CR-170892

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TECHNICAL NOTE

Lockheed
Missiles & Space Company, Inc
Huntsville Research & Engineering Center

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Title RESULTS OF TESTS OF "INSTA-FOAM" THERMAL PROTECTION SYSTEM (TPS) MATERIAL FOR PROTECTION OF EQUIPMENT INSIDE THE SRB AFT SKIRT

BACKGROUND

On some of the early Space Shuttle flights the aft skirt heat shield curtain failed during reentry. This allowed the hot gases to damage some of the equipment, etc., inside the skirt. For example, some of the propellant lines were overheated and ruptured and some of the NSI (nozzle severance) cables were damaged. It has been suggested that "Insta-Foam" TPS be sprayed over these lines, etc., to protect them during future flights in case of a curtain failure. The tests presented herein were devised and run to check out the feasibility of this idea.

TEST OBJECTIVE

The objective of these tests was to determine whether Insta-Foam can be used successfully to protect items inside the SRB aft skirt during reentry.

TEST DESCRIPTION

Before running the Insta-Foam TPS models, three calibration models were run in position 1 of the HGF. Sketches of these three models are shown in Fig. 1. Results from two runs of the first model KSC-IF-CAL-1 are shown in Fig. 2. As seen, these two runs show good repeatability. Figure 3 shows a photo of this first cal model.

Results of the second cal model (KSC-ISF-CAL-2) are not presented because this model was too large and choked the tunnel.

(NASA-CR-170892) RESULTS OF TESTS OF INSTA-FOAM THERMAL PROTECTION SYSTEM (TPS) MATERIAL FOR PROTECTION OF EQUIPMENT INSIDE THE SRB AFT SKIRT (Lockheed Missiles and Space Co.) 16 p HC A02/MF A01 CSCL 11C G3/27

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After post-test examination of these cal models/results, the first TPS model was run. Figure 4 shows a pretest photo of this model. This model was initially made at KSC then modified at MSFC. Its approximate dimensions are shown in Fig. 1 (the same as KSC-ISF-CAL-1 with a 20 deg ramp angle). Simulated propellant tubes were placed insde the foam.

The heat load required for this model and run time were determined as follows: The required heat load was assumed to be the same as that previously used for the NSI cables inside the aft skirt, and taken from Memo ED-31-82-1 to be 650 Btu/ft^2-sec. The over-test factor was taken to be 1.0 per Bob Fisher, NASA/EP44. The heating rate was taken to be the peak value from the cal runs of this same shape - 32 Btu/ft^2-sec. This yields a required run time of 20.3 sec.

This model was run r 20.06 sec in position 1 of the HGF. The results are shown in Figs. 5 and 6. The foam was almost destroyed, exposing the propellant tubes and burned metal under the foam. Because of these poor results it was decided to reconfigure the test and rerun a similar model at a lower heating rate, because the 32 Btu/ft^2-sec was much higher than the value of approximately 12 Btu/ft^2-sec measured during flight inside the skirt after curtain failure.

This model was then modified to a 10 deg ramp angle with about 2 in. height at the rear as seen in Fig. 1. It was rerun with the resulting heating rates as seen in Fig. 7. Two run conditions were used, the standard high enthalpy condition and an "off nominal" medium enthalpy level. The lower enthalpy level gave a peak heating rate of 15 Btu/ft^2-sec (near the desired value). Therefore this lower enthalpy level was used for the next TPS test. This resulted in a 43-sec test time requirement. Figure 8 shows this 10 deg ramp angle cal model, and Fig. 9 shows the 10 deg ramp angle TPS model. This TPS model was made at MSFC.

Results of this test are shown in Figs. 10 and 11.

Recession results are shown in Table 1. A summary of cal and TPS runs is given in Table 2.

