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NASA Contractor Report 166418

(NASA-CR-166418) THE OPTIMIZATION OF
AIRCRAFT SEAT CUSHION FIRE-BLOCKING LAYERS.
FULL SCALE: TEST DESCRIPTION AND RESULTS
Final Report, Sep. 1981 - Sep. 1982 (Douglas
Aircraft Co., Inc.) 235 p HC A11/MF A01

N83-11097

Unclass
G3/03 00776

Final Report

**Study for the Optimization of Aircraft
Seat Cushion Fire-Blocking Layers — Full Scale —
Test Description and Results**

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Kenneth J. Schutter and Fred E. Duskin

**McDonnell Douglas Corporation
Douglas Aircraft Company
Long Beach, California 90846**

**CONTRACT NASA2-11095
MAY 1982**



NASA

National Aeronautics and
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1. Report No. NASA CR-1166418	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle STUDY FOR THE OPTIMIZATION OF AIRCRAFT SEAT CUSHION FIRE BLOCKING LAYERS - FULL SCALE - TEST DESCRIPTION AND RESULTS		5. Report Date May, 1982	6. Performing Organization Code
7. Author(s) Kenneth J. Schutter Fred E. Duskin		8. Performing Organization Report No. MDC J2525	10. Work Unit No.
9. Performing Organization Name and Address Douglas Aircraft Company 3855 Lakewood Blvd. Long Beach, Ca. 90846		11. Contract or Grant No. NAS2-11095	13. Type of Report and Period Covered Final Report 9-81 to 9-82
12. Sponsoring Agency Name and Address Ames Research Center Moffet Field, Ca. 94035		14. Sponsoring Agency Code	
15. Supplementary Notes Technical Monitor: Demetrious A. Kourtides			
16. Abstract <p>This report describes the work done by Douglas Aircraft Company under contract to the National Aeronautic and Space Agency, Ames Research Center (NASA ARC) to determine the burn characteristics of presently used and proposed seat cushion materials and types of constructions. These tests were conducted in the Douglas Cabin Fire Simulator (CFS) at the Space Simulation Laboratory, Huntington Beach, California. Thirteen different seat cushion configurations were subjected to full-scale burn tests. The fire source used was a quartz lamp radiant energy panel with a propane pilot flame. During each test, data were recorded for cushion temperatures, radiant heat flux, rate of weight loss of test specimens, and cabin temperatures. When compared to existing passenger aircraft seat cushions, the test specimens incorporating a fire barrier and those fabricated from advance materials, using improved construction methods, exhibited significantly greater fire resistance. Results of these tests were similar to those obtained from tests conducted by Douglas Aircraft Company under contract to NASA Johnson Space Center, Contract NAS9-16062.</p>			
17. Key Words (Suggested by Author(s)) Aircraft Fire Safety, Fires, Aircraft Passenger Seats		18. Distribution Statement Unlimited	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page)	21. No. of Pages 229	22. Price*

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SECTION I INTRODUCTION

Aircraft passenger seats represent a high percentage of the organic materials used in a passenger cabin. These organics can contribute to a cabin fire if subjected to a severe ignition source such as post-crash fuel fire. Since 1976, programs funded by NASA have been conducted at Douglas Aircraft Company to study and develop a more fire-resistant passenger seat. The first program dealt with laboratory screening of individual materials (Report No. NASA CR-152056, Contract No. NAS 2-9337). The second program continued laboratory screening of individual materials, conducted laboratory burn tests of multilayer materials, developed a full-scale standard fire source and prepared a preliminary fire-hardened passenger seat guideline (Report No. NASA CR-152184, Contract No. NAS 2-9337). The third program consisted of additional laboratory burn testing of multilayer materials, fabricating a fire-hardened three-abreast tourist class passenger seat, and a design guideline for fire-resistant seats (Contract No. NASA 2-9337, Report No. NASA CR-152408). The fourth program fabricated and burn tested full-scale seat cushions utilizing the fire blocking concept for protecting the inner cushion (Contract No. NASA 9-16026).

The tests documented in this report involve a continuation of full-scale burning of seat cushions utilizing the fire-blocking concept.

SECTION 2
SYMBOLS AND ABBREVIATIONS

Btu	British thermal unit
°C	Degrees Celsius (centigrade)
cm	Centimeter
cm ²	Square centimeter
DAC	Douglas Aircraft Company
°F	Degrees Fahrenheit
ft	Feet
hr	Hour
in.	Inch
kg	Kilogram
kg/m ²	Kilogram per square meter
kw	Kilowatt
lb	Pound
lb/ft ²	Pounds per square foot
lb/ft ³	Pounds per cubic foot
m	Meter
mm	Millimeter
min	Minutes
NASA	National Aeronautics and Space Administration
PCT, %	Percent
psi	Pounds per square inch
sec	Second
T	Thermocouple
W	Watt

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SECTION 3
TEST ARTICLES

3.1 Test Specimens

Thirteen different seat cushion constructions were tested (Table 1). Fire blocking, when incorporated, covered all sides of the cushion. All seams were sewn with nylon thread. The overall dimensions for the back cushions were 43 by 61 by 5 centimeters (17 by 24 by 2 inches). The bottom cushions dimensions were 46 by 50 by 8 centimeters (18 by 20 by 3 inches).

3.2 Materials

The 13 test specimens were fabricated using a combination of materials shown in Table 2. These materials were selected and supplied for use in this program by NASA-AMES Research Center.

All cushions were fabricated by Expanded Rubber and Plastics Corporation in Gardena, California.

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**TABLE 1
SEAT CONSTRUCTIONS**

Construction Number	Decorative Upholstery	Slip Cover	Fire Blocking	Foam
1	Wool-Nylon	None	None	F. R. Urethane*
2	Wool-Nylon	Cotton-Muslin	Vonar-3	F. R. Urethane
3	Wool-Nylon	Cotton-Muslin	Vonar-2	F. R. Urethane
4	Wool-Nylon	None	3/8 LS 200	F. R. Urethane
5	Wool-Nylon	None	Celiox 101	F. R. Urethane
6	Wool-Nylon	None	Norfab 11 HT-26-AL	F. R. Urethane
7	Wool-Nylon	Cotton-Muslin	Vonar-3	N. F. Urethane*
8	Wool-Nylon	None	Norfab 11 HT-26-AL	N. F. Urethane
9	Wool-Nylon	None	None	LS 200 Neoprene
10	Wool-Nylon	None	None	Polyimide
11	Polyester	None	None	Polyimide
12	Wool-Nylon	None	Norfab 11 HT-26	F. R. Urethane
13	Wool-Nylon	None	PBI	F. R. Urethane

*F. R. Urethane (Fire Retarded Urethane)
N. F. Urethane (Non-Fire Retarded Urethane)

TABLE 2
MATERIAL

Material	Source
#2043 urethane foam, fire-retardant (FR), 0.032 g/cm ³ (2.0 lb/ft ³) 43 ILD	North Carolina Foam Ind. Mount Airy, NC
Urethane foam, non-fire retardant (NF), 0.022 g/cm ³ (1.4 lb/ft ³) 24-35 ILD	CPR Division of Upjohn Torrance, Ca.
Vonar-3, 3/16-inch thick with Osaburg cotton scrim (23.5 oz/yd ²) .079 g/cm ²	Chris Craft Industries Trenton, NJ
Norfab 11HT26-aluminized (12.9 oz/yd ²) .044 g/cm ² , aluminized one side only	Amatex Corporation Norristown, Pa
Gentex preox (celiox) (10.9 oz/yd ²) .037 g/cm ² , aluminized one side only	Gentex Corporation Carbondale, Pa
Wool nylon (0.0972 lb/ft ²) .0474 g/cm ² , 90% wool/100% nylon, R76423 sun eclipse, azure blue 78-3080 (ST7427-115, color 73/3252)	Collins and Aikem Albermarle, NC
Vonar 2, 2/16 inch thick, .068 g/cm ² , (19.9 oz/yd ²) osaburg cotton scrim	Chris Craft Industries Trenton, NJ
LS-200 foam, 3/8" thick (33.7 oz/yd ²) .115 g/cm ² LS-200 foam, 3-4 inches thick (7.5 lb/ft ³) 0.12 g/cm ³	Toyad Corporation Latrobe, Pa
Polyimide Foam (1.05 lb/ft ³) .017 g/cm ³	Solar San Diego, Ca
100% polyester (10.8 oz/yd ²) .037 g/cm ² 4073/26	Langenthal Corporation Bellevue, Wa
Norfab 11HT26 Approximately (11.3 oz/yd ²) .038 g/cm ²	Gentex Corporation Carbondale, Pa
PBI Woven Cloth Approximately (10.8 oz/yd ²) .037 g/cm ²	Calarese Plastic Company Charlette, NC

SECTION 4 TEST PROGRAM

4.1 Test Setup

All tests were conducted within the Cabin Fire Simulator (CFS). The CFS is a double-walled steel cylinder 12 feet in diameter and 40 feet long, with a double-door entry airlock at one end and a full-diameter door at the other. It is equipped with a simulated ventilation system and, for environmental reasons, all exhaust products are routed through an air scrubber and filter system. A view port in the airlock door allows the tests to be monitored visually. The radiant heat panels used in these tests were positioned as shown in Figures 1 and 2.

The radiant panels consisted of 46 quartz lamps producing a 10 watt/square centimeter heat flux at 6 inches from the surface of the panels. Prior to testing, the heat flux upon the cushion surface was mapped using calorimeters. Figure 3 shows the positions at which heat flux measurements were taken and their recorded values.

4.2 Instrumentation

The relative location of instrumentation for the tests is shown in Figure 4.

4.2.1 Post test still photographs were taken for each seat construction. These photographs are located in Appendix A. In addition, a video recording was made during each test.

4.2.2 Thermal Instrumentation

Temperatures were obtained using chromel-alumel thermocouples placed within the seat constructions. The number of thermocouples varied between 2 and 3 per cushion depending on whether or not a fire blocking layer was used (Figure 5). In the CFS, chromel-alumel thermocouples were located along the ceiling and at the cabin air exhaust outlet. Two heat flux sensors were installed facing the seat assembly. The upper calorimeter was used to monitor the heat flux given off by the radiant panels to insure consistency among tests. The thermocouple and calorimeter signals were fed through a Hewlett-Packard 3052A Automatic Data Acquisition System which provided a real-time printout of data (Figure 6).

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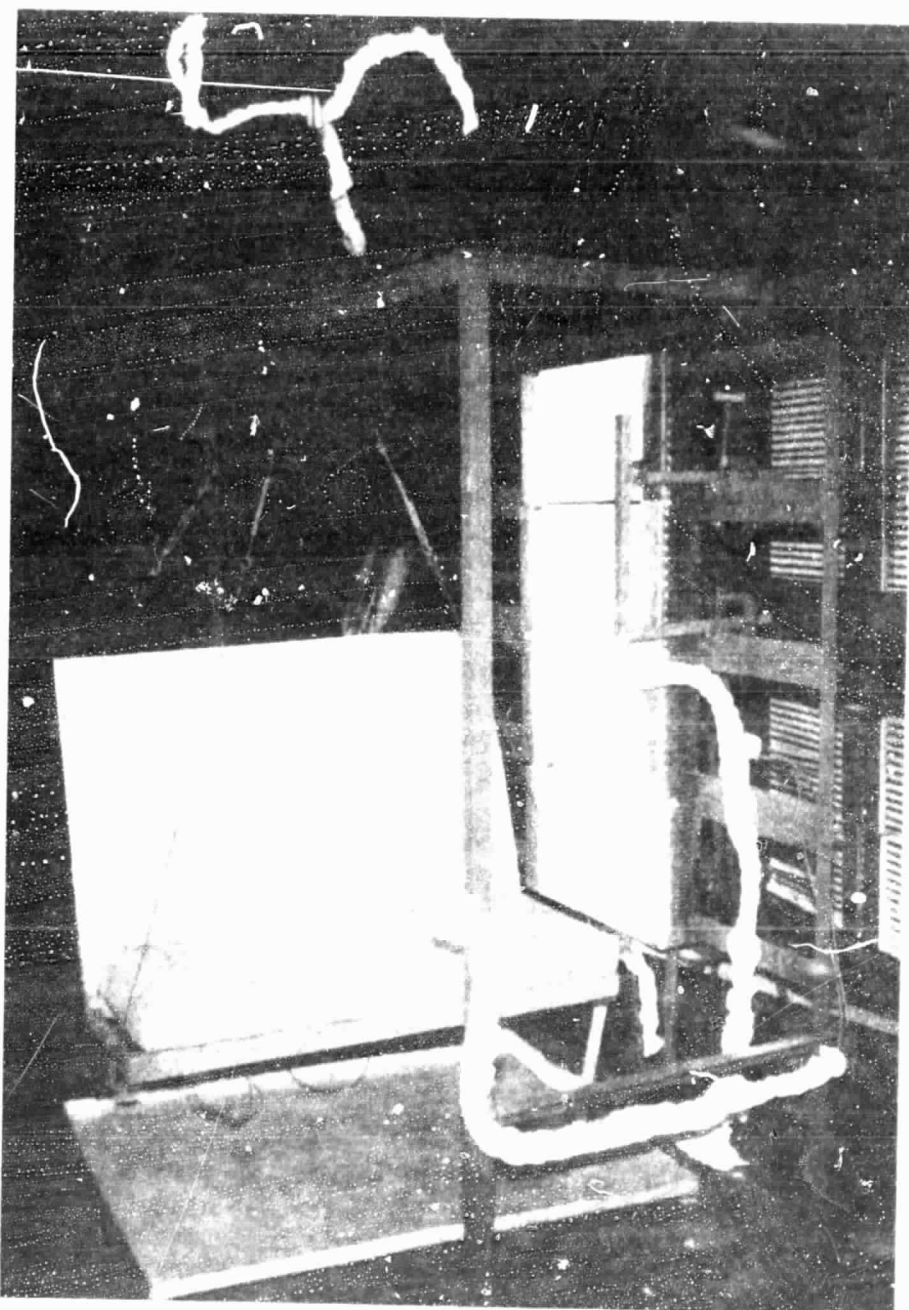


FIGURE 1. TEST STEUP

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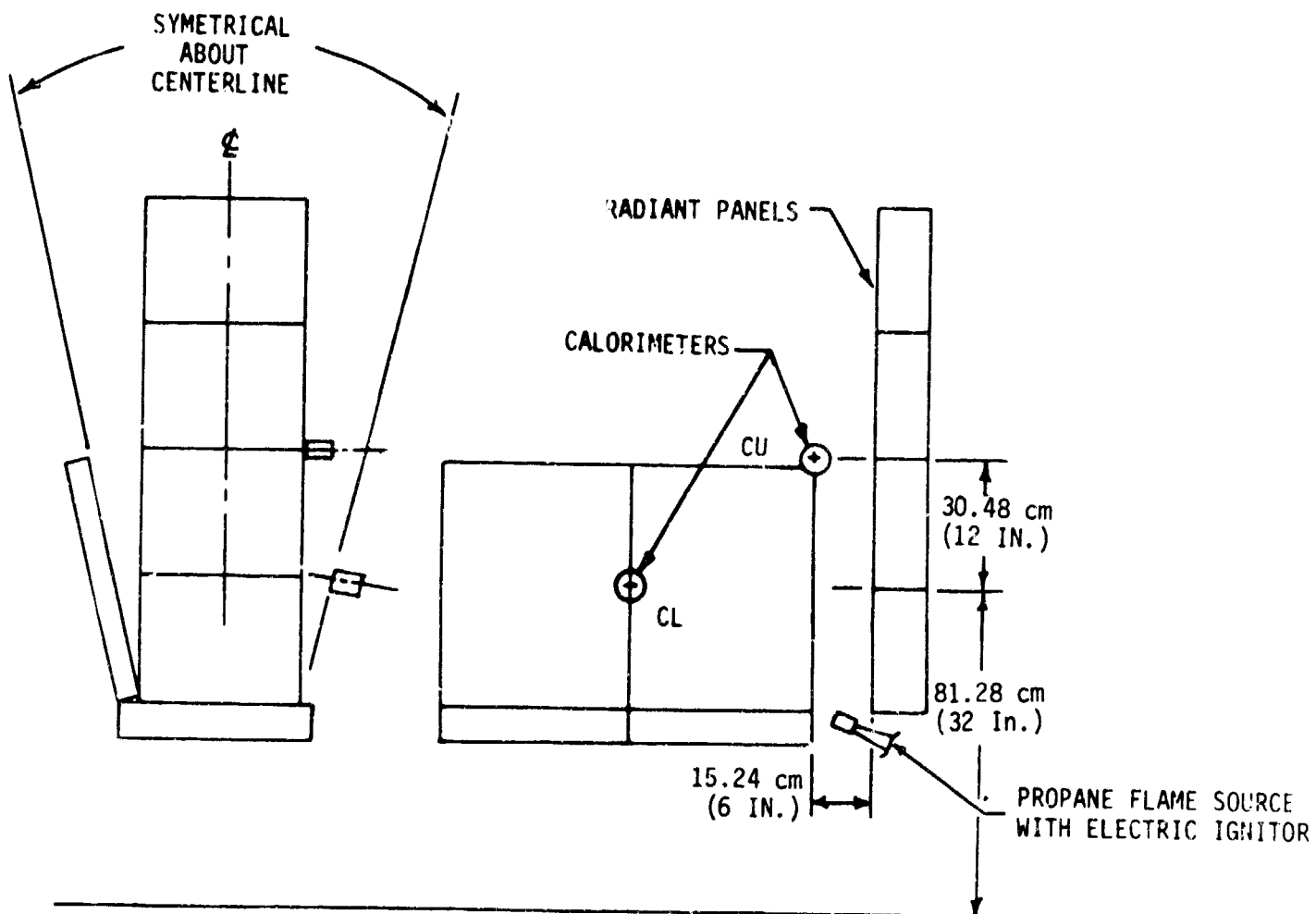


FIGURE 2. FUEL SOURCE AND CALORIMETER LOCATION

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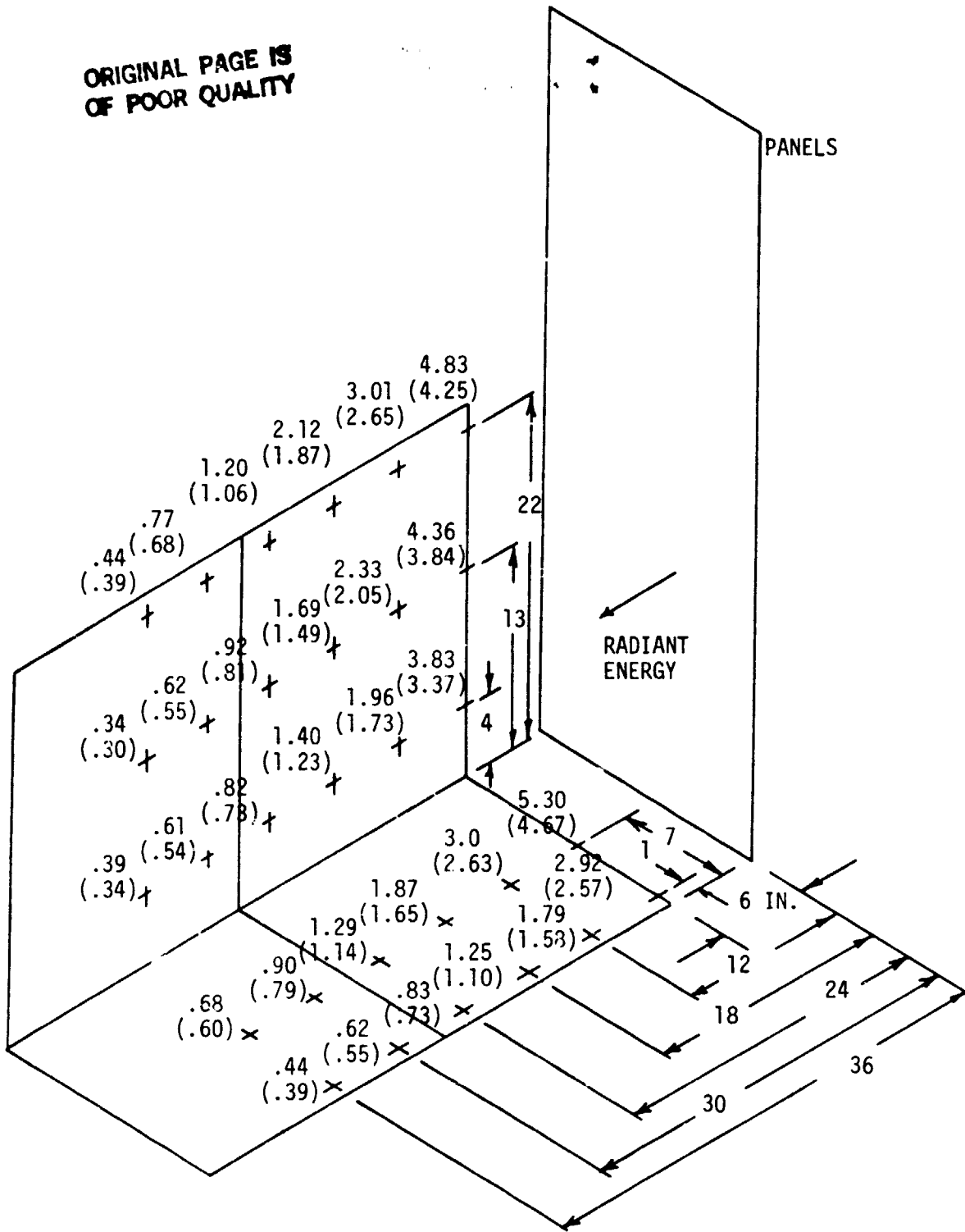
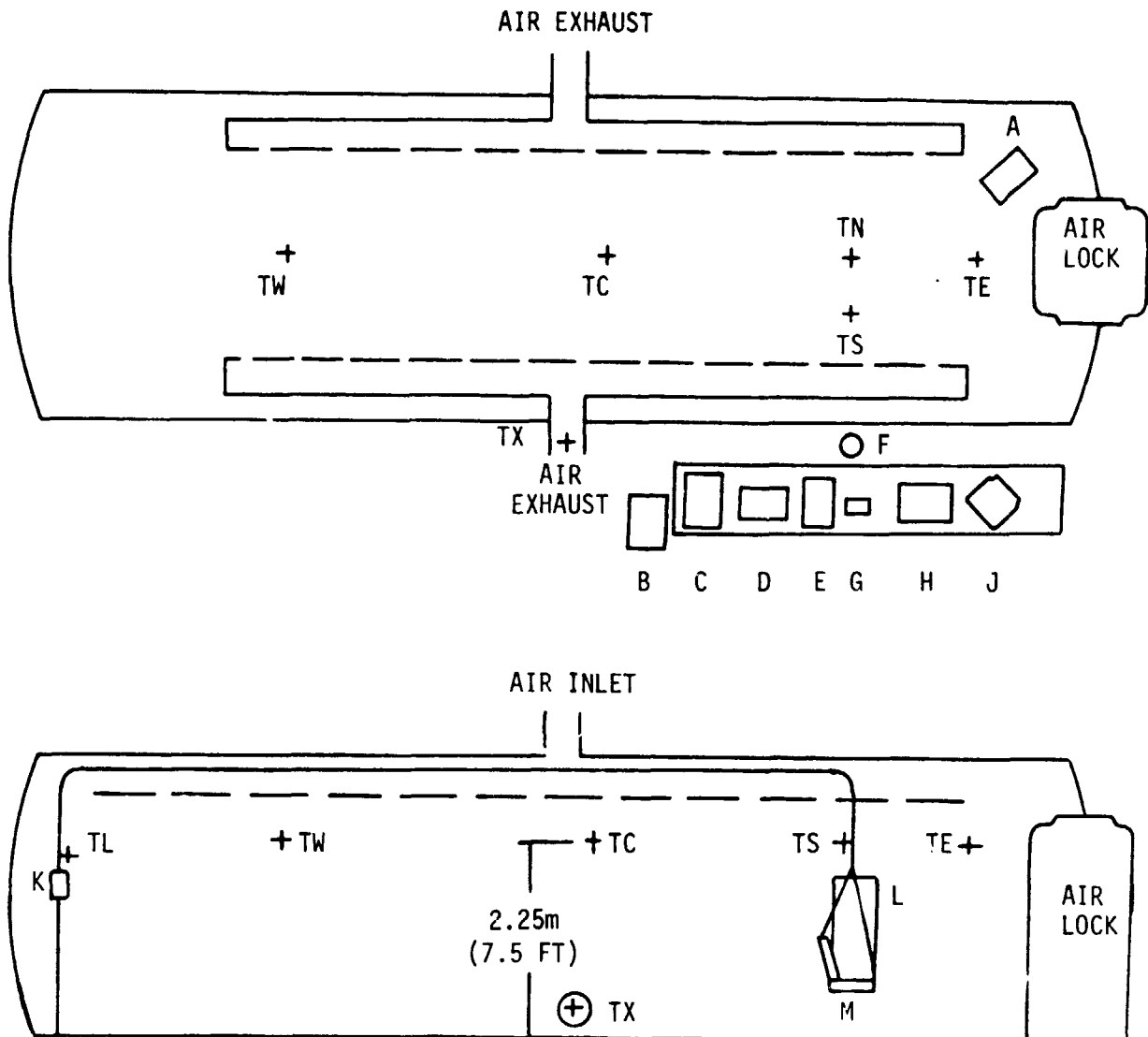


FIGURE 3. HEAT FLUX MAPPING w/cm^2 (Btu/FT²-SEC)



- LEGEND:
- A = VIDEO CAMERA
 - B = HEWLETT PACKARD SCANNER AND DIGITAL VOLTMETER
 - C = HEWLETT PACKARD CALCULATOR
 - D = HEWLETT PACKARD PLOTTER
 - E = HEWLETT PACKARD PRINTER
 - F = PROPANE ON/OFF VALVE
 - G = VARIABLE TRANSFORMER
 - H = VIDEO CASSETTE RECORDER
 - J = VIDEO MONITOR
 - K = 100 LB. LOAD CELL
 - L = RADIANT ENERGY PANELS
 - M = SEAT FRAME
 - T = THERMOCOUPLE

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FIGURE 4. CFS INSTRUMENTATION

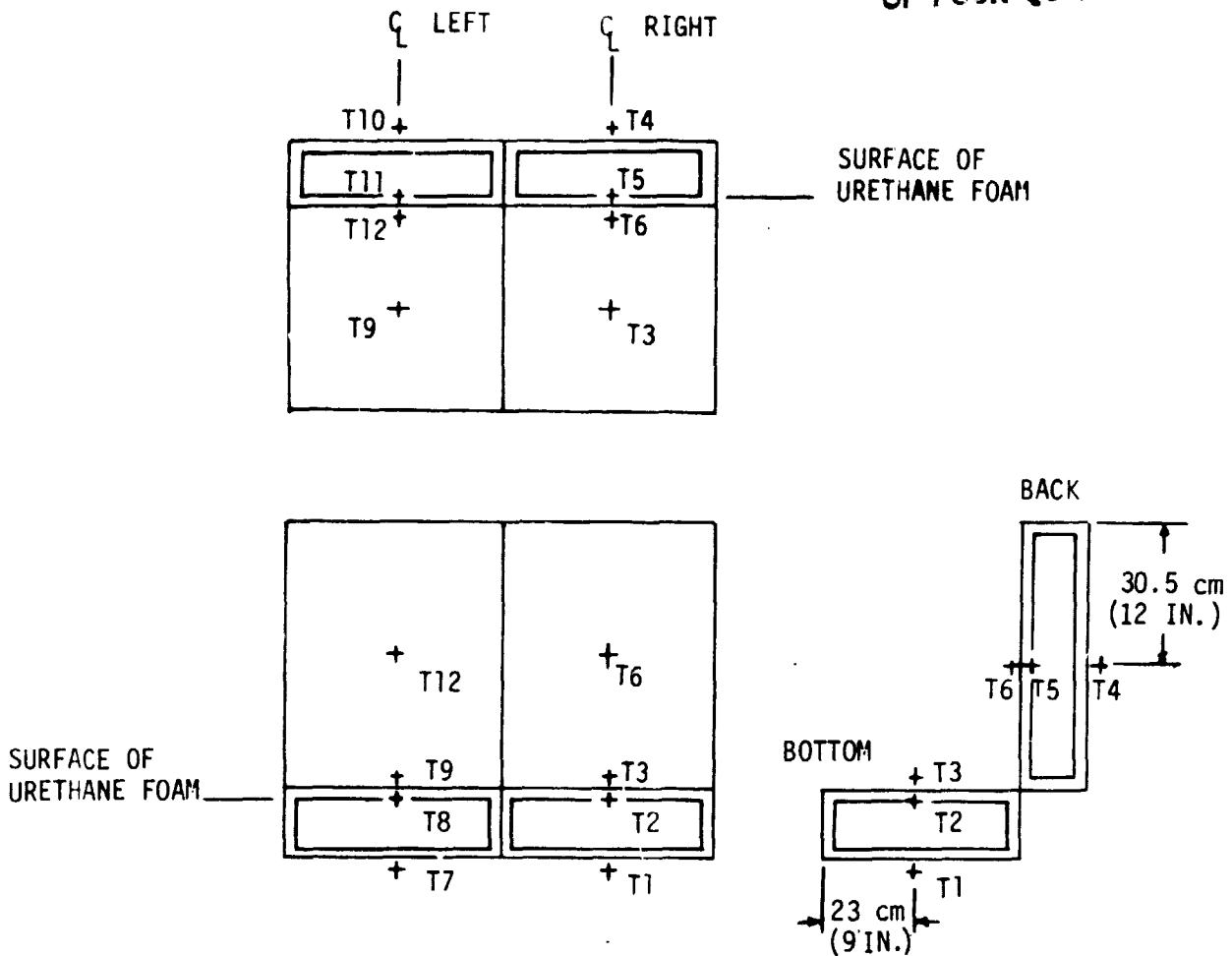


FIGURE 5. CUSHION THERMOCOUPLES (LOCATION AND IDENTIFICATION)

4.3 Test Procedures

Cushions instrumented with thermocouples were weighed, then positioned on the seat frame. The seat frame was rigged with suspension cables and hung from one end of a cable located in the ceiling of the CFS. The other end of the ceiling cable was attached to a load cell. Thermocouples, heat flux sensors, and load cells were checked for proper operation and calibration. The computer and video were started, the propane gas was ignited, and then the radiant panel was switched on. The radiant panels remained on for five minutes. After fifteen minutes, the tests were complete and post-test photos were taken of the cushion residue. The residue was removed from the seat frame and weighed.

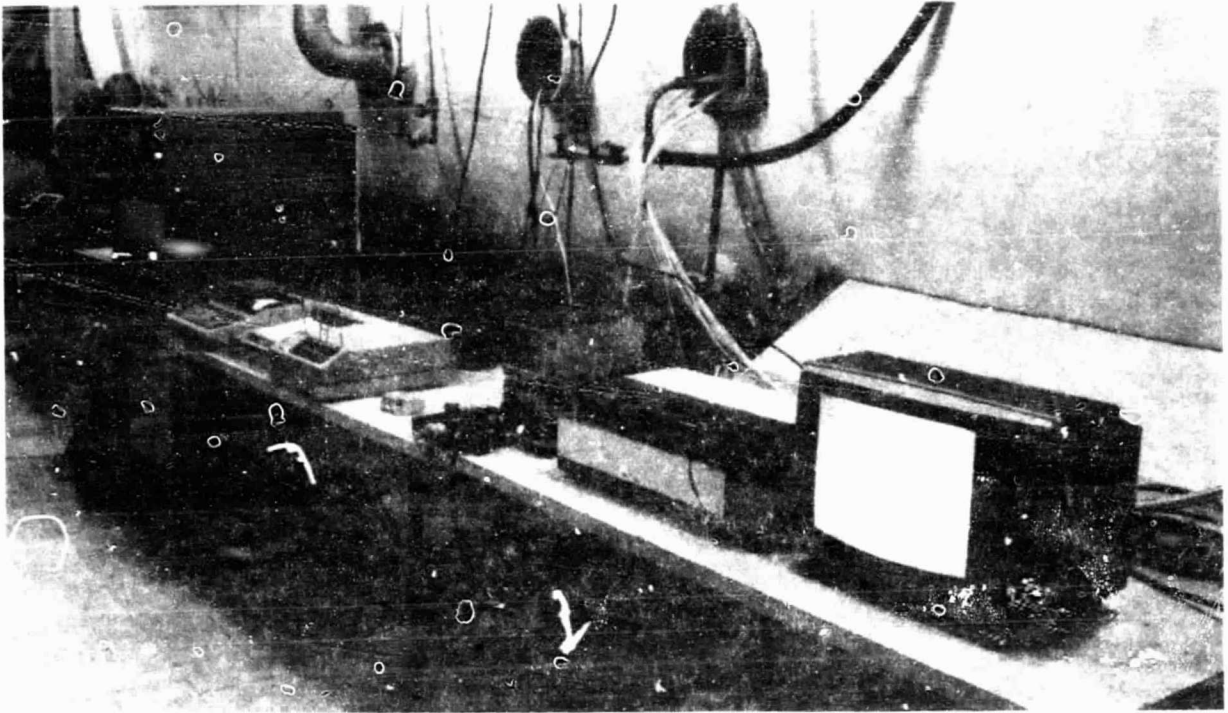


FIGURE 6. DATA ACQUISITION

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SECTION 5 TEST RESULTS

A total of 23 full-scale cushion burn tests were conducted. Each seat construction listed in Table 1 was tested twice with the exception of constructions 8, 11, 12 and 13. For these constructions, only enough material for one test was available. However, when two tests of the same construction were made, the results were identical and therefore a third test was considered unnecessary.

The purpose of these tests was to investigate the burning characteristics of cushion employing fire resistant designs. It was the peculiar designs and how the materials were used which were evaluated and not so much the individual materials themselves. To give an example, construction number 2 was designed to employ one layer of Vonar-3 as a fire blocking layer. The evaluation of the performance of this cushion was not so much decided on what material was used, Vonar-3, as the way in which it was used, one layer as fire blocking.

5.1 General

The constructions tested can be classified in four groups. These groups are standard cushion construction, standard cushion construction with a protective covering enveloping the urethane foam core, standard cushion construction with a protective covering enveloping non-fire retarded urethane foam core and standard cushion construction with the urethane foam core replaced by an advance fire resistant foam.

The test results of these constructions is graphically provided in plots presented in Appendix B. To aid in comparison of these constructions, the peak values for each test and the time at which they occurred were taken from the respective plots and are presented in Table 3. The weight loss results are in Table 4. Post-test photographs for each construction are located in Appendix B.

5.2 Standard Seat Construction

Construction number 1 is representative of the type of materials most commonly used in the construction of aircraft passenger seat cushions. These cushions were totally consumed by the fire in a matter of minutes.

Characteristically, the fire-retarded urethane foam thermally decomposes under the extreme heat into a fluid form and subsequently to a gas. In the fluid form, the urethane drips from the seat cushion onto the floor forming a puddle or pool. This pool of urethane fluid gives off gases which are ignited by burning debris falling from the seat. This results in a very hot pool fire engulfing the seat in a matter of minutes.

TABLE 3
TEST DATA PEAK VALUES

C = CALORIMETER T = THERMOCOUPLE S = SECONDS

CUSHION CONSTRUCTION	CL	80/RT-SEC																TC	DP IN	DP IN 1/20		
		T1 °F	T2 °F	T3 °F	T4 °F	T5 °F	T6 °F	T7 °F	T8 °F	T9 °F	T10 °F	T11 °F	T12 °F	TS °F	TM LB	BEFORE LB	AFTER LB				DELTA LB	TX °F
1 TEST 1	4.0	1494	1666	1309	1218	1326	1690	912	1341	747	750	7.4	0	7.4	293	308	388	11.11				
	2005	1505	1645	1625	2025	2225	2225	1805	2285	2225	1805	2405	2325	2345	1605							
1 TEST 17	3.40	1779	1303	1376	1652	1762	1800	1111	1491	943	1216	7.5	0	7.5	181	359	386	15.77				
	1525	1345	1265	1225	1185	1765	1745	2265	1785	1725	1265	2165	1805	1865	1245							
2 TEST 2	1.40	652	820	1284	1319	1368	108	199	372	98	155	384	254	379	12.75	8.20	4.55	154	163	187	5.24	
	1065	8985	3045	1225	6545	5085	5125	3365	4825	3185	8525	6025	3165	1645	3145	3245	3185	3005	705			
2 TEST 4	1.62	517	800	1505	1008	724	1170	157	170	418	102	204	384	261	392	11.97	8.3	3.67	111	172	191	3.01
	1025	3985	3145	1265	4765	2805	1185	8985	5265	3225	8725	4785	3205	1205	3085	3165	3185	2985	6345			
3 TEST 11	1.64	917	964	1380	1531	1213	1131	234	188	391	114	326	232	268	437	11.5	7.2	4.3	121	183	216	5.72
	1125	5405	2825	985	5705	5445	104	8905	5485	3205	8885	3205	3965	2625	2085	3245	2825	3145	645			
3 TEST 12	1.66	991	872	1399	1372	1157	1231	233	245	407	112	232	367	282	496	11.5	7.2	4.3	126	196	229	6.0
	1025	3845	3105	1025	7165	2585	1565	8365	4705	3185	8465	4065	3185	3185	3085	3185	3185	3125	645			
4 TEST 3	1.54	929	1327	1242	1038	1647	1448	235	265	398	108	129	450	302	414	11.65	7.65	4.0	111	183	214	5.3
	605	4605	3945	1305	3305	3185	1725	6865	455	3165	8605	8845	3145	2865	3185	3165	3225	3265	605			
4 TEST 10	1.50	1106	1310	1682	1225	1461	1294	180	264	432	129	244	428	265	472	11.95	7.8	4.15	115	186	206	5.43
	1145	3605	3105	1205	5825	3605	1225	8745	3885	3165	8985	4205	3145	3165	3125	3205	3205	3205	565			
5 TEST 7	1.57	975	958	1314	711	1209	1230	143	375	406	130	409	419	267	439	9.05	6.82	2.23	122	190	209	5.76
	1045	3745	3165	925	3725	3065	1645	3465	3265	3185	5825	3305	3185	2165	1945	3305	3265	2705	565			
5 TEST 13	1.65	1098	975	1425	767	1070	1165	150	323	415	122	306	401	272	477	9.20	6.50	2.70	118	191	222	6.26
	965	3465	1505	1285	3445	2425	1125	3645	3505	3165	5685	3445	3165	2885	2105	3305	2985	3105	645			
6 TEST 6	1.70	660	1034	1495	867	979	1599	127	331	458	113	239	388	274	498	9.4	7.13	2.27	194	217	217	5.81
	1005	4225	2785	985	3865	2285	1045	4465	3525	3165	6165	3705	3225	3065	2765	3205	3045	3185	605			

TABLE 3
TEST DATA PEAK VALUES (CONTINUED)

CUSHION CONSTRUCTION	CL	BTU/FT ² -SEC										TM	BEFORE LB	AFTER LB	DELTA LB	TK OF	TC OF	TE OF	TOP OF IN. H ₂ O			
		T1 OF	T2 OF	T3 OF	T4 OF	T5 OF	T6 OF	T7 OF	T8 OF	T9 OF	T10 OF									T11 OF	T12 OF	TS
6 TEST 14	1.74	705	1002	1012	890	807	1352	307	120	469	127	254	490	274	473	9.32	7.0	2.32	117	185	211	6.64
	1005	3565	3165	1125	4765	1885	1665	3805	3765	3185	6165	3785	3165	3125	2565				3165	3145	3185	585
7 TEST 15	1.39	793	782	1366	201	1031	1115	135	198	412	110	176	382	277	405	11.25	8.45	2.8	115	171	204	5.64
	965	9185	3085	945	2965	3365	1205	6605	5565	3205	8925	6045	3225	2985	3105				3265	3125	3025	665
7 TEST 16	1.54	950	778	1156	983	945	1165	148	229	400	101	175	350	269	396	11.03	8.10	2.93	108	160	200	6.03
	1065	8505	3165	1265	6965	3145	1365	8945	4645	3185	8825	5265	3185	3185	3145				3265	3185	3185	665
8 TEST 18	1.54	783	1020	1180	1198	880	1133	142	334	459	146	285	393	310	507	8.47	6.05	2.42	126	206	229	6.08
	965	3665	3085	1045	3425	2365	1305	3825	3525	3185	4025	3705	3185	2865	2965				3305	3145	3185	645
9 TEST 8	1.51	132	1026	168	968	100	968	100	280	94	94	323	270	333	19.6			104	143	171	5.34	
	1145	3225	3185	3605	3225	3945	3225	3945	3285	8485	8485	3185	2245	2345				3105	2665	2925	625	
9 TEST 19	1.46	145	988	161	988	161	516	95	308	92	92	318	264	329	19.01	17.65	1.36	98	137	169	5.43	
	1185	3245	3185	4185	3225	4645	3225	4645	3405	8825	8825	3205	2245	2505				3065	3105	3105	645	
10 TEST 9	1.60	774	1393	1335	1029	411	1029	411	1061	161	161	729	290	350	5.05	3.60	1.45	113	162	185	5.81	
	865	1765	1085	3345	1245	3685	1245	3685	2905	4585	4585	3325	2365	3065				3185	2305	2725	525	
10 TEST 6	1.67	1153	1425	1794	1141	556	1141	556	895	152	152	373	302	346	6.48	3.70	2.78	111	166	194	5.76	
	1025	2585	985	2425	1345	4765	1345	4765	3265	5245	5245	3885	2605	3105				3165	2745	3205	545	
11 TEST 20	1.46	588	1100	886	1252	134	1252	134	436	176	176	368	261	353	4.20	3.67	0.53	104	150	184	5.18	
	1085	3685	1105	2285	1545	3585	1545	3585	3245	4505	4505	3225	2665	3025				3185	3245	3205	685	
12 TEST 21	1.63	1504	1231	1414	1091	1204	1450	783	1039	1185	628	772	324	392	9.1	3.66	5.54	137	214	238	6.02	
	1145	3405	3225	1205	3965	3005	2385	3465	3805	7925	4005	3205	3205	2105				3965	3325	3205	665	
13 TEST 22	1.81	1259	1059	1331	698	1052	1462	497	405	457	131	338	452	305	432	9.8	6.0	3.8	122	182	223	6.53
	1005	3225	3205	1125	3445	1745	1565	5065	3265	3185	6785	3425	3165	3005	2125				3125	2805	2525	745

C = CALORIMETER T = THERMOCOUPLE S = SECONDS

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TABLE 4
WEIGHT DATA

Cushion Construction		Weight Before kg (LB)	Weight After kg (LB)	Weight Loss kg (LB)
1	Test 1	3.36 (7.4)	0 (0)	3.36 (7.4)
1	Test 17	3.40 (7.5)	0 (0)	3.40 (7.5)
2	Test 2	5.78 (12.75)	3.72 (8.20)	2.06 (4.55)
2	Test 4	5.43 (11.97)	3.76 (8.3)	1.67 (3.67)
3	Test 11	5.22 (11.5)	3.27 (7.2)	1.95 (4.3)
3	Test 12	5.22 (11.5)	3.27 (7.2)	1.95 (4.3)
4	Test 3	5.28 (11.65)	3.47 (7.65)	1.81 (4.0)
4	Test 10	5.42 (11.95)	3.54 (7.8)	1.88 (4.15)
5	Test 7	4.11 (9.05)	3.00 (6.62)	1.11 (2.23)
5	Test 13	4.17 (9.20)	2.95 (6.50)	1.22 (2.70)
6	Test 5	4.26 (9.40)	3.23 (7.13)	1.03 (2.27)
6	Test 14	4.23 (9.32)	3.18 (7.0)	1.05 (2.32)
7	Test 15	5.10 (11.25)	3.8 (8.45)	1.30 (2.80)
7	Test 16	5.00 (11.03)	3.67 (8.10)	1.33 (2.93)
8	Test 18	3.84 (8.47)	2.74 (6.05)	1.10 (2.42)
9	Test 8	8.89 (19.6)	N/A	--
9	Test 19	8.62 (19.01)	8.0 (17.65)	.62 (1.36)
10	Test 9	2.29 (5.05)	1.63 (3.60)	.66 (1.45)
10	Test 6	2.94 (6.48)	1.68 (3.70)	1.26 (2.78)
11	Test 20	1.91 (4.20)	1.66 (3.67)	.25 (.53)
12	Test 21	4.13 (9.10)	1.66 (3.66)	2.47 (5.54)
13	Test 22	4.45 (9.80)	2.72 (6.00)	1.73 (3.80)

5.3 Protected Fire-Blocked Standard Cushions

The purpose of the fire-blocking layer surrounding the urethane foam core is to thermally isolate the foam from the heat source by either conducting the heat laterally away and by providing an insulative char layer.

5.3.1 Aluminized Fabric

The celiox and norfab fire blocking constructions employed a reflective aluminum coating bonded to their outer surface.

All three constructions resulted in identical test results. These constructions were unable to protect the urethane foam in the cushions closest to the radiant heat source. They were able to slow down the burn rate of the urethane thus producing a less severe fire. This fire was unable to penetrate the adjacent cushions also protected by these materials.

Characteristically, in these constructions the urethane thermally decomposes within the fire-blocking layer and produces fluids and gases. The gas leaks through the cushion seams, ignites, burn and continues to open the seams. This results in a small controlled pool fire burning within the fire-blocking envelope with flames reaching through the seam areas. The radiant heat source in combination with the controlled pool fire, is adequate to thermally decompose the urethane foam on the closest side of the adjacent cushions. The heat source is not adequate to ignite these gases.

Reversing the edges at which the seams were located, i.e, placing the seams at the bottom edge instead of the top edge of the cushion, made no appreciable difference for the cushions adjacent to the fire source. Placing the seam on the bottom edge of the cushions farthest from the radiant panel helped to prevent the escaping gases from igniting, and the seam from opening. All cushions using this fire-blocking material were vented in the back to prevent ballooning of the cushions by the gas generated within them. However, the decomposed urethane tended to plug the vent and restrict the out-gasing. The overall final appearance of the cushion closest to the radiant panels showed a fragile, charred, empty fire-blocking envelope with its seams burned open.

The final appearance of the cushions farthest from the radiant panels showed a partially charred upholstery cover. The urethane cushion had some minor hollow spots. When the seams were placed on the bottom edge of the cushion, a fully intact fire-blocking envelope remained.

The percent weight loss between the fire and non-fire retarded urethane cushions was small, as shown by Figure 7.

5.3.2 Non-Aluminized Fire Blocking

Constructions 2, 3 and 7 used Vonar foam, construction 4 used LS-200 foam, construction 12 used non-aluminized norfab fabric and construction 13 used PBI fabric.

The constructions were unable to protect the urethane foams in the cushions closest to the radiant panels. However, they did slow down the burn rate of the urethane thus subjecting the adjacent cushion to a less intense fire.

The fire-blocking foams performed much like the aluminized fabric fire-blocking in that even though the heat was intense enough to thermally decompose the urethane into a fluid and gas, the fire blocking layer was able to contain and subdue the burning urethane. Flames exited where the fire-blocking char layer had fallen away.

The non-aluminized norfab fabrics were unable to contain the decomposed urethane. The urethane fluid dripped onto the floor where it pooled and ignited. The cushions were completely consumed when this floor fire engulfed it. The overall final appearance of the cushion remains closest to the radiant panels for foam fire blocking constructions 2, 3, 4 and 7 was thoroughly charred fire-blocking material void of all urethane foam.

The final appearance of the cushions farthest from the radiant panels were very similar. They varied in the amount of thermal decomposition of the urethane foam core, i.e., the size of the void or hollowing of the urethane. Construction number 2 using Vonar-3 material produced the smallest amount of urethane decomposition. It was followed by construction number 4, 3/8 LS 200 neoprene, and construction number 3, Vonar-2. Construction number 7 used a non-fire retarded urethane with Vonar-3. It did not fair as well as construction number 2 employing fire retarded urethane.

Typically, the foam fire-blocking layer adjacent to the urethane hollow spots were completely charred but intact.

5.4 Advanced Foam

Construction numbers 9, 10 and 11 used advanced foams in place of the urethane foam.

Construction number 9, LS 200 neoprene, produced a deep seated fire which did not produce a significant amount of heat or flames. It smoldered long after the test was completed and required total emersion in water to extinguish. This cushion had the lowest weight loss as shown by Figure 7. However, an all LS-200 neoprene seat cushion would result in a large aircraft weight impact because of its high density.

The foam in the seat cushion closest to the radiant panels was completely charred with the upholstery burned off of all surfaces except the bottom and back.

The foam in the seat cushions farthest from the radiant panels had a thick char on the edge closest to the heat source. This char gradually diminished halfway across the cushions. The upholstery on the back and bottom of these cushions was not burned.

Constructions 10 and 11, polyimide foam, had different upholstery materials. Construction 10, 90/10 wool-nylon upholstery, performed identically to a previous test program. The cushions closest to the radiant panels shrunk to one-half inch in thickness or less with a char of one-quarter inch or greater.

The cushion farthest from the radiant panels shrank to within one-half inch thickness with a char of one-quarter inch or less.

Characteristically, the polyimide foam thermally decomposes by giving off gases, and produces a char layer as it decreases in size.

The decomposing of the foam beneath the upholstery on the seat farthest from the radiant panel creates a pocket or void where the gases generated by the foam accumulates. When these trapped gases burn, the foam further thermally decomposes. Construction number 11, polyester upholstery, reacted differently from that characteristic of construction number 10. When the radiant panel was turned on, the polyester upholstery on the cushion farthest from the heat source rapidly decomposed into a liquid which dripped off the seat cushions.

With the upholstery gone, the majority of the gas from the decomposing polyimide foam escaped without igniting. These cushions decomposed less as exemplified by the small weight loss and a thinner char layer.

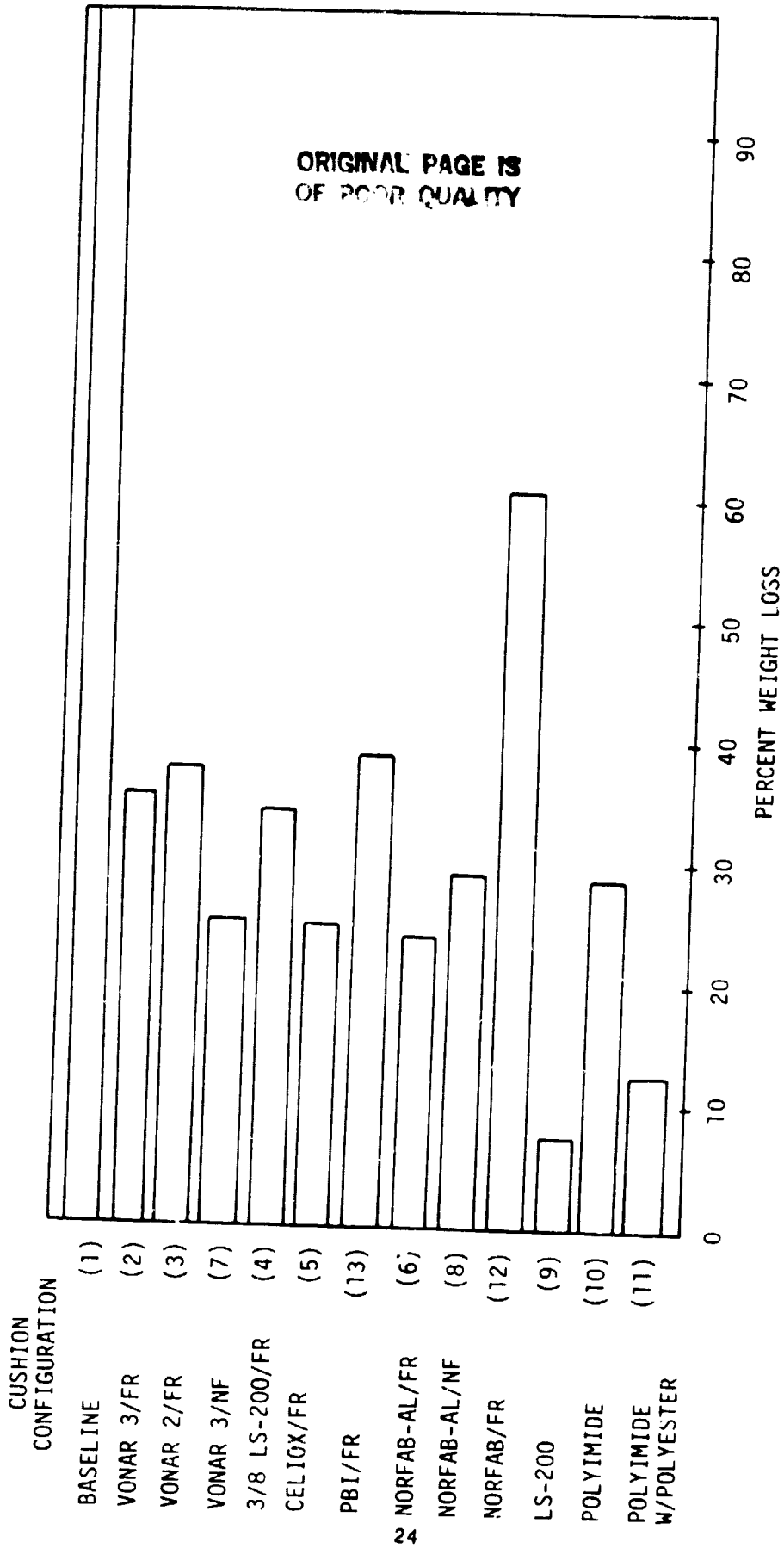


FIGURE 7. PERCENT WEIGHT LOSS

SECTION 6

CONCLUSIONS

Urethane foam decomposes into a volatile gas when exposed to a severe heat source. If this generated gas can be contained in such a manner as to prevent its igniting or to control the rate at which it burns, the severity of the fire will be reduced. This was clearly shown in the testing of standard cushion constructions with a protective covering, "fire-blocking", enveloping the urethane foam.

When the fire blocking was able to contain the decomposing urethane by-products, i.e., fluid and gas, the cushions closest to the heat source burned with less intensity, generated a minimum of heat and were unable to ignite the adjacent cushions. However, when the decomposing urethane fluid was able to escape from the fire-blocking envelope and pool on the floor, an uncontrolled fire erupted which resulted in total burning of all cushion materials.

Some of the Norfab and Celiox materials utilized aluminum coatings. It was not the aluminums reflecting properties which made the cushions perform well as it was its non-permeable properties. This coating helped contain the decomposed by-products and prevented propagation to the adjacent cushion.

Had the seams held and all the gases vented out the back of the cushions and away from the heat, the decomposing of the cushions may have been even less severe. Undoubtedly, the reflective properties had an effect in slowing down the decomposing of the urethane, but only by a few seconds. The reason being the emissivity and thermal conductivity of the aluminum coating was inadequate to resist the severe radiant energy being applied to the surfaces.

The charred foam fire-blocking layers did not act primarily as a heat barrier as they did a liquid and gas barrier. In the cushions farthest from the radiant source, the urethane foam still thermally decomposed. It formed a pocket of gas behind the intact charred envelope. This was verified in post test inspection. However, the gas escaped slowly and only created a small pilot flame. The flame extinguished itself when the radiant energy source was switched off.

The polyimide cushions are examples of a foam which thermally decomposes at high temperatures and generates gas and char but no noticeable liquids. The wool-nylon upholstery trapped gases between itself and the foam. When these gases ignited, the foam decomposed rapidly. The polyester upholstery decomposed from the cushions fast enough to prevent the trapping of these gases. Subsequently, the foam in the cushions decomposed at a slower rate. From these tests, it is concluded that no matter the foam used as a core for the cushion, if the gases generated by the foam can be expelled or contained in such a manner as to prevent their burning or reduce the rate at which they burn, a severe fire can be avoided or delayed. It is further concluded that if the thermal decomposition characteristics can be altered so as to slow down the generation of gas, the time before a fire becomes severe can be extended to the point where appropriate extinguishment of the fire may be possible.

SECTION 7
RECOMMENDATIONS

It is recommended that a study be made to incorporate cushion designs and fire-blocking materials which are thermally stable and nonpermeable to urethane fluids and gases to prevent or reduce the rate at which a seat cushion burns.

This study should include considerations for wearability of fire blocking layers, fatigue life of cushion foams and methods of venting decomposition gases from the cushion assembly. Test results from this program have shown that seam constructions significantly affect cushion burn performance. Therefore, seam constructions previously studied by the NASA seat program should be reconsidered in future cushion designs.

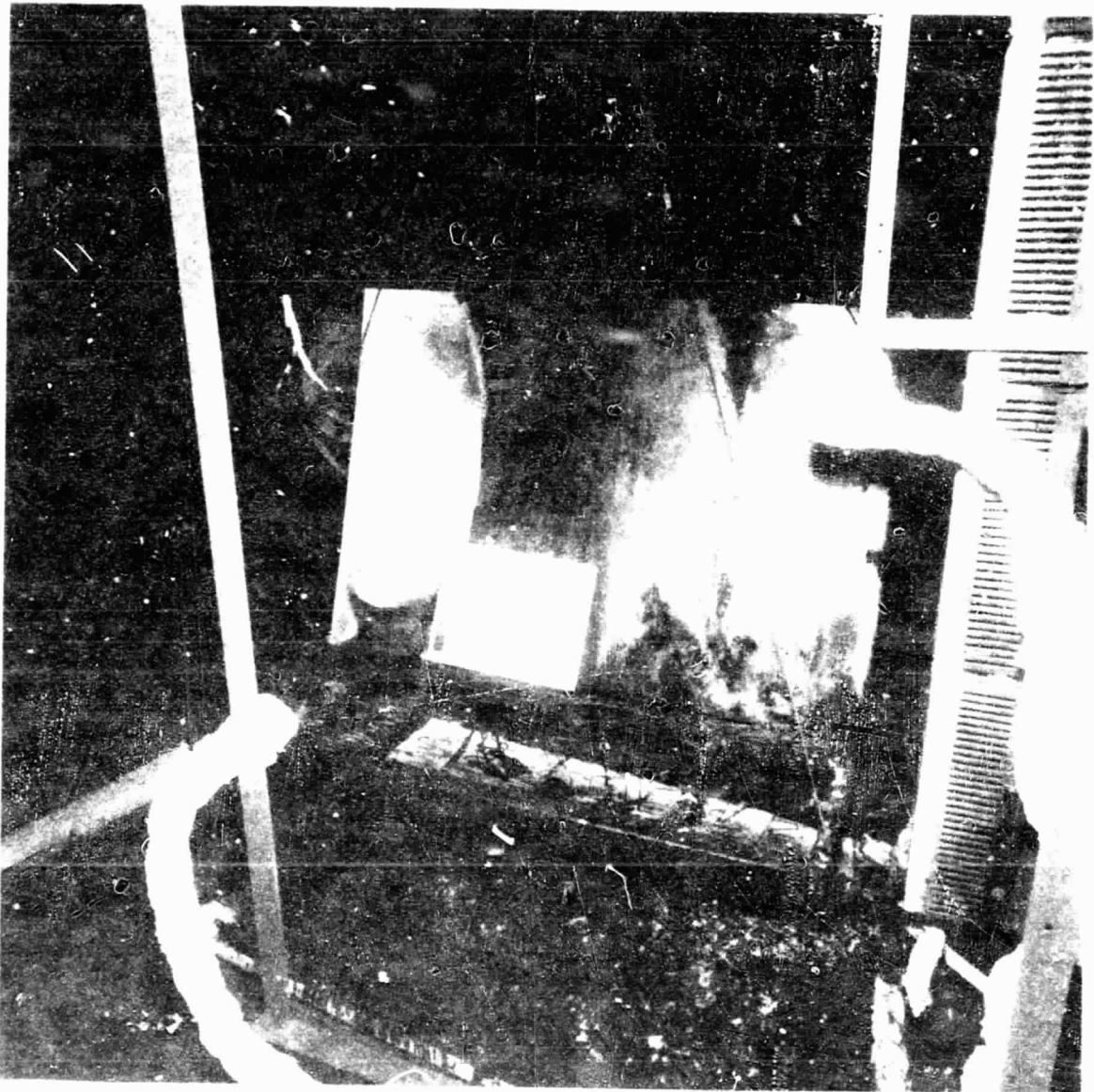
It is also recommended to use these studies as a basis to develop a design standard for a fire resistant passenger seat. This standard must be supported by inexpensive laboratory burn test methods that can verify these standards are being met.

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APPENDIX A
Posttest Photographs

Construction	Page
1 Test 1 17	30 31
2 Test 2 4	32 33
3 Test 11 12	34 35
4 Test 3 10	36 37
5 Test 7 13	38 39
6 Test 5 14	40 41
7 Test 15 16	42 43
8 Test 18	44
9 Test 8 19	45 46
10 Test 9 6	47 48
11 Test 20	49
12 Test 21	50
13 Test 22	51

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Construction
Number

1

Decorative
Upholstery

Wool-Nylon

Slip Cover

None

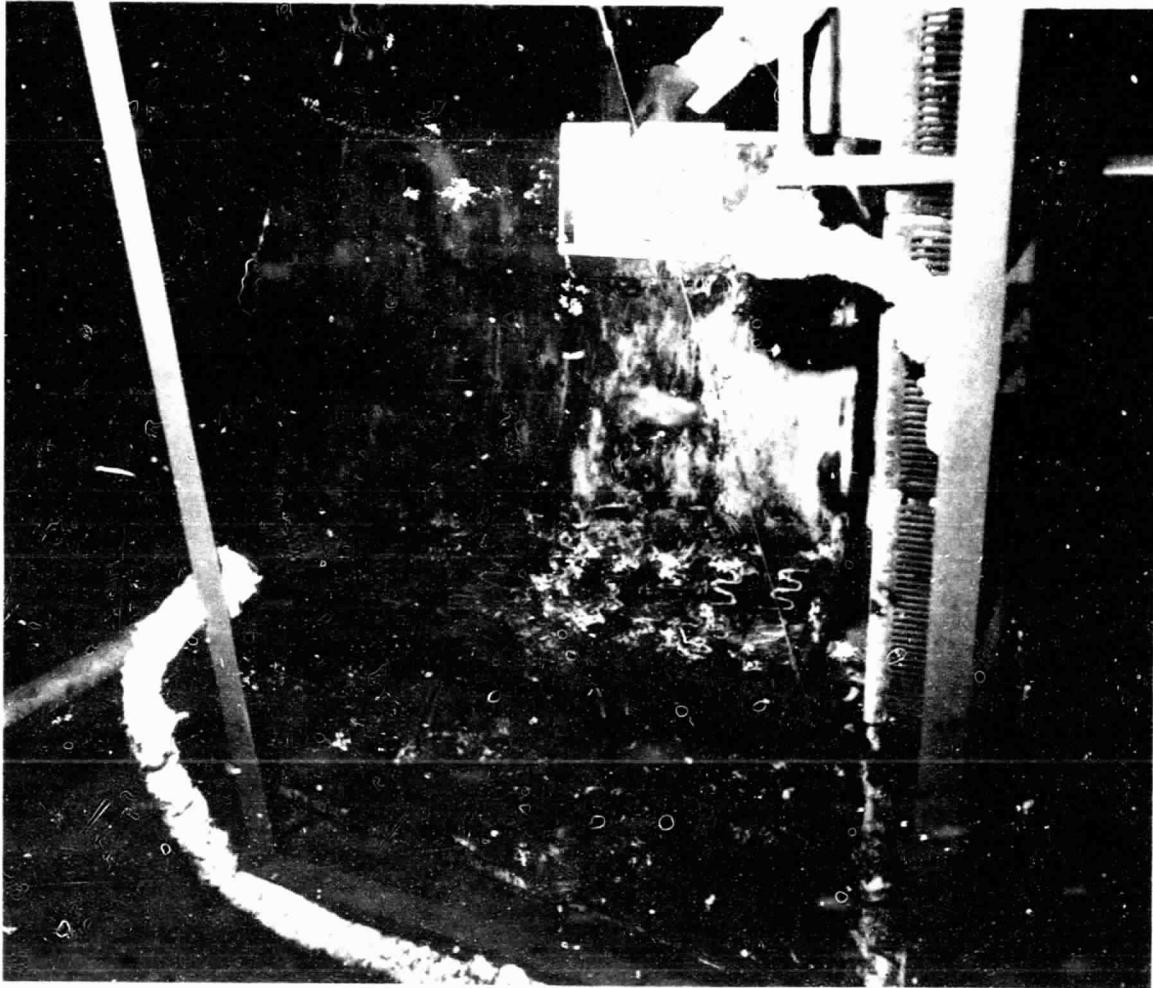
Fire Blocking

None

Foam

F. R. Urethane

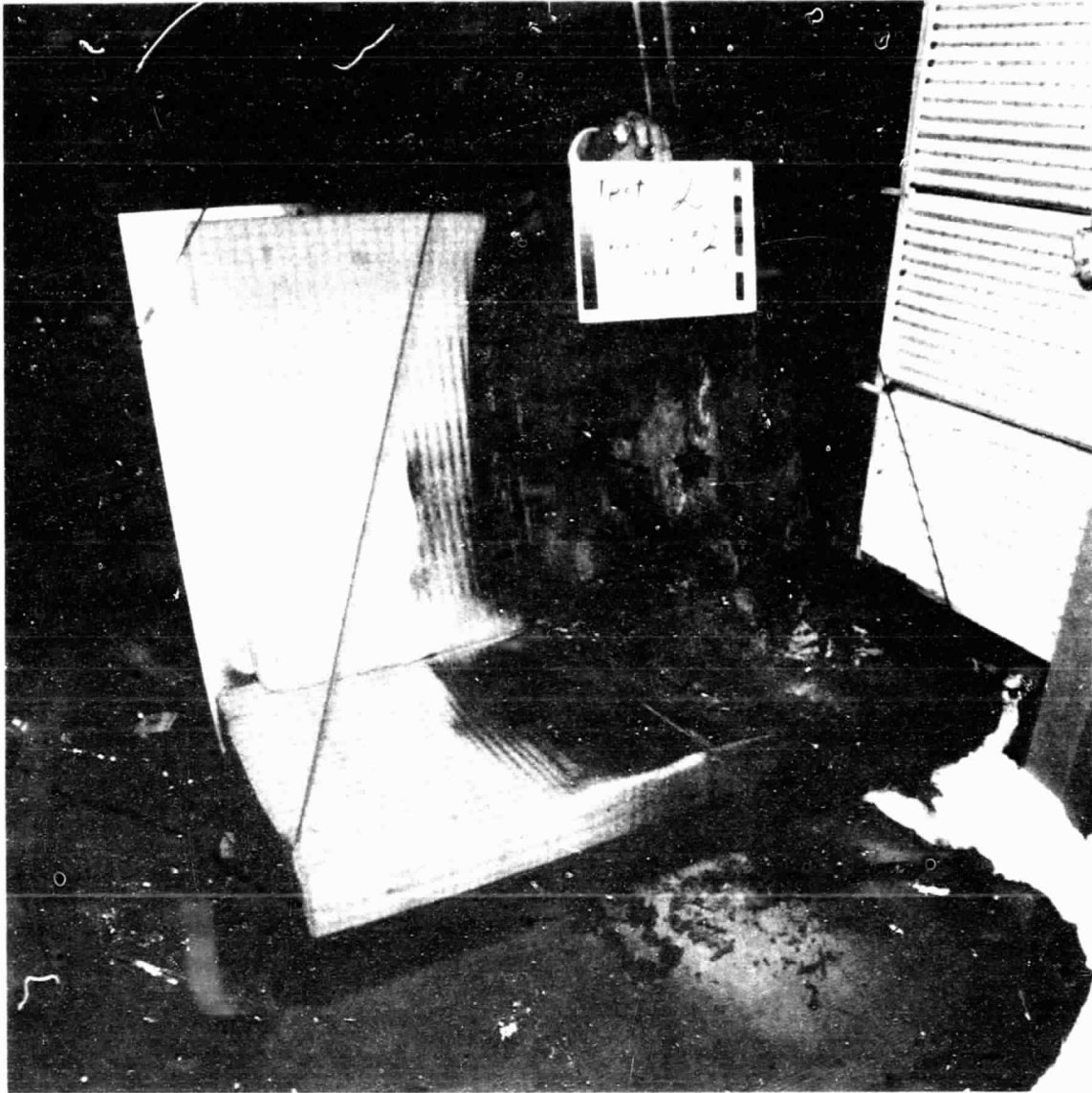
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Construction Number	Decorative Upholstery	Slip Cover	Fire Blocking	Foam
1	Wool-Nylon	None	None	F. R. Urethane

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Construction
Number

2

Decorative
Upholstery

Wool-Nylon

Slip Cover

Cotton-Muslin

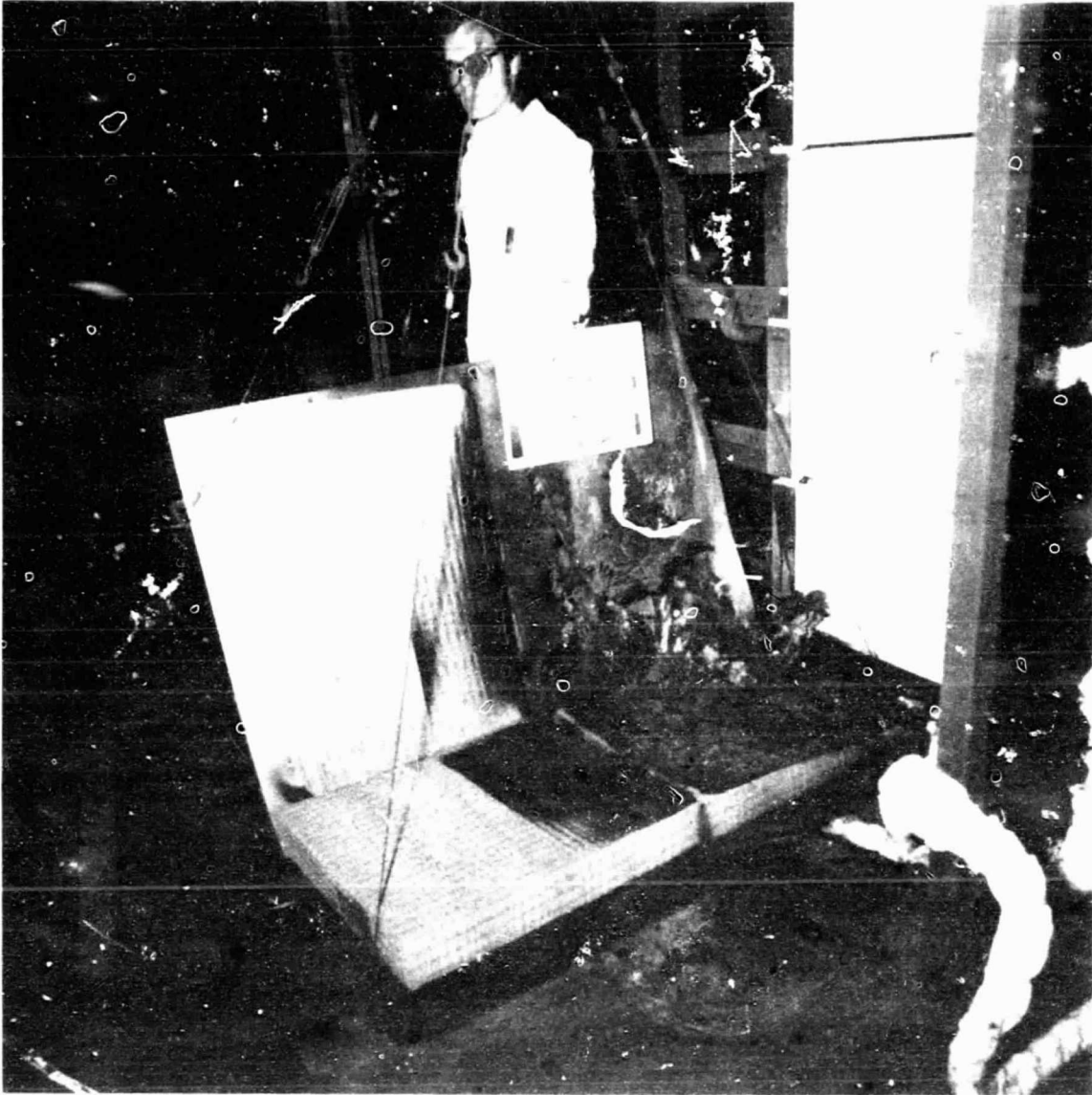
Fire Blocking

Vonar-3

Foam

F. R. Urethane

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Construction
Number

2

Decorative
Upholstery

Wool-Nylon

Slip Cover

Cotton-Muslin

Fire Blocking

Vonar-3

Foam

F. R. Urethane

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Construction
Number

3

Decorative
Upholstery

Wool-Nylon

Slip Cover

Cotton-Muslin

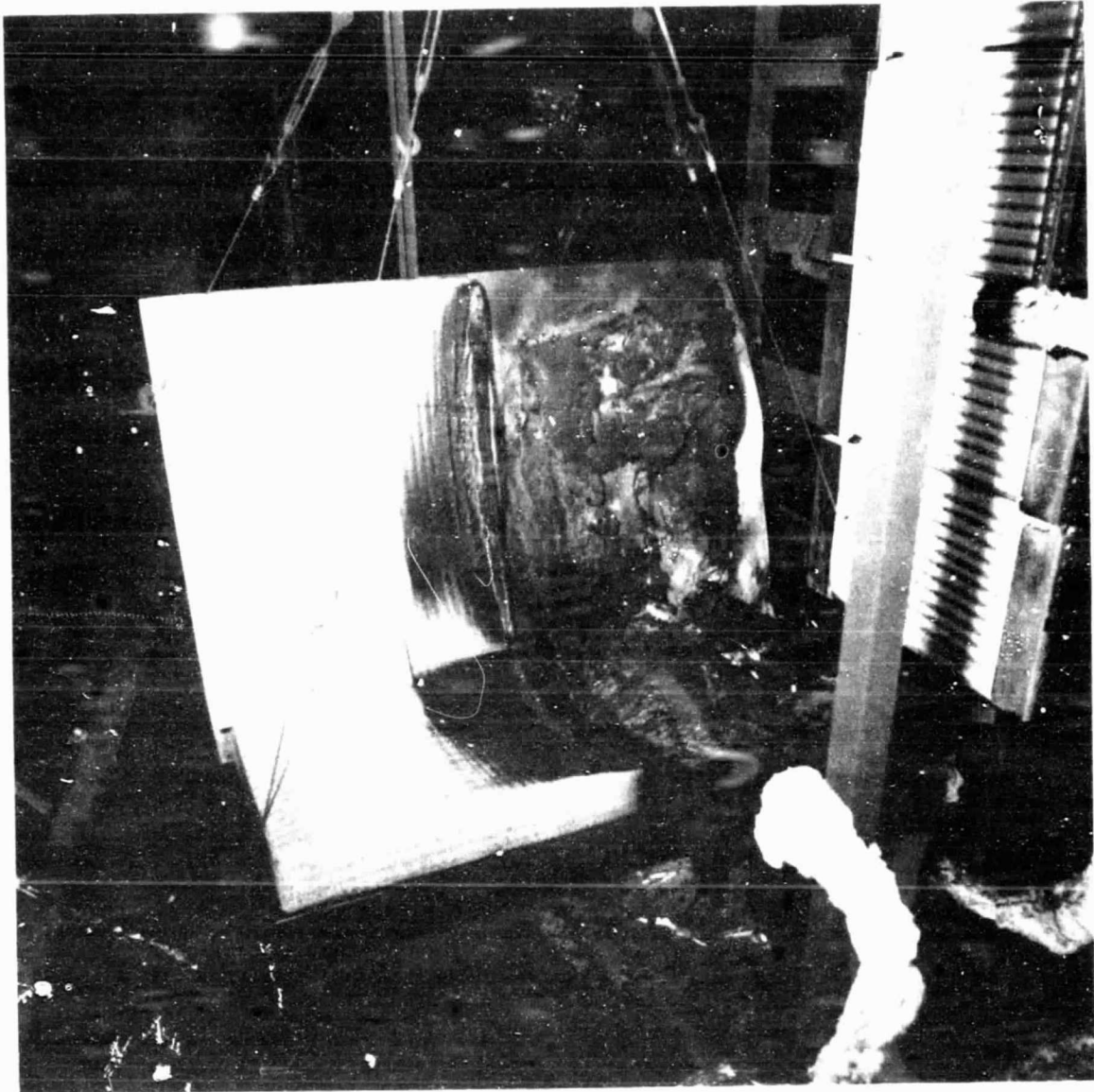
Fire Blocking

Vonar-2

Foam

F. R. Urethane

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Construction
Number
3

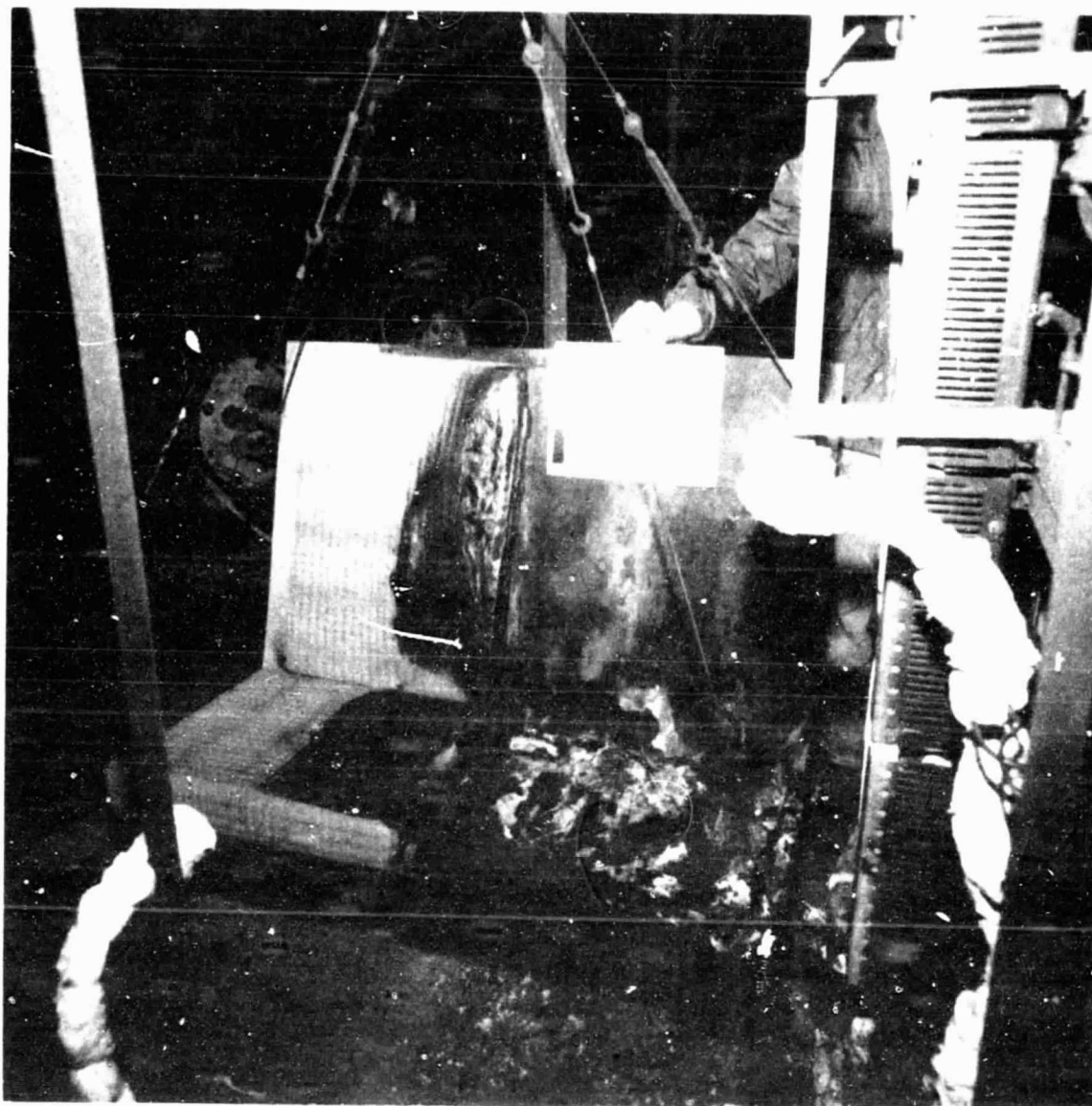
Decorative
Upholstery
Wool-Nylon

Slip Cover
Cotton-Muslin

Fire Blocking
Vonar-2

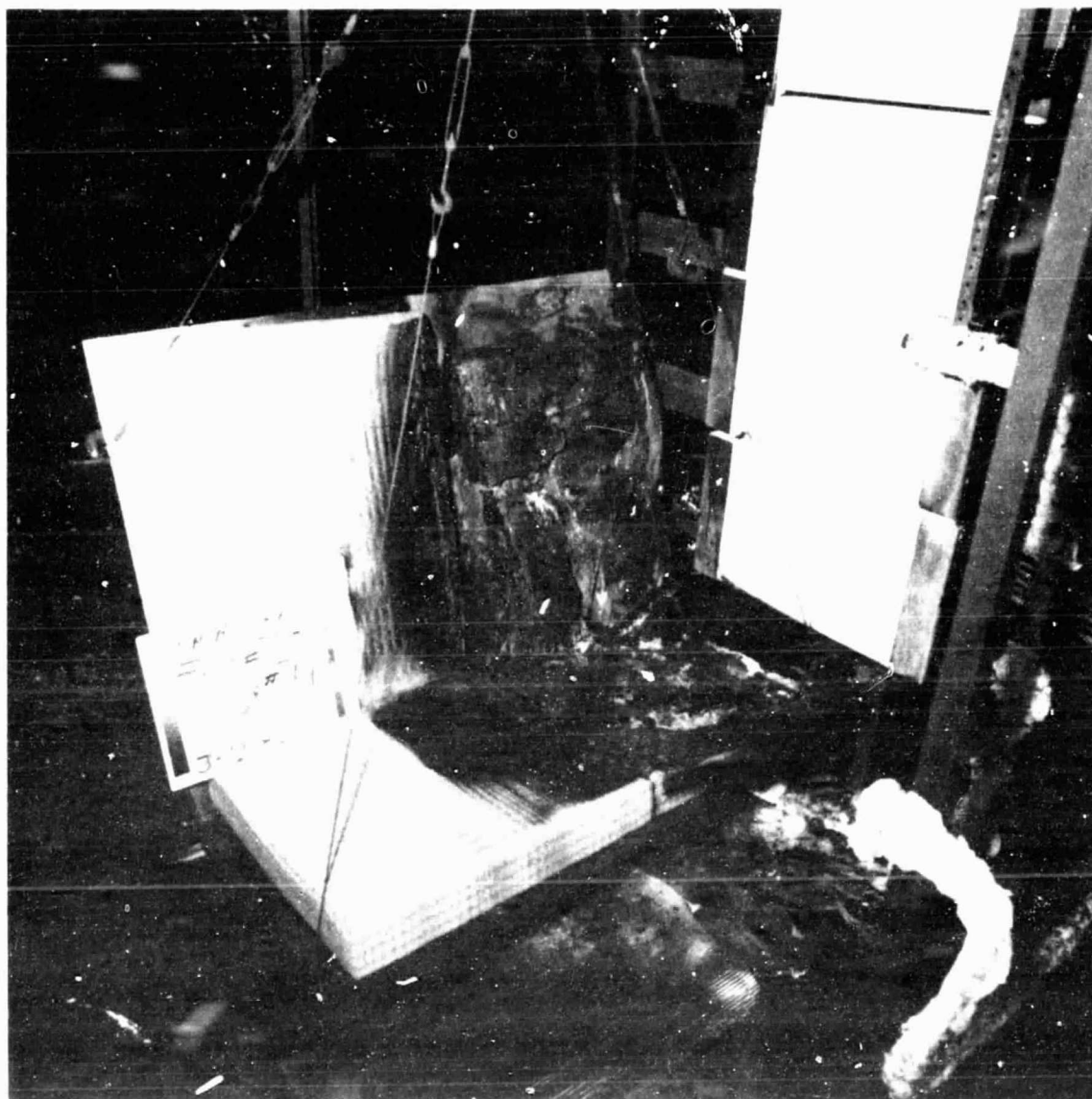
Foam
F. R. Urethane

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Construction Number	Decorative Upholstery	Slip Cover	Fire Blocking	Foam
4	Wool-Nylon	None	3/8 LS 200	F. R. Urethane

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Construction
Number
4

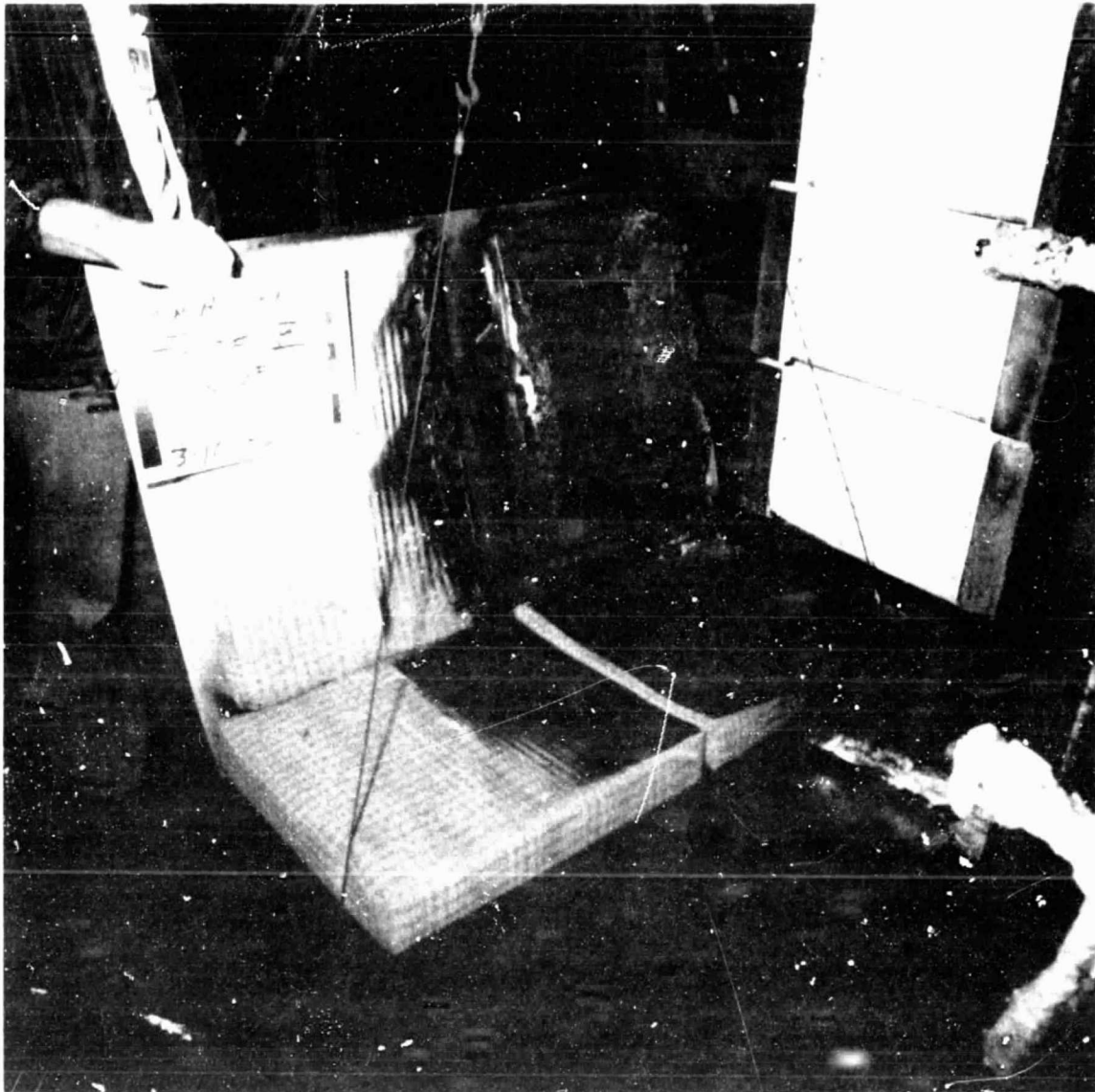
Decorative
Upholstery
Wool-Nylon

Slip Cover
None

Fire Blocking
3/8 LS 200

Foam
F. R. Urethane

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Construction
Number

5

Decorative
Upholstery

Wool-Nylon

Slip Cover

None

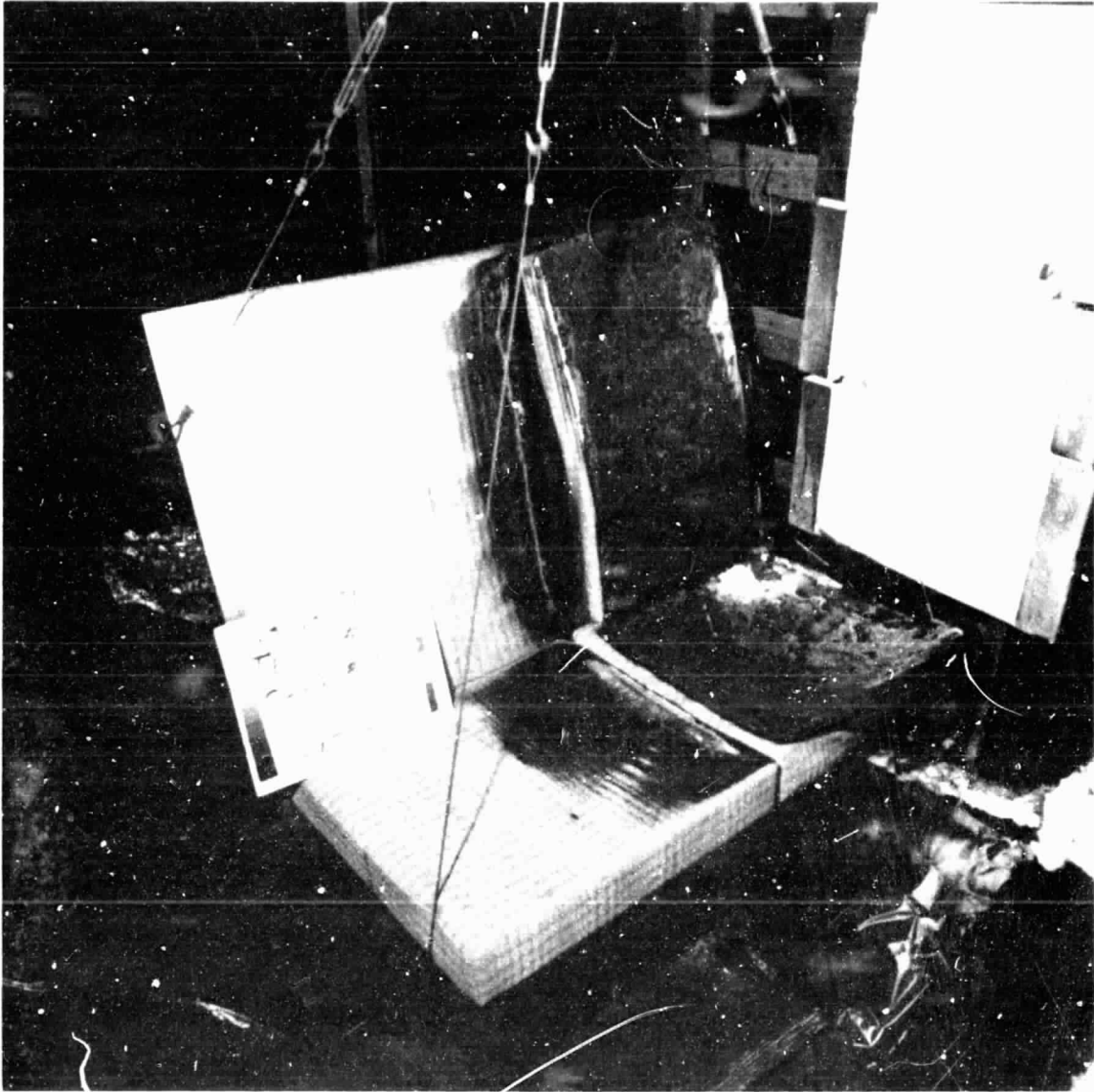
Fire Blocking

Celiox 101

Foam

F. R. Urethane

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Construction Number	Decorative Upholstery	Slip Cover	Fire Blocking	Foam
5	Wool-Nylon	None	Celiox 101	F. R. Urethane

