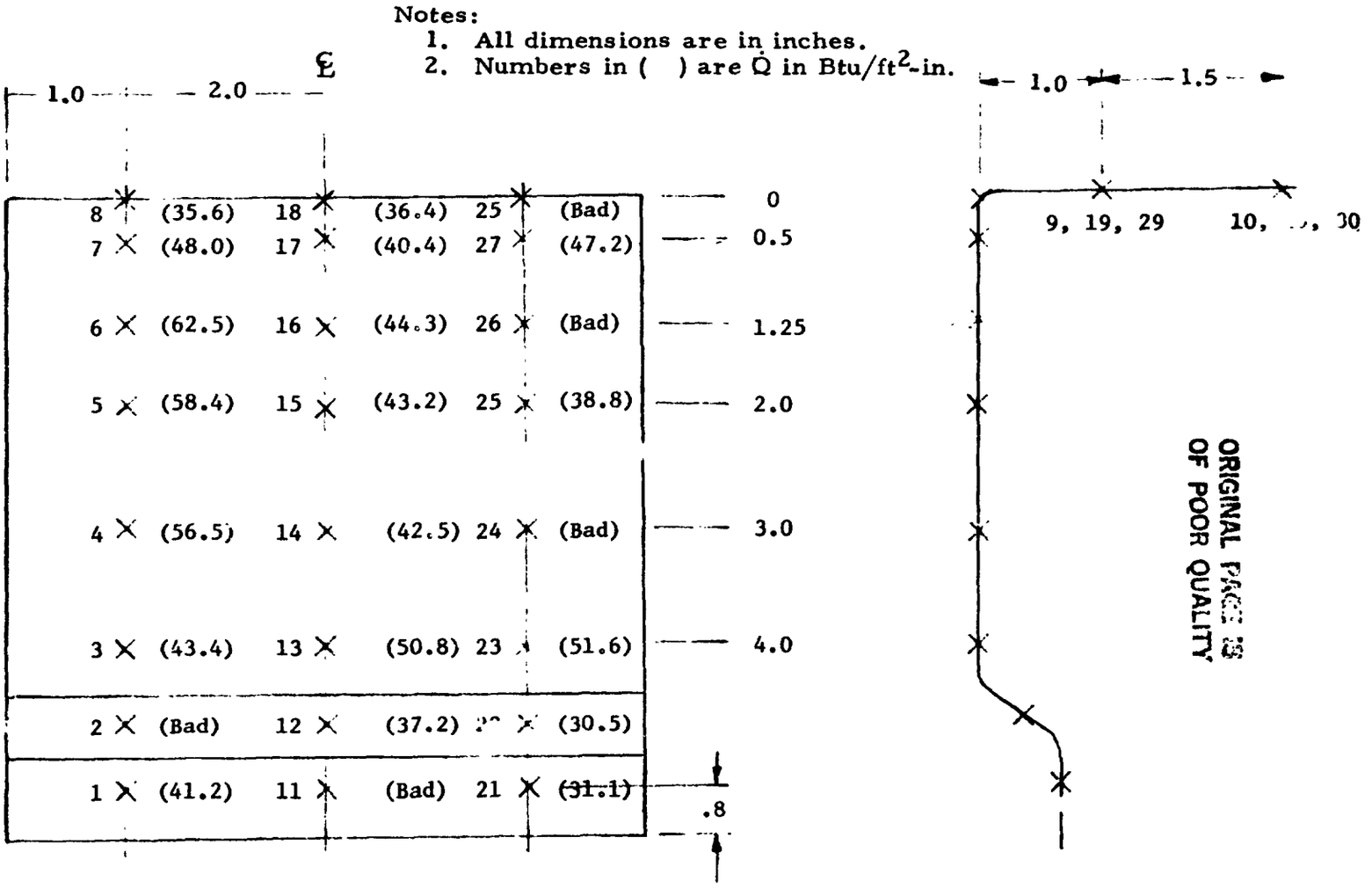

Fig. 5a - Front and Side View of Kick Rin[illegible]ward Face Thin Skin Thermocouple Cal Model Showing Measured Heating Rates (Run 1135)

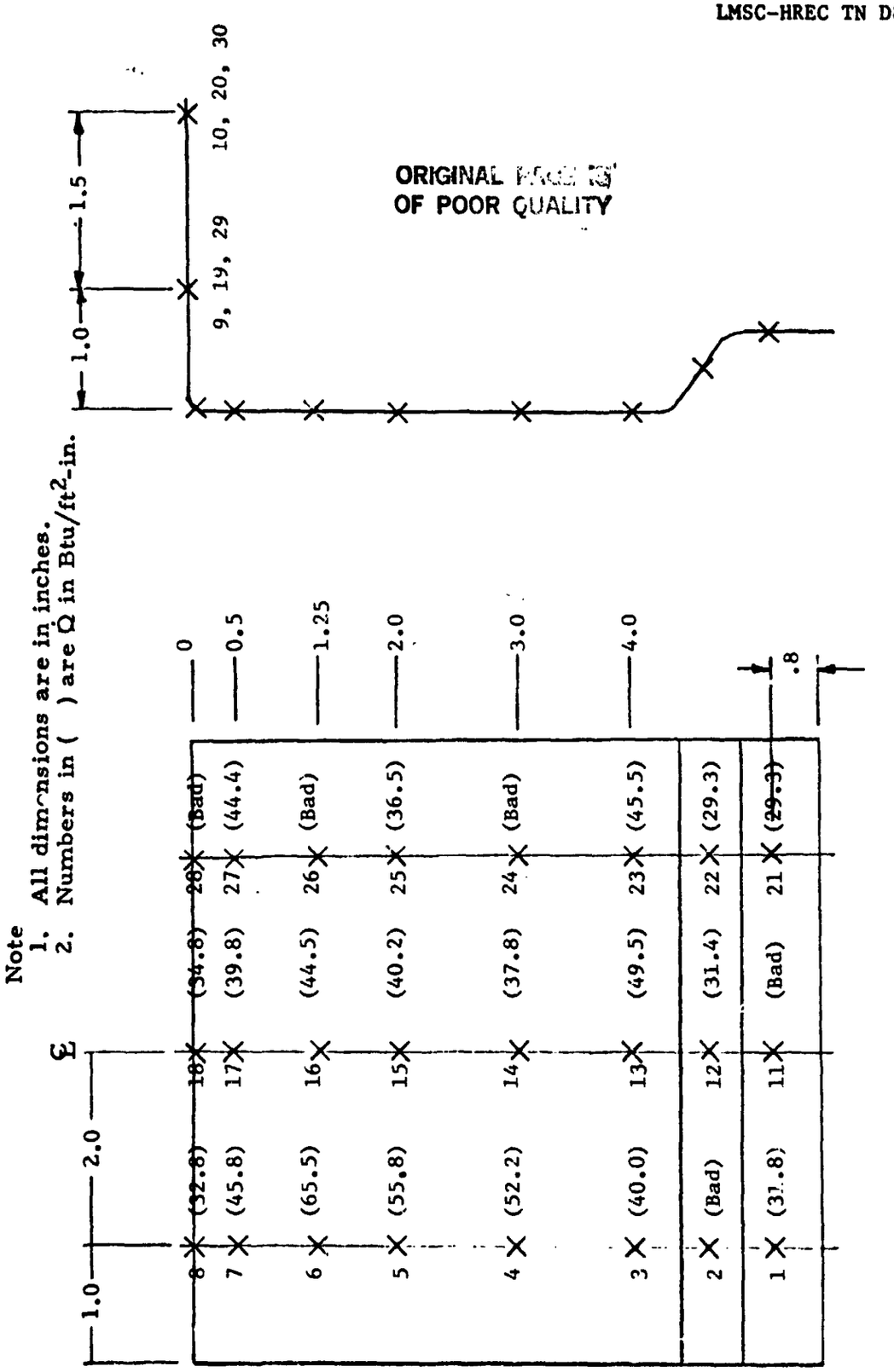

Fig. 5b - Front and Side View of Kick Ring Forward Face Thin Skin Thermocouple Cal Model Showing Measured Heating Rates (Run 1136)