Extrapolation to Flight Vehicle: If the maximum recession rate point (39.38 mils per second at a heating rate of 11) is used, then the required foam thickness required to protect against the heat load of 650 Btu/ft^2 would be

$$\frac{650 \text{ Btu/ft}^2}{11 \text{ Btu/ft}^2\text{-sec}} \times 39.38 \text{ mils/sec} = 2326 \text{ mils or } 2.3 \text{ in.}$$

Using a 1.25 overdesign factor would yield a 2.9 or nominal 3 in. of foam required to do the job.

CONCLUSIONS

As a result of these tests it is concluded that approximately 3.0 in. of "Insta-Foam" would be required to protect equipment inside the SRB Aft Skirt from reentry heating.

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Approved:

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Attach: (1)

(1) Tables 1 and 2
(2) Figs. 1 through 11

Table 1 - RECESSION RESULTS FOR RUN NO. 1118, MODEL NO. KSC-IF-3

Distance from L.E.	Pretest Thick. (mils)	Avg. Post-Test Thick. (mils)	Recession (mils)	Recession Rate (mil/sec)	Heating Rate (Btu/ft^2-sec)
6	1240	76.5	1163.5	29.05	11.6
7	1400	203.7	1196.3	29.87	11.4
8	1600	310.3	1289.7	32.20	11.3
9	1800	377.8	1422.2	35.51	10.9
10	2000	423.0	1577.0	39.38	11.0
11	—	—	—	—	—
12	2000	827.5	1172.5	29.28	4.8
13	—	—	—	—	—
14	2000	1221.0	779.0	19.45	2.9
15	—	—	—	—	—
16	2000	1330.0	670.0	16.73	3.3

Notes:
1. Test 1118, Model No. IF-3
2. HGF Test Pos. 1
3. Test Time — 40.05 sec

Table 2 - SUMMARY OF RUNS ON INSTA-FOAM MATERIALS AND CAL MODELS IN HGF

Run No.	Run Time (sec)	Model Description	Remarks
1094	5	20-deg Ramp, 3.5 in. High, Cal (KSC-IF-CAL-1)	Data O.K.
1095	5	↓	Run Bad. Duct purges on by mistake.
1096	5		Repeat of Run 1094. Data very repeatable
1097	5	~30-deg Ramp, 6 in. High, Cal (KSC-ISF-CAL-2)	Model Too High. Choked tunnel. Data no good.
1098	5	↓	(Same as 1097)
1099	20	20-deg Ramp, 3.5 in. High, Insta-Foam TPS, (KSC-IF-1)	Foam receded to substrate in some areas.
1116	5	10-deg Ramp, 2 in. High, Cal (KSC-ISF-CAL-3)	Ran at "standard" high enthalpy HGF conditions; $\dot{q}$ still too high.
1117	5	↓	Ran at "off-nominal" medium enthalpy HGF conditions. Heating rates down from Run 1116; Max $\dot{q}$ = ~15 Btu/ft^2-sec, an acceptable level.
1118	40	10-deg Ramp, 2 in. High, Insta-Foam TPS (KSC-IF-3)	Foam receded down to metal or "ramp." Run at "off-nominal" medium enthalpy