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BLACK AND WHITE



Construction
Number
6

Decorative
Upholstery
Wool-Nylon

Slip Cover
None

Fire Blocking
Norfab 11 HT-26-AL

Foam
F. R. Urethane

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Construction
Number

6

Decorative
Upholstery

Wool-Nylon

Slip Cover

None

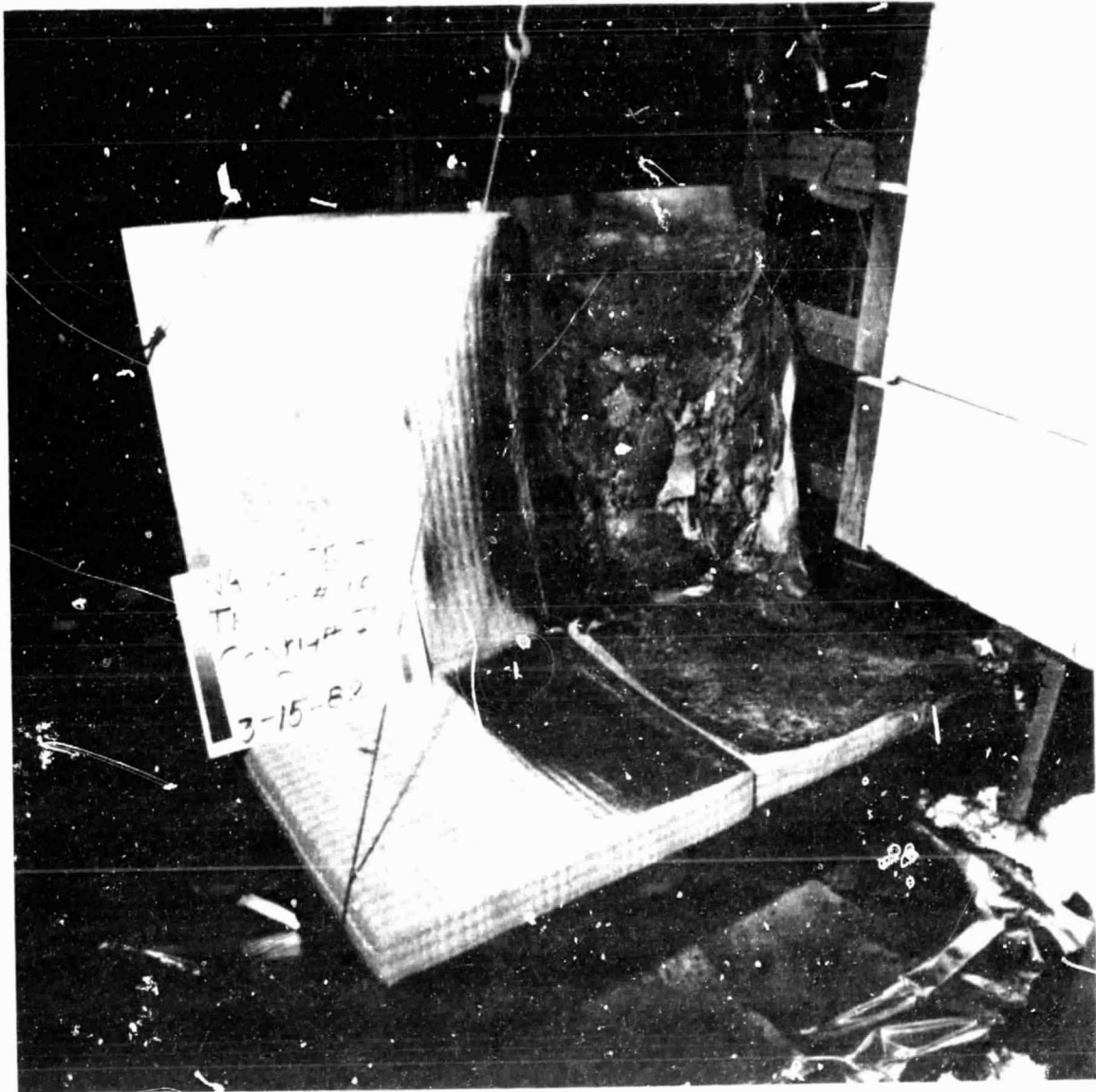
Fire Blocking

Norfab 11 HT-26-AL

Foam

F. R. Urethane

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Construction
Material

7

Decorative
Upholstery

Wool-Nylon

Slip Cover

Cotton-Muslin

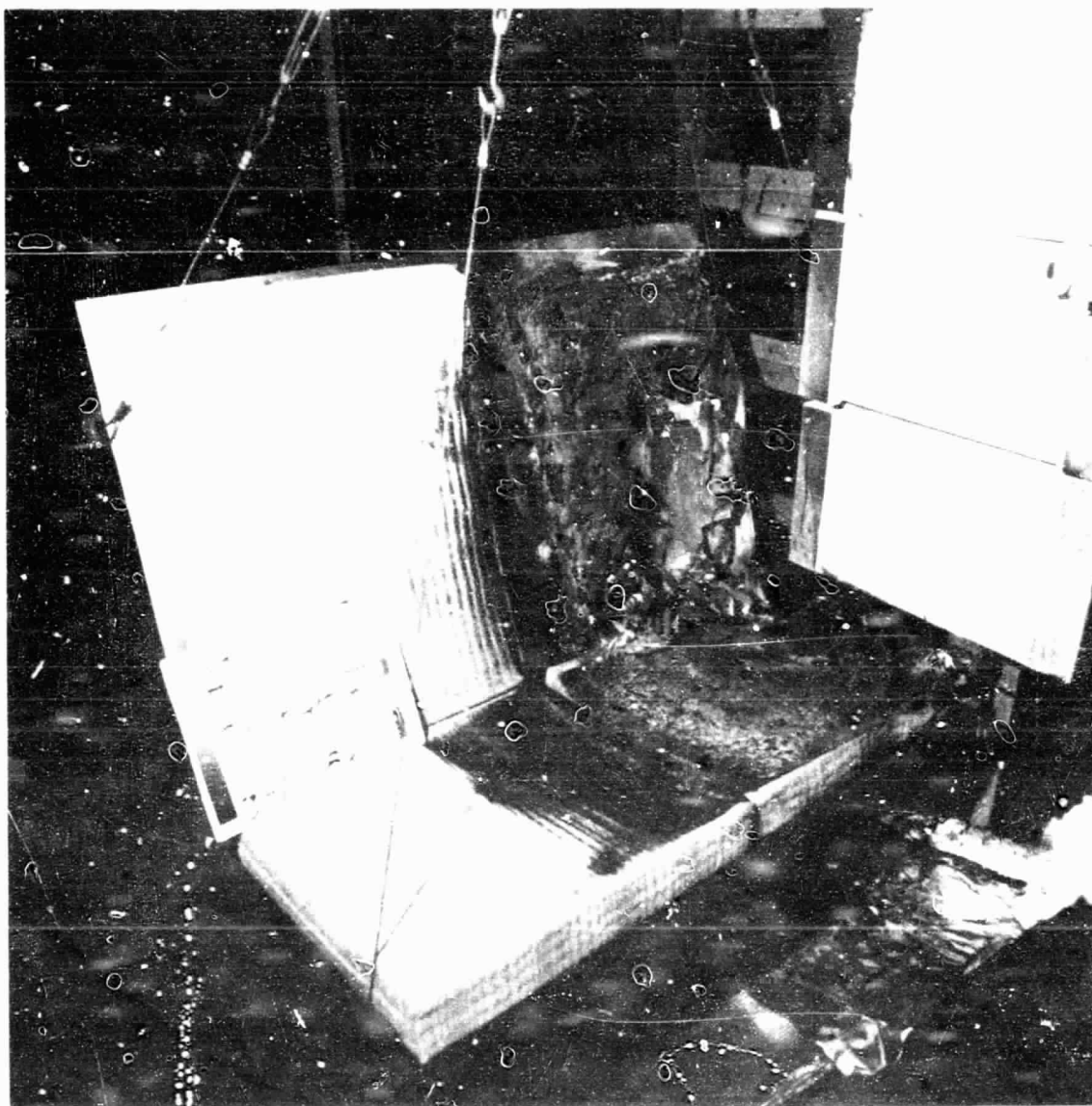
Fire Blocking

Vonar-3

Foam

N. F. Urethane

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Construction
Number

7

Decorative
Upholstery

Wool-Nylon

Slip Cover

Cotton-Muslin

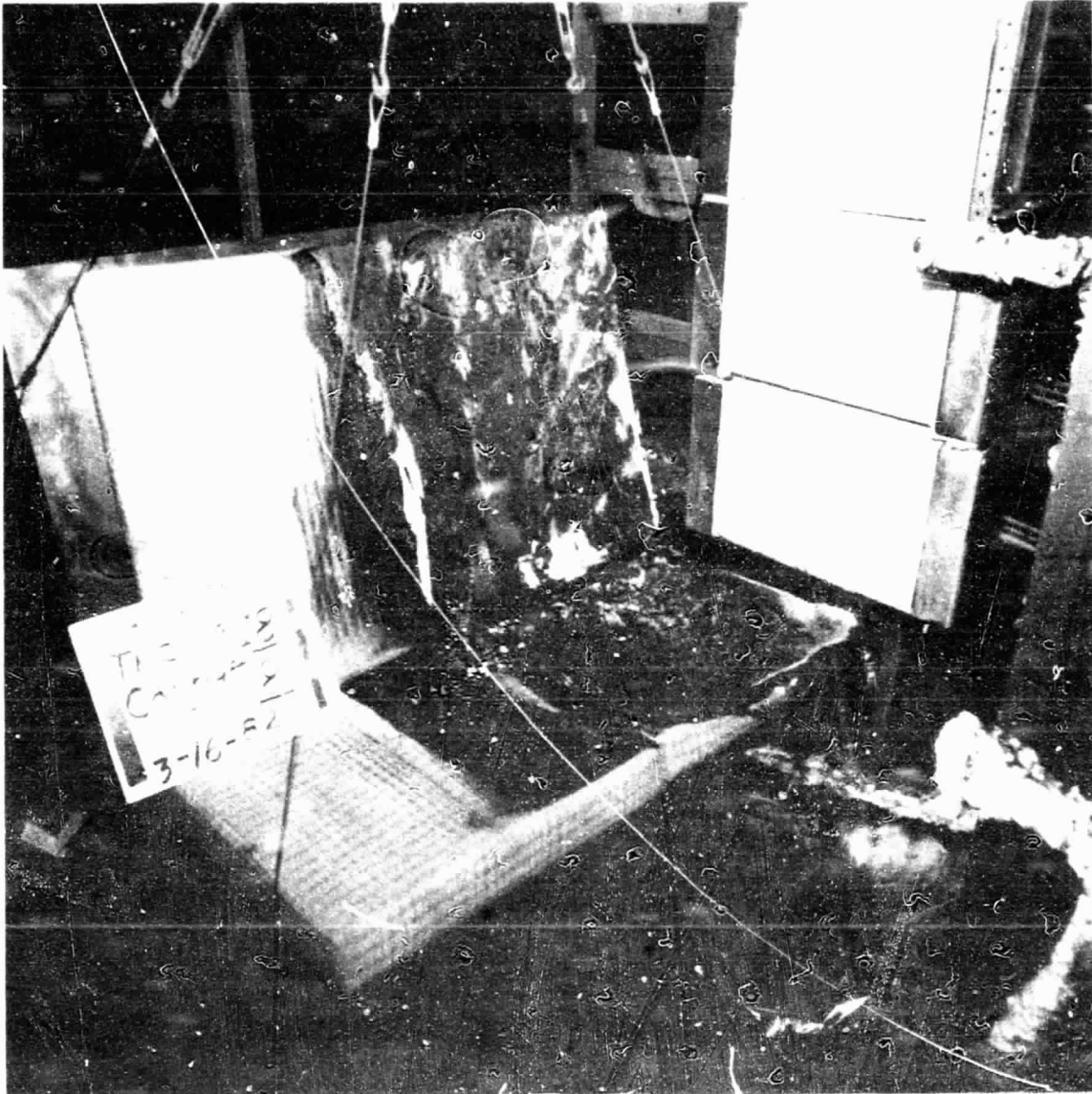
Fire Blocking

Vonar-3

Foam

N. F. Urethane

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Construction
Number
8

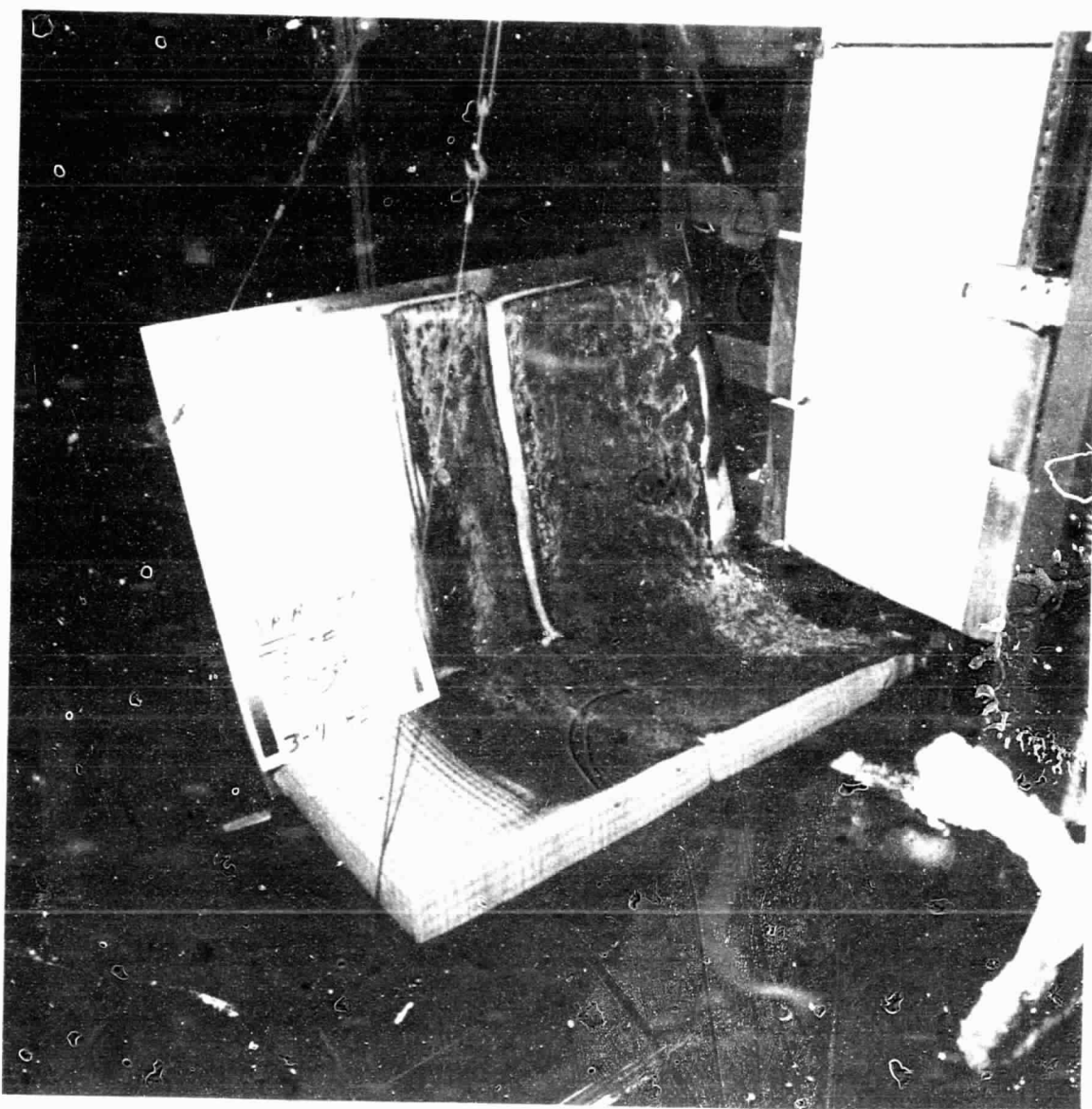
Decorative
Upholstery
Wool-Nylon

Slip Cover
None

Fire Blocking
Norfab 11 HT-26-AL

Foam
N. F. Urethane

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Construction
Number

9

Decorative
Upholstery

Wool-Nylon

Slip Cover

None

Fire Blocking

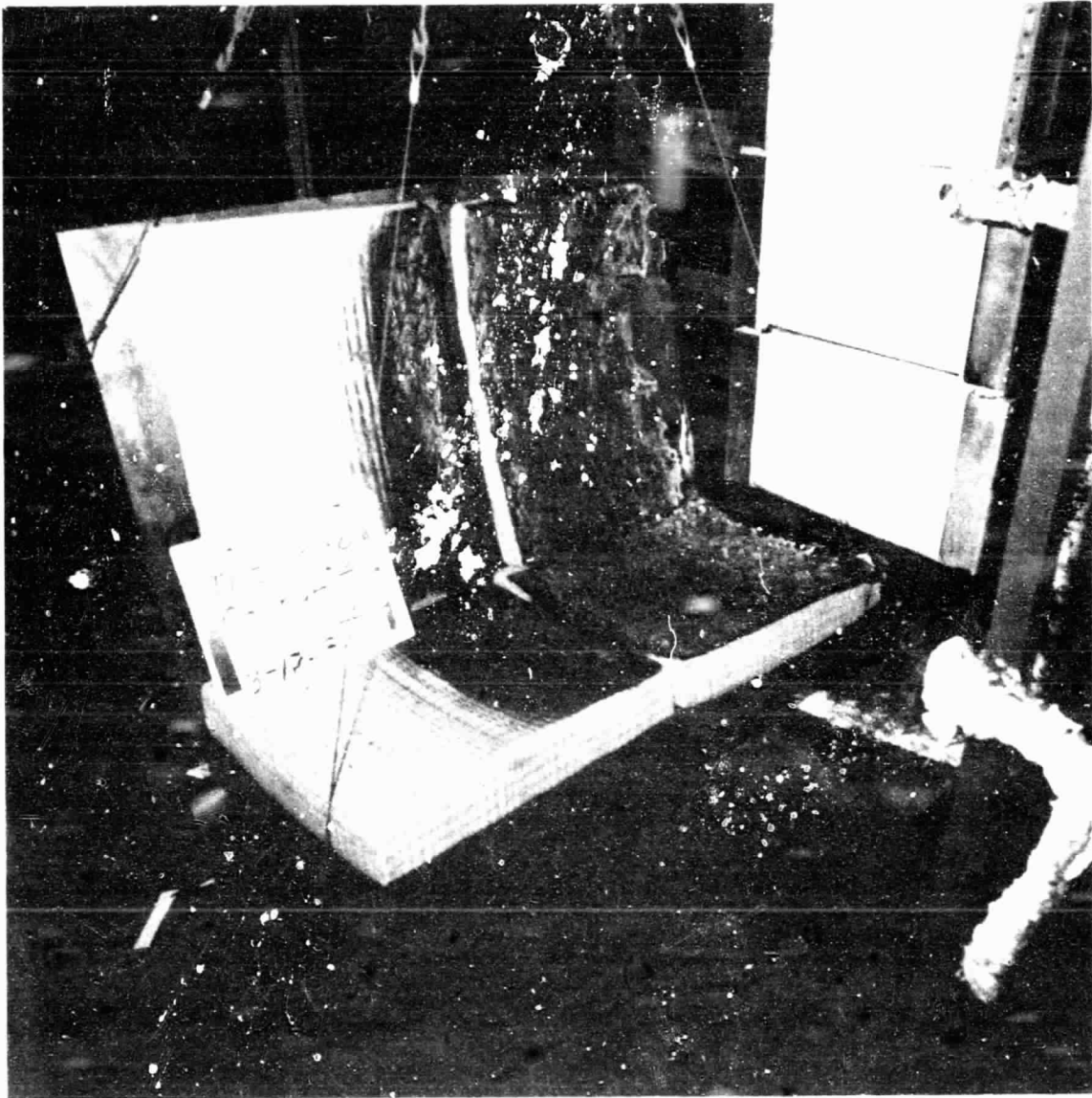
None

Foam

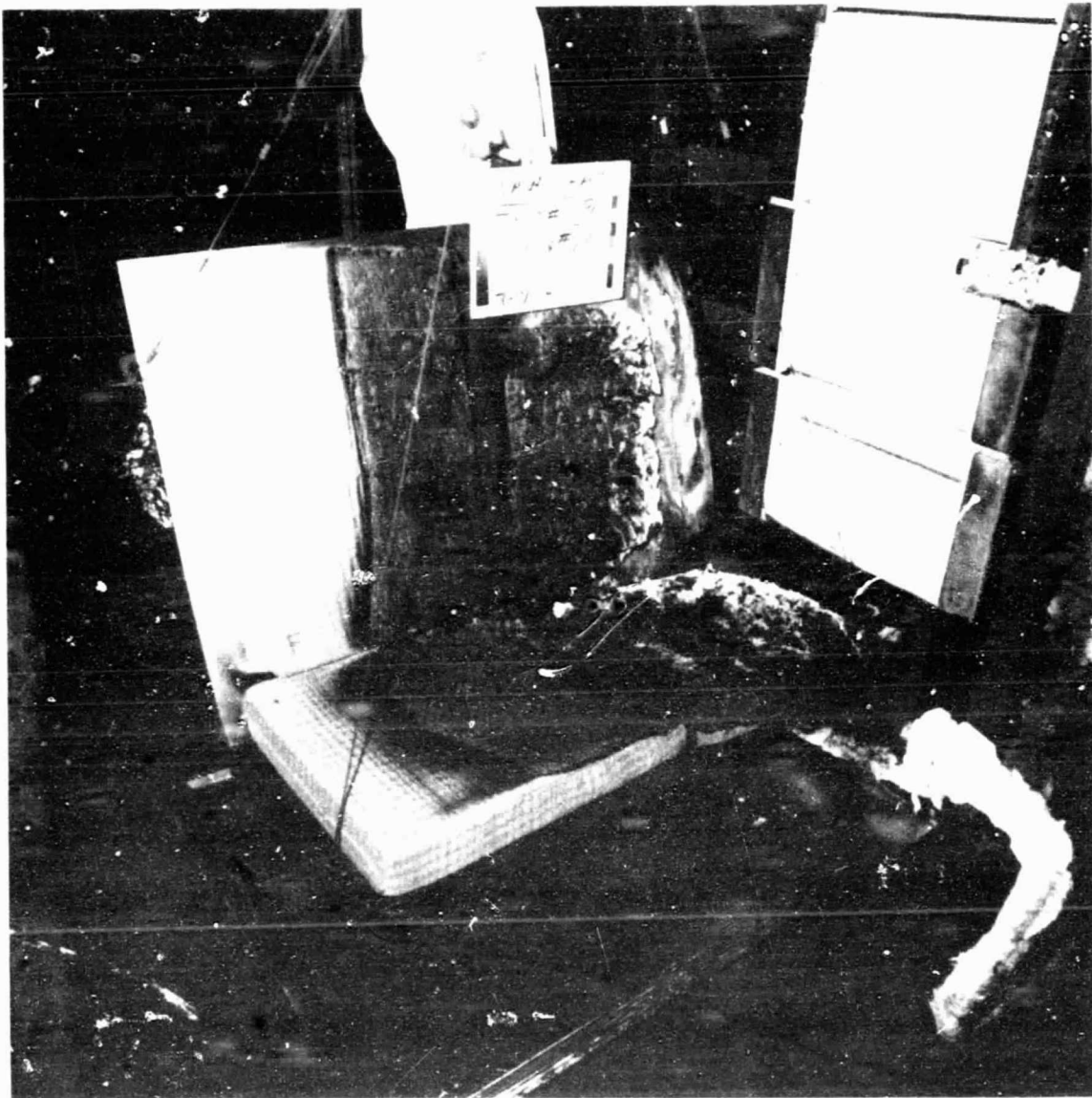
LS 200 Neoprene

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REPAIR AND WHITE WASH



Construction Number	Decorative Upholstery	Slip Cover	Fire Blocking	Foam
8	Wool-Nylon	None	Norfab 11 HT-26-AL	N. F. Urethane



Construction
Number
10

Decorative
Upholstery
Wool-Nylon

Slip Cover
None

Fire Blocking
None

Foam
Polyimide

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Construction
Number
10

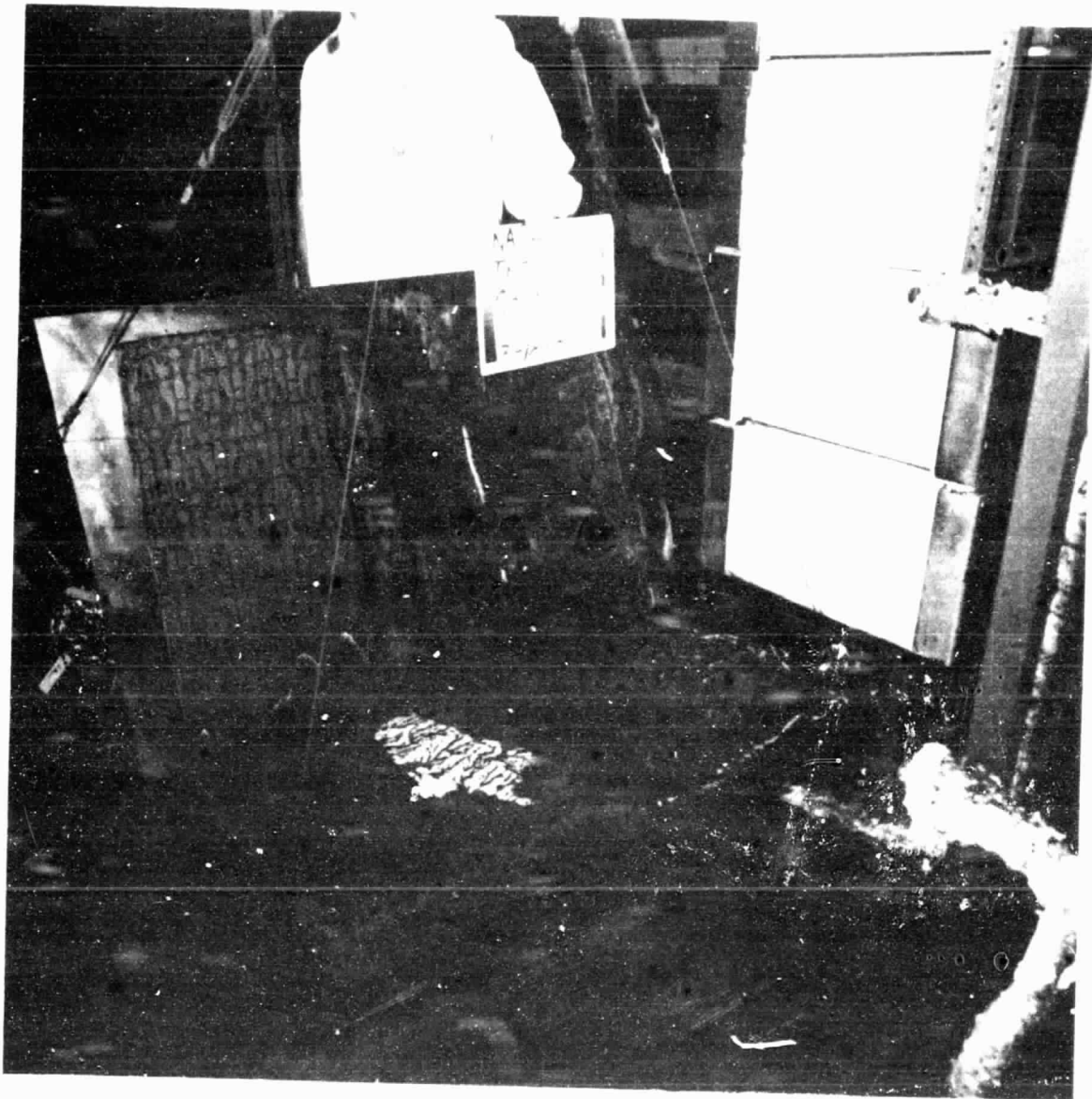
Decorative
Upholstery
Wool-Nylon

Slip Cover
None

Fire Blocking
None

Foam
Polyimide

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Construction
Number
11

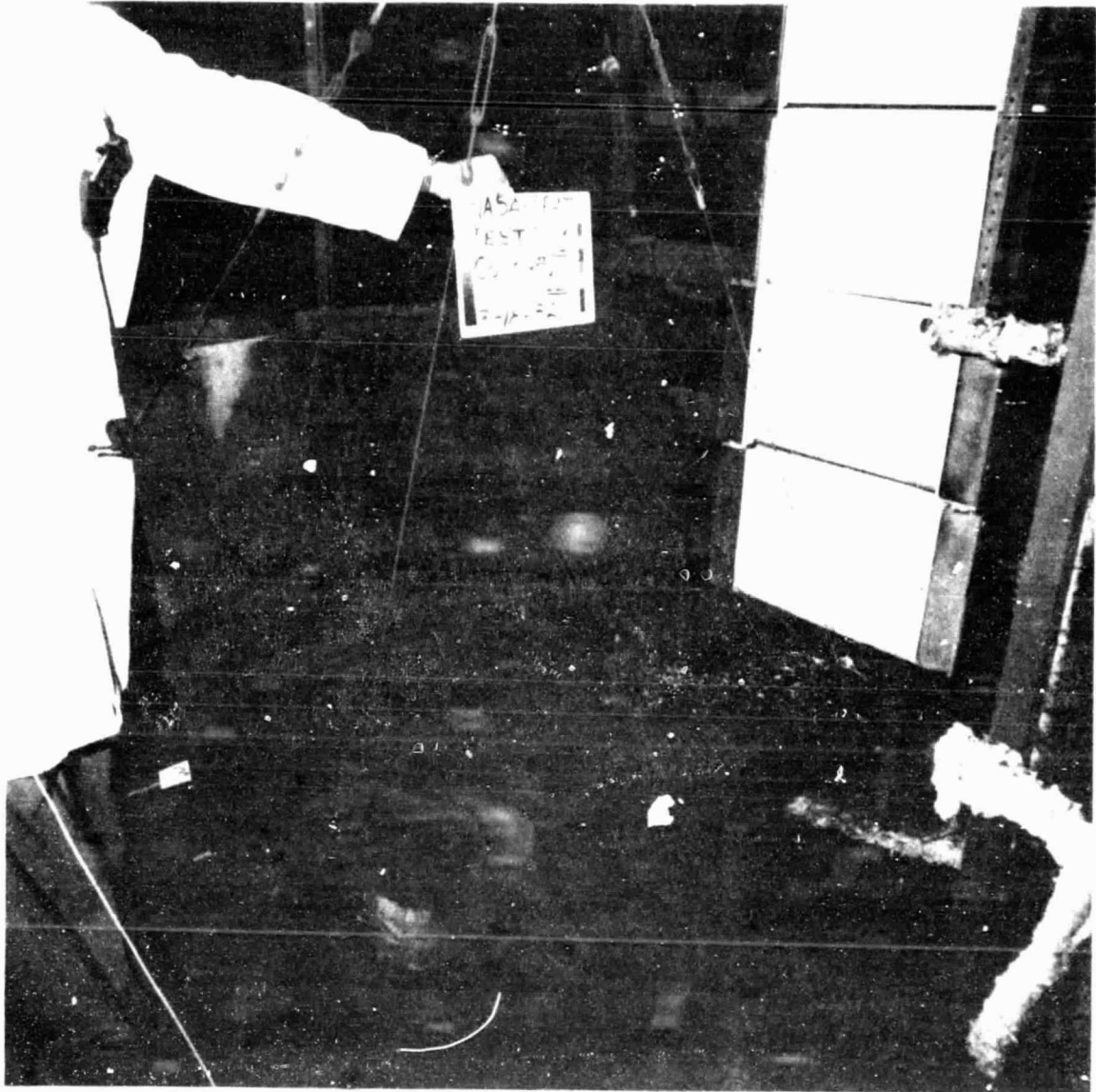
Decorative
Upholstery
Polyester

Slip Cover
None

Fire Blocking
None

Foam
Polyimide

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Construction
Number
12

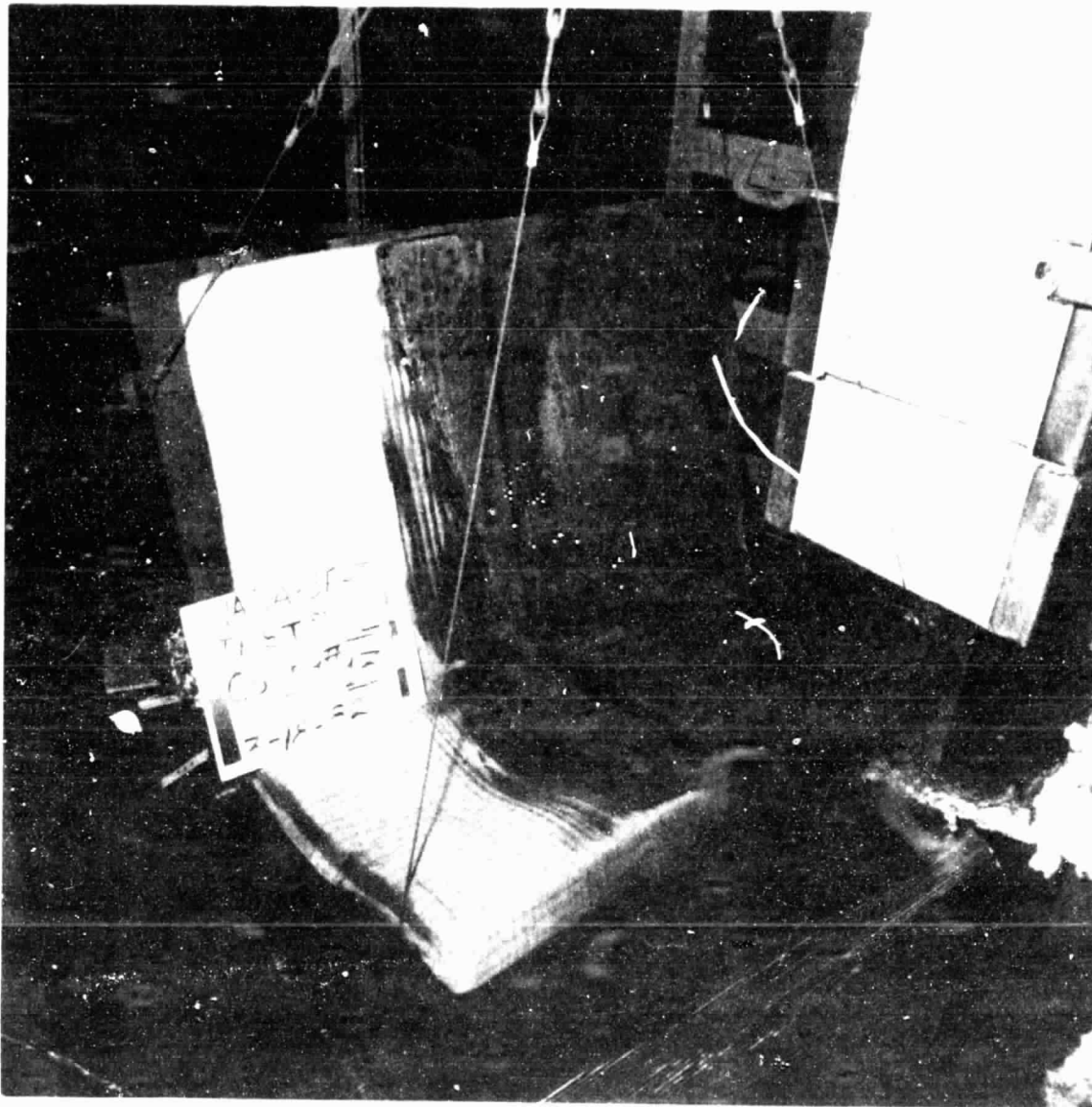
Decorative
Upholstery
Wool-Nylon

Slip Cover
None

Fire Blocking
Norfab 11 HT-26

Foam
F. R. Urethane

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Construction
Number

13

Decorative
Upholstery

Wool-Nylon

Slip Cover

None

Fire Blocking

PBI

Foam

F. R. Urethane

CO. 1/12
2-14-52

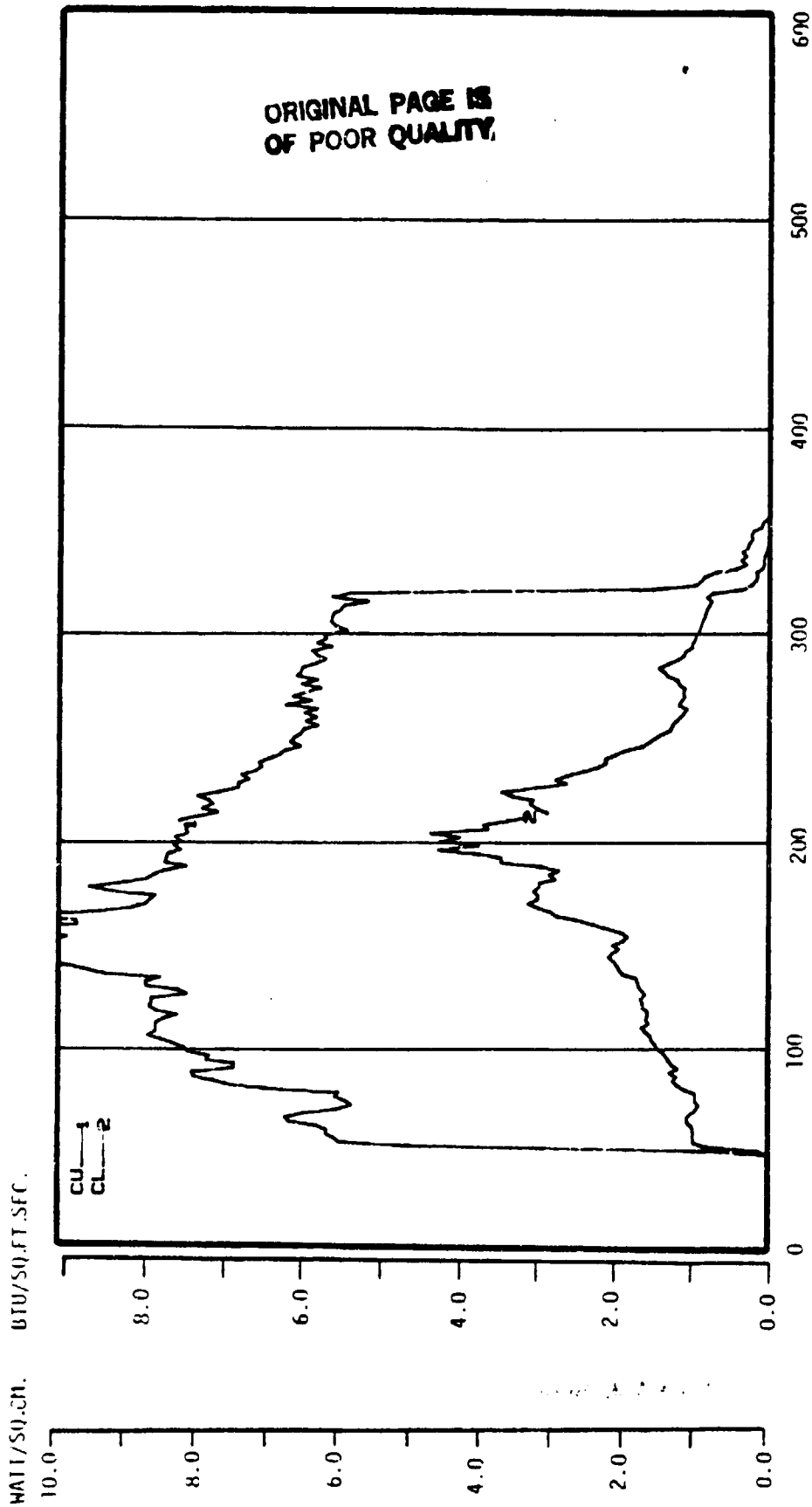
APPENDIX B

Test Plots

Construction	Page
1 Test 1 17	54 62
2 Test 2 4	70 78
3 Test 11 12	86 94
4 Test 3 10	102 110
5 Test 7 13	118 126
6 Test 6 14	134 142
7 Test 15 16	150 158
8 Test 18	166
9 Test 8 19	174 182
10 Test 9 6	190 198
11 Test 20	206
12 Test 21	214
13 Test 22	222

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HEAT FLUX

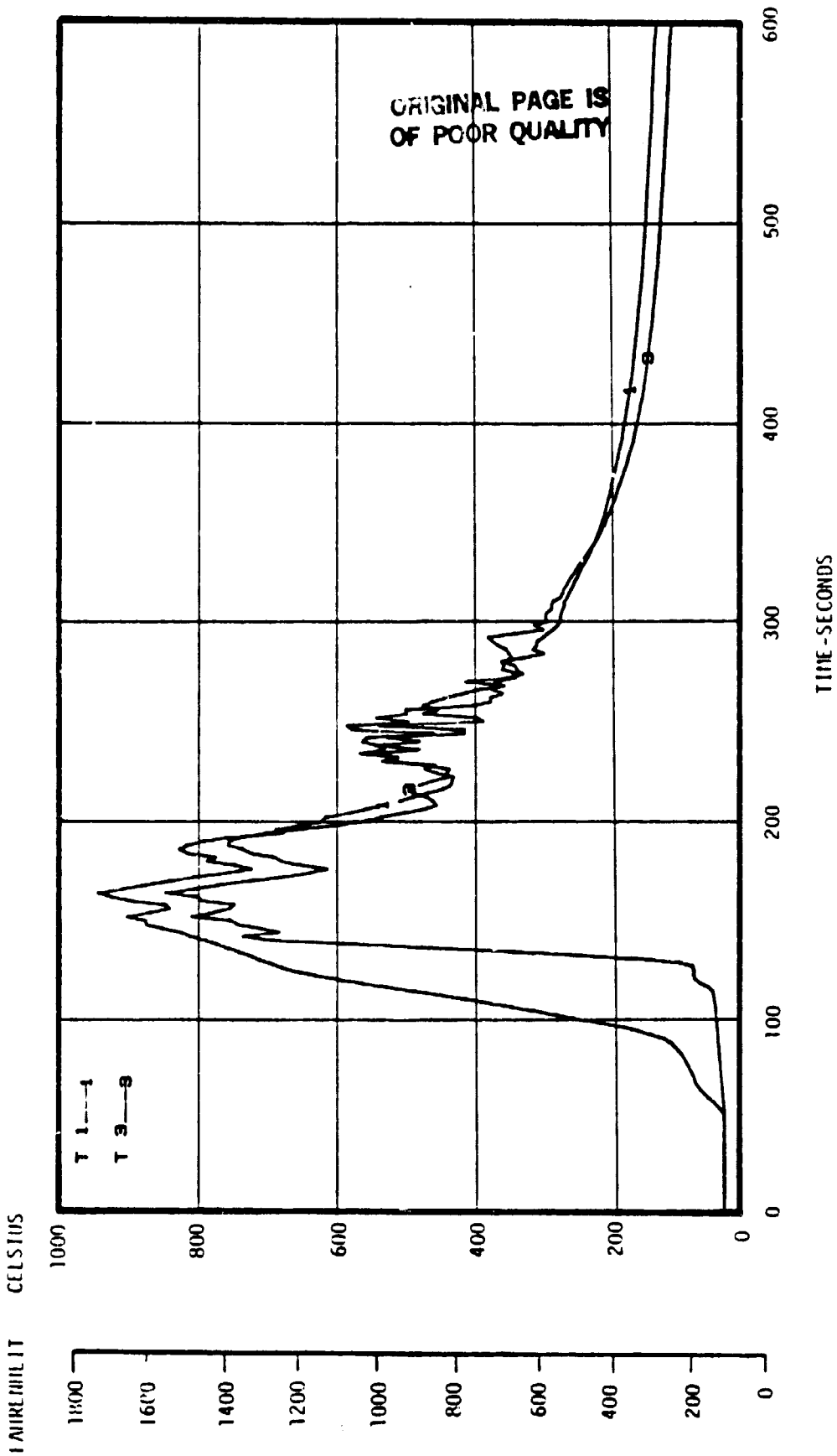


DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 25/05/02 06.38

NASA-MES FULL SCALE CUSHION BURN TEST NUMBER 1

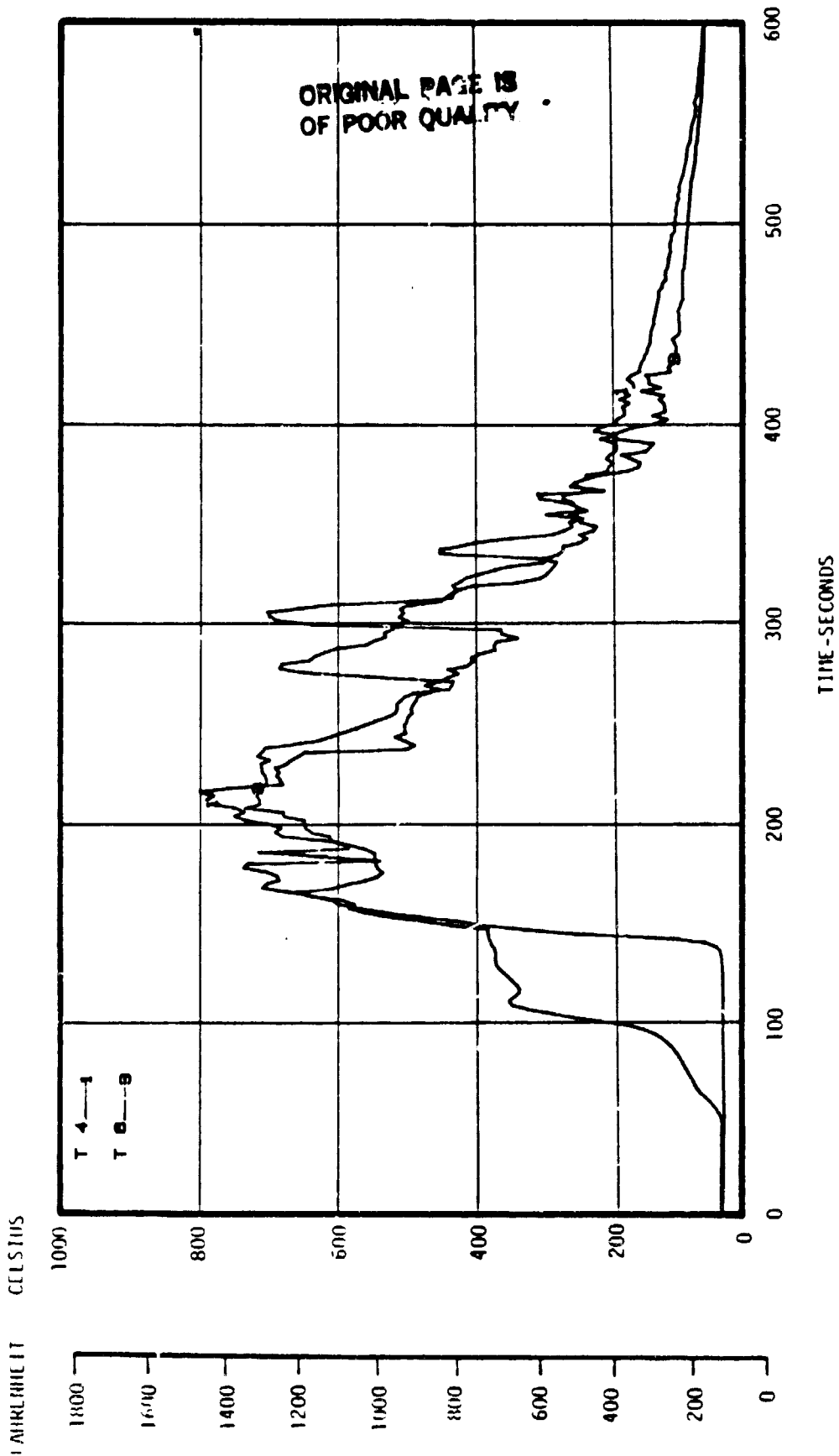
CUSHION CONSTRUCTION NUMBER 1.0

SEAT CUSHION TEMPERATURES



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CUSHION CONSTRUCTION NUMBER 1.0

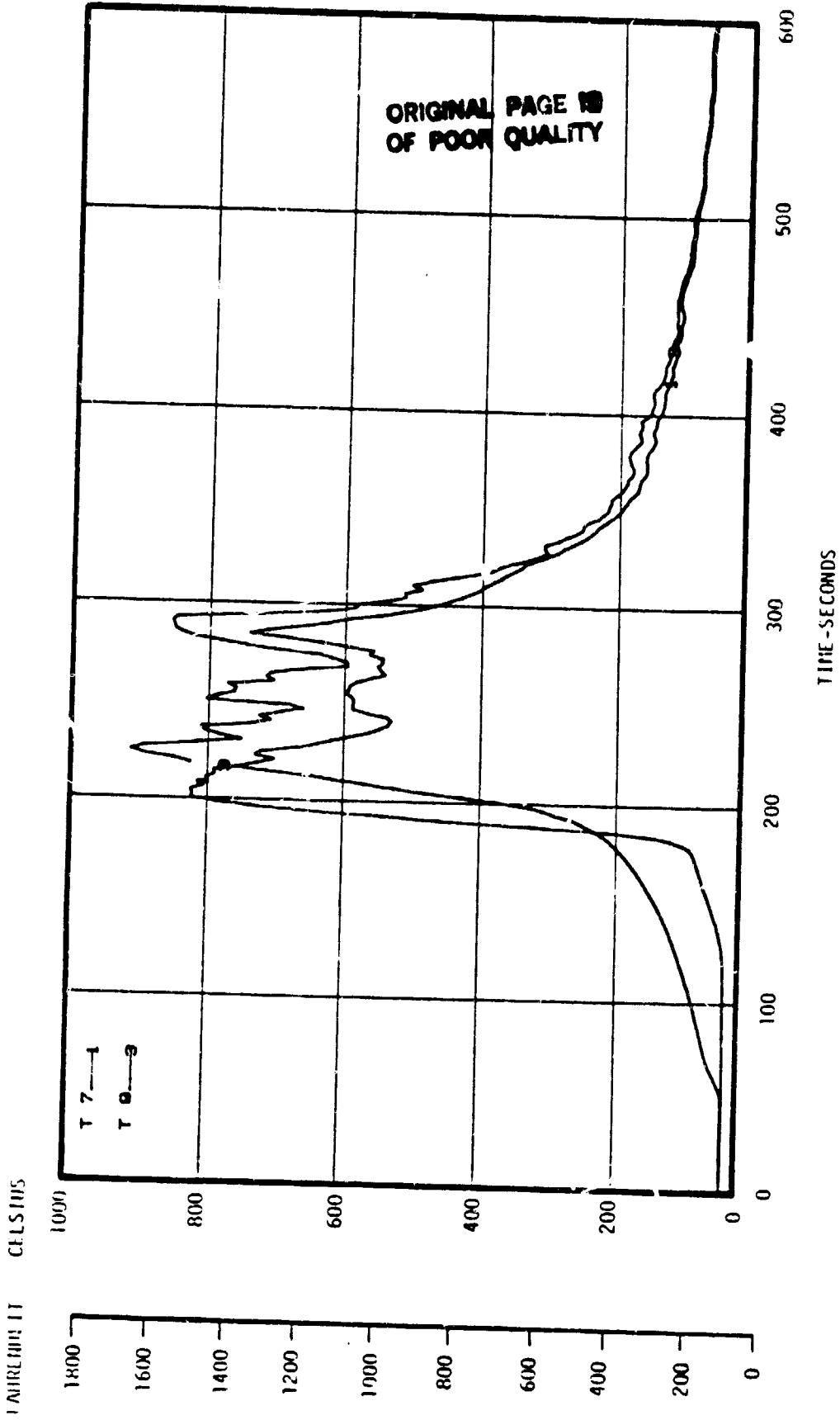
SEAT CUSHION TEMPERATURES



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CUSHION CONSTRUCTION NUMBER 1. B

SEAT CUSHION TEMPERATURES

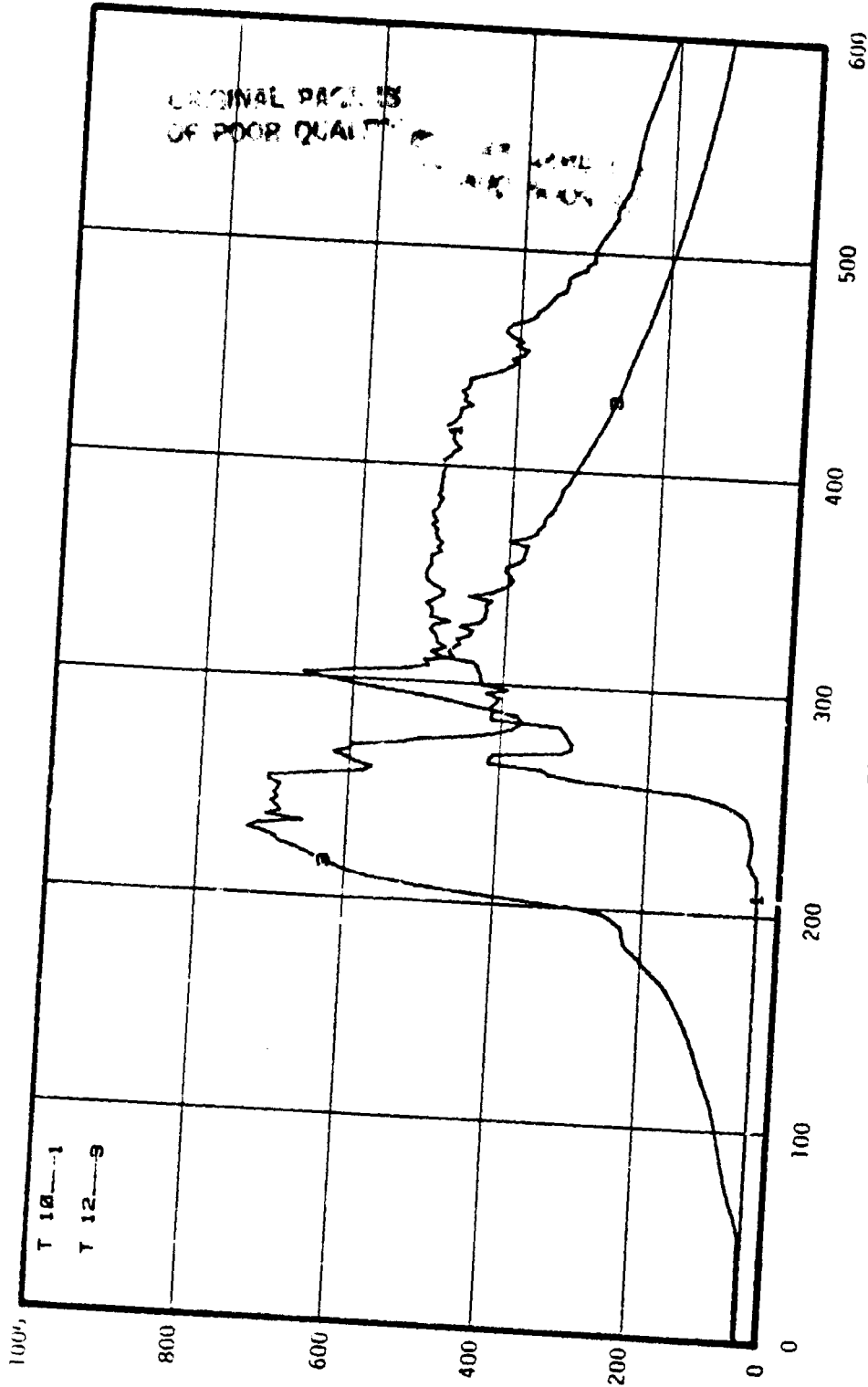
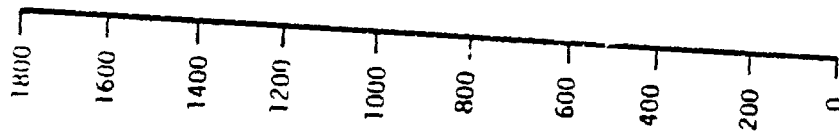


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NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER :
CUSHION CONSTRUCTION NUMBER 1.0

SEAT CUSHION TEMPERATURES

FAHRENHEIT

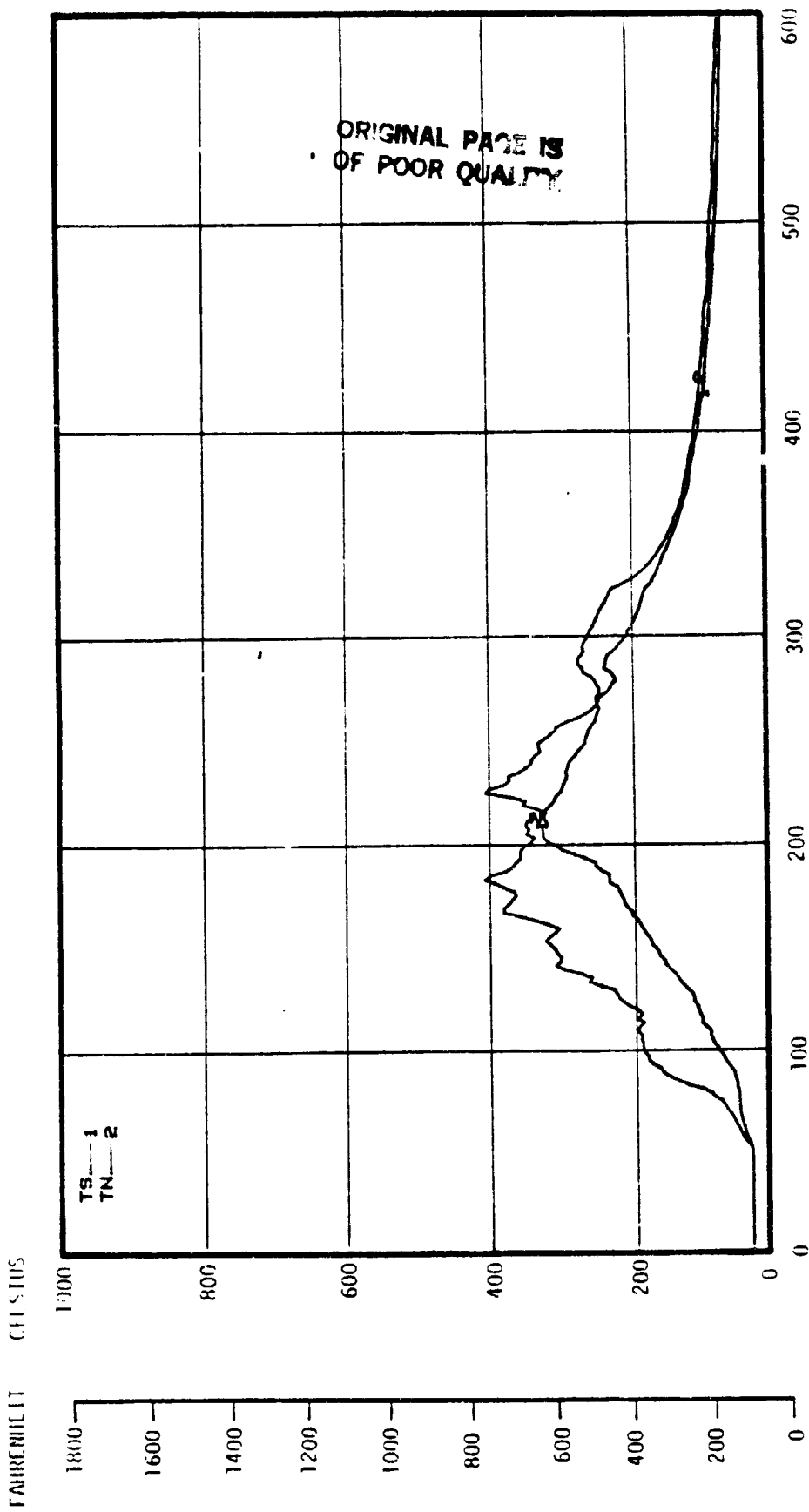


TIME - SECONDS

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NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 1
CUSHION CONSTRUCTION NUMBER 1.0

CEILING TEMPERATURE



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TS---1
TN---2

TIME-SECONDS

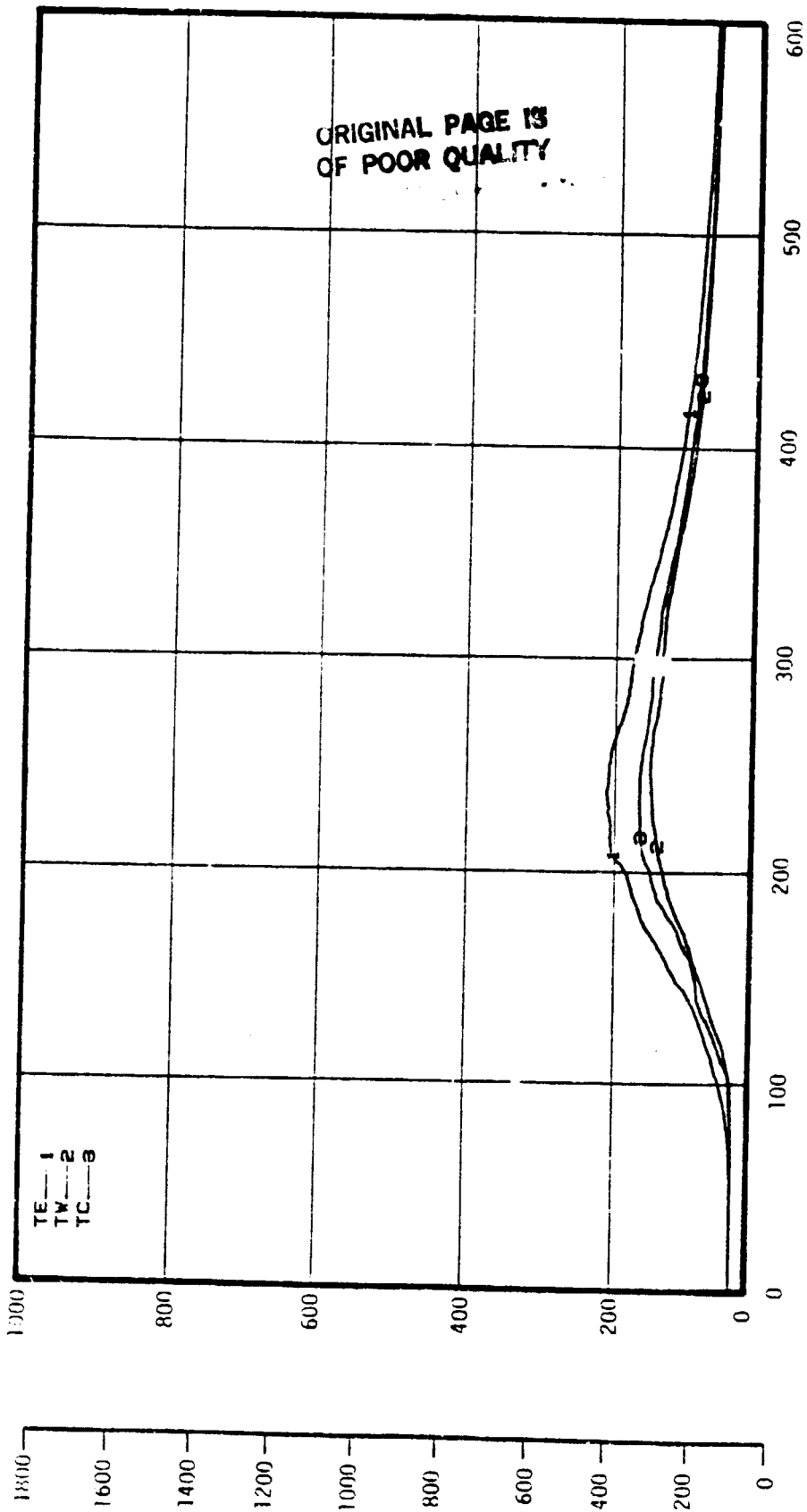
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NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 1

CUSHION CONSTRUCTION NUMBER 1.0

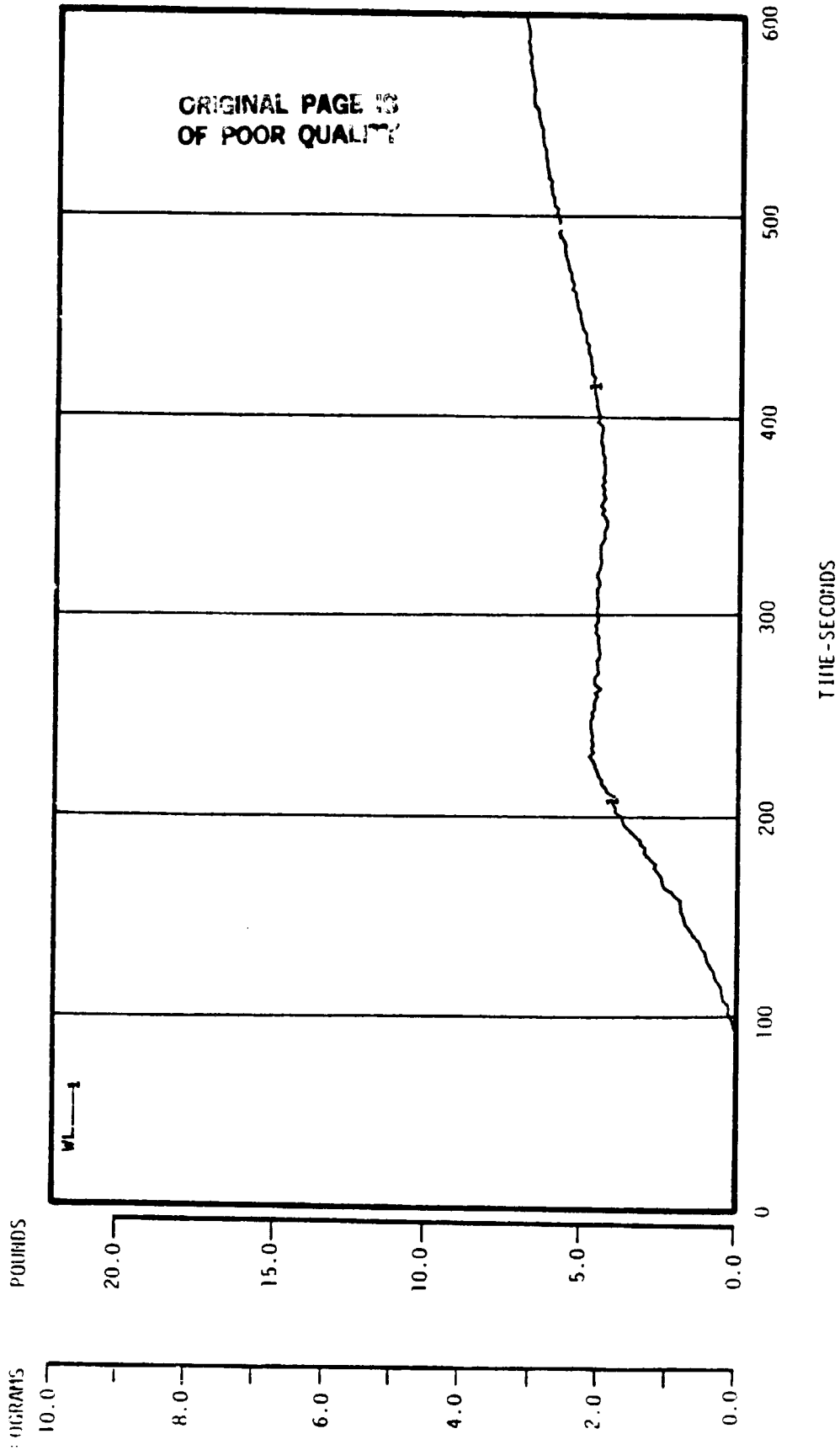
CEILING TEMPERATURE

FAHRENHEIT CELSIUS



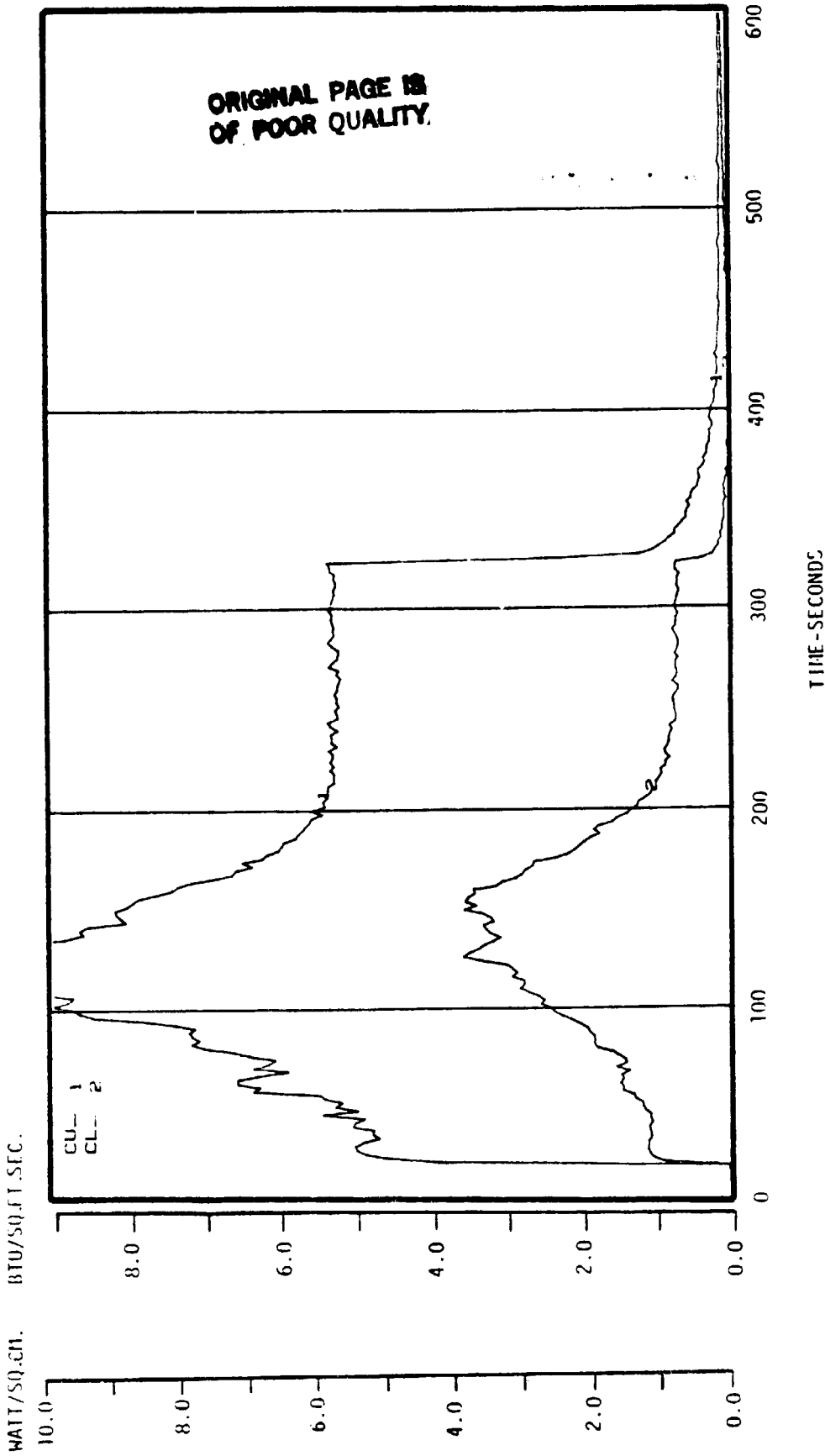
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NASA-MES FULL SCALE CUSHION BURN TEST NUMBER 1
CUSHION CONSTRUCTION NUMBER 1.0

WEIGHT LOSS



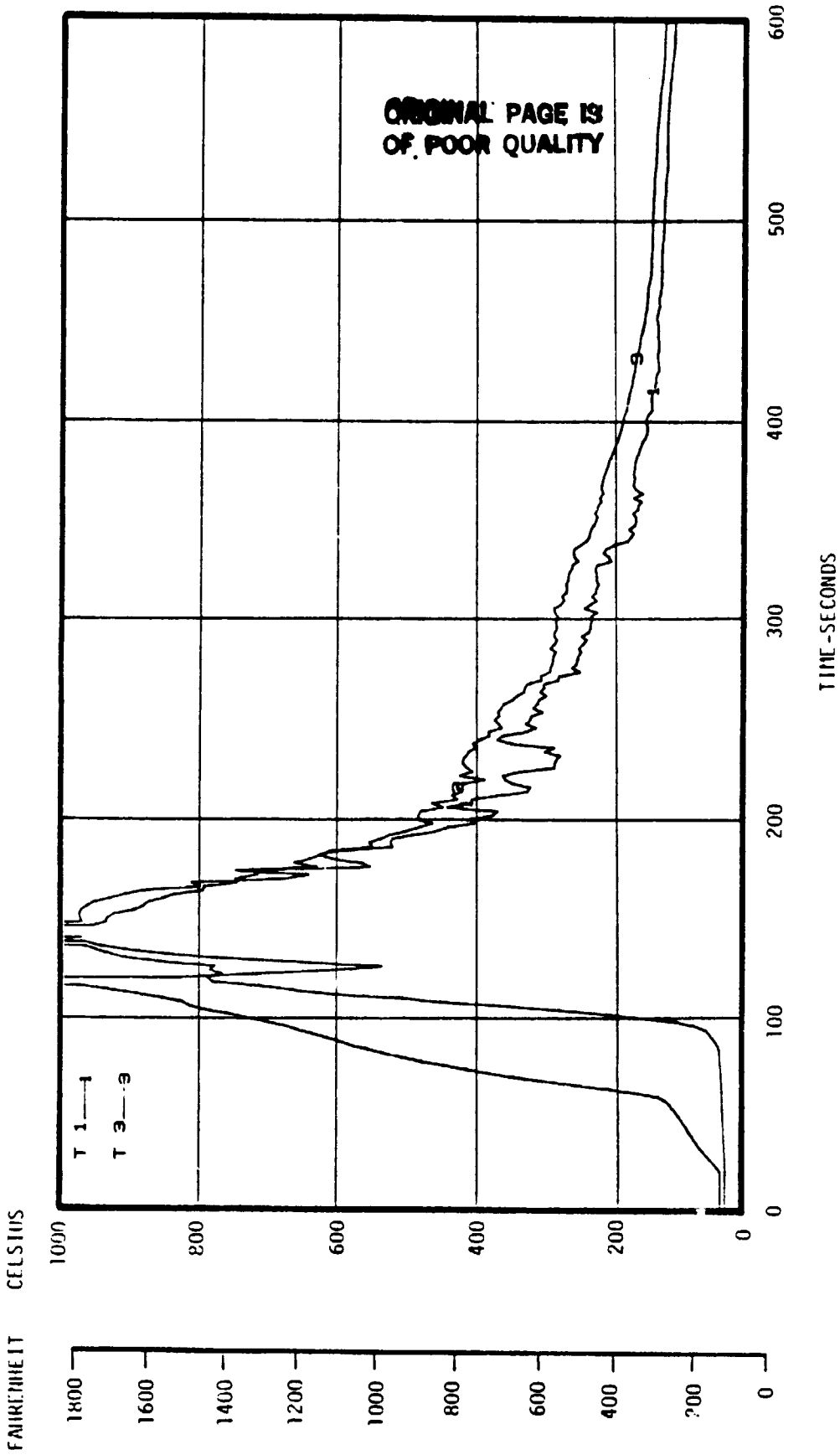
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NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 1
CUSHION CONSTRUCTION NUMBER 1.0

HEAT FLUX



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/16/82 11:11
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CUSHION CONSTRUCTION NUMBER 1.0

SEAT CUSHION TEMPERATURES

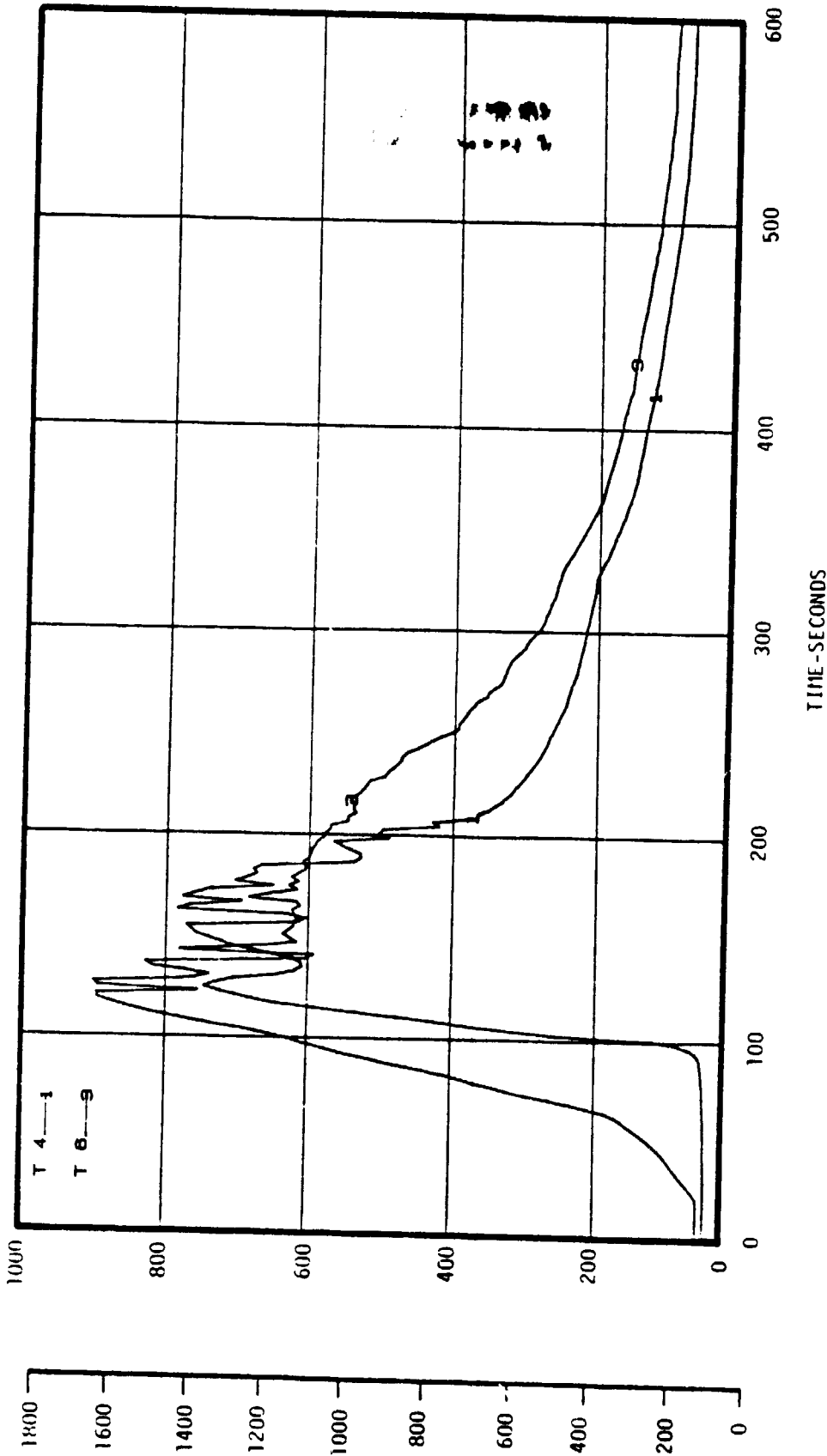


DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/16/82 11.11
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CUSHION CONSTRUCTION NUMBER 1.0

SEAT CUSHION TEMPERATURES

FAHRENHEIT

CELSIUS



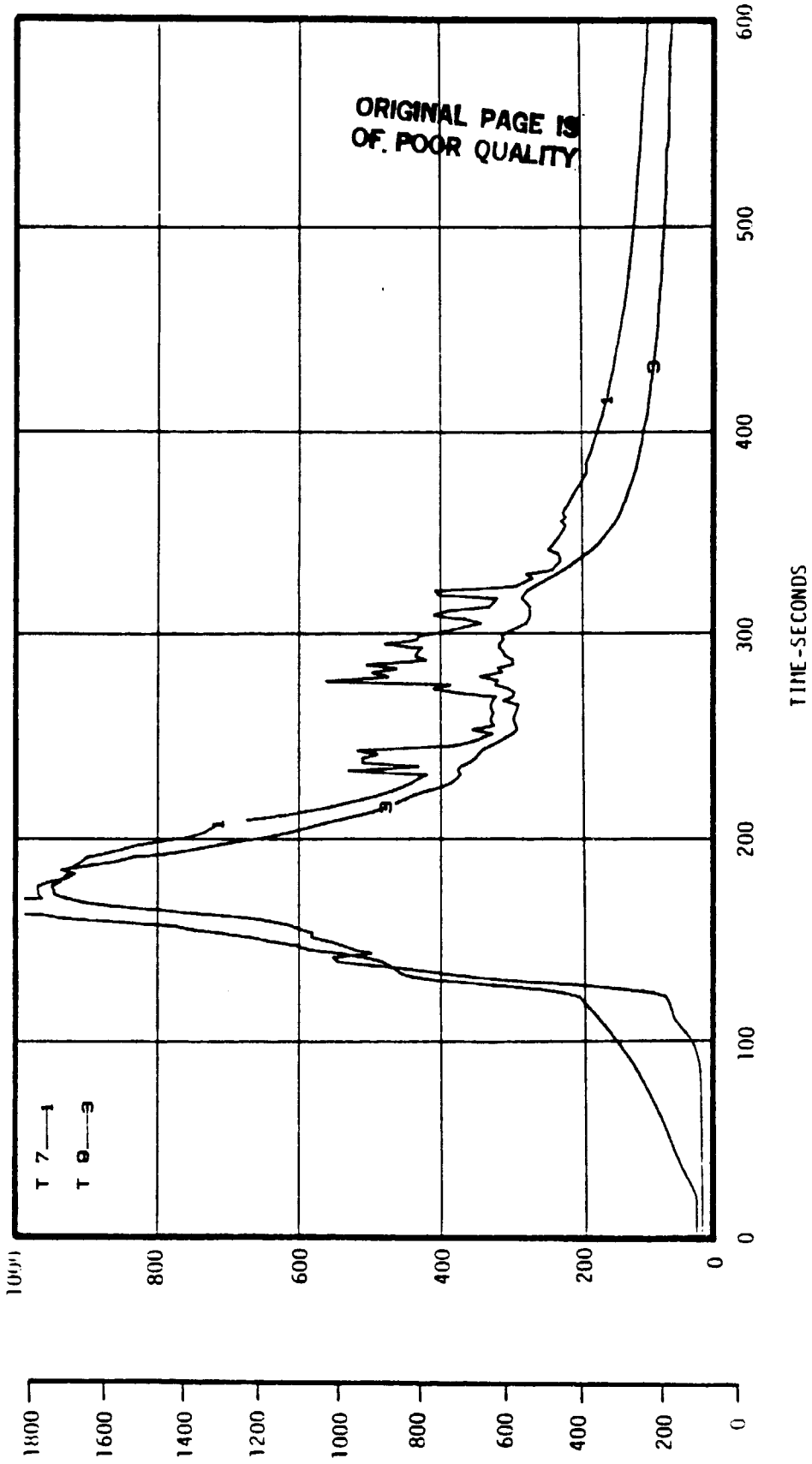
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NASA-AIES FULL SCALE CUSHION BURN TEST NUMBER 17
CUSHION CONSTRUCTION NUMBER 1.0

SEAT CUSHION TEMPERATURES

FAHRENHEIT

CELSIUS

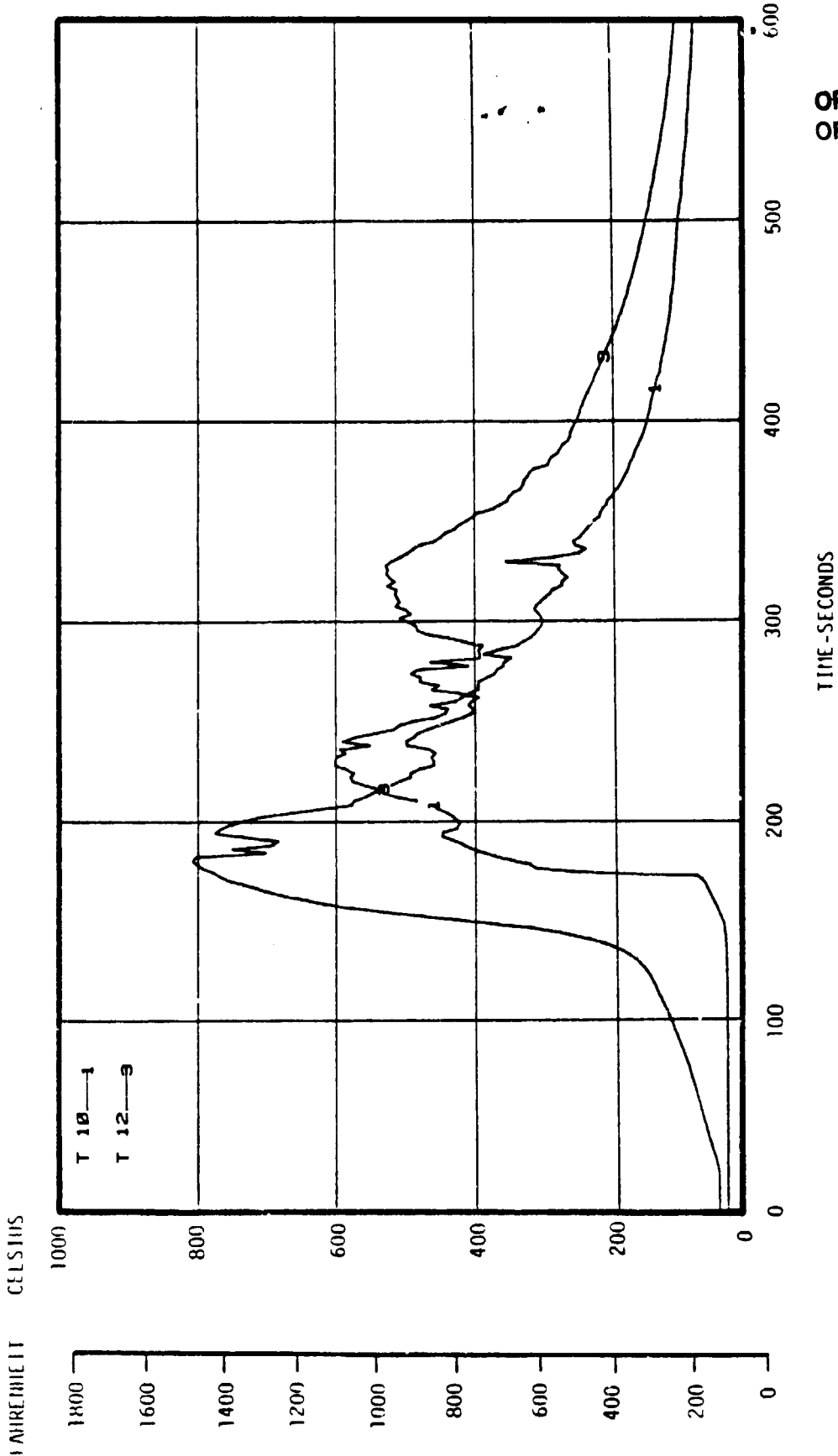


DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/16/82 11:11

NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 17

CUSHION CONSTRUCTION NUMBER 1.0

SEAT CUSHION TEMPERATURES

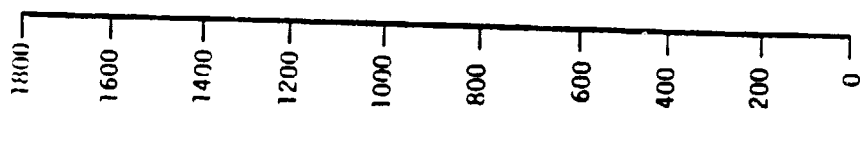


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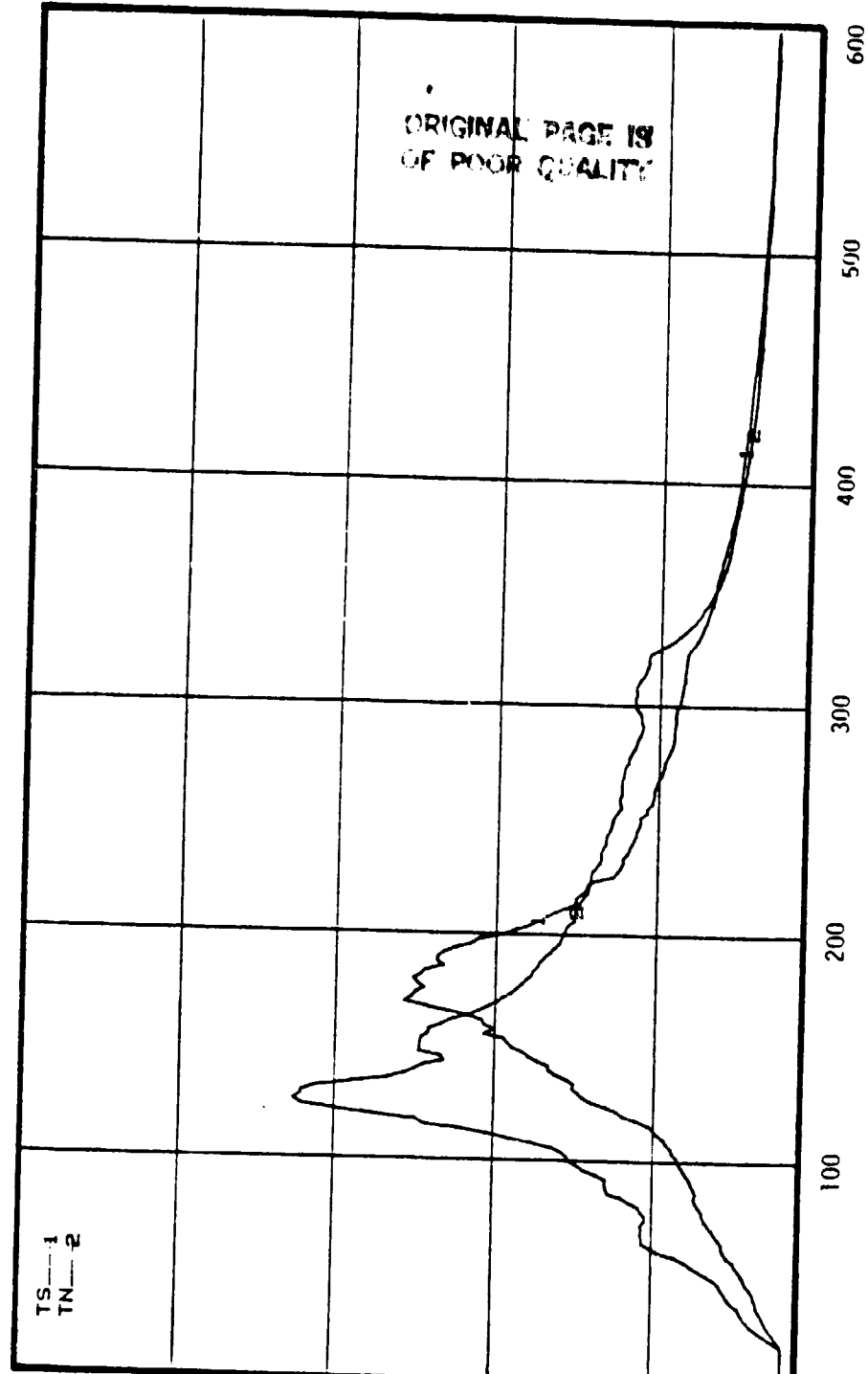
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NASA-NIES FULL SCALE CUSHION BURN TEST NUMBER 17
CUSHION CONSTRUCTION NUMBER 1.0

CEILING TEMPERATURE

FAHRENHEIT



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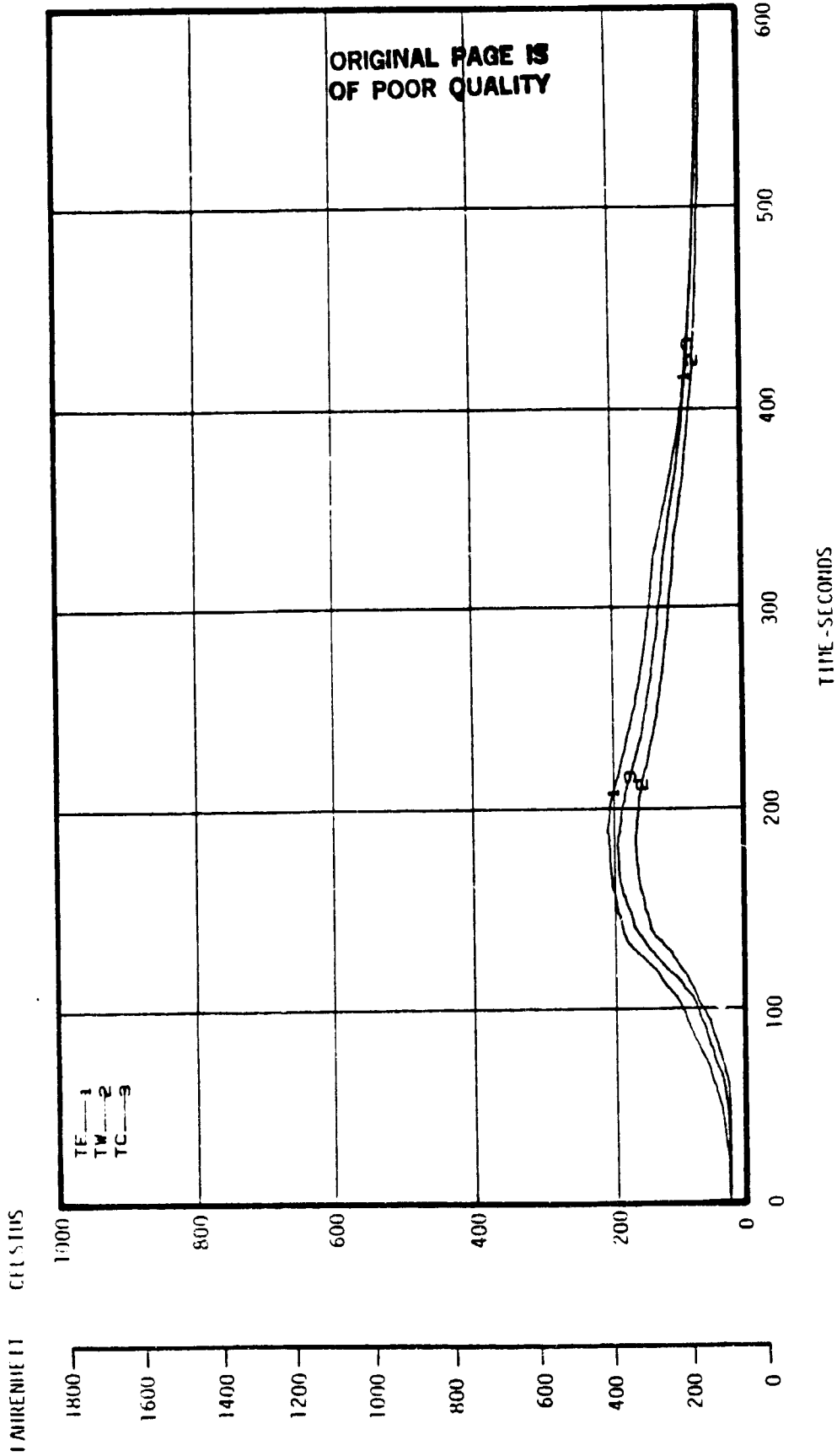


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TIME-SECONDS

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NASA-NYES FULL SCALE CUSHION BURN TEST NUMBER 17
CUSHION CONSTRUCTION NUMBER 1.0

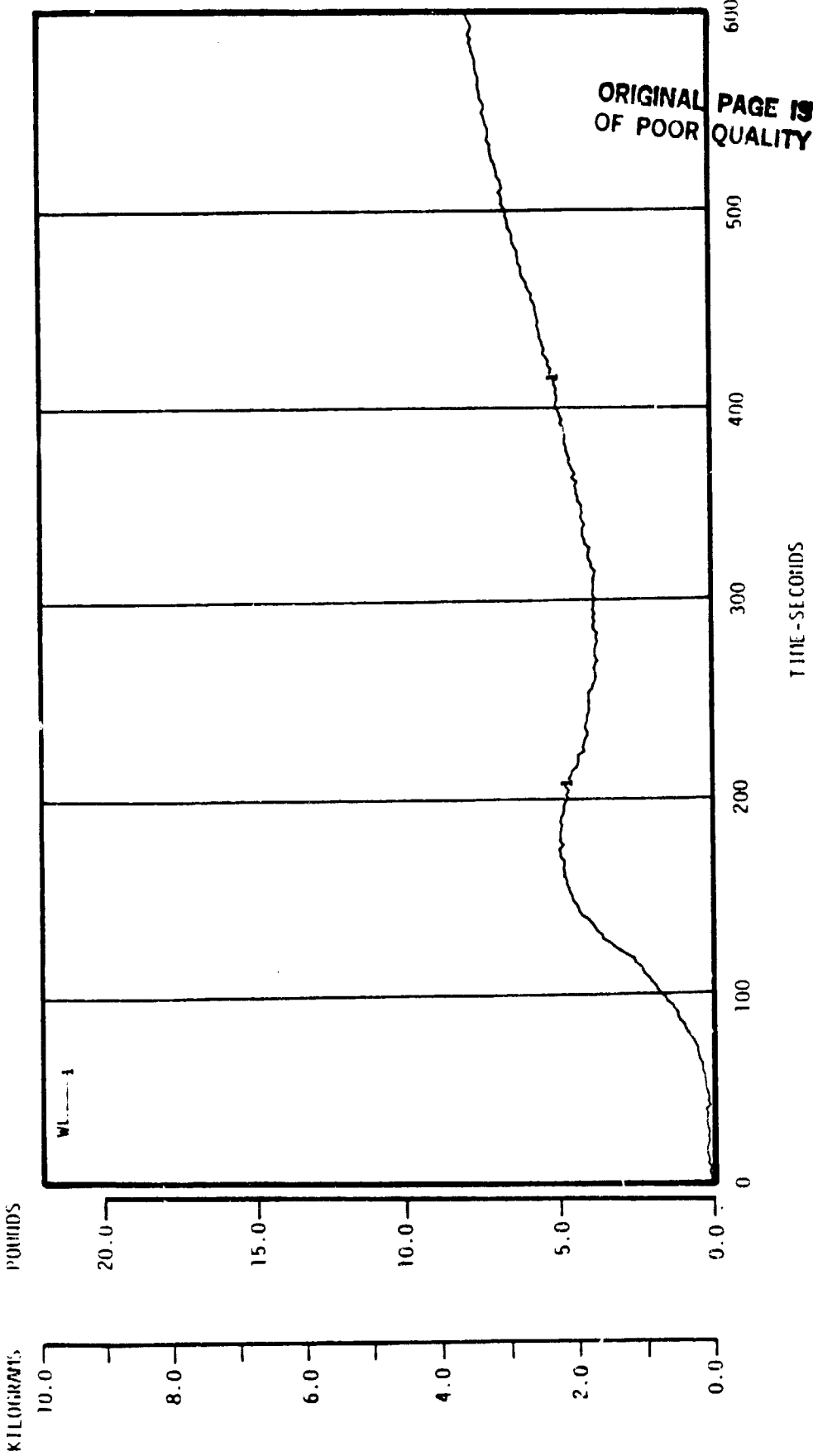
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NASA-NES FULL SCALE CUSHION BURN TEST NUMBER 17
CUSHION CONSTRUCTION NUMBER 1.0

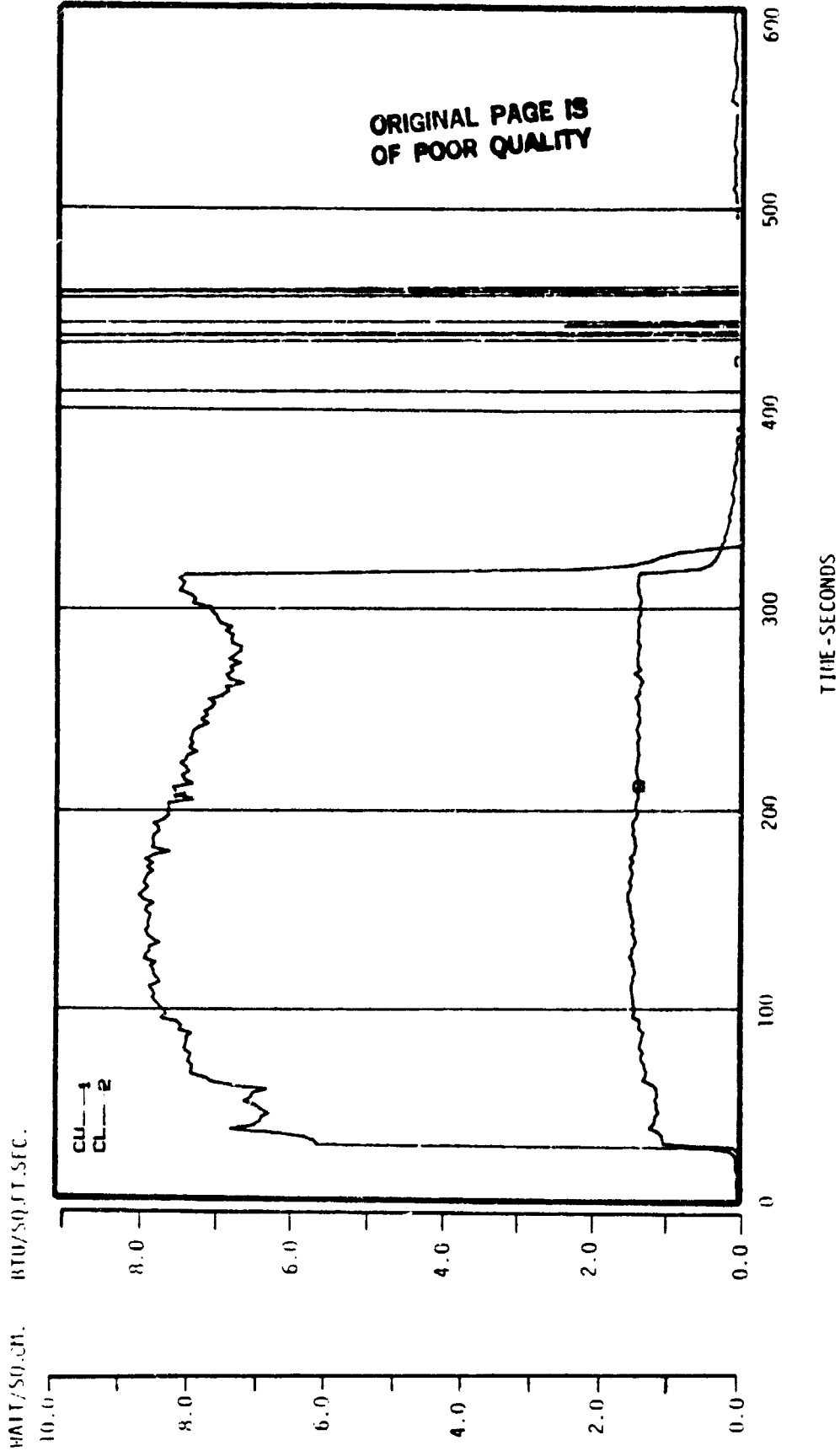
WEIGHT LOSS



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Douglas Aircraft Cabin Fire Simulator 03/16/02 11.11
NASA-Ames Full Scale Cushion Burn Test Number 17
Cushion Construction Number 1.0