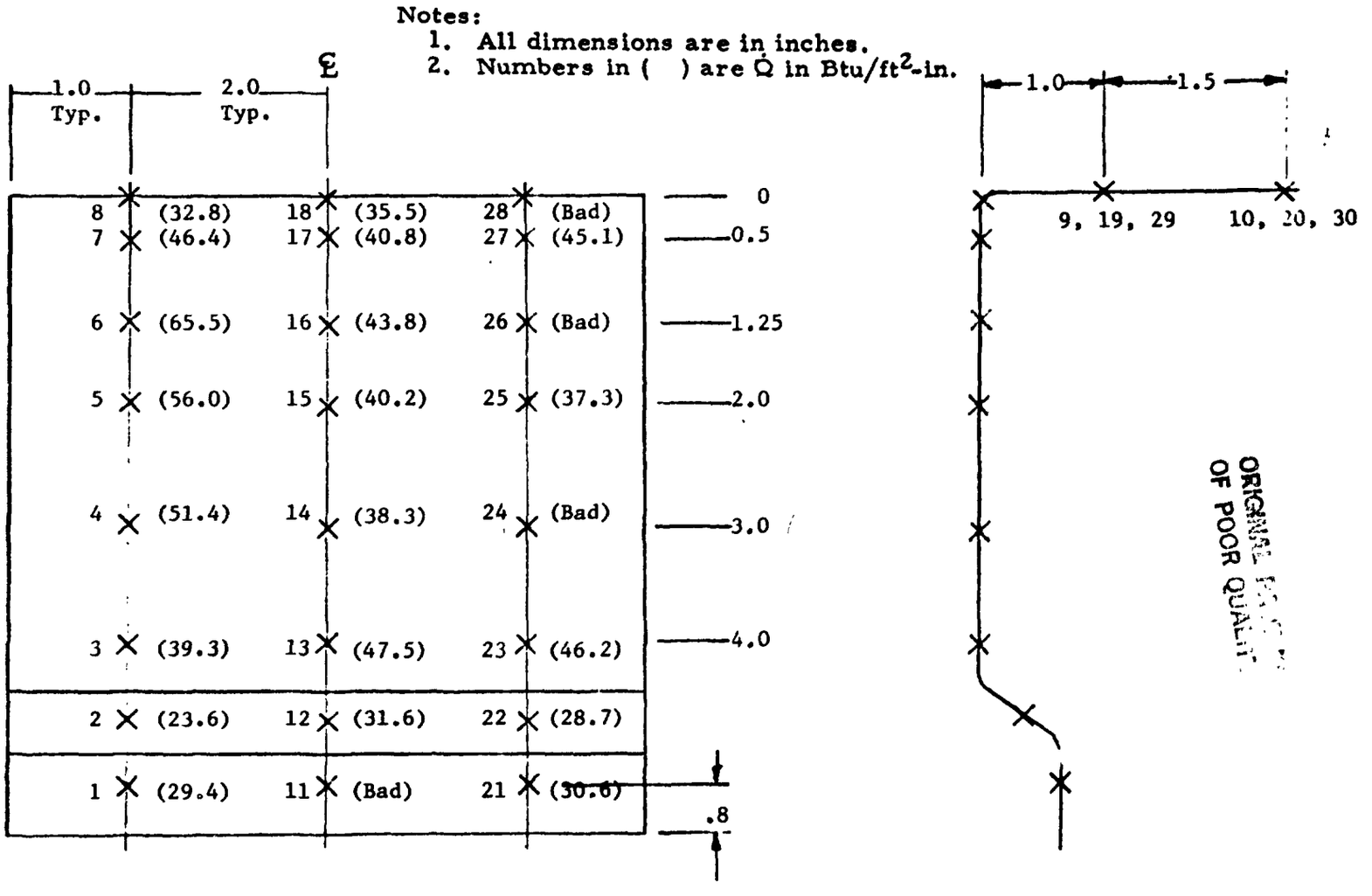

Fig. 5c - Front and Side View of Kick Ring Forward Face Thin Skin Thermocouple Cal Model Showing Heating Rates (Run 1137)

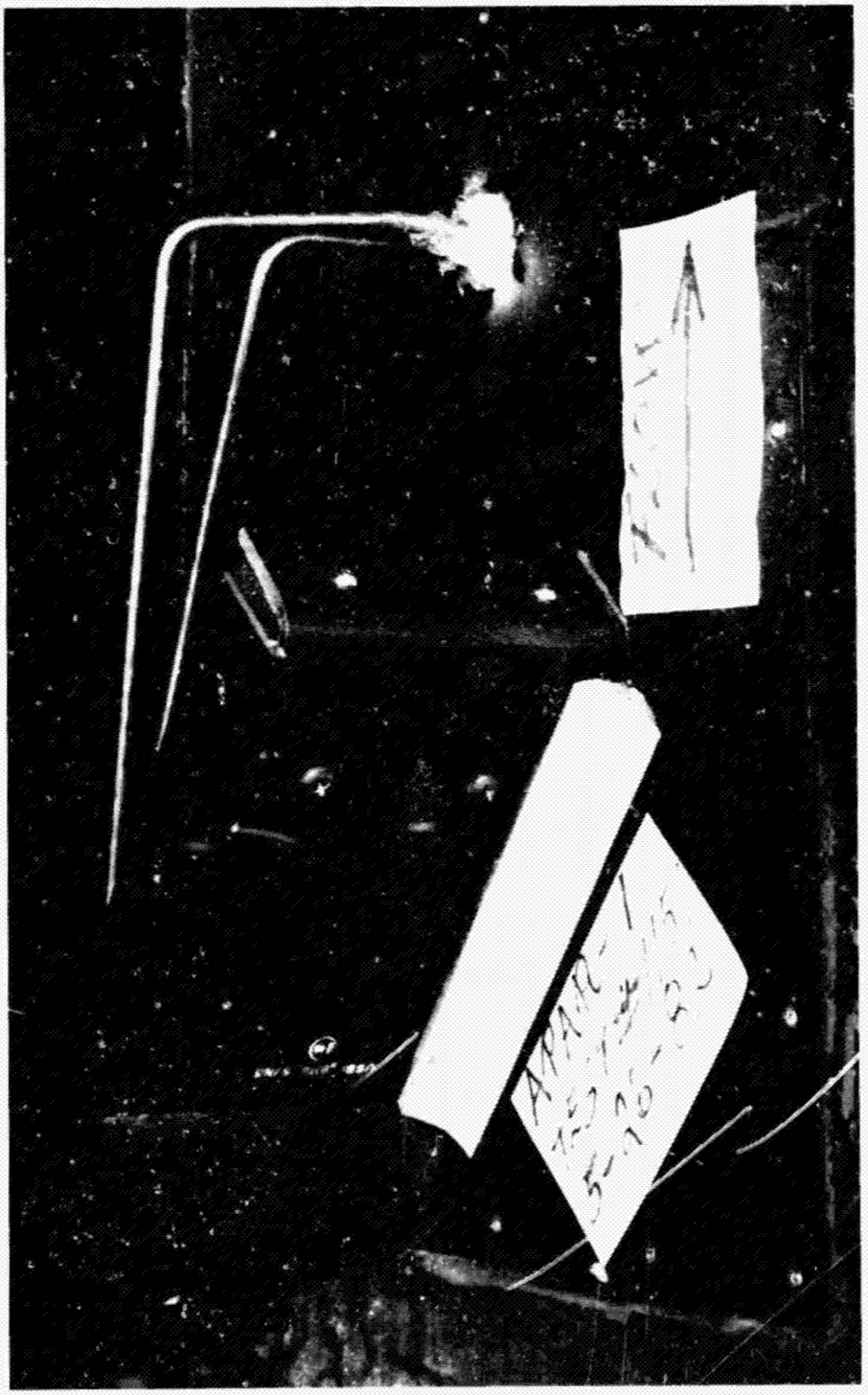

Fig. 6 - Pretest Photograph of Alternate Phenolic TPS Model with Old "Edler" Fishtail Seal Mounted At 35 Deg Angle to Flow