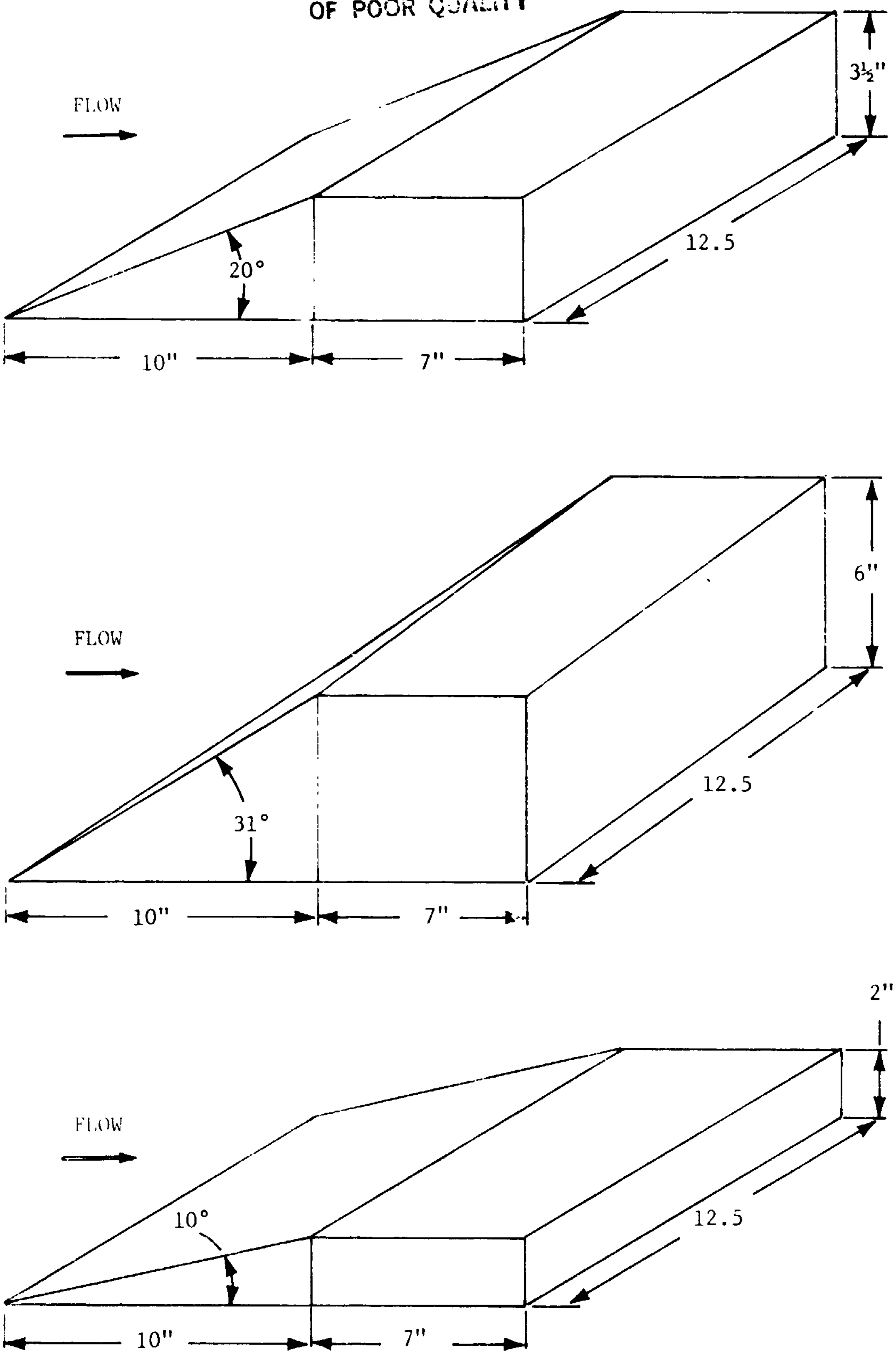


Fig. 1 - Insta- n Calibration Models