HEAT FLUX



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/05/02 13.43

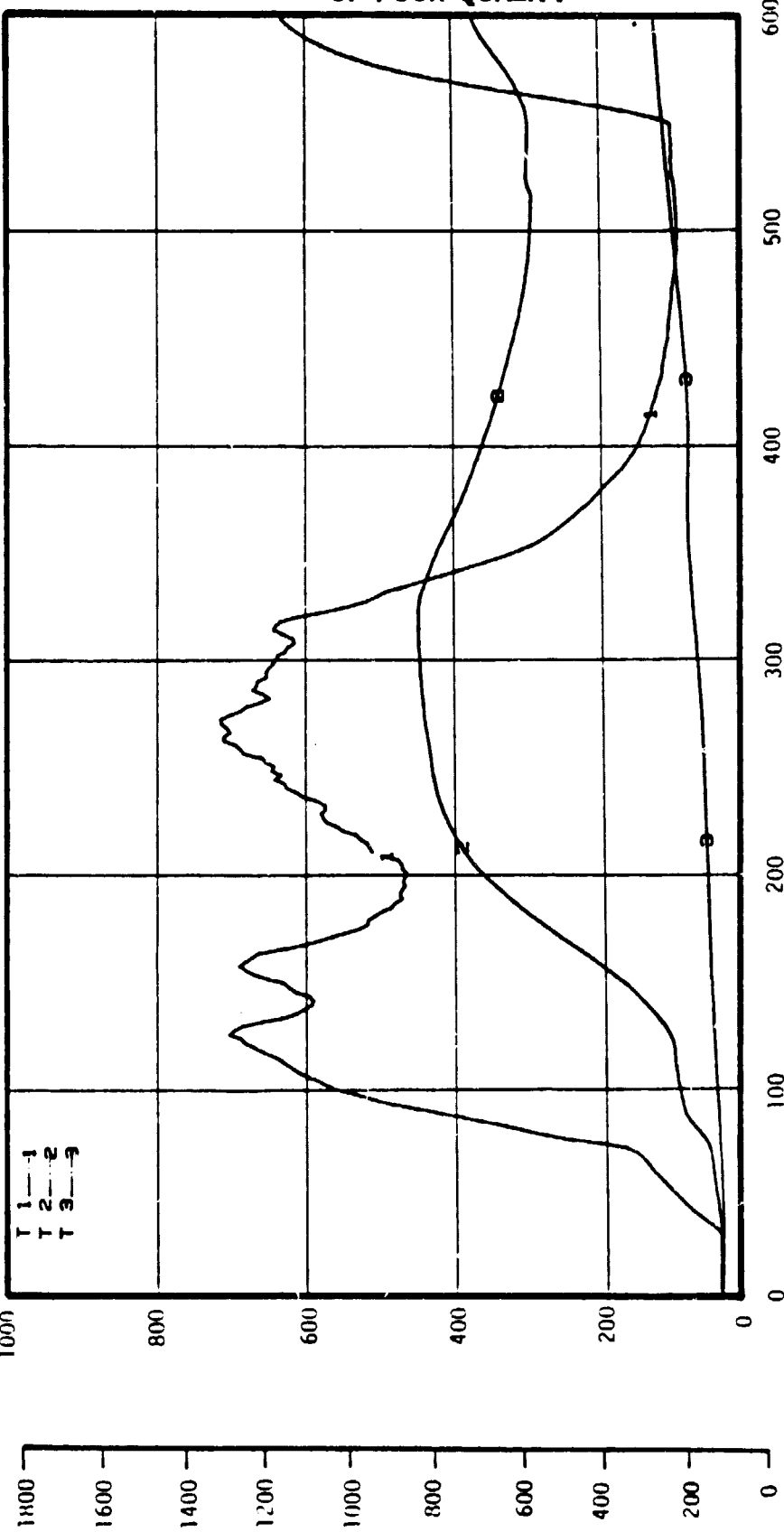
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CUSHION CONSTRUCTION NUMBER 2.0

SEAT CUSHION TEMPERATURES

FAHRENHEIT CELSIUS

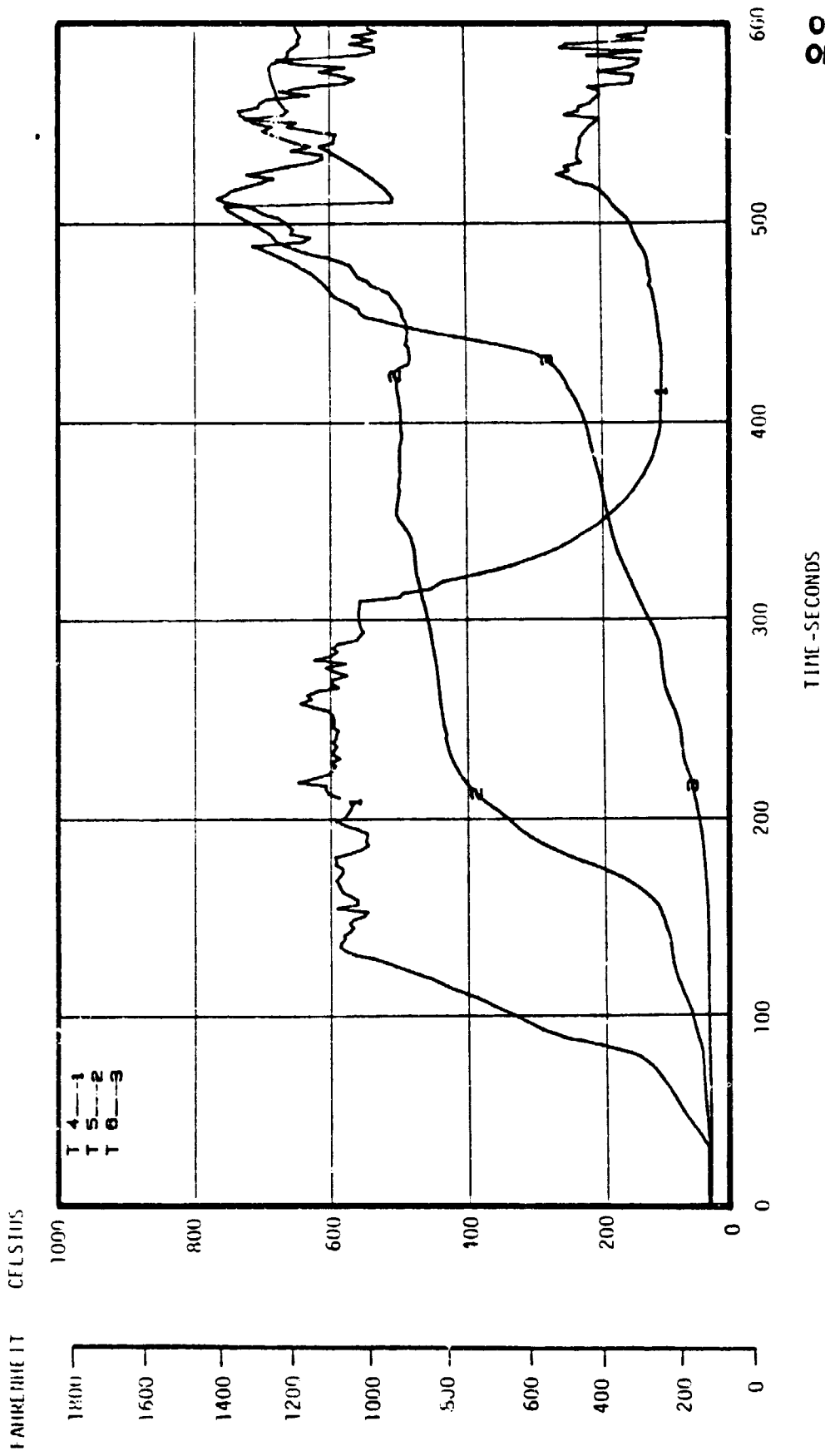
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CUSHION CONSTRUCTION NUMBER 2.0

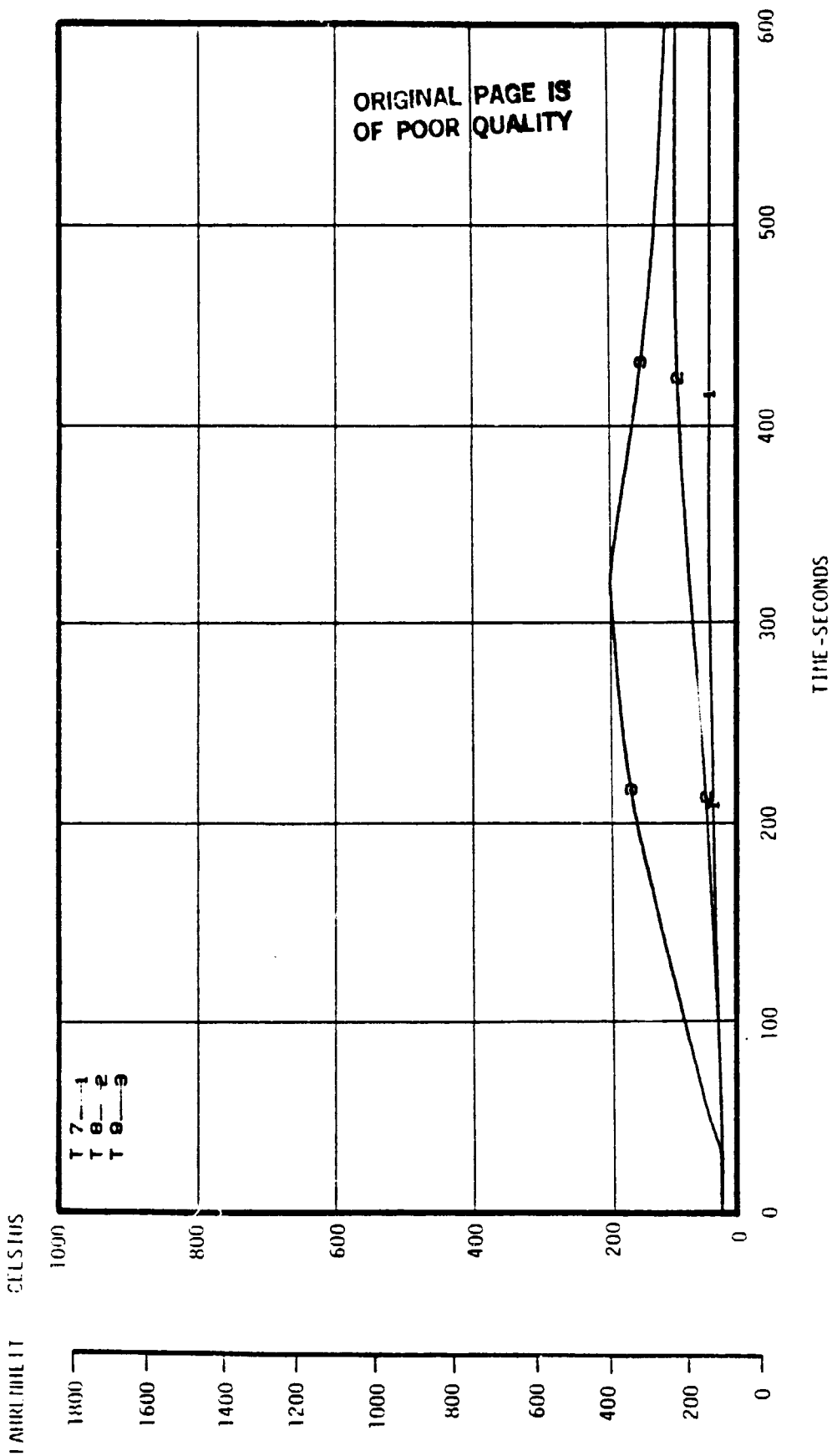
SEAT CUSHION TEMPERATURES



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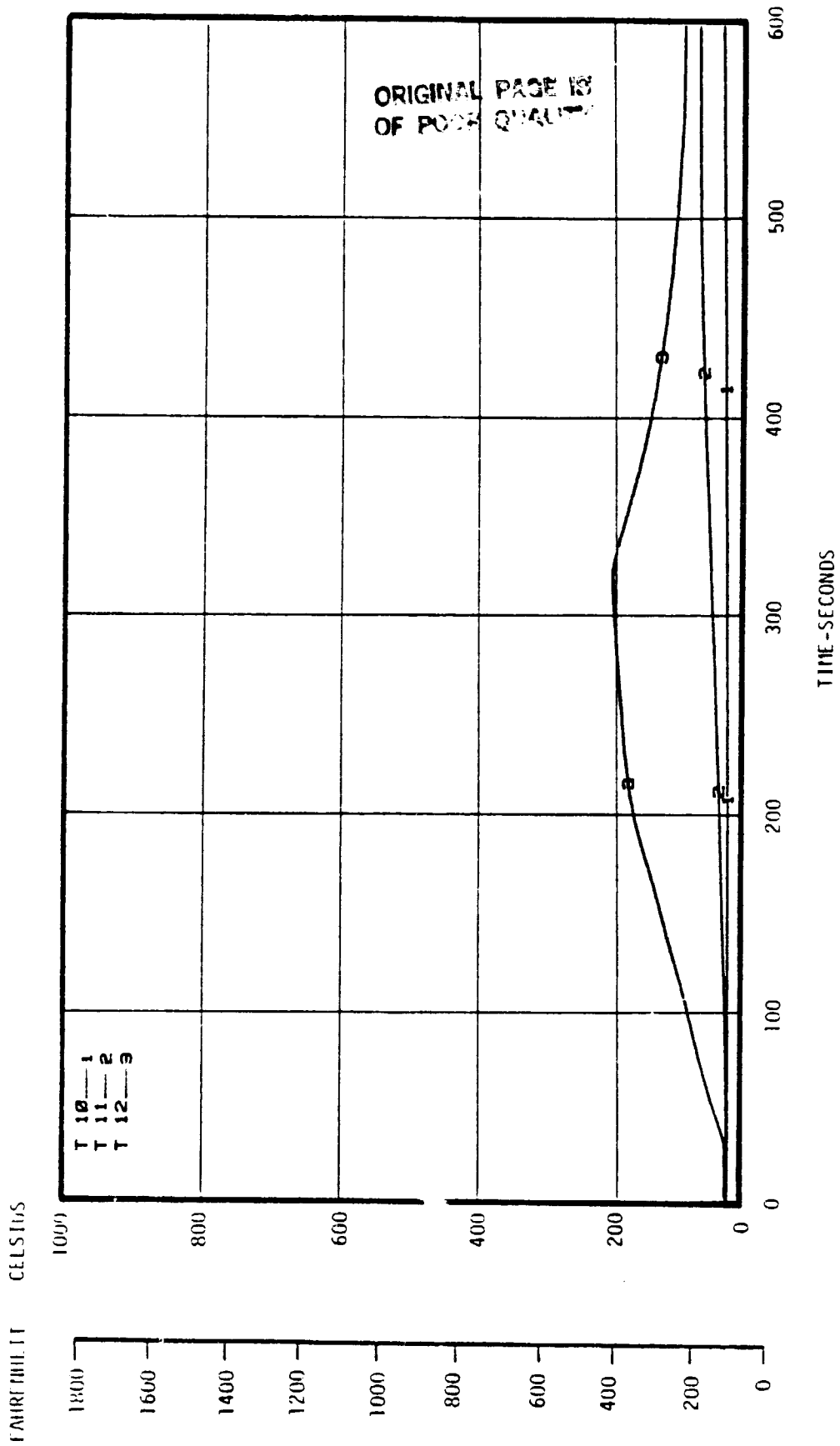
DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/05/82 19.49
 NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 2
 CUSHION CONSTRUCTION NUMBER 2.0

SLAT CUSHION TEMPERATURES



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/05/62 13-43
 NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 2
 CUSHION CONSTRUCTION NUMBER 2.0

SEAT CUSHION TEMPERATURES

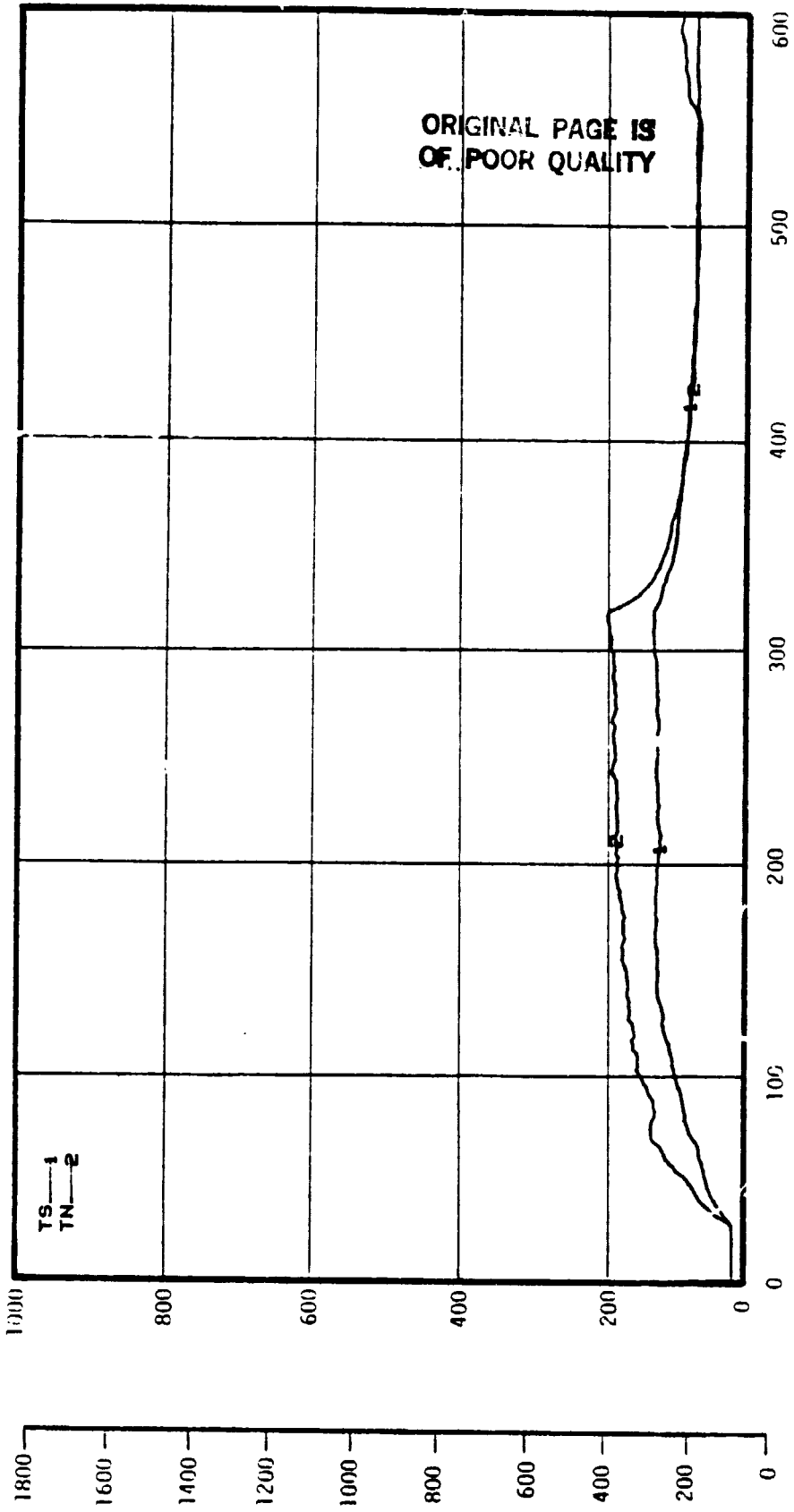


DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 89/85/82 13.49
 NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 2
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CEILING TEMPERATURE

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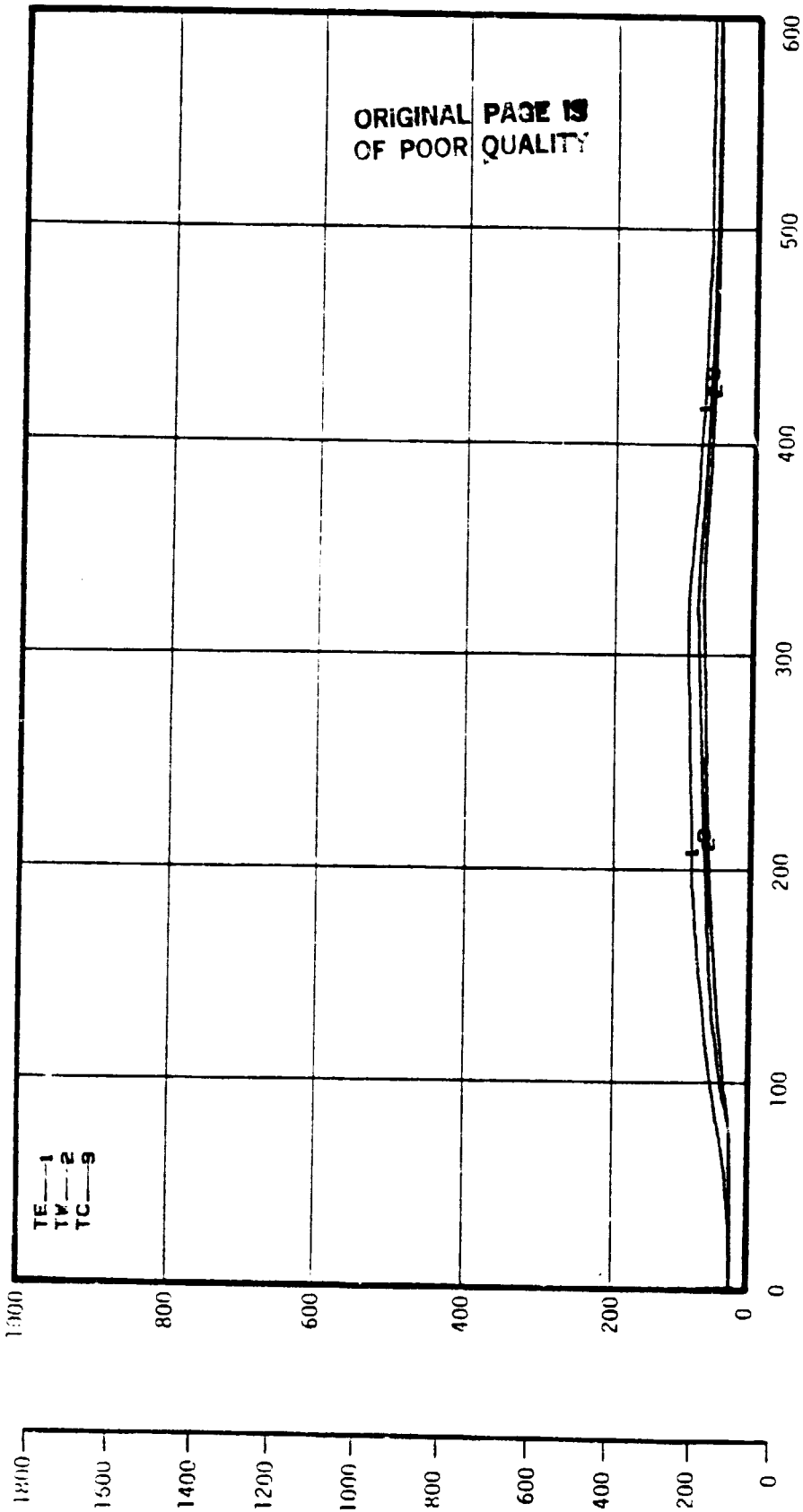
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DOUGLAS AIRCRAFT CO. IN FIRE SIMULATOR 03/05/62 19-43
NASA-AIES FULL SCALE CUSHION BURN TEST NUMBER 2
CUSHION CONSTRUCTION NUMBER 2-0

CYLING TEMPERATURE

FARRENHEIT CELSIUS

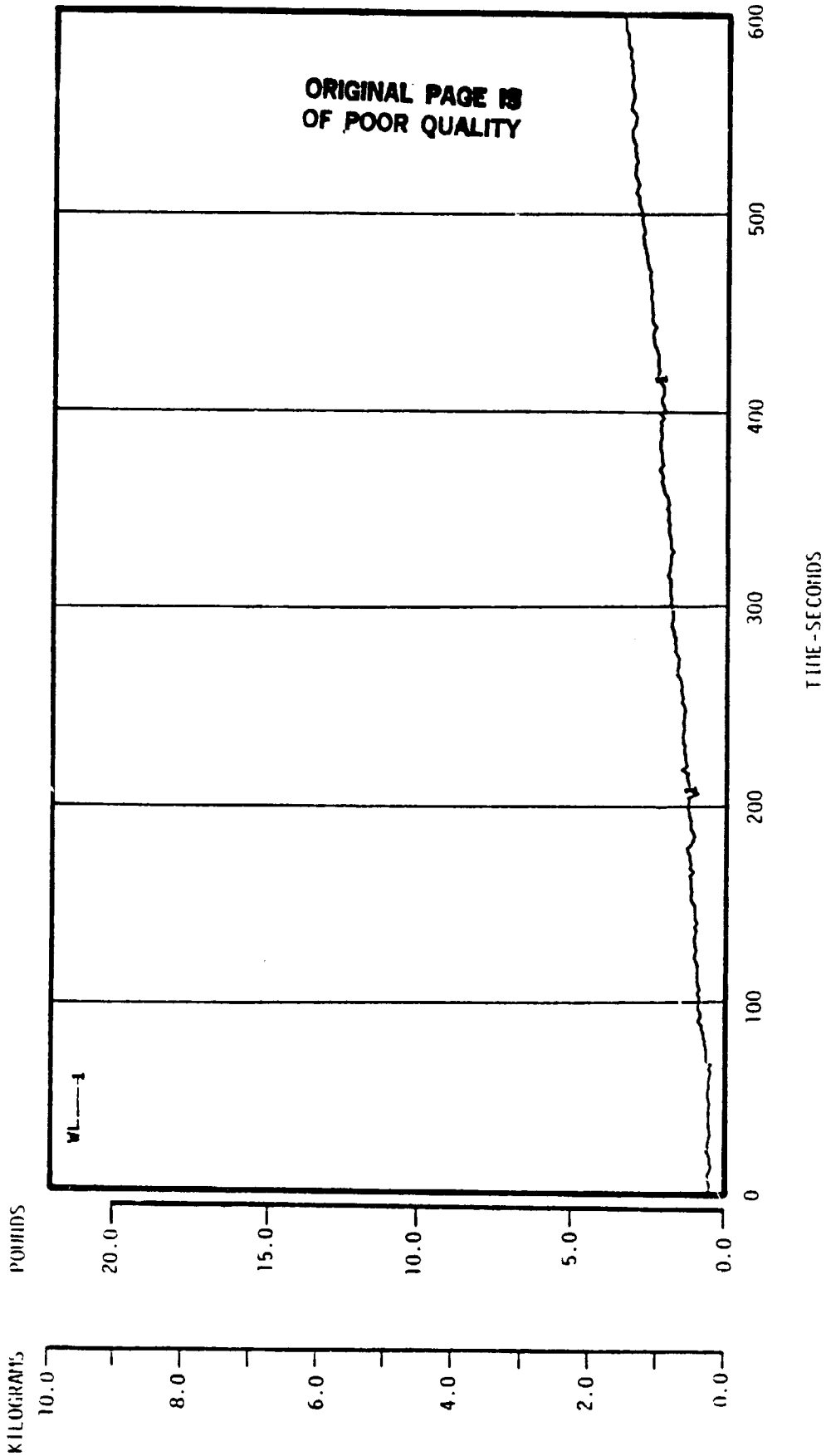


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NASA-NIES FULL SCALE CUSHION BURN TEST NUMBER 2

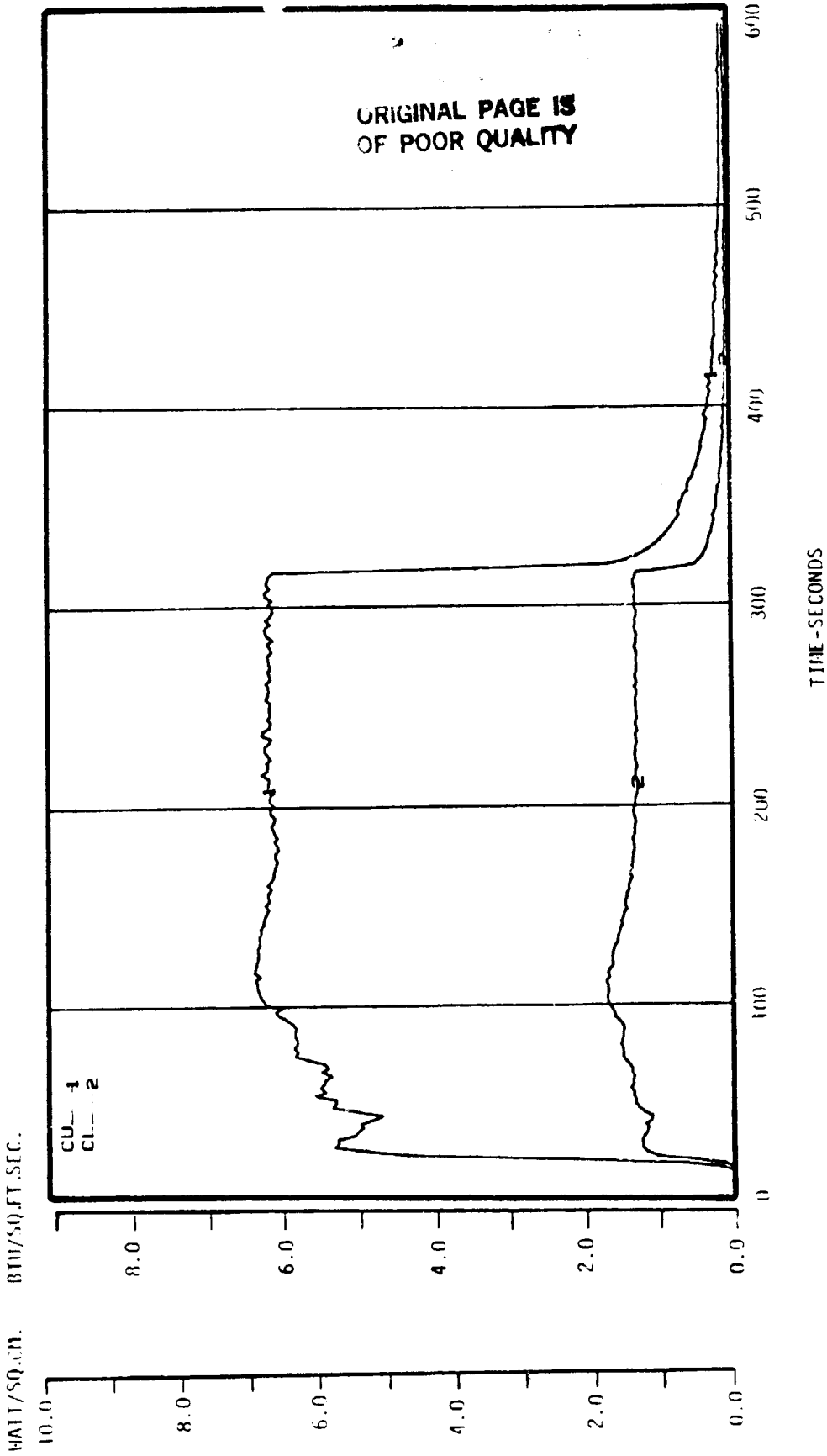
CUSHION CONSTRUCTION NUMBER 2.0

WEIGHT LOSS



JOHNSAS AIRCRAFT CABIN FIRE SIMULATOR 03/05/82 19:43
NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 2
CUSHION CONSTRUCTION NUMBER 2.0

HEAT FLUX

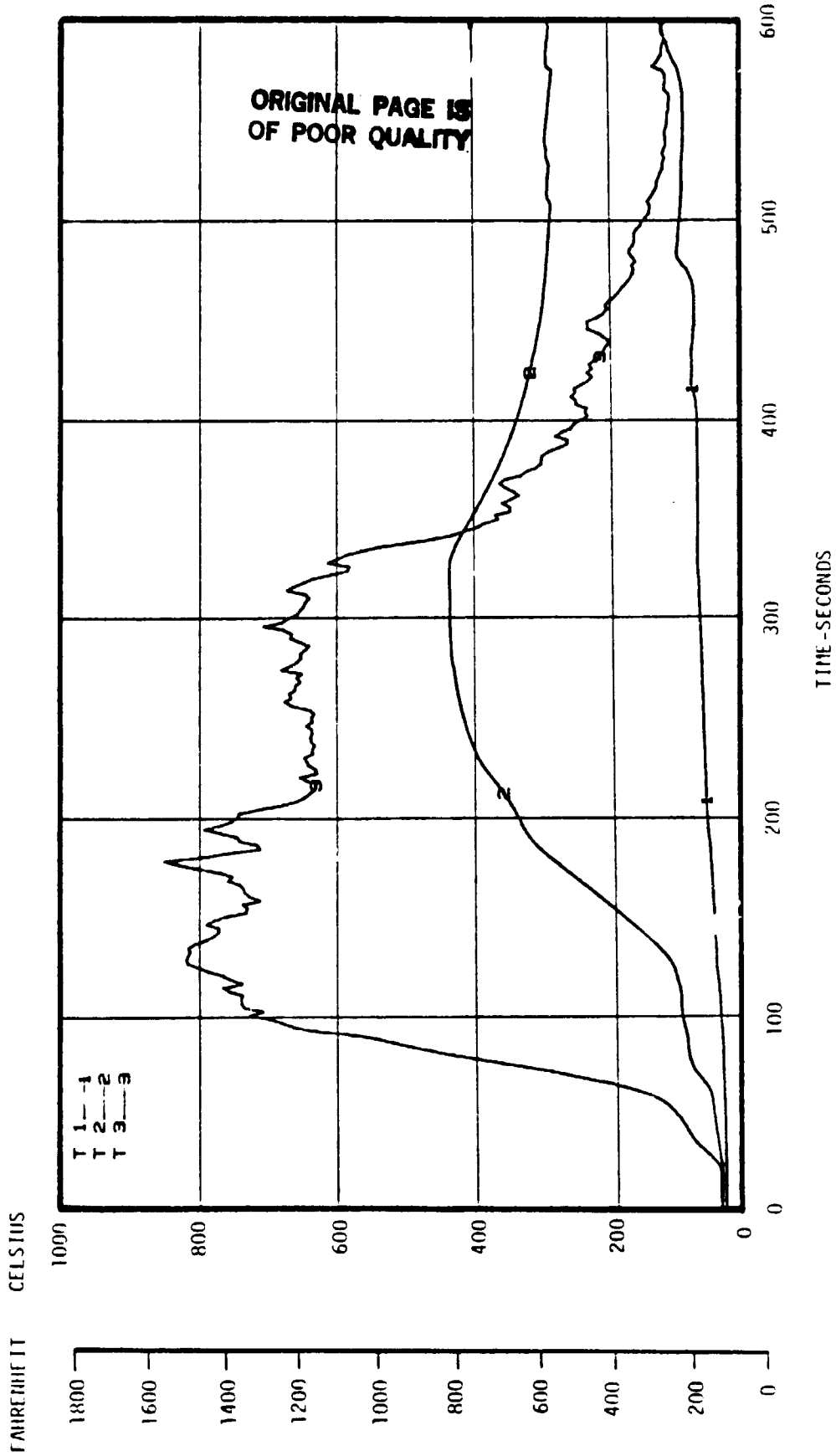


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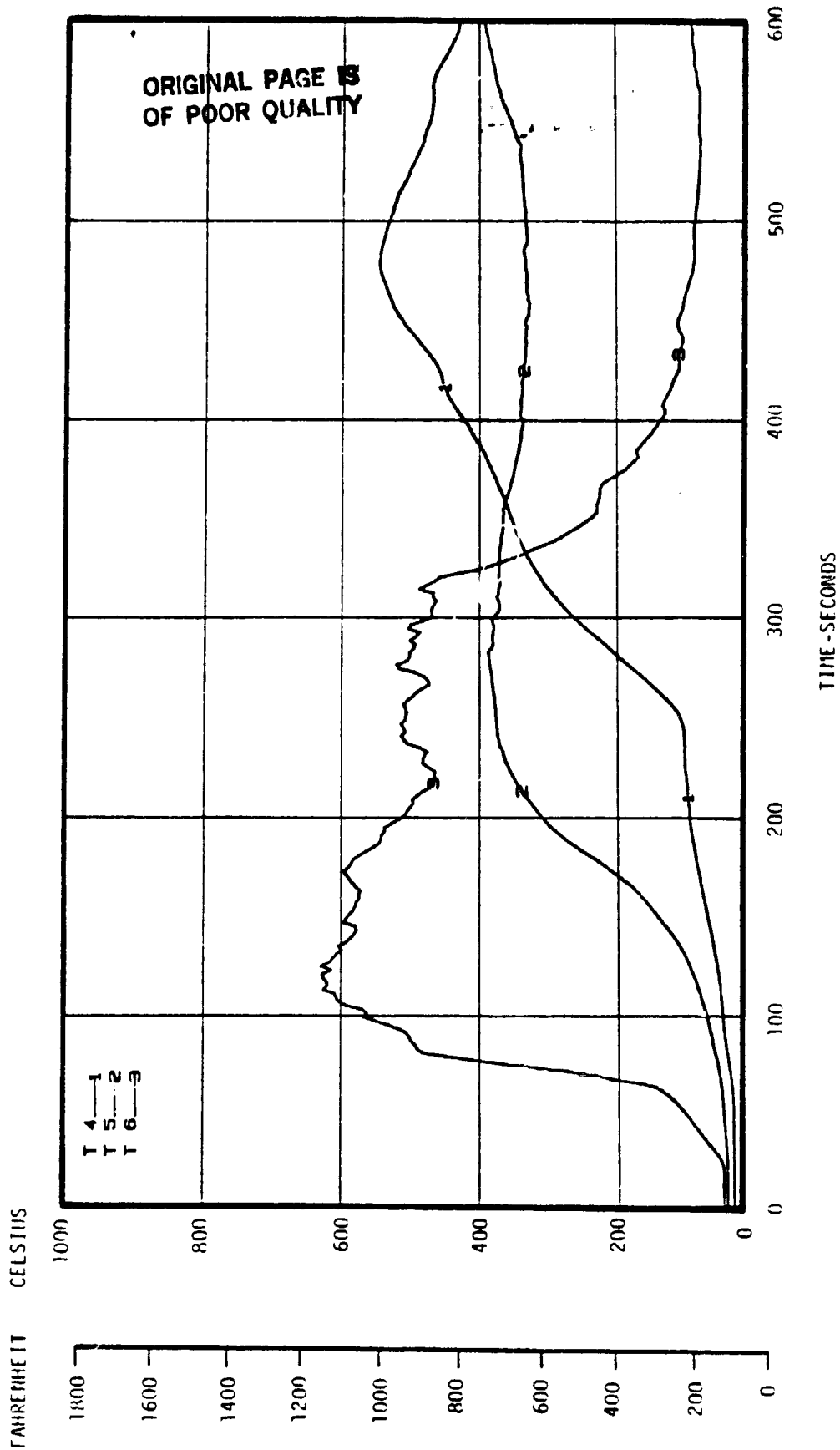
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SEAT CUSHION TEMPERATURES



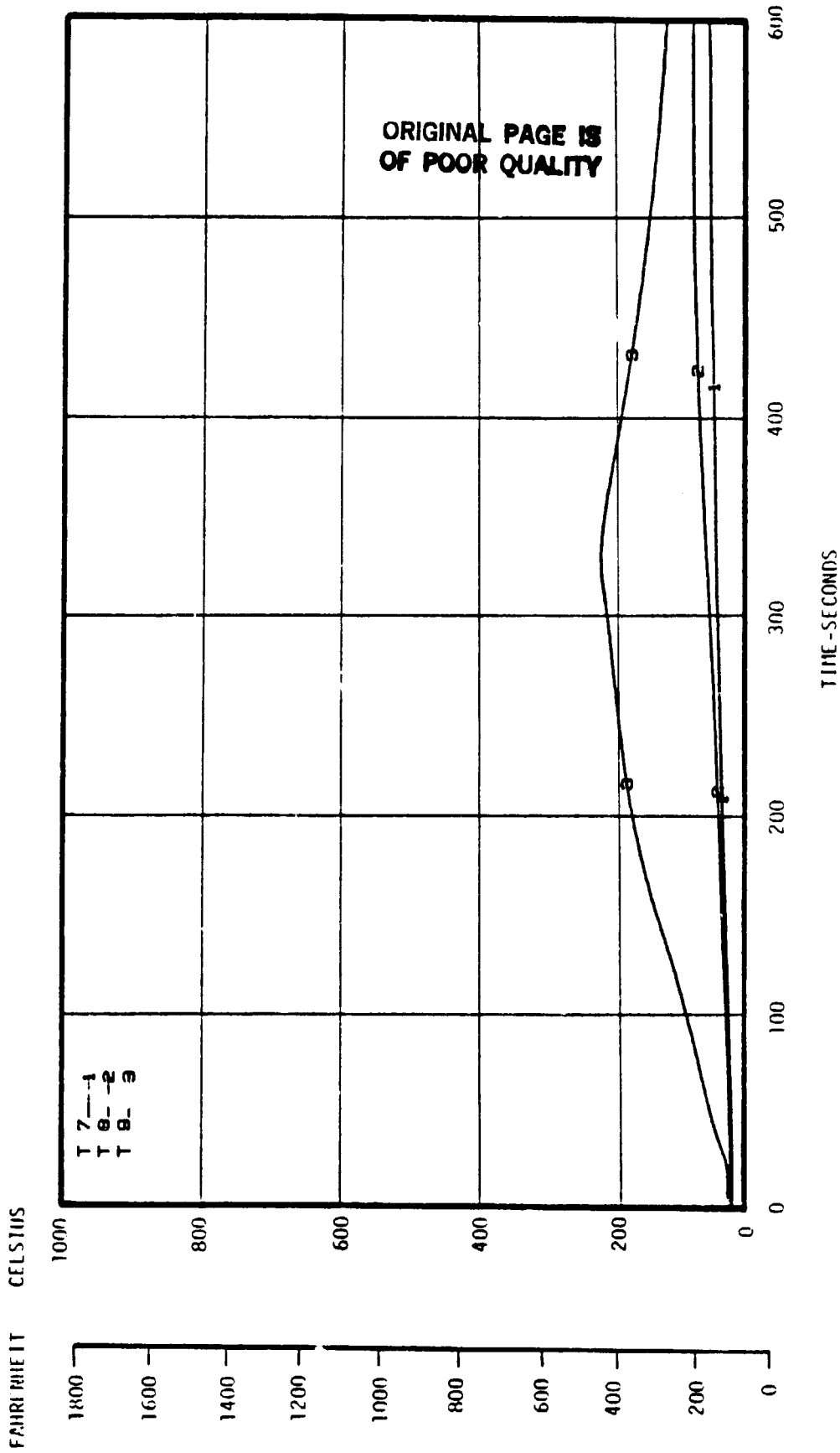
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CUSHION CONSTRUCTION NUMBER 2.0

SEAT CUSHION TEMPERATURES



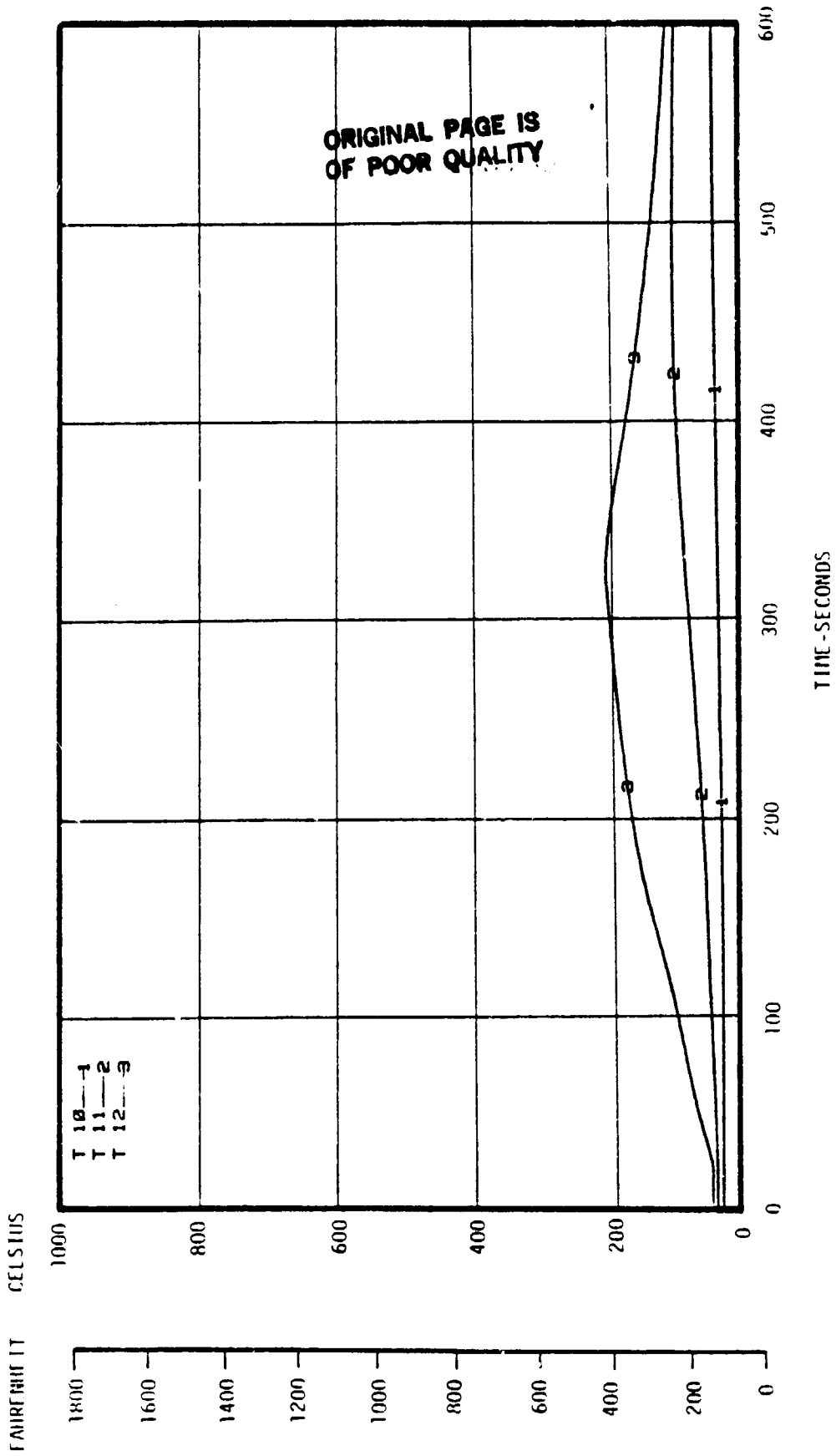
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 CUSHION CONSTRUCTION NUMBER 2.0

SEAT CUSHION TEMPERATURES



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/00/02 10, 01
 NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 4
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SEAT CUSHION TEMPERATURES



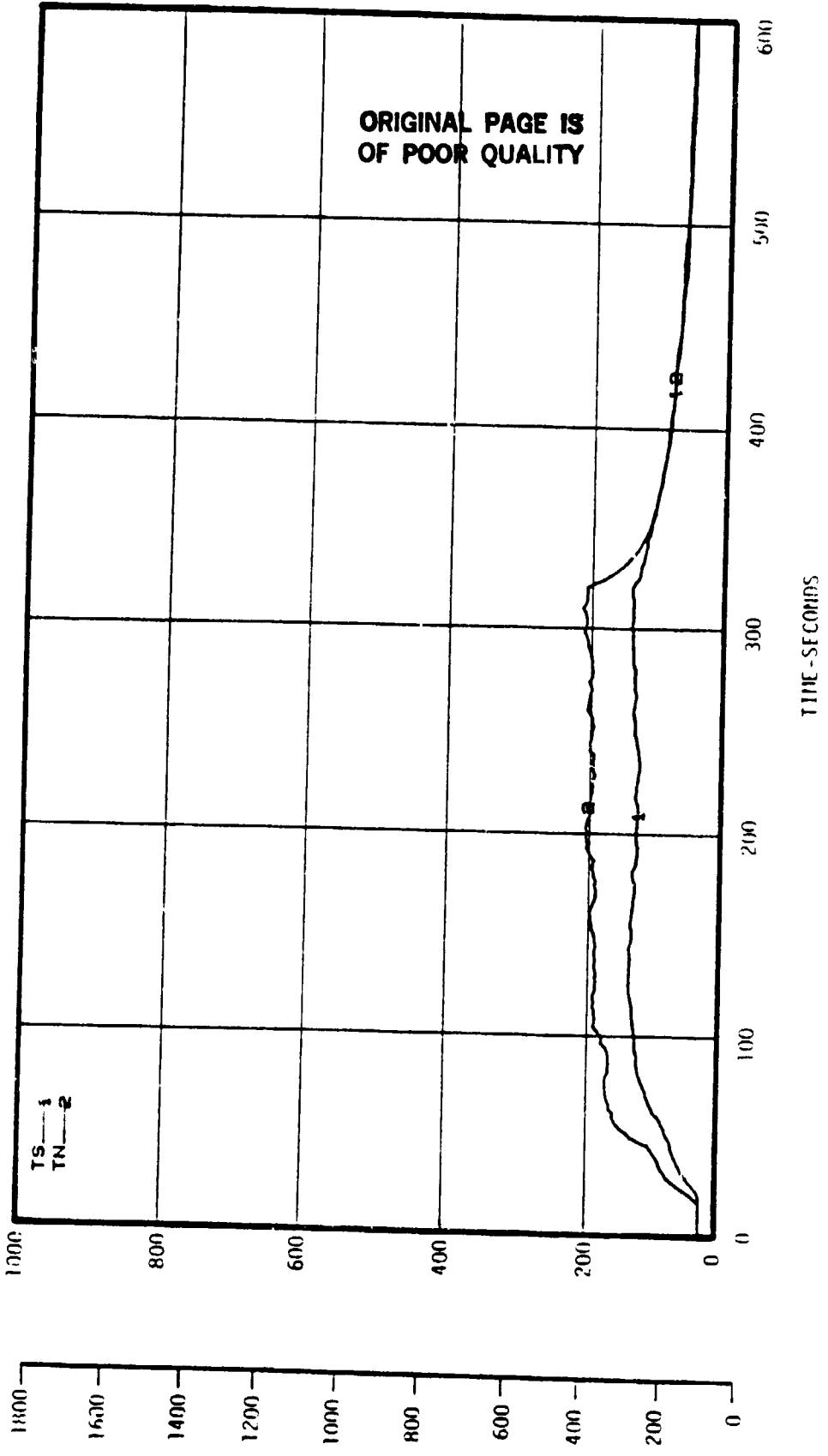
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CEILING TEMPERATURE

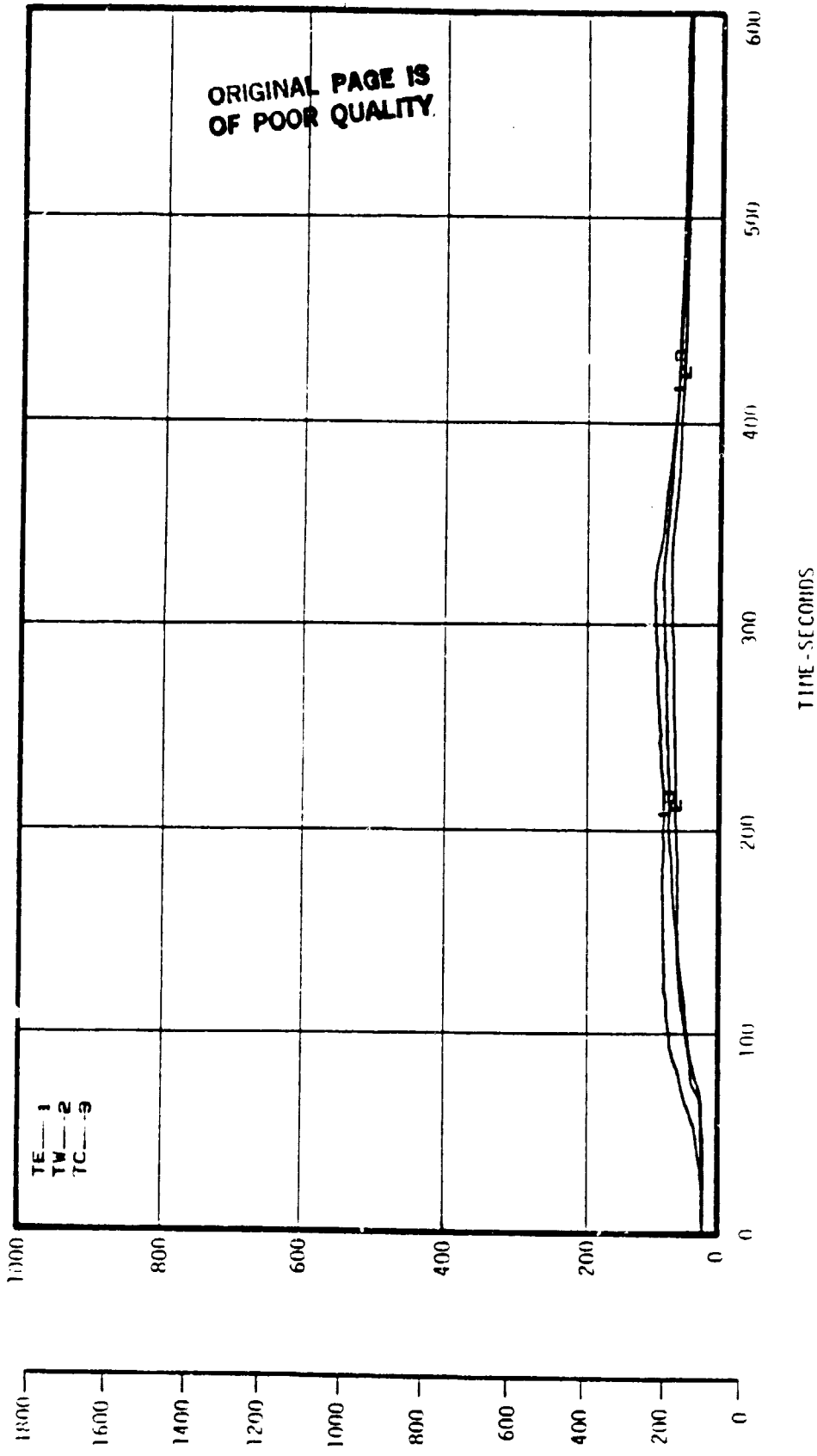
FAHRENHEIT CELSIUS



BOEING AIRCRAFT CABIN FIRE SIMULATOR 03/09/62 10.01
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CEILING TEMPERATURE

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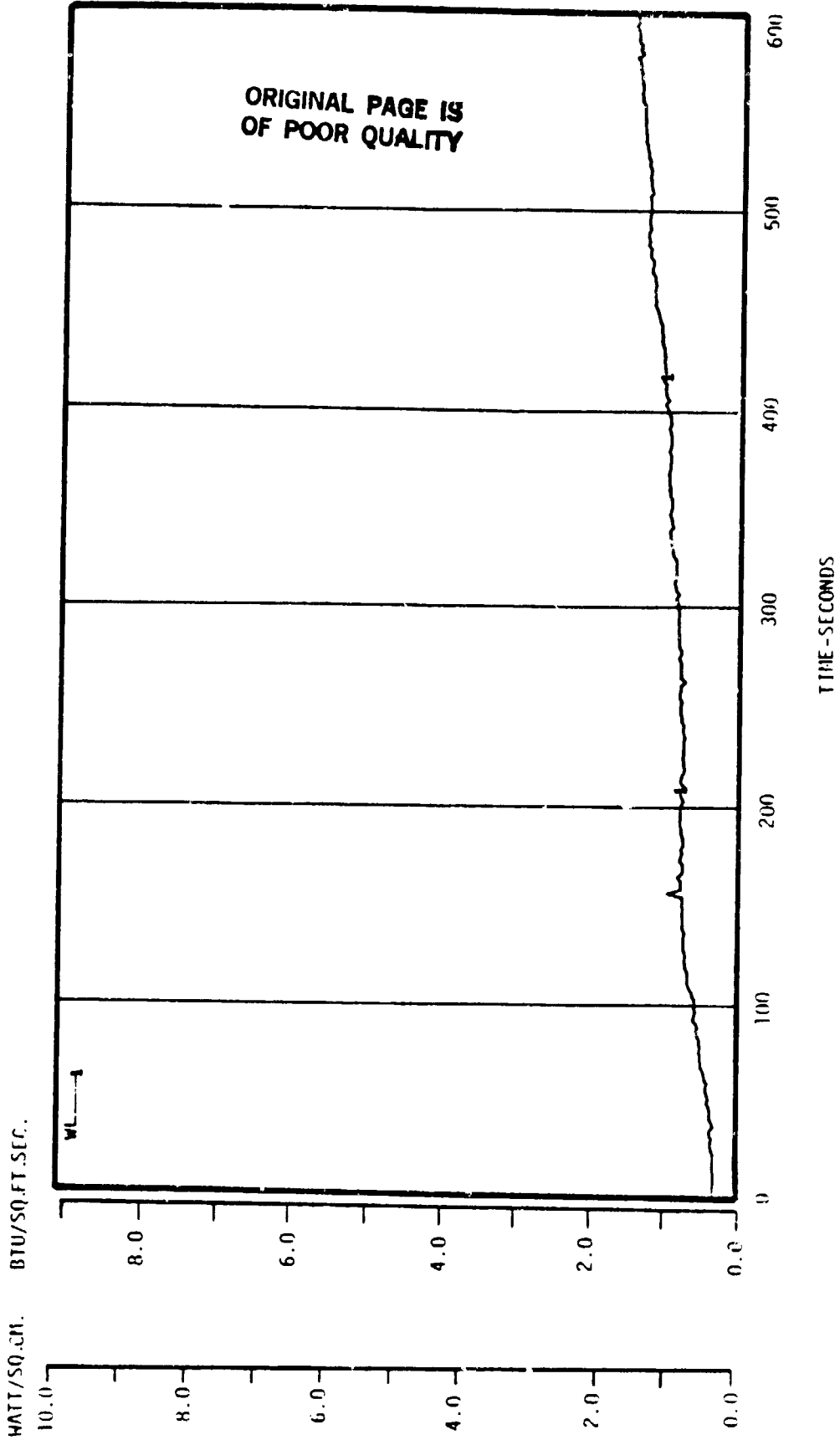


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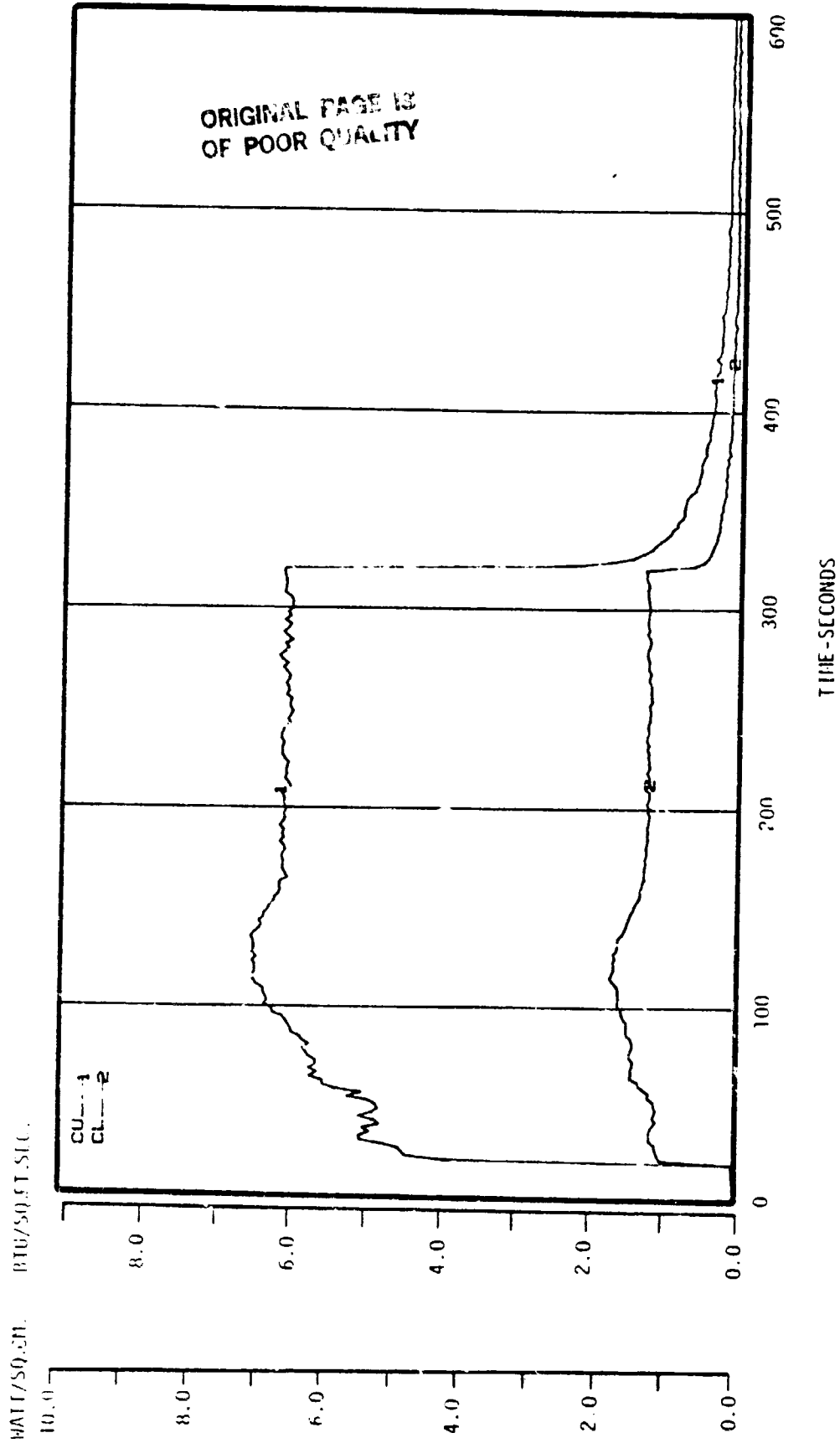
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HEAT FLUX



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CUSHION CONSTRUCTION NUMBER 2.0

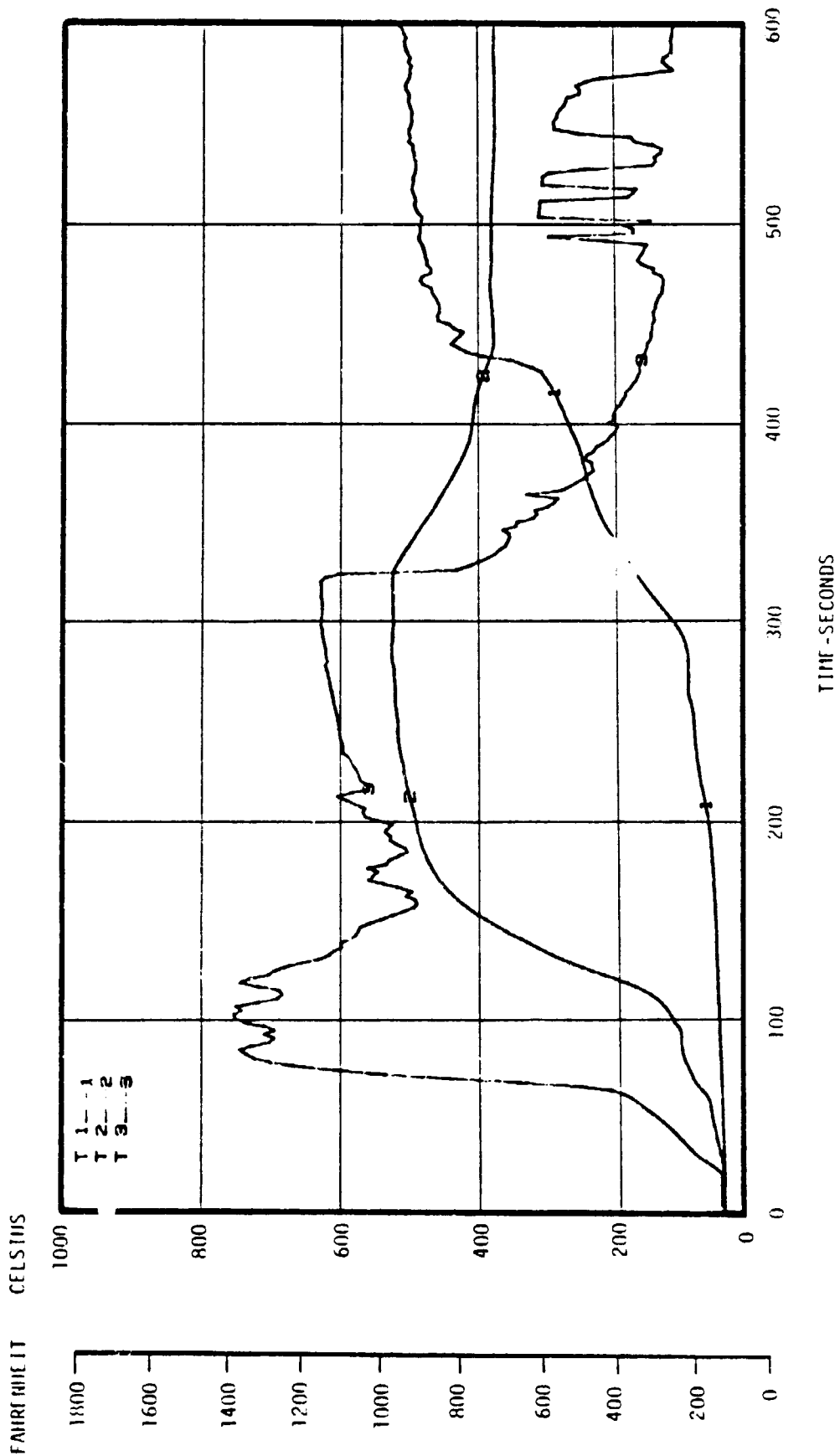
HEAT FLUX



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NASA-NIES FULL SCALE CUSHION BURN TEST NUMBER 11
CUSHION CONSTRUCTION NUMBER 3.0

SEAT CUSHION TEMPERATURES

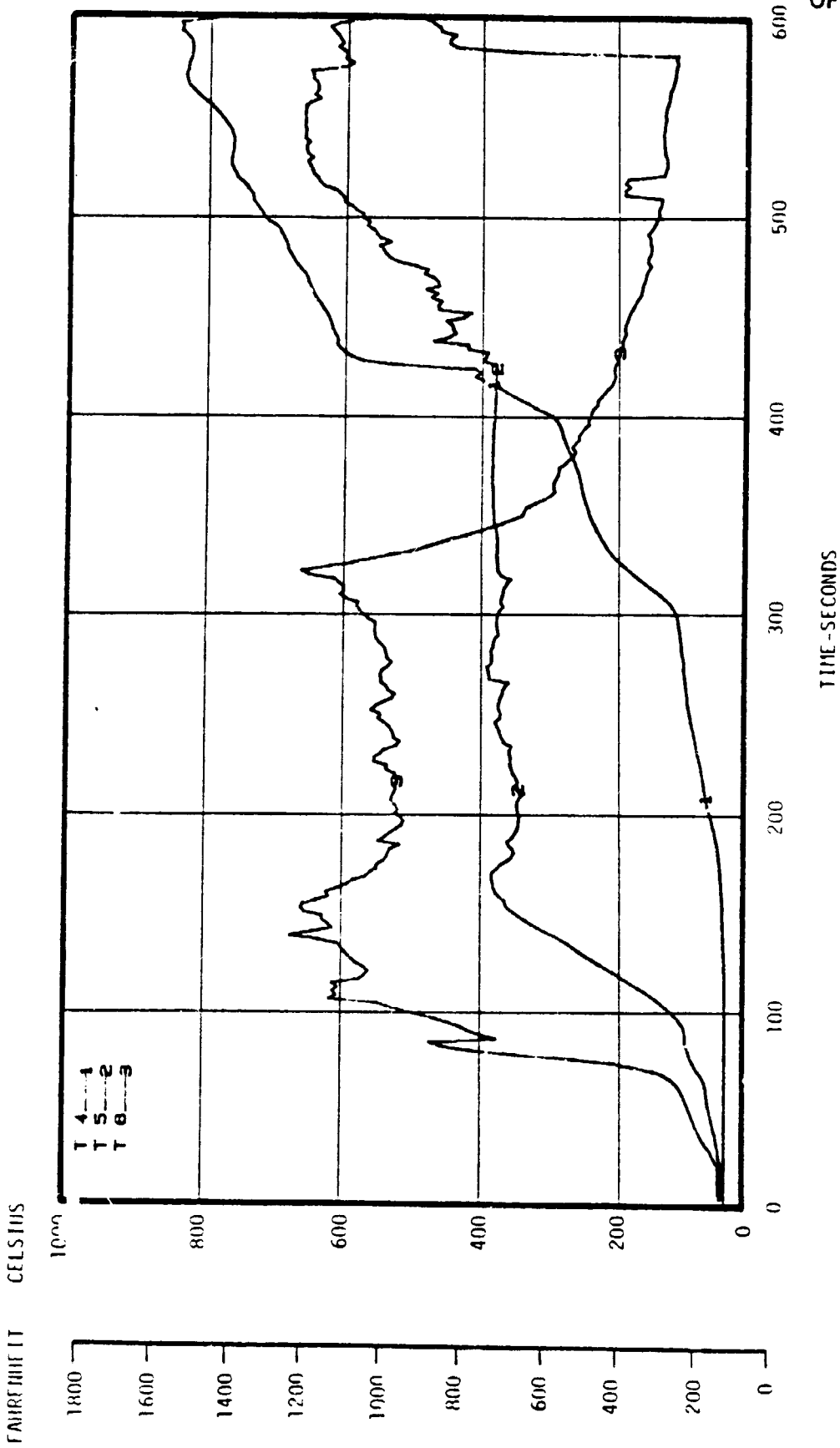


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NASA-AMES FULL SCALE CUSHION PURN TEST NUMBER 11

CUSHION CONSTRUCTION NUMBER 3.0

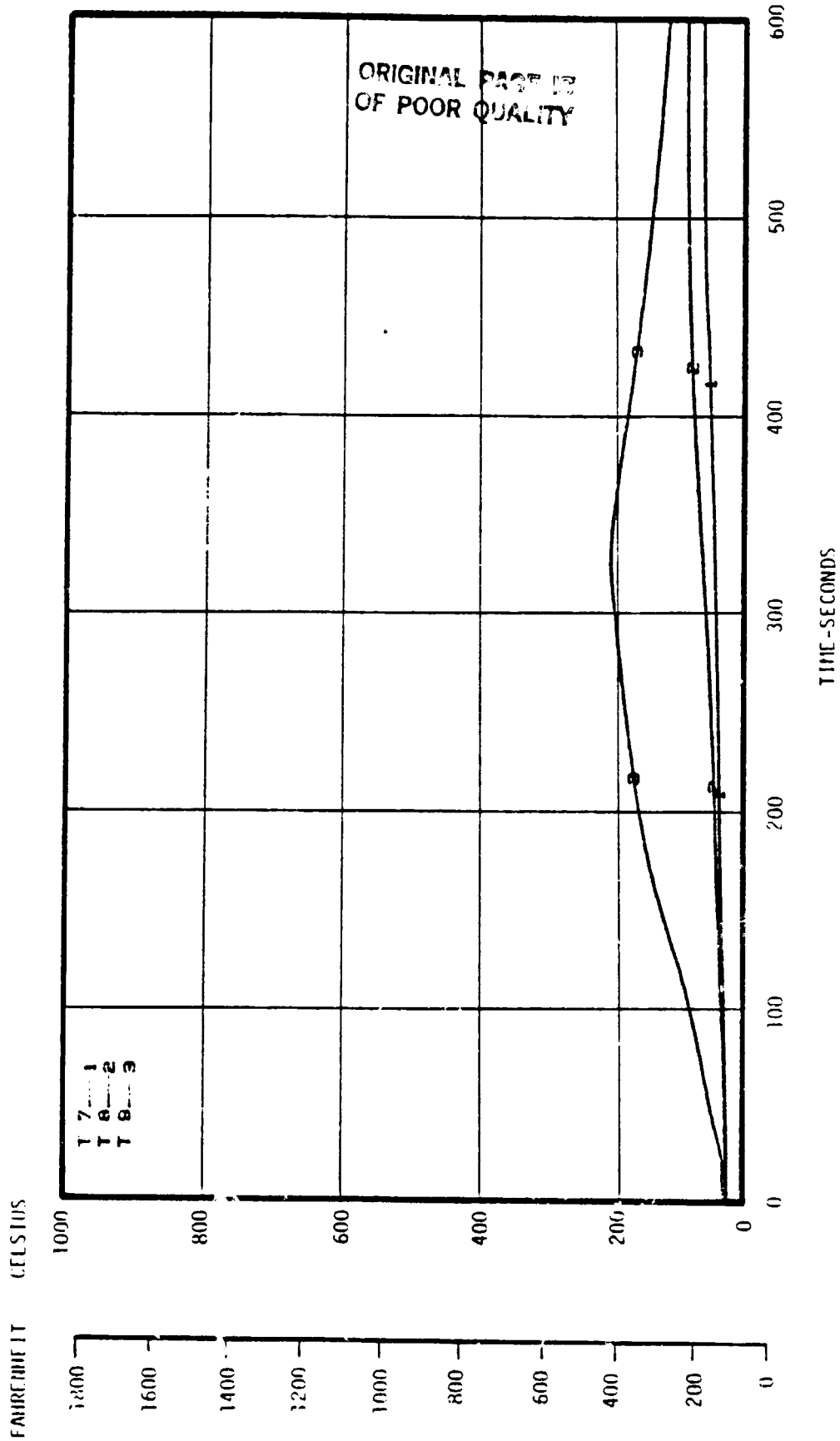
SEAT CUSHION TEMPERATURES



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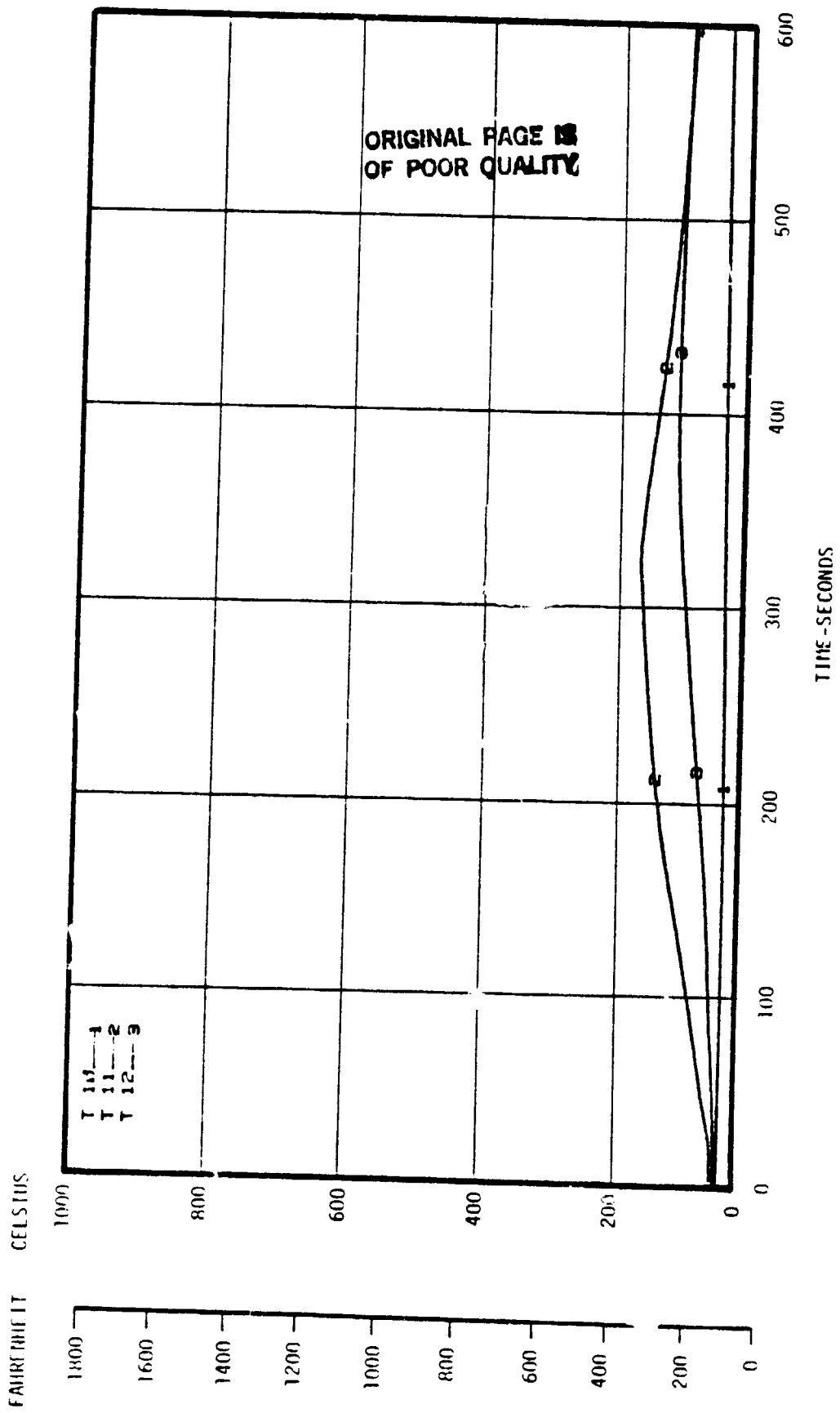
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NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 11
CUSHION CONSTRUCTION NUMBER 3.0

SEAT CUSHION TEMPERATURES



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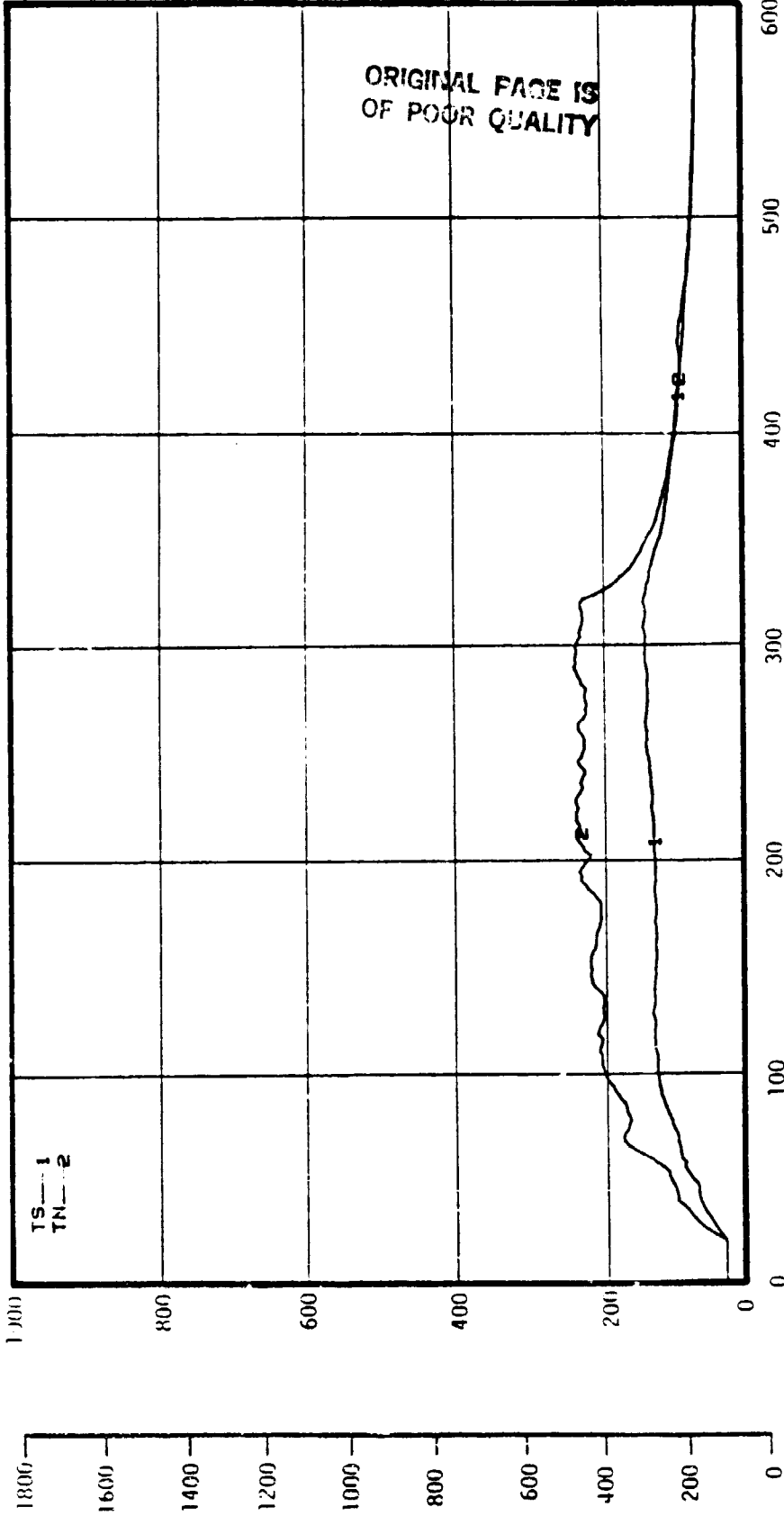
SEAT CUSHION TEMPERATURES



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CEILING TEMPERATURE

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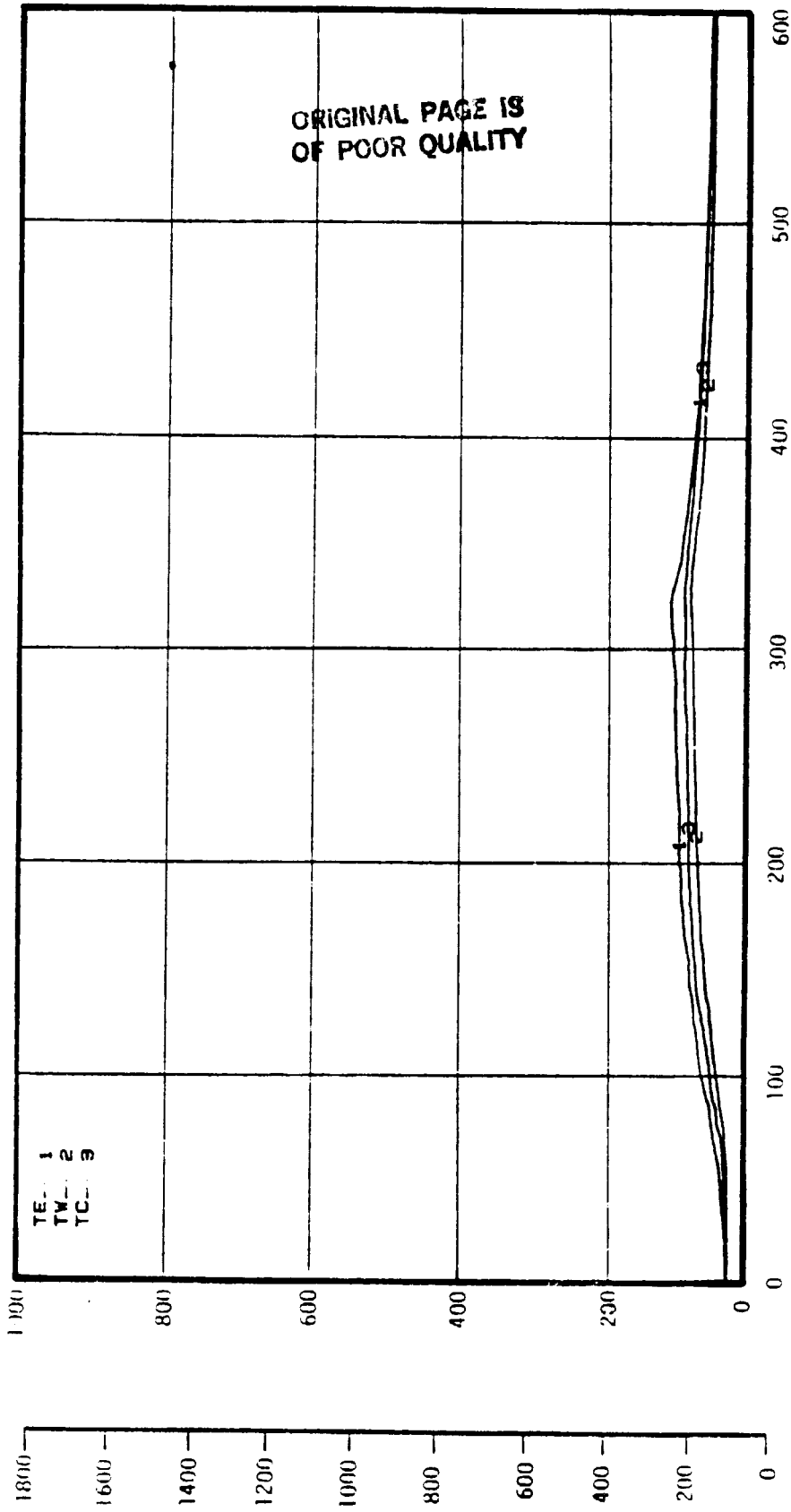
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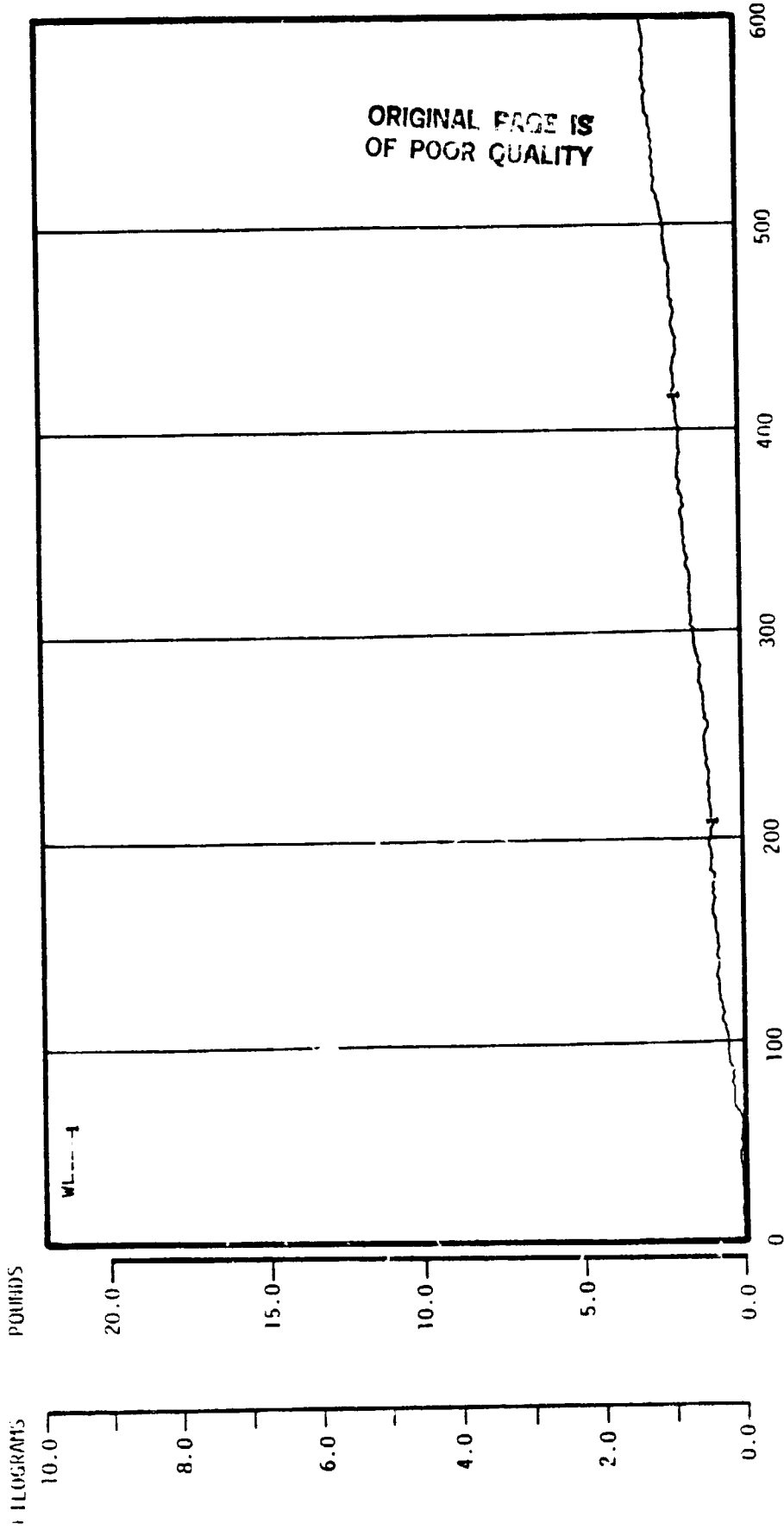


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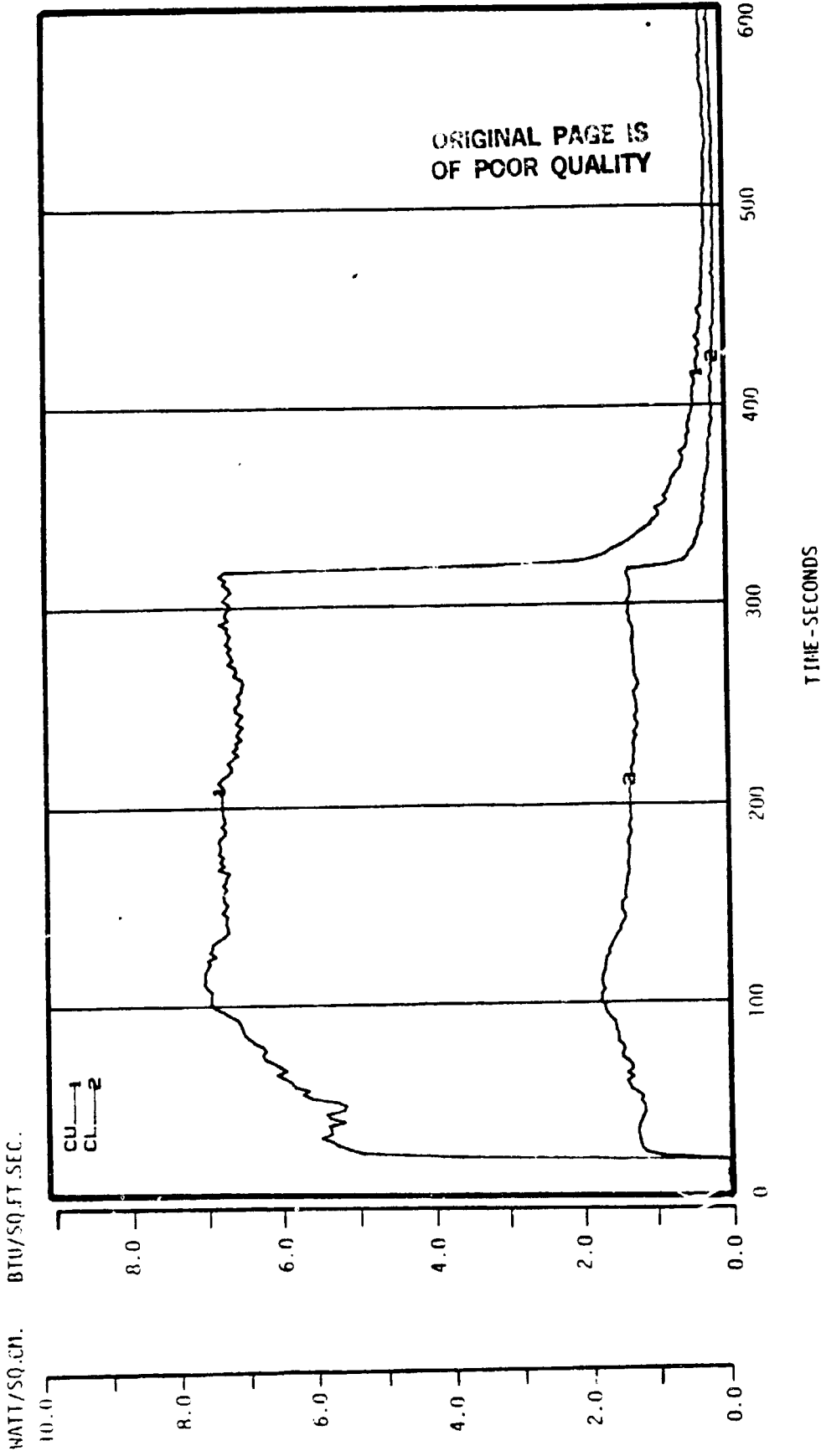
CUSHION CONSTRUCTION NUMBER 3.0

WEIGHT LOSS



JOHNS AS AIRCRAFT CABIN FIRE SIMULATOR 03/12/82 10:54
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CUSHION CONSTRUCTION NUMBER 3.0

HEAT FLUX

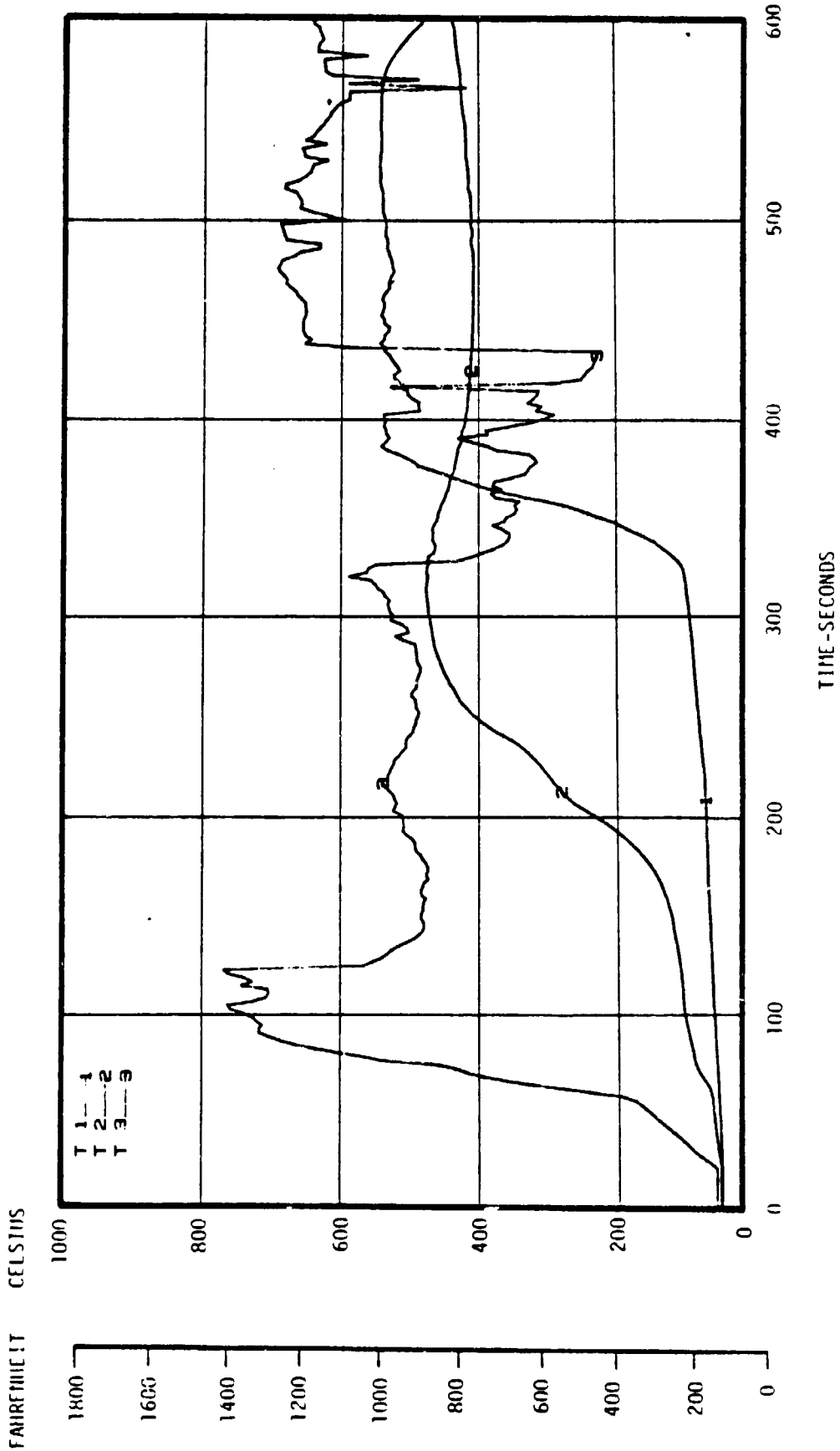


DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/12/82 13.51

NASA-NIES FULL SCALE CUSHION BURH TEST NUMBER 12

CUSHION CONSTRUCTION NUMBER 3.0

SEAT CUSHION TEMPERATURES



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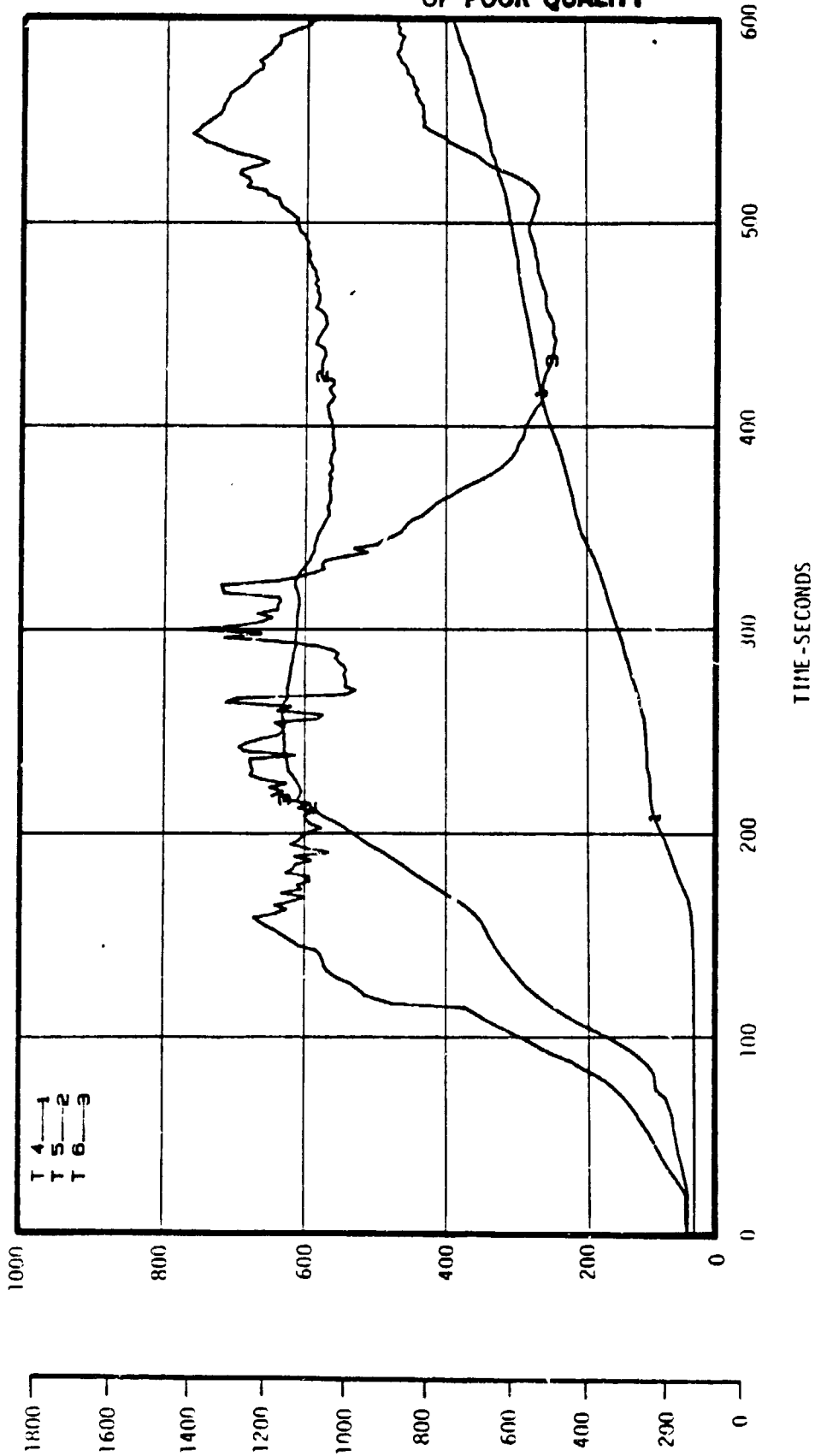
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SEAT CUSHION TEMPERATURES