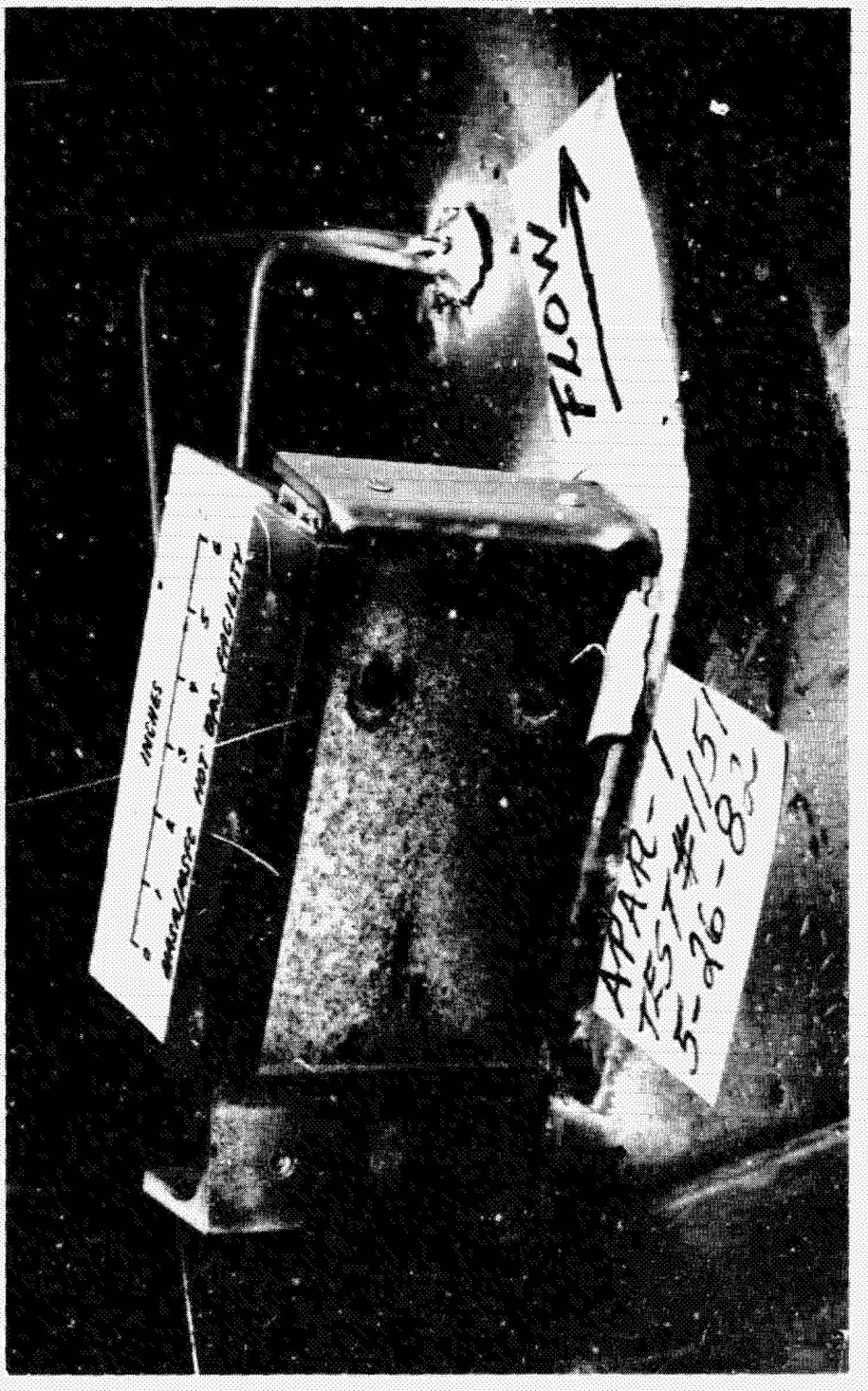

Fig. 7 - Post-Test Photograph of Model in Fig. 6

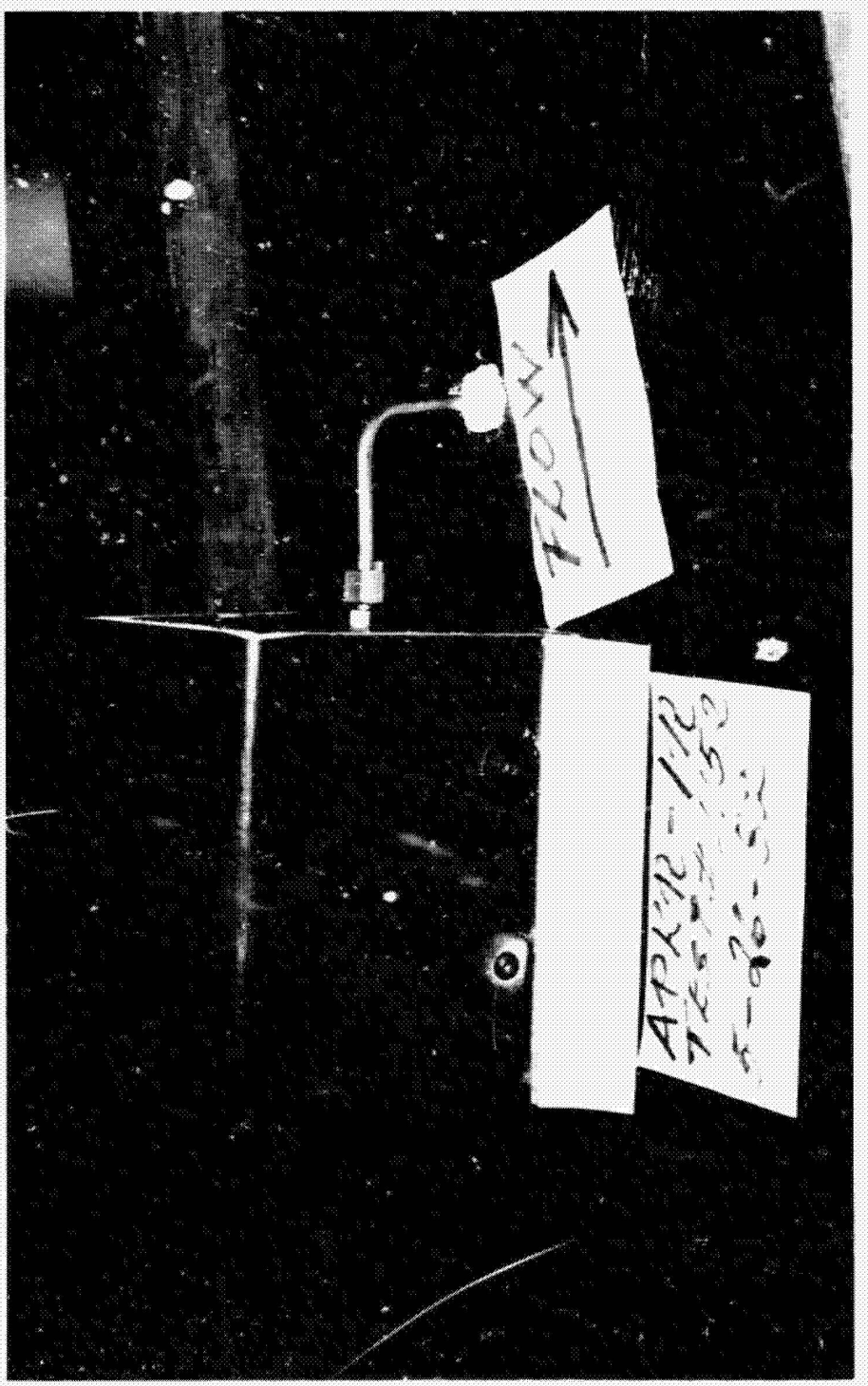

Fig. 8 - Pretest Photograph of Kick Ring Rear Face Model with Alternate Phenolic and Old Edler Grey Fishtail Seal