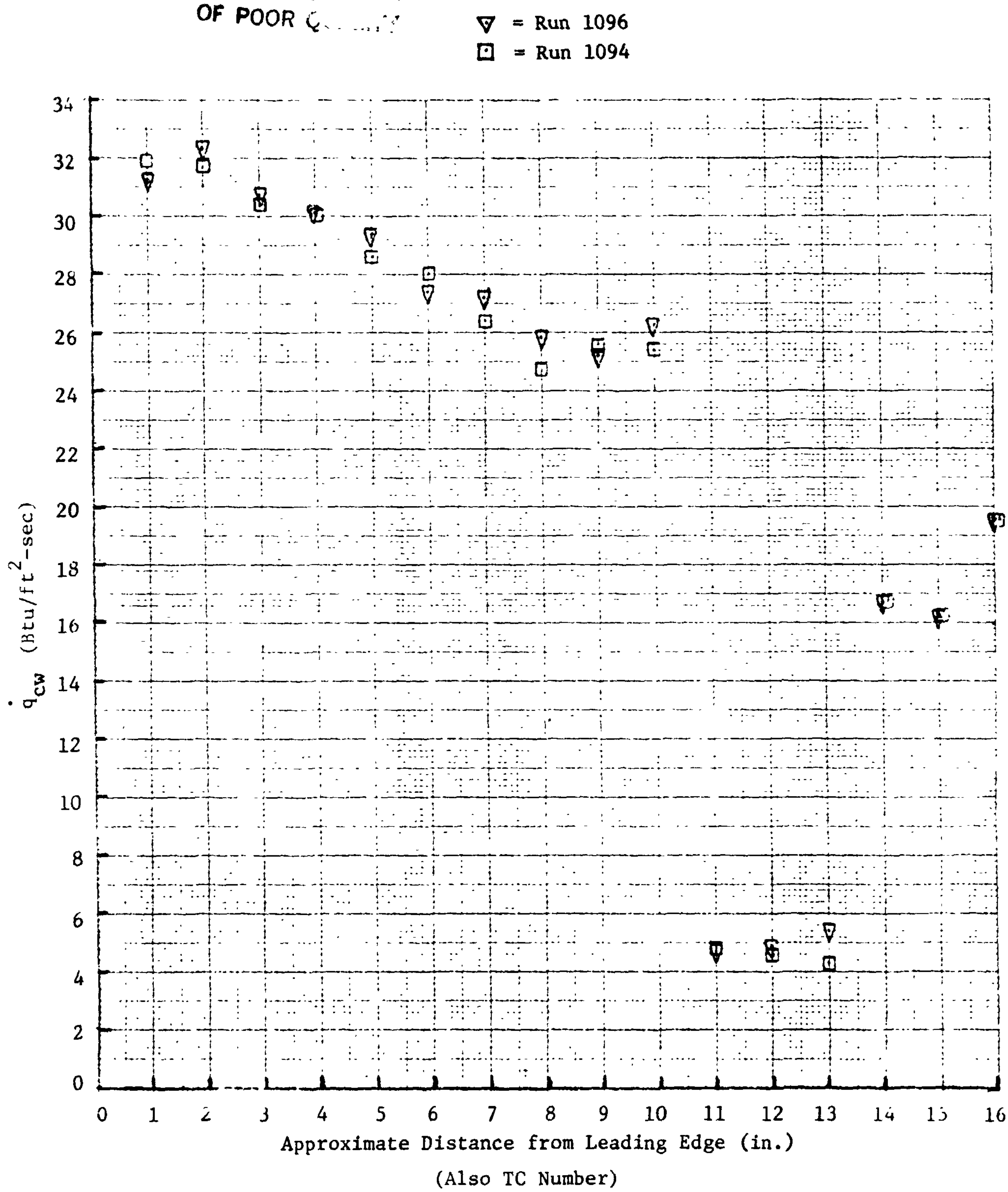


Fig. 2 - Cal Runs for KSC-IF-CAL-1

Fig. 3 - Thin-Skin Calibration