FAHRENHEIT

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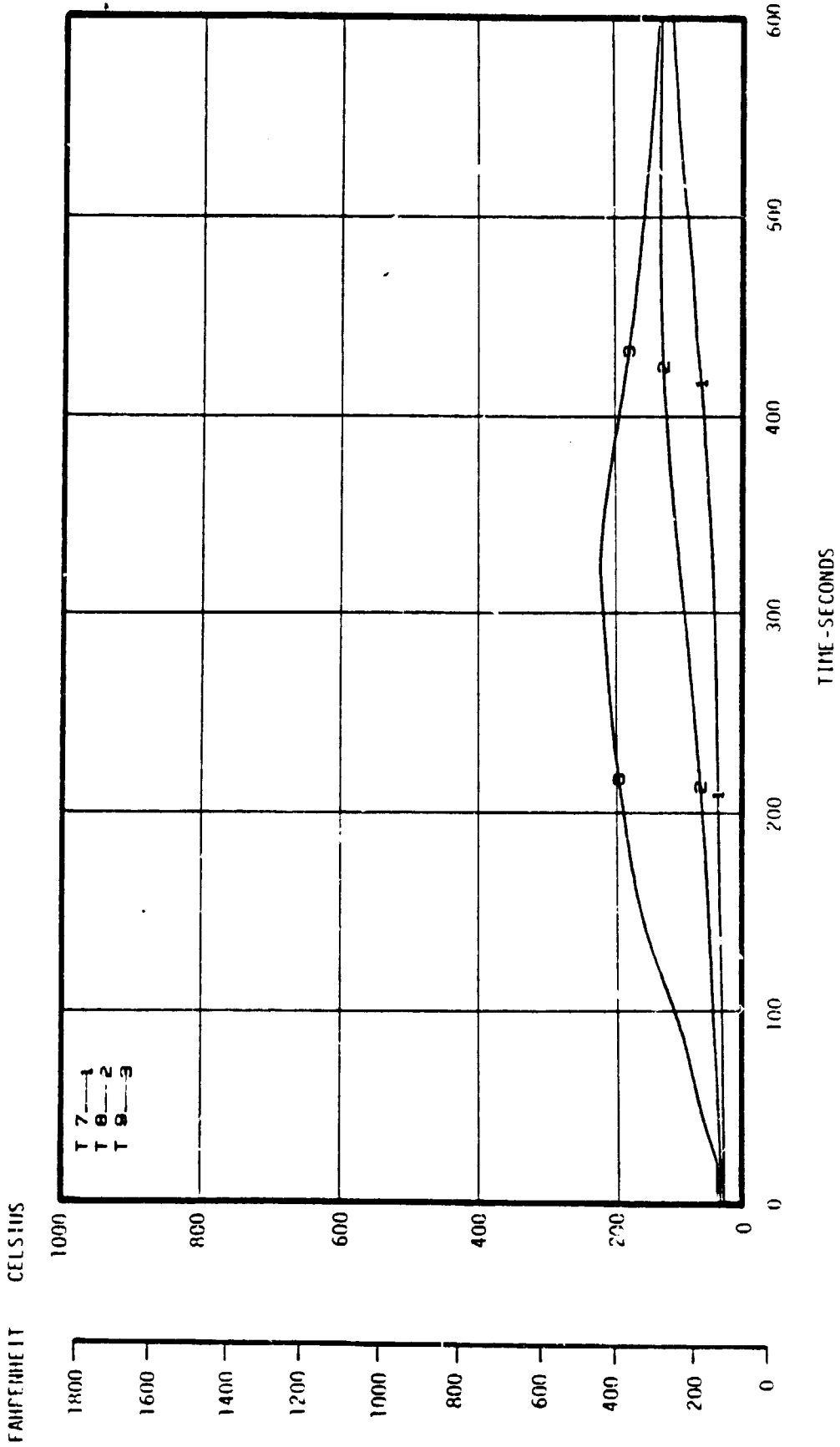
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SEAT CUSHION TEMPERATURES

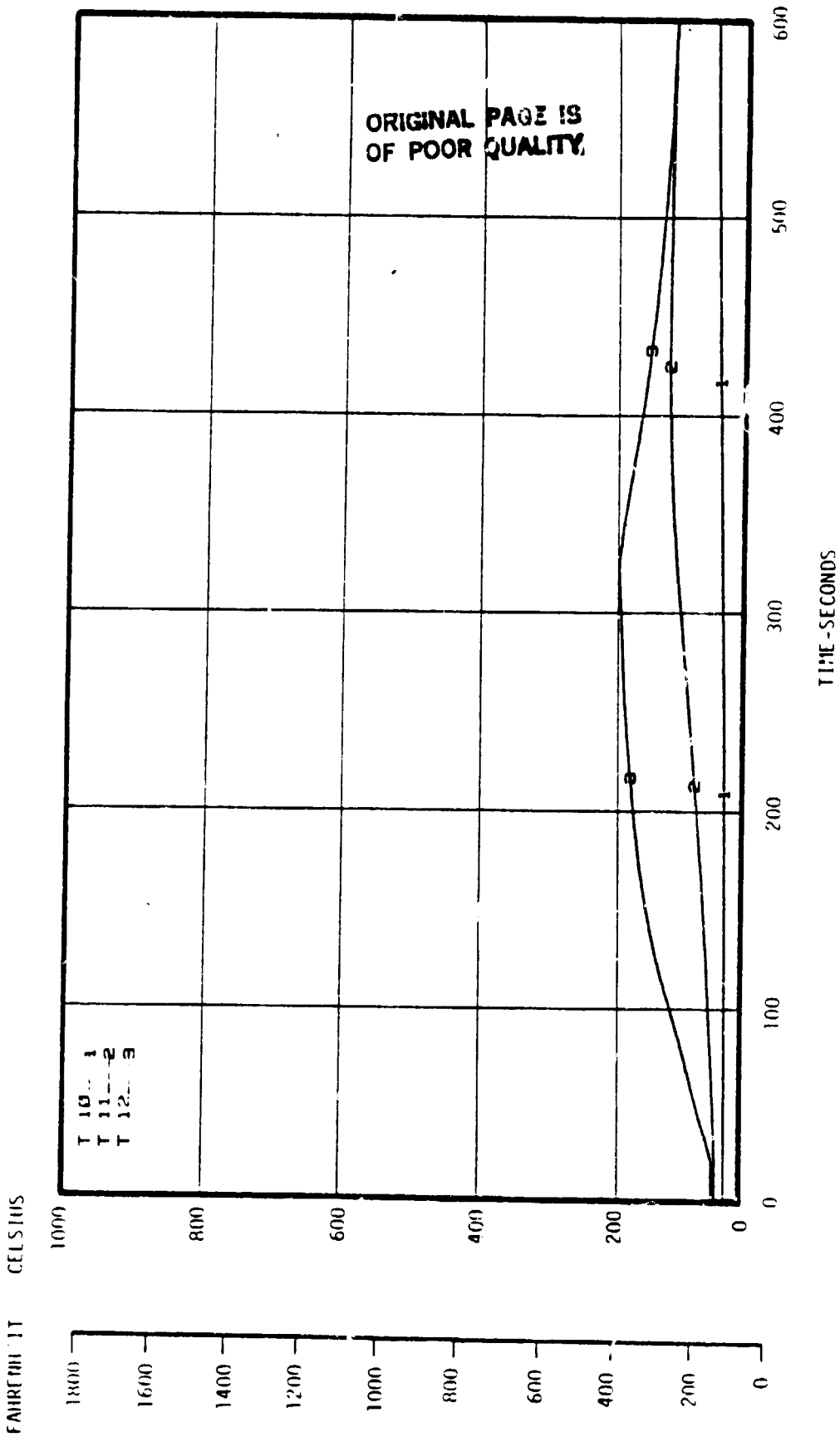


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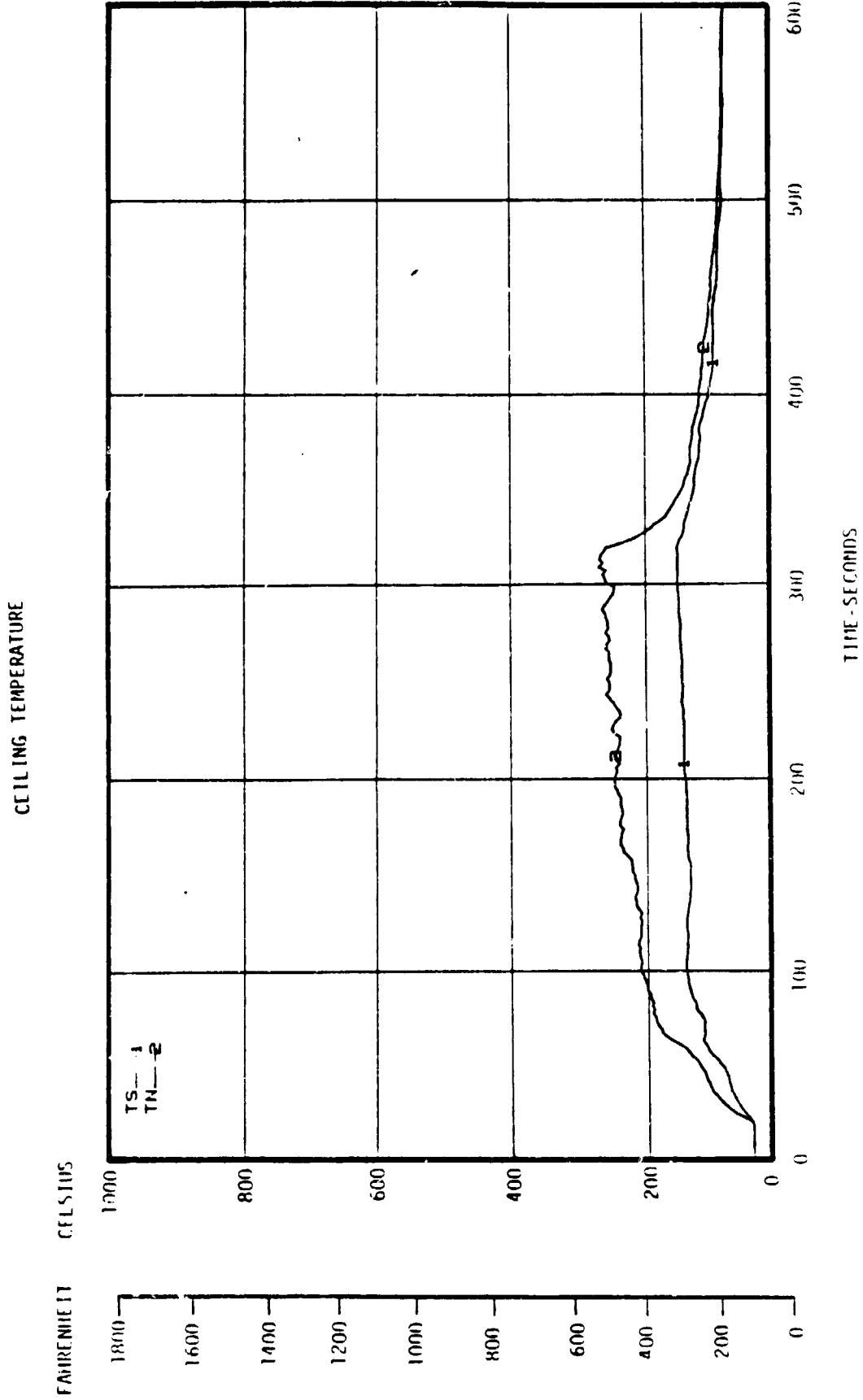
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SEAT CUSHION TEMPERATURES



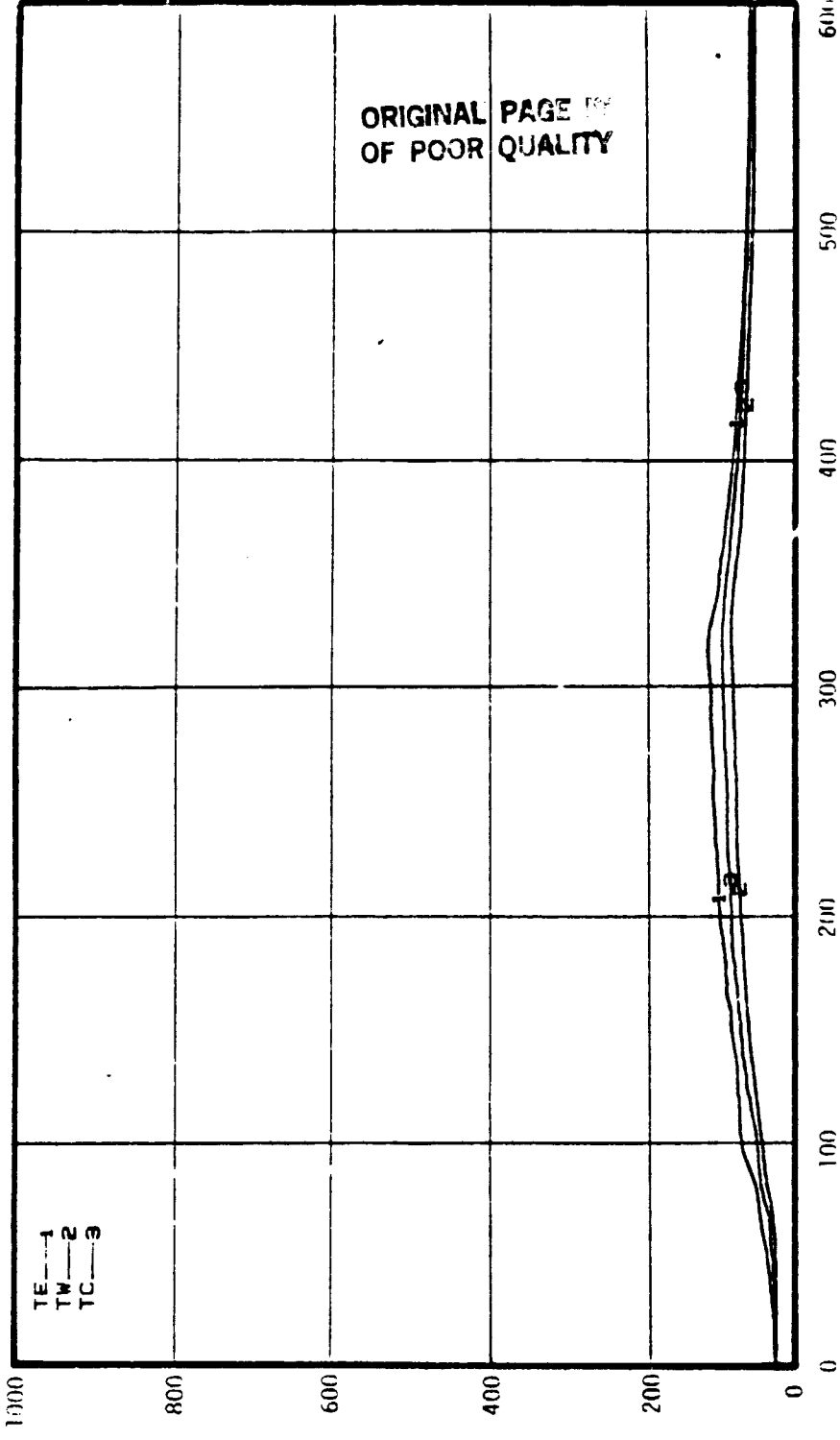
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 NASA-AE'S FULL SCALE CUSHION BURN TEST NUMBER 12
 CUSHION CONSTRUCTION NUMBER 3.0



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/12/82 13:51
NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 12
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CEILING TEMPERATURE

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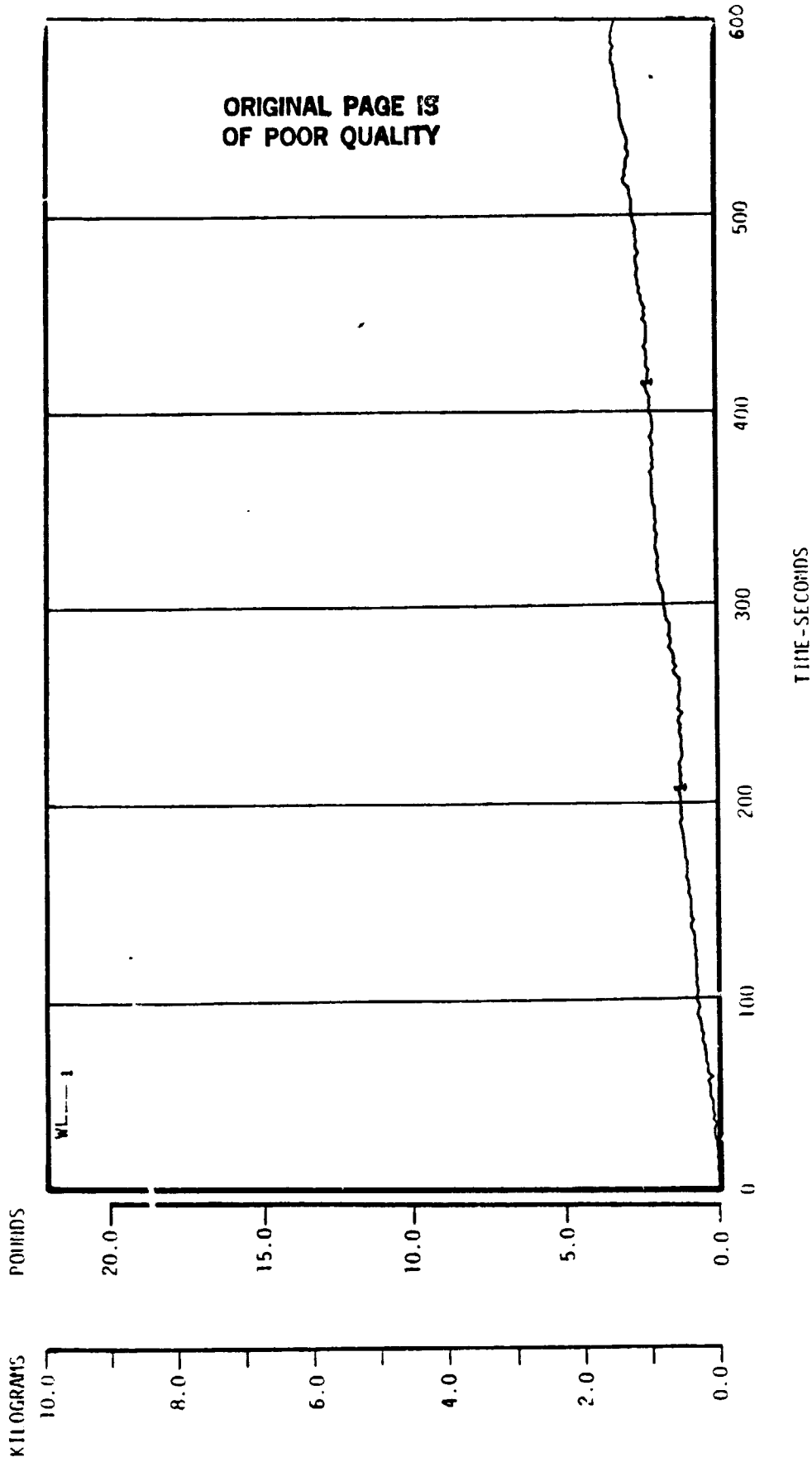


TIME-SECONDS

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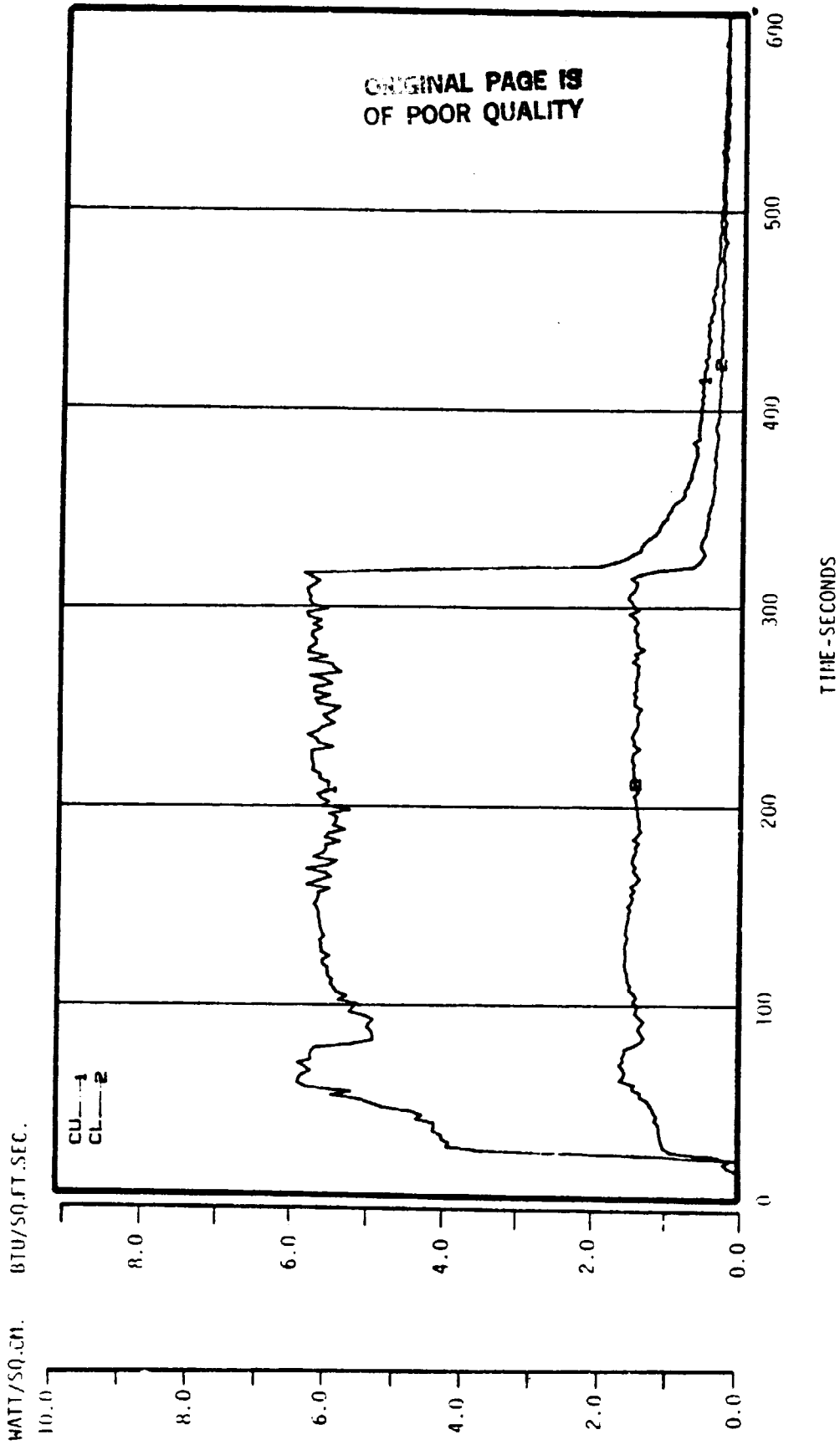
WEIGHT LOSS



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NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 12
CUSHION CONSTRUCTION NUMBER 3.0

HEAT FLUX

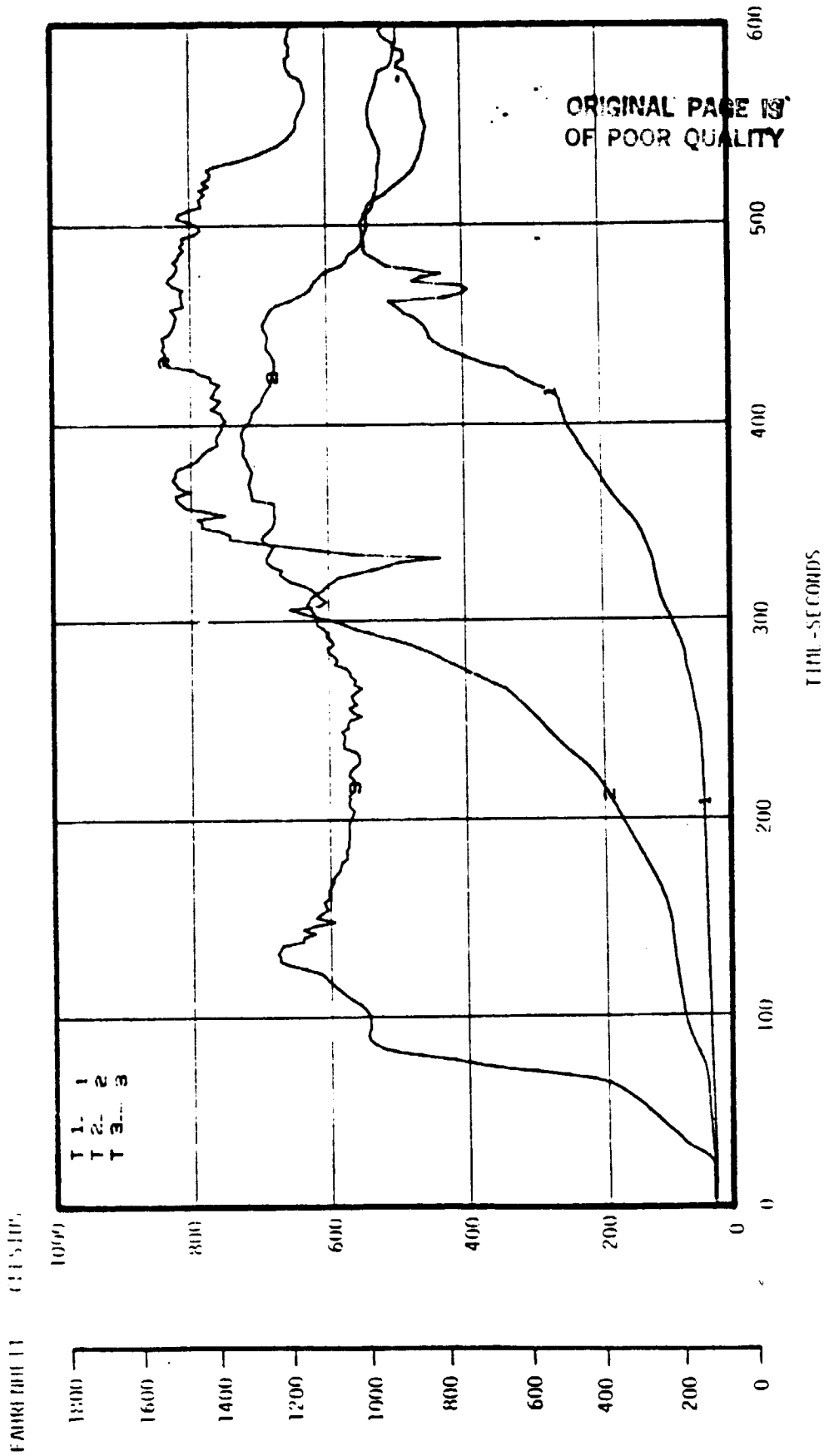


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CUSHION CONSTRUCTION NUMBER 4.0

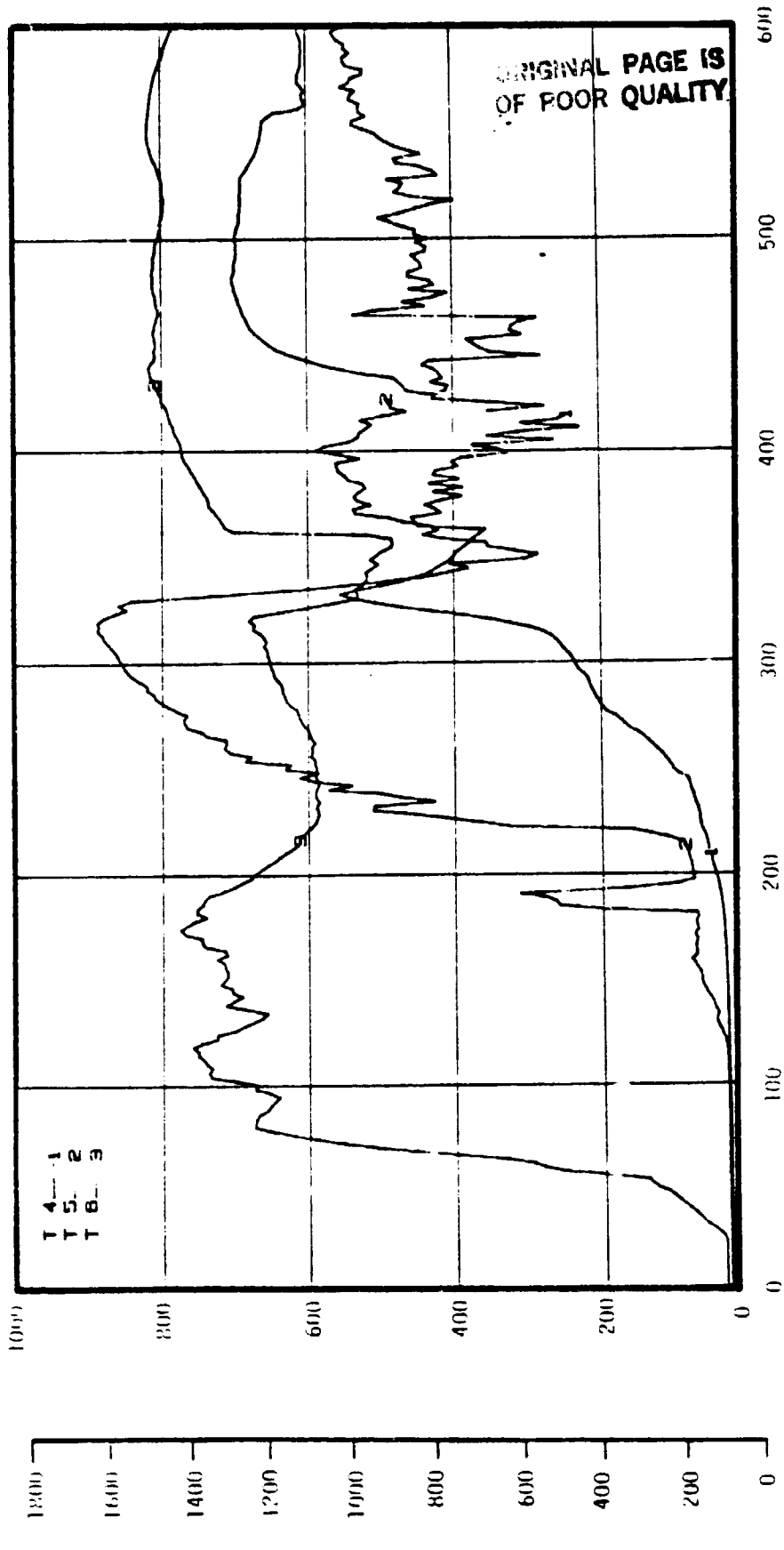
SEAT CUSHION TEMPERATURES



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CUSHION CONSTRUCTION NUMBER 4.0

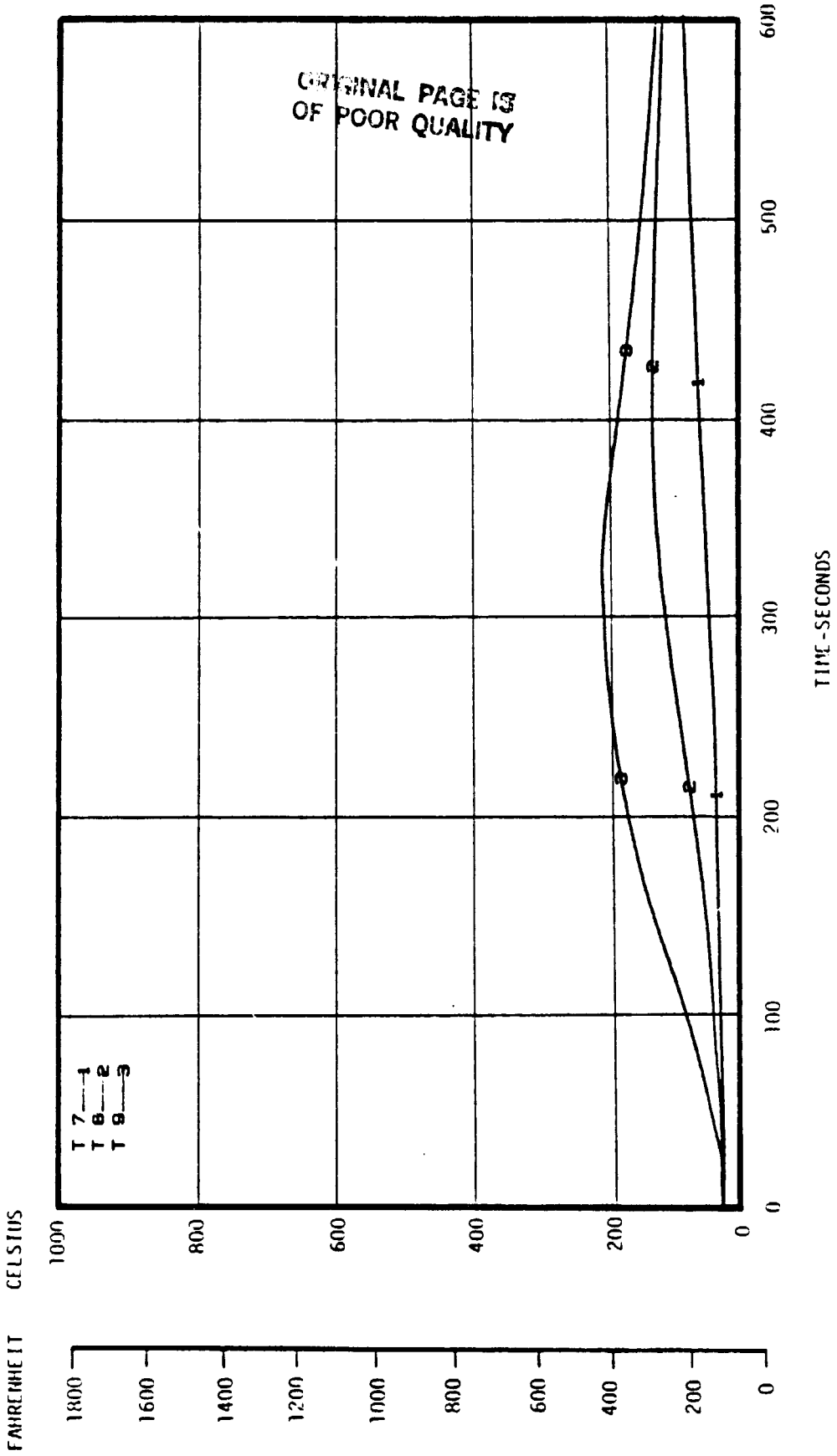
HEAT CUSHION TEMPERATURES

FABRIC TEST CELS/FIPS



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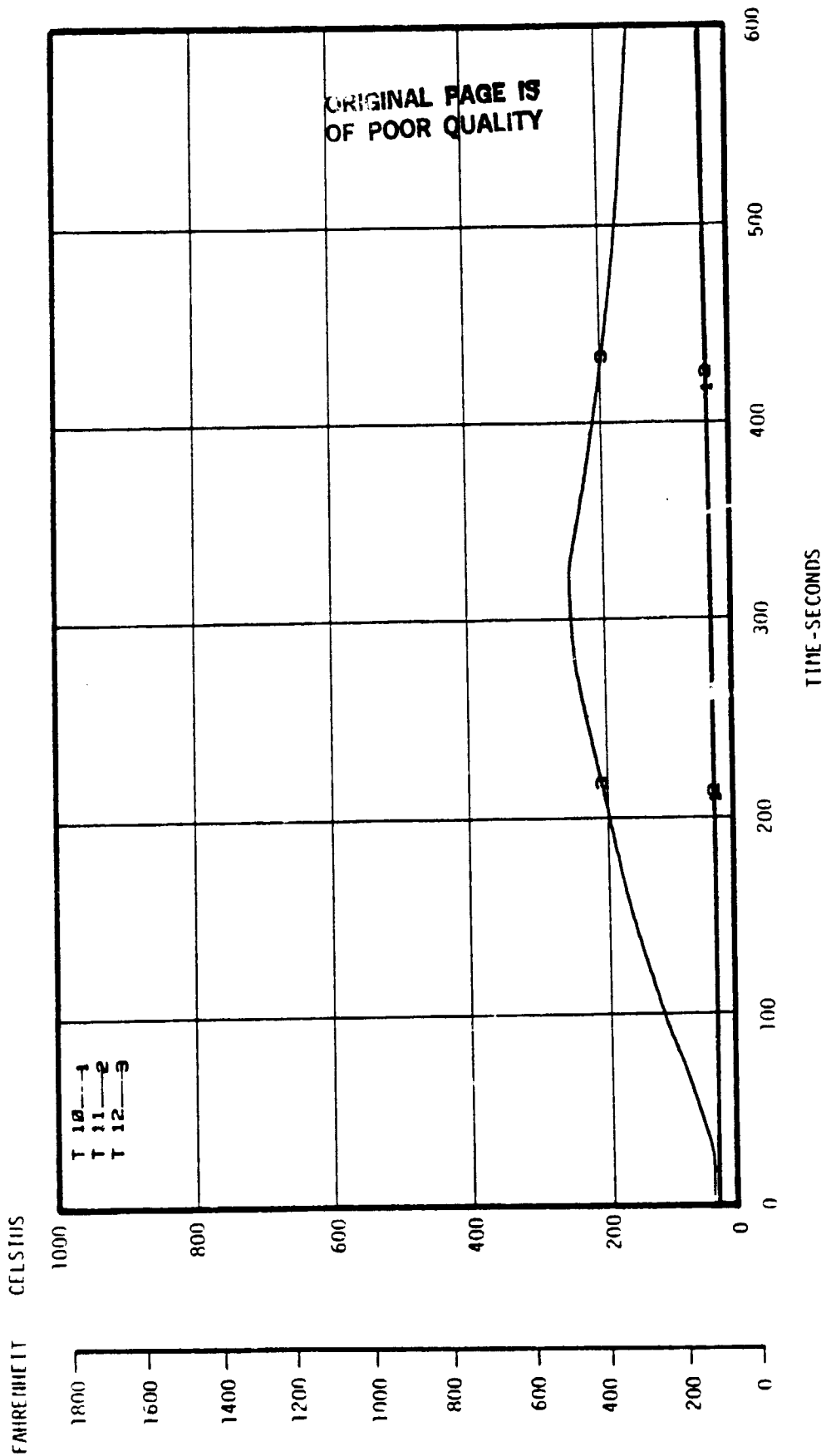
SEAT CUSHION TEMPERATURES



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SEAT CUSHION TEMPERATURES

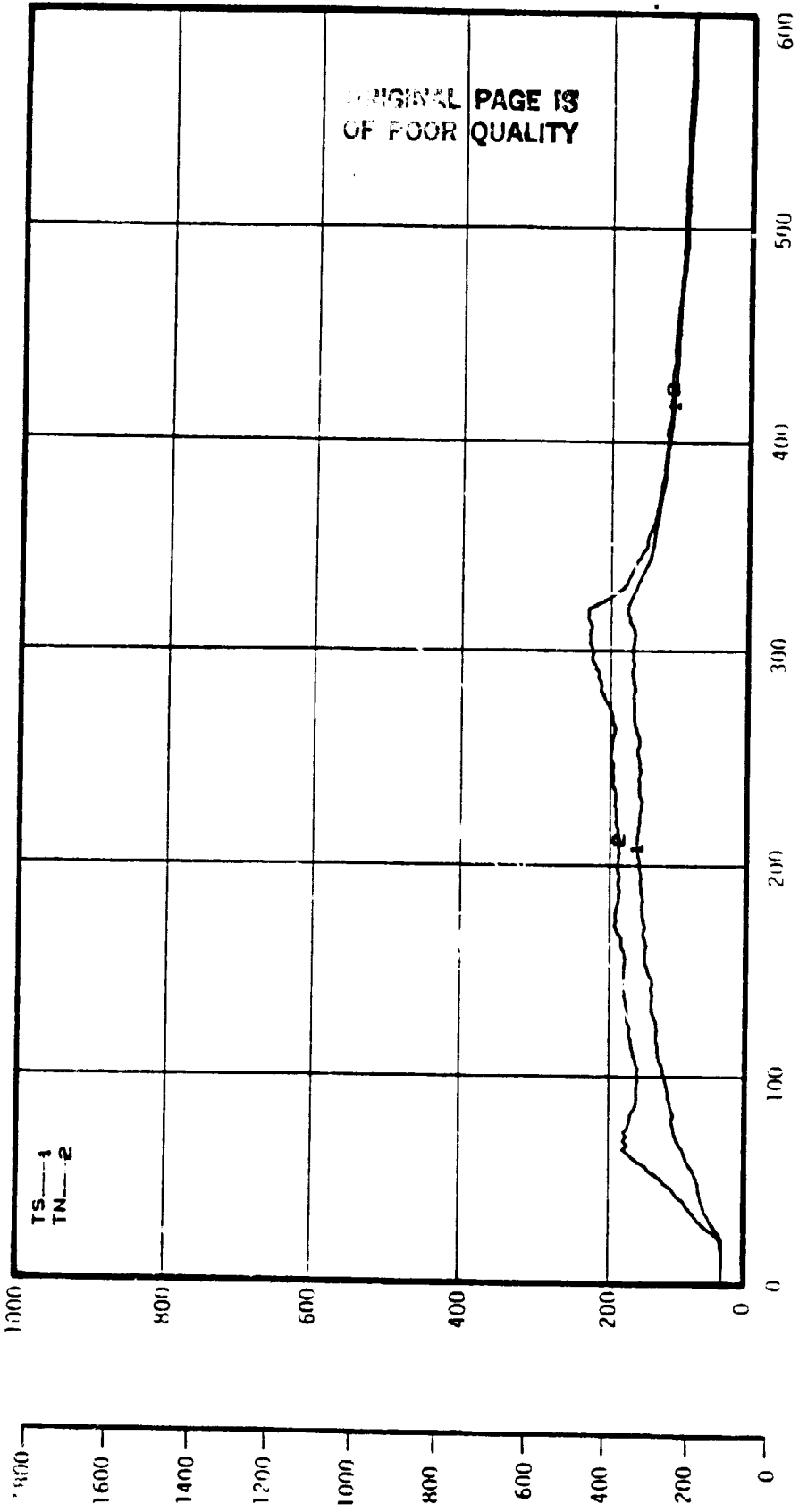


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 NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 3
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CEILING TEMPERATURE

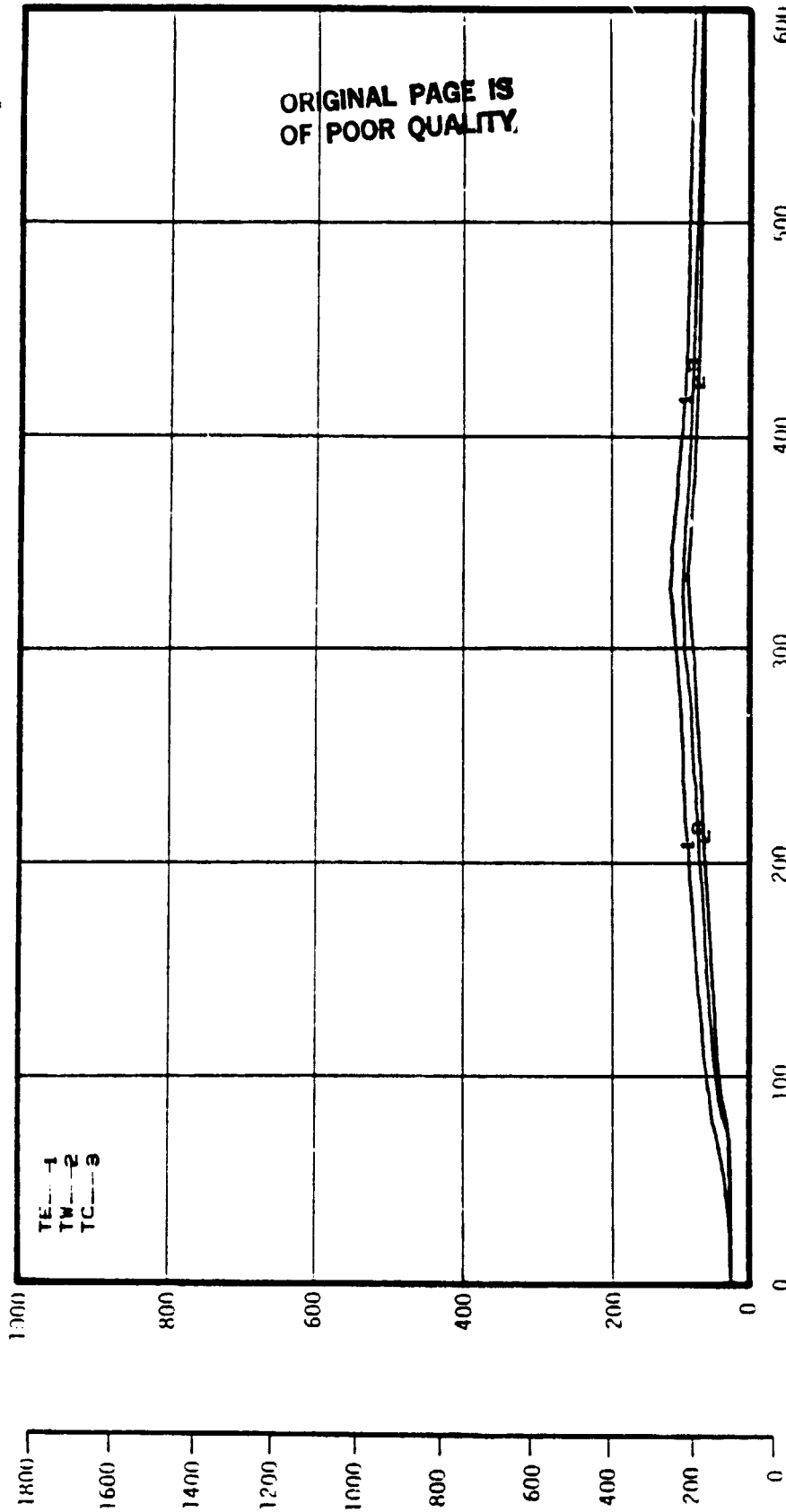
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CEILING TEMPERATURE

FAHRENHEIT CELSIUS

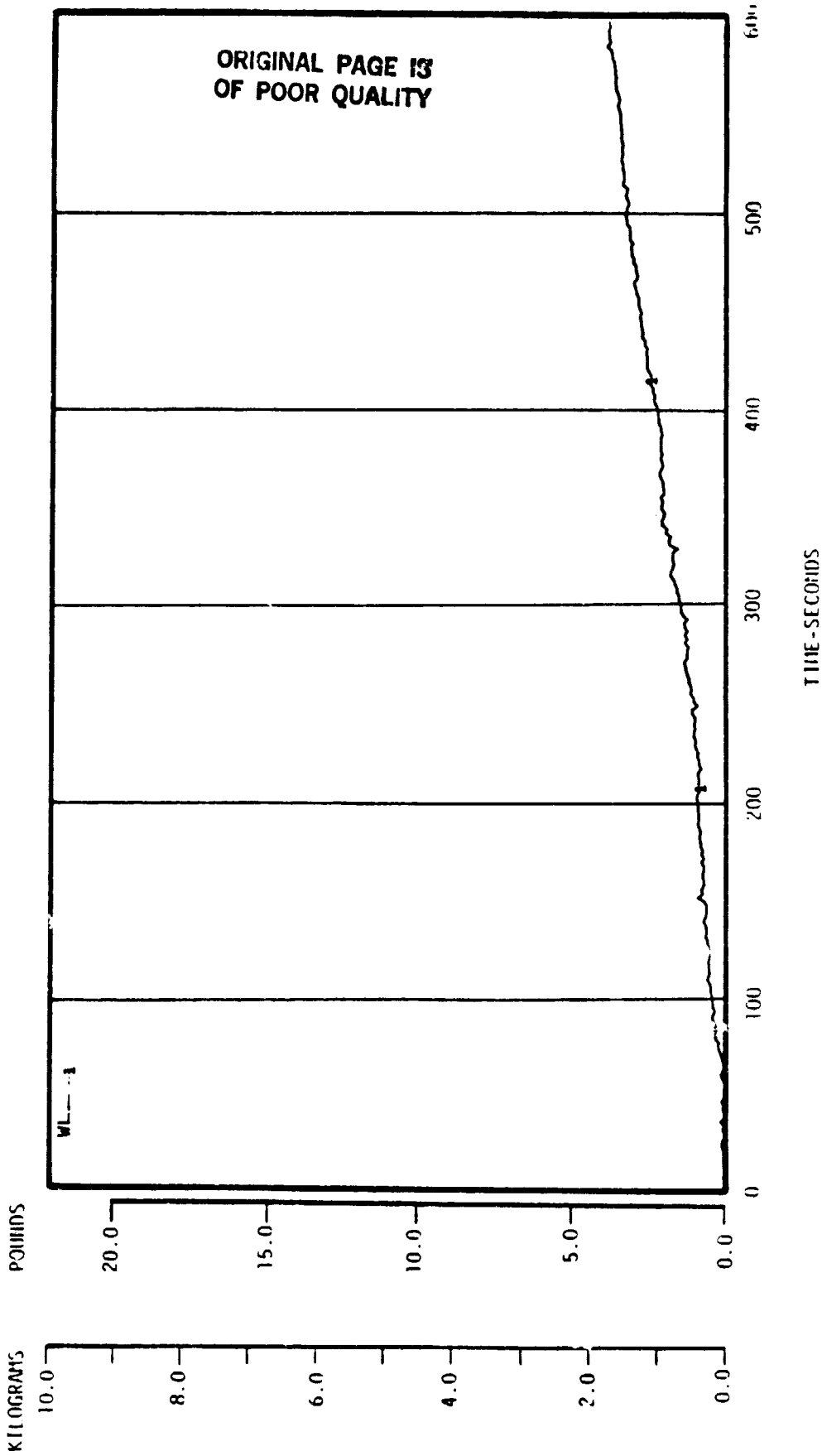


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NASA-MES FULL SCALE CUSHION BURN TEST NUMBER 3

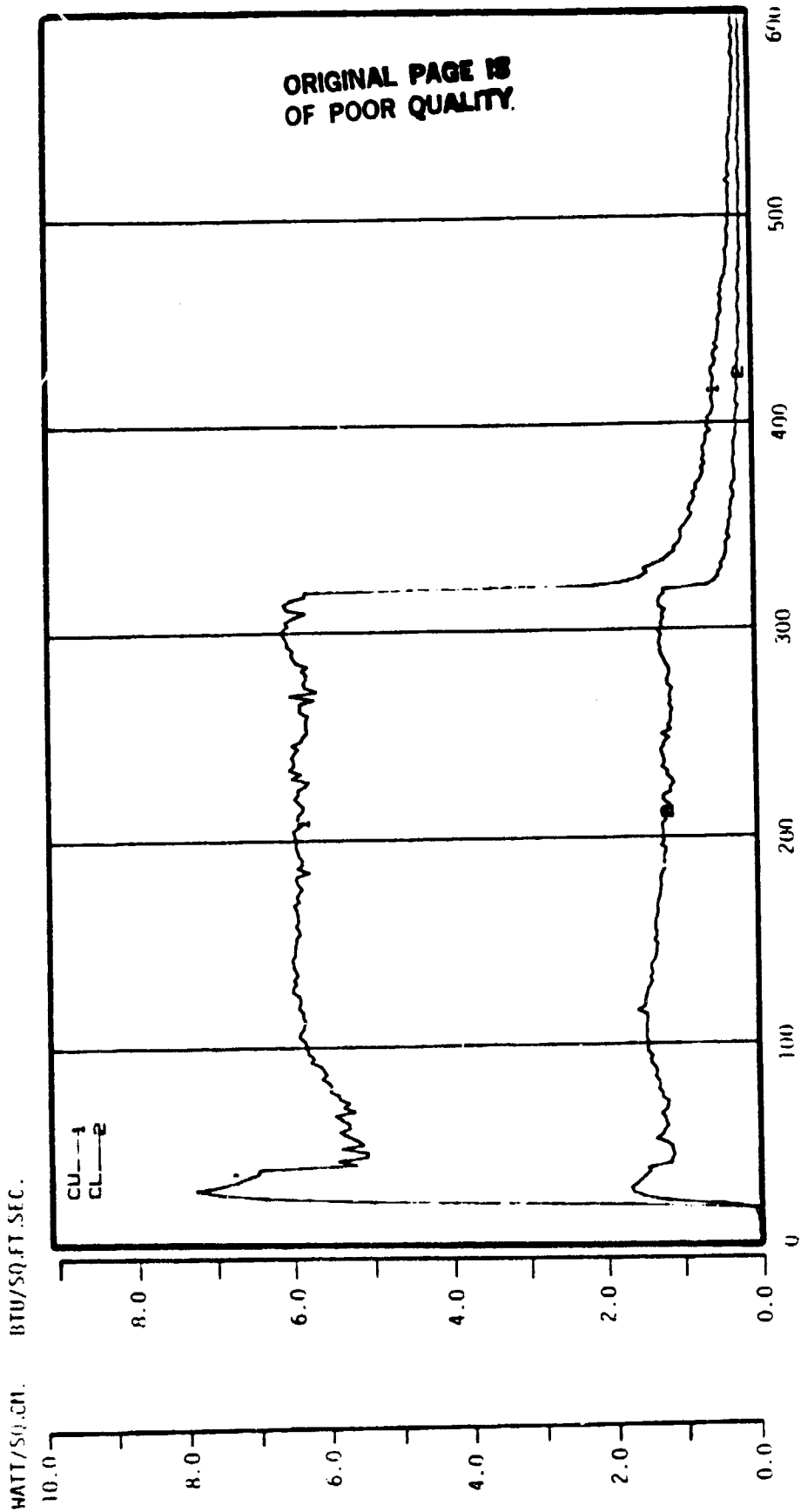
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WEIGHT LOSS



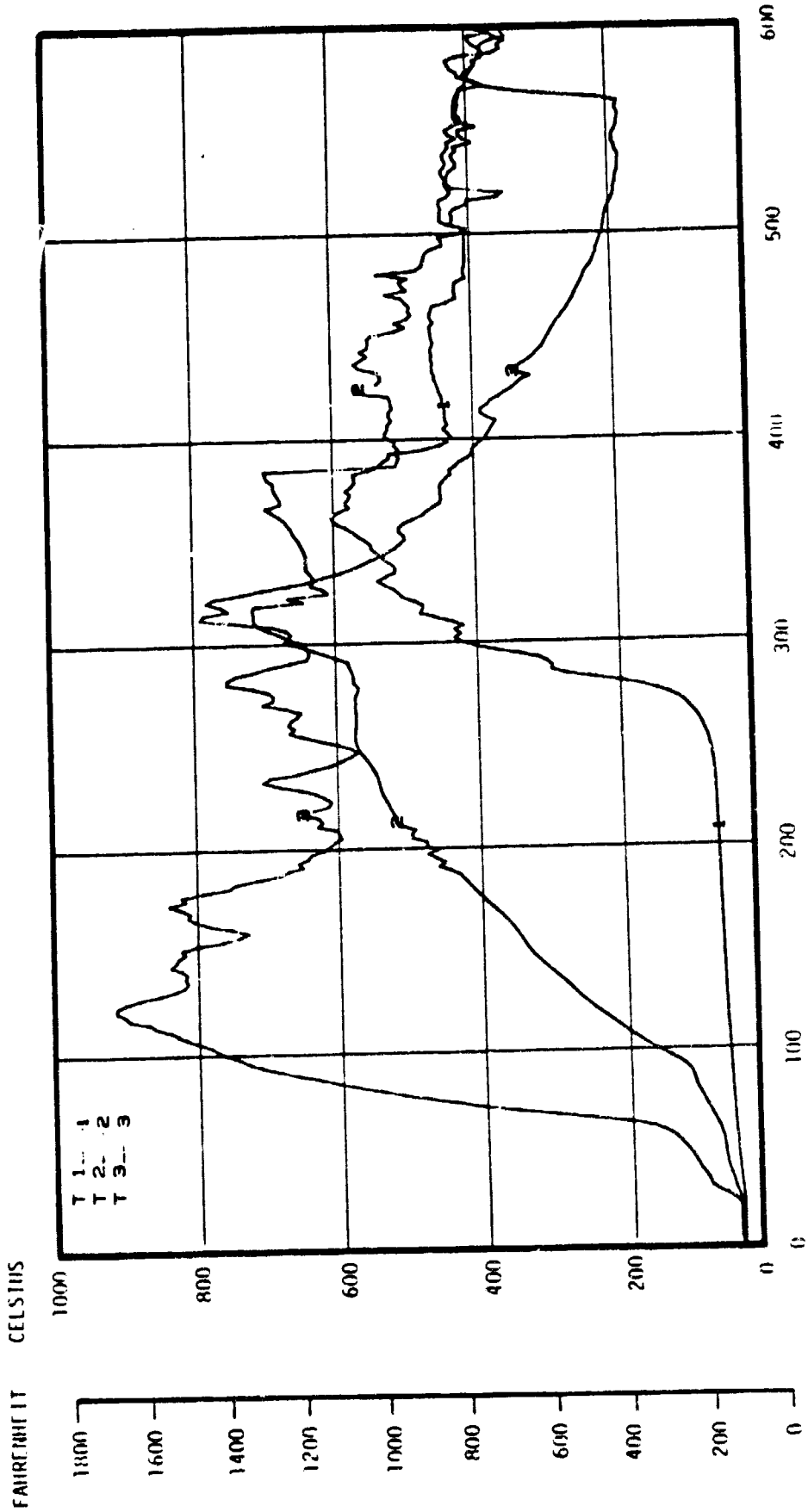
ORIGINAS AIRCRAFT CABIN FIRE SIMULATOR 03/08/82 13, 27
NASA-AMES FULL SCALE CUSHION BURST TEST NUMBER 3
CUSHION CONSTRUCTION NUMBER 4.0

HEAT FLUX



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/12/82 09.02
NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 10
CUSHION CONSTRUCTION NUMBER 4.0

SEAT CUSHION TEMPERATURES

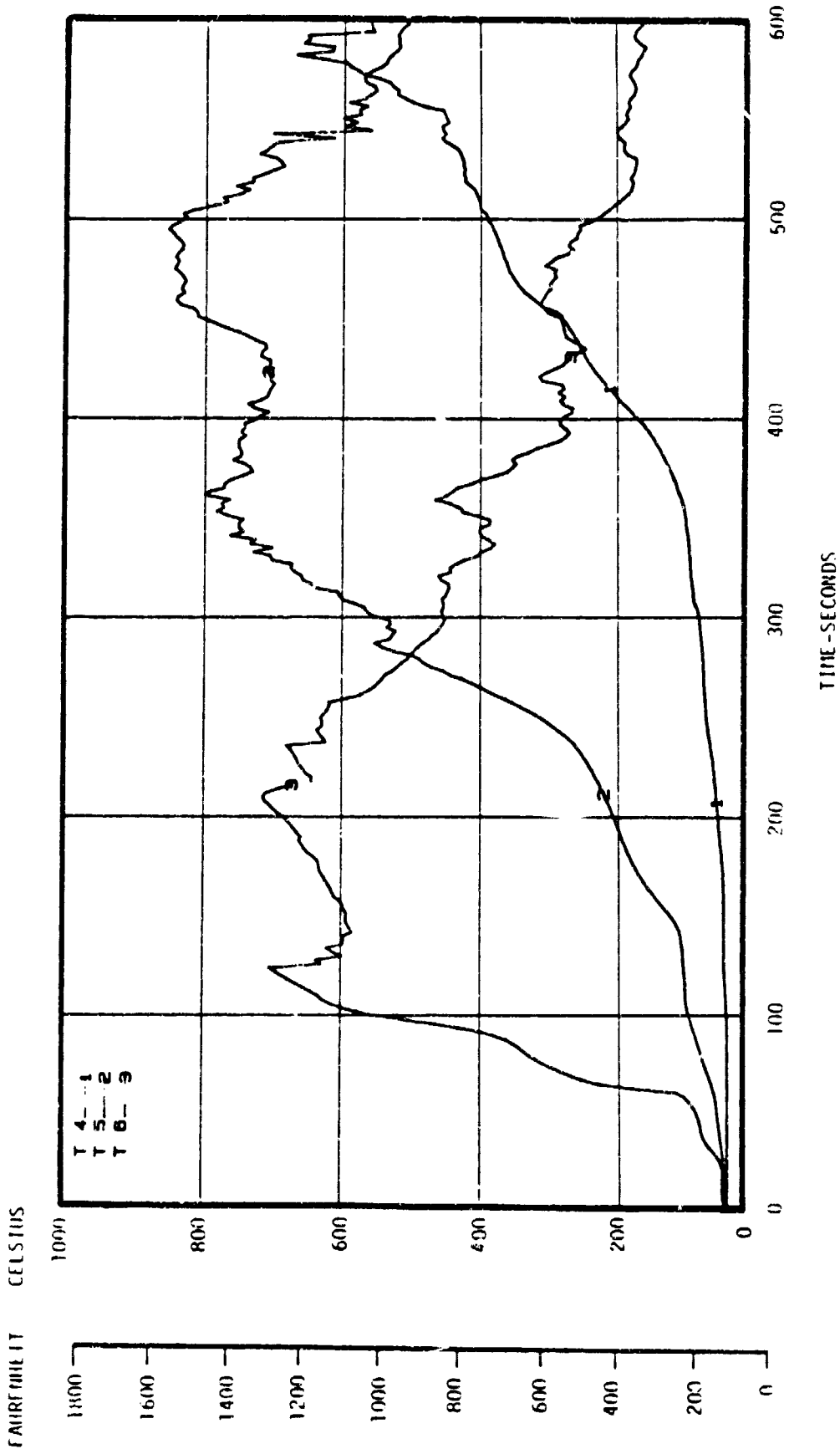


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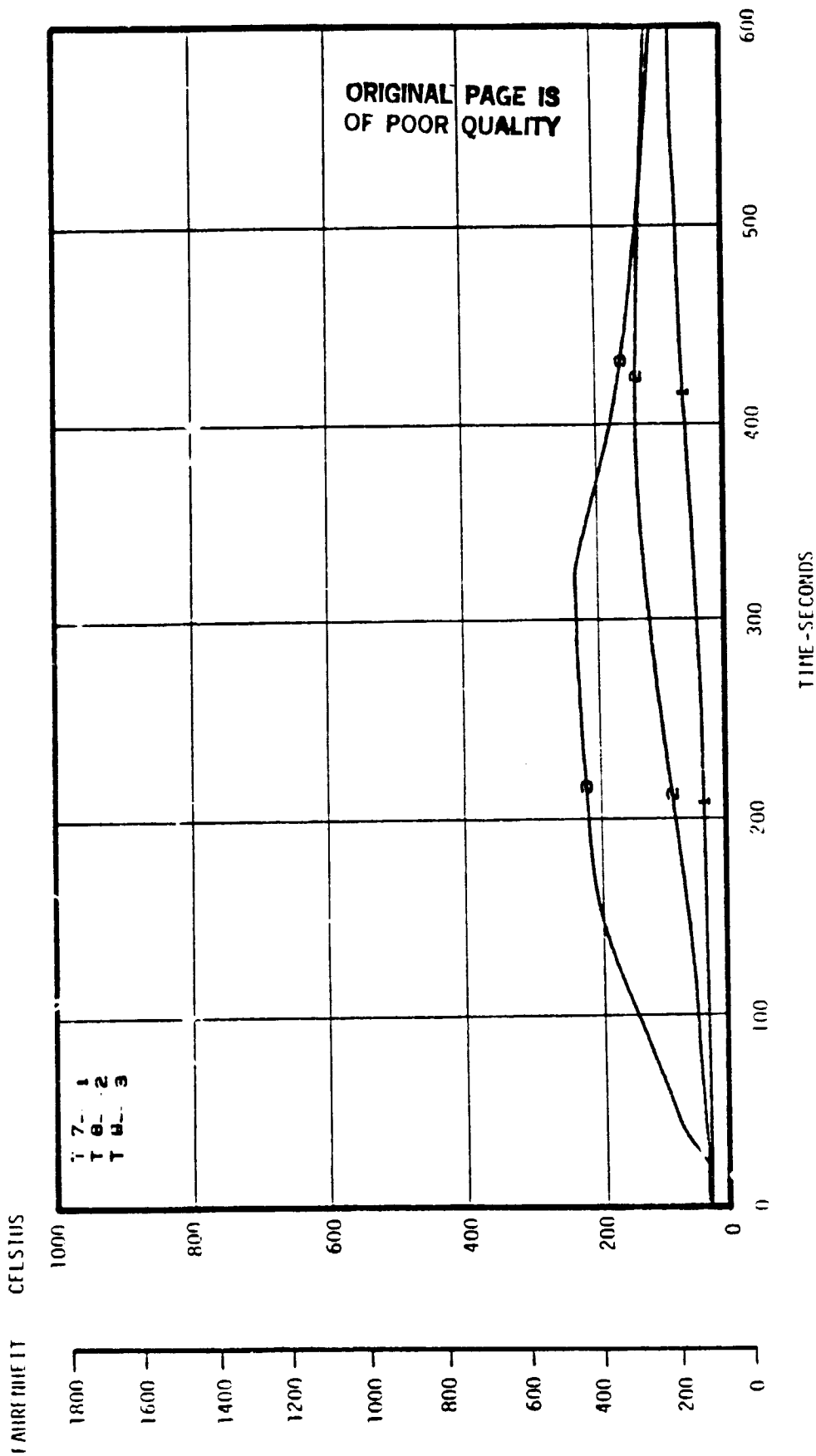
CUSHION CONSTRUCTION NUMBER 4.0

SEAT CUSHION TEMPERATURES



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/12/82 00.02
NASA-AE'S FULL SCALE CUSHION BURN TEST NUMBER 10
CUSHION CONSTRUCTION NUMBER 4.0

SEAT CUSHION TEMPERATURES

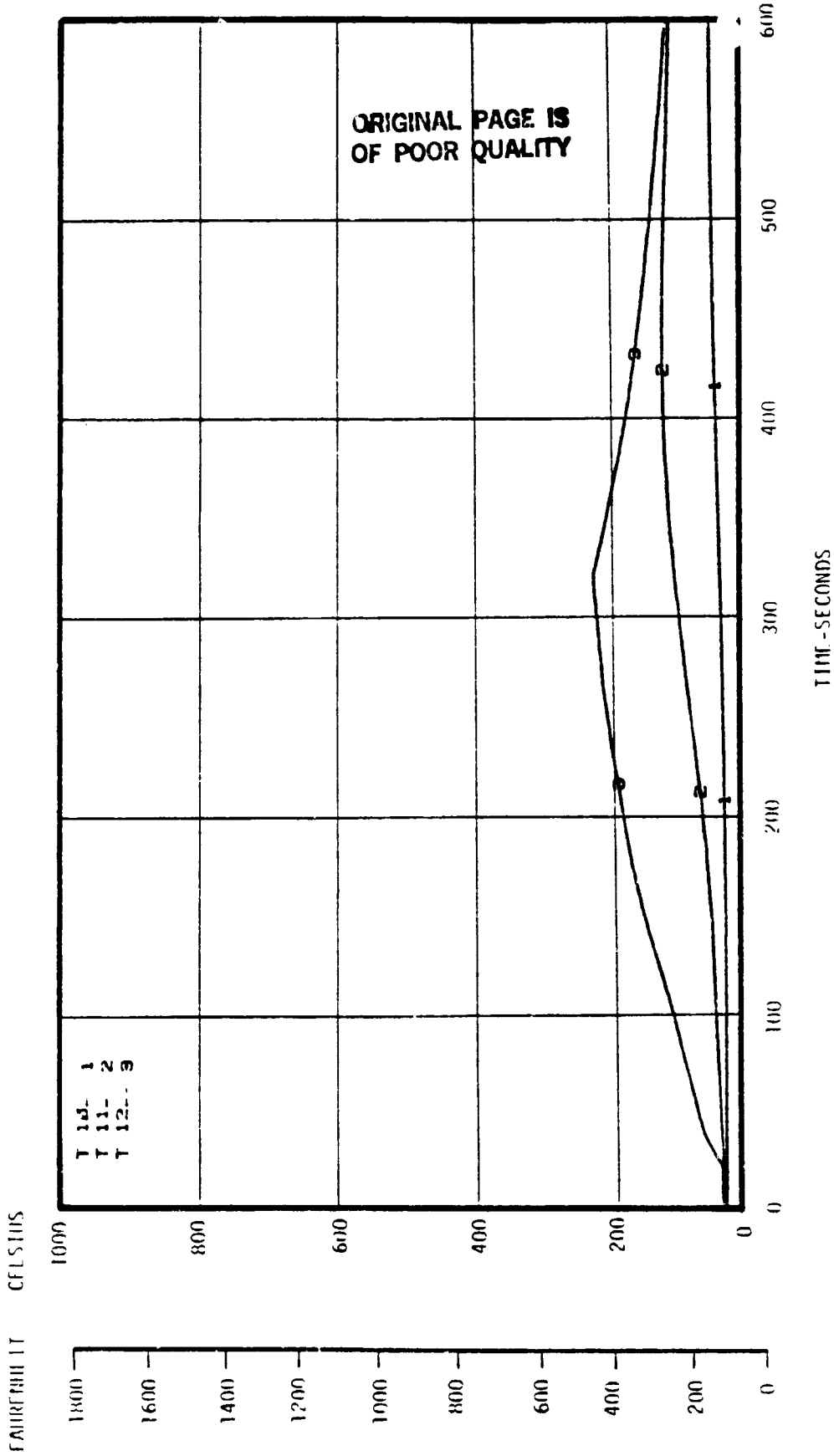


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DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/12/62 00.02
 NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 10
 CUSHION CONSTRUCTION NUMBER 4.0

SEAT CUSHION TEMPERATURES



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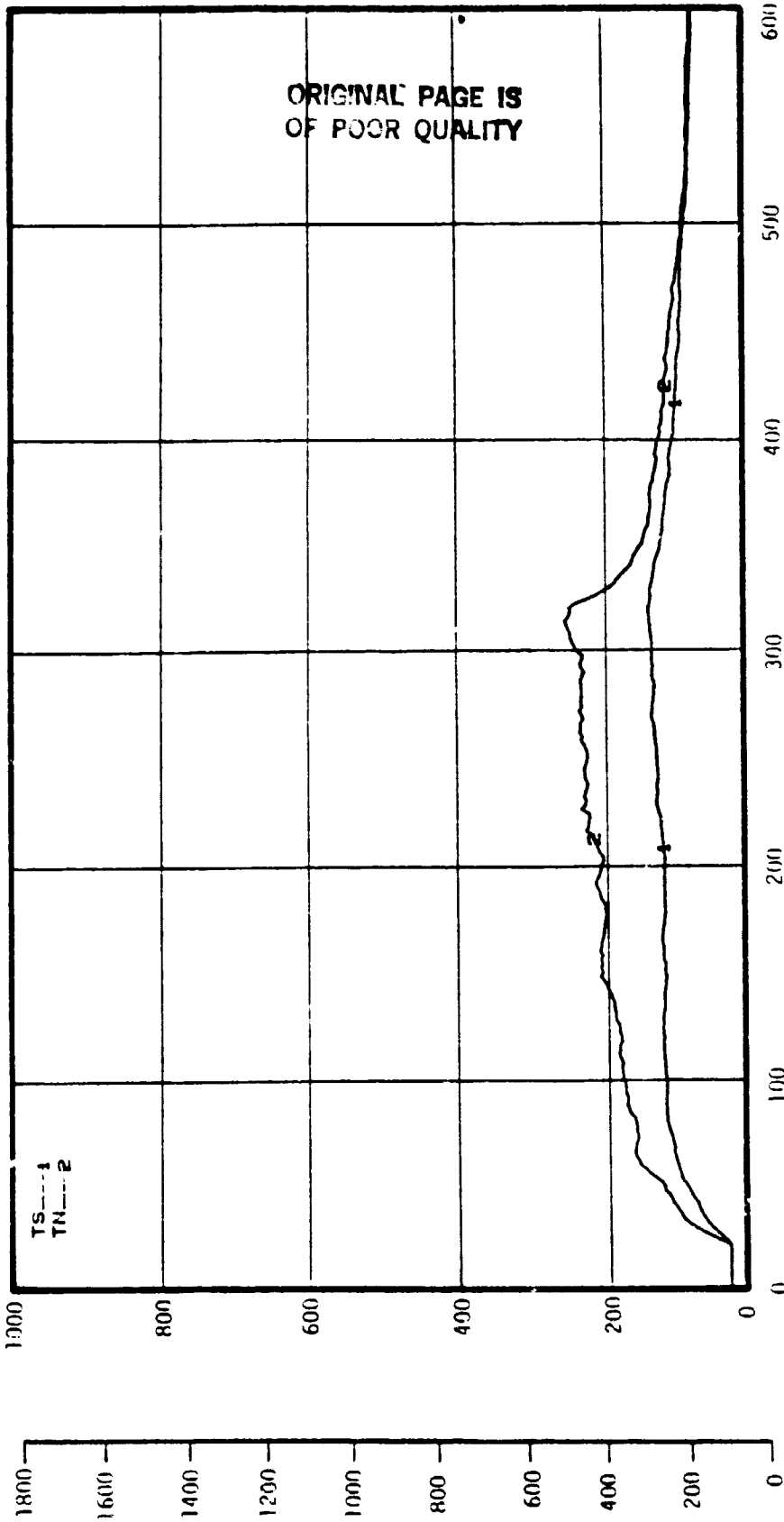
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CUSHION CONSTRUCTION NUMBER 4.0

CEILING TEMPERATURE

FAHRENHEIT

CELSIUS



TIME - SECONDS

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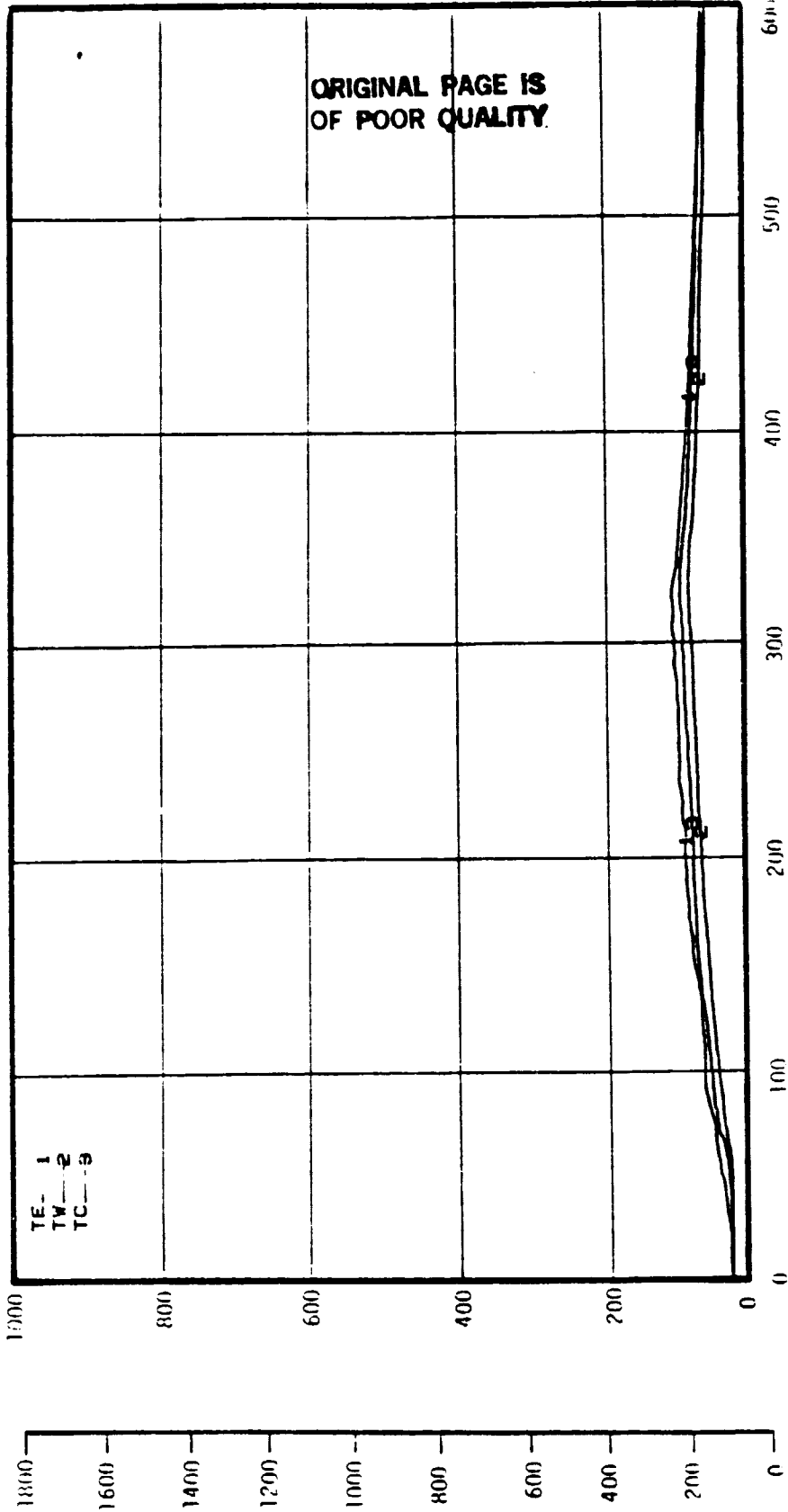
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CEILING TEMPERATURE

F° FRENHEIT

C° CELSIUS



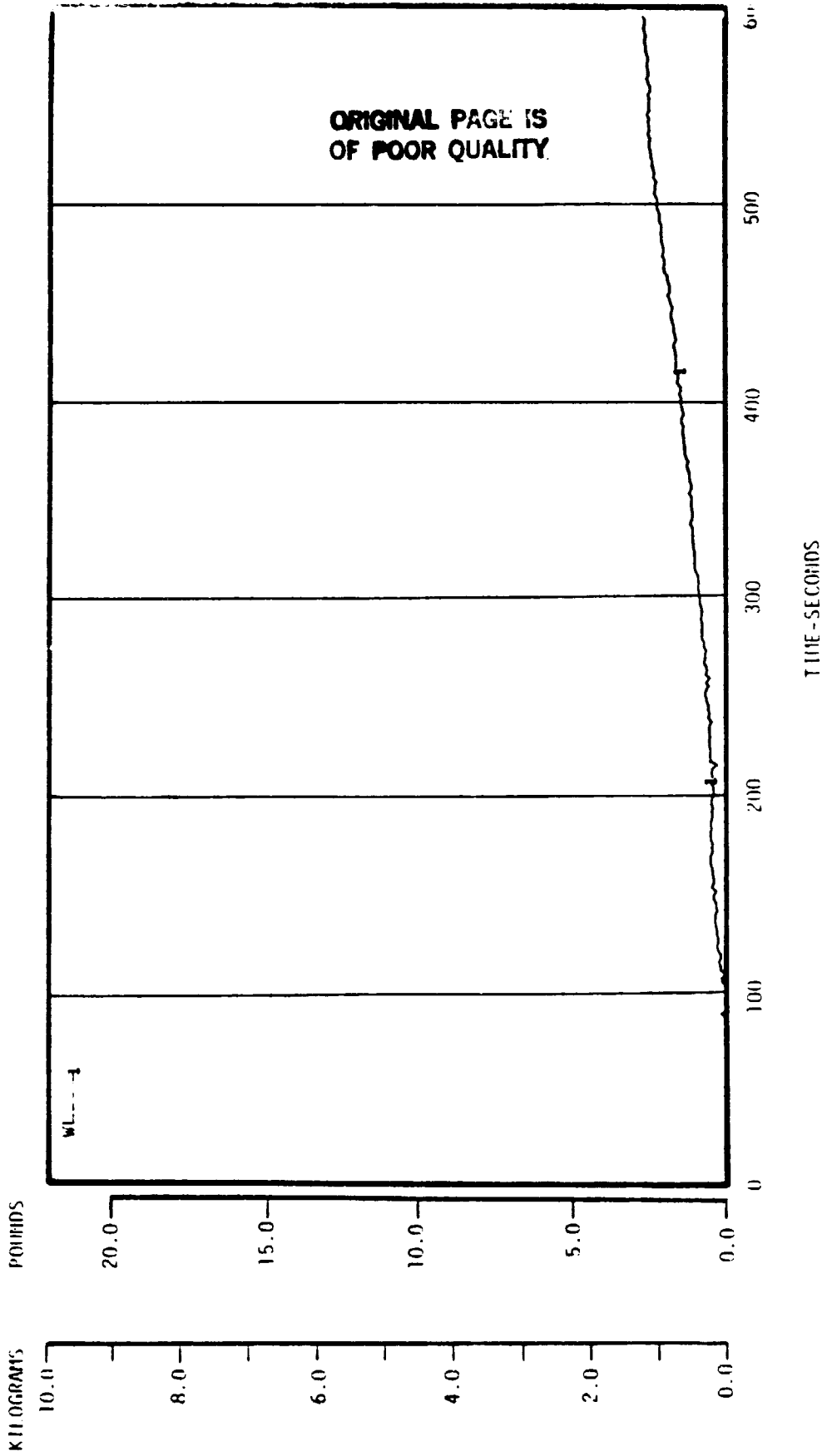
TIME - SECONDS

DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/12/82 00.02

NASA-AIES FULL SCALE CUSHION BURN TEST NUMBER 10

CUSHION CONSTRUCTION NUMBER 4.0

WEIGHT LOSS

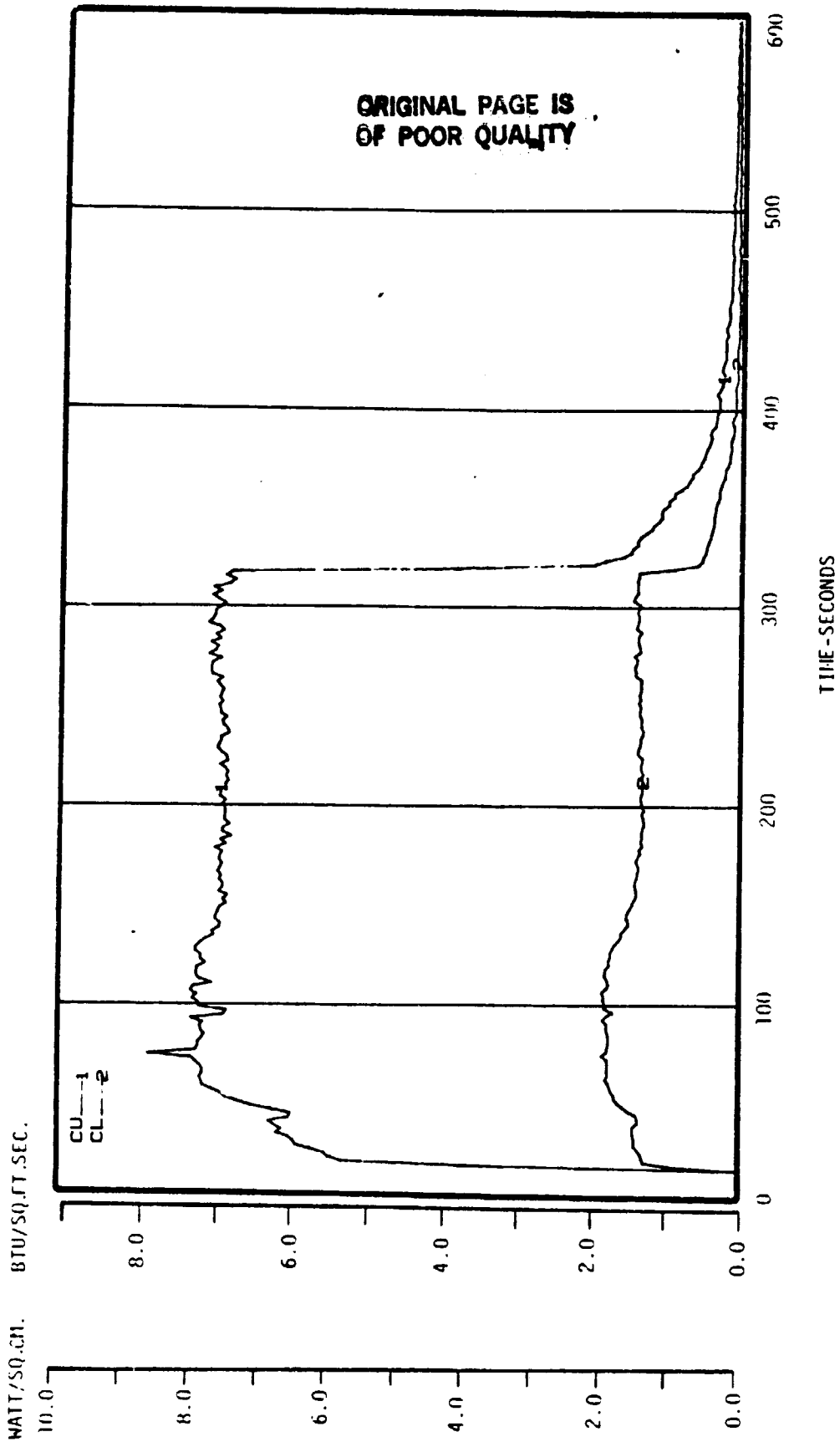


DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/12/82 09:02

NASA-AMES FULL SCALE CUSHION BURR TEST NUMBER 10

CUSHION CONSTRUCTION NUMBER 4.0

HEAT FLUX

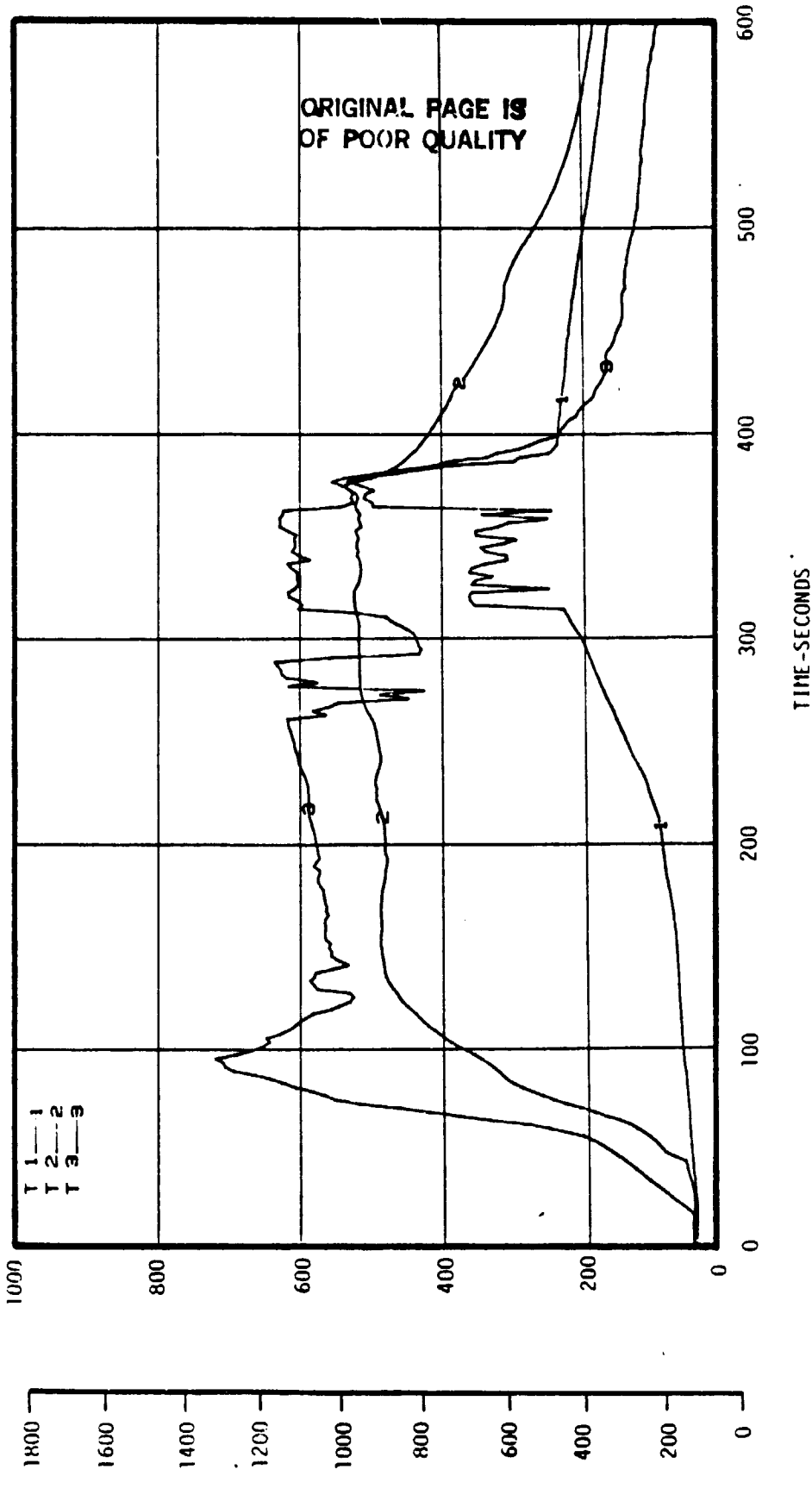


DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/10/62 13.12
NASA-MSC FULL SCALE CUSHION BURN TEST NUMBER 7
CUSHION CONSTRUCTION NUMBER 5.0

SEAT CUSHION TEMPERATURES

FAHRENHEIT

CELSIUS



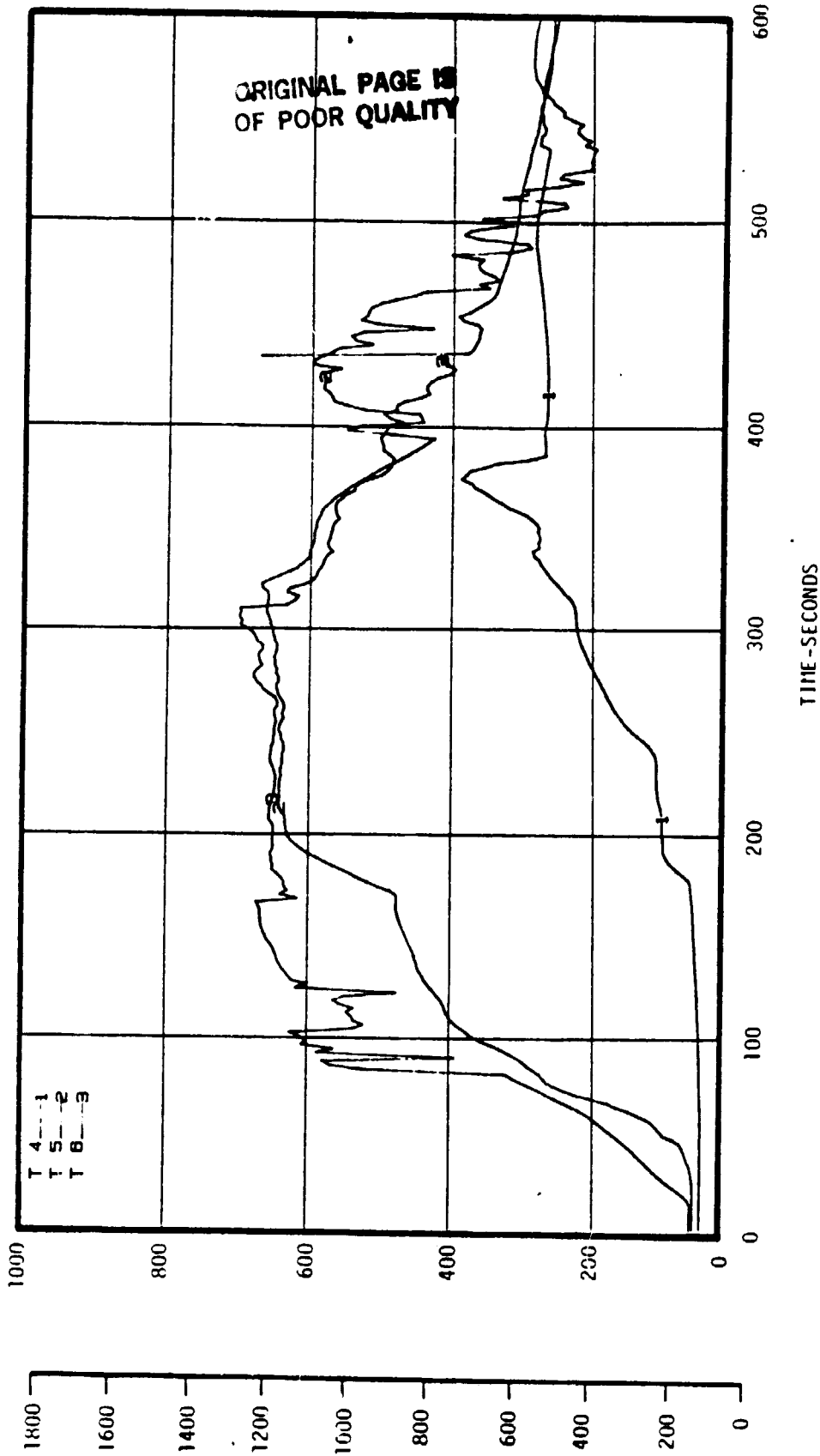
DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 05/10/62 13.12

NASA-MES FULL SCALE CUSHION BURN TEST NUMBER 7

CUSHION CONSTRUCTION NUMBER 5. A

SEAT CUSHION TEMPERATURES

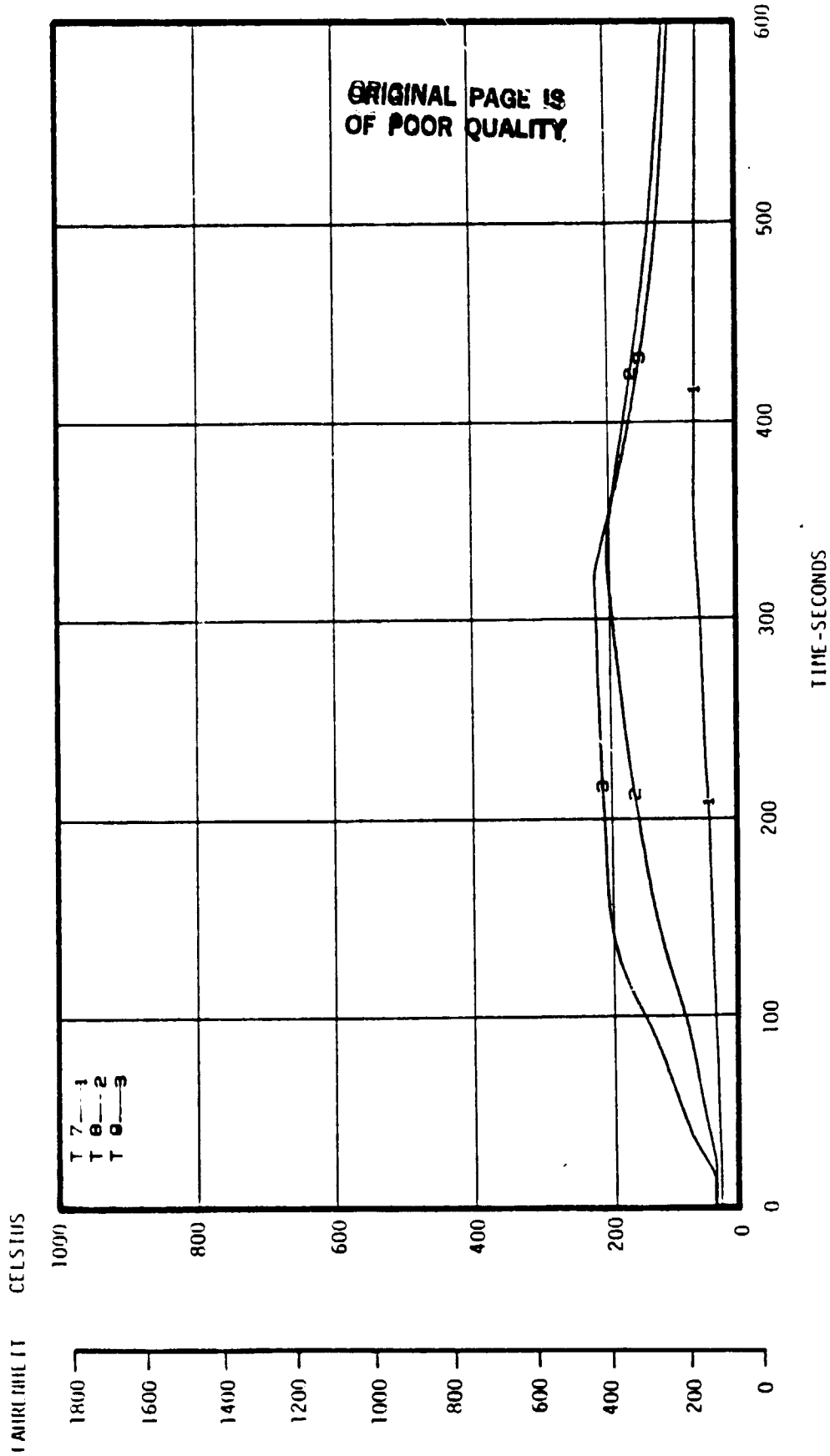
FAHRENHEIT CELSIUS



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 CUSHION CONSTRUCTION NUMBER 5.0