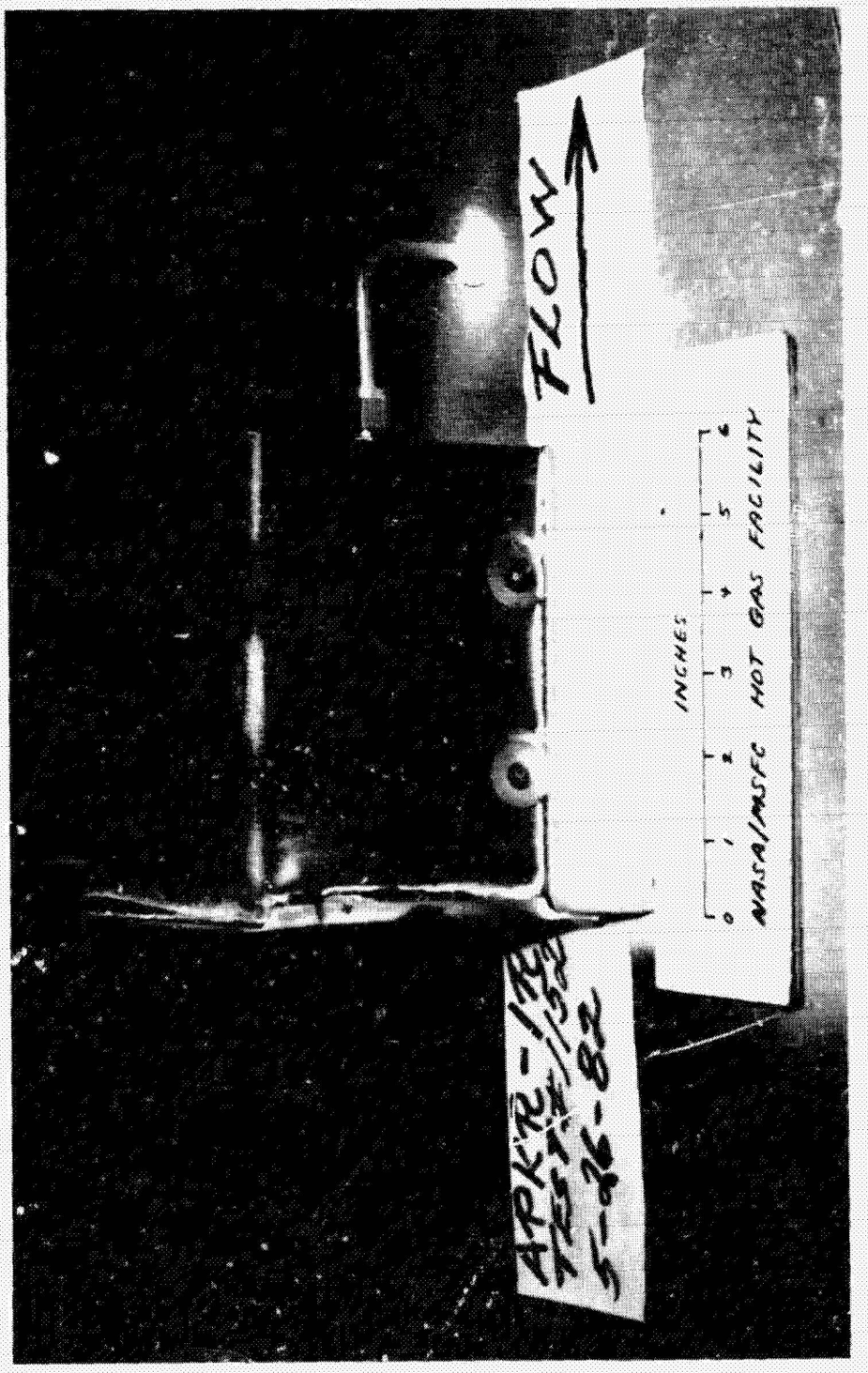

Fig. 9 - Post-Test Photo of Model in Fig. 8

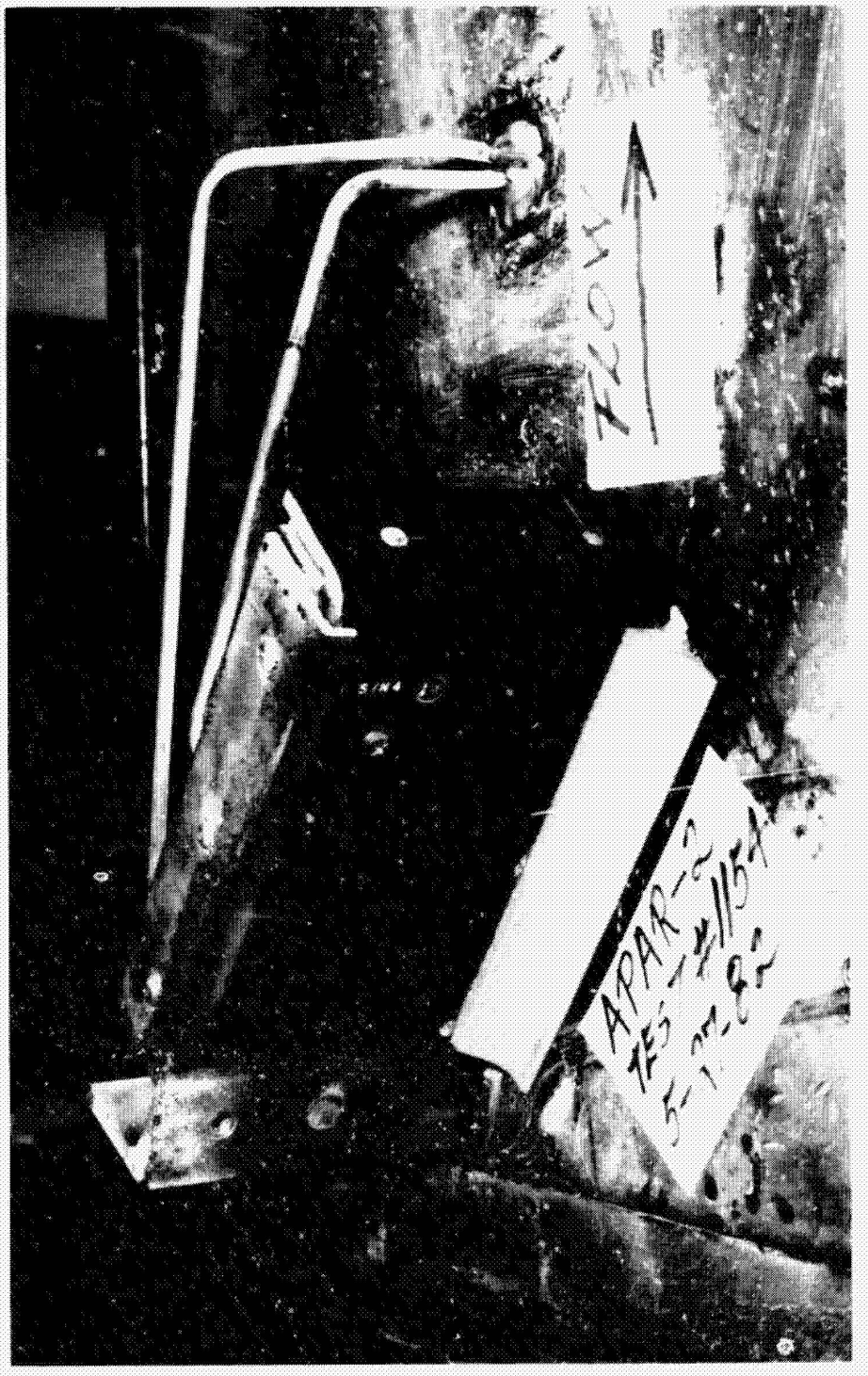

Fig. 10 - Model Setup for a Repeat Test of Attach Ring Shown in Fig. 6

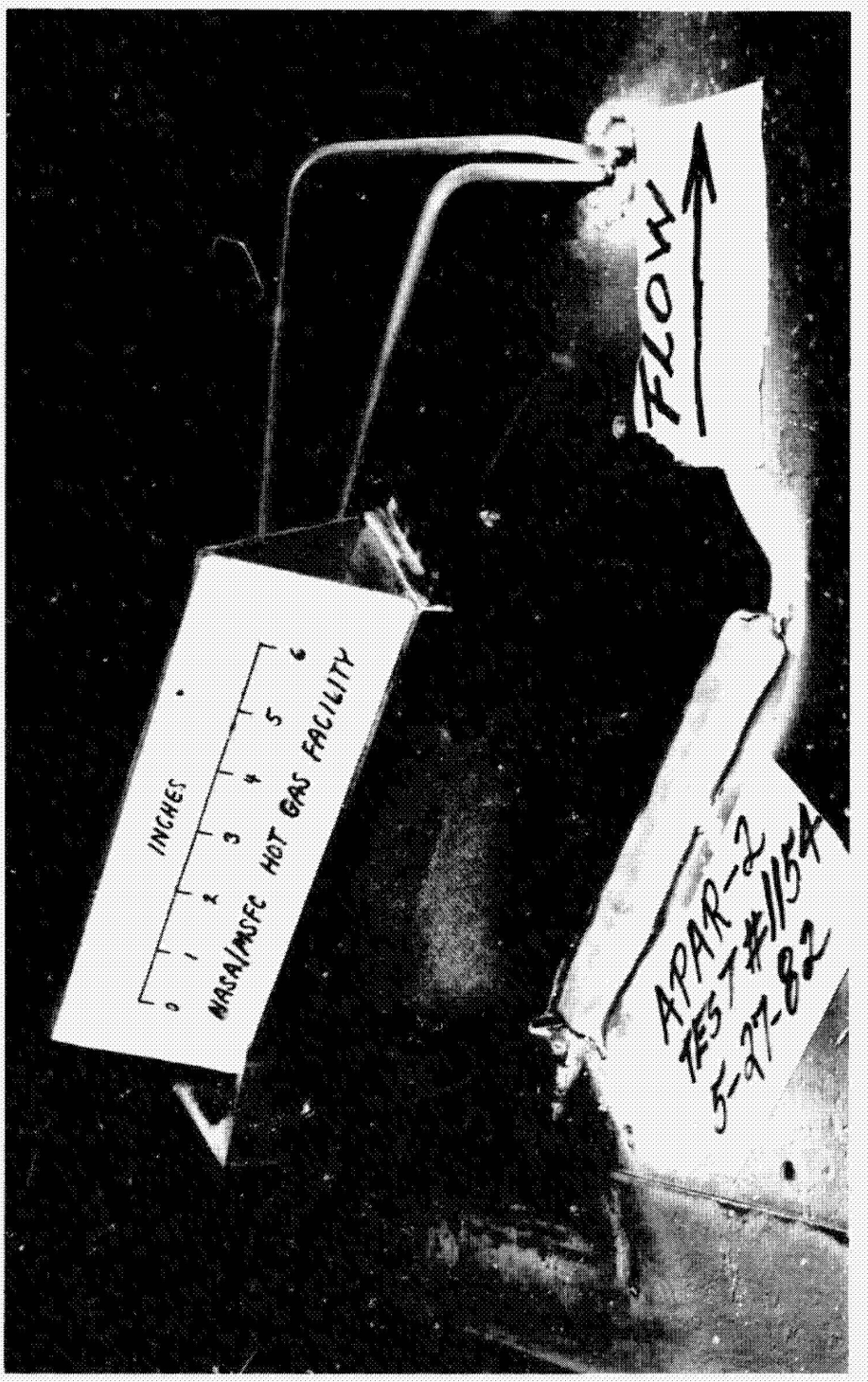