Model with 20 deg Ramp Angle

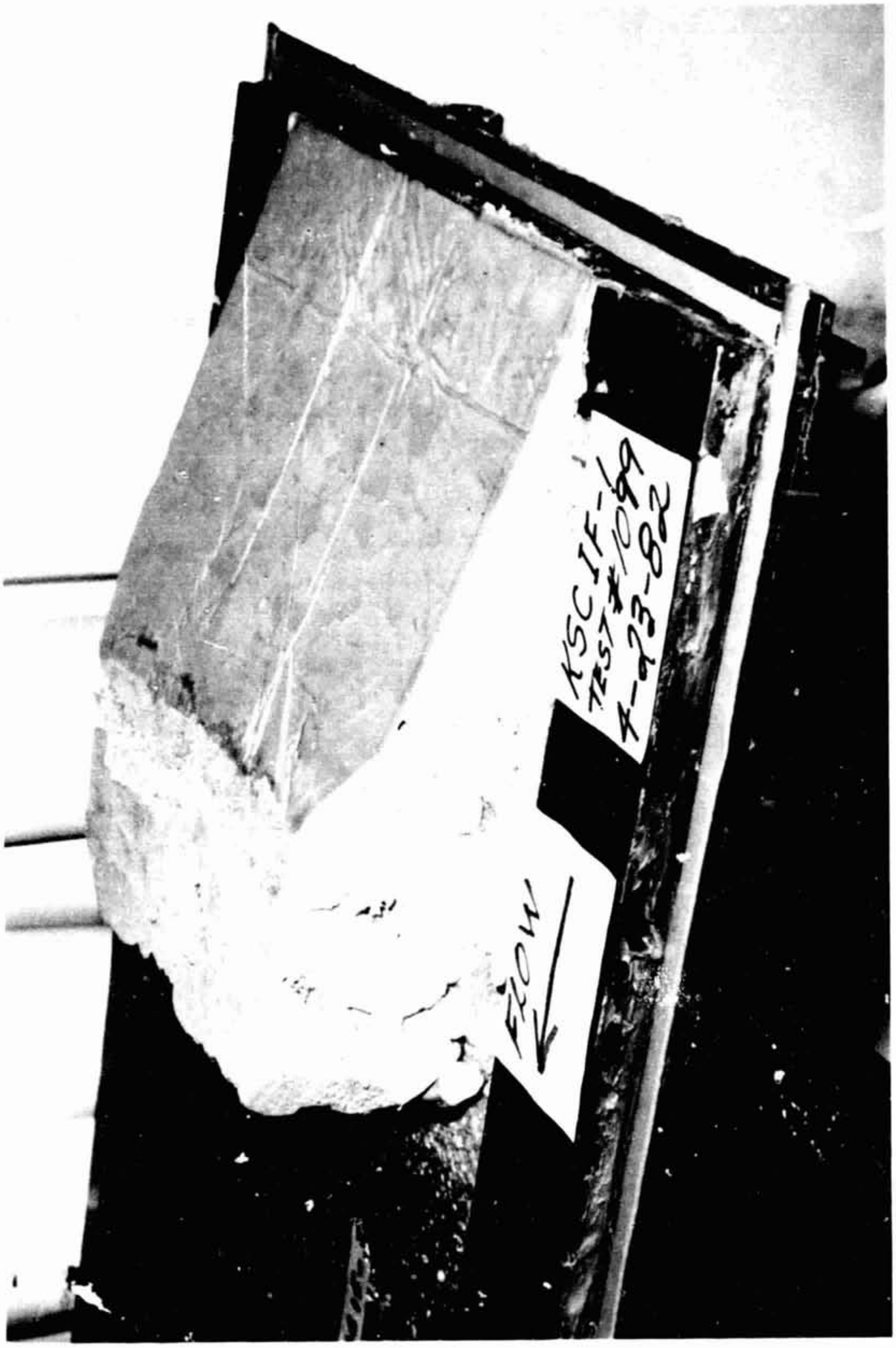