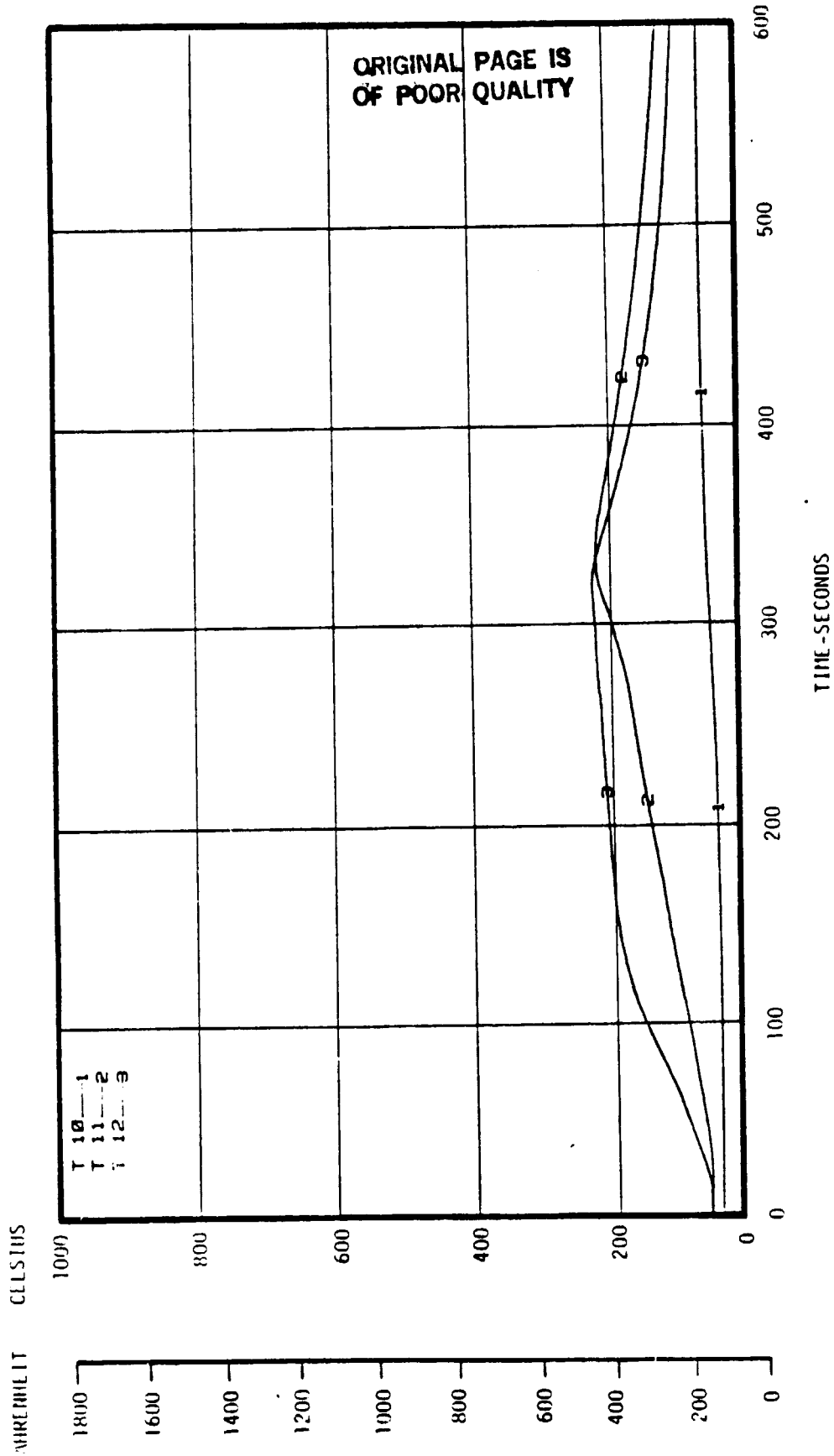
SEAT CUSHION TEMPERATURES



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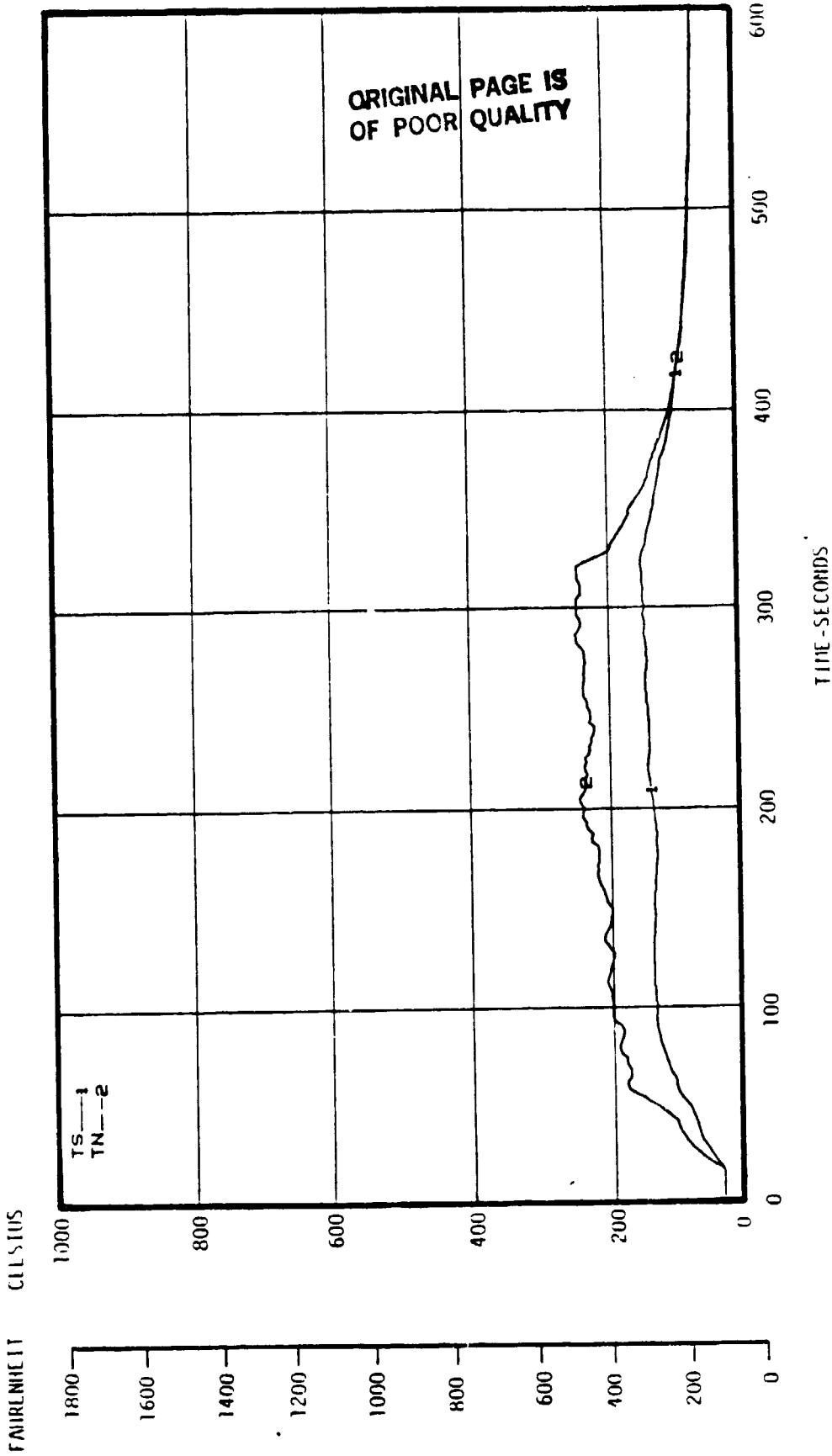
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 NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 7
 CUSHION CONSTRUCTION NUMBER 5.0

SEAT CUSHION TEMPERATURES



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/10/82 13.12
 NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 7
 CUSHION CONSTRUCTION NUMBER 5.0

CEILING TEMPERATURE



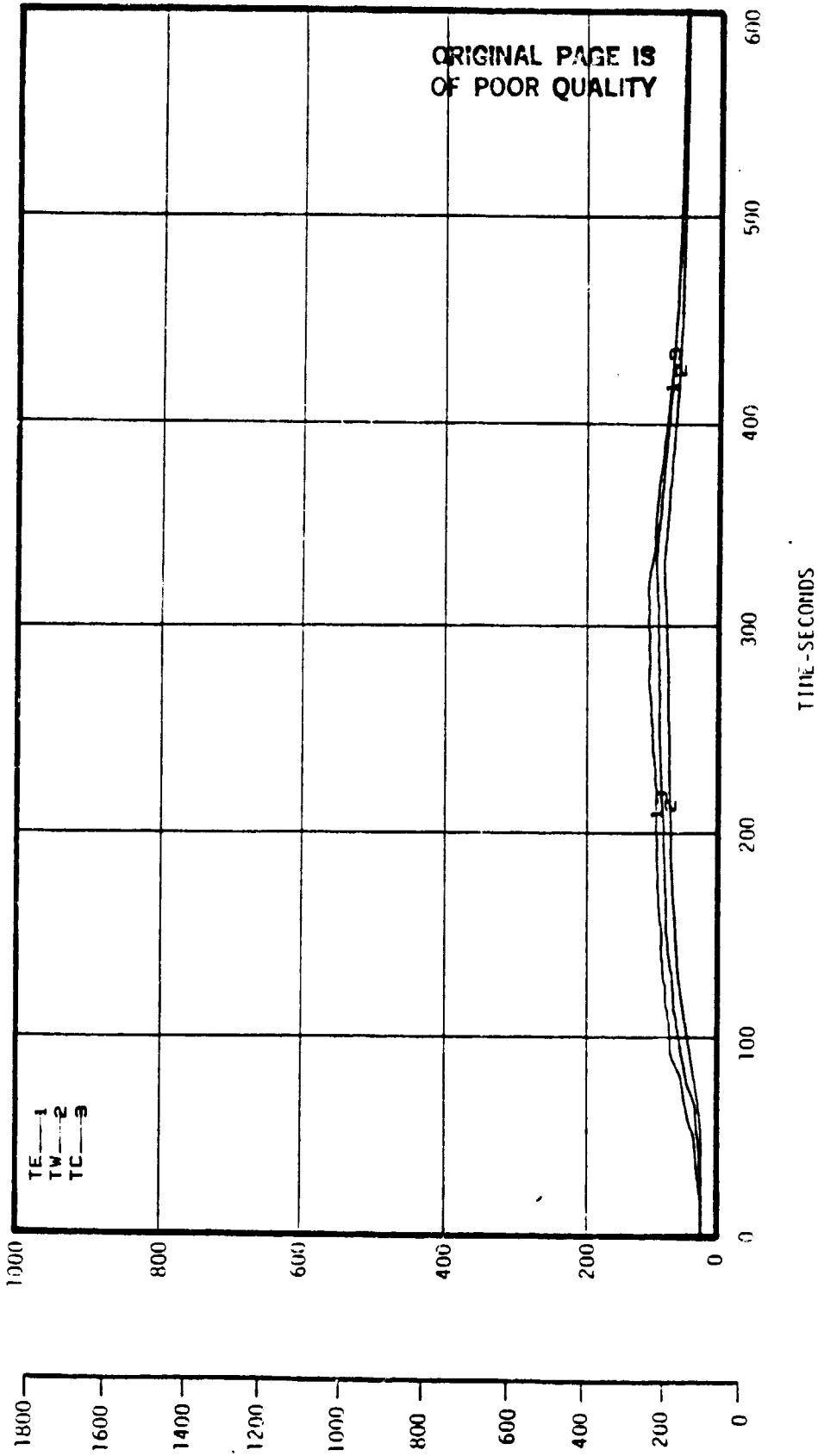
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NASA-NES FULL SCALE CUSHION BURN TEST NUMBER 7

CUSHION CONSTRUCTION NUMBER 5.0

CEILING TEMPERATURE

FAHRENHEIT CELSIUS

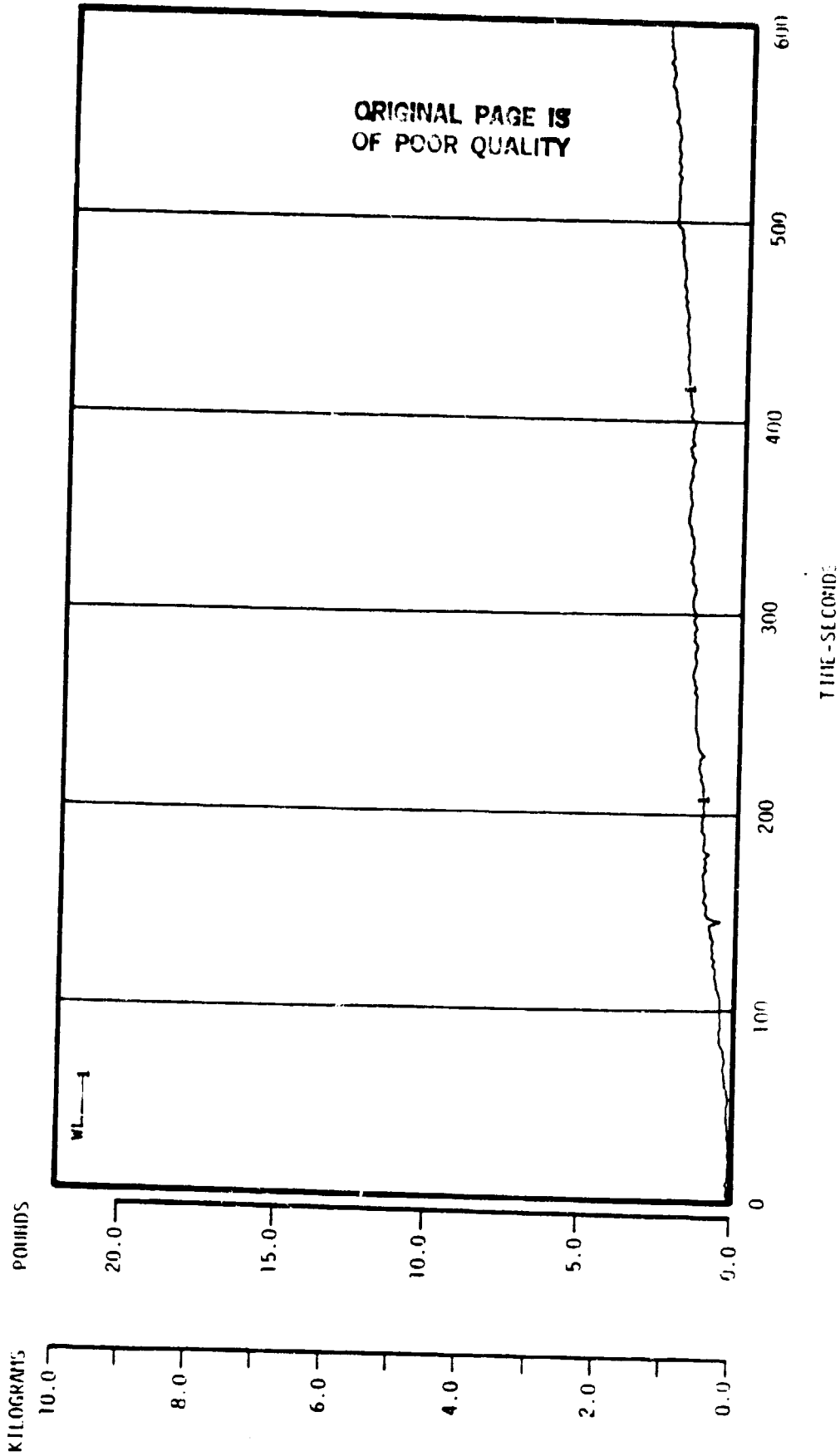


DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/10/62 13.12

NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 7

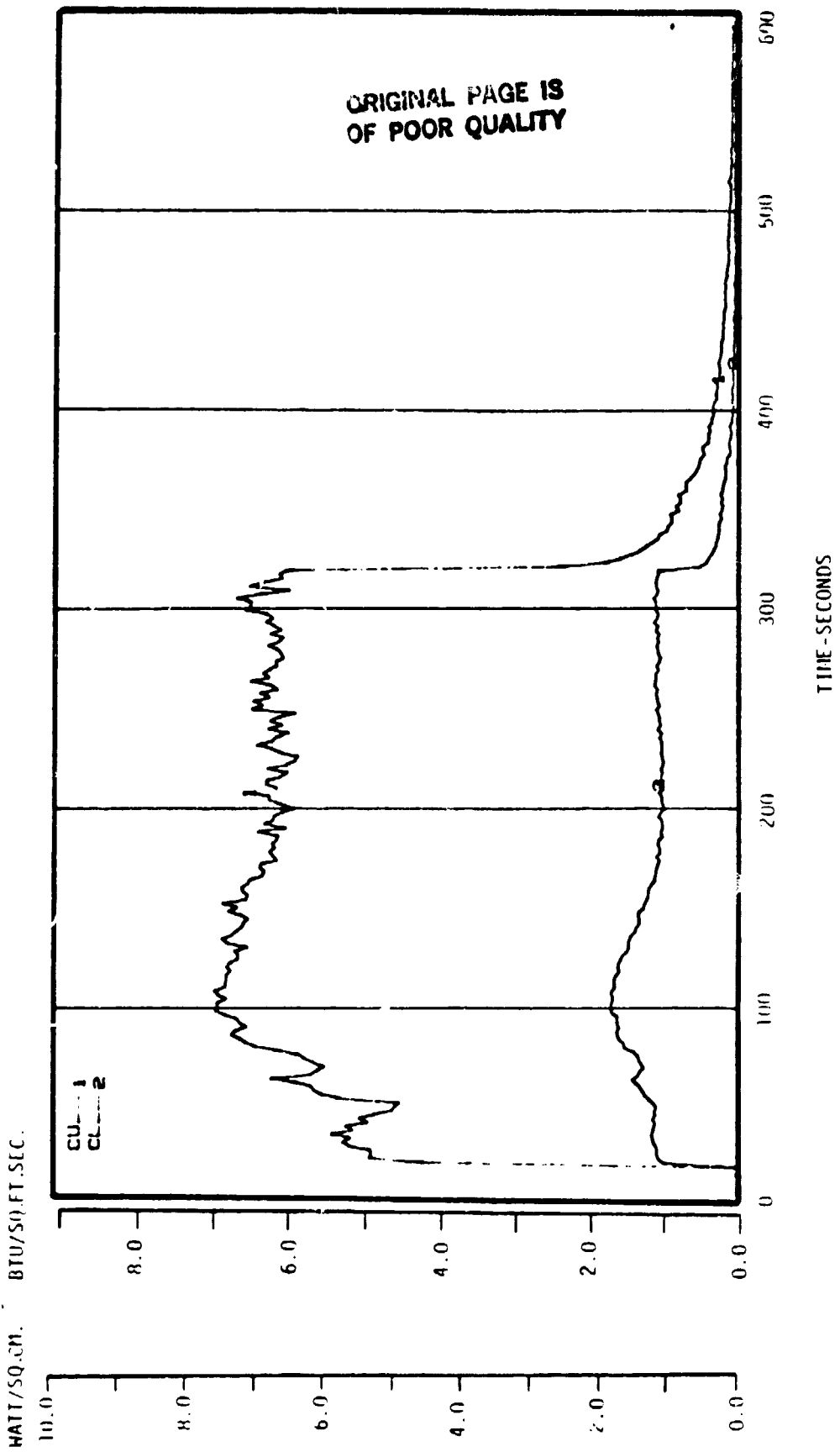
CUSHION CONSTRUCTION NUMBER 5.0

WEIGHT LOSS



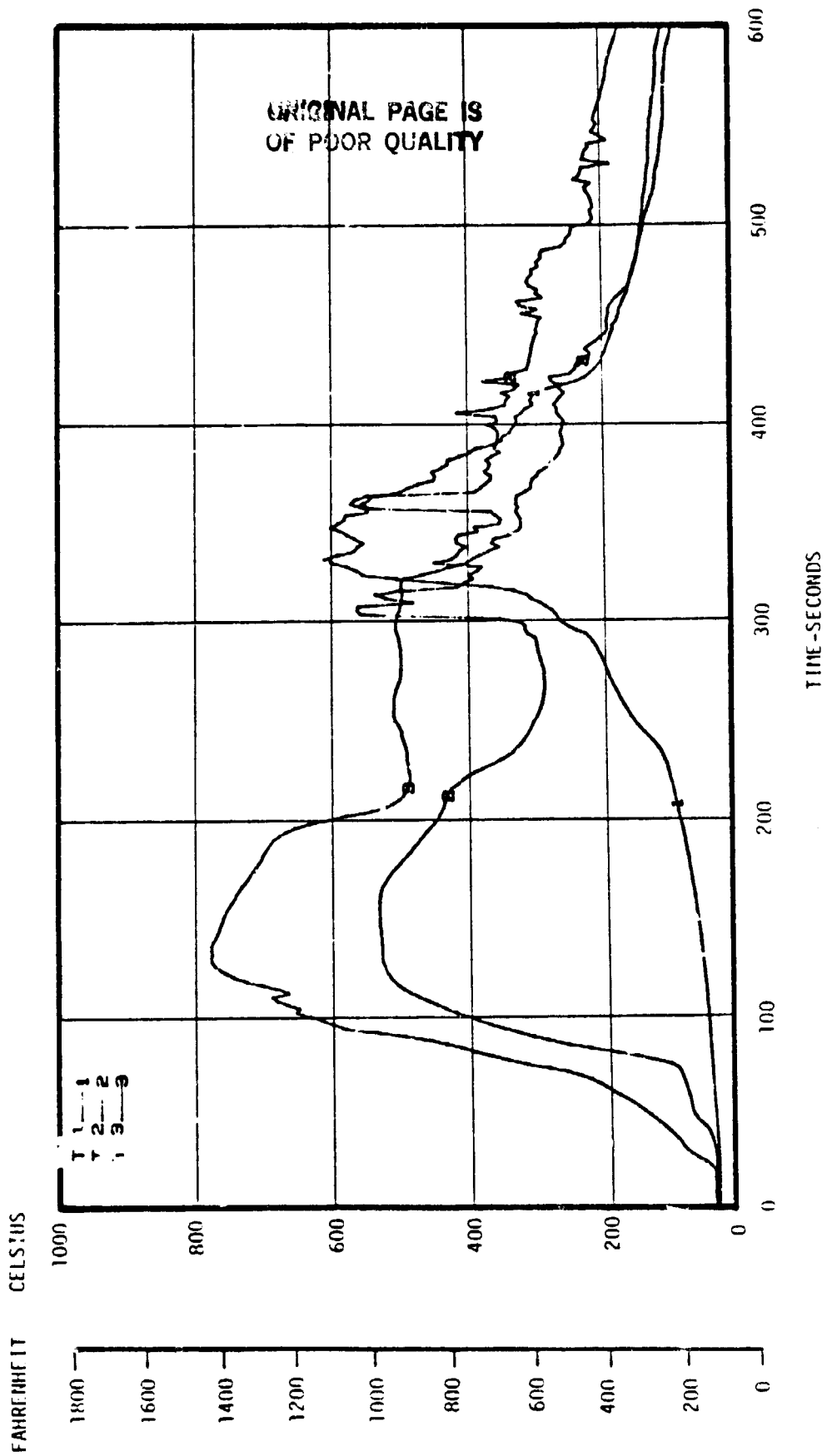
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NASA-AMES FULL SCALE CUSHION BURR TEST NUMBER 7
CUSHION CONSTRUCTION NUMBER 5.0

HEAT FLUX



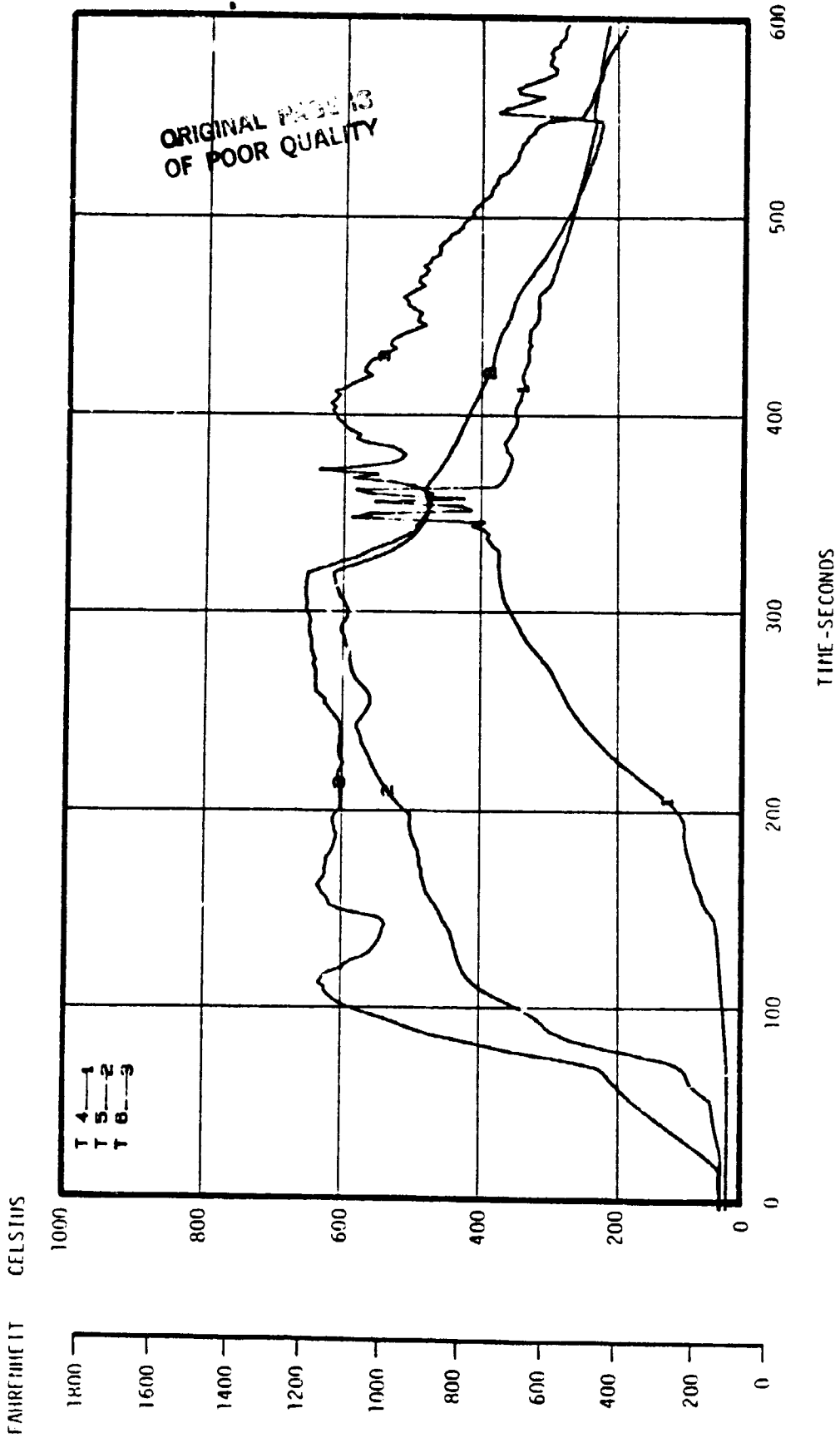
DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/15/62 00-12
NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 19
CUSHION CONSTRUCTION NUMBER 9.0

SEAT CUSHION TEMPERATURES



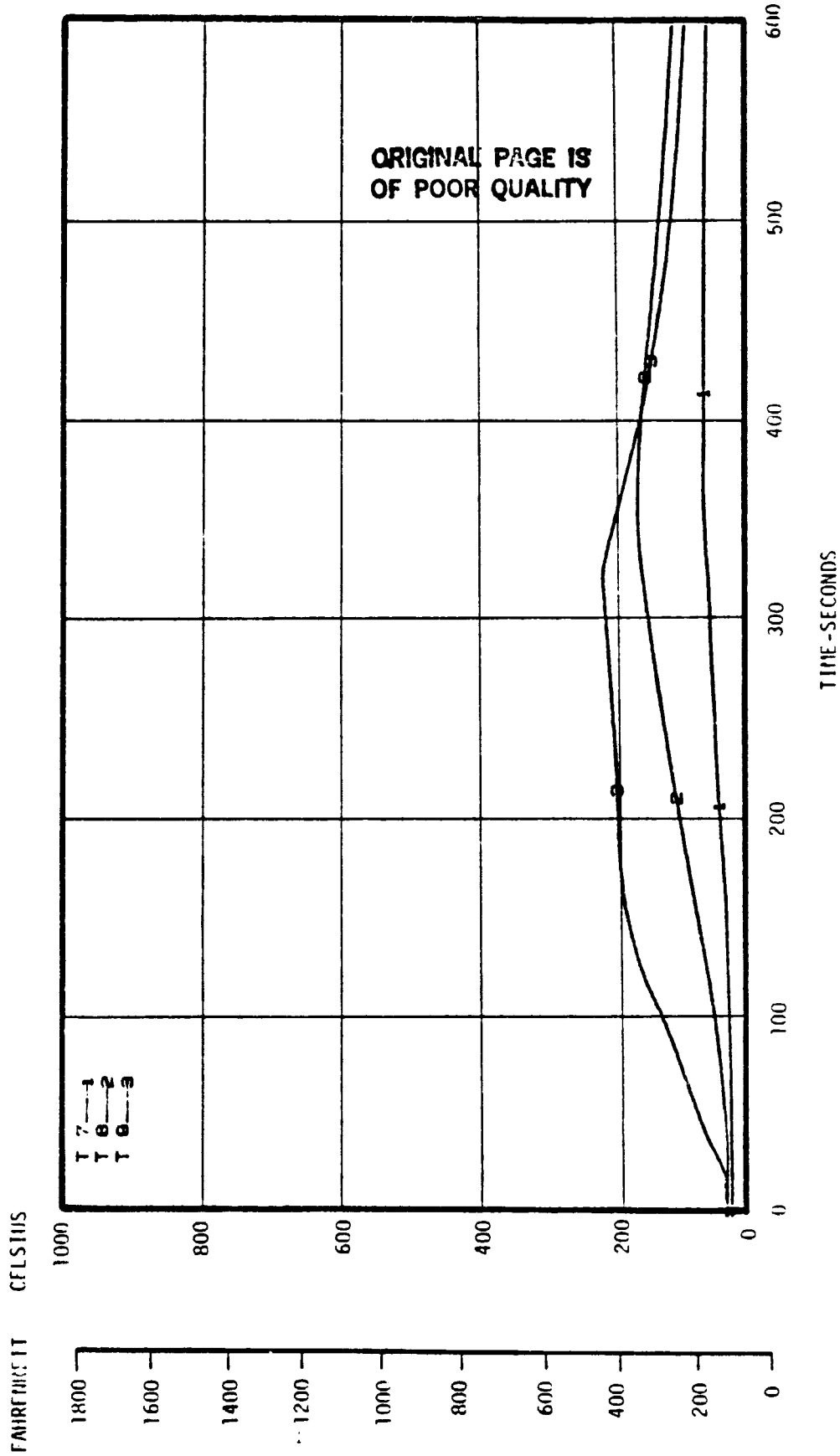
DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/15/02 00.12
 NASA-AF'S FULL SCALE CUSHION BURN TEST NUMBER 13
 CUSHION CONSTRUCTION NUMBER 5.0

SEAT CUSHION TEMPERATURES



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 09/15/62 00.12
 NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 13
 CUSHION CONSTRUCTION NUMBER 5.0

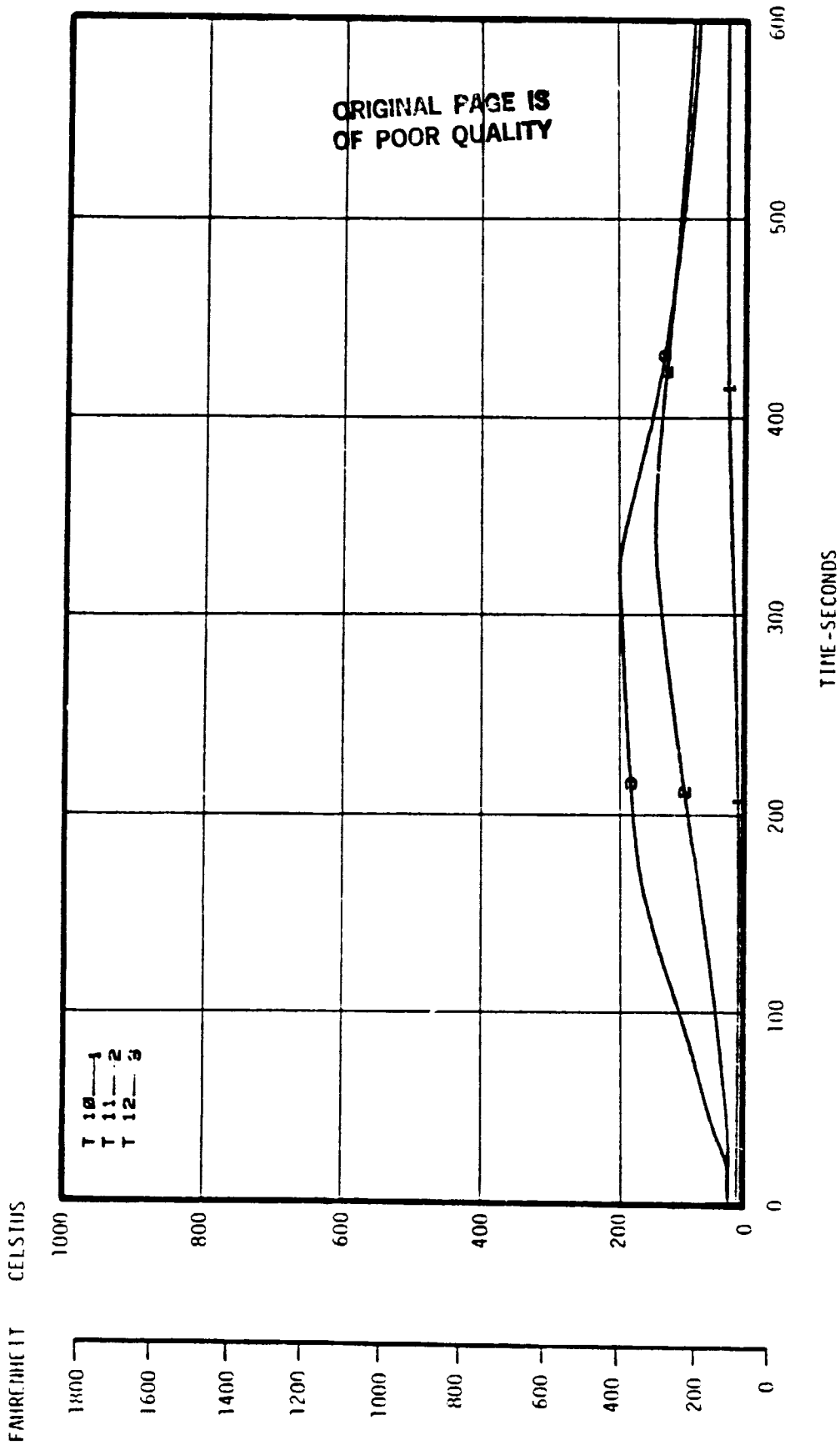
SEAT CUSHION TEMPERATURES



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 NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 13
 CUSHION CONSTRUCTION NUMBER 5.0

SEAT CUSHION TEMPERATURES

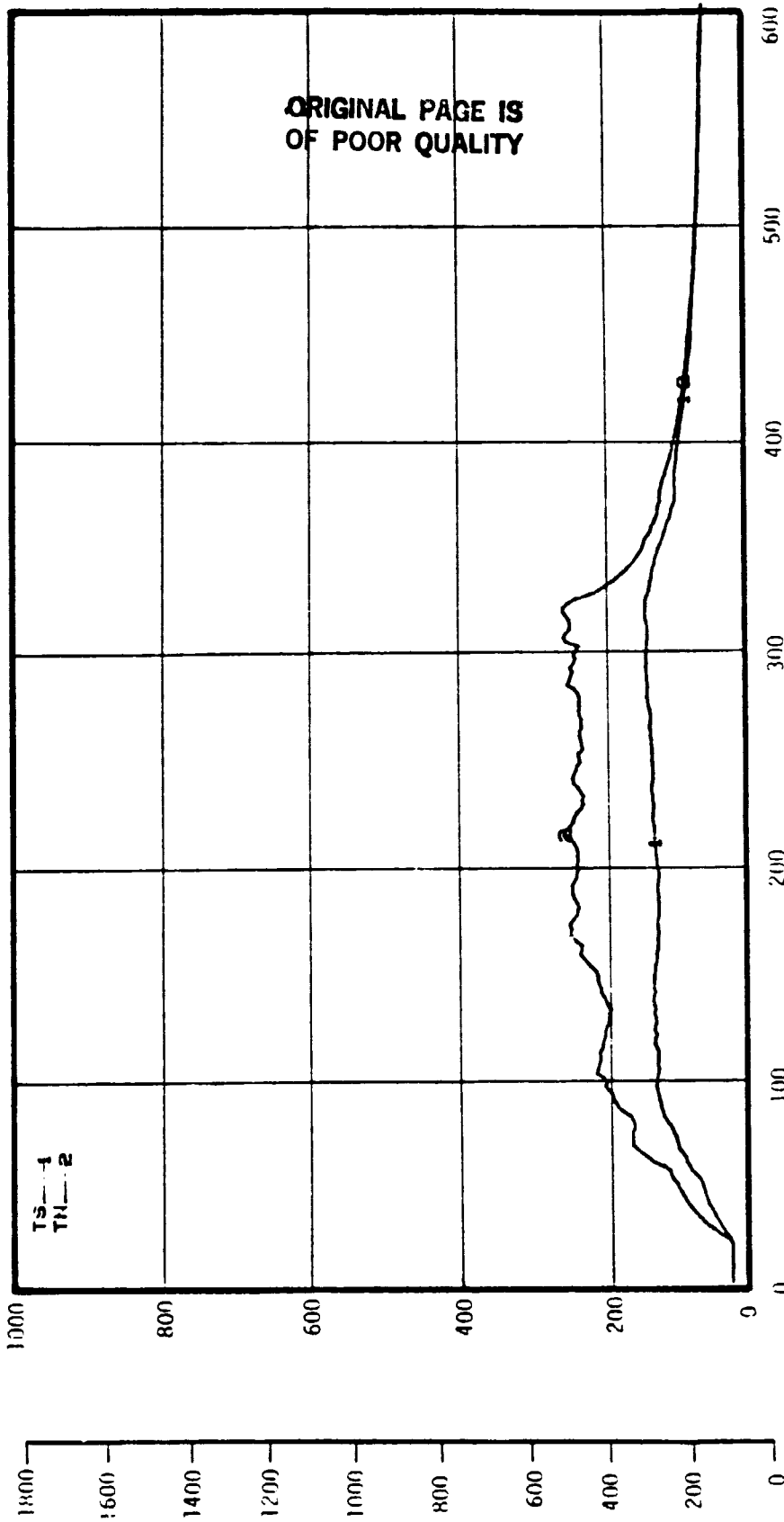


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DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/15/62 00.12
 NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 10
 CUSHION CONSTRUCTION NUMBER 5.0

CEILING TEMPERATURE

FAHRENHEIT CELSIUS



TIME - SECONDS

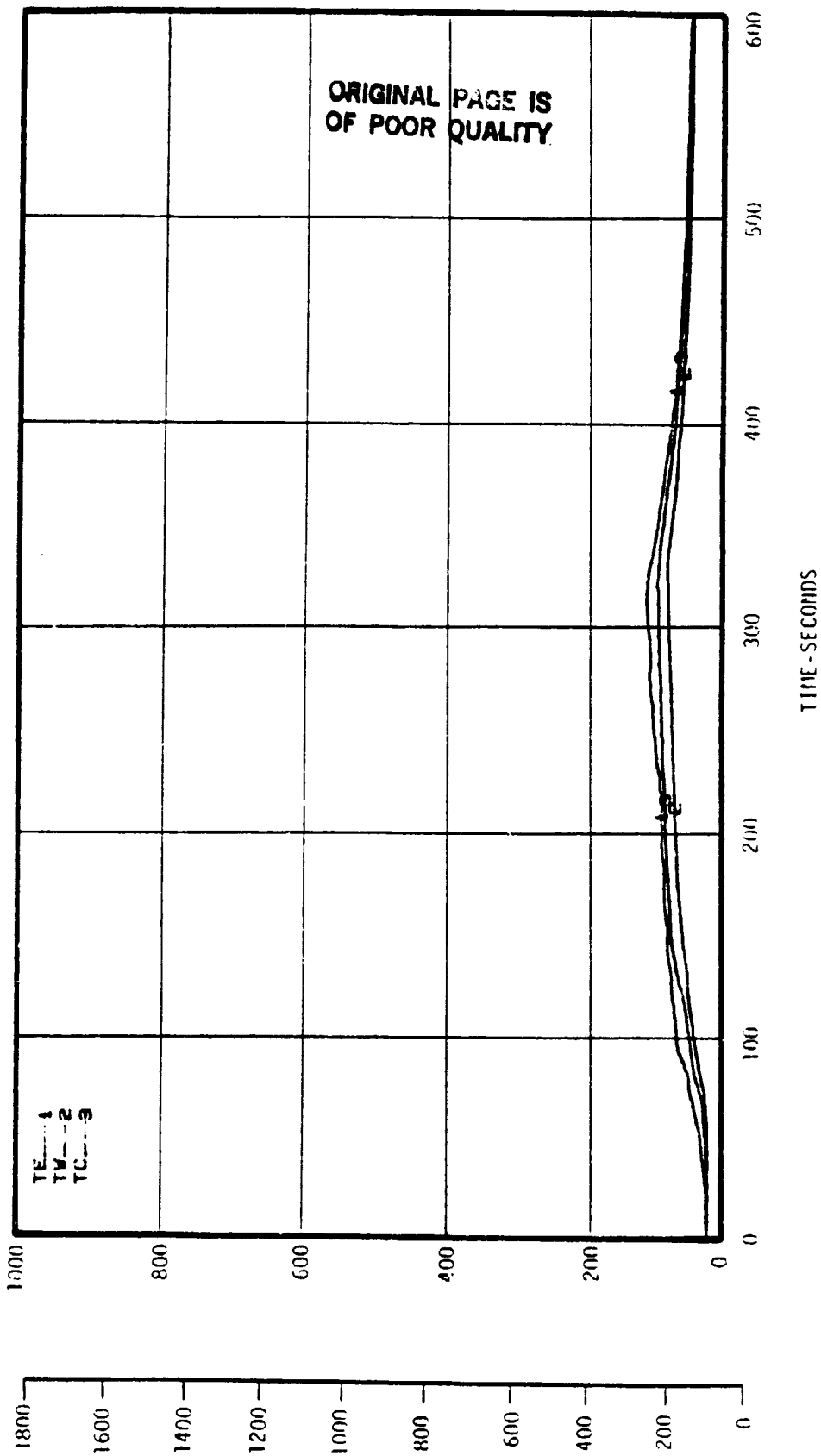
BOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/15/82 09.12

NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 13

CUSHION CONSTRUCTION NUMBER 5.0

CEILING TEMPERATURE

FAHRENHEIT CELSIUS

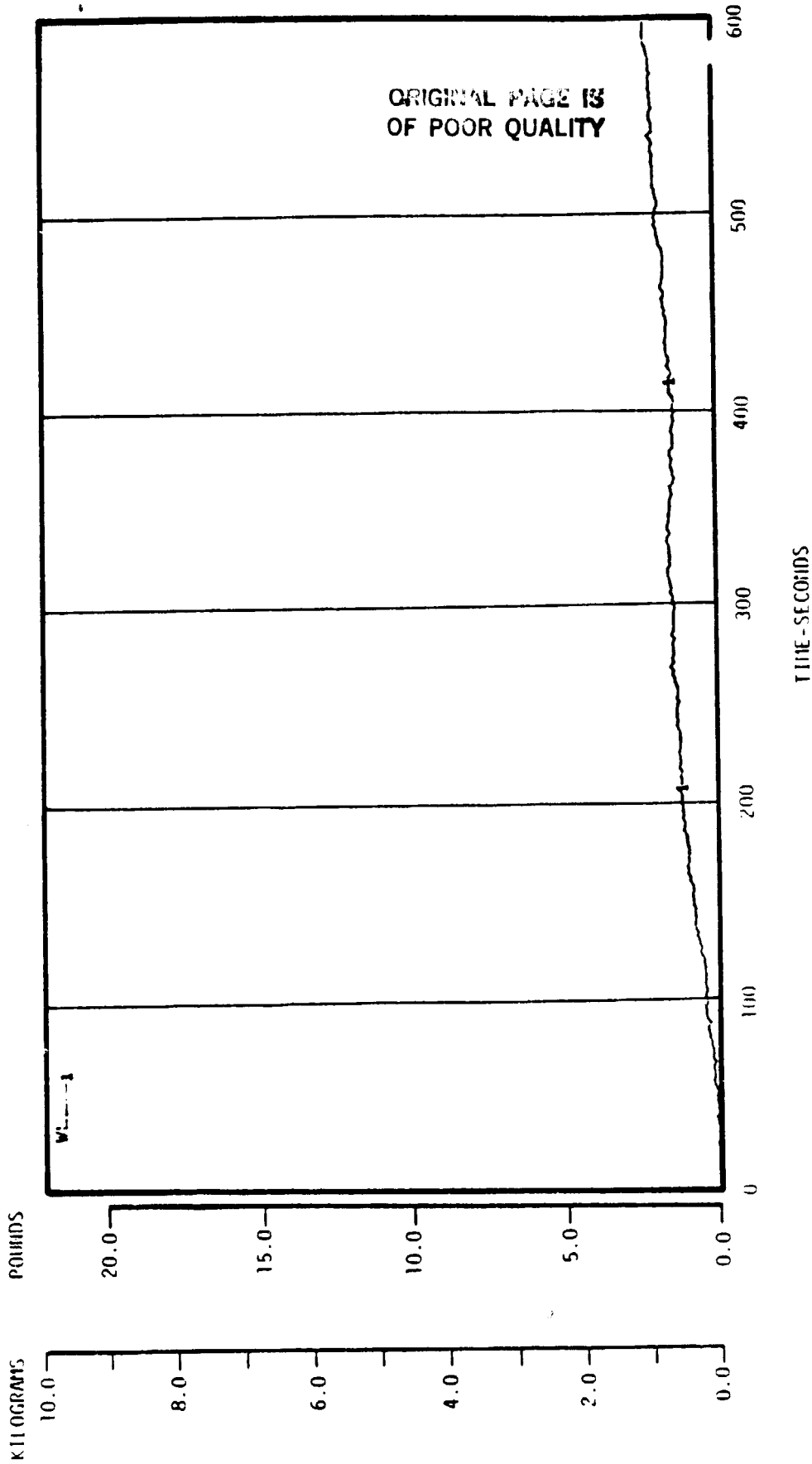


DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 09/15/62 00.12

NASA-AIR'S FULL SCALE CUSHION BURN TEST NUMBER 13

CUSHION CONSTRUCTION NUMBER 5.0

WEIGHT LOSS



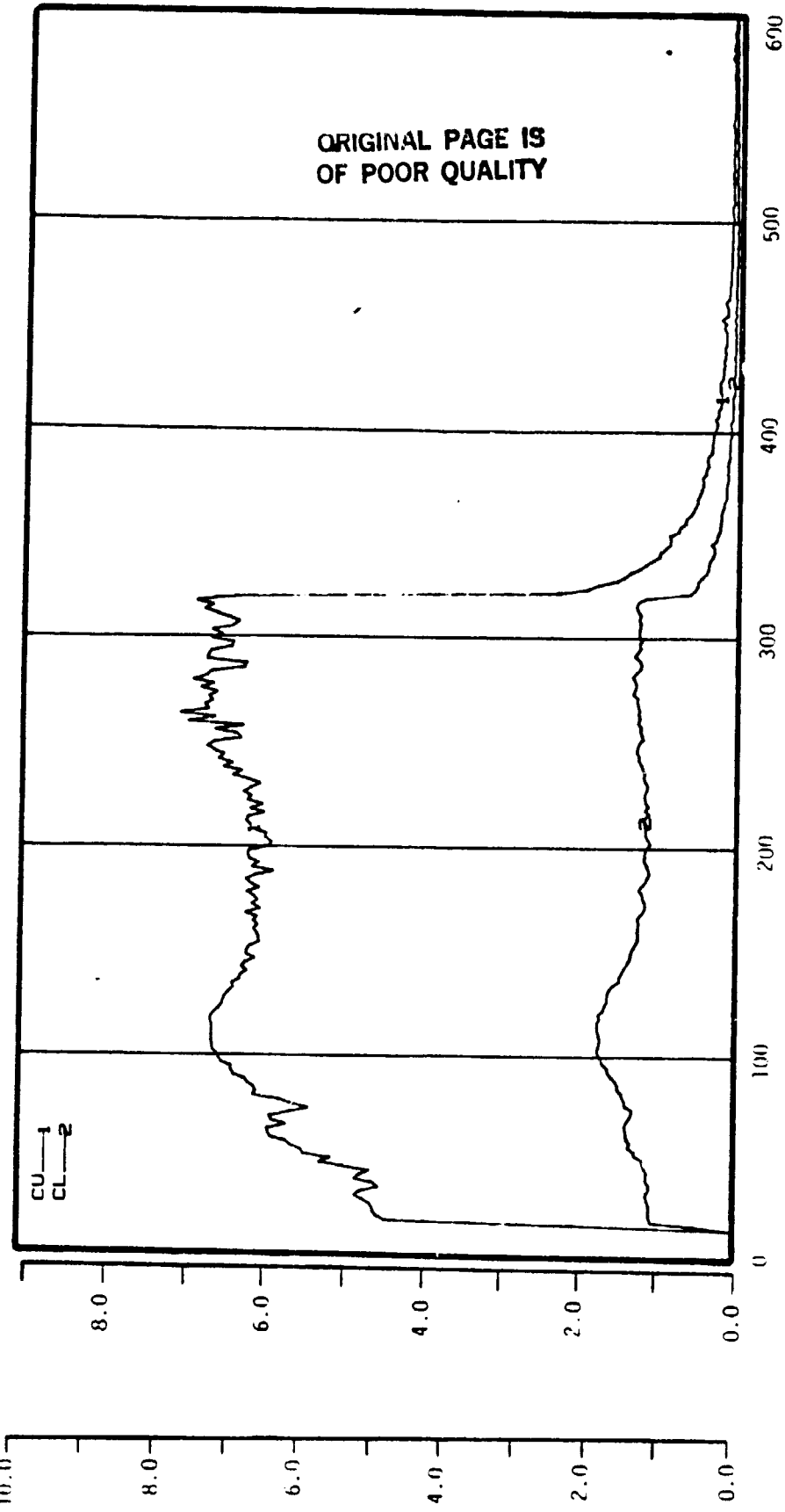
BOEING AIRCRAFT CABIN FIRE SIMULATOR 03/15/62 28.12

NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 13

CUSHION CONSTRUCTION NUMBER 3.0

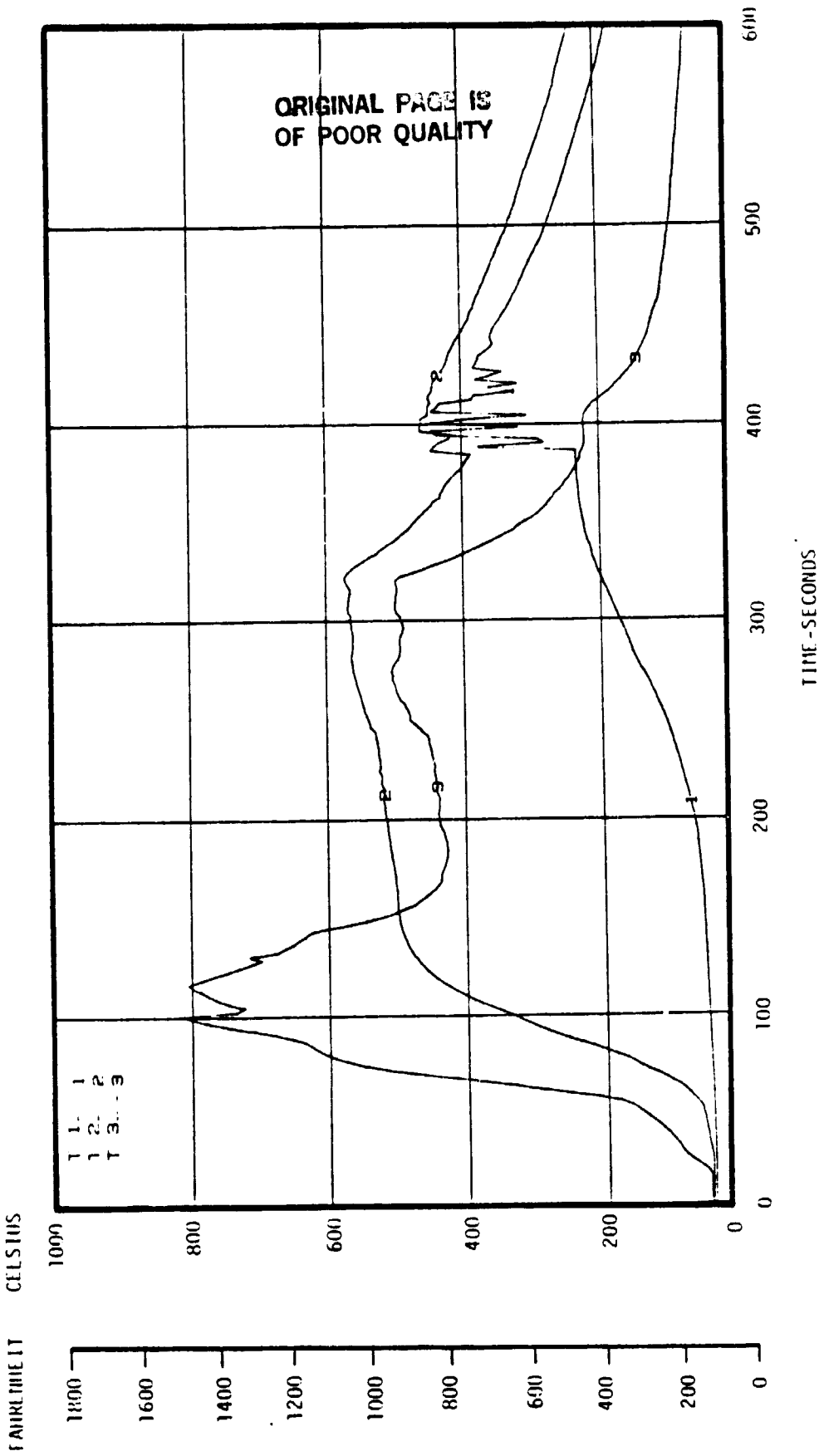
HEAT FLUX

WATT/SQ. CM. BTU/SQ. FT. SEC.



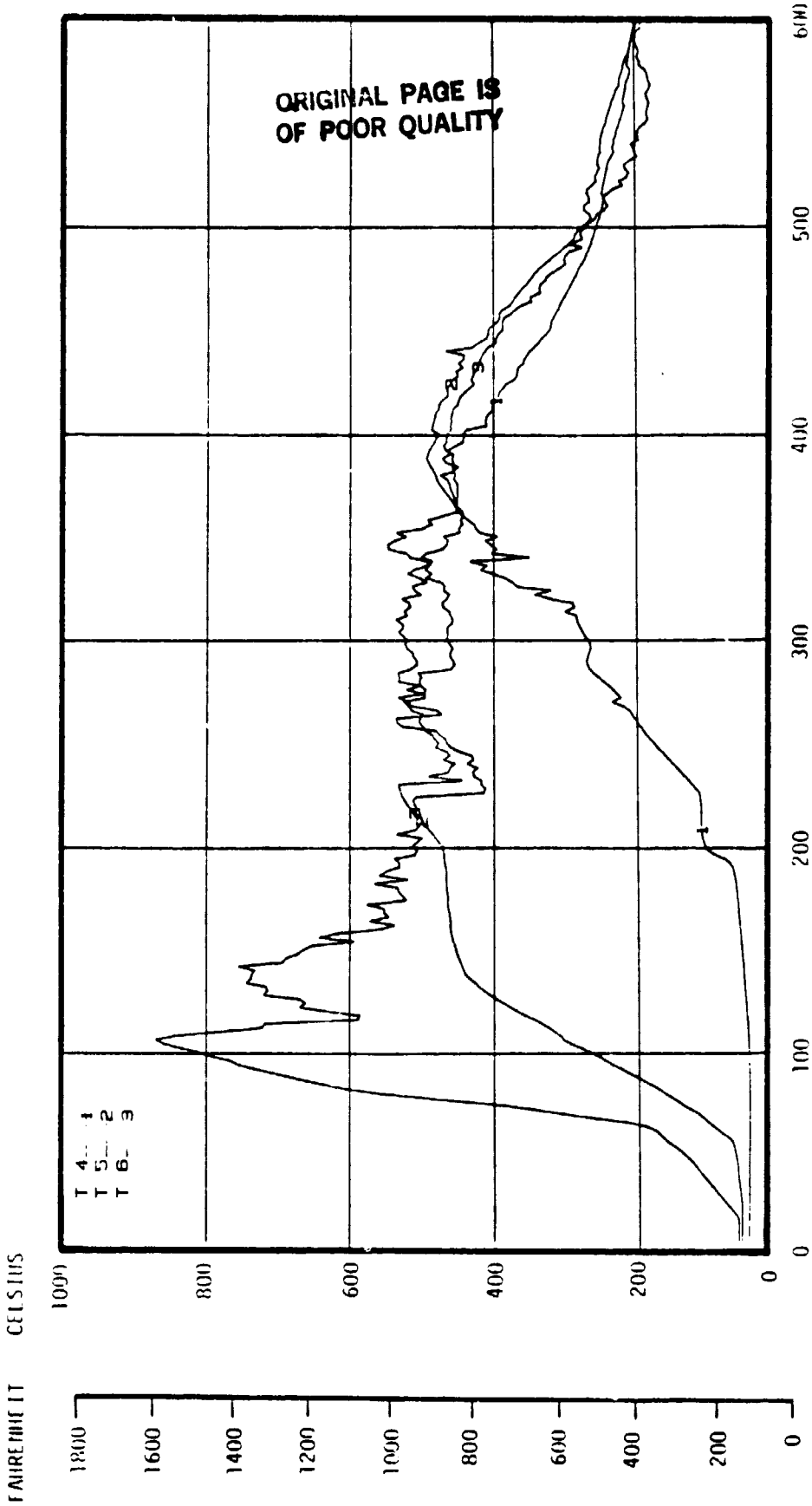
DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/00/82 14:28
NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 5
CUSHION CONSTRUCTION NUMBER 6.0

SEAT CUSHION TEMPERATURES



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/09/82 14:28
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 CUSHION CONSTRUCTION NUMBER 6.0

SEAT CUSHION TEMPERATURES

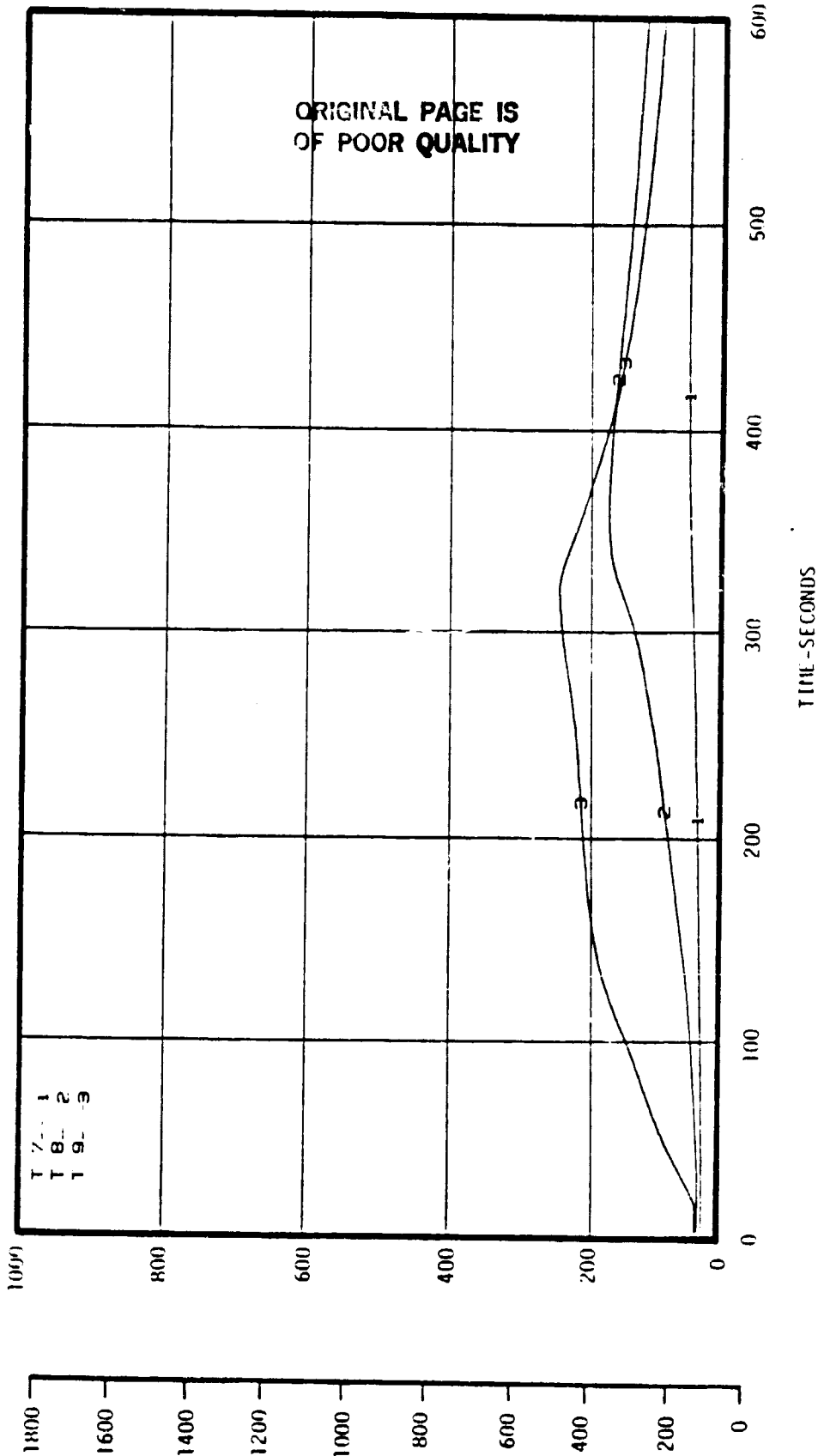


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DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/09/82 14:28
NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 5
CUSHION CONSTRUCTION NUMBER 6.0

SEAT CUSHION TEMPERATURES

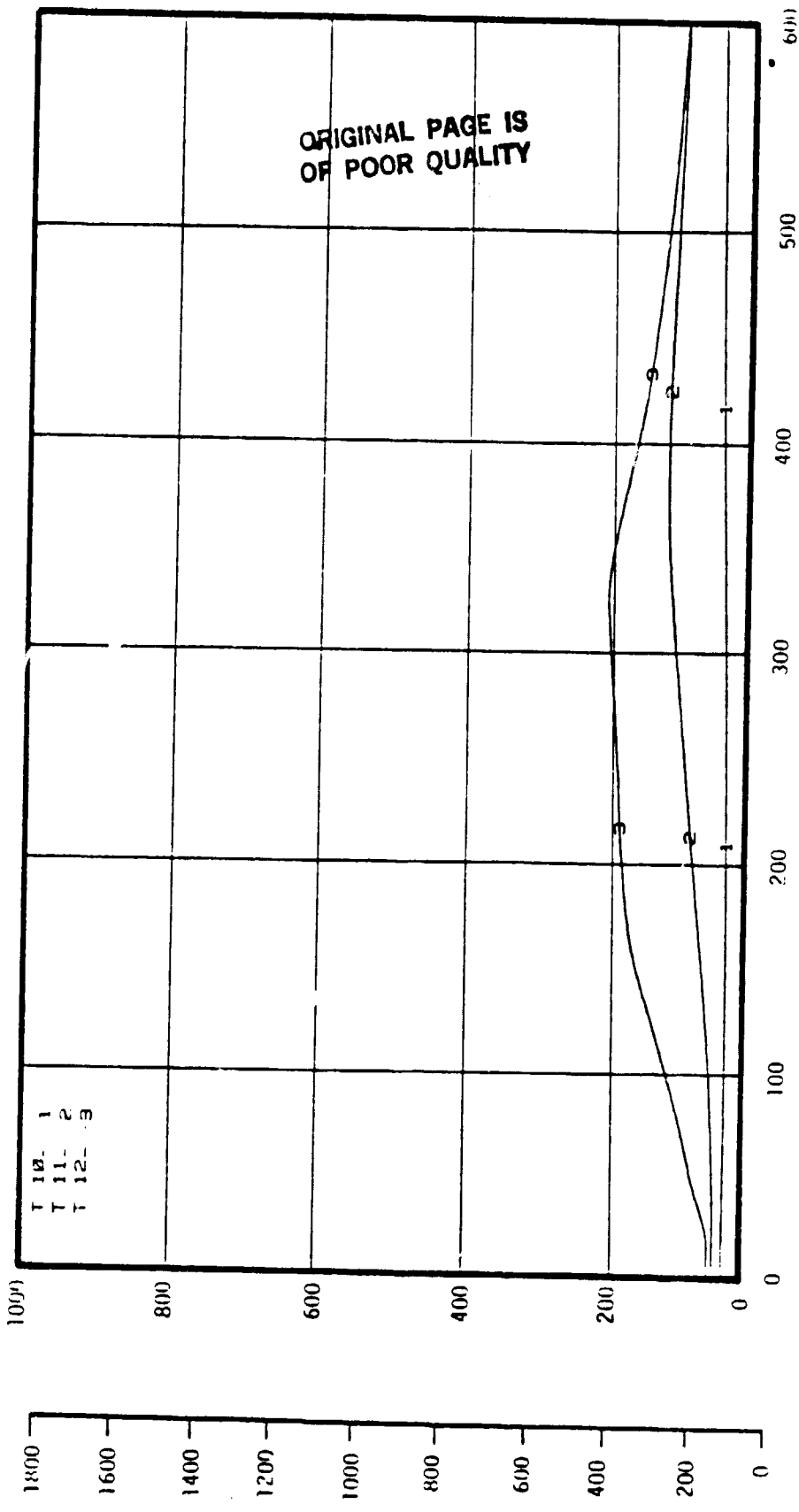
FAHRENHEIT CELSIUS



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/09/82 14.20
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 CUSHION CONSTRUCTION NUMBER 6.0

SEAT CUSHION TEMPERATURES

FAHRENHEIT CELSIUS

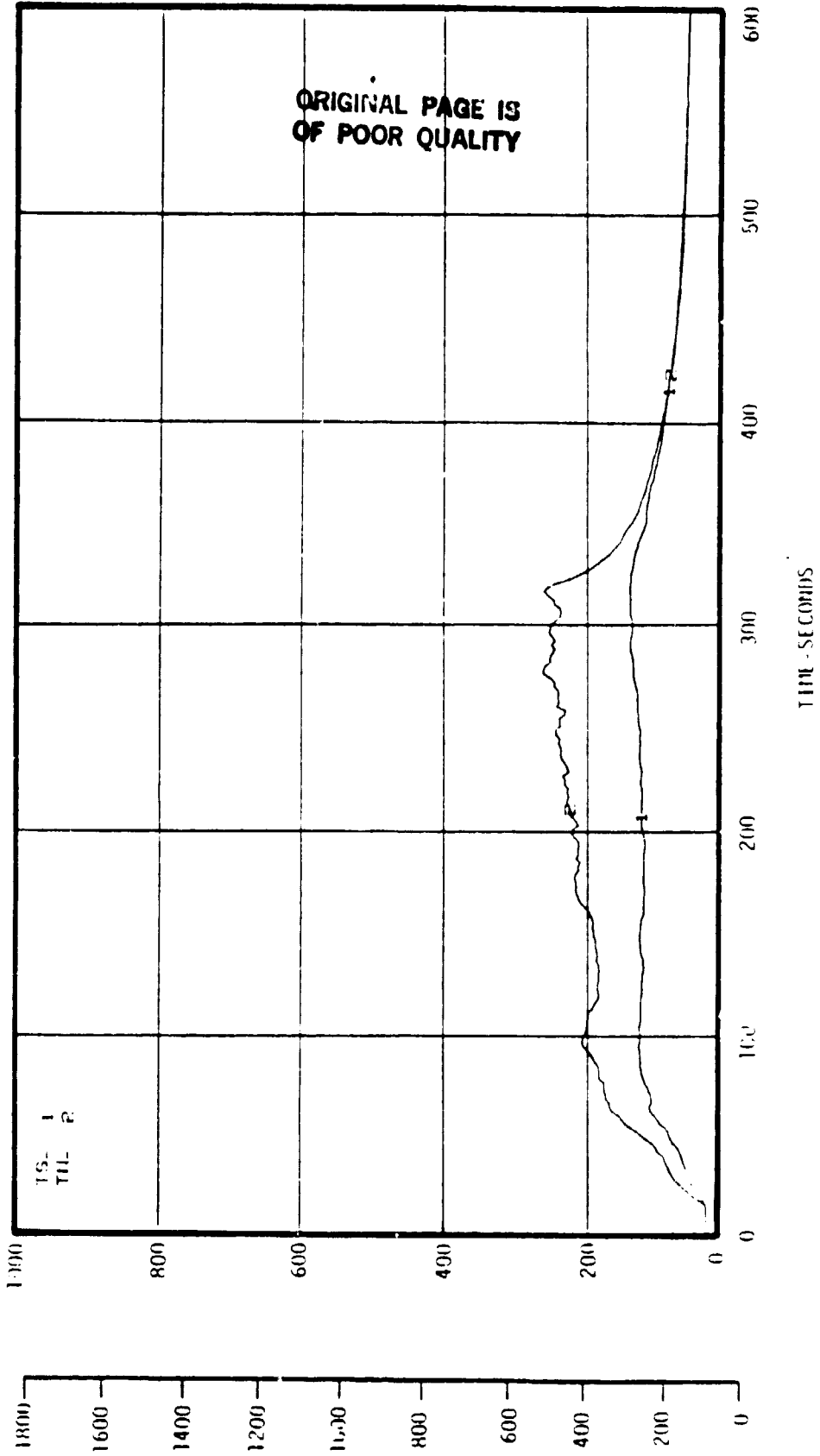


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 CUSHION CONSTRUCTION NUMBER 6.0

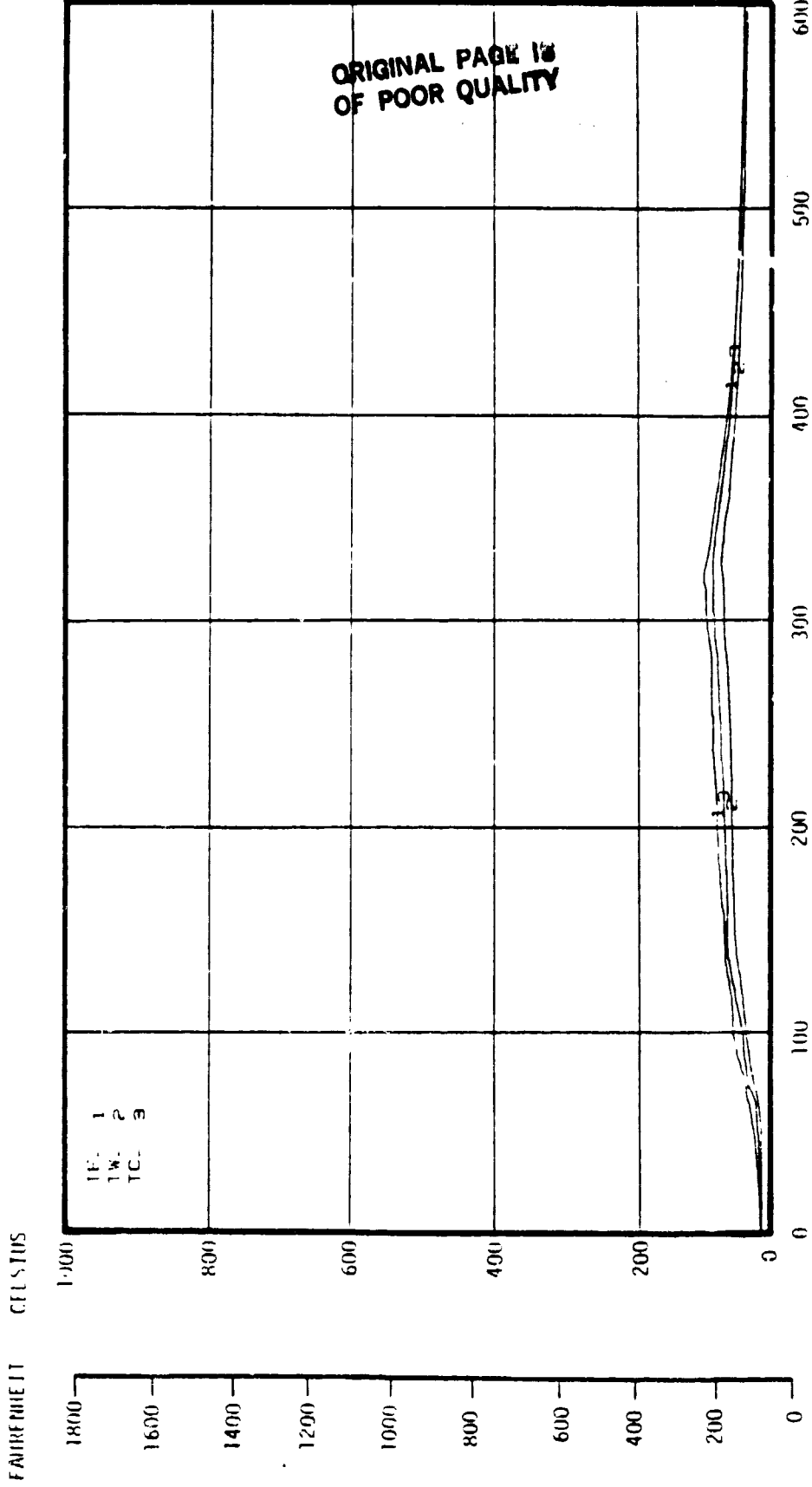
CULMING TEMPERATURE

FARENHEIT CELSIUS



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/09/82 14.28
NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 5
CUSHION CONSTRUCTION NUMBER 6.0

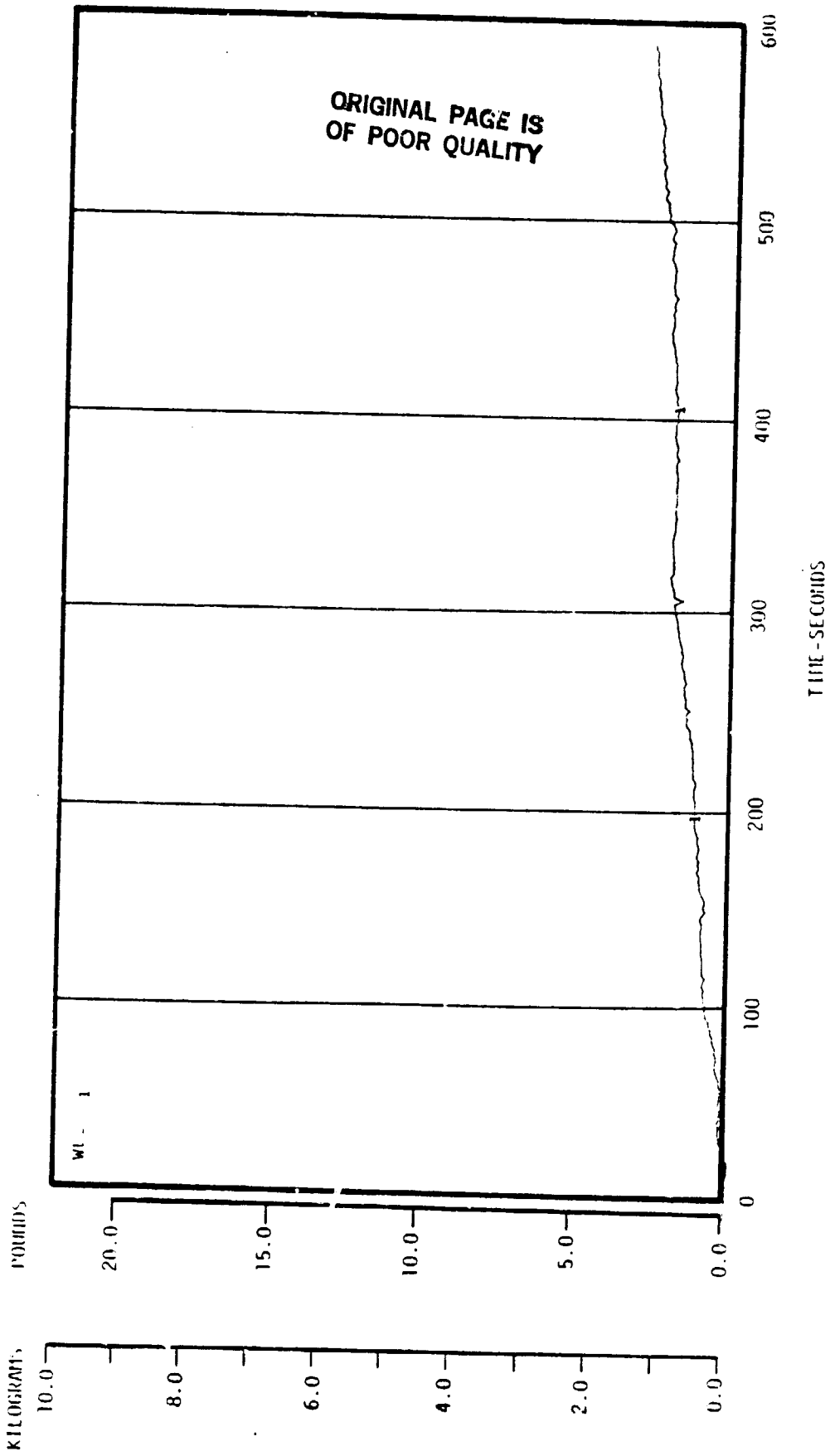
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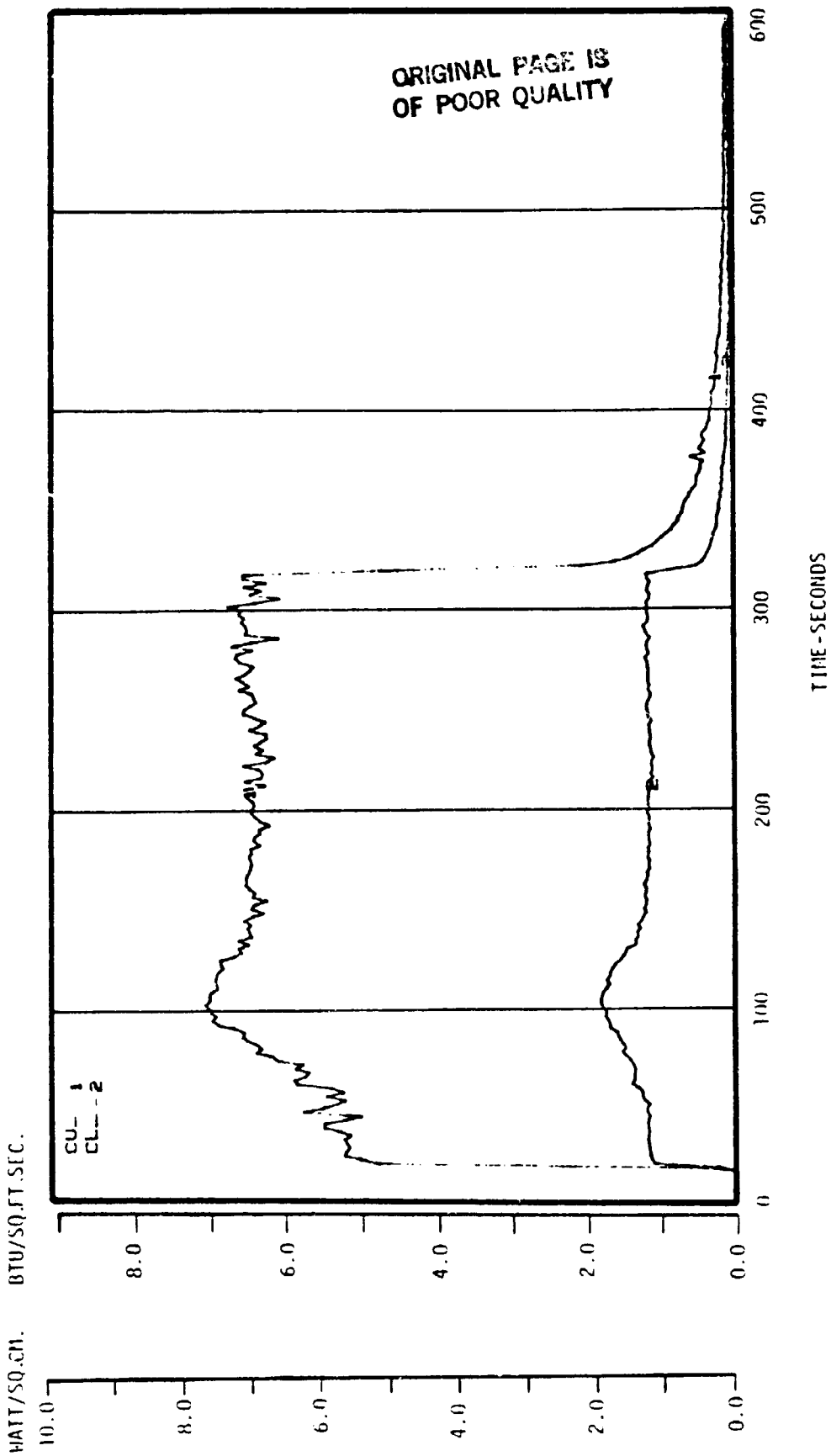
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NASA-WES FULL SCALE CUSHION BURR TEST NUMBER 5
CUSHION CONSTRUCTION NUMBER 6.0

WEIGHT LOSS



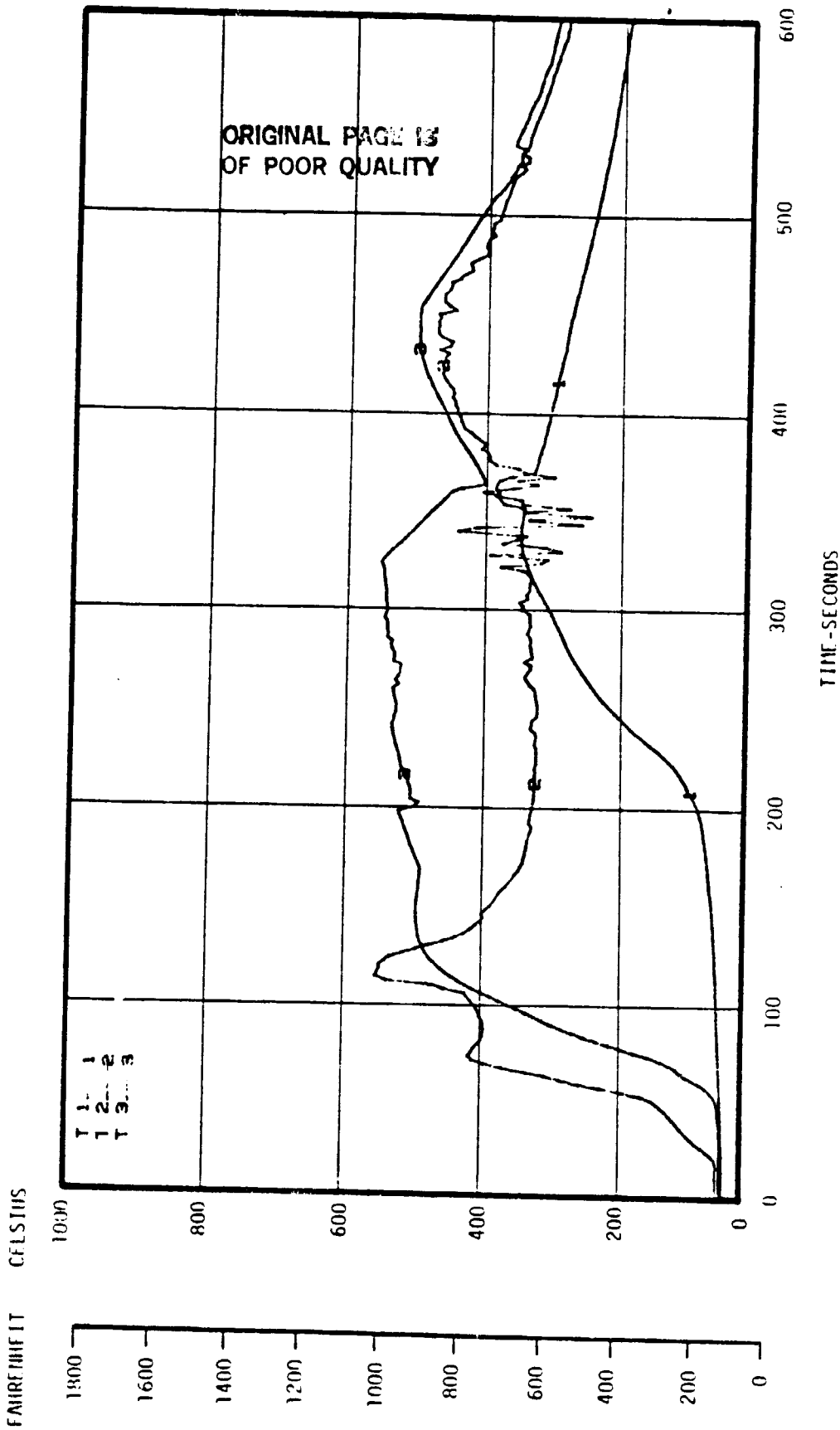
DOUGLAS AIRCRAFT CABIN FIRE SIMULATION 89/09/62 14:28
NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 5
CUSHION CONSTRUCTION NUMBER 6.0

HEAT FLUX



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 23/15/62 11-43
NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 14
CUSHION CONSTRUCTION NUMBER 6.0

SEAT CUSHION TEMPERATURES

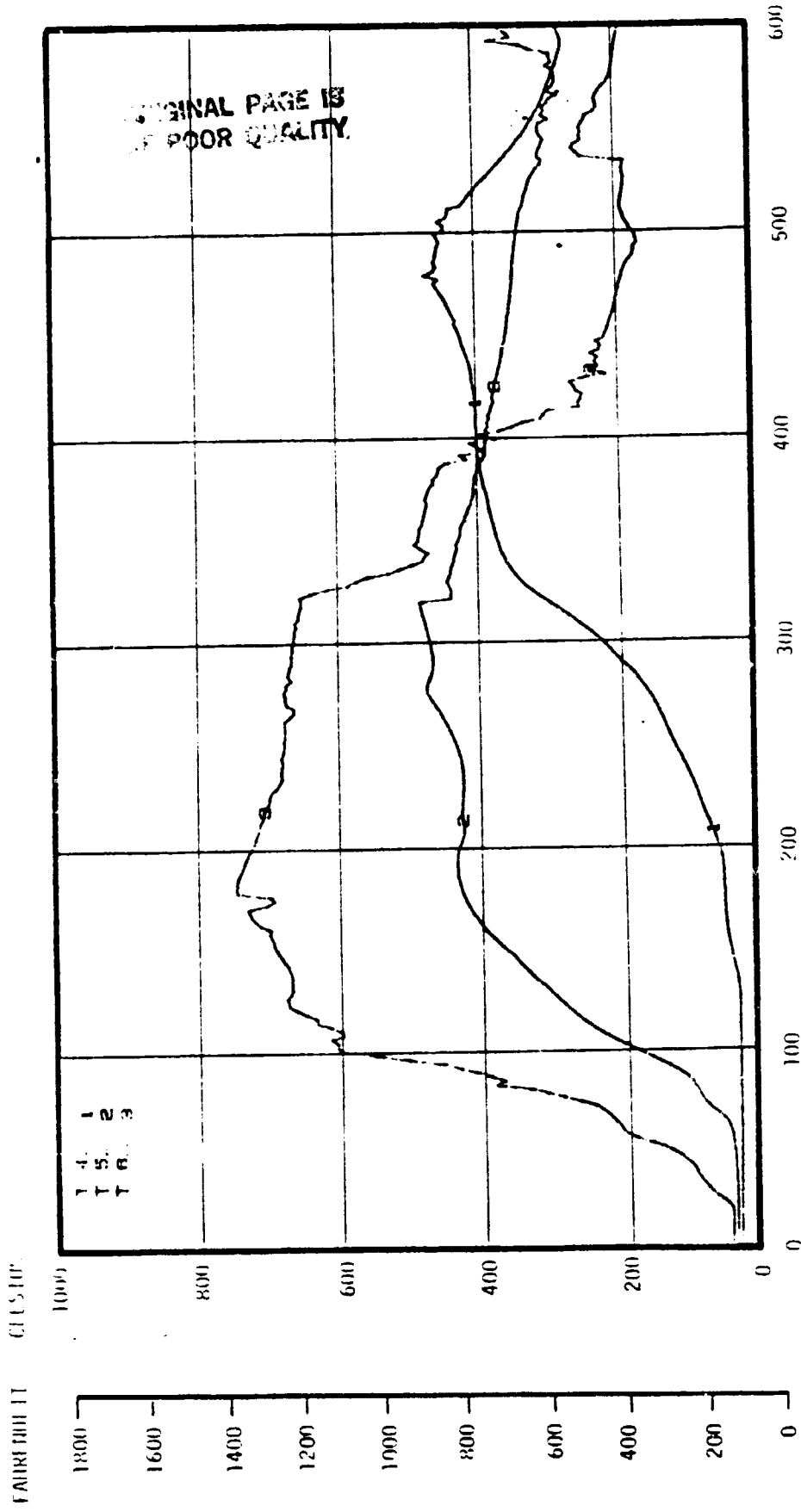


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T 2- 2
T 3- 3

DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/15/82 11.40
NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 14
CUSHION CONSTRUCTION NUMBER 8.0

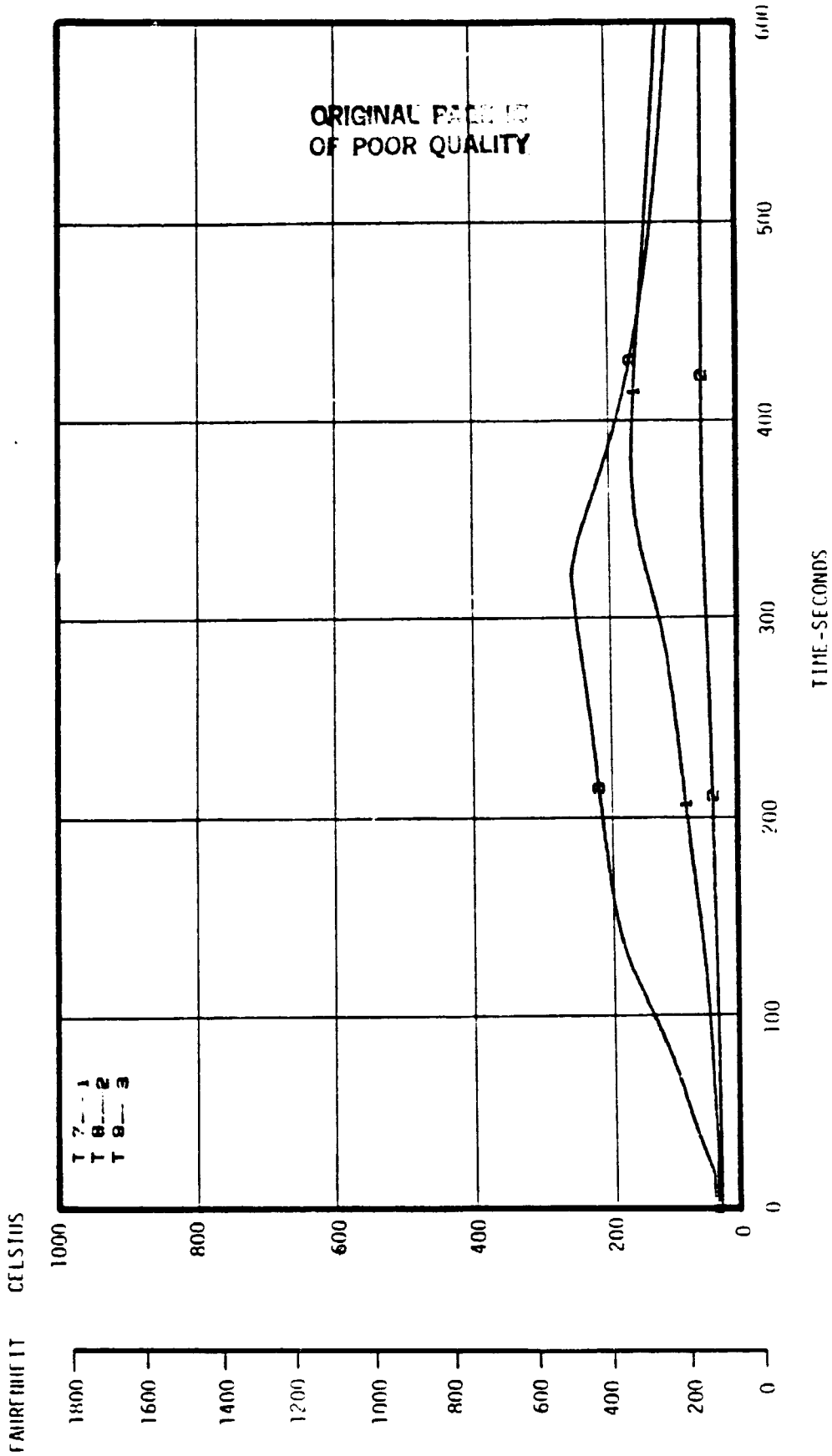
SEAT CUSHION TEMPERATURES



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DOUGLAS AIRCRAFT CABIN FIRE SIM. FOR 33/15/82 11:40
 NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 14
 CUSHION CONSTRUCTION NUMBER R. 0

SEAT CUSHION TEMPERATURES

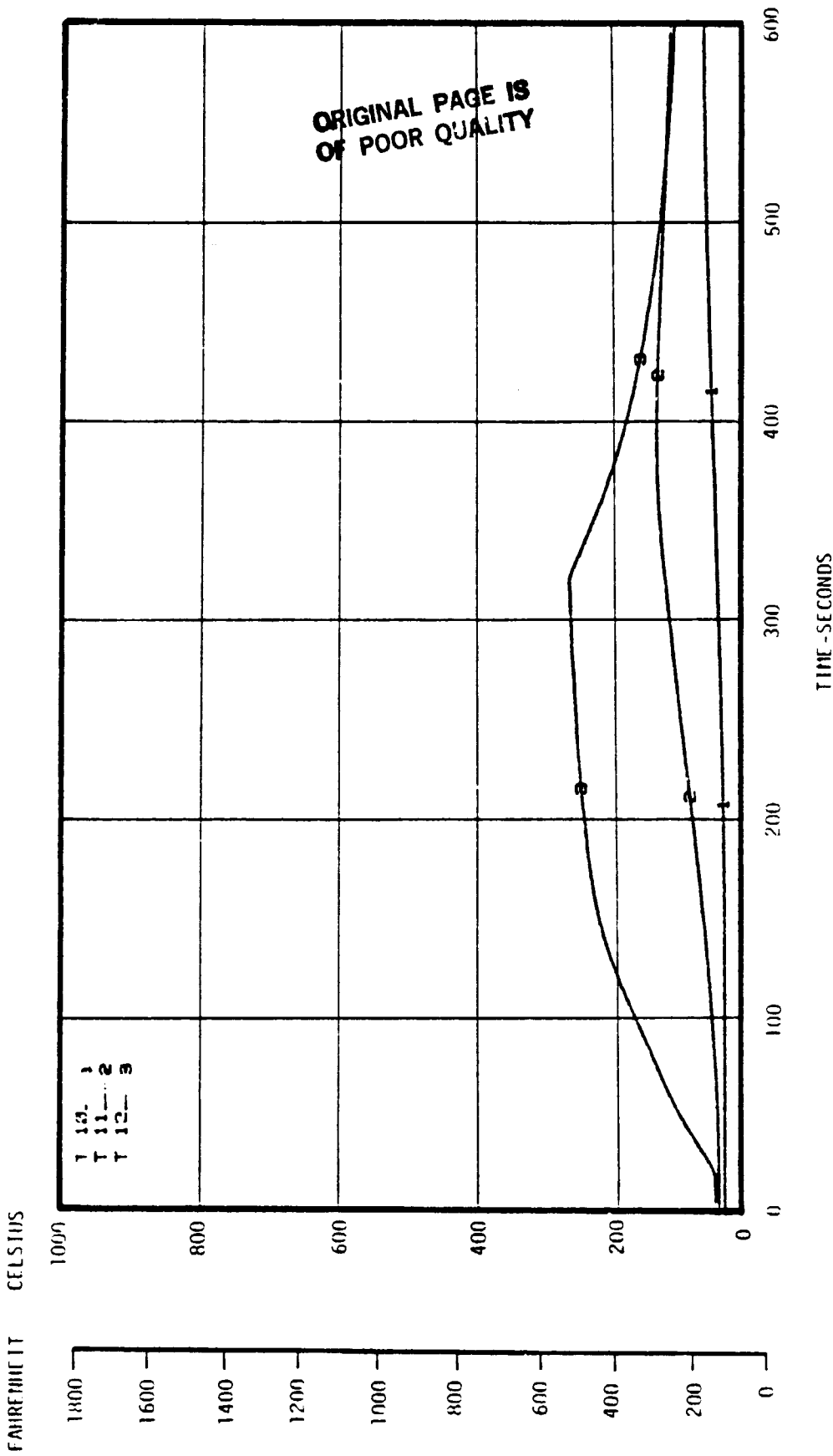


DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/15/82 11:40

NASA-AHS FULL SCALE CUSHION BURH TEST NUMBER 14

CUSHION CONSTRUCTION NUMBER 8.0

SEAT CUSHION TEMPERATURES

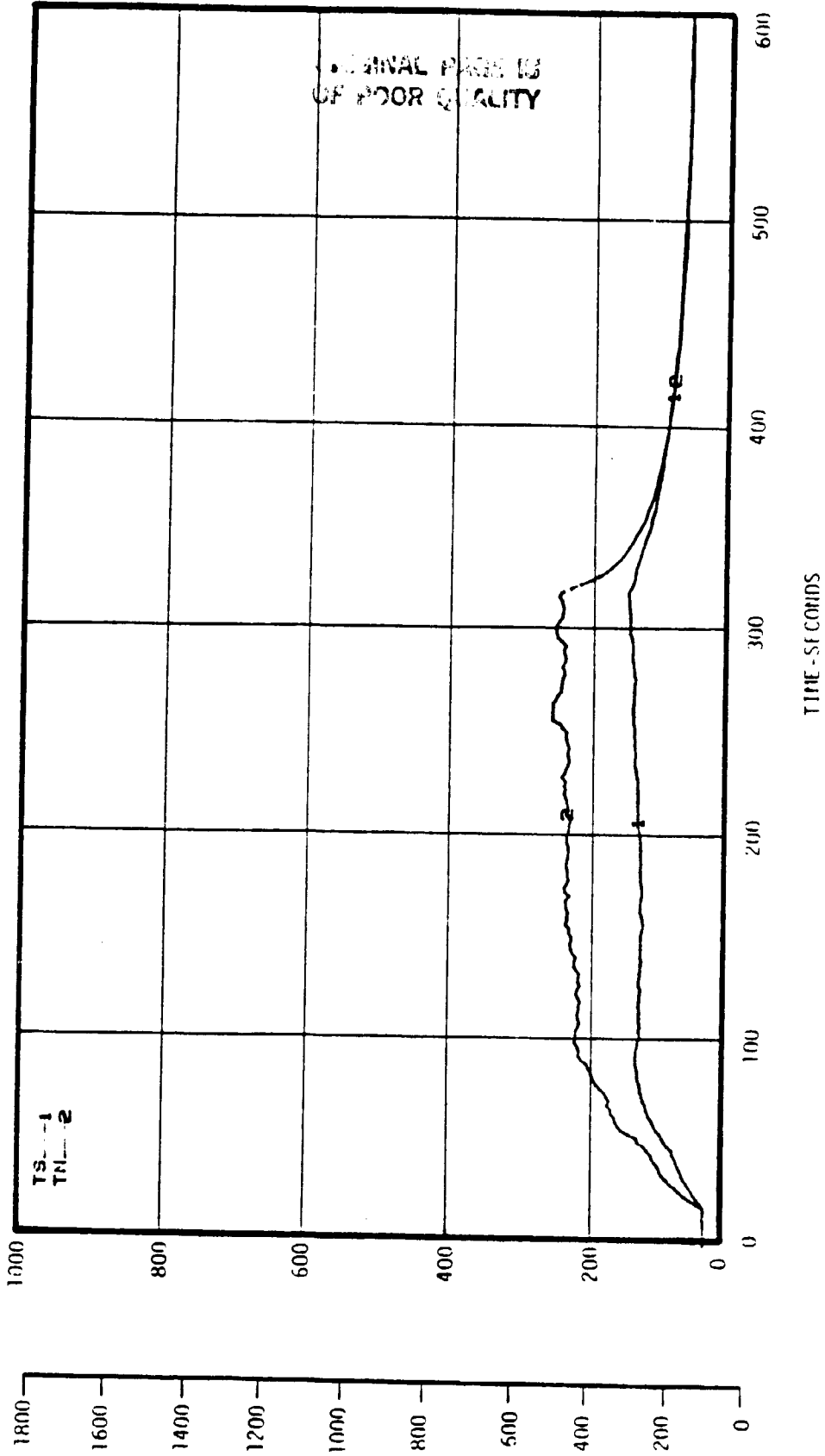


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DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 83-15-84C : 11-53
 NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER : 1
 CUSHION CONSTRUCTION NUMBER 6.3