Fig. 11 - Post-Test Photo of Model in Fig. 10

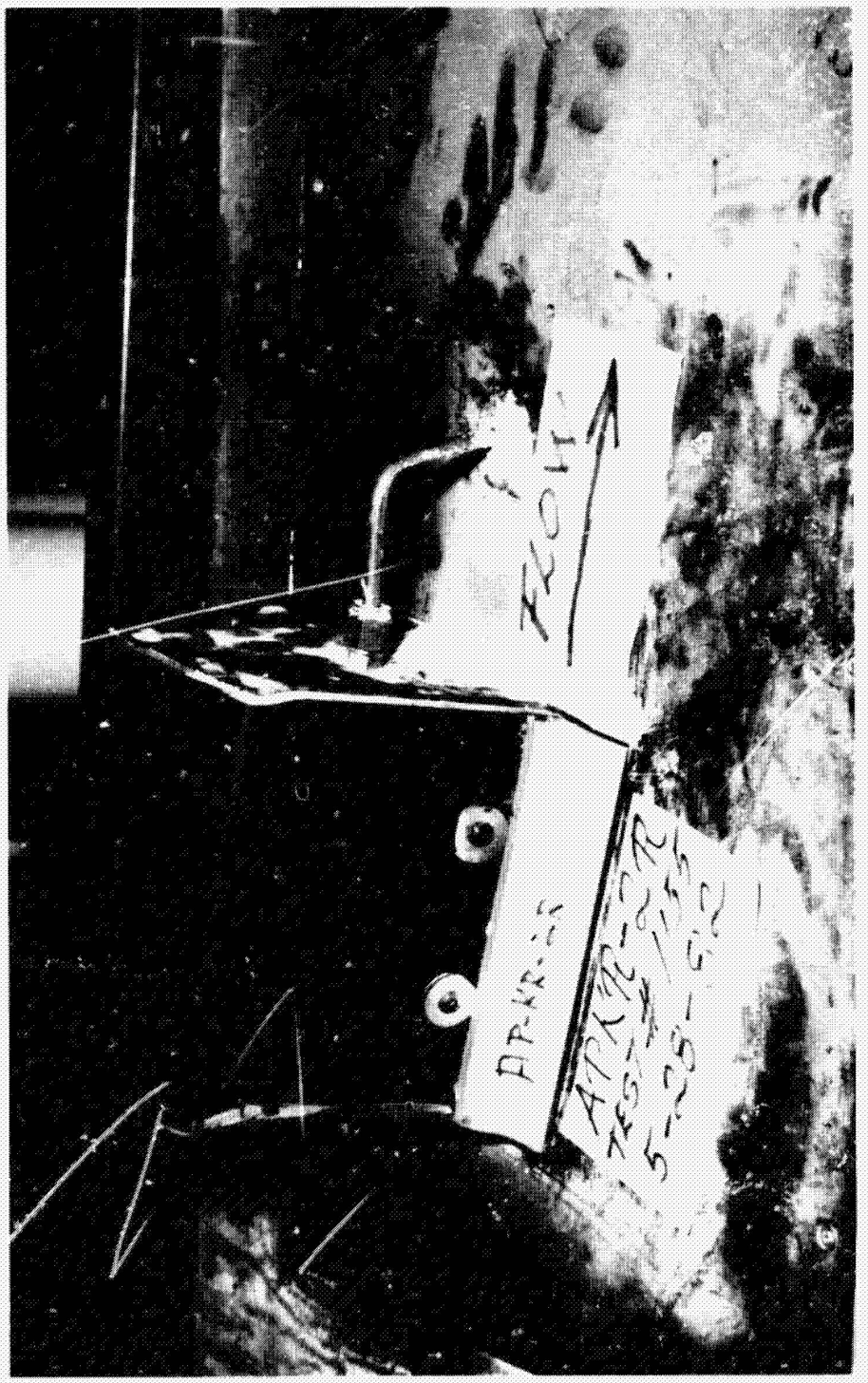

Fig. 12 - Model Setup for a Repeat Test of Kick Ring Rear Face as in Fig. 8

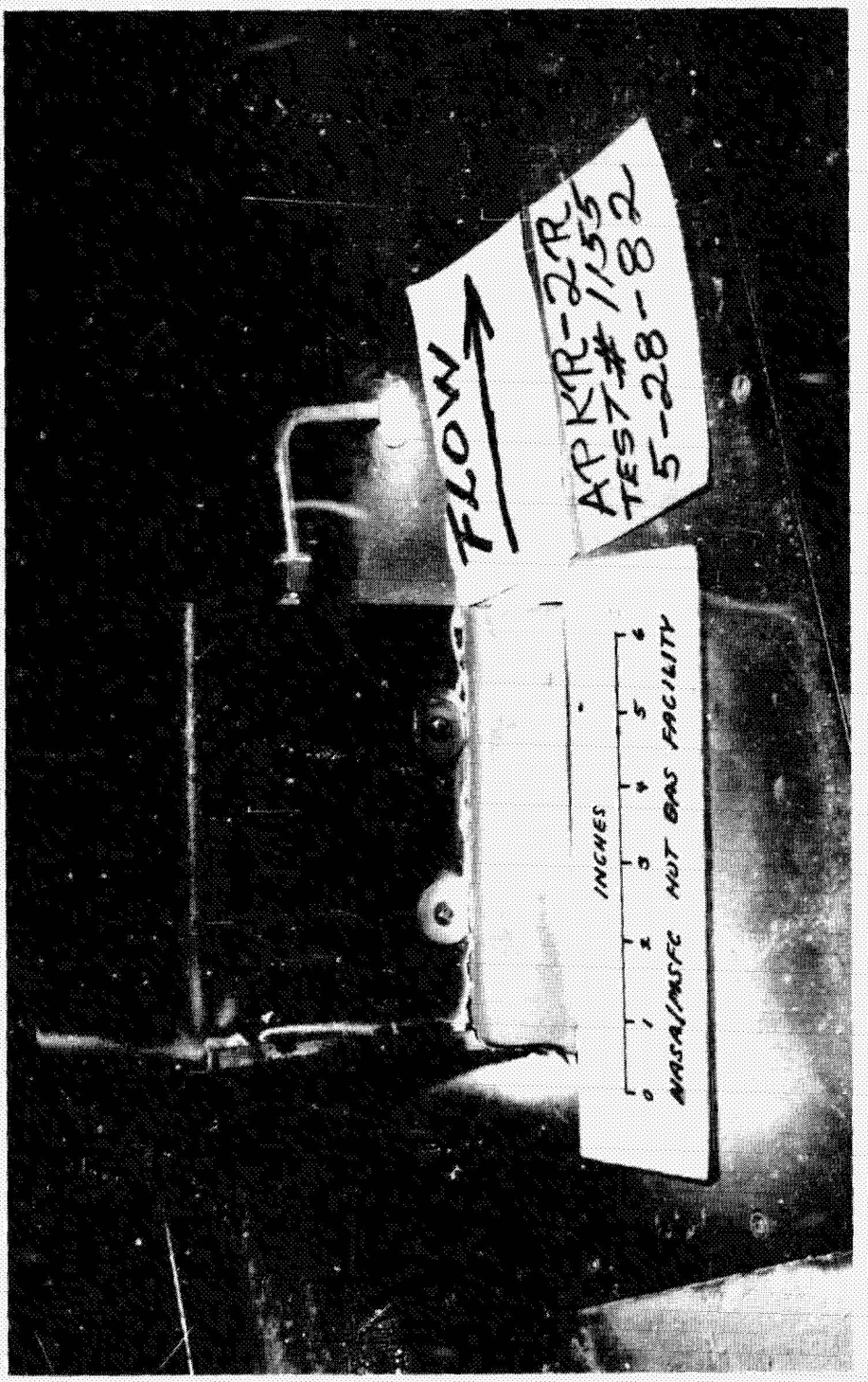

Fig. 13 - Post-Test Photo of Model in Test of Fig. 12