Fig. 4 - Pretest Photo of Insta-Foam Model No. KSC-IF-1

Fig. 5 - Post-Test Photo of Insta-Foam Model No. KSCIF-1

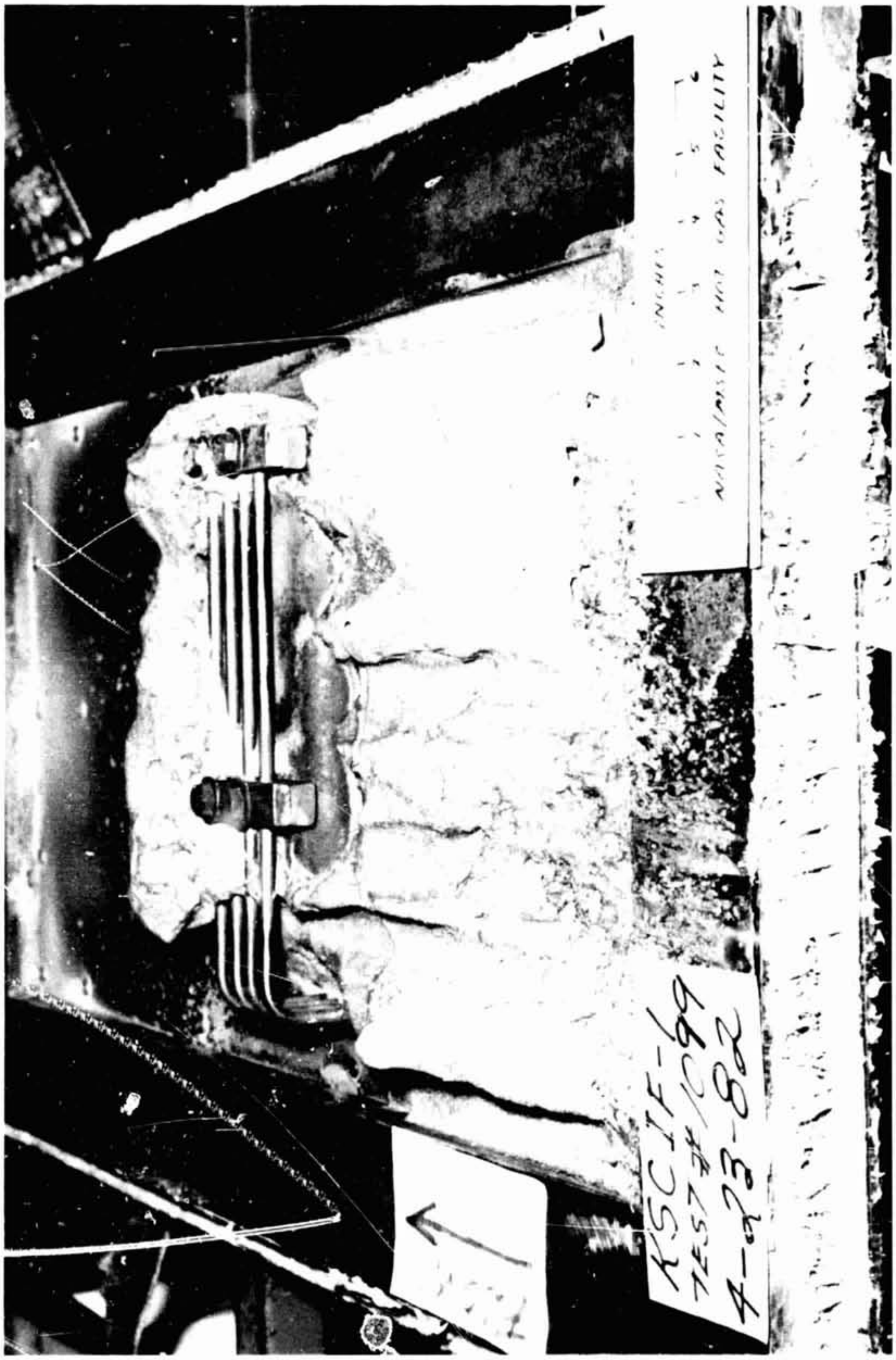
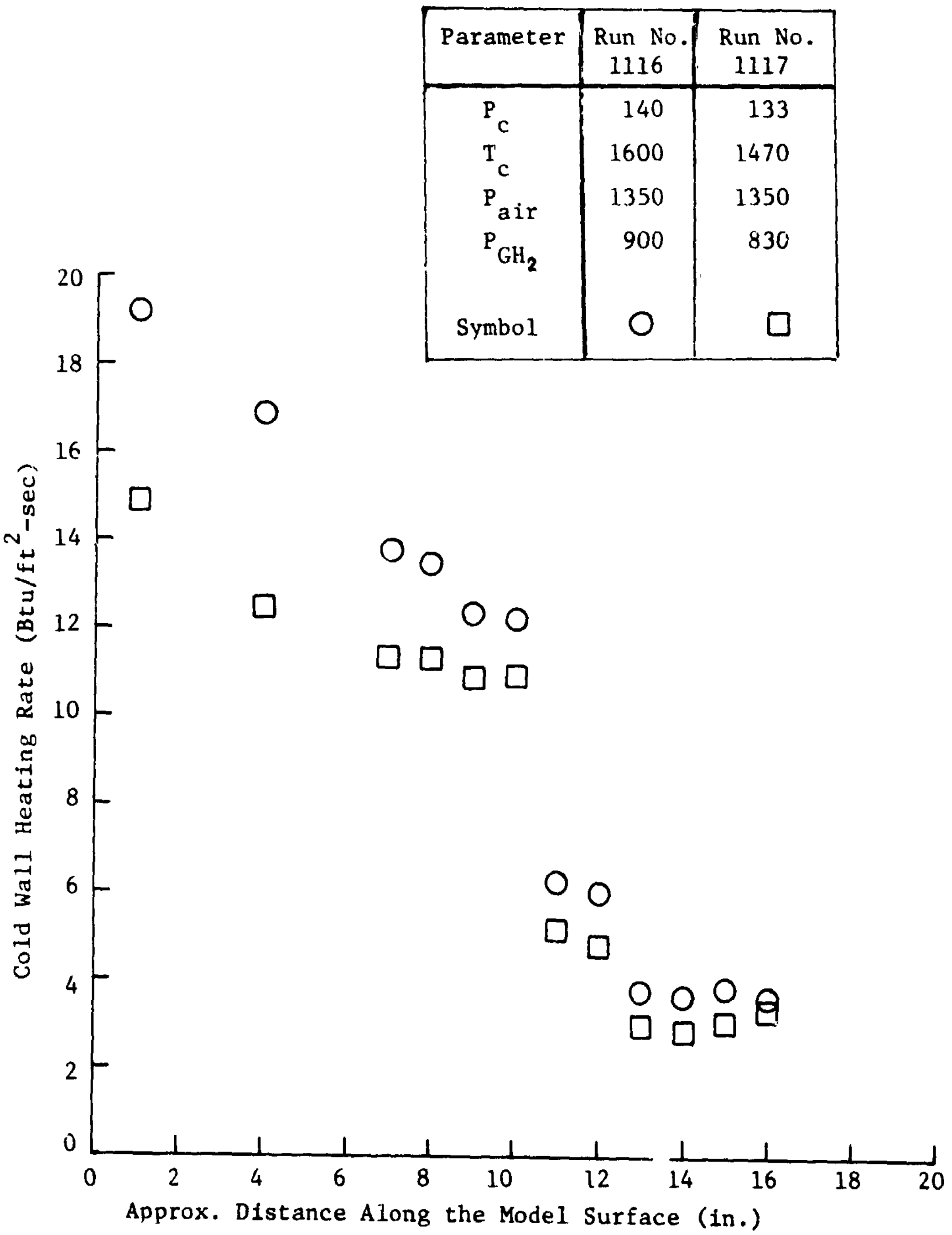