CEILING TEMPERATURE

FAHRENHEIT CELSIUS

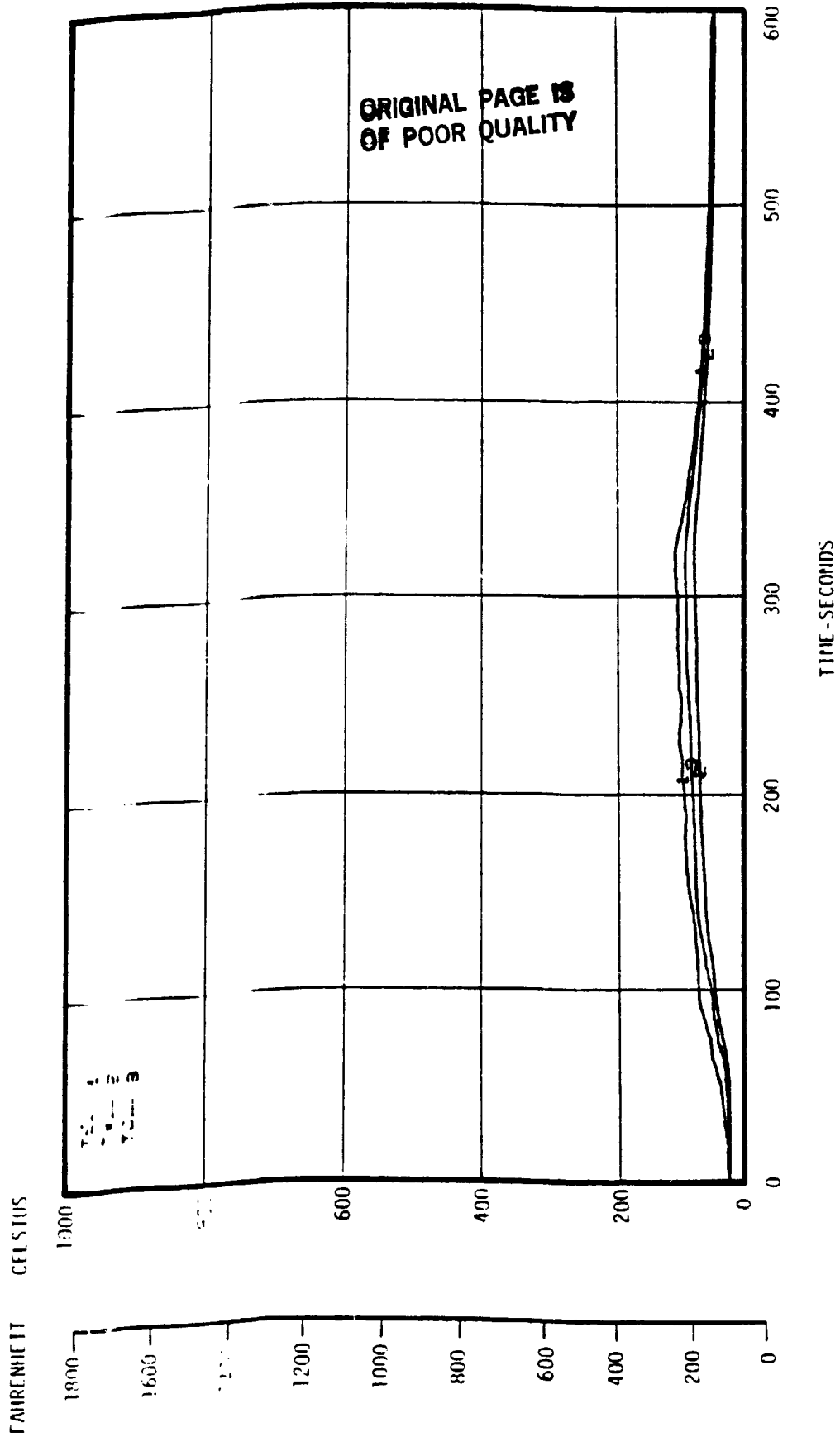


DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/15/82 11.40

MASA-AMES FULL SCALE CUSHION BURH TEST NUMBER 14

CUSHION CONSTRUCTION NUMBER 0.0

CETILING TEMPERATURE

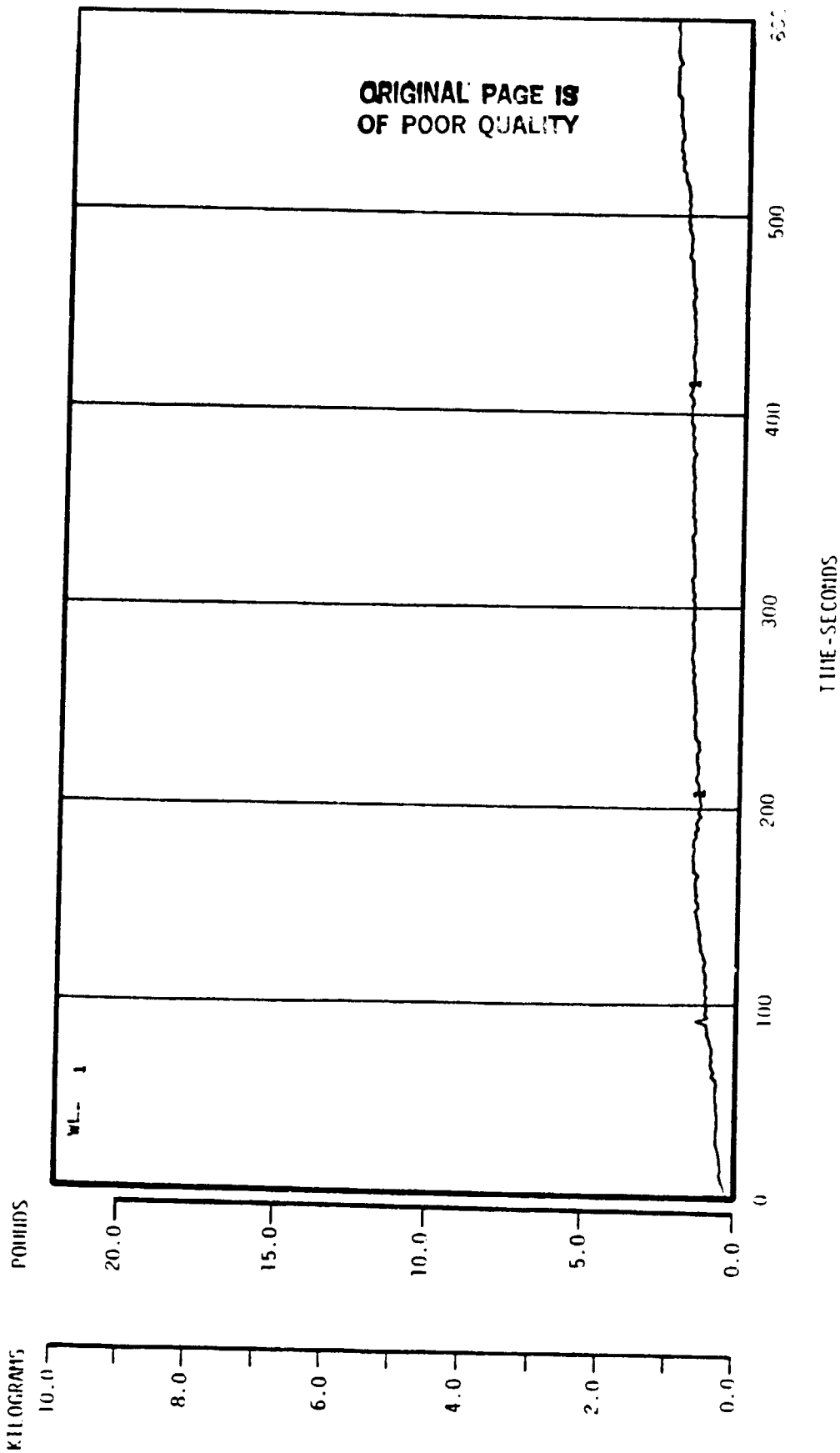


DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03.15/82 11.48

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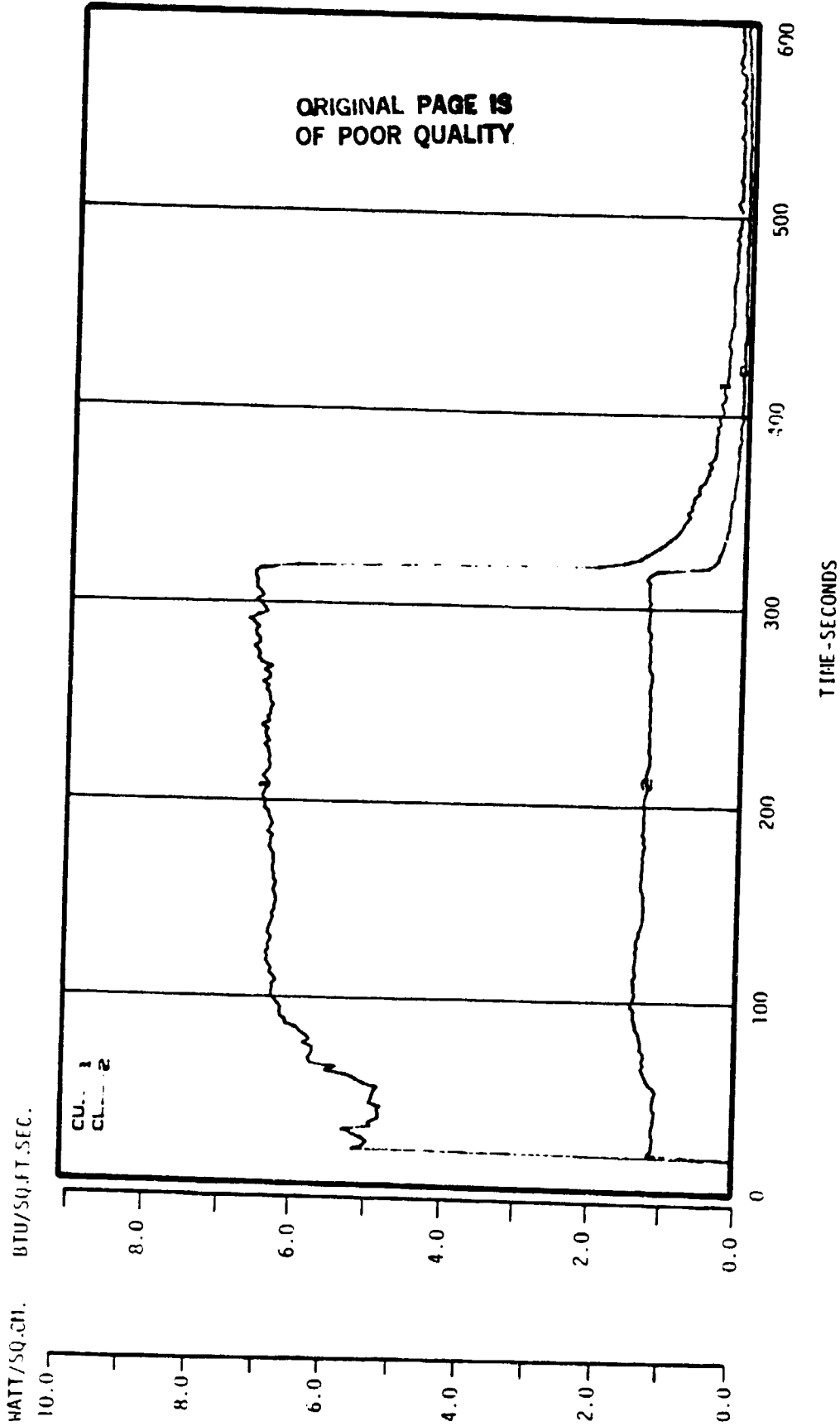
CUSHION CONSTRUCTION NUMBER 6.0

WEIGHT LOSS



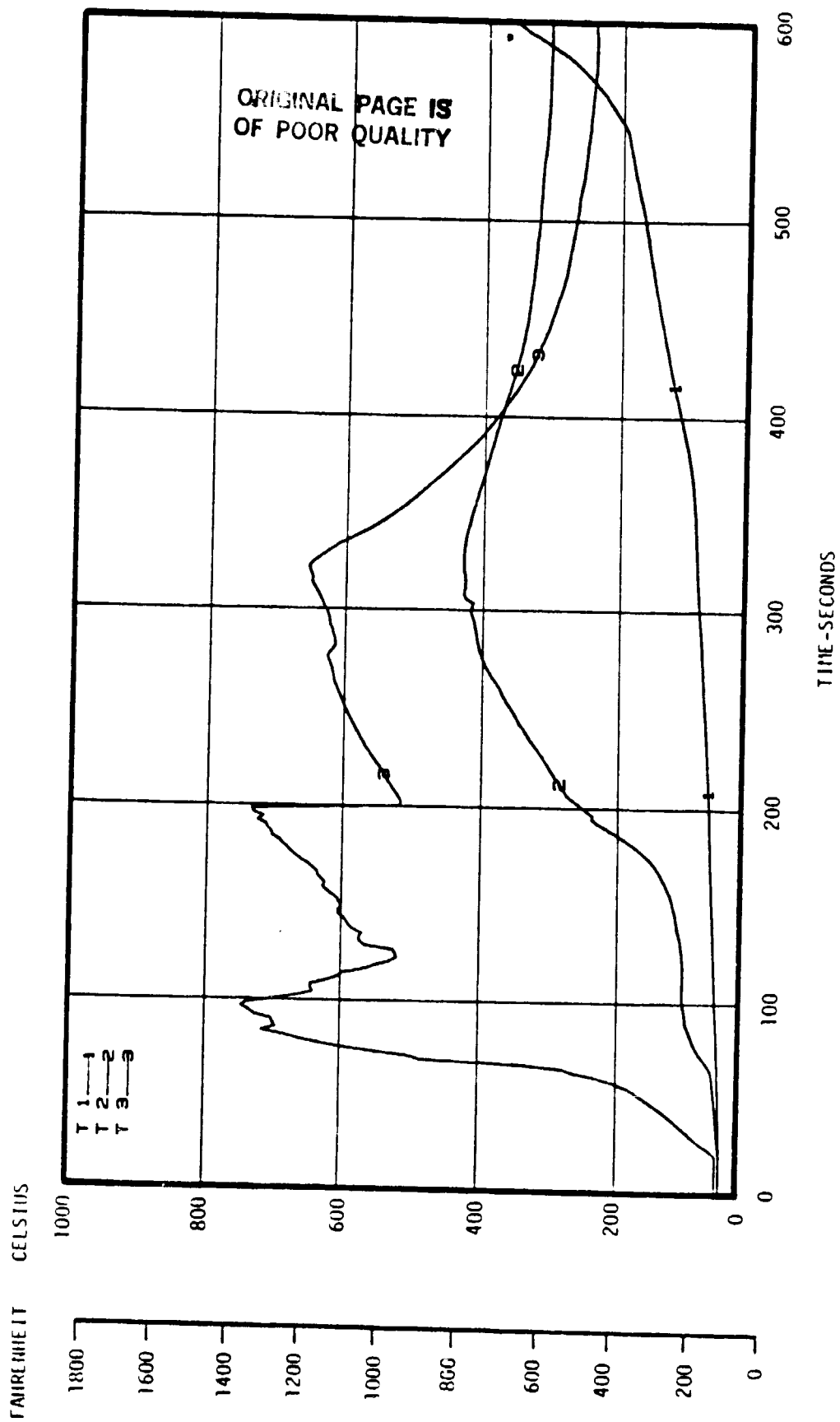
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NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 14
CUSHION CONSTRUCTION NUMBER 6.0

HEAT FLUX



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03, 15/82 14, 33
NASA-MES FULL SCALE CUSHION BURN TEST NUMBER 15
CUSHION CONSTRUCTION NUMBER 7.0

SEAT CUSHION TEMPERATURES

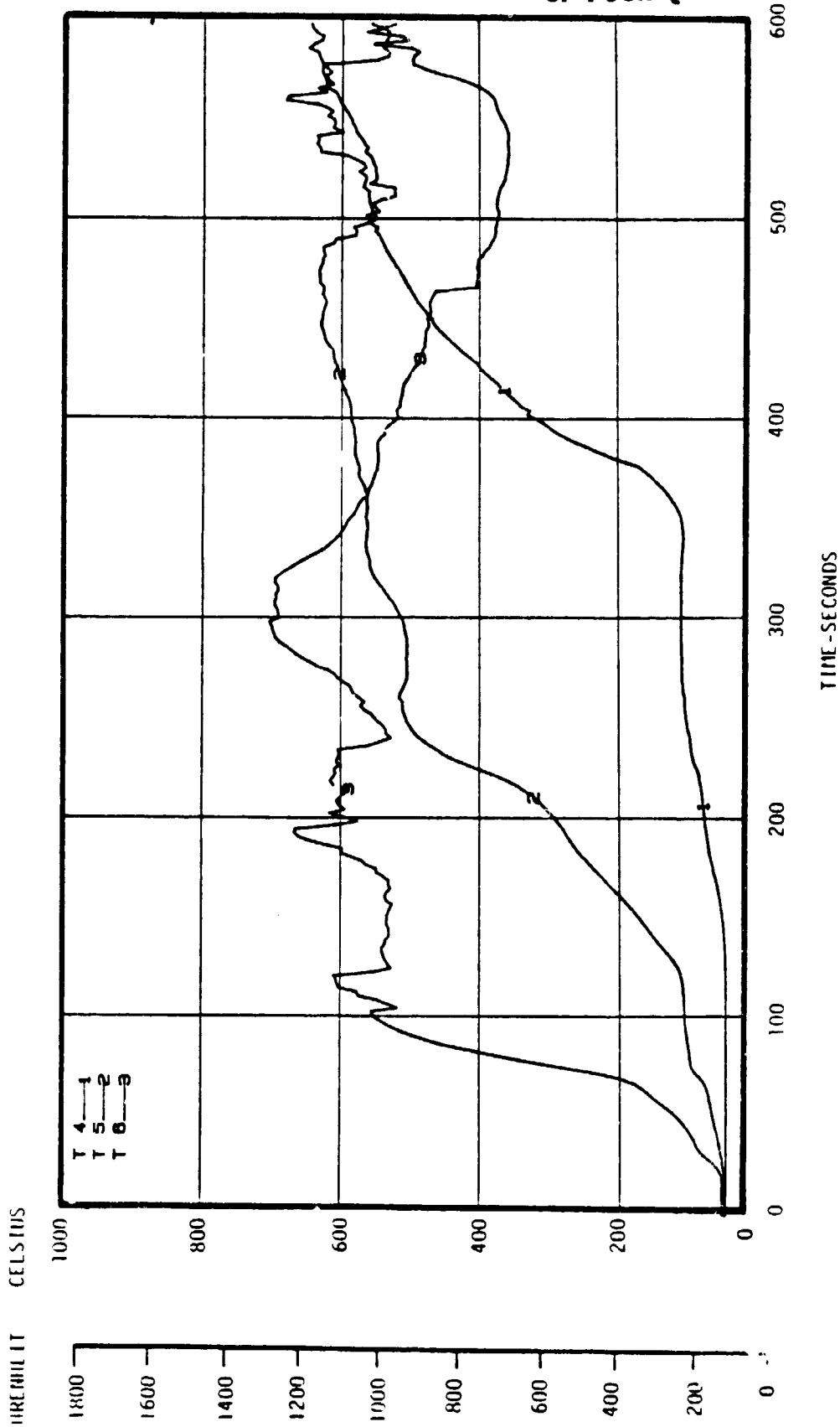


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DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/15/02 14, 93
NASA-AIES FULL SCALE CUSHION BURN TEST NUMBER 15
CUSHION CONSTRUCTION NUMBER 7.0

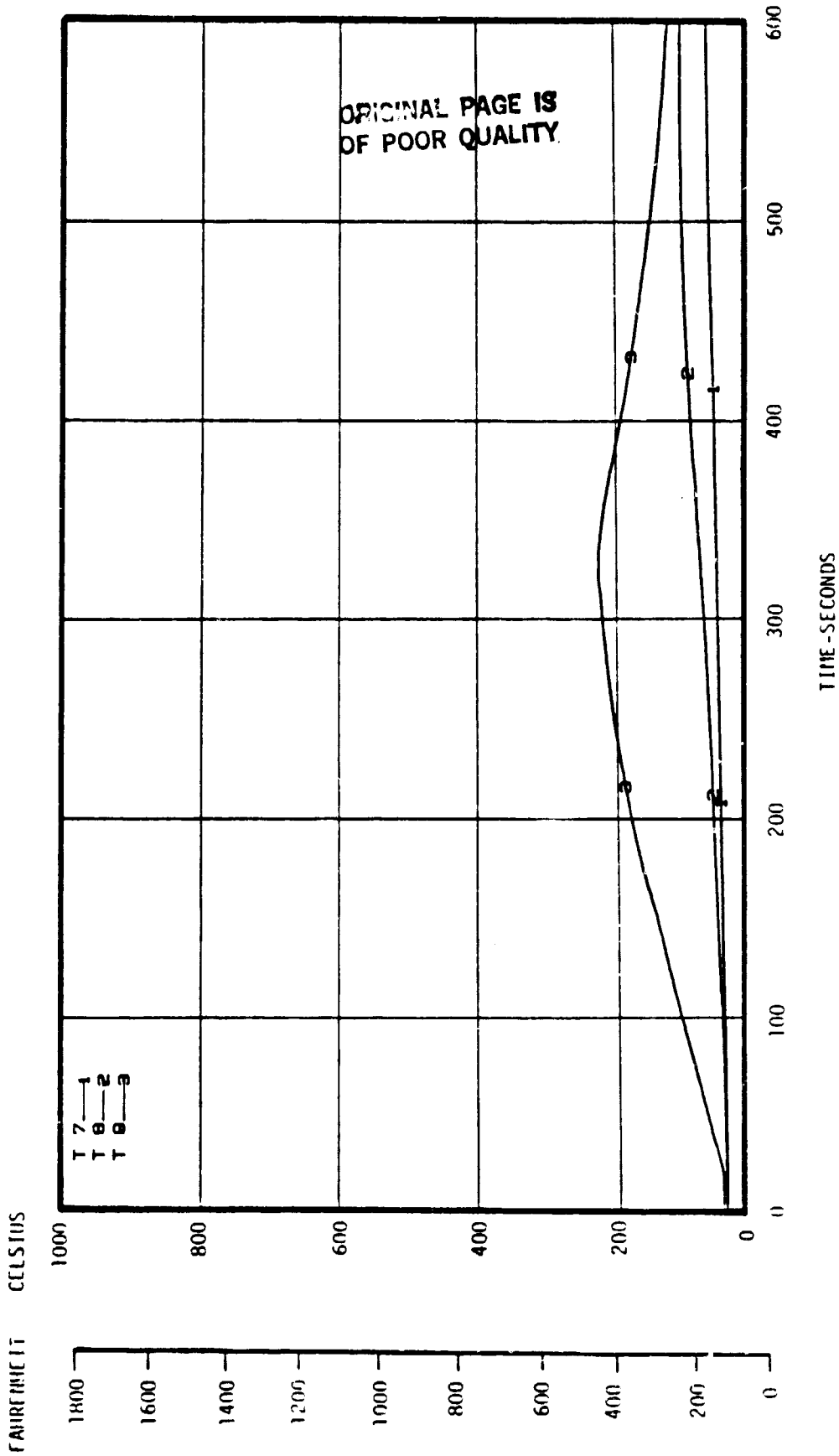
SEAT CUSHION TEMPERATURES



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NASA-AIES FULL SCALE CUSHION BURN TEST NUMBER 15
CUSHION CONSTRUCTION NUMBER 7.0

SEAT CUSHION TEMPERATURES

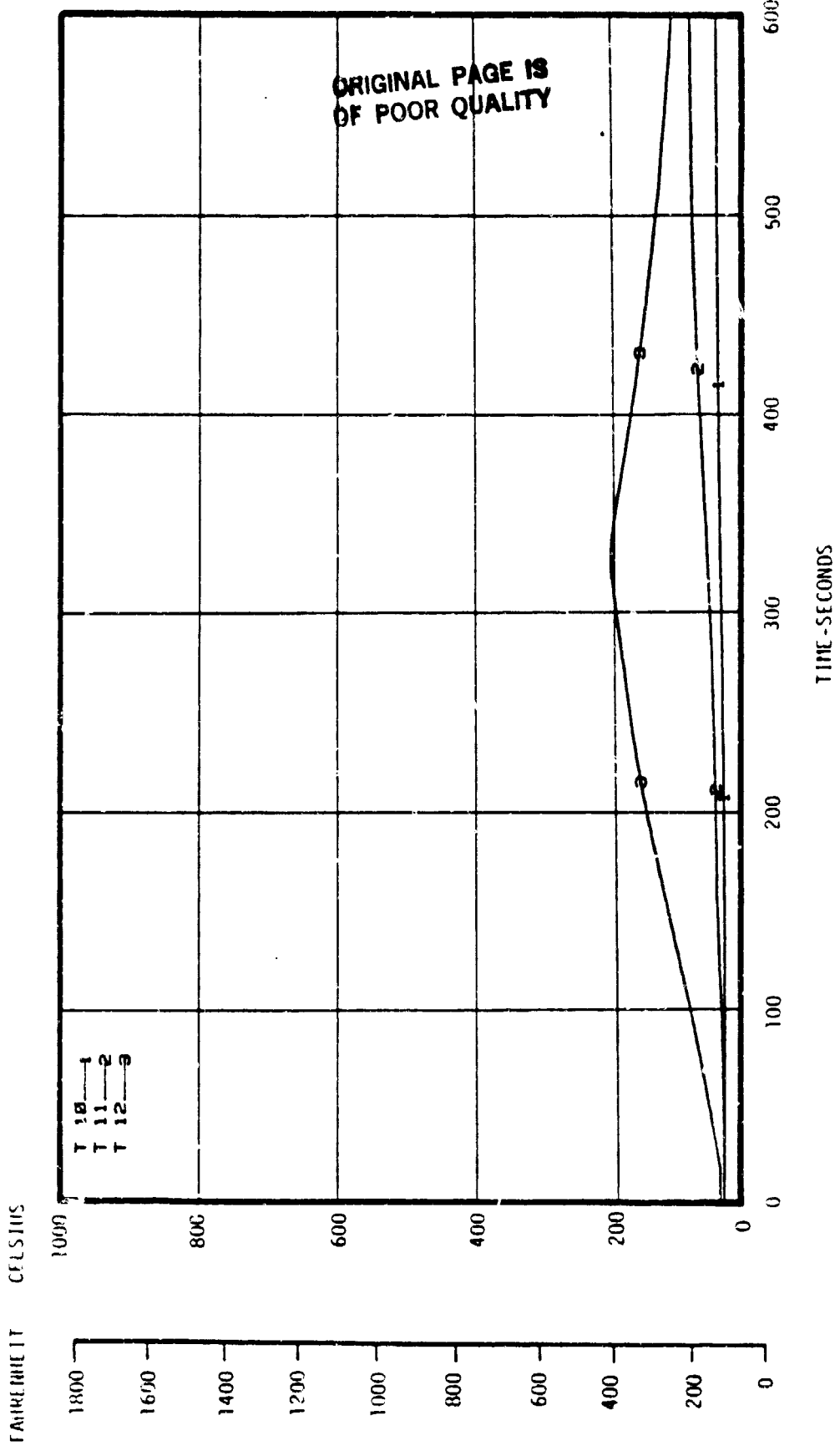


DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/15/82 14:33

NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 15

CUSHION CONSTRUCTION NUMBER 7.0

SEAT CUSHION TEMPERATURES

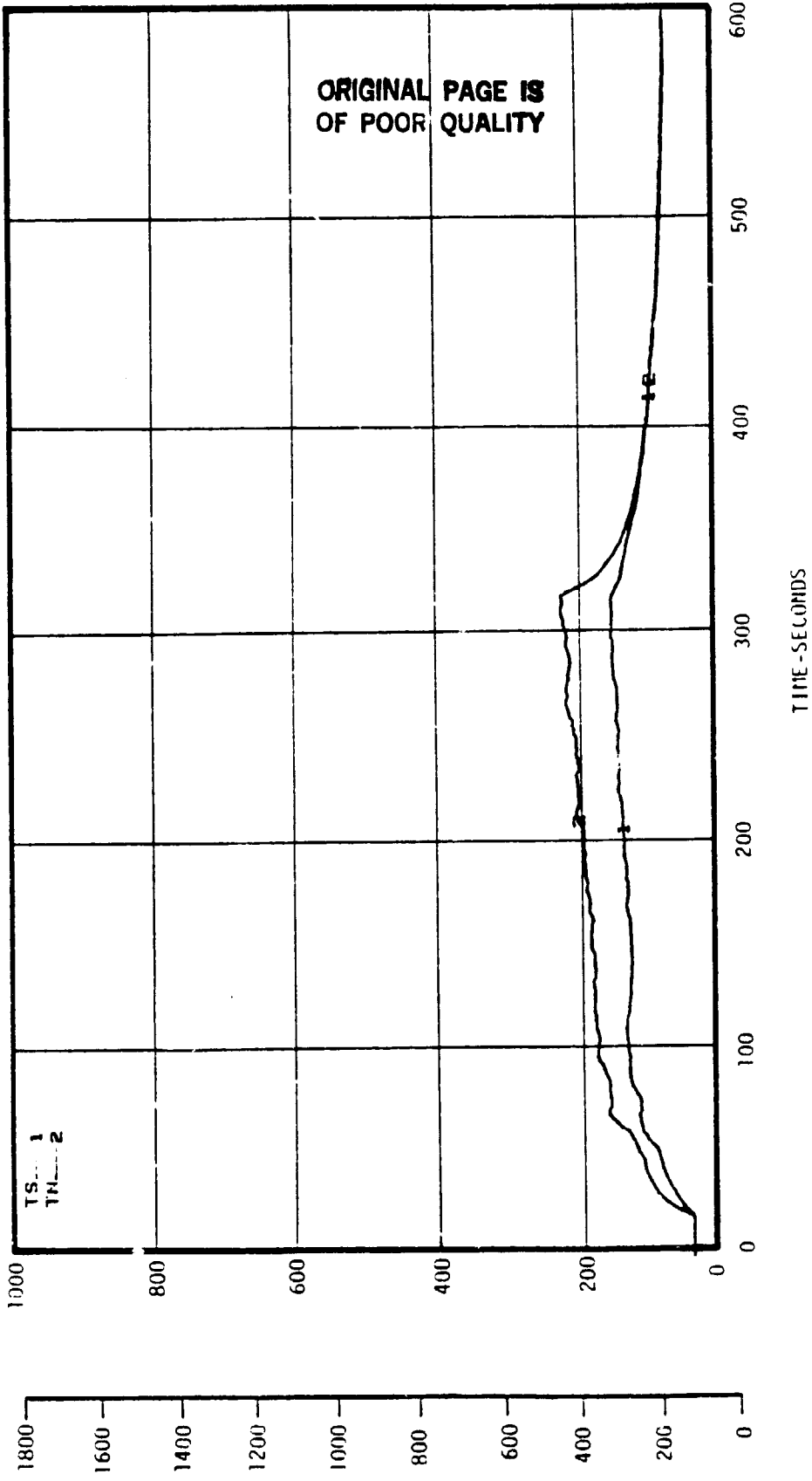


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DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 93/15/82 14.33
 NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 15
 CUSHION CONSTRUCTION NUMBER 7.8

CELL'S TEMPERATURE

FAHRENHEIT CELSIUS

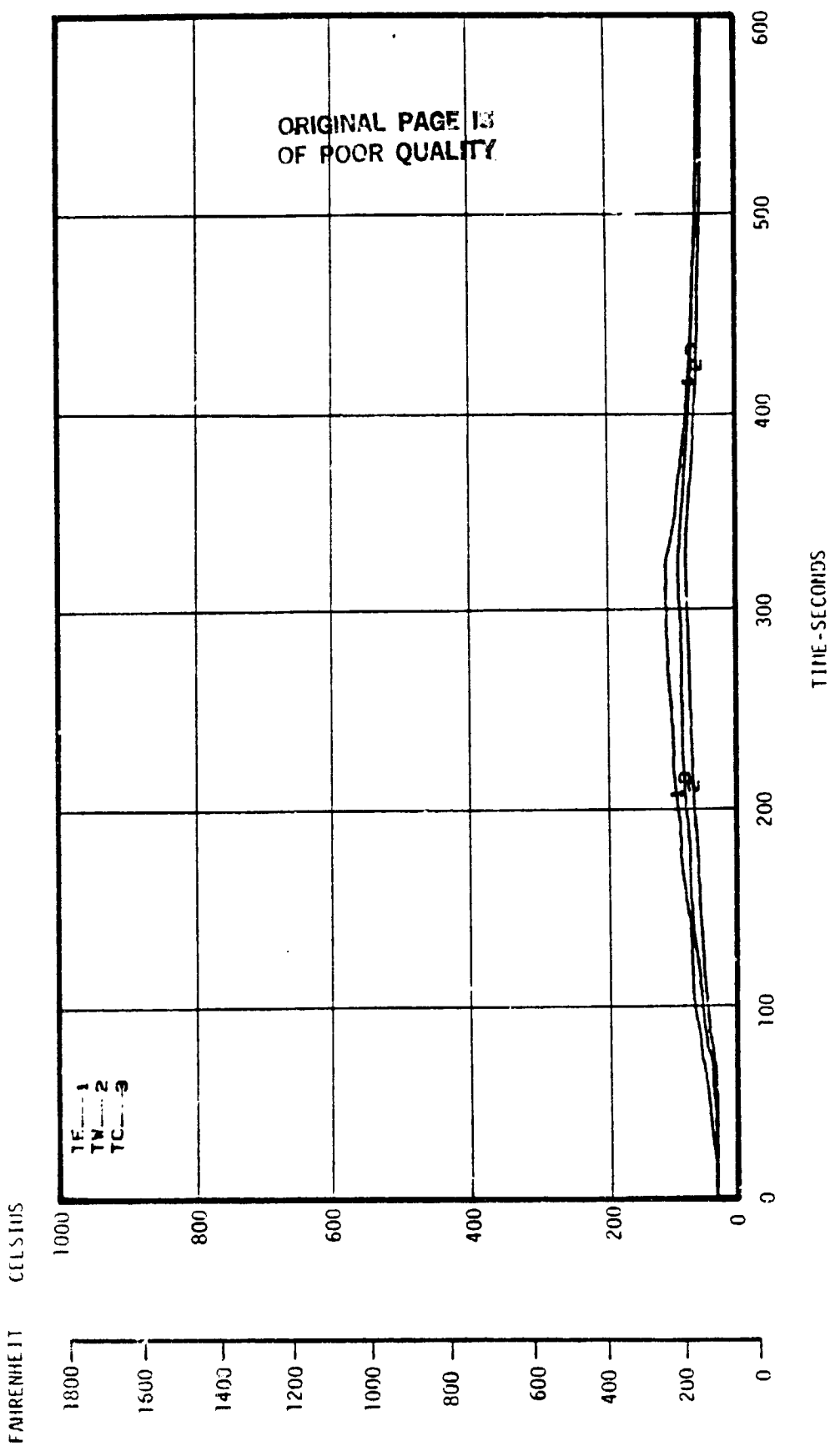


DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/15/82 14:33

NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 15

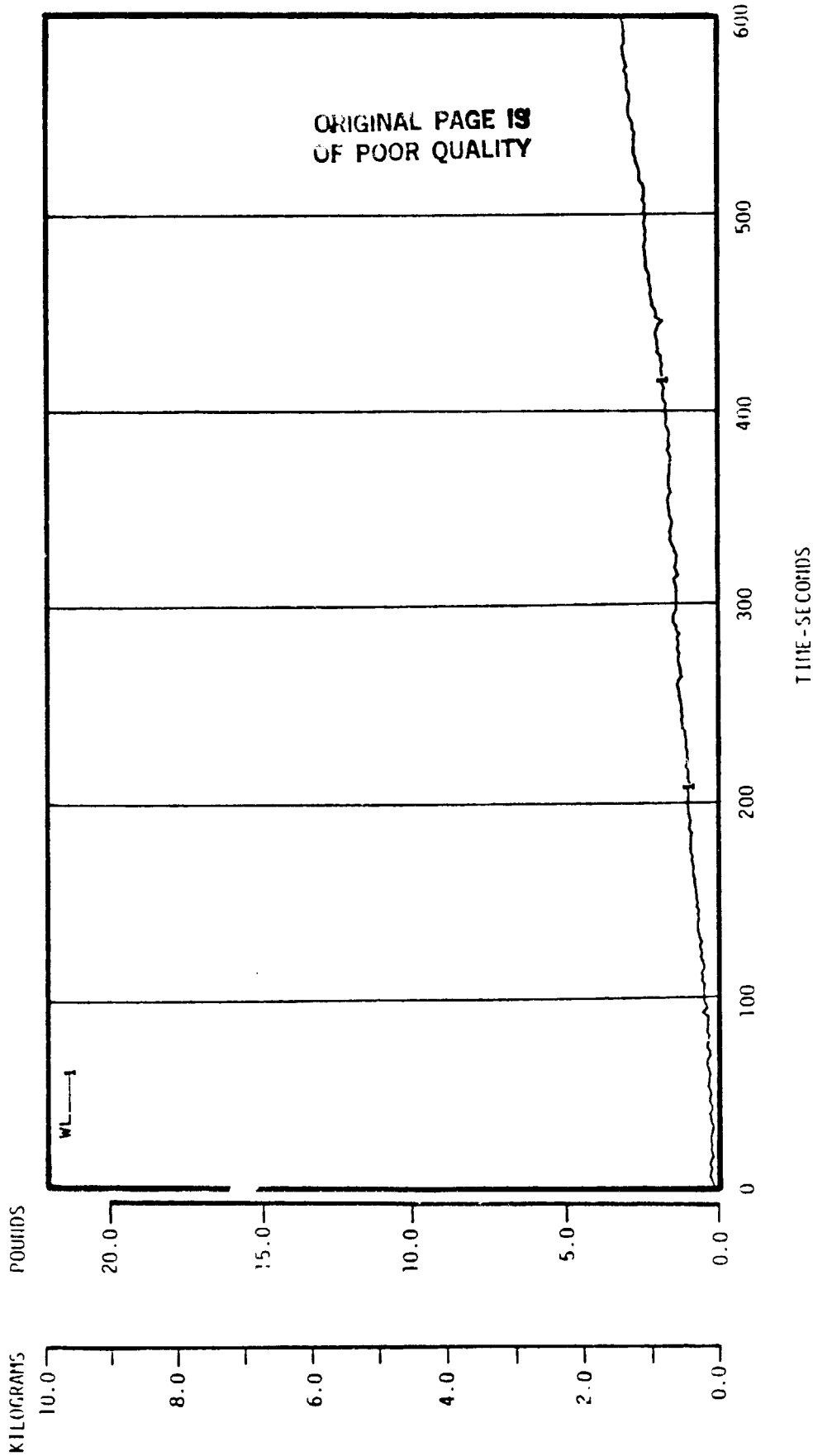
CUSHION CONSTRUCTION NUMBER 7.0

CEILING TEMPERATURE



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/15/87 14.33
NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 15
CUSHION CONSTRUCTION NUMBER 7.0

WEIGHT LOSS

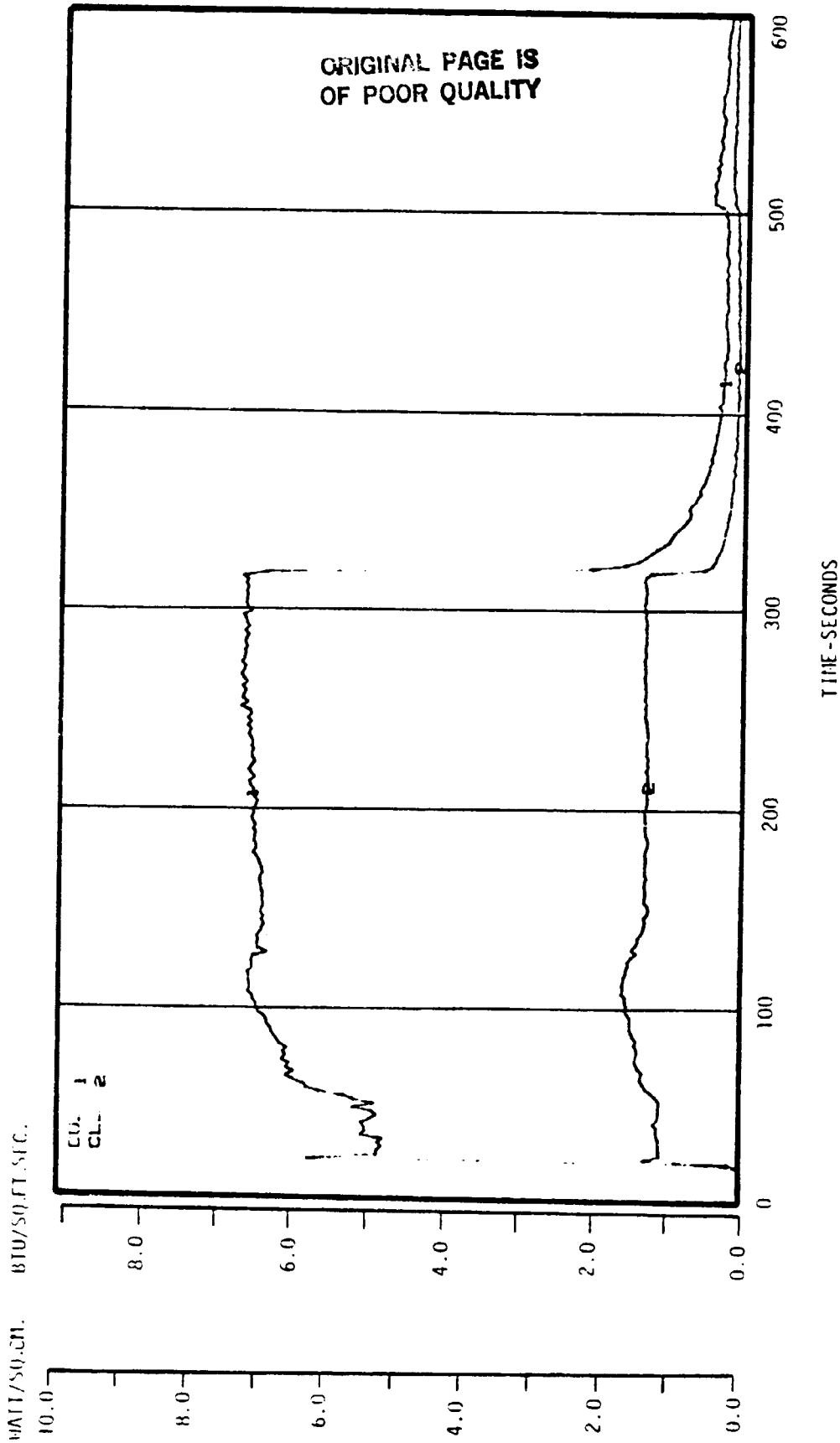


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NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 15

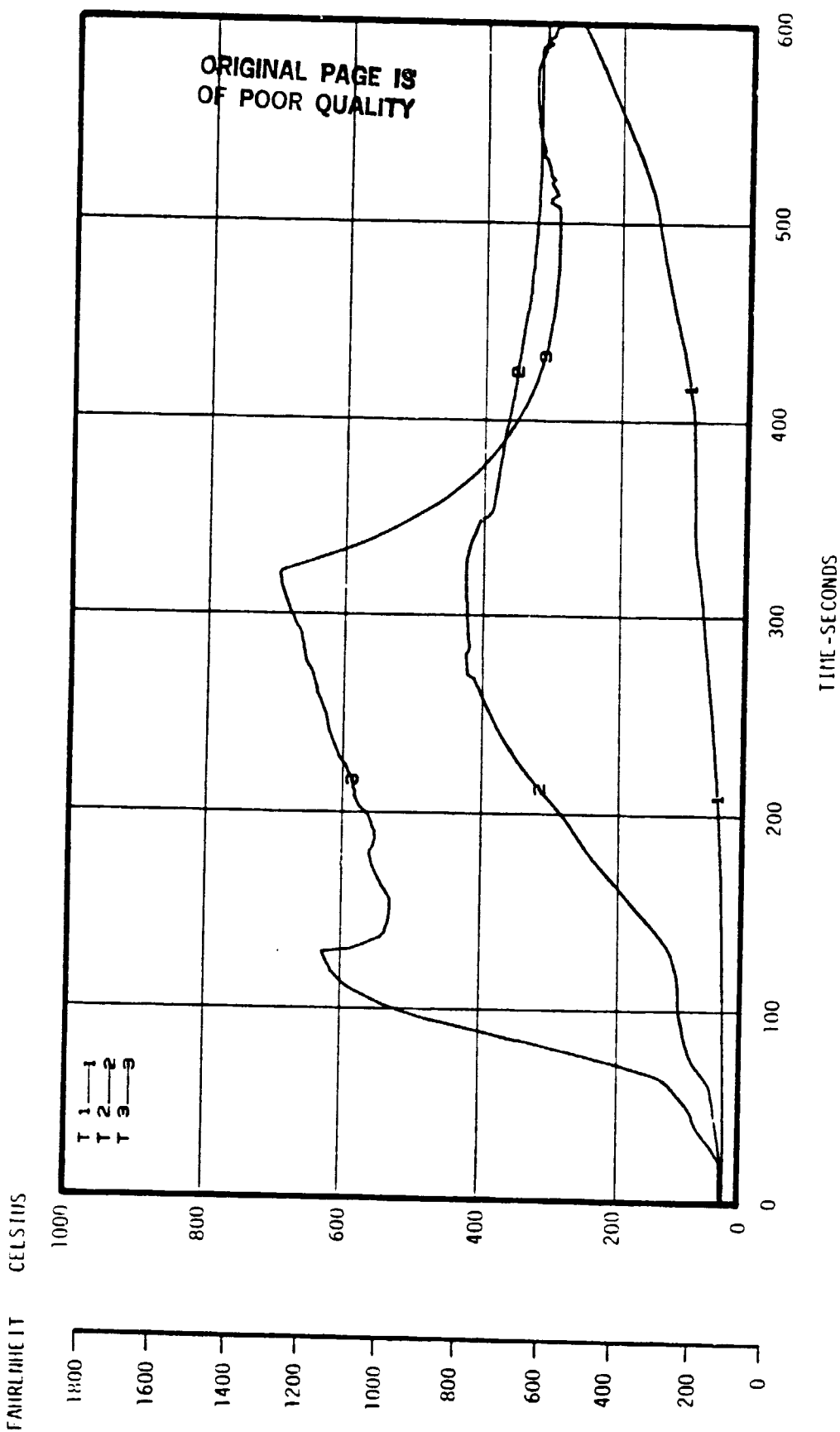
CUSHION CONSTRUCTION NUMBER 7.0

HEAT FLUX



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 3-16-82 88, 59
NASA-NIES FULL SCALE CUSHION BURN TEST NUMBER : 6
CUSHION CONSTRUCTION NUMBER 7.0

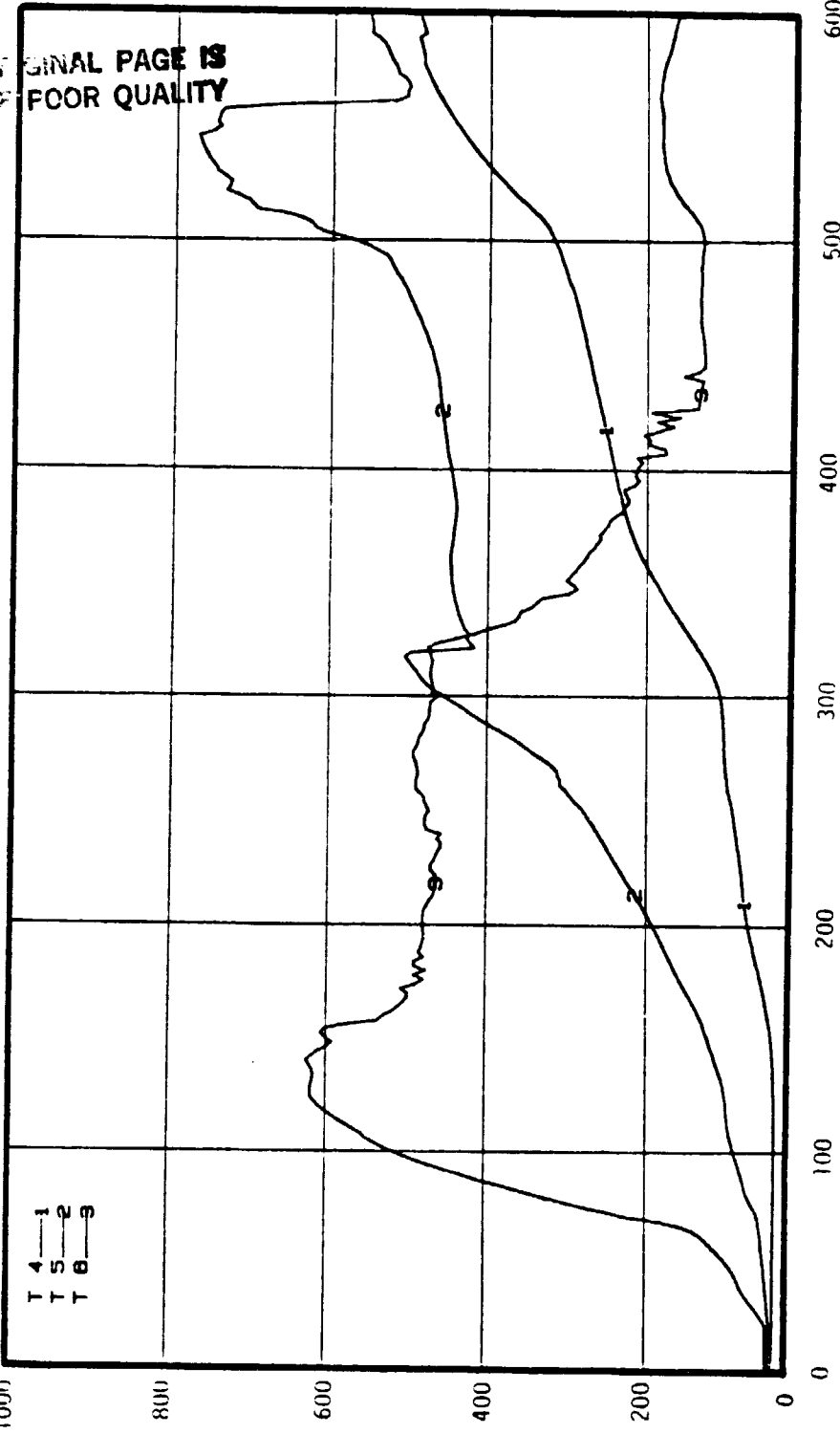
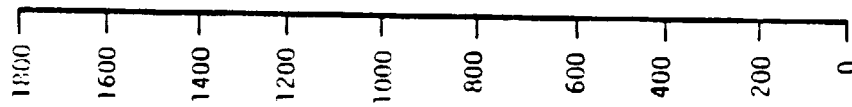
SEAT CUSHION TEMPERATURES



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/18/62 00.50
 NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 18
 CUSHION CONSTRUCTION NUMBER 7.0

SEAT CUSHION TEMPERATURES

TEMPERATURE CELSIUS

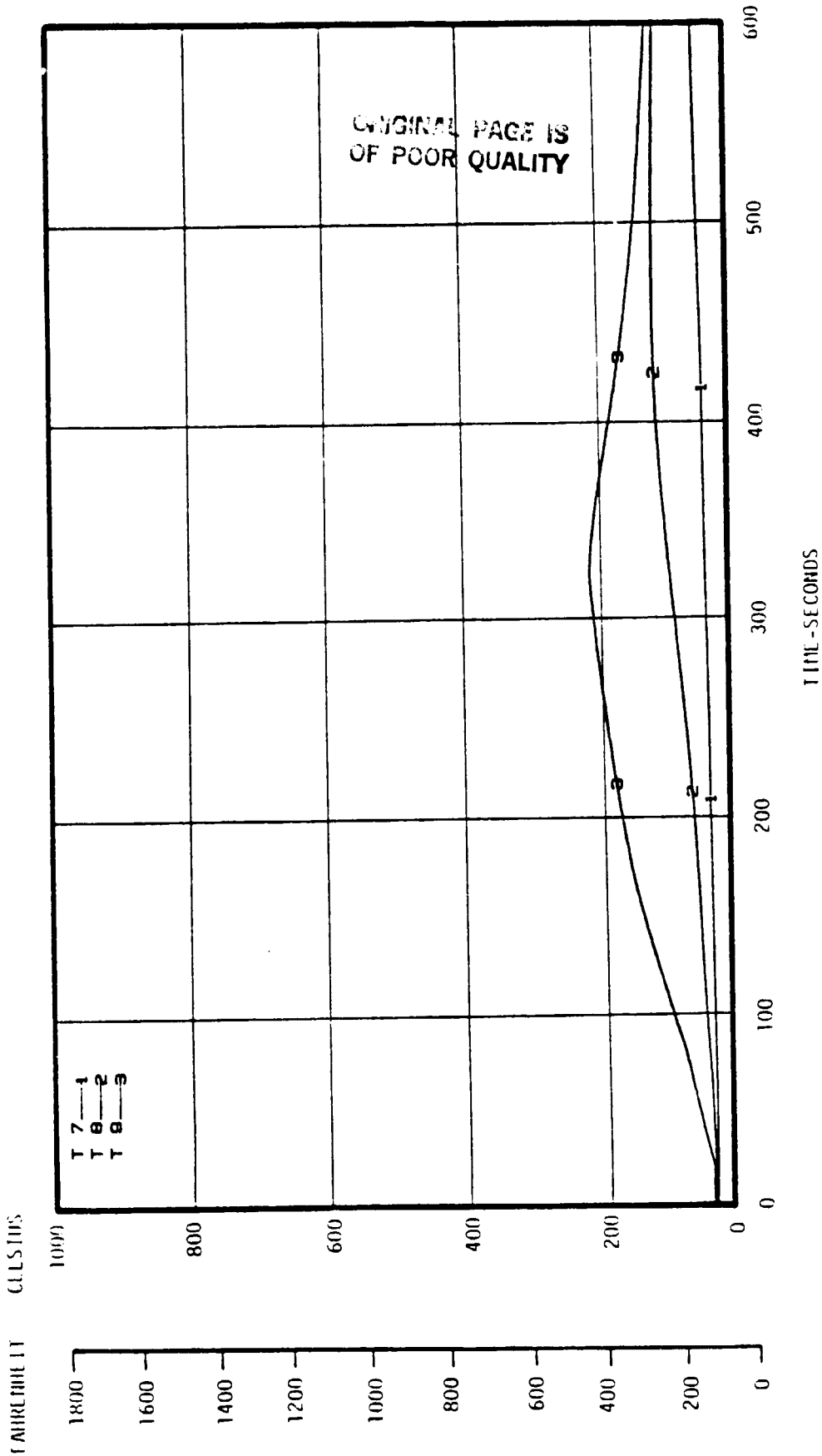


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TIME-SECONDS

DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/16/62 08, 59
 NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 10
 CUSHION CONSTRUCTION NUMBER 7.0

SEAT CUSHION TEMPERATURES

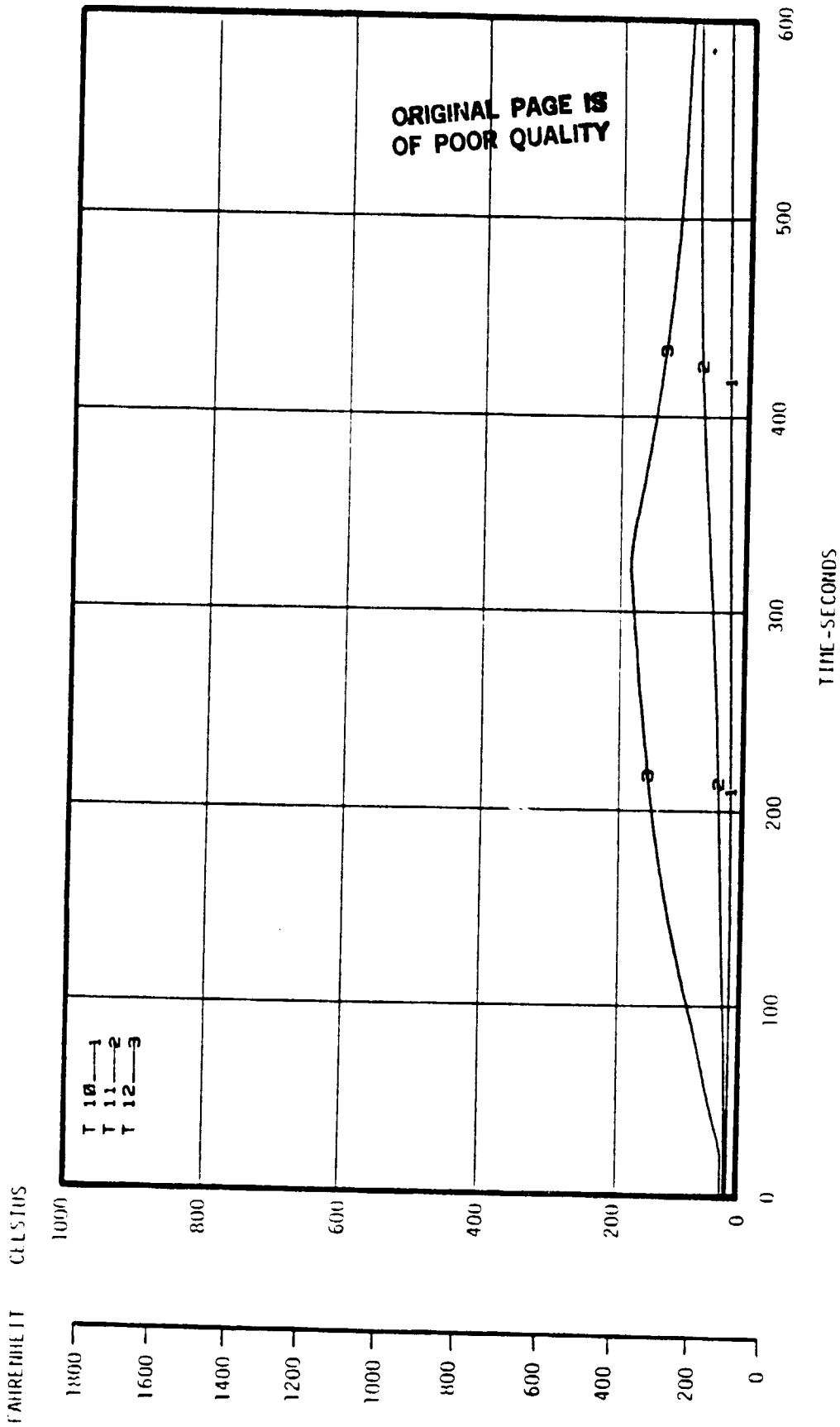


DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/18/82 08.59

NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 10

CUSHION CONSTRUCTION NUMBER 7.0

SEAT CUSHION TEMPERATURES



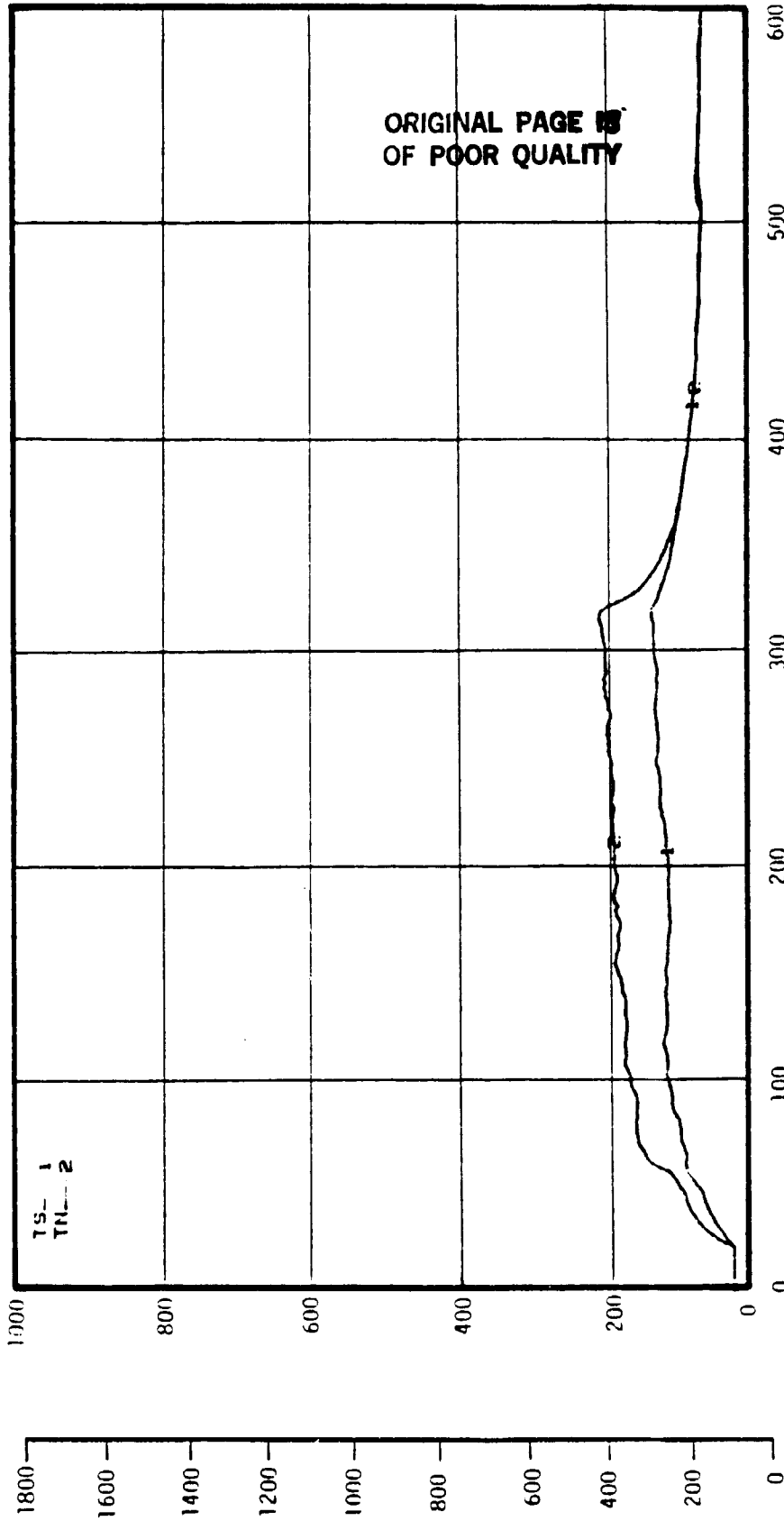
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DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/16/02 08.50
 NASA-MES FULL SCALE CUSHION BURN TEST NUMBER 10
 CUSHION CONSTRUCTION NUMBER 7.0

CEILING TEMPERATURE

FAHRENHEIT

CELSIUS



TIME - SECONDS

DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/16/82 04.50

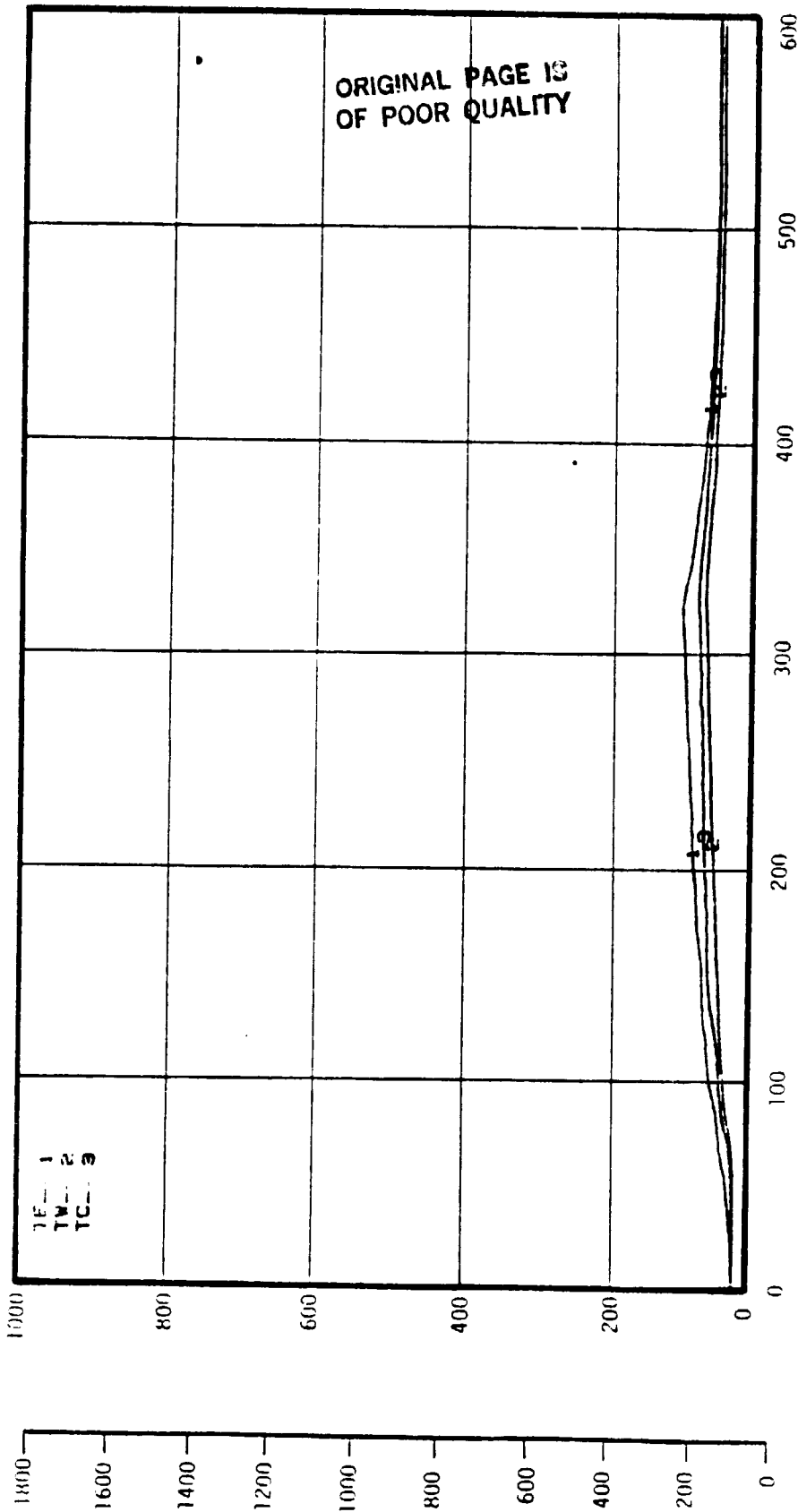
NASA-MES FULL SCALE CUSHION BURN TEST NUMBER 18

CUSHION CONSTRUCTION NUMBER 7.0

CEILING TEMPERATURE

FAHRENHEIT

CELSIUS



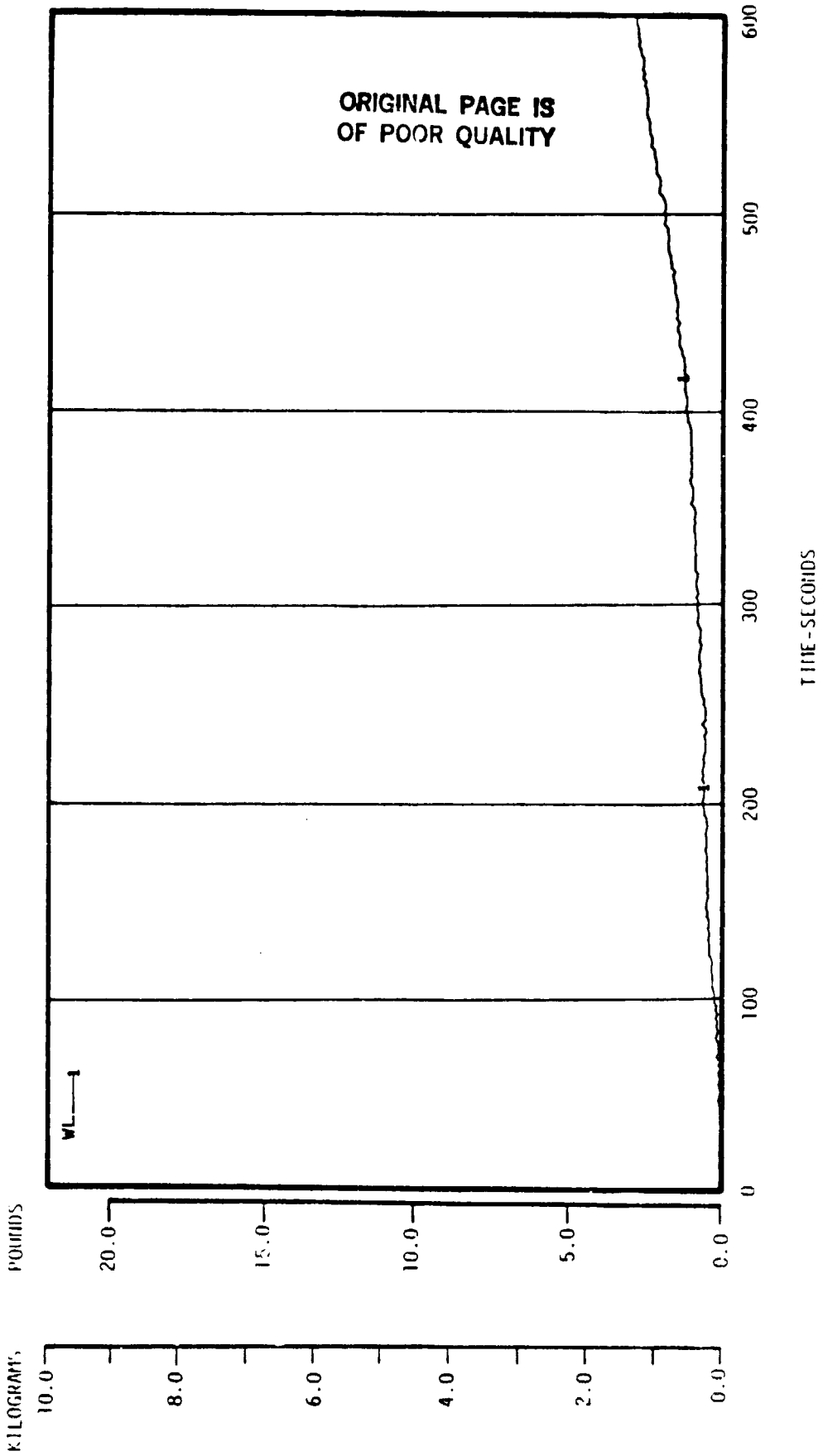
TIME - SECONDS

DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03-18/62 06.58

NASA-NIES FULL SCALE CUSHION BURN TEST NUMBER 16

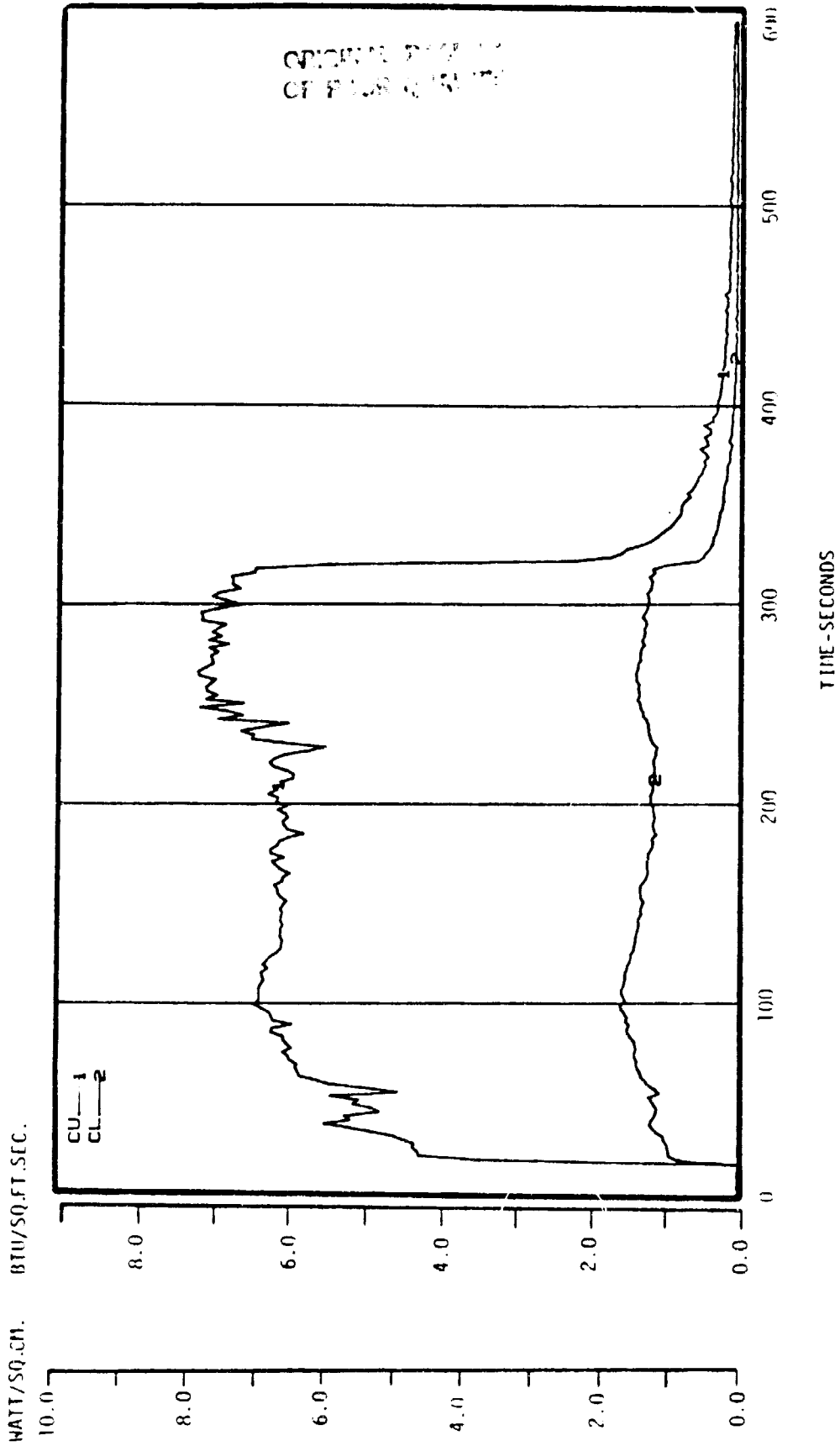
CUSHION CONSTRUCTION NUMBER 7.0

WEIGHT LOSS



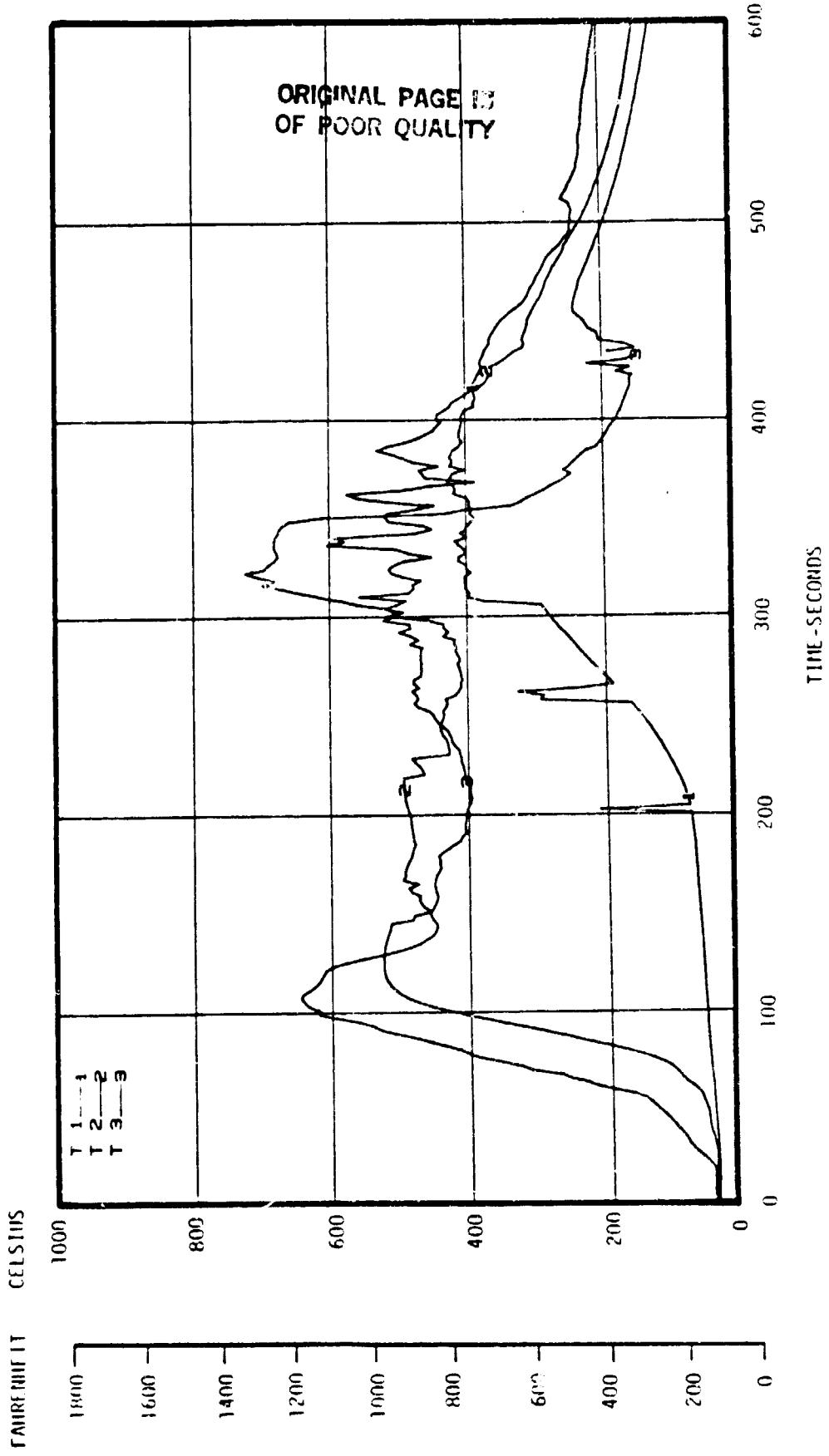
Douglas Aircraft Cabin Fire Simulator 03/18/82 08:58
NASA-Ames Full Scale Cushion Burn Test Number 18
Cushion Construction Number 7.0

HEAT FLUX



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/1E/92 15.06
NASA-MES FULL SCALE CUSHION BURN TEST NUMBER 18
CUSHION CONSTRUCTION NUMBER 8.0

SEAT CUSHION TEMPERATURES

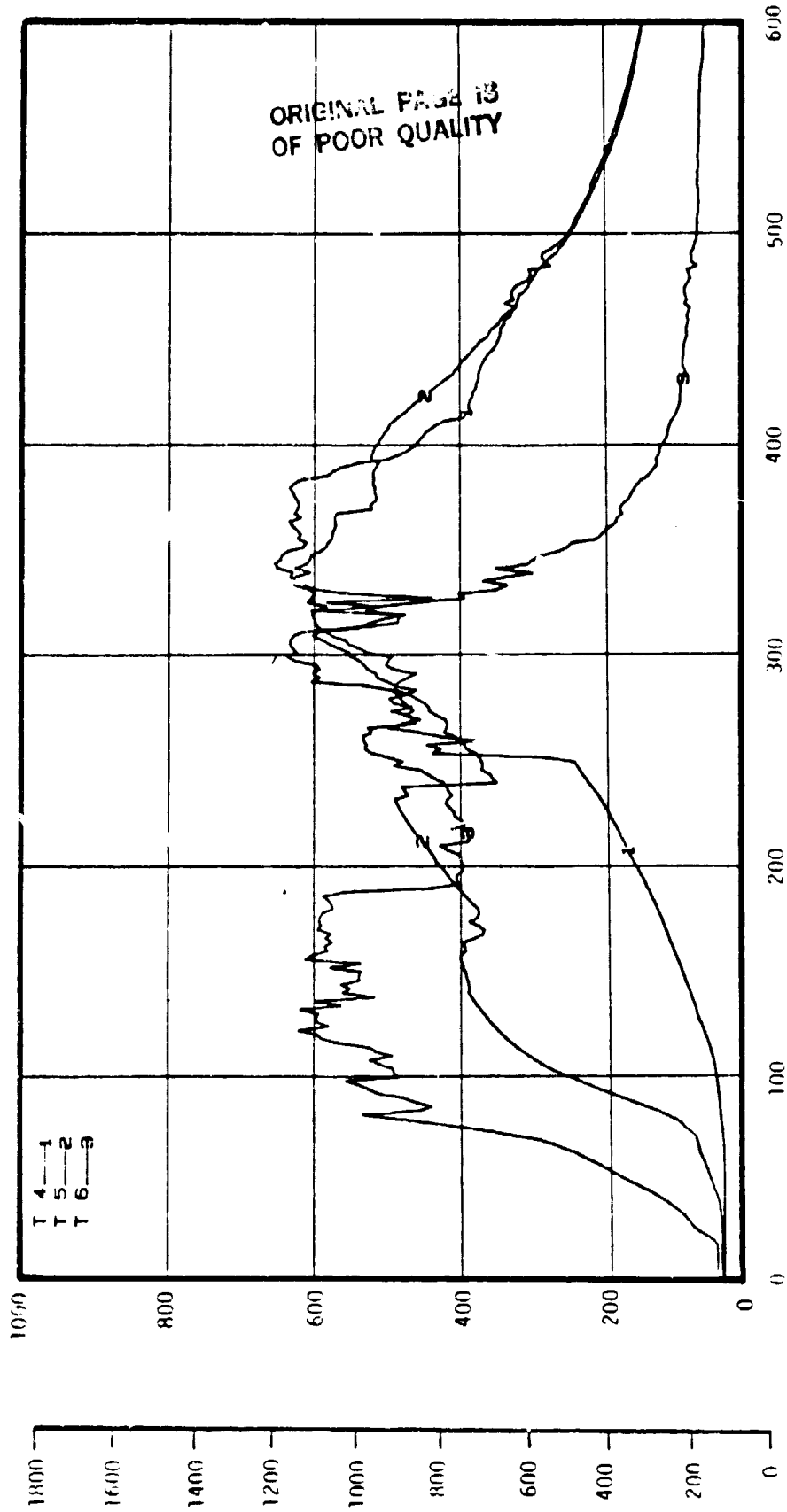


DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/16/82 15.06
NASA-AMES FULL SCALE CUSHION BURST TEST NUMBER 10
CUSHION CONSTRUCTION NUMBER 8.0

SEAT CUSHION TEMPERATURES

FAHRENHEIT

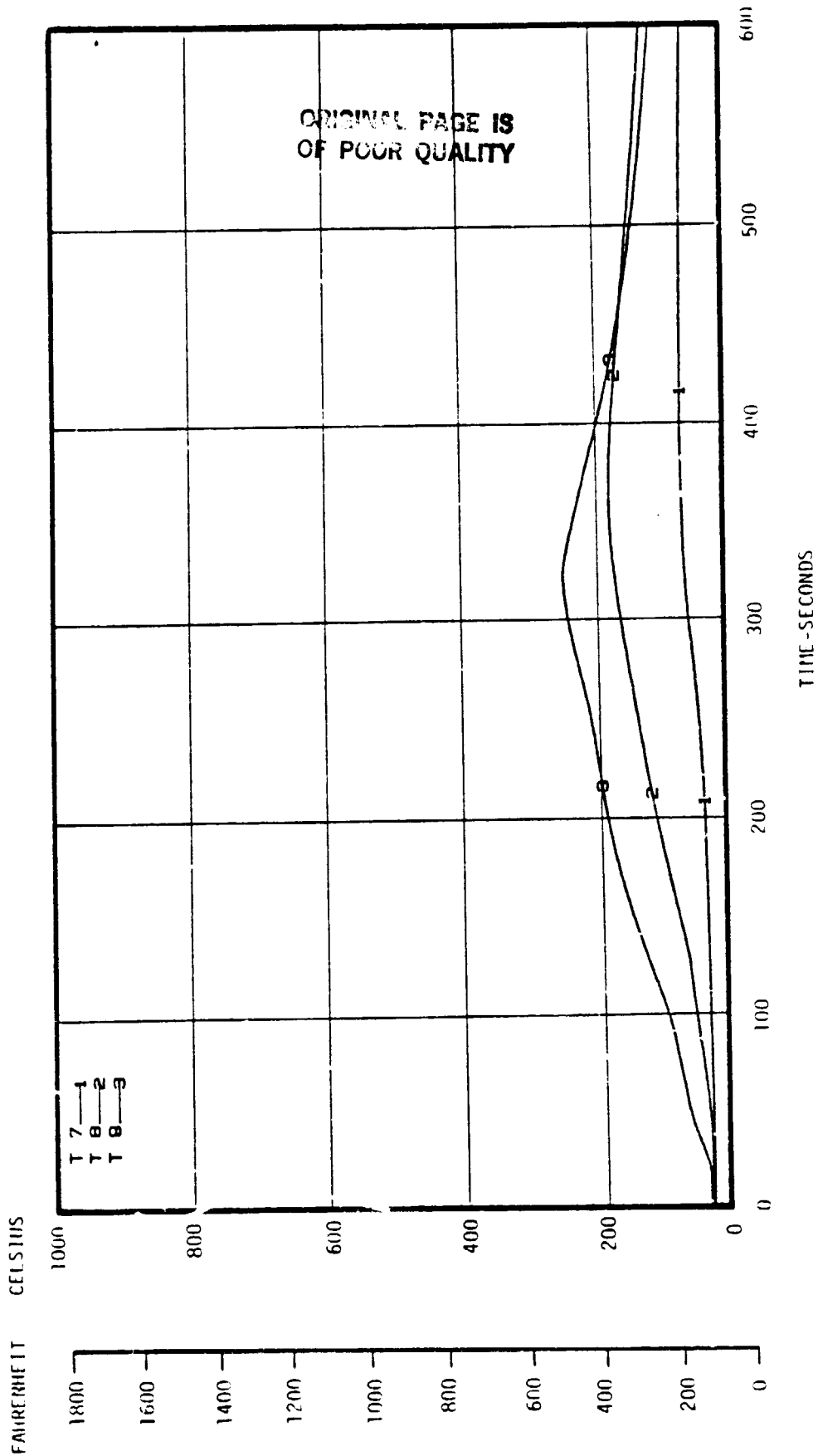
CELSIUS



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DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/16/62 15.00
NASA-AFES FULL SCALE CUSHION BURN TEST NUMBER 18
CUSHION CONSTRUCTION NUMBER 8.0

SEAT CUSHION TEMPERATURES

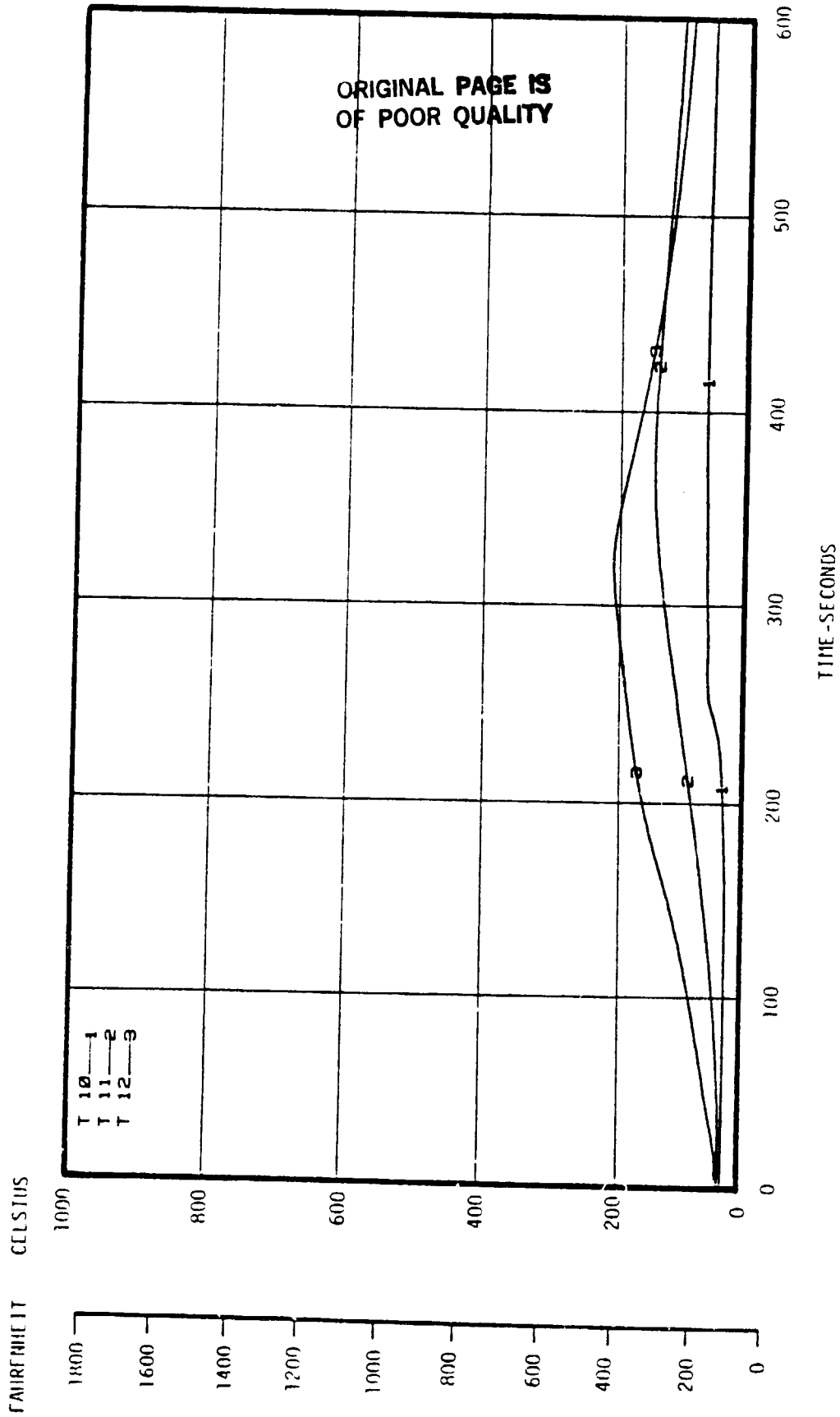


DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/16/62 15.06

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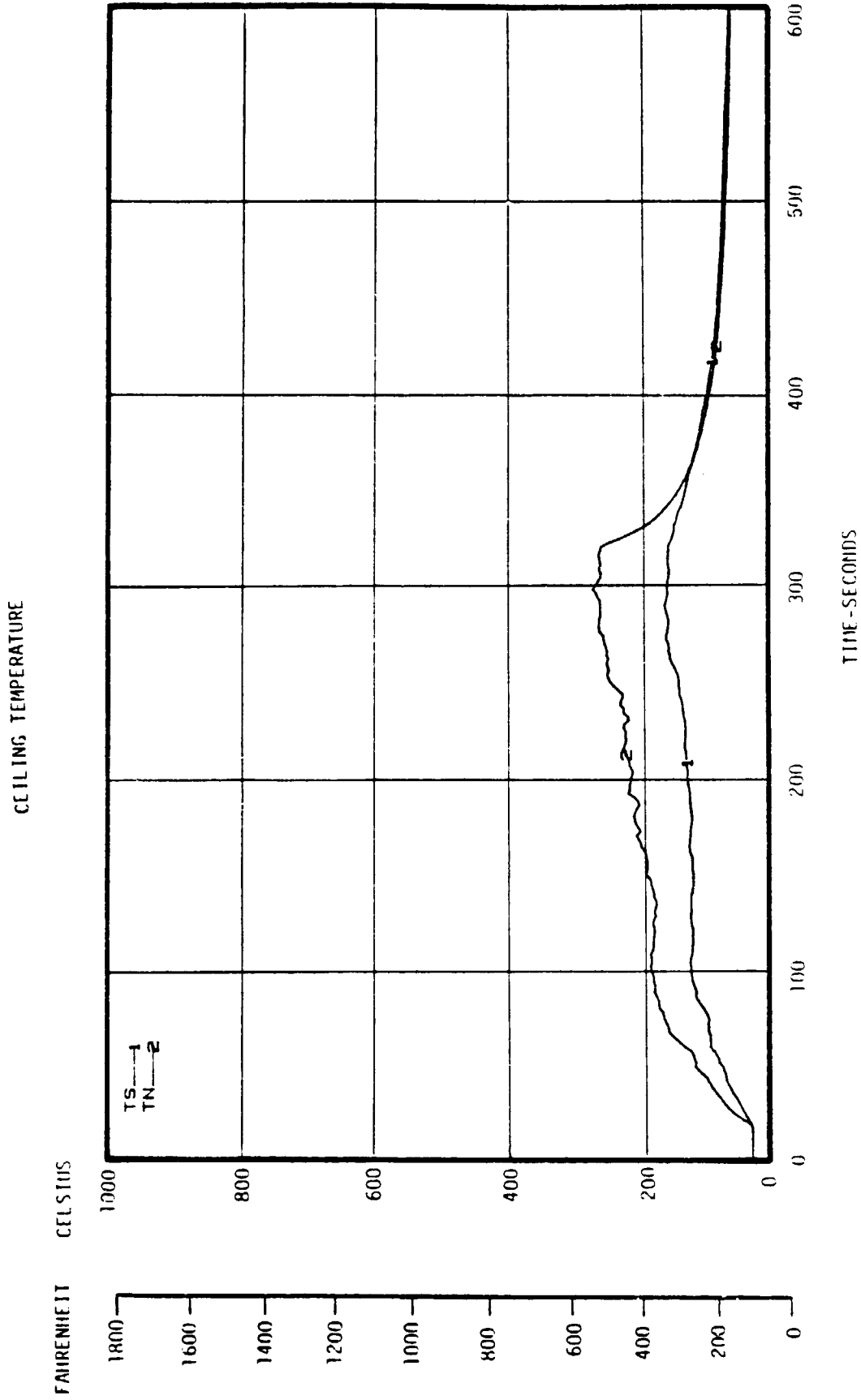
CUSHION CONSTRUCTION NUMBER 6.0

SEAT CUSHION TEMPERATURES

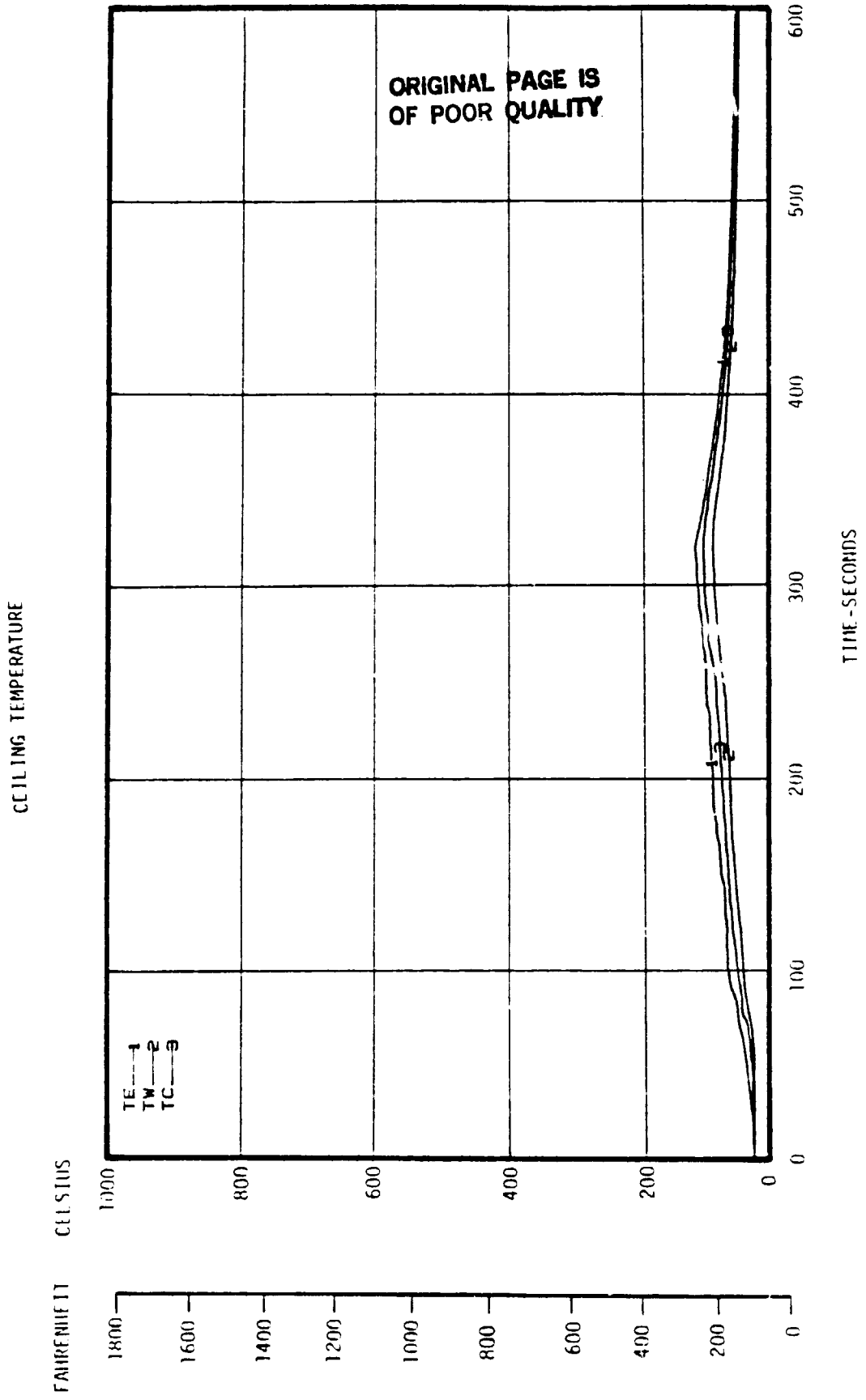


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DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 09/18/82 15.06
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 CUSHION CONSTRUCTION NUMBER 8.0