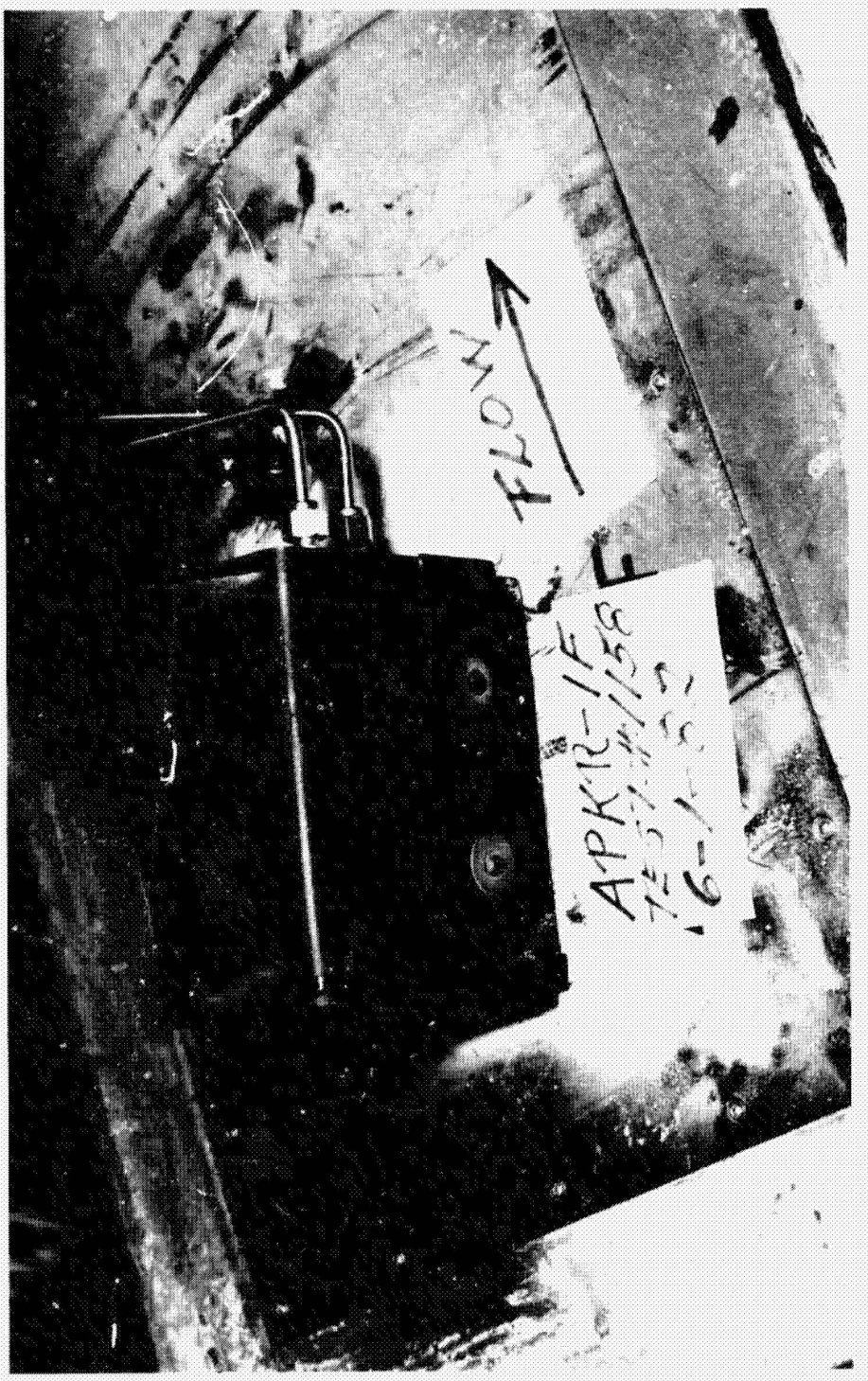

Fig. 14 - Pretest Photograph of Alternate Phenolic Fwd Face Model (The lower Z-section phenolic part made of old Edler material. The other face of this model was previously tested - see Fig. 8)