Fig. 6 - Post-Test Photo of Insta-Foam Model No. KSC-IF-1



Parameter	Run No. 1116	Run No. 1117
P_c	140	133
T_c	1600	1470
P_{air}	1350	1350
P_{GH_2}	900	830
Symbol	○	□

Fig. 7 - Cold Wall Heating Rate from 10 deg
Ramp Angle Model KSC-CAL-3

Fig. 8 - Photo of Thin-Skin Cal Model with 10 deg Ramp Angle

Fig. 9 - Pretest Photo of Insta-Foam Model No. KSC-IF-3 with 10 deg Ramp Angle

Fig. 10 - Post-Test Photo of Model No. KSC-IF-3

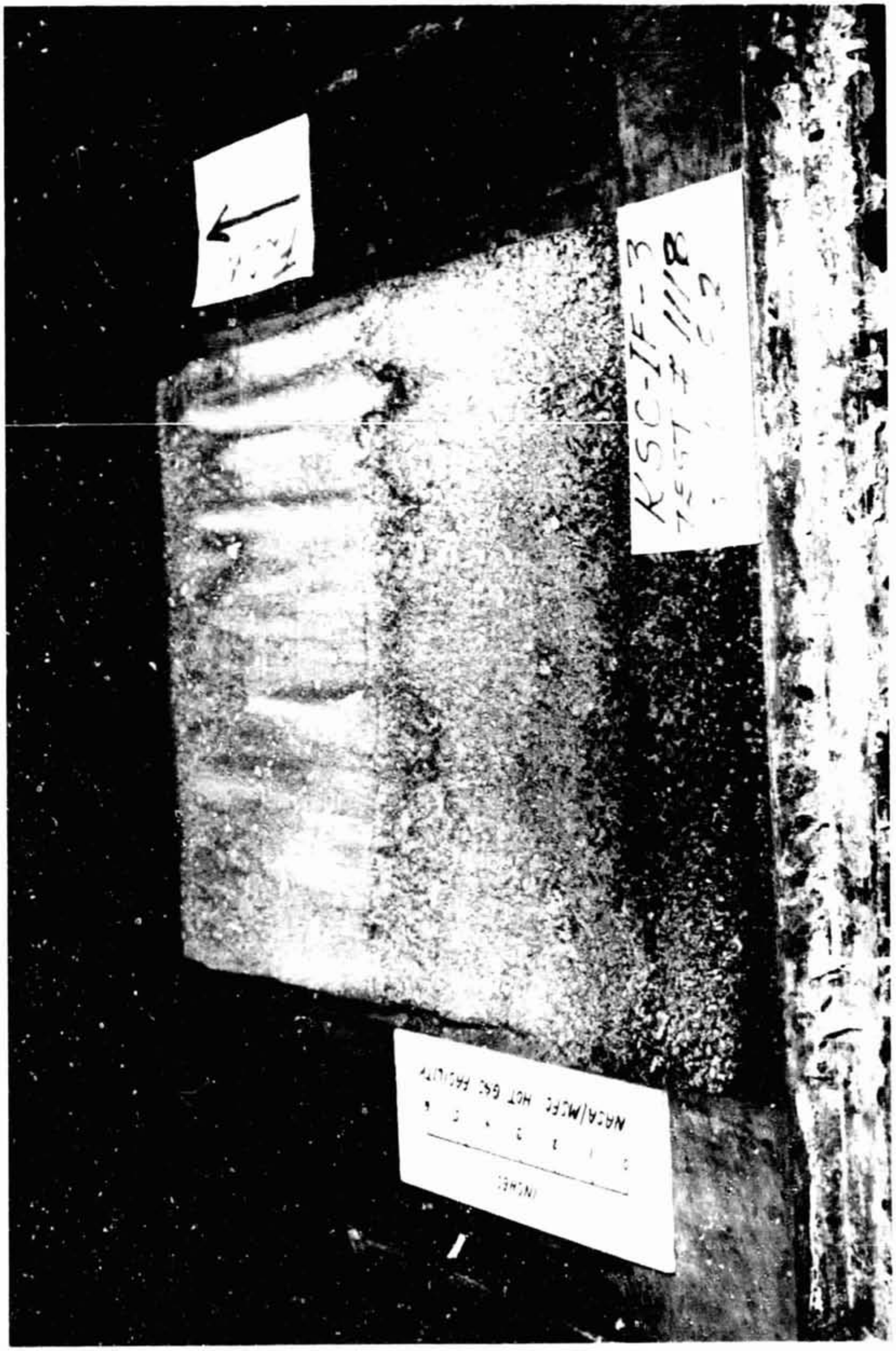


Fig. 11 - Post-Test Photo of Model No. KSC-IF-3