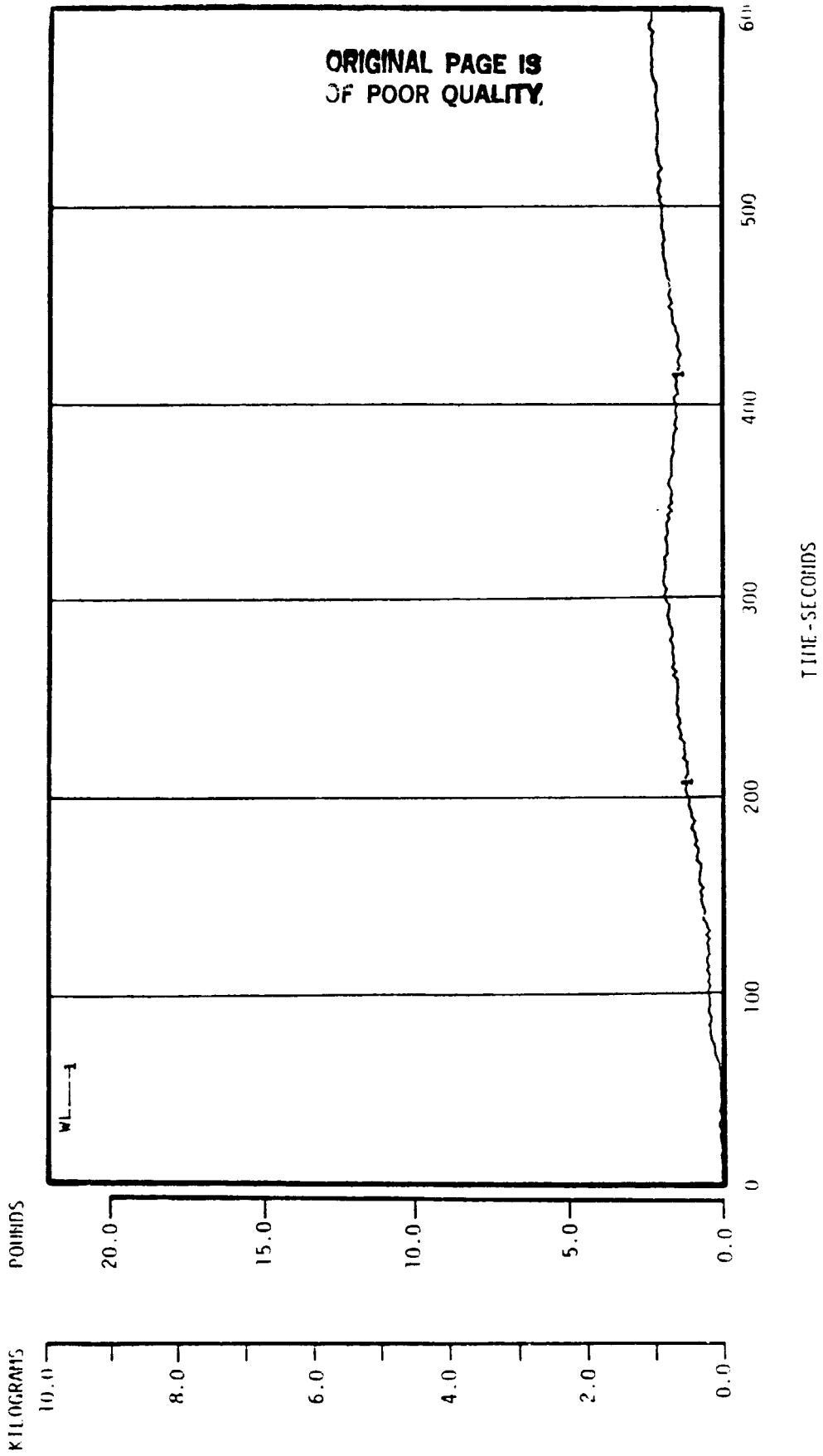


DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/10/82 15.00
NASA-AMES FULL SCALE CUSHION BURH TEST NUMBER 10
CUSHION CONSTRUCTION NUMBER 8.0



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 09/16/82 15.08
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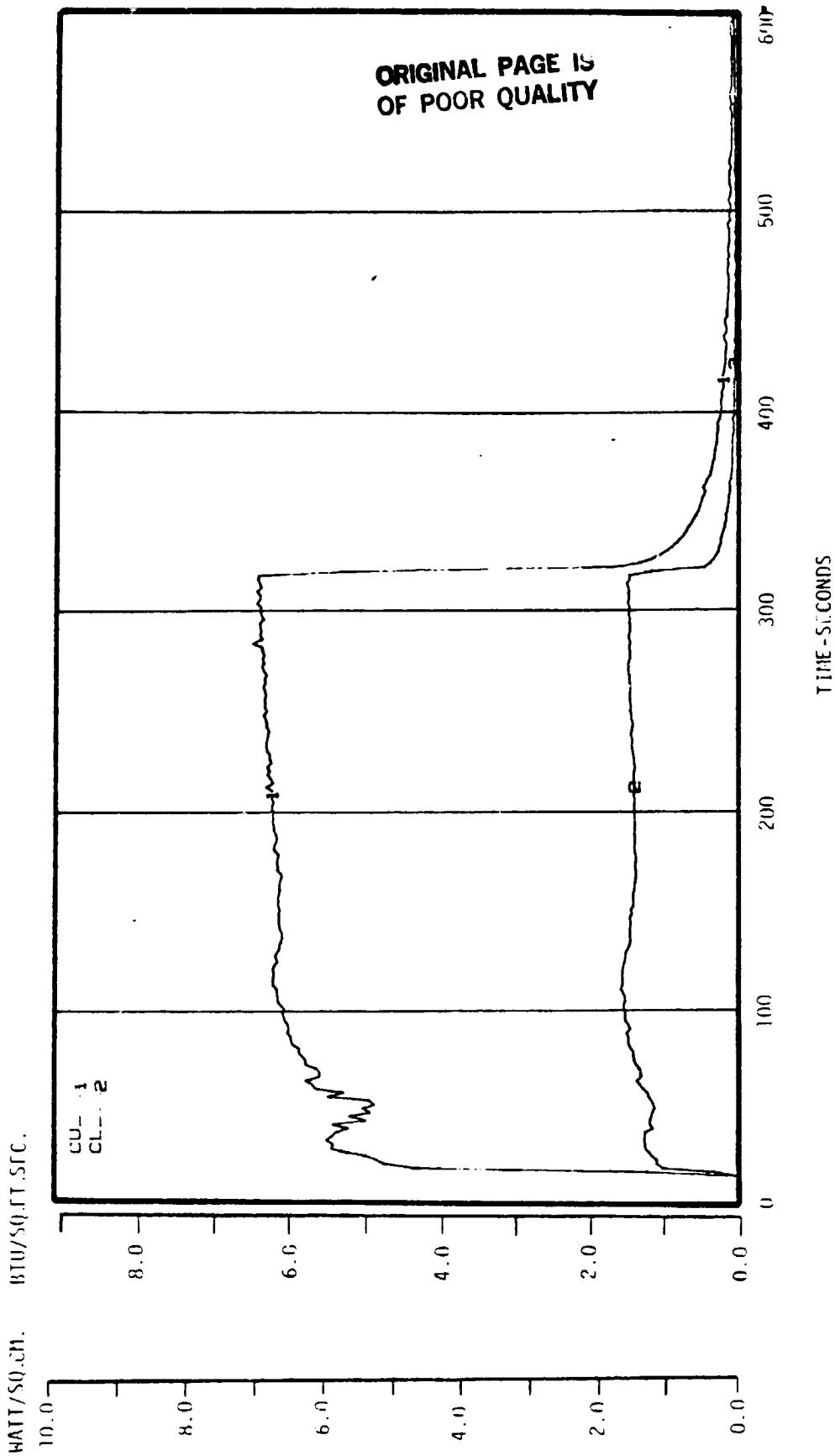
WEIGHT LOSS



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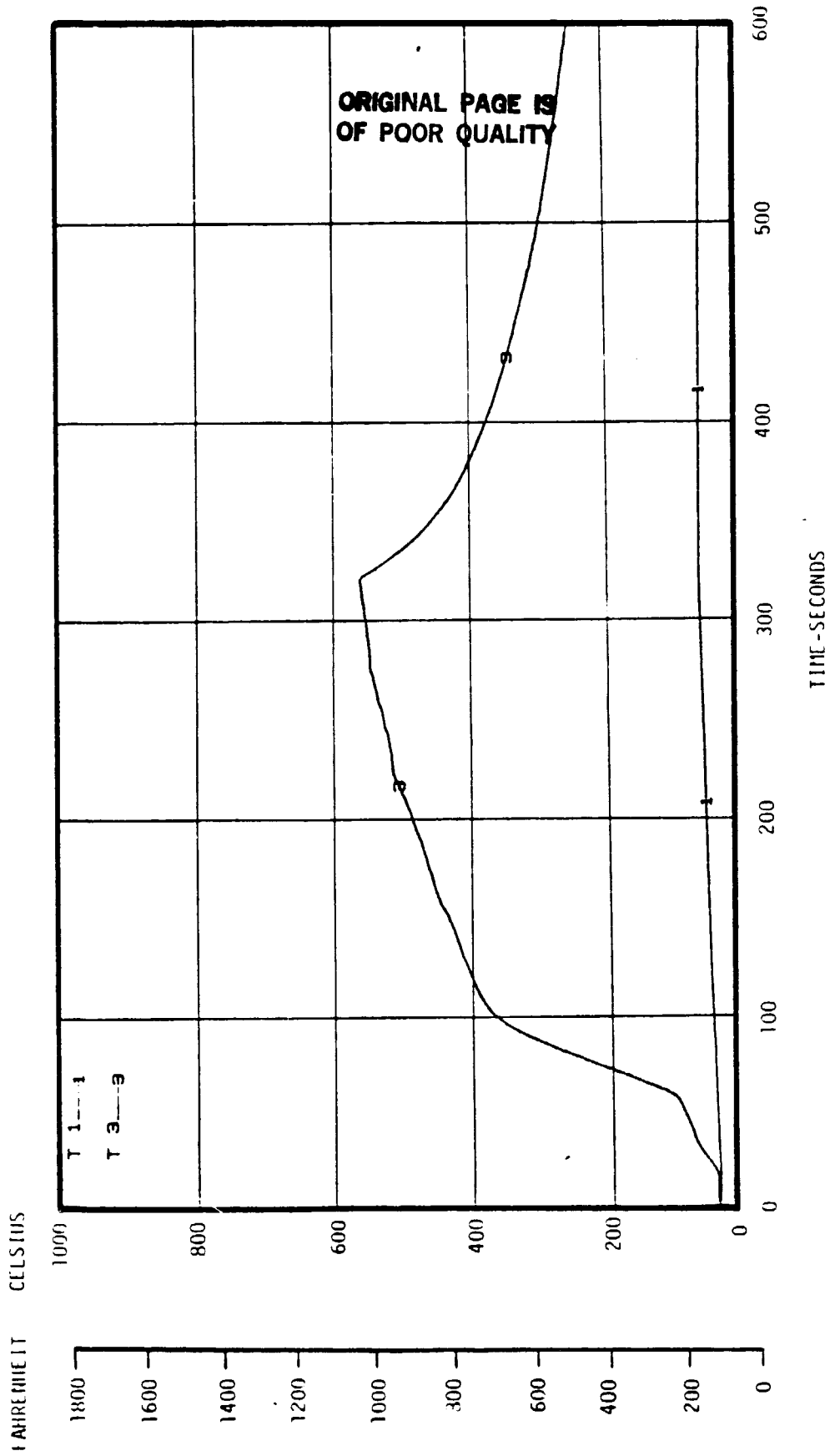
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NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 18
CUSHION CONSTRUCTION NUMBER 8.0

HEAT FLUX



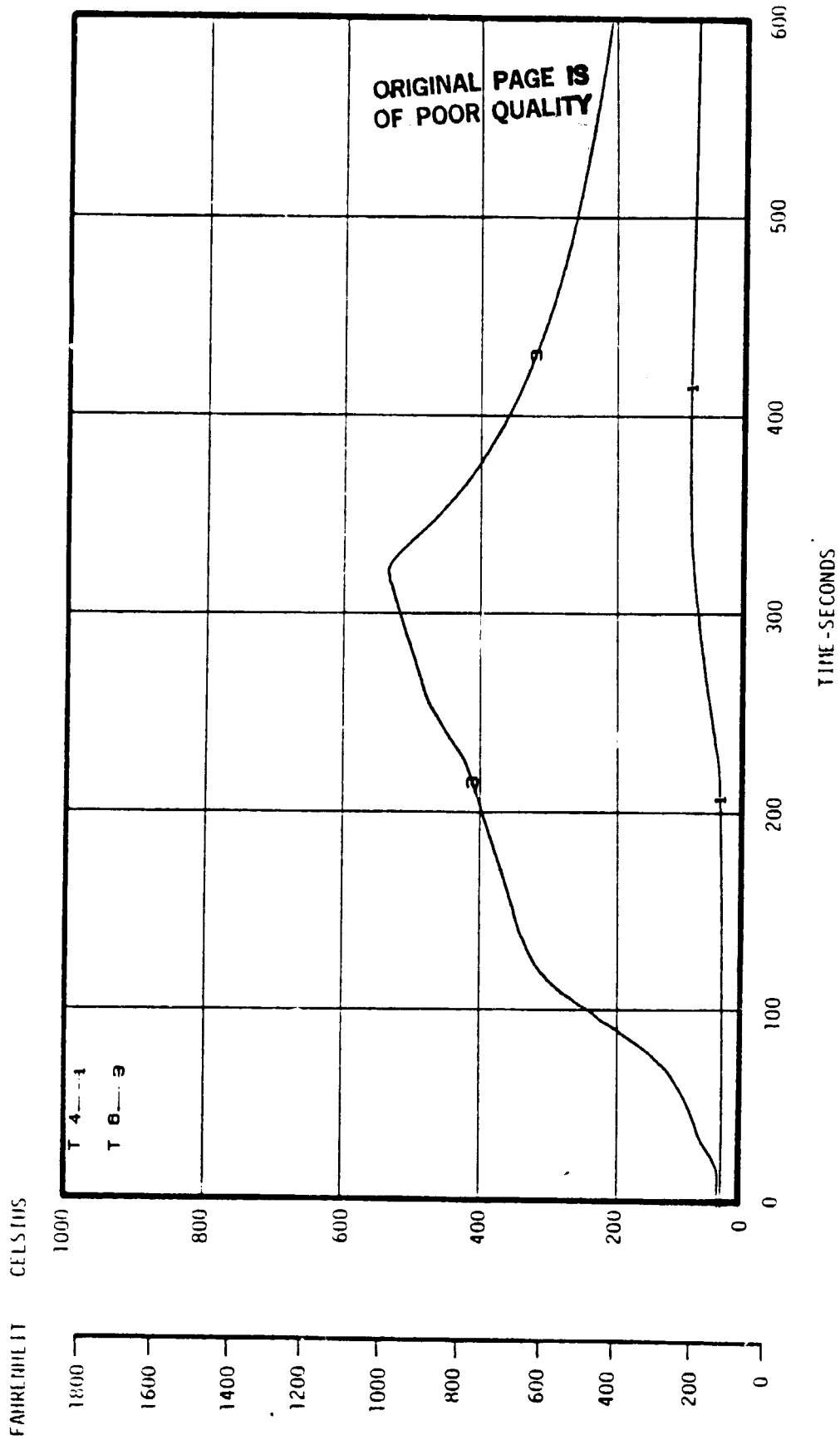
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CUSHION CONSTRUCTION NUMBER 6.0

SEAT CUSHION TEMPERATURES



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/11/82 09.40
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 CUSHION CONSTRUCTION NUMBER 9.0

SEAT CUSHION TEMPERATURES

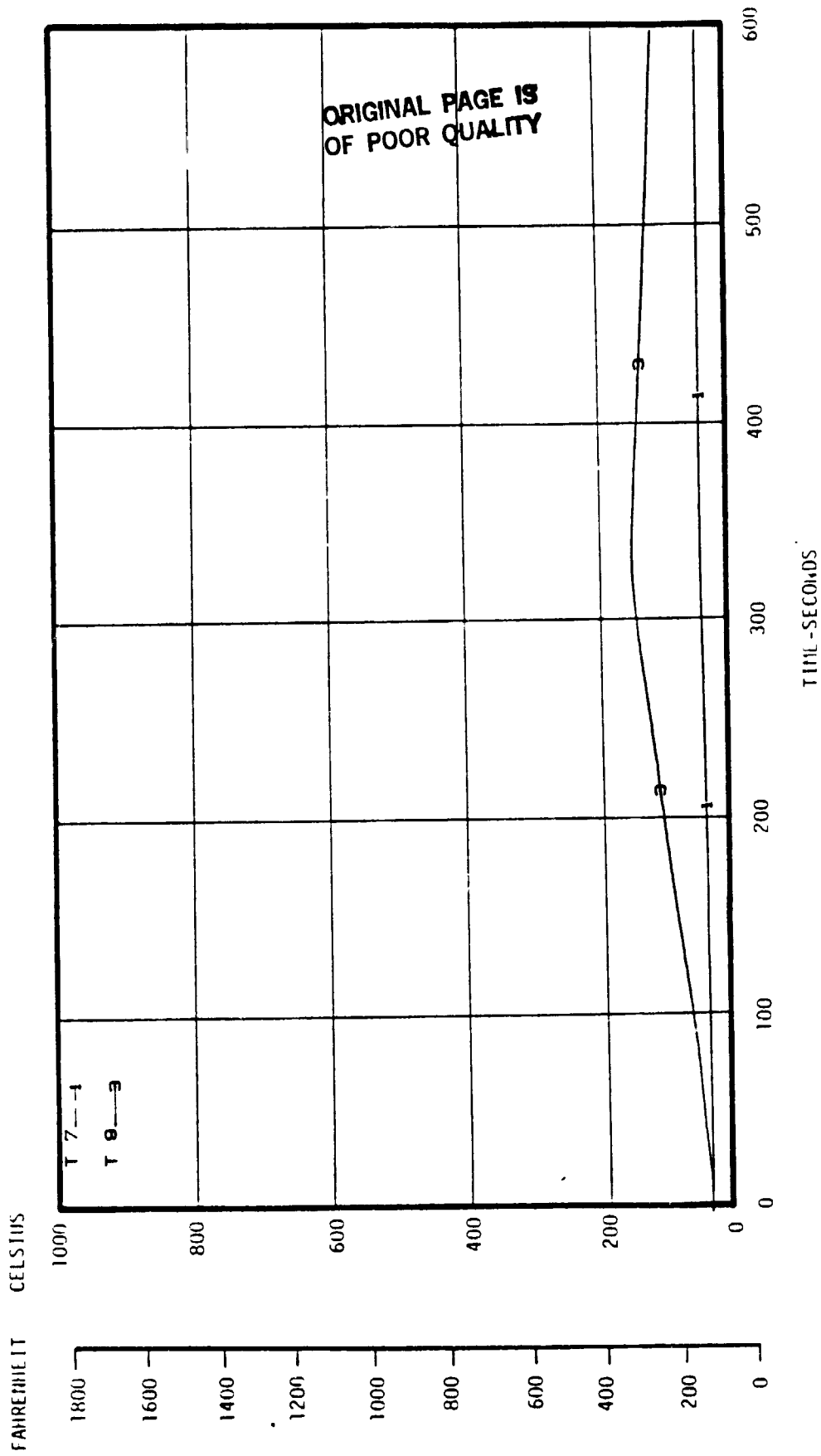


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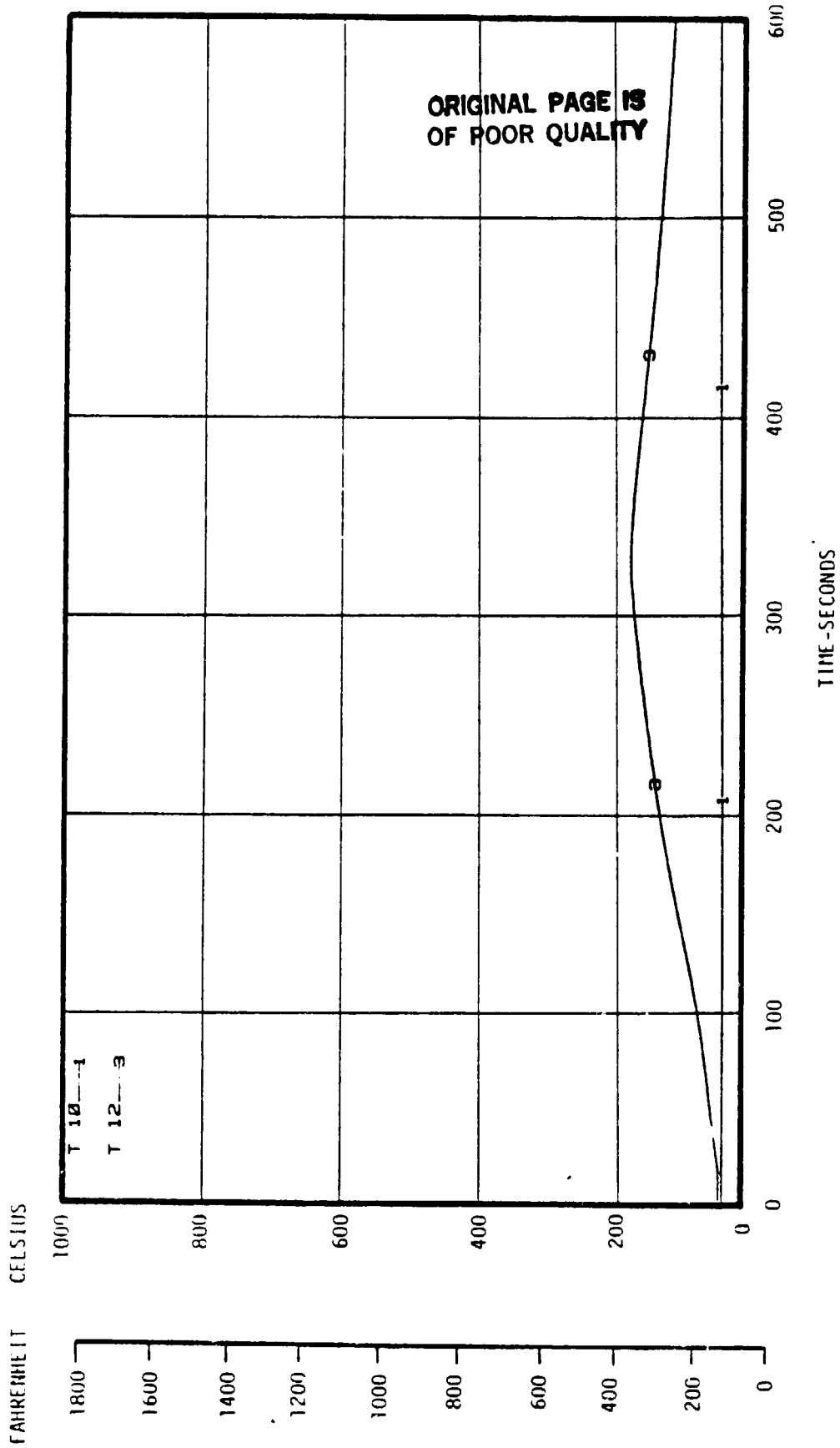
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SEAT CUSHION TEMPERATURES



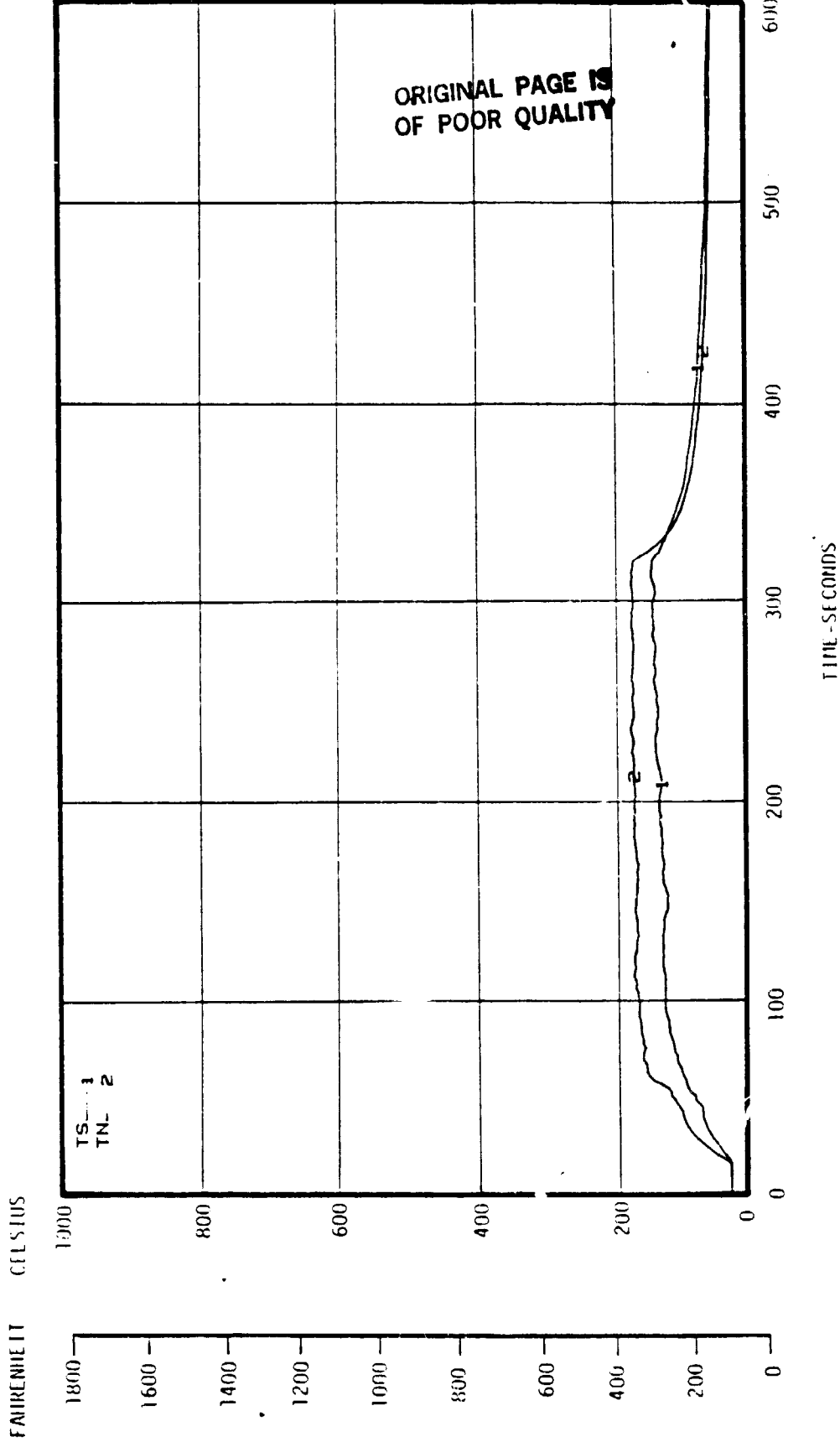
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CUSHION CONSTRICTION NUMBER 9-1

SEAT CUSHION TEMPERATURES



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/11/82--06-40
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CEILING TEMPERATURE



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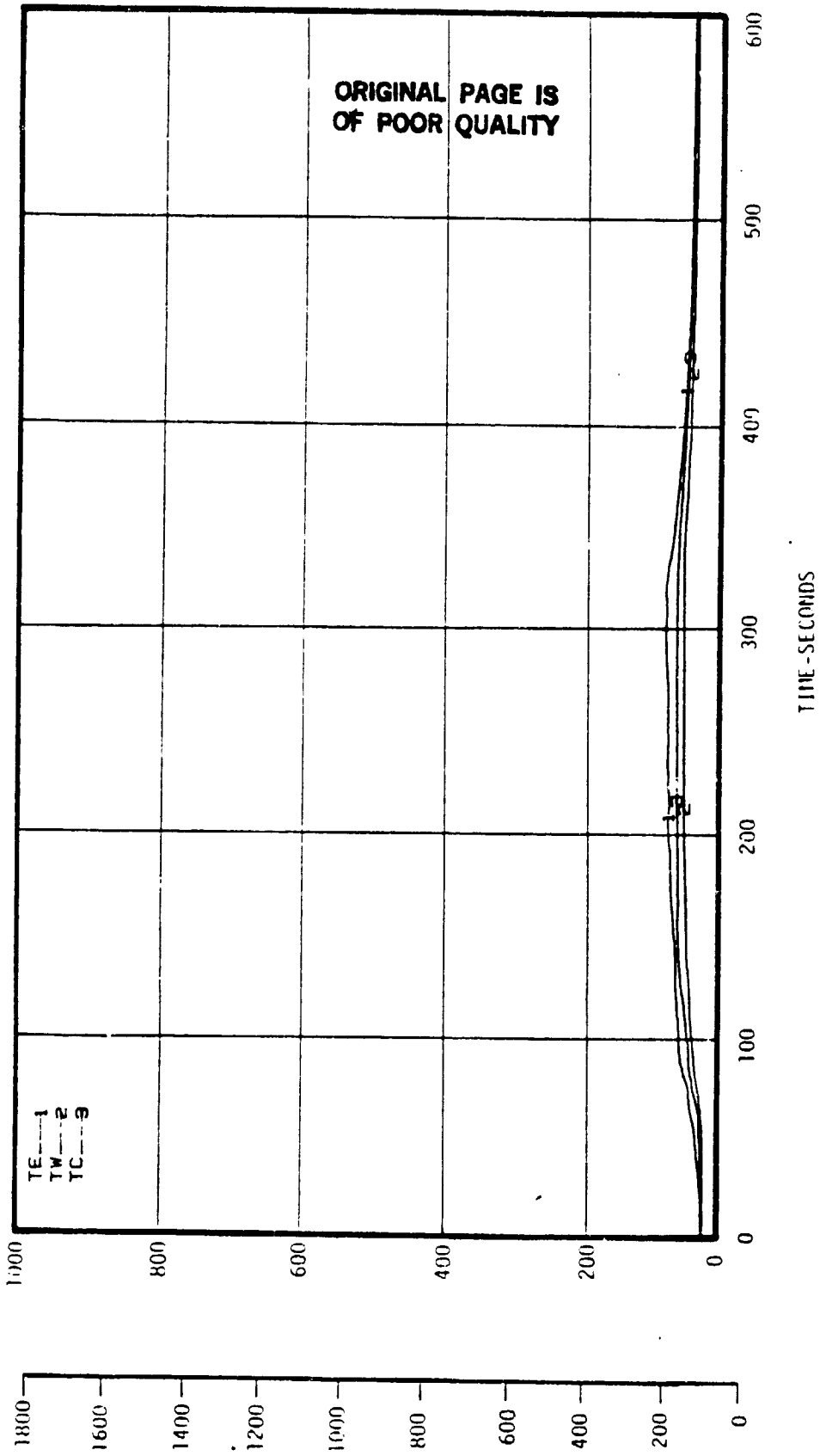
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DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/11/82 09:40
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CEILING TEMPERATURE

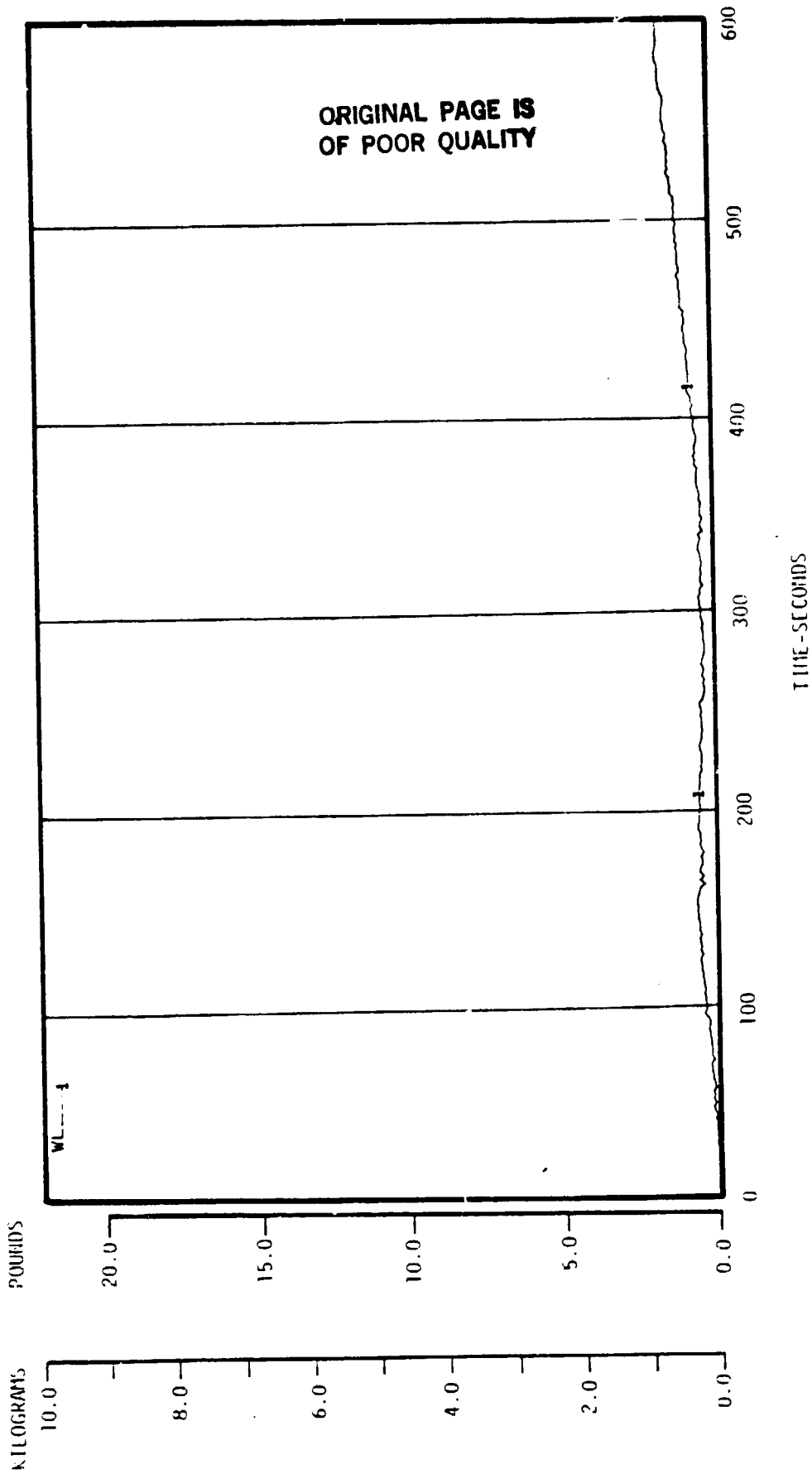
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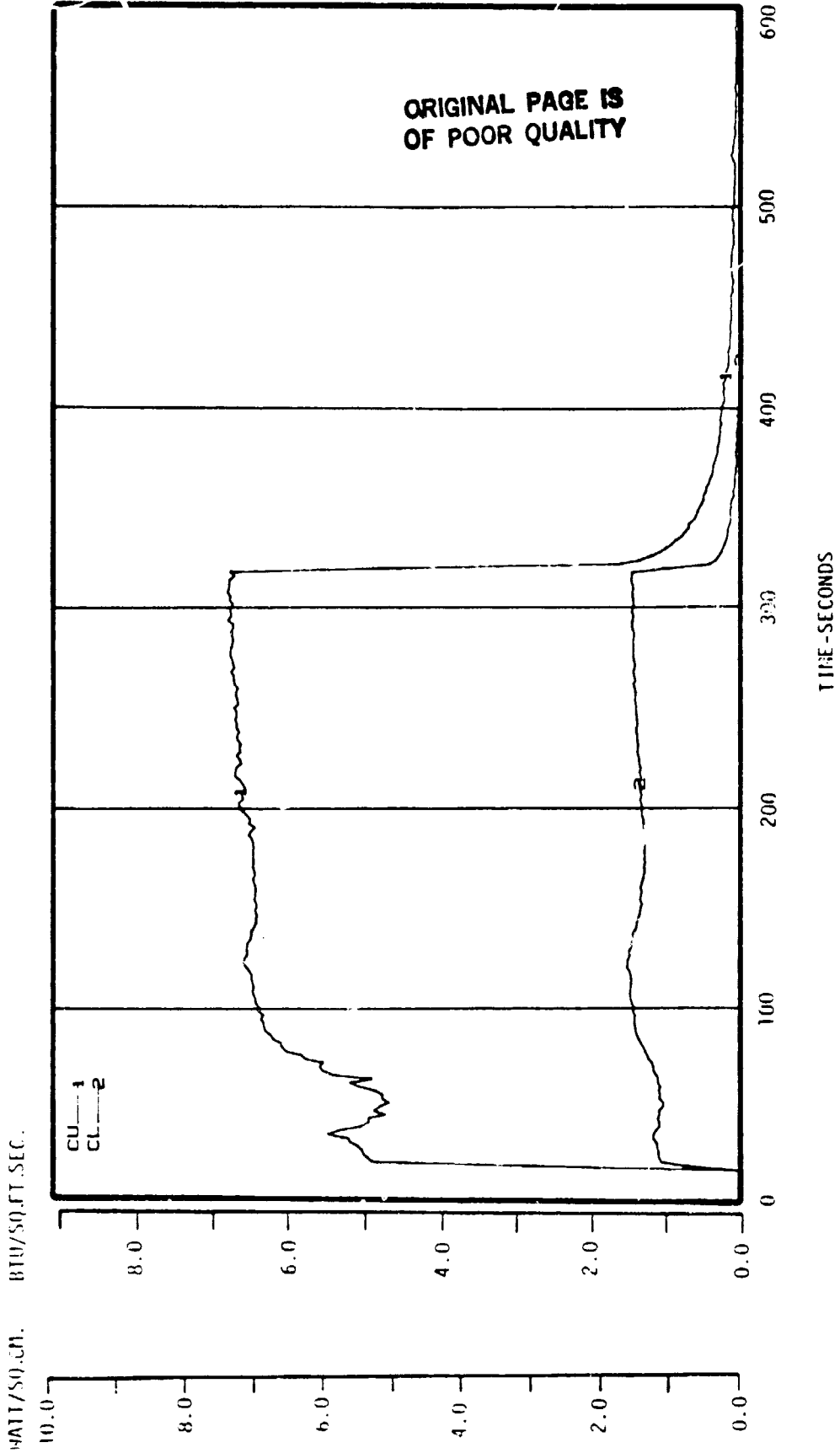
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CUSHION CONSTRUCTION NUMBER 9.0

WEIGHT LOSS



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/11/62 09.40
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HEAT FLUX

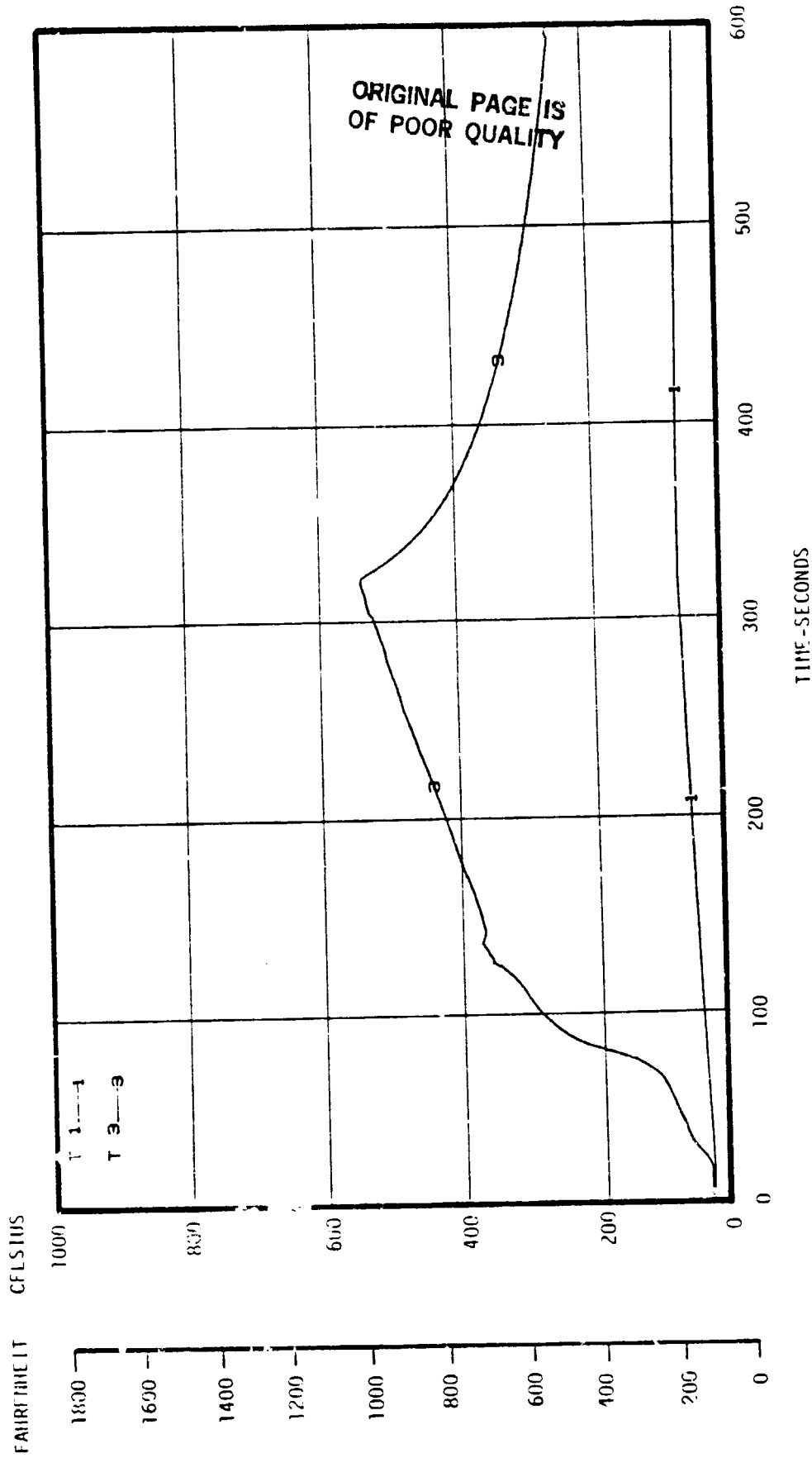


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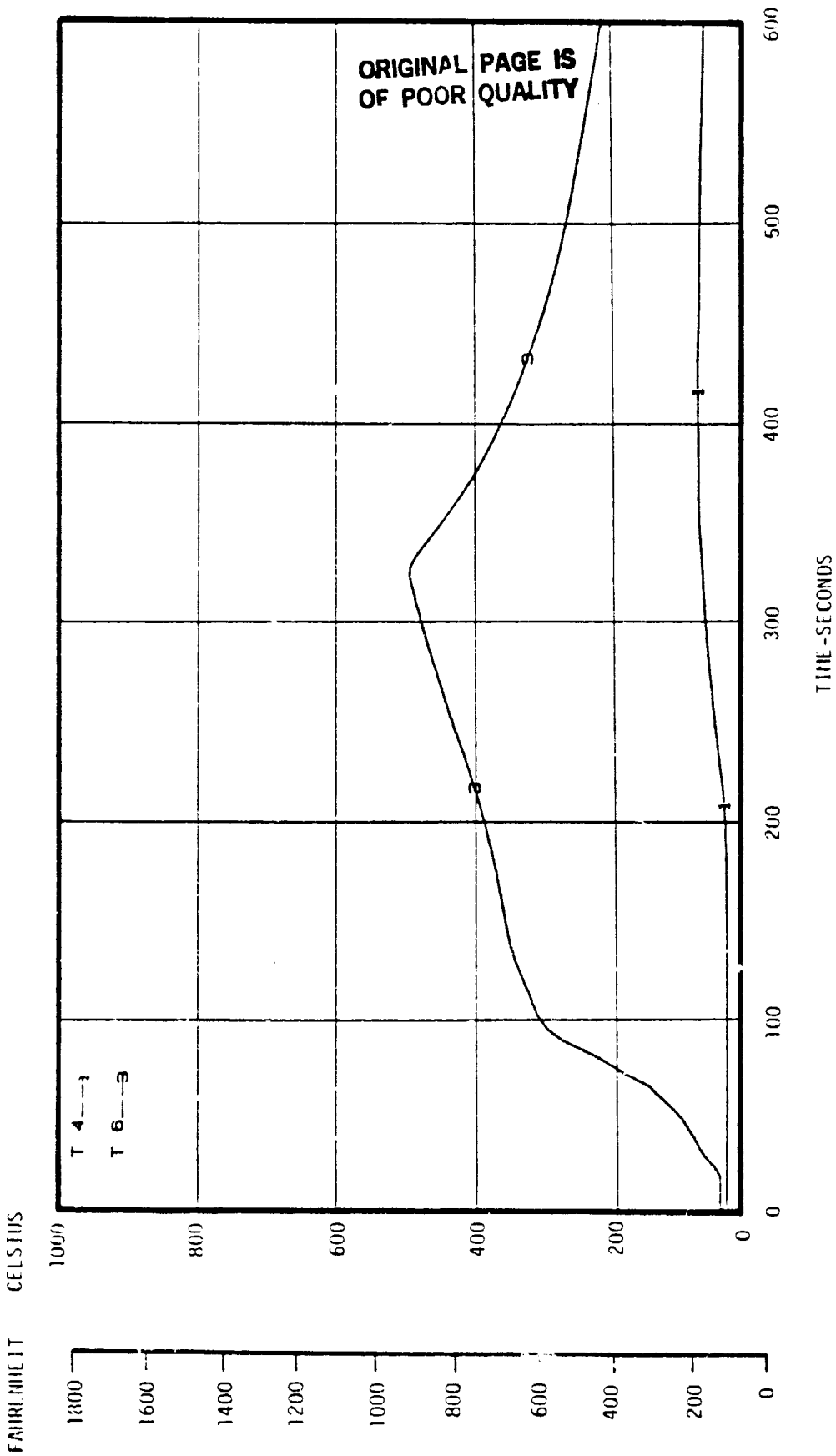
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SEAT CUSHION TEMPERATURES



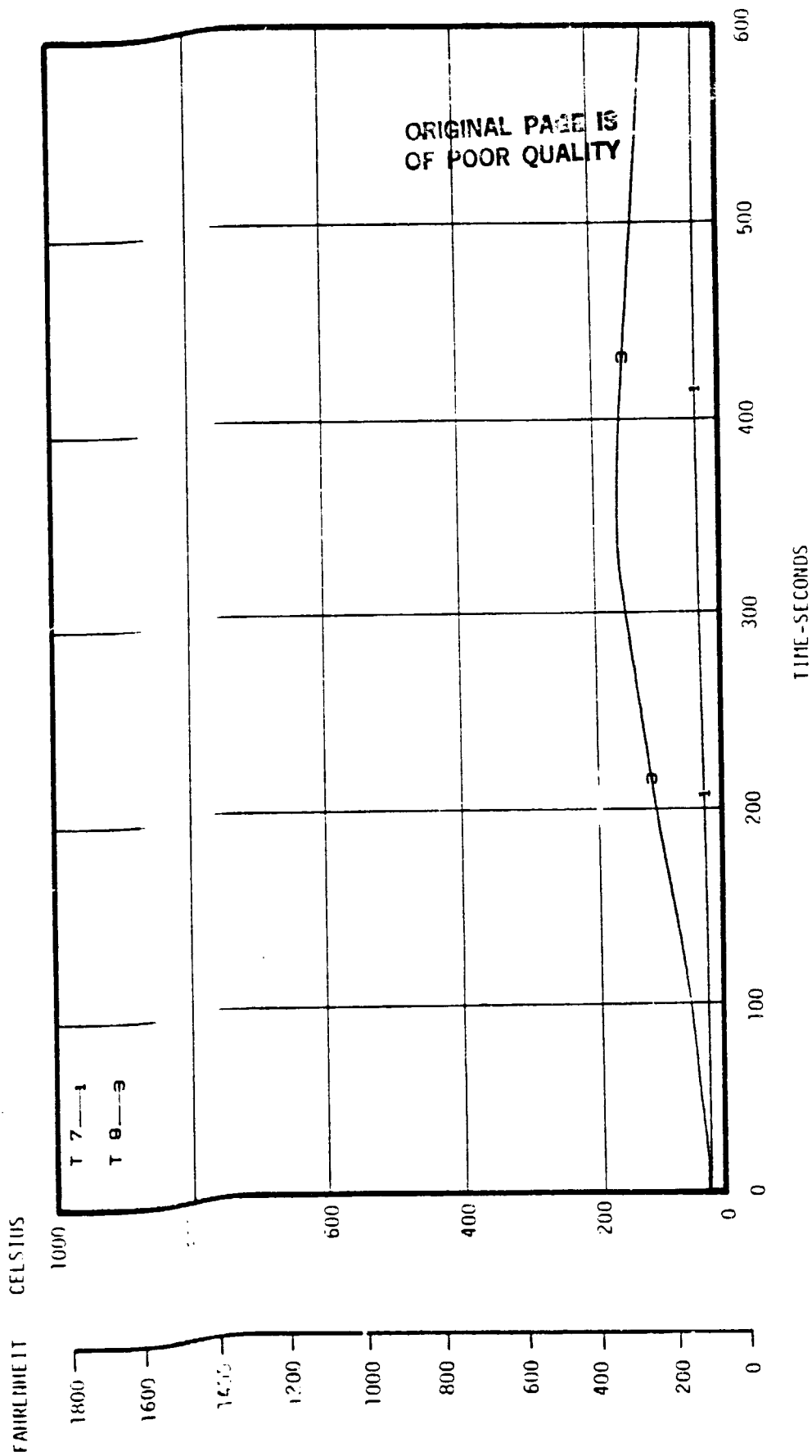
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 CUSHION CONSTRUCTION NUMBER 8.0

SEAT CUSHION TEMPERATURES



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/17/62 08, 10
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SEAT CUSHION TEMPERATURES

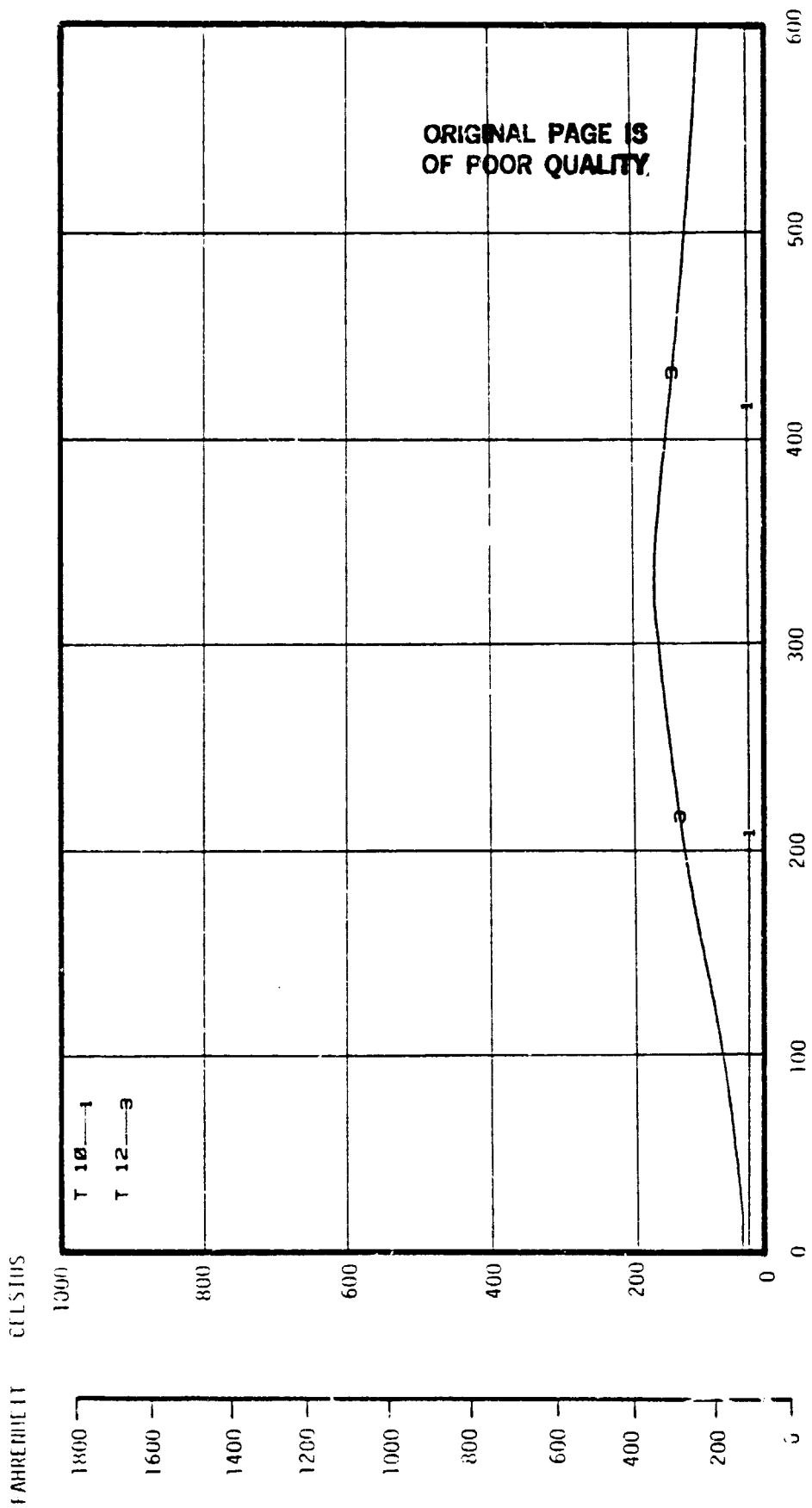


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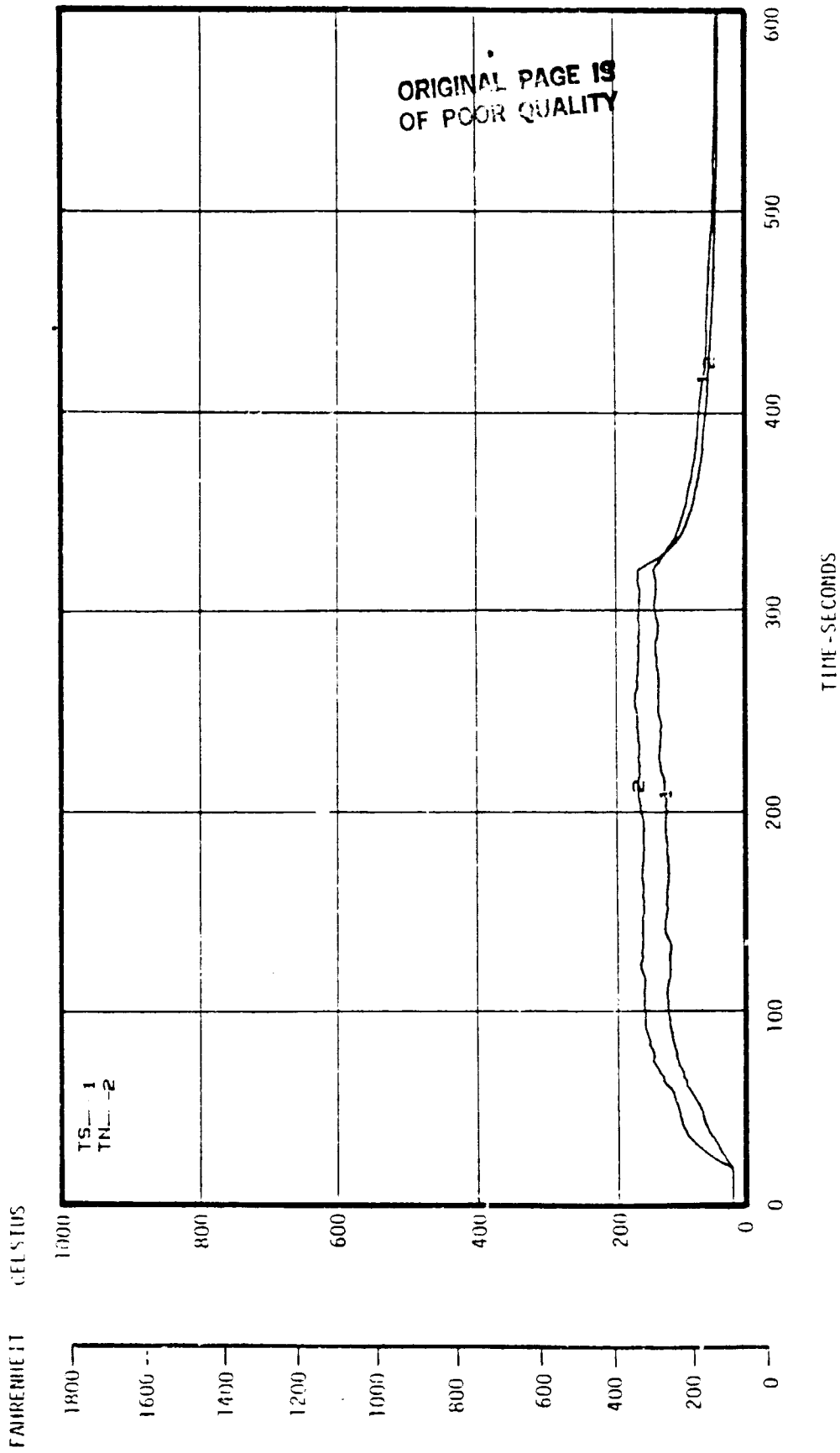
SEAT CUSHION TEMPERATURES



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CEILING TEMPERATURE



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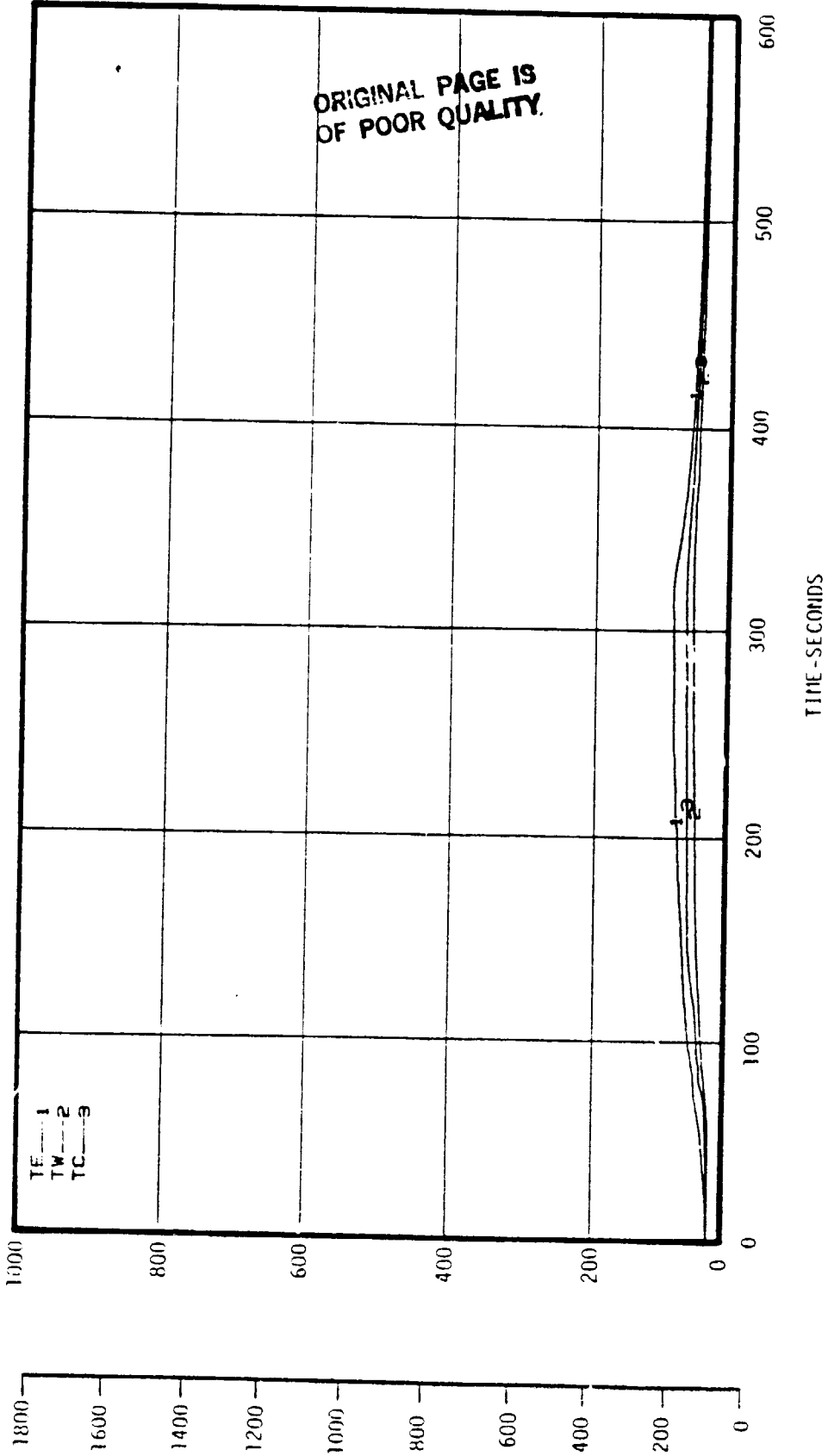
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CEILING TEMPERATURE

FARENHEIT

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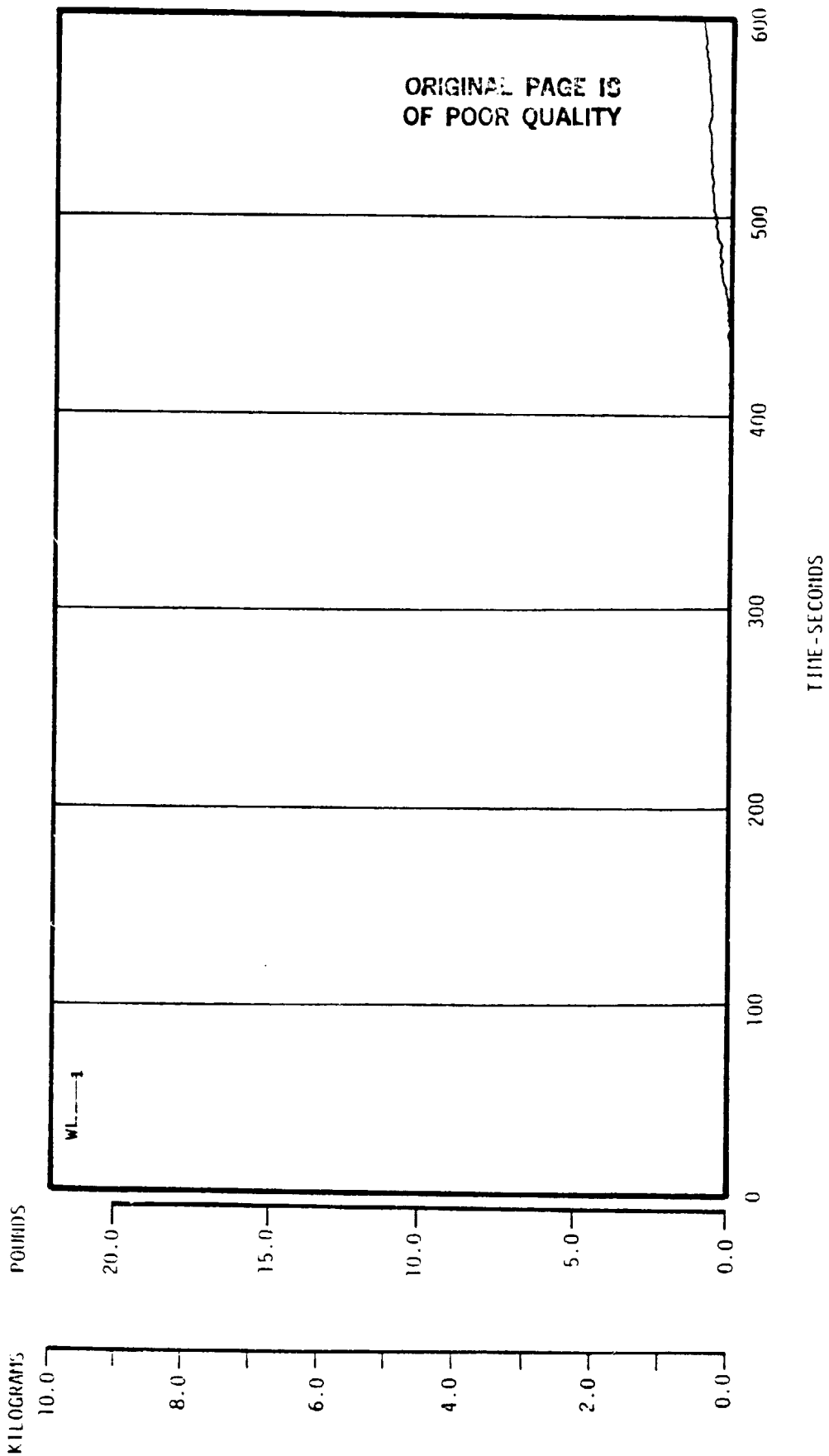


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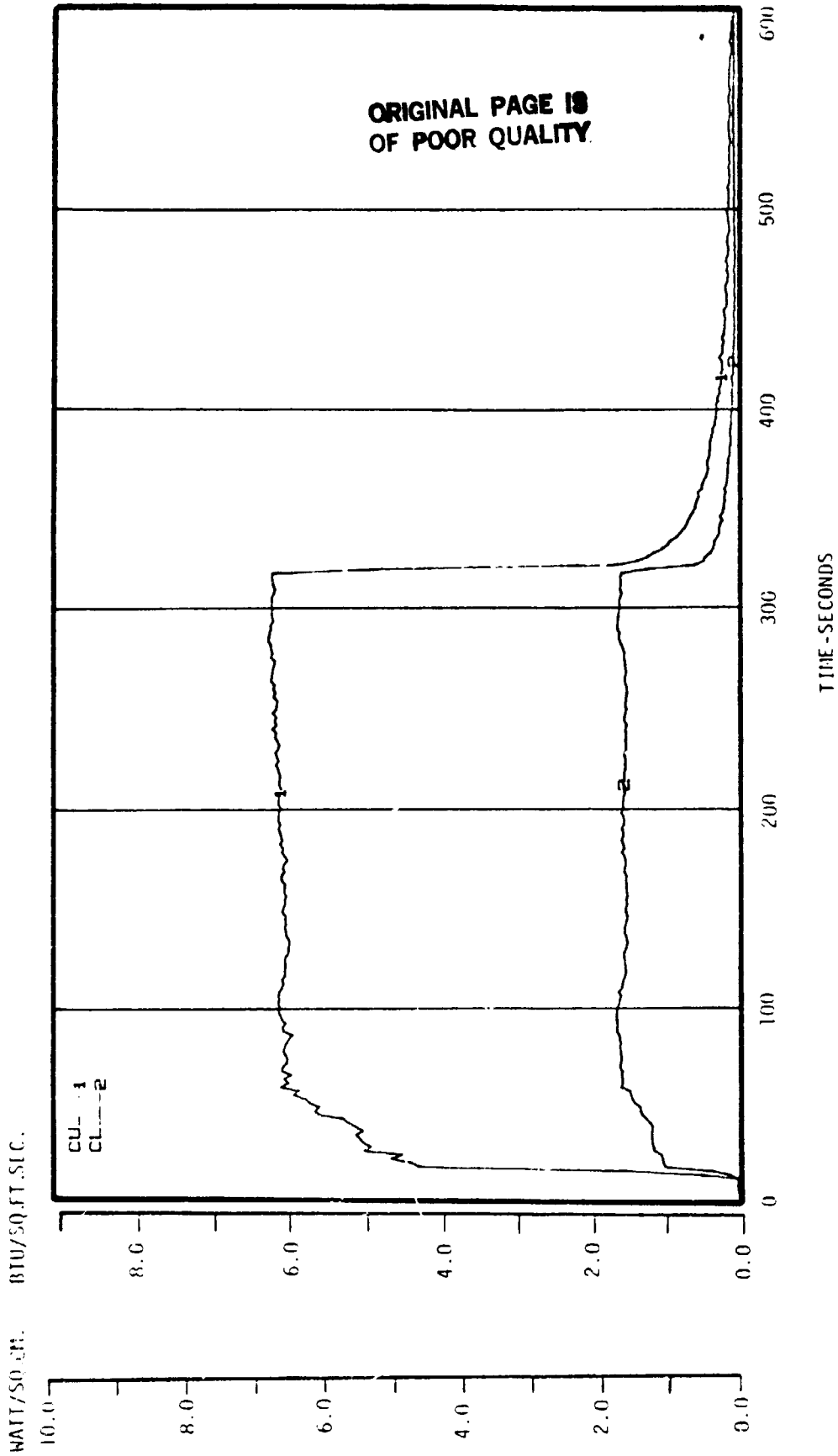
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WEIGHT LOSS



Douglas Aircraft Cabin Fire Simulator 03/17/82 08:10
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HEAT FLUX

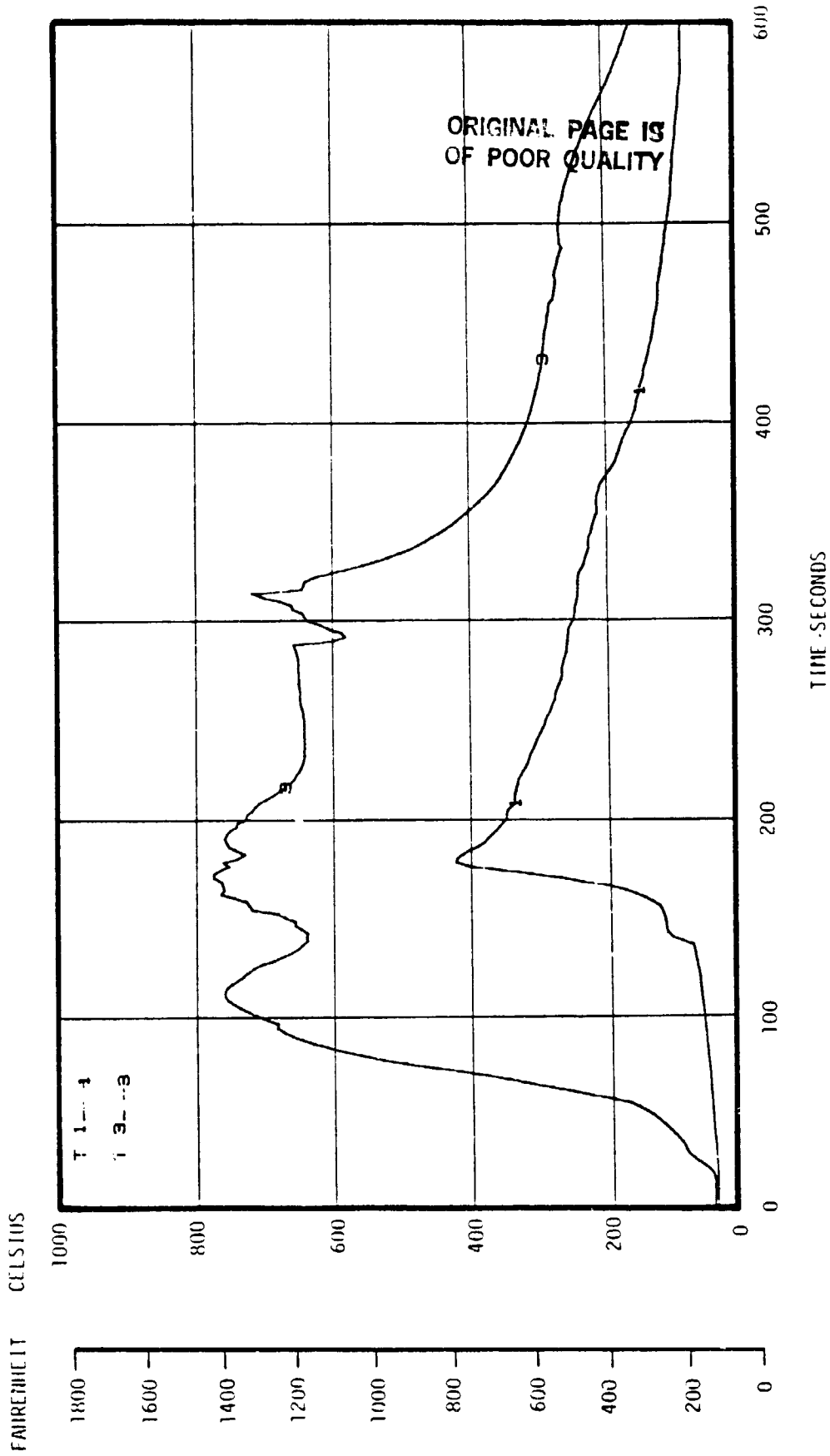


DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 09/11/82 1.4.91

NASA-MES FULL SCALE CUSHION BURN TEST NUMBER 8

CUSHION CONSTRUCTION NUMBER 15.0

SEAT CUSHION TEMPERATURES



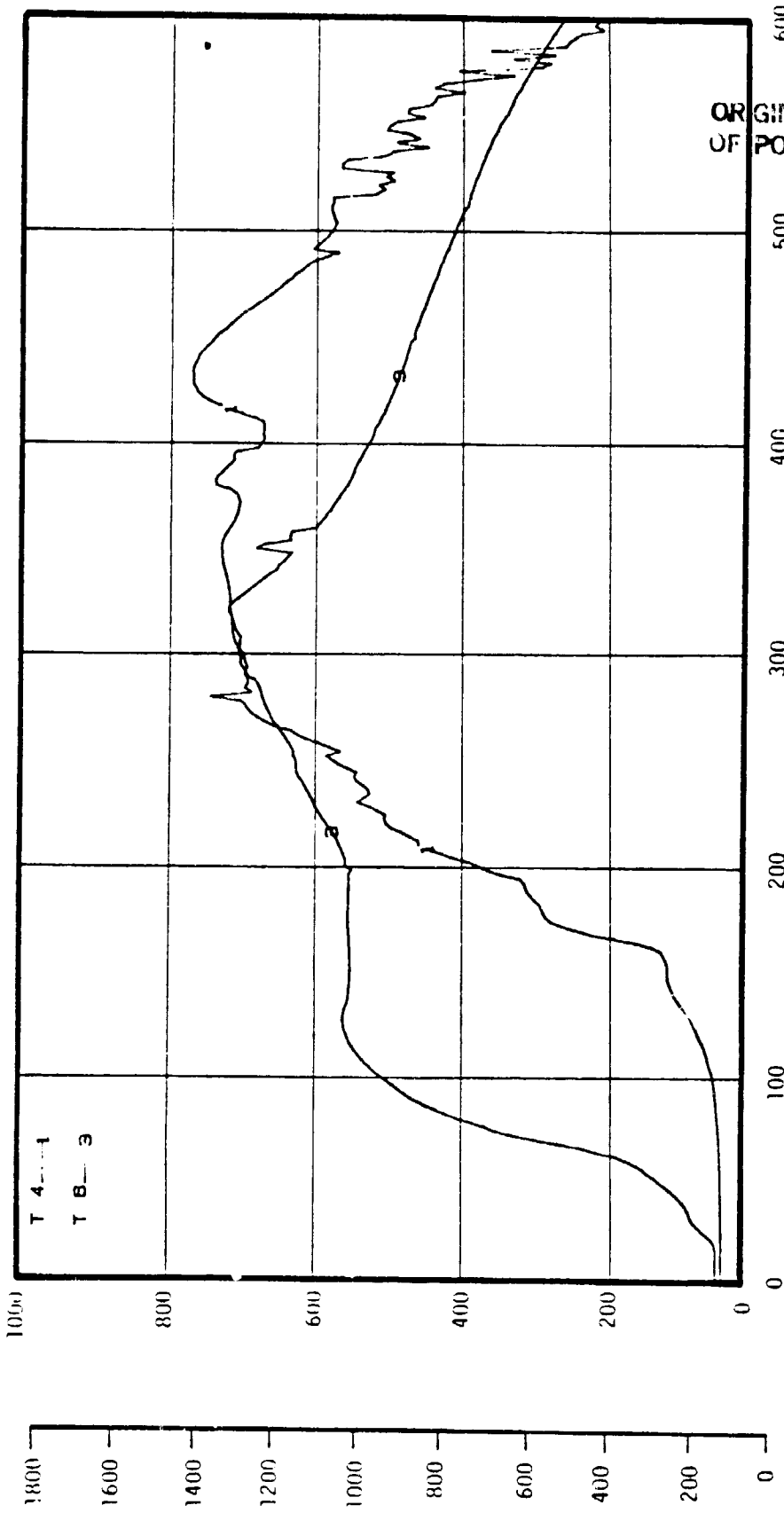
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CUSHION CONSTRUCTION NUMBER 10.0

SEAT CUSHION TEMPERATURES

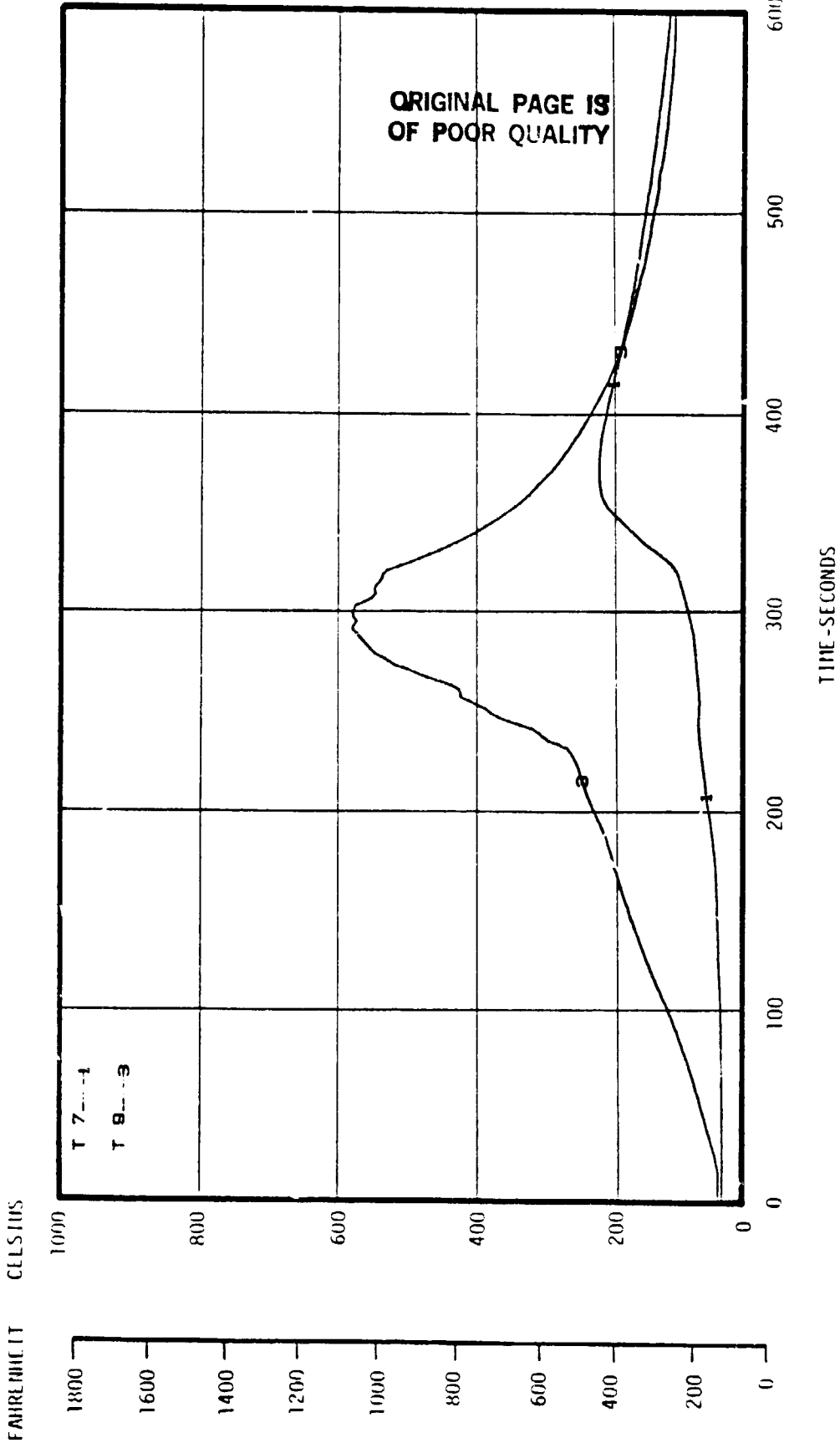
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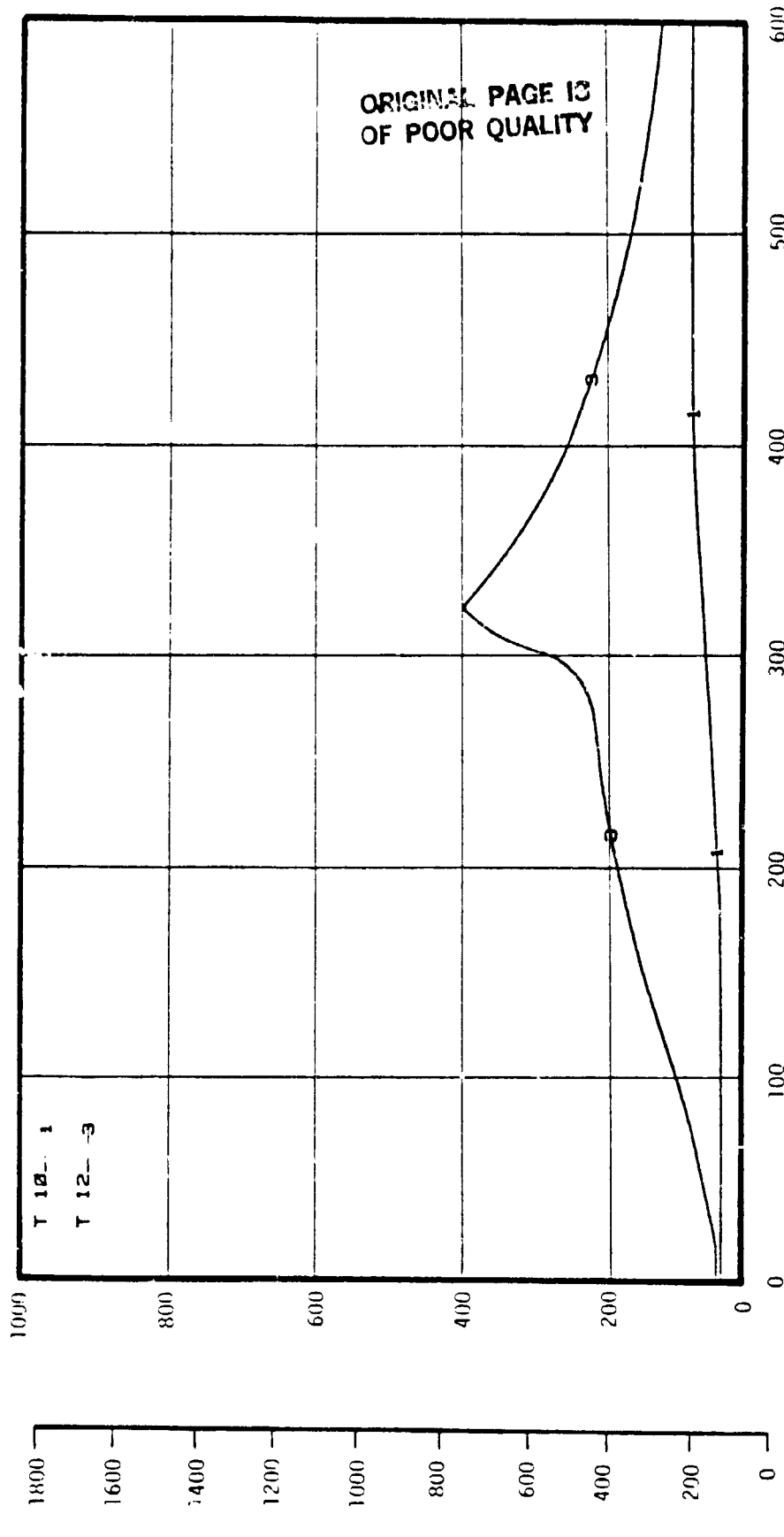
SEAT CUSHION TEMPERATURES



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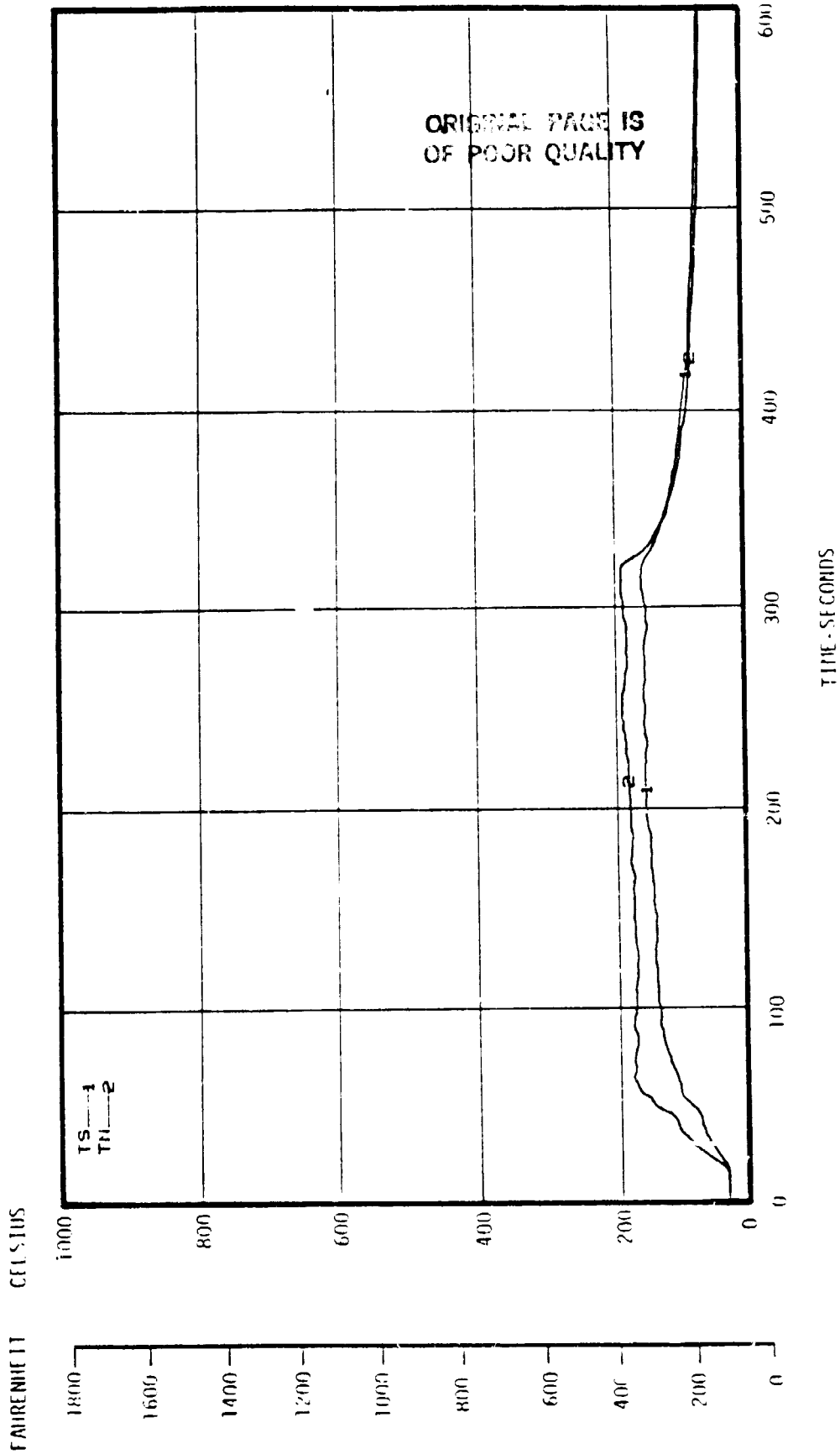
SEAT CUSHION TEMPERATURES

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CEILING TEMPERATURE



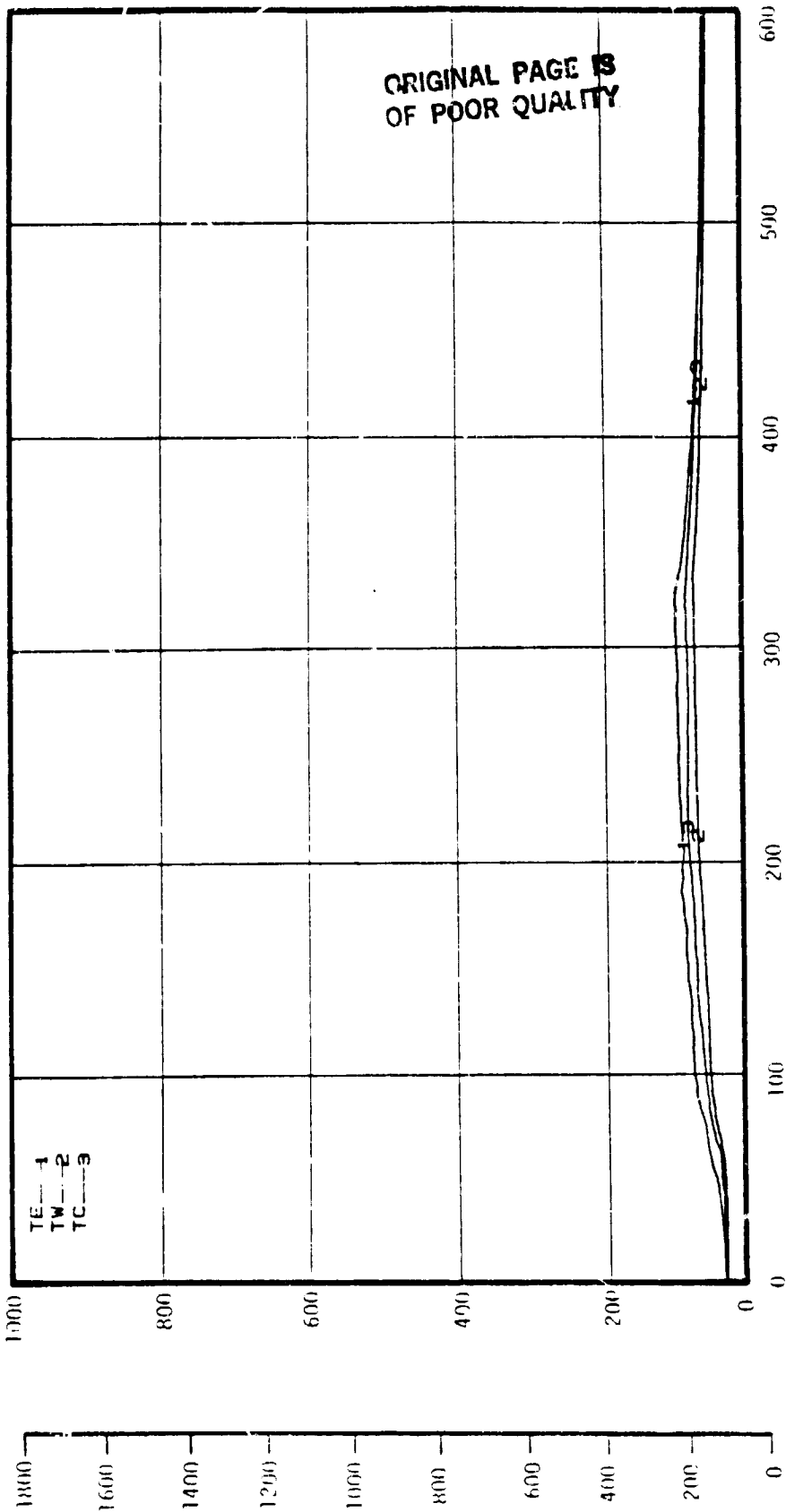
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CUSHION CONSTRUCTOR NUMBER 10.0

CYLINDER TEMPERATURE

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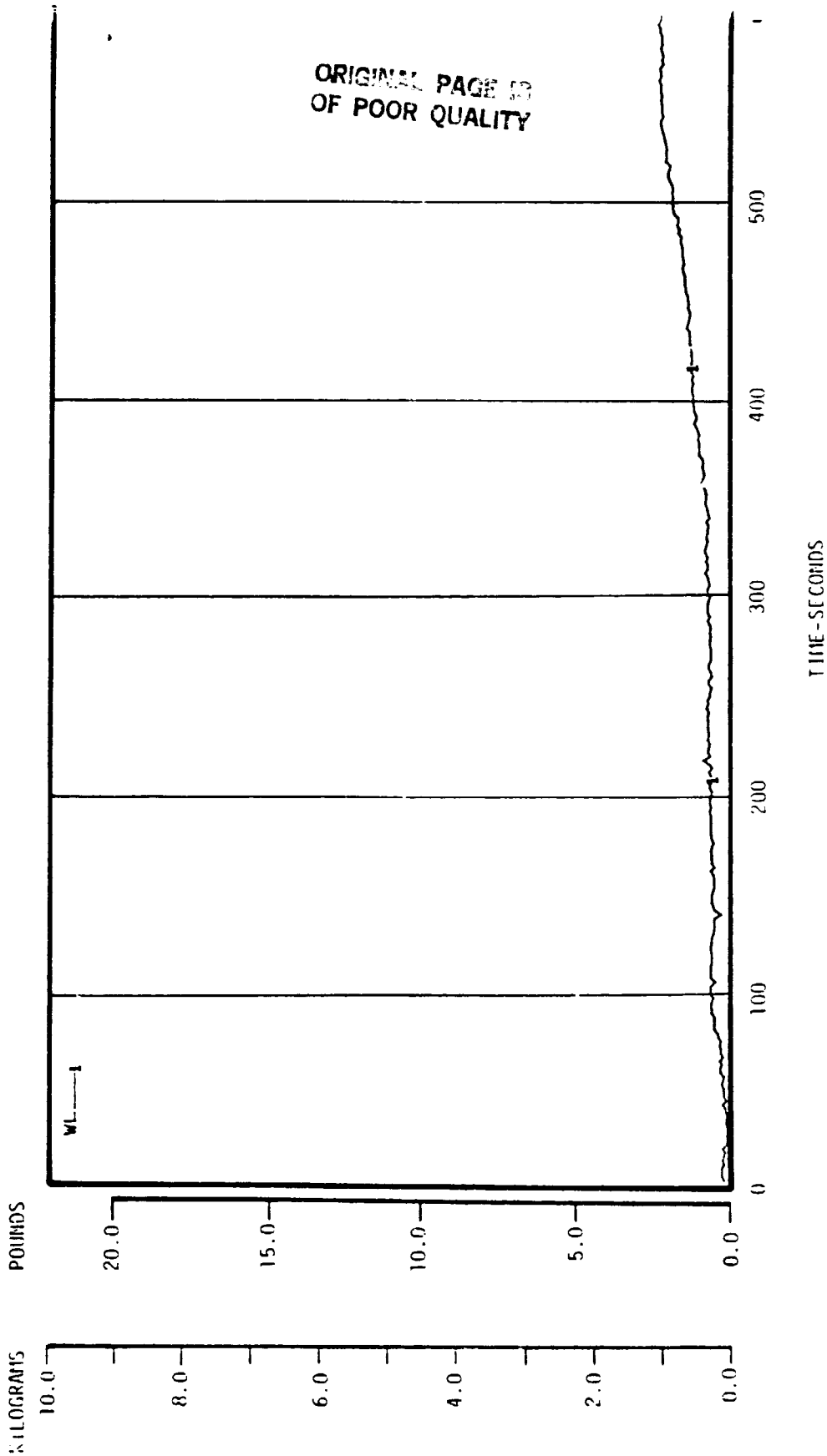


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CUSHION CONSTRUCTION NUMBER 10.0