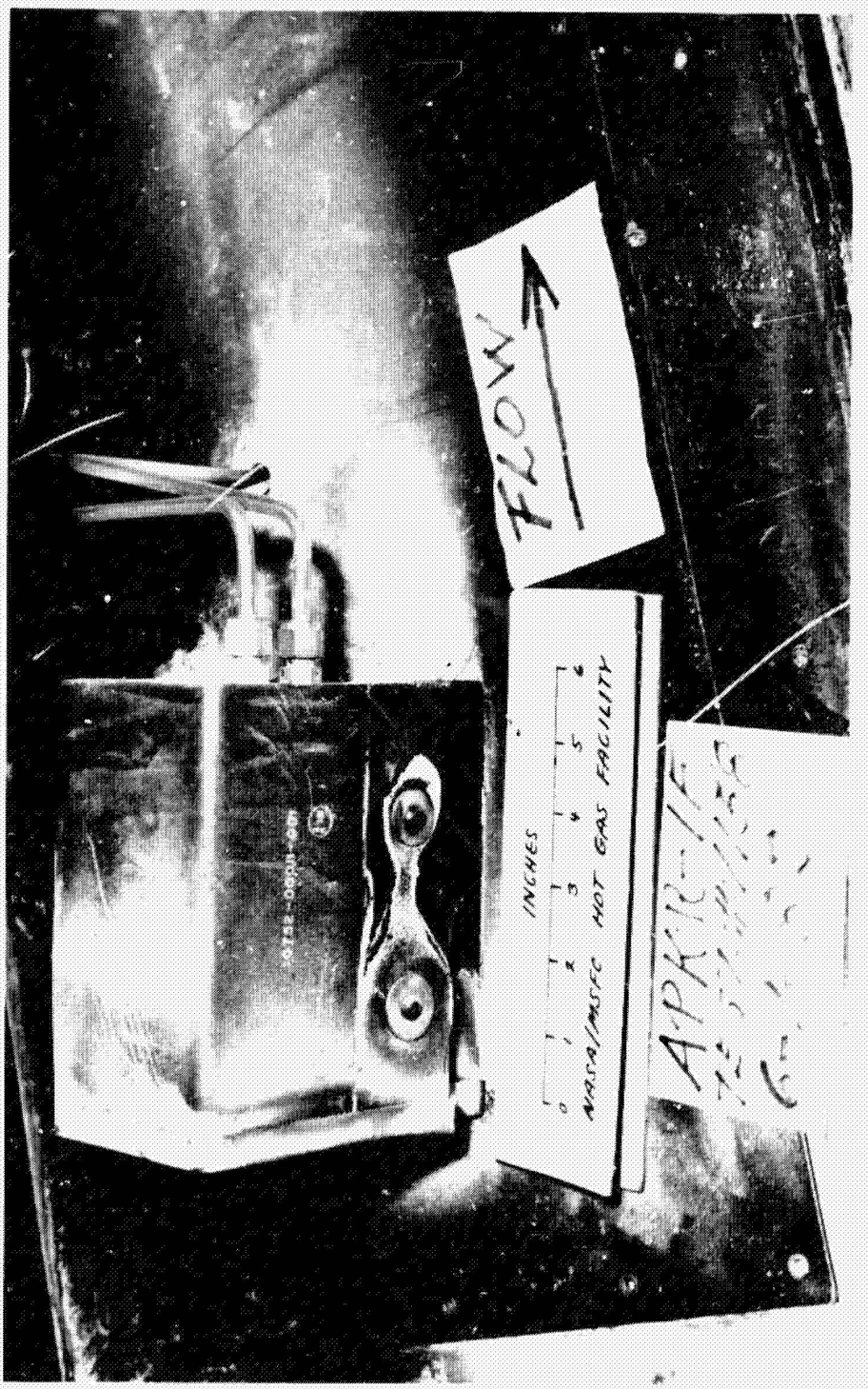

Fig. 15 - Post-Test Photo of Model in Fig. 14

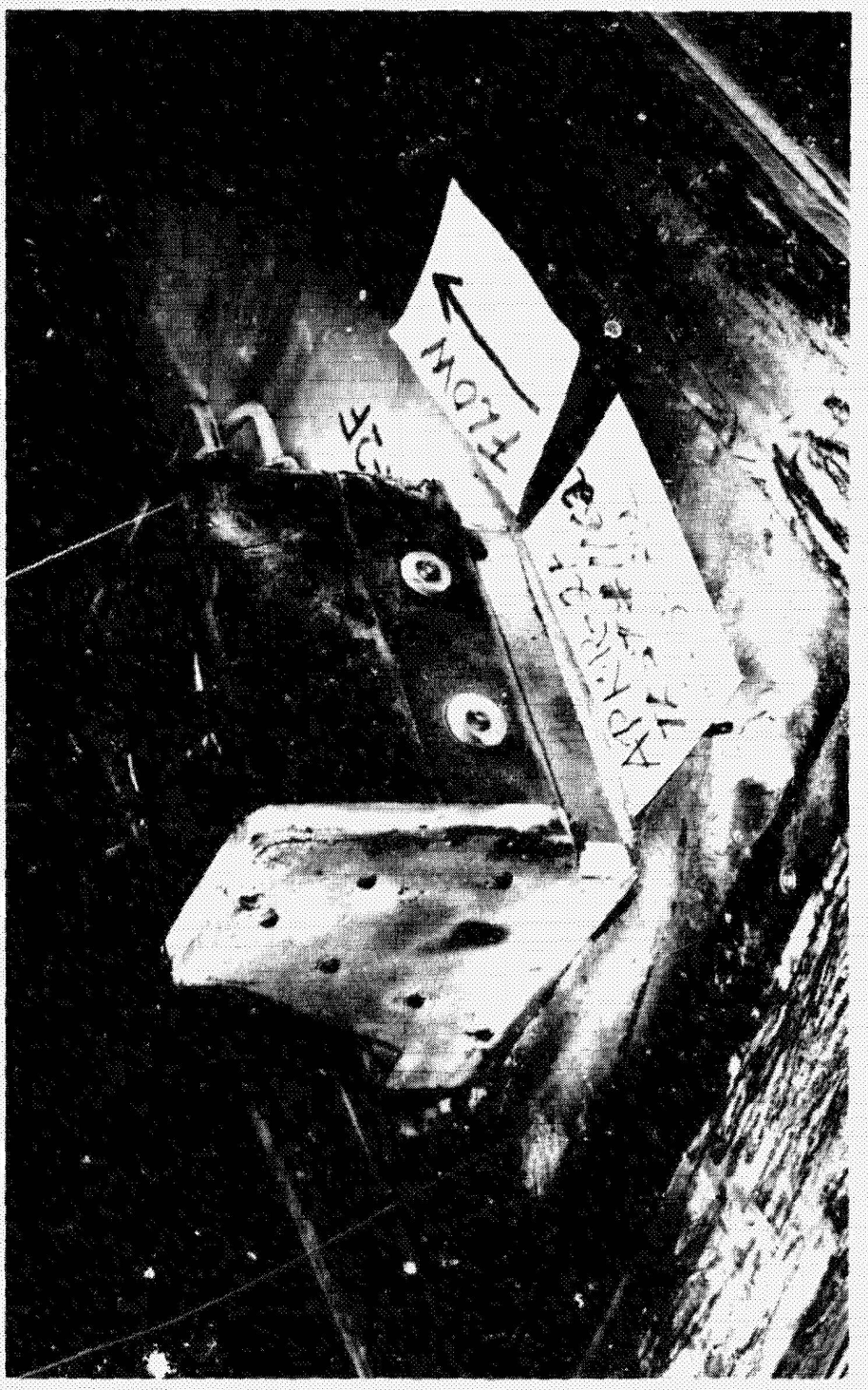

Fig. 16 - Model Setup for a Repeat Test of Kick Ring Fwd Face Shown in Fig. 14
(The other face of this model was tested previously in Run of Fig. 12)