WEIGHT LOSS

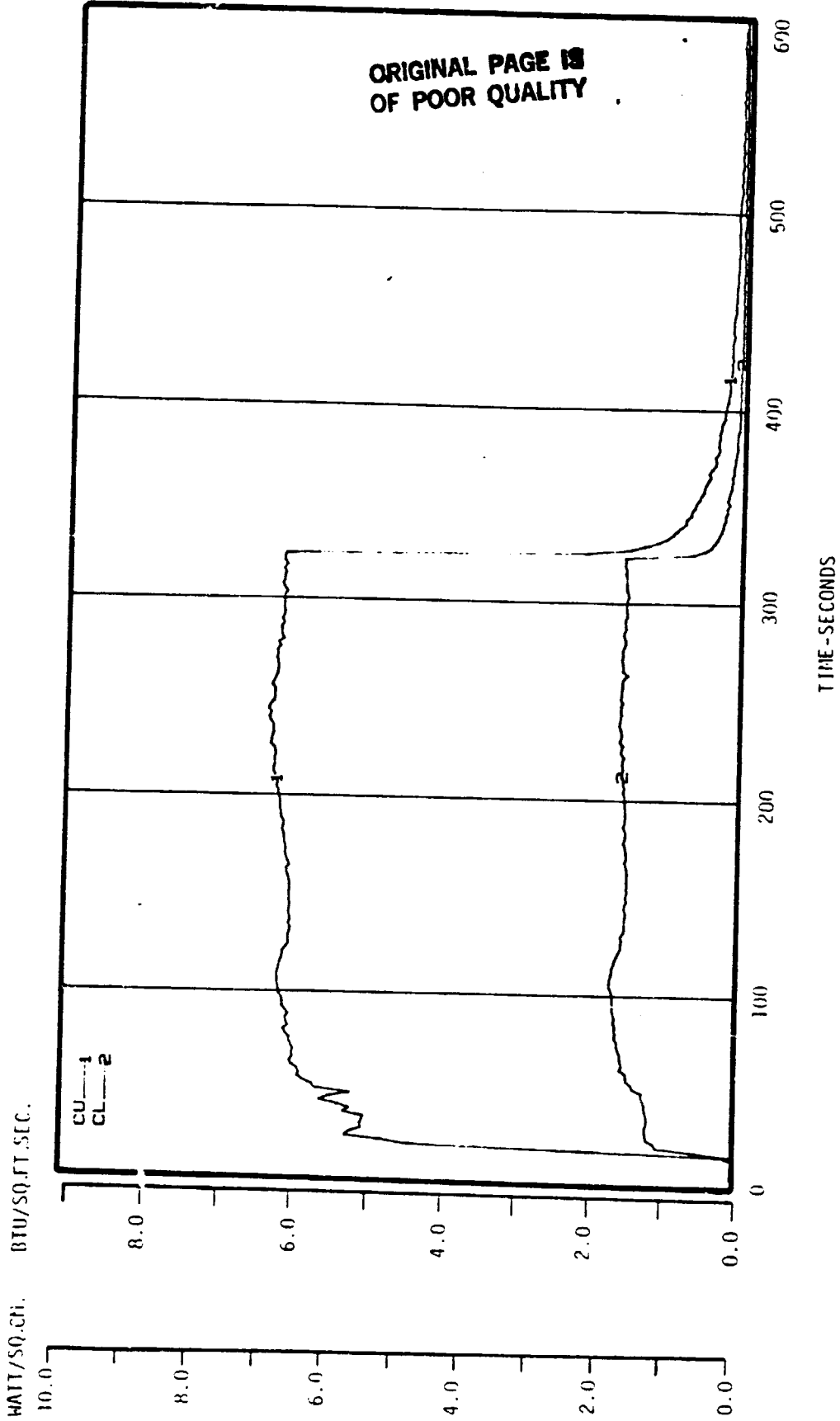


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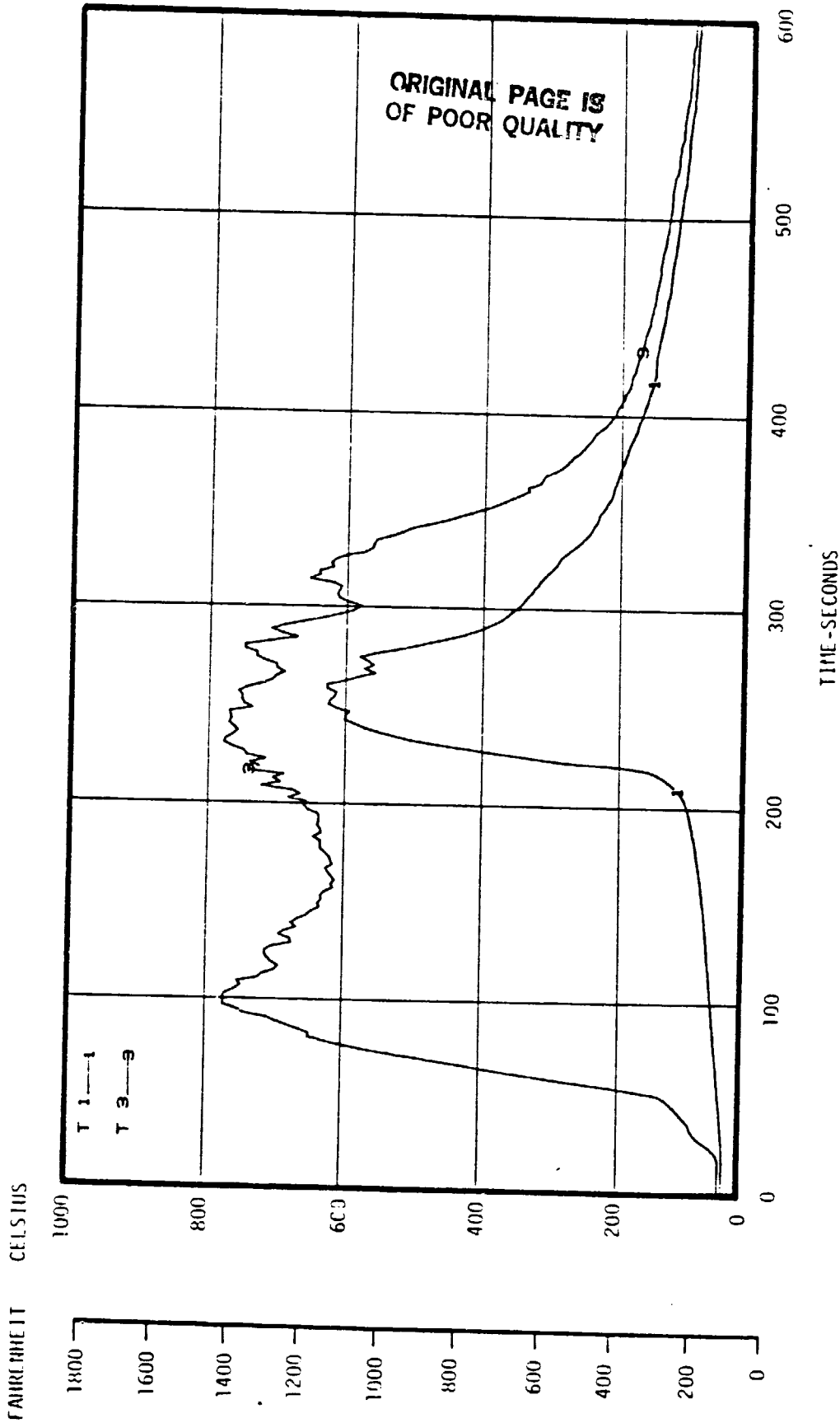
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HEAT FLUX



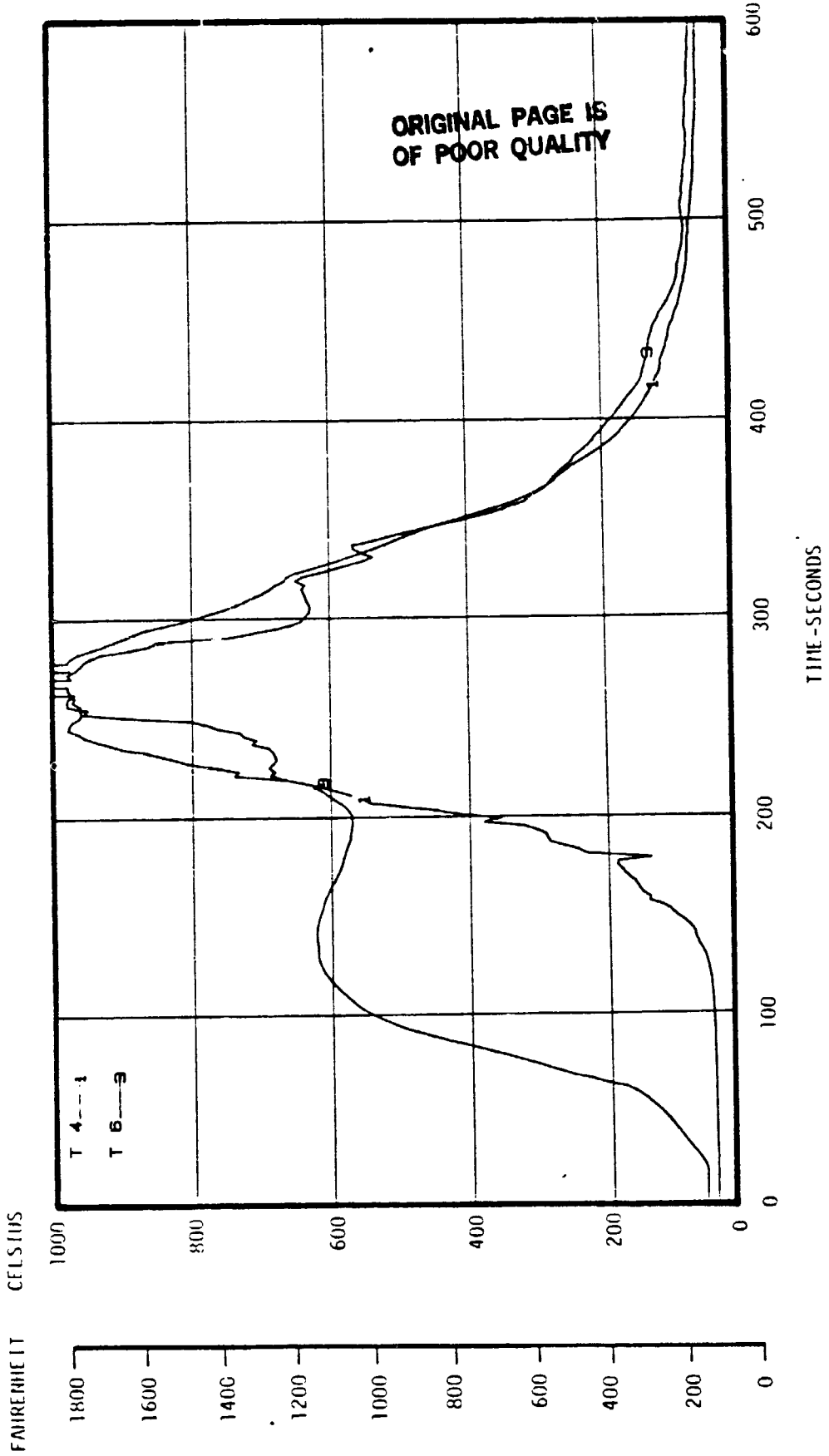
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NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 6
CUSHION CONSTRUCTION NUMBER 10.0

SEAT CUSHION TEMPERATURES



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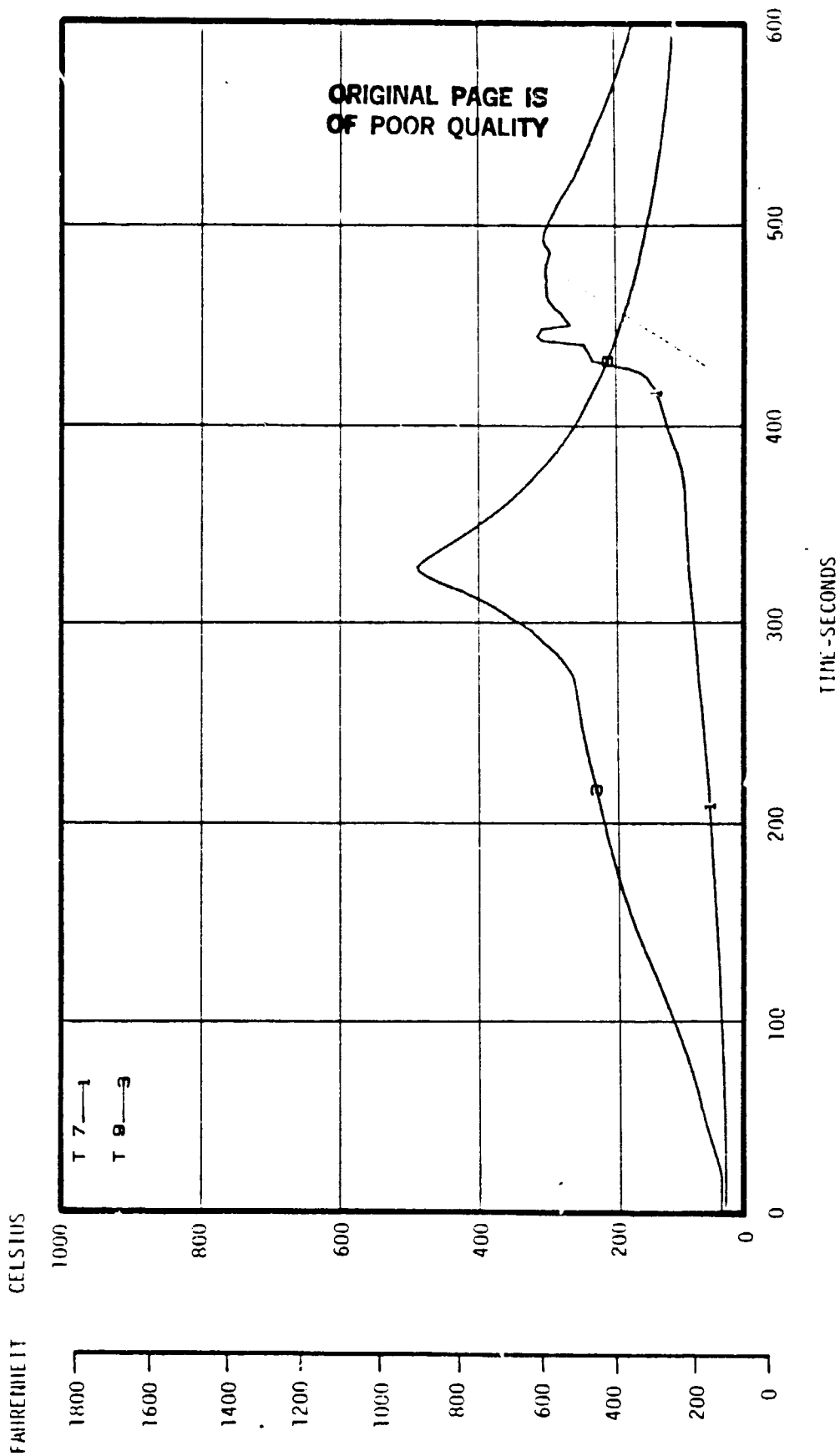
SEAT CUSHION TEMPERATURES



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CUSHION CONSTRUCTION NUMBER 10.0

SEAT CUSHION TEMPERATURES

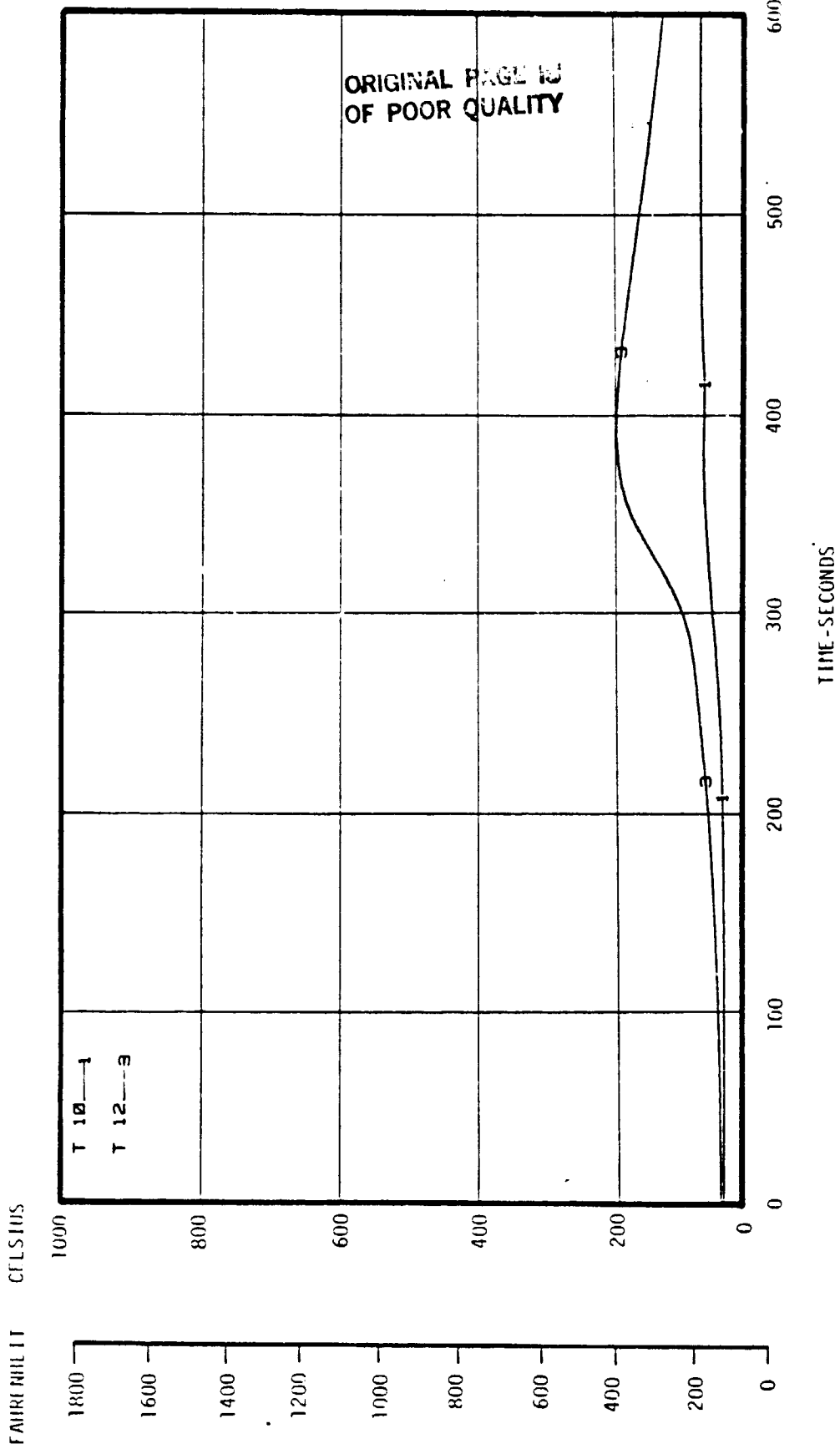


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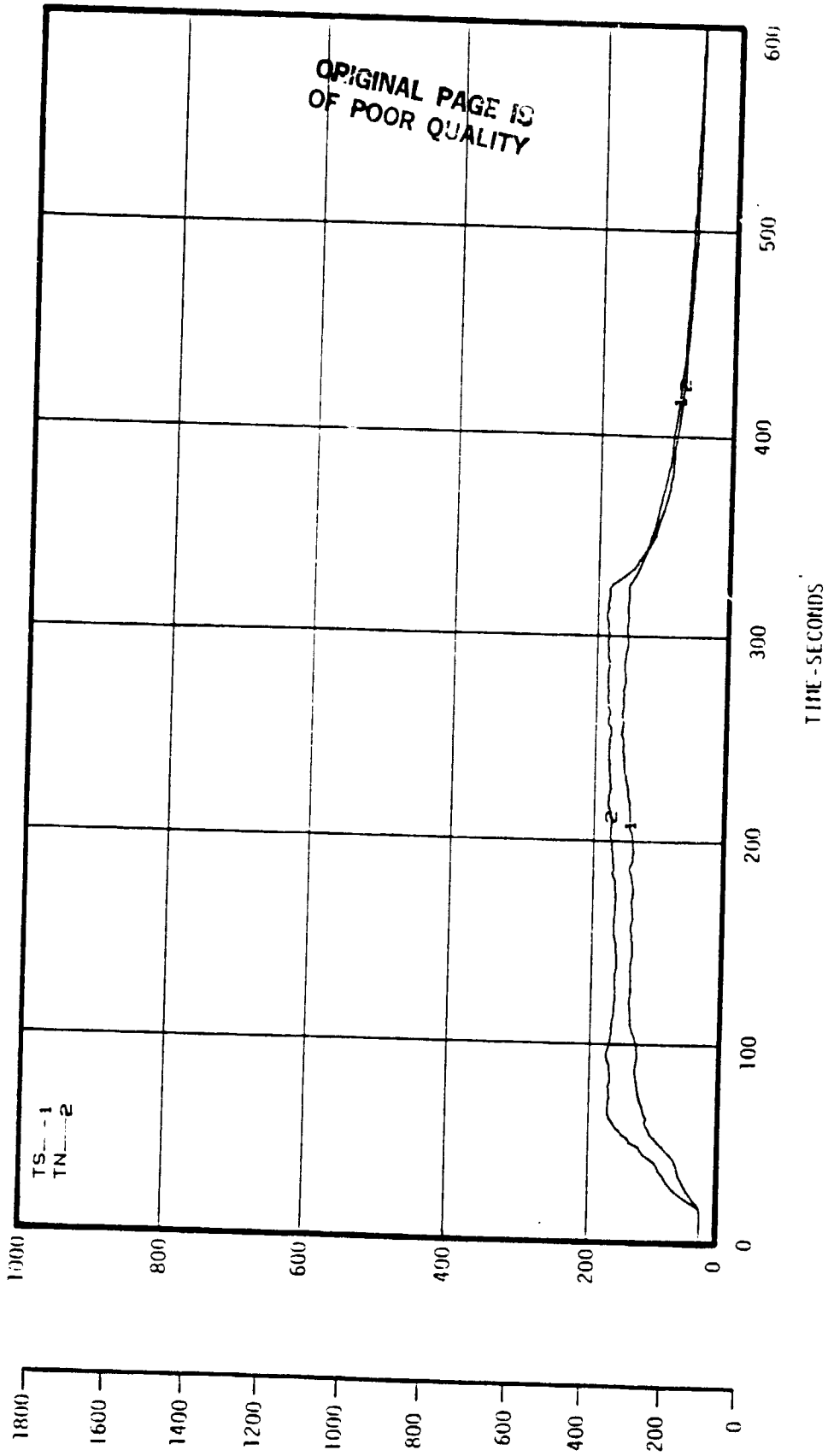
SEAT CUSHION TEMPERATURES



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CEILING TEMPERATURE

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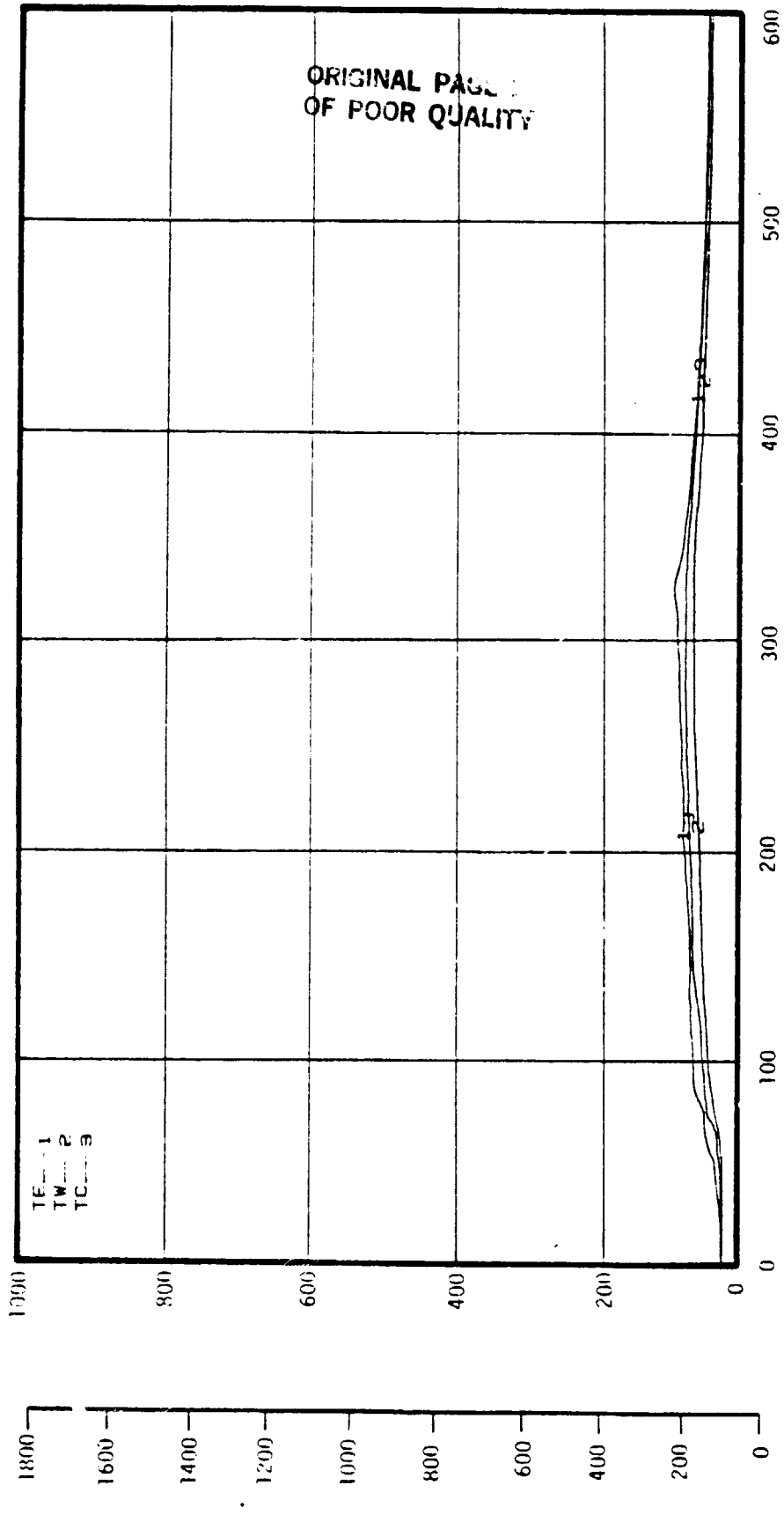


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CEILING TEMPERATURE

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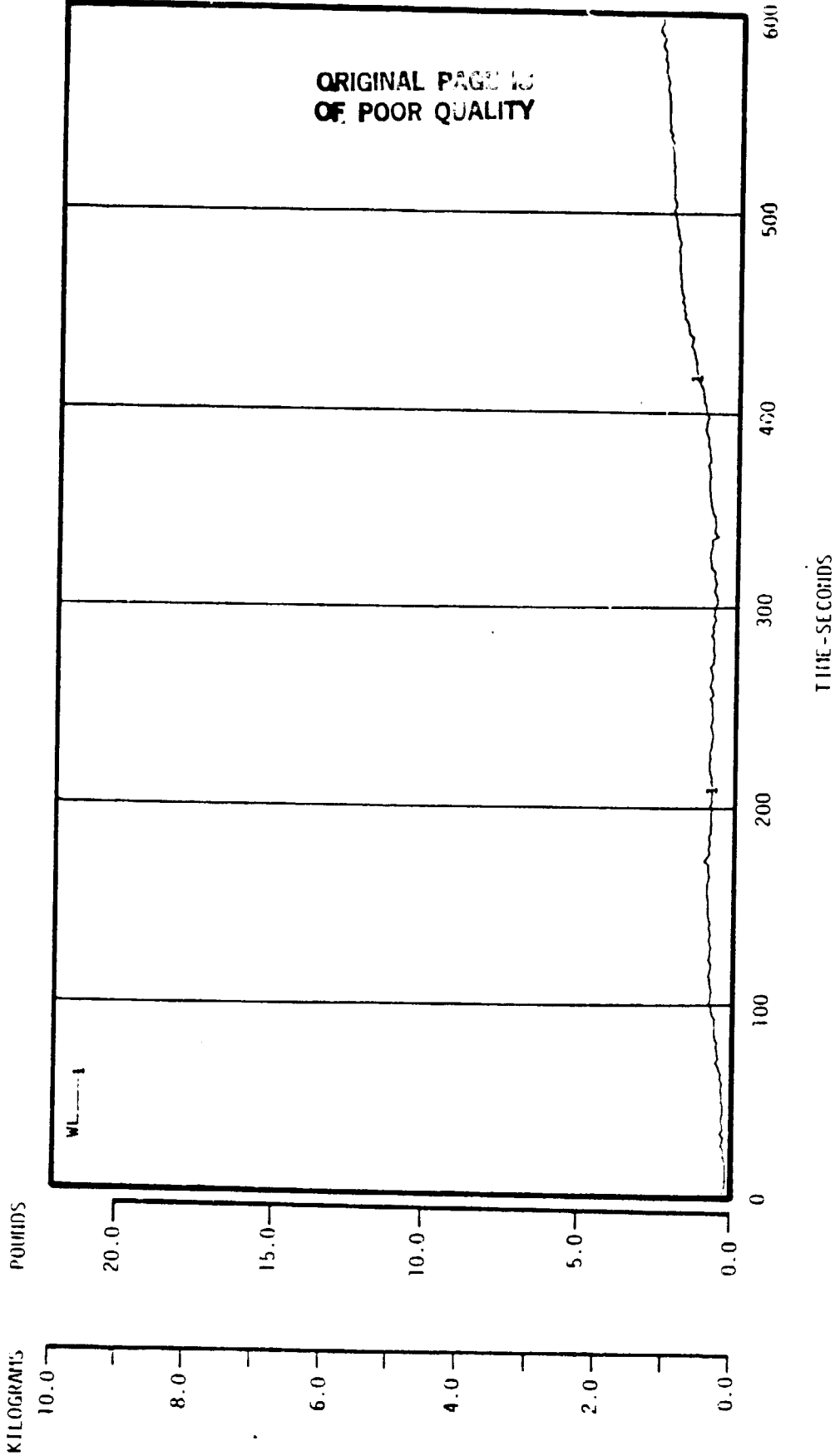


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CUSHION CONSTRUCTION NUMBER 10.0

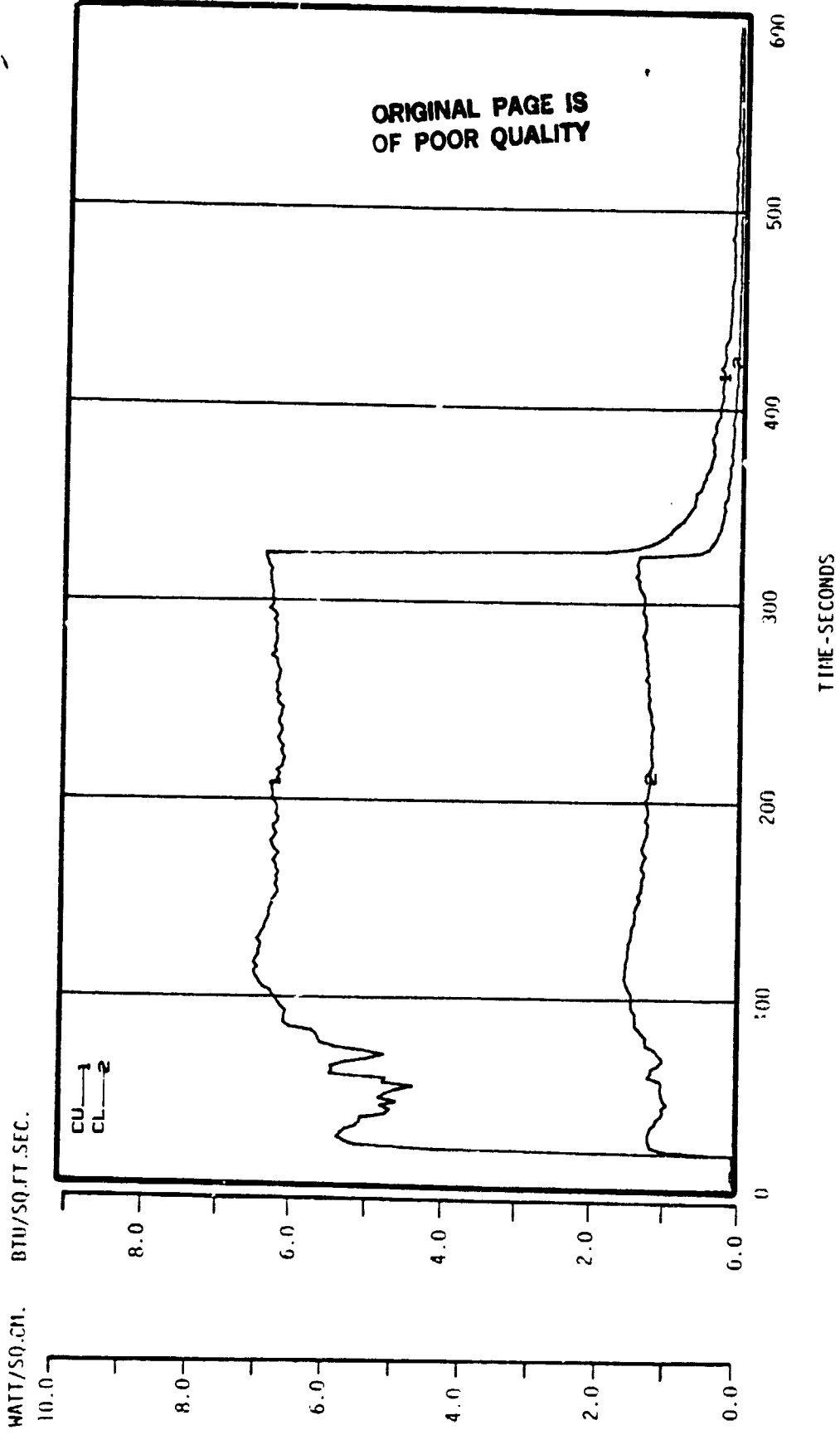
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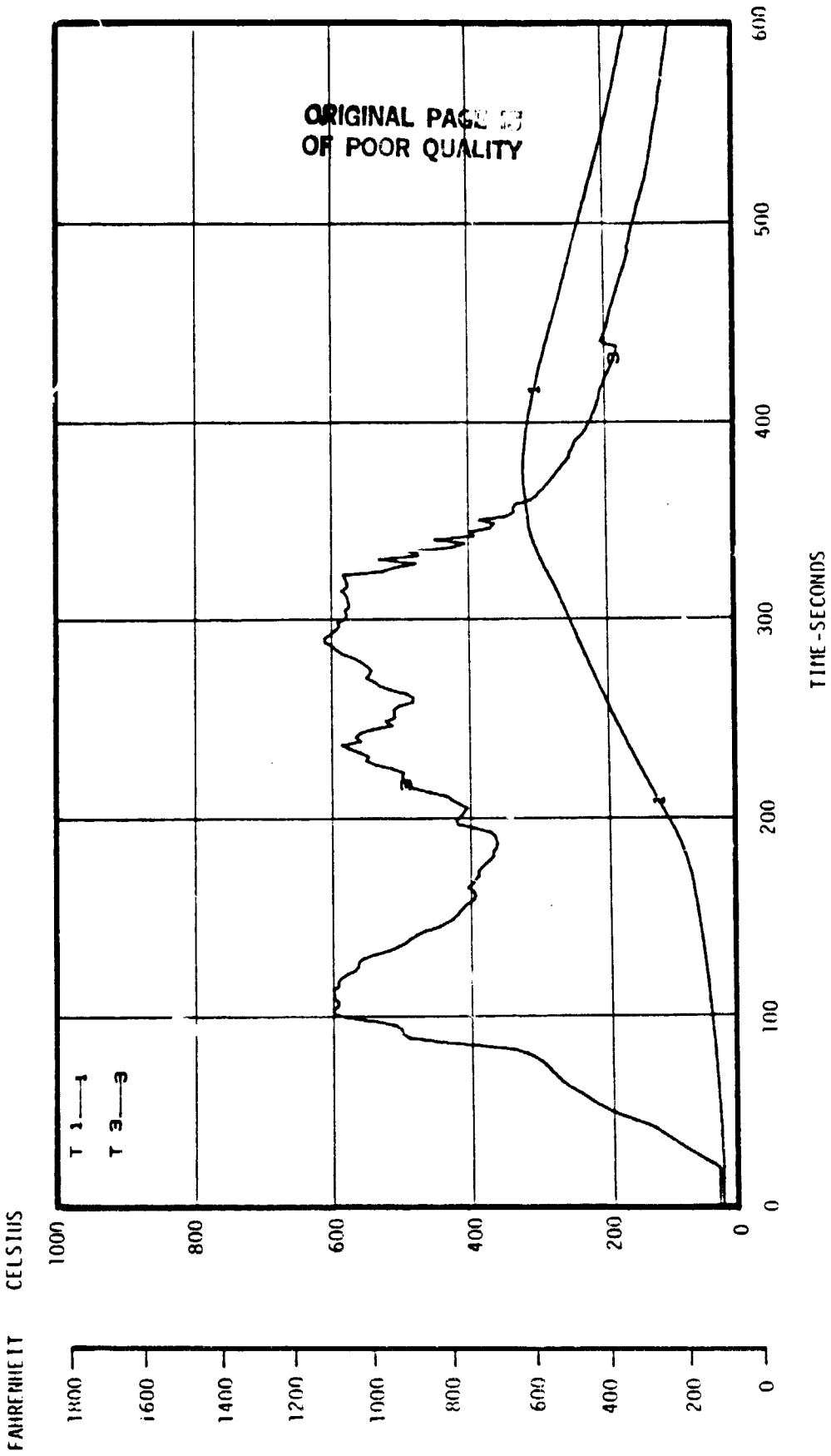
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CUSHION CONSTRUCTION NUMBER 10.0

HEAT FLUX



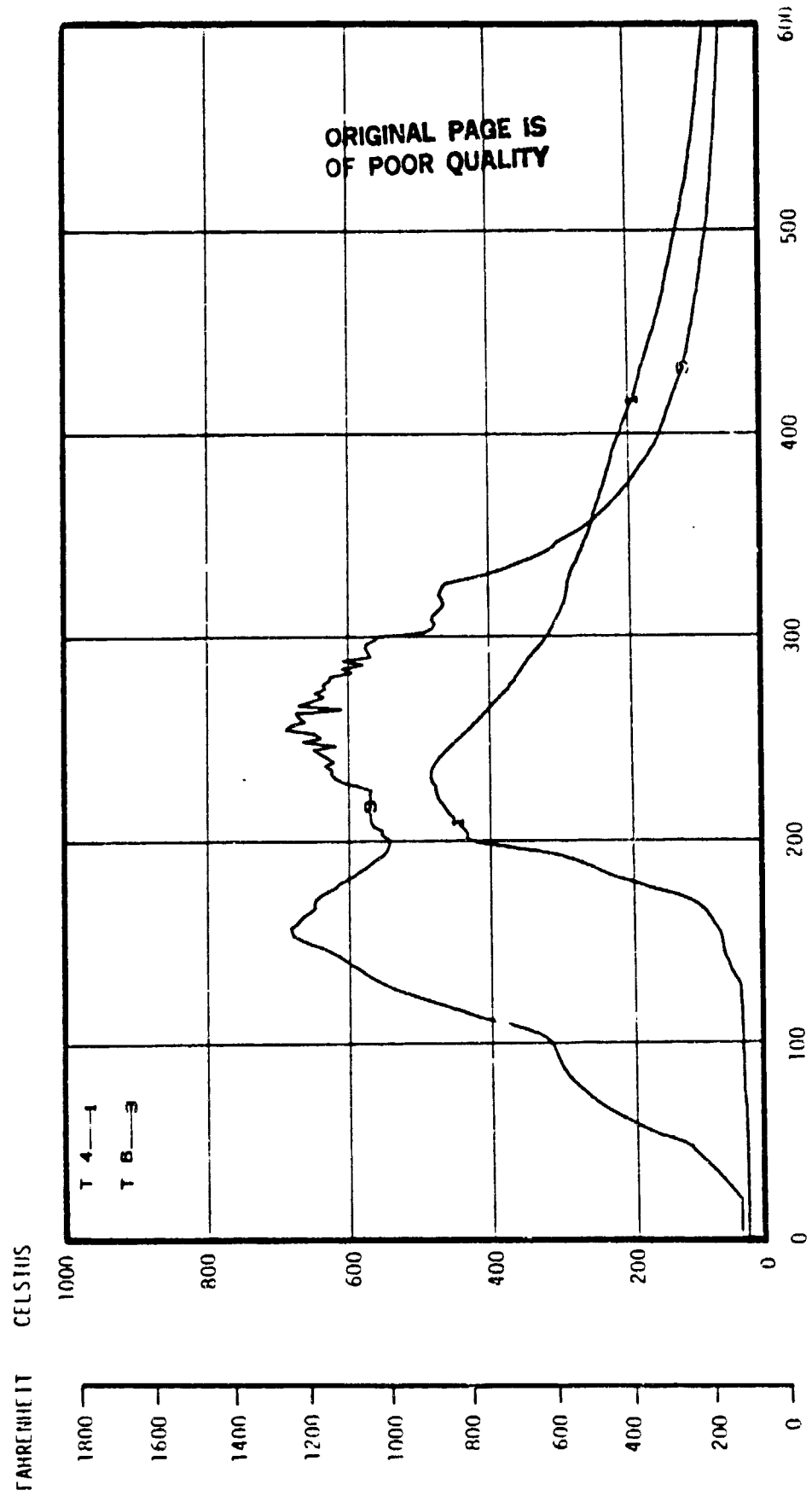
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NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 20
CUSHION CONSTRUCTION NUMBER 11.0

SEAT CUSHION TEMPERATURES



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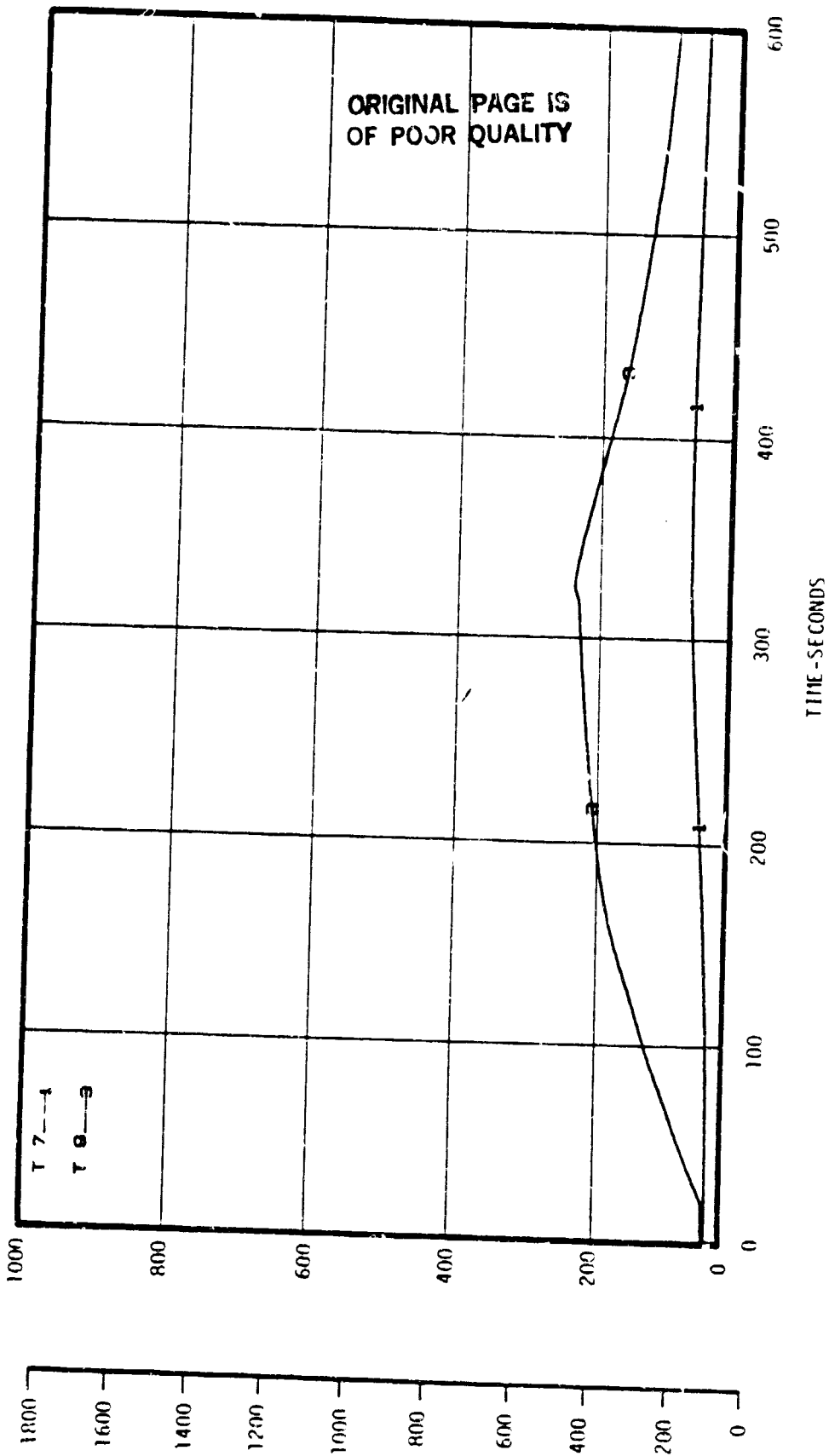
SEAT CUSHION TEMPERATURES



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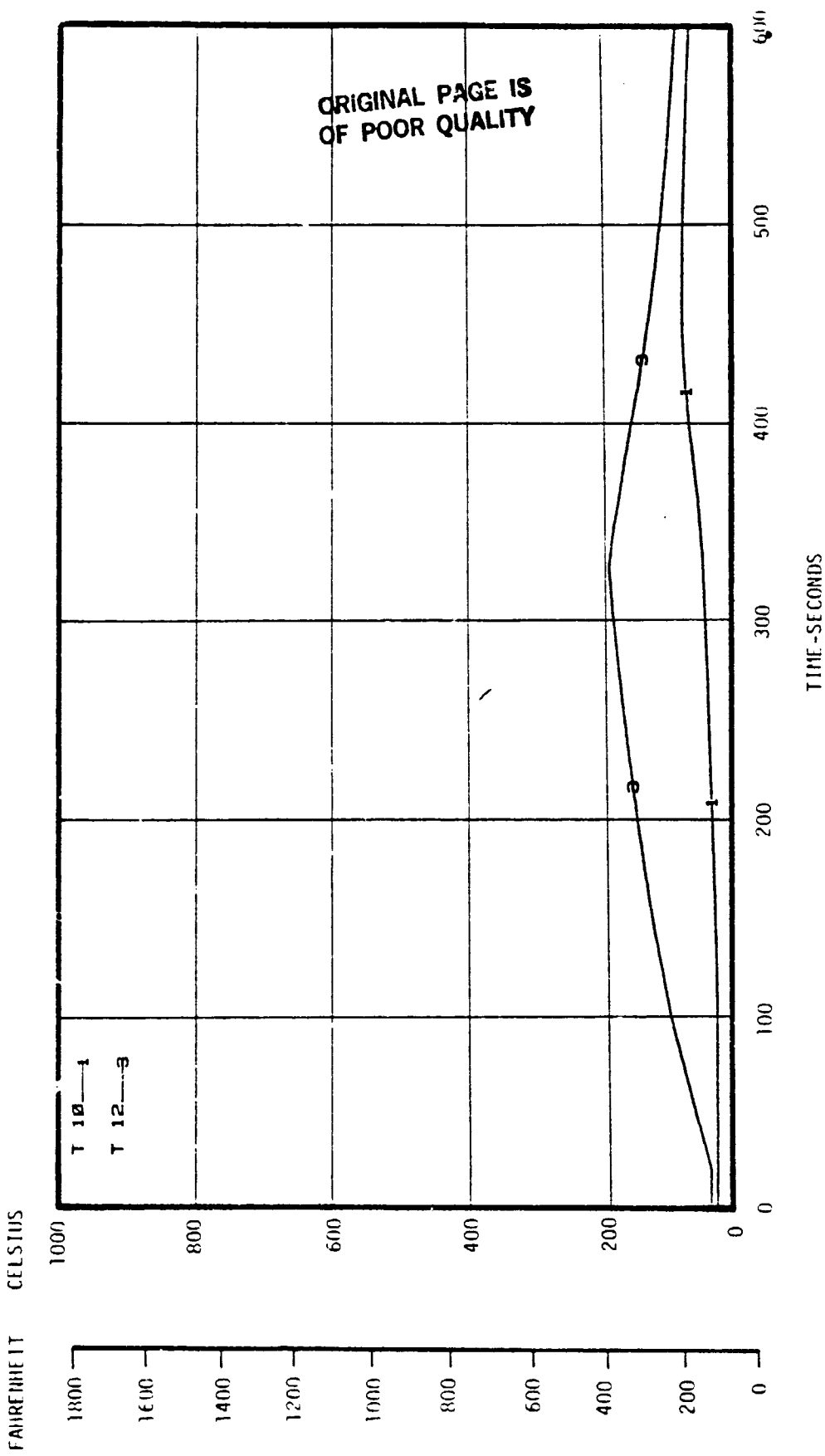
SEAT CUSHION TEMPERATURES

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DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/10/82 P. 04
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SEAT CUSHION TEMPERATURES

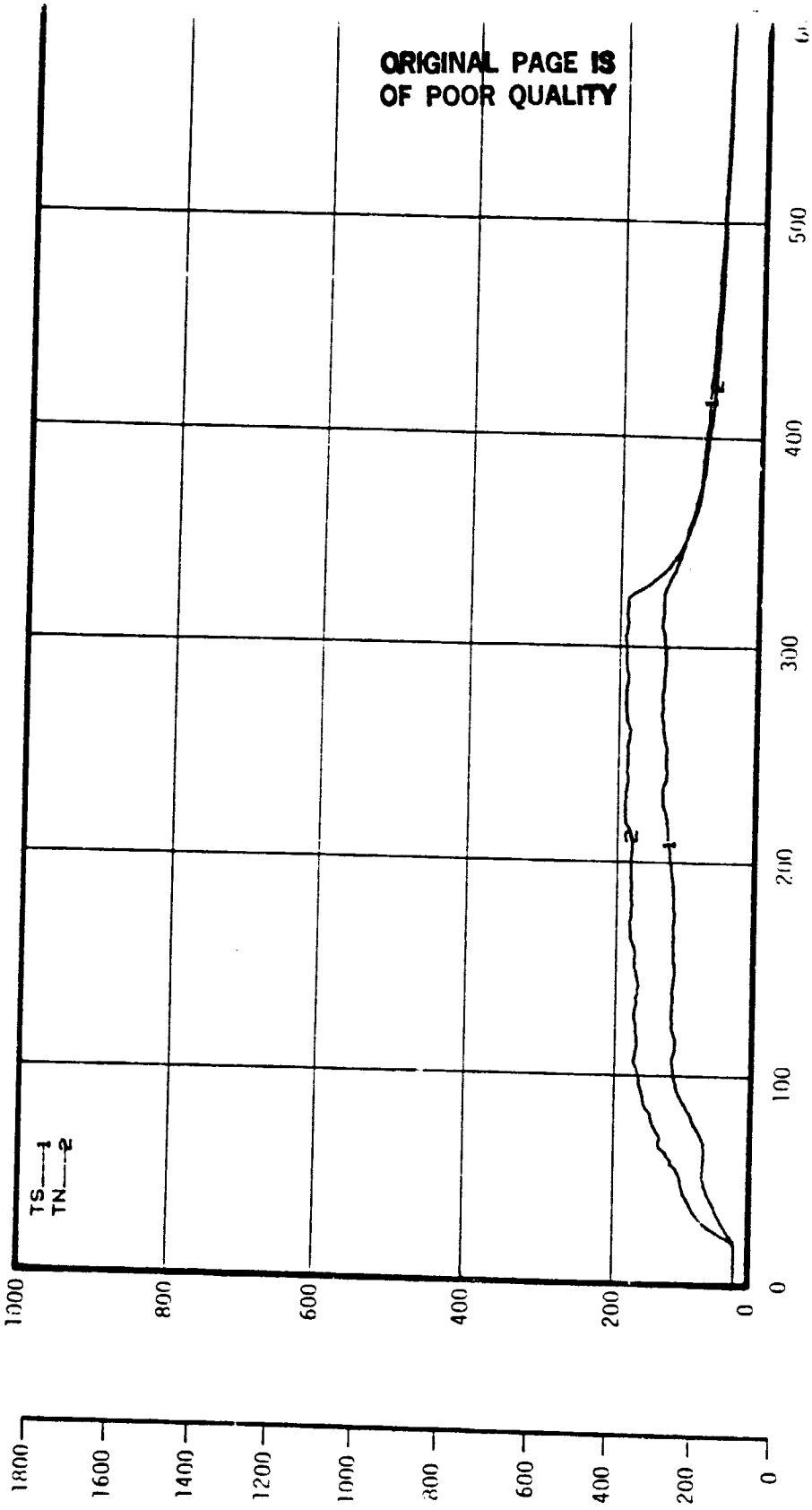


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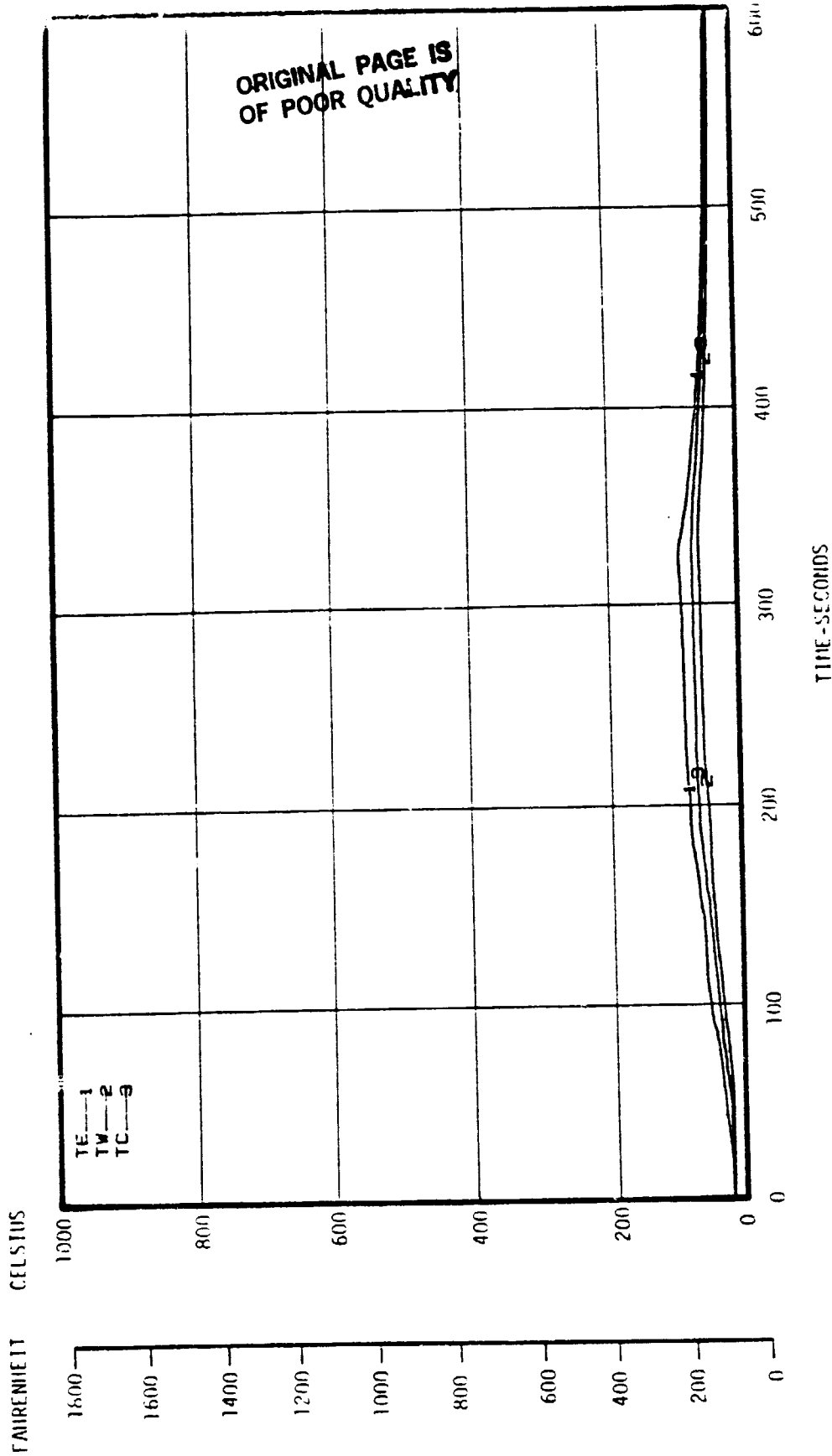
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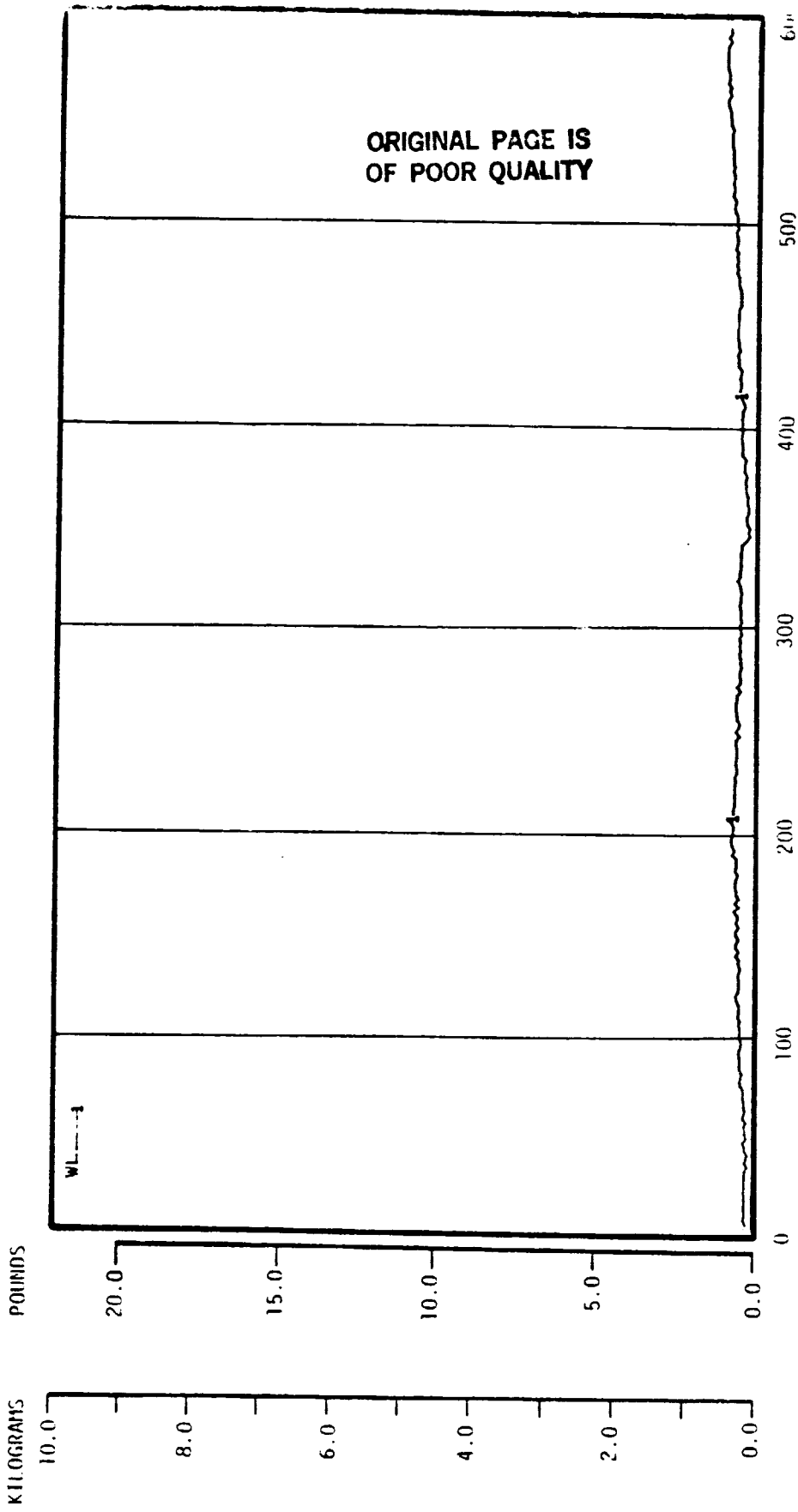
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NASA-MES FULL SCALE CUSHION BURN TEST NUMBER 20
CUSHION CONSTRUCTION NUMBER 11.0

CEILING TEMPERATURE



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WEIGHT LOSS



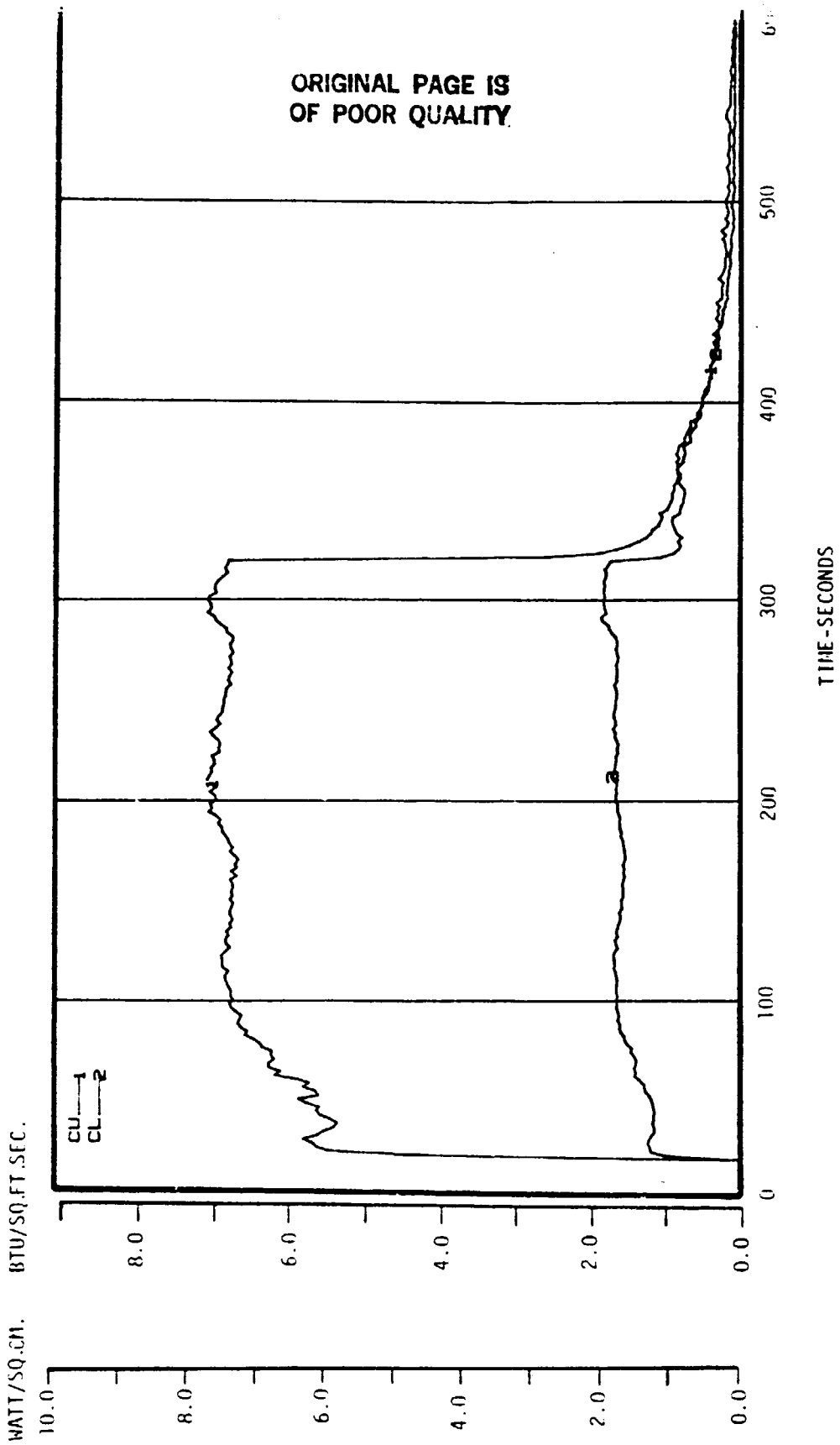
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NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 20

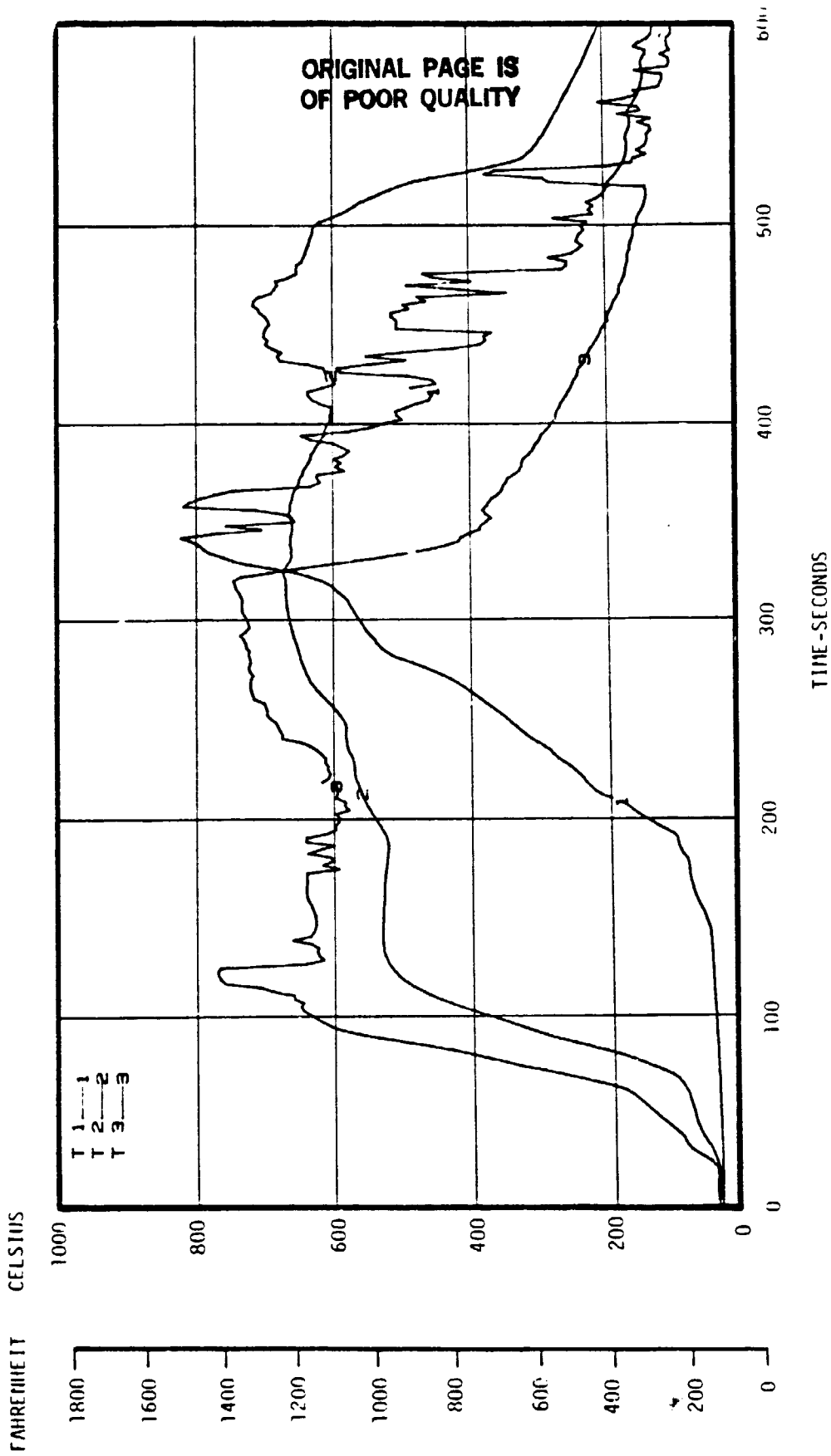
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HEAT FLUX



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/10/82 11.00
NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 21
CUSHION CONSTRUCTION NUMBER 12.0

SEAT CUSHION TEMPERATURES

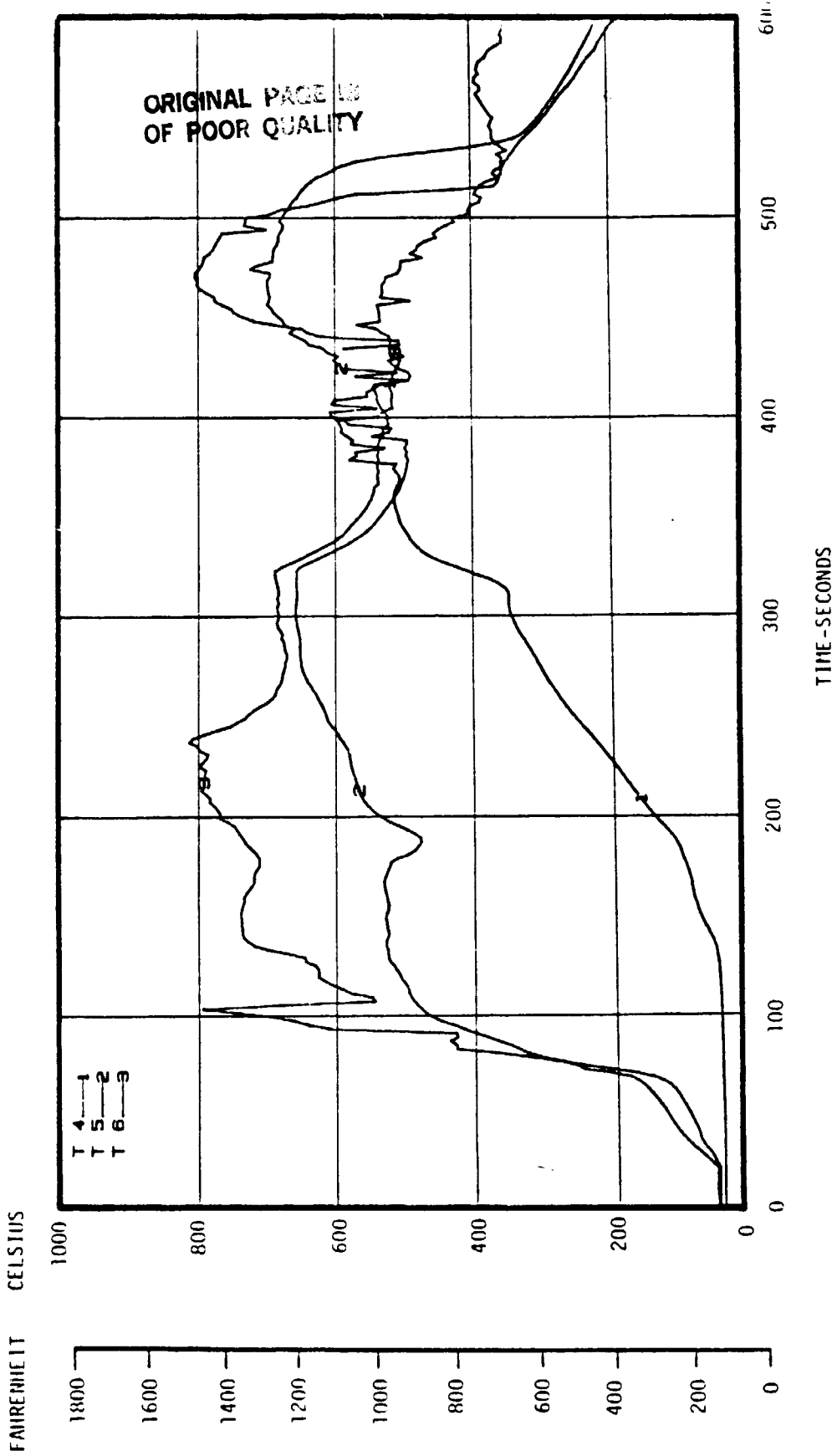


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DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/10/02 11.00
NASA-AHS FULL SCALE CUSHION BURN TEST NUMBER 21
CUSHION CONSTRUCTION NUMBER 12.0

SEAT CUSHION TEMPERATURES



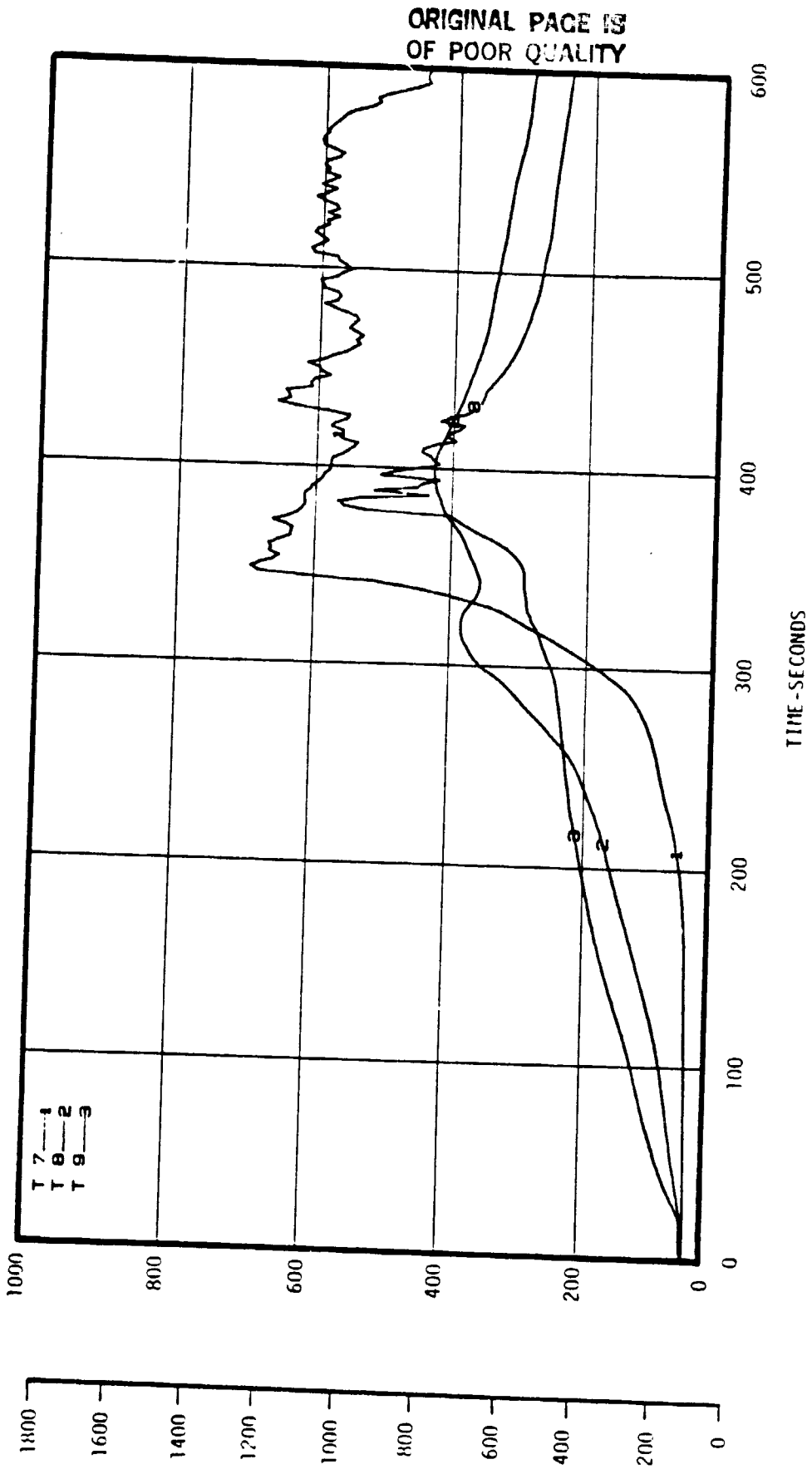
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CUSHION CONSTRUCTION NUMBER 12.0

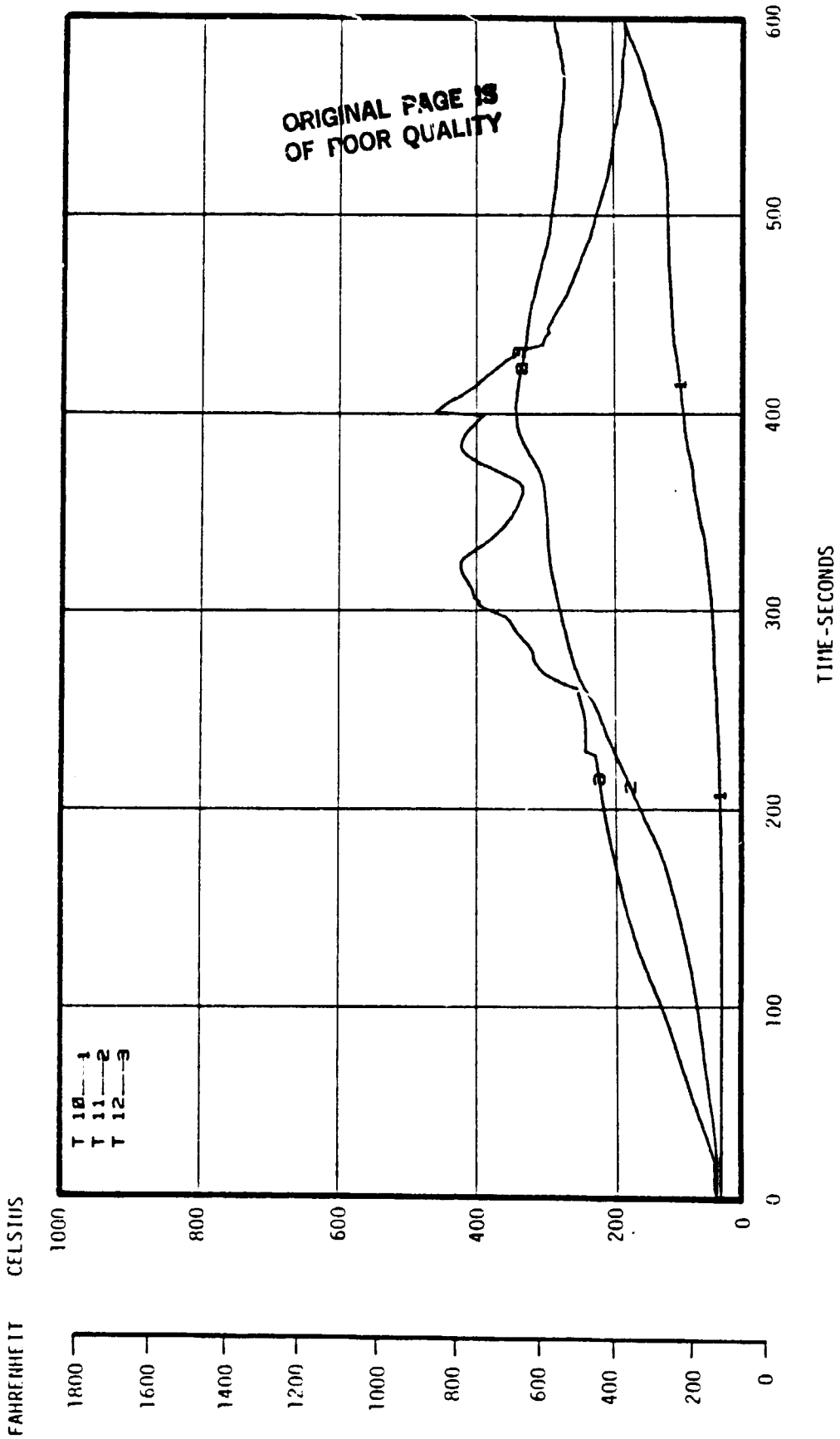
SEAT CUSHION TEMPERATURES

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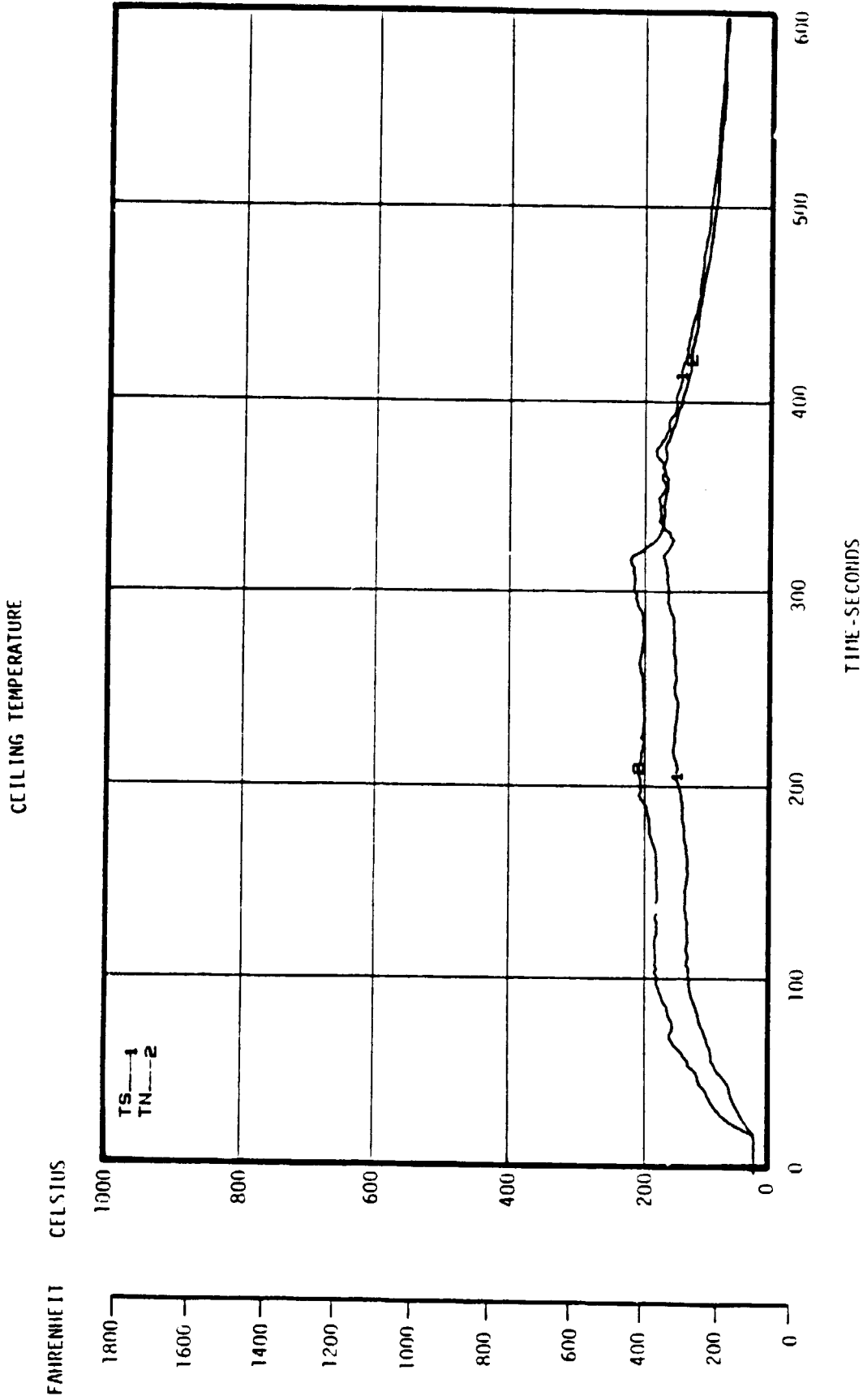
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CUSHION CONSTRUCTION NUMBER 12.0

SEAT CUSHION TEMPERATURES



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/18/82 11.00
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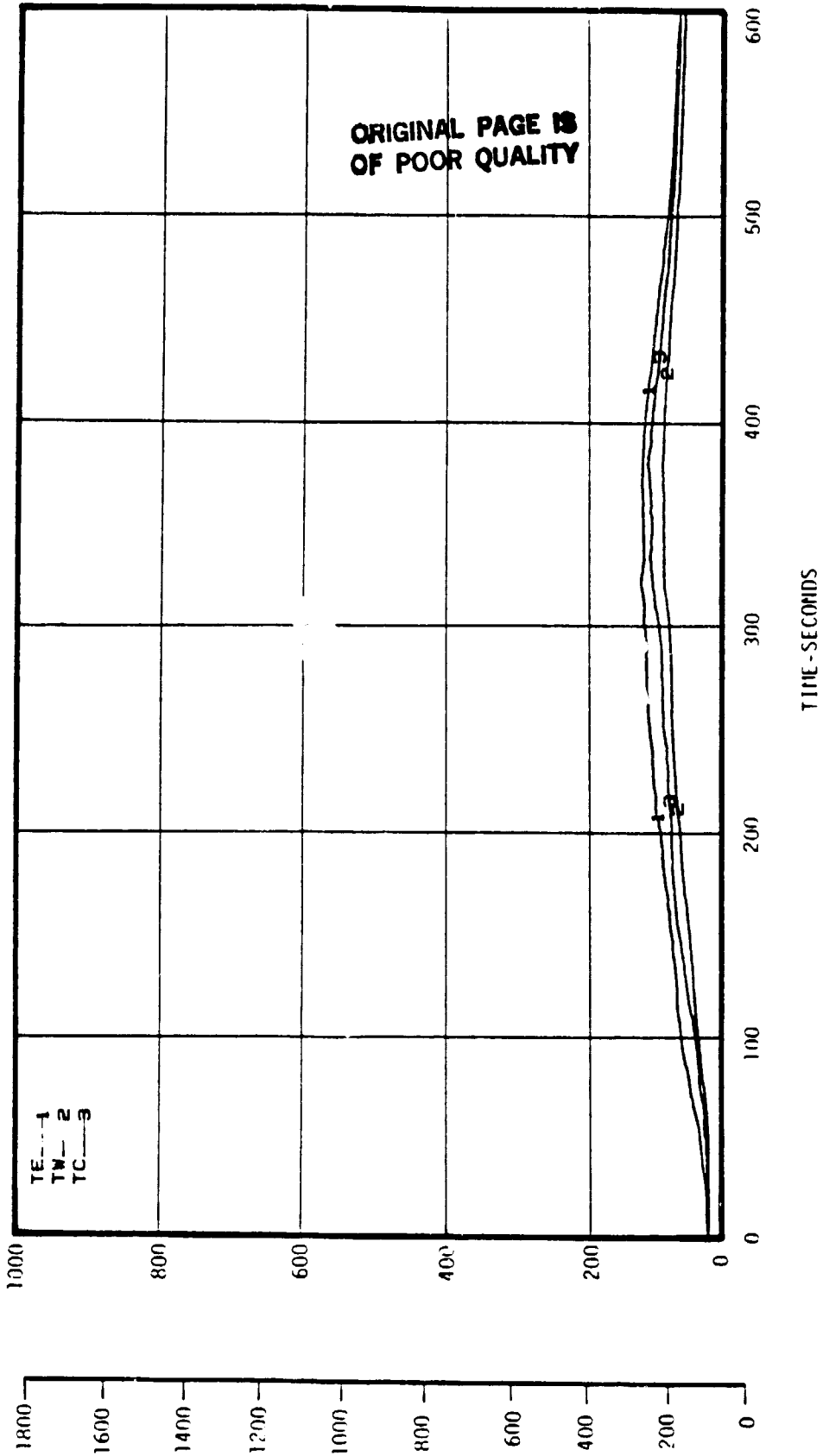


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CEILING TEMPERATURE

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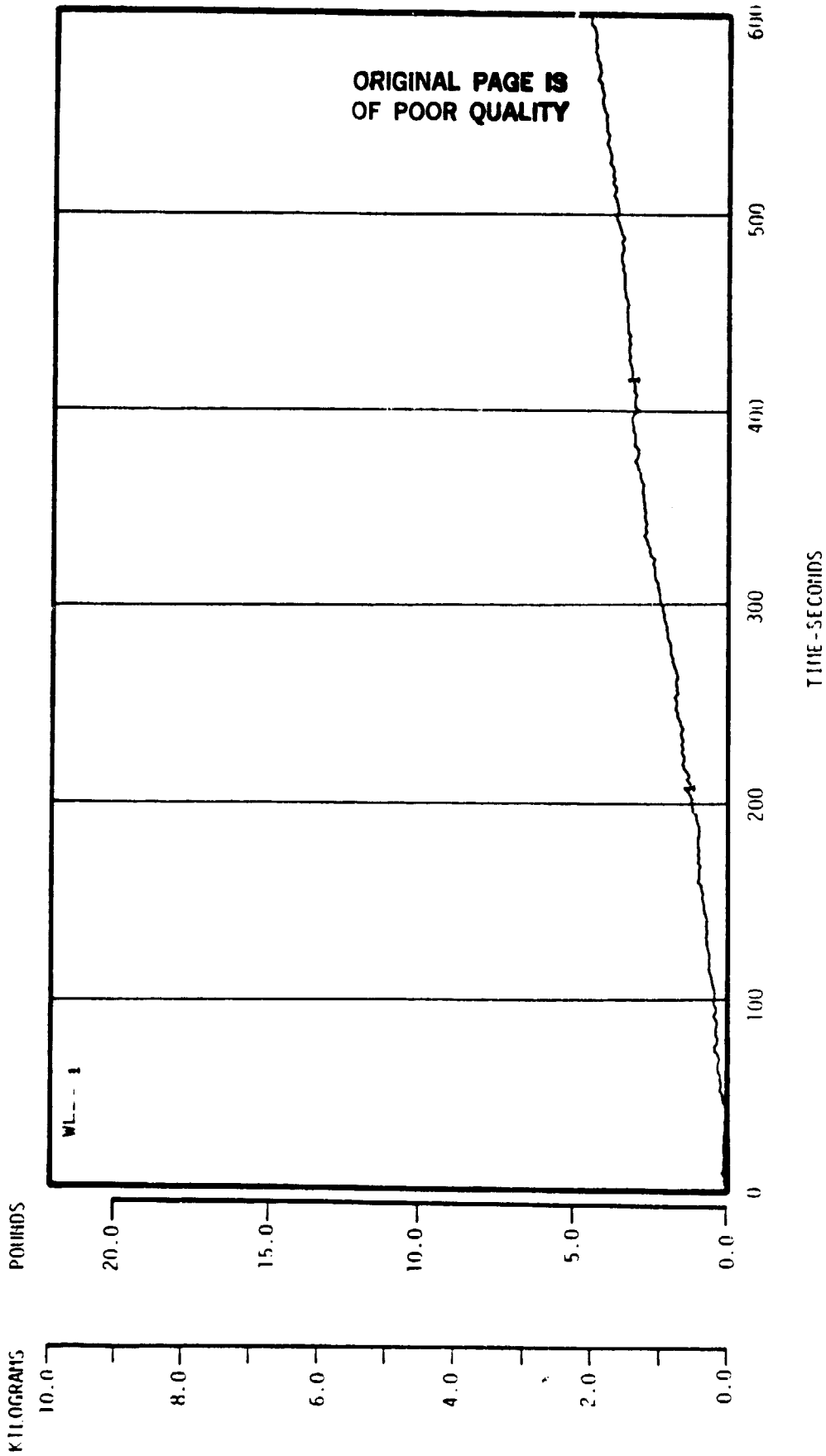


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CUSHION CONSTRUCTION NUMBER 12.0

WEIGHT LOSS

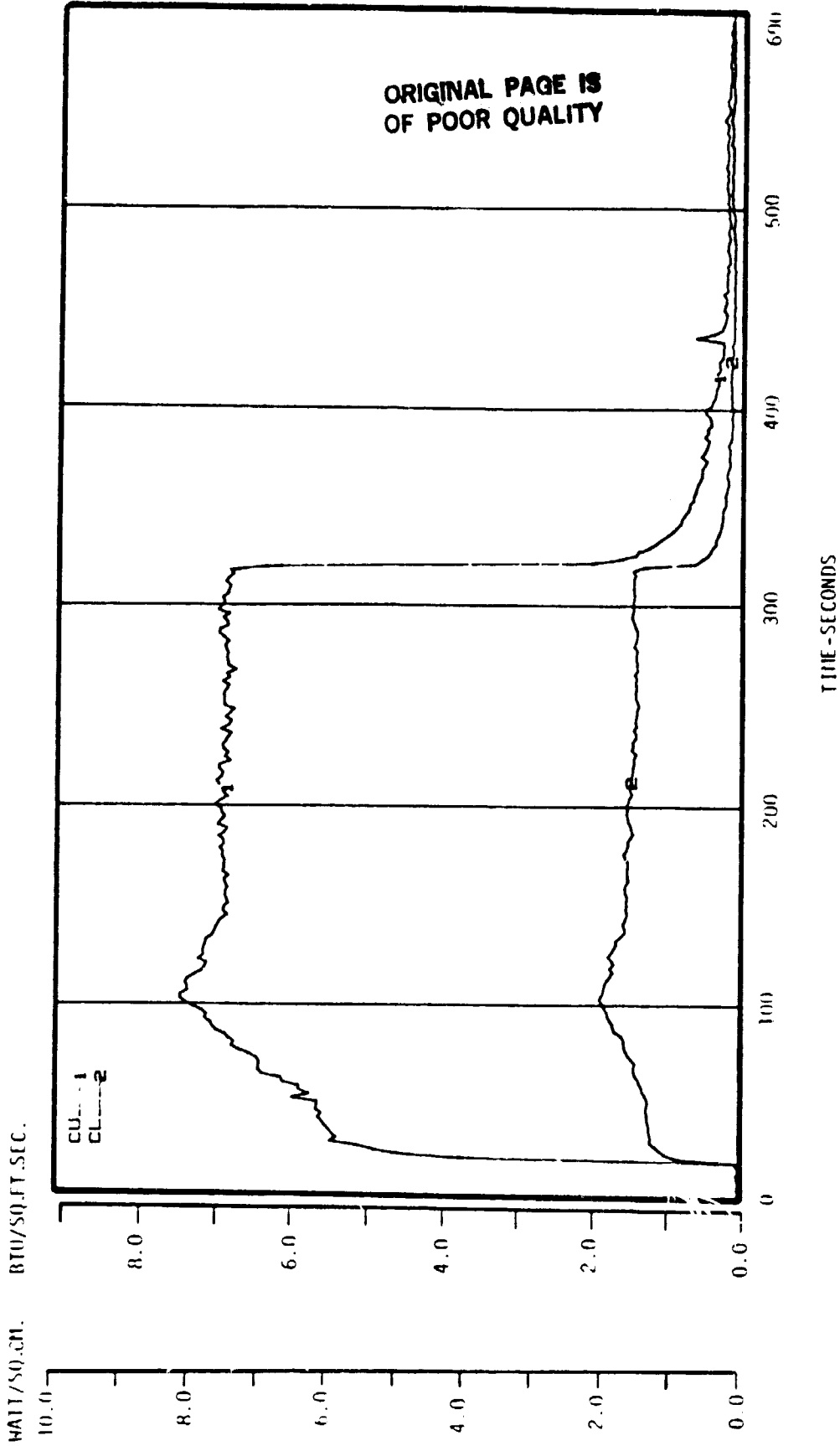


UNIVERSITY OF MICHIGAN AIRCRAFT CABIN FIRE SIMULATOR 03/18/82 11.00

NASA-AMES FULL SCALE CUSHION BURST TEST NUMBER 21

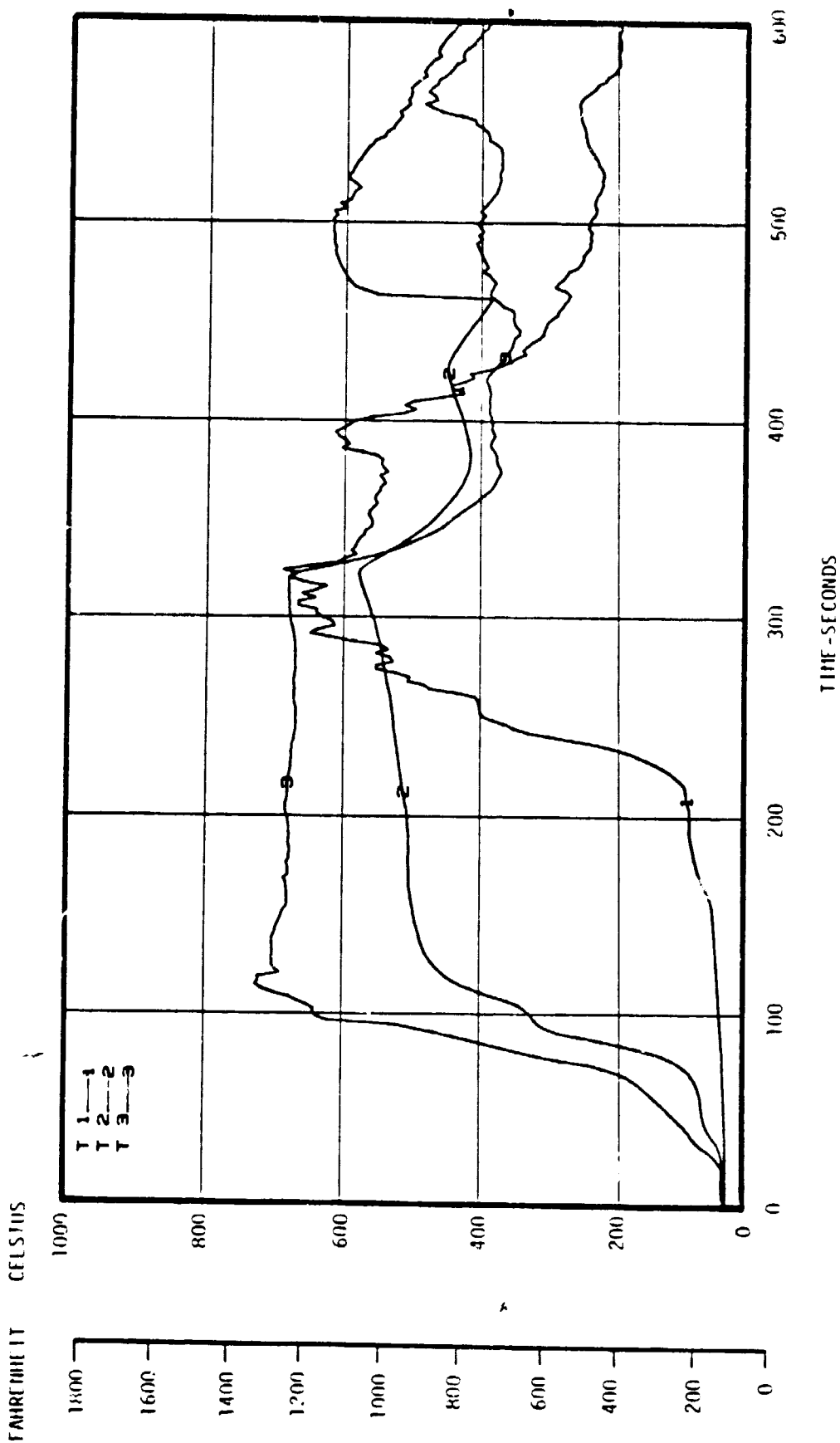
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HEAT FLUX



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/10/82 13.42
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SEAT CUSHION TEMPERATURES