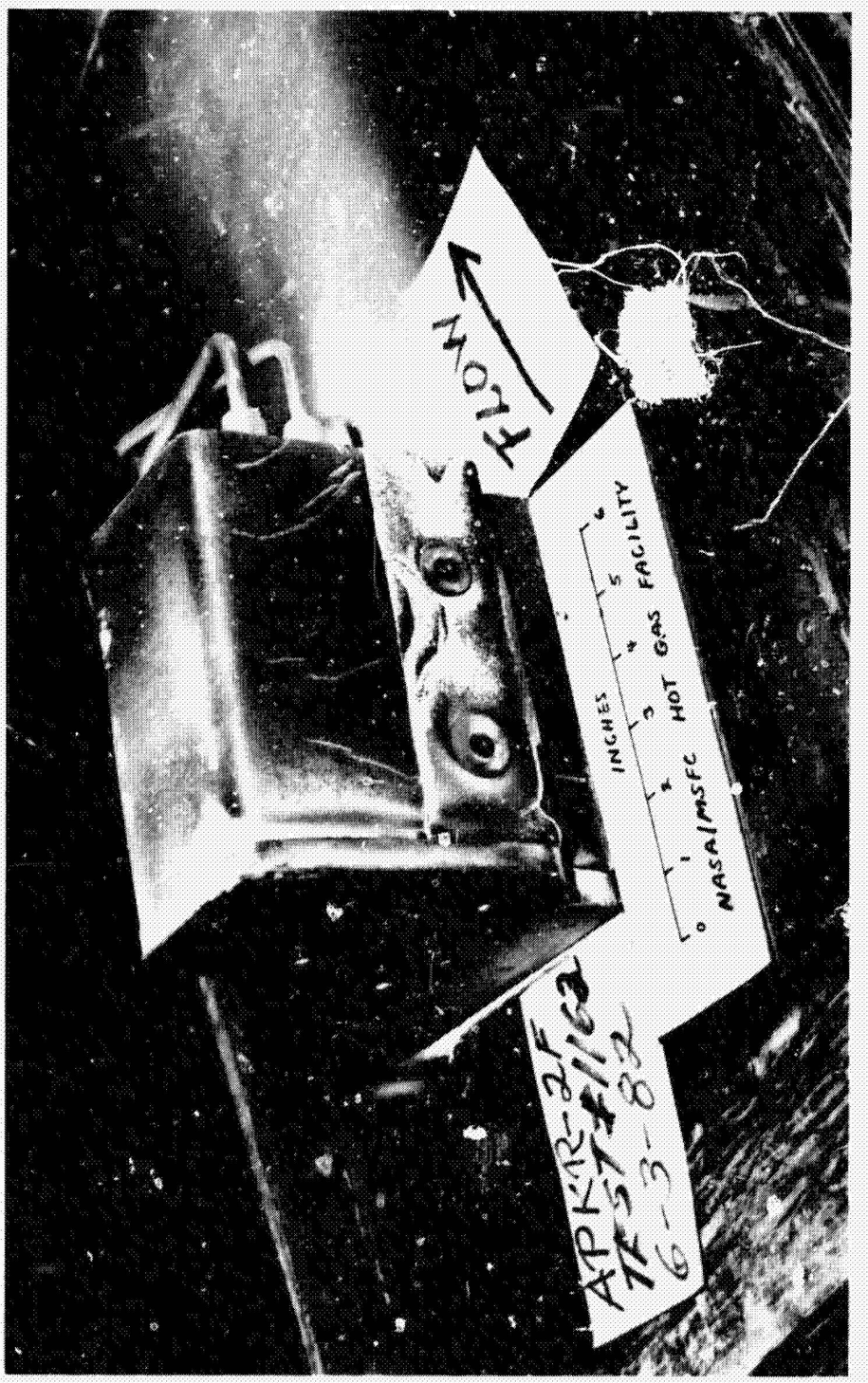

Fig. 17 - Post-Test Photo of Model in Fig. 16

HGF TEST REQUIREMENTS

Run No. 1151, Enthalpy Req'd: Low /_/ Med /_/ Hi /x/

Heat Load Req'd:

Ascent:	_____	Btu/ft^2
Plume/Separation:	_____	Btu/ft^2
SOFI Burning:	_____	Btu/ft^2
Radiation:	_____	Btu/ft^2
Reentry:	_____	Btu/ft^2
Other:	_____	Btu/ft^2
Total Heat Load (A)	2434	Btu/ft^2

Applicable Body Point or Vehicle Location: BP 971 (Fwd Face of Attach Ring $\theta = 45°$)

Overtest Factor (B) _____ Heat Load Req'd for Test: (A) X (B) = 2434

Source of Heat Loads: LMSC TM D697991

Heat Rate During Test: 90.3 Btu/ft^2-sec, Peak /x/ Ave /_/ Other /_/

Applicable Cal Run#: 1139-40-41

Test Time Req'd.: 37.4 sec

Max Temp Allowed: 500 ° F

Other Requirements: 90.3 Btu/ft^2-sec is average for TC 8 on cal runs 1139-40-41. Because of the effects of the leading edge protector which changed the $\dot{q}$ distribution on the new cal runs near the leading edge from the old cal runs (1-26-79), it was decided to base the new run time on a point near the center of the mode. (TC 8). The old $\dot{q}$ was 96.5, Btu/ft^2-sec and the old run time was 35 sec; the new run time is, therefore, 37.4 sec.

Fig. 18 - Test Requirements for the Alternate Phenolic Attach Ring Model

HGF TEST REQUIREMENTS

Run No. 1152, Enthalpy Req'd: Low /_/ Med /_/ Hi /x/

Heat Load Req'd:

Ascent:	_____	Btu/ft^2
Plume/Separation:	_____	Btu/ft^2
SOFI Burning:	_____	Btu/ft^2
Radiation:	_____	Btu/ft^2
Reentry:	_____	Btu/ft^2
Other:	_____	Btu/ft^2
Total Heat Load (A)	728	Btu/ft^2

Kick Ring Rear Face

Applicable Body Point or Vehicle Location: BP 6533 (Rear Face of Kick Ring, $\theta = 90°$)

Overtest Factor (B) 1.0 Heat Load Req'd for Test:
(A) X (B) = 728

Source of Heat Loads: LMSC TM D697991

Heat Rate During Test: 29.0* Btu/ft^2-sec, Peak /x/ Ave /_/ Other /_/

Applicable Cal Run#: 1143, 44, 45

Test Time Req'd.: 25 sec**

Max Temp Allowed: 500 ° F

Other Requirements:

*29.0 is average of $\dot{q}$ at TC 10 for Runs 1143/44/45.

**Run time was ratioed from the old Edler TPS in LMSC TM D697991 where the run time was 29 and the $\dot{q}$ was 25 at the same location.

Fig. 19 - Test Requirements for Alternate Phenolic Kick Ring Rear Face Model

HGF TEST REQUIREMENTS

Run No. 1158, Enthalpy Req'd: Low /_/ Med /_/ Hi /x/

Heat Load Req'd:

Ascent:	_____	Btu/ft^2
Plume/Separation:	_____	Btu/ft^2
SOFI Burning:	_____	Btu/ft^2
Radiation:	_____	Btu/ft^2
Reentry:	_____	Btu/ft^2
Other:	_____	Btu/ft^2
Total Heat Load (A)	2228	Btu/ft^2

Applicable Body Point or Vehicle Location: BP 6502 (Fwd Face of Kick Ring, $\theta = 0°$)

Overtest Factor (B) _____ Heat Load Req'd for Test:
(A) X (B) = 2228

Source of Heat Loads: LMSC TM D697991

Heat Rate During Test: 64.5* Btu/ft^2-sec, Peak /x/ Ave /_/ Other /_/

Applicable Cal Run#: 1135-36-37

Test Time Req'd.: 44.5 sec**

Max Temp Allowed: 500 ° F

Other Requirements: _____

*64.5 is average for TC 6 from runs 1135-36-37.

**Run time was ratioed from the old Edler TPS test in LMSC TM D697991 where the run time was 42.2 sec and the $\dot{q}$ was 68 at the same location.

Fig. 20 - Test Requirements for Alternate Phenolic Kick Ring Fwd Face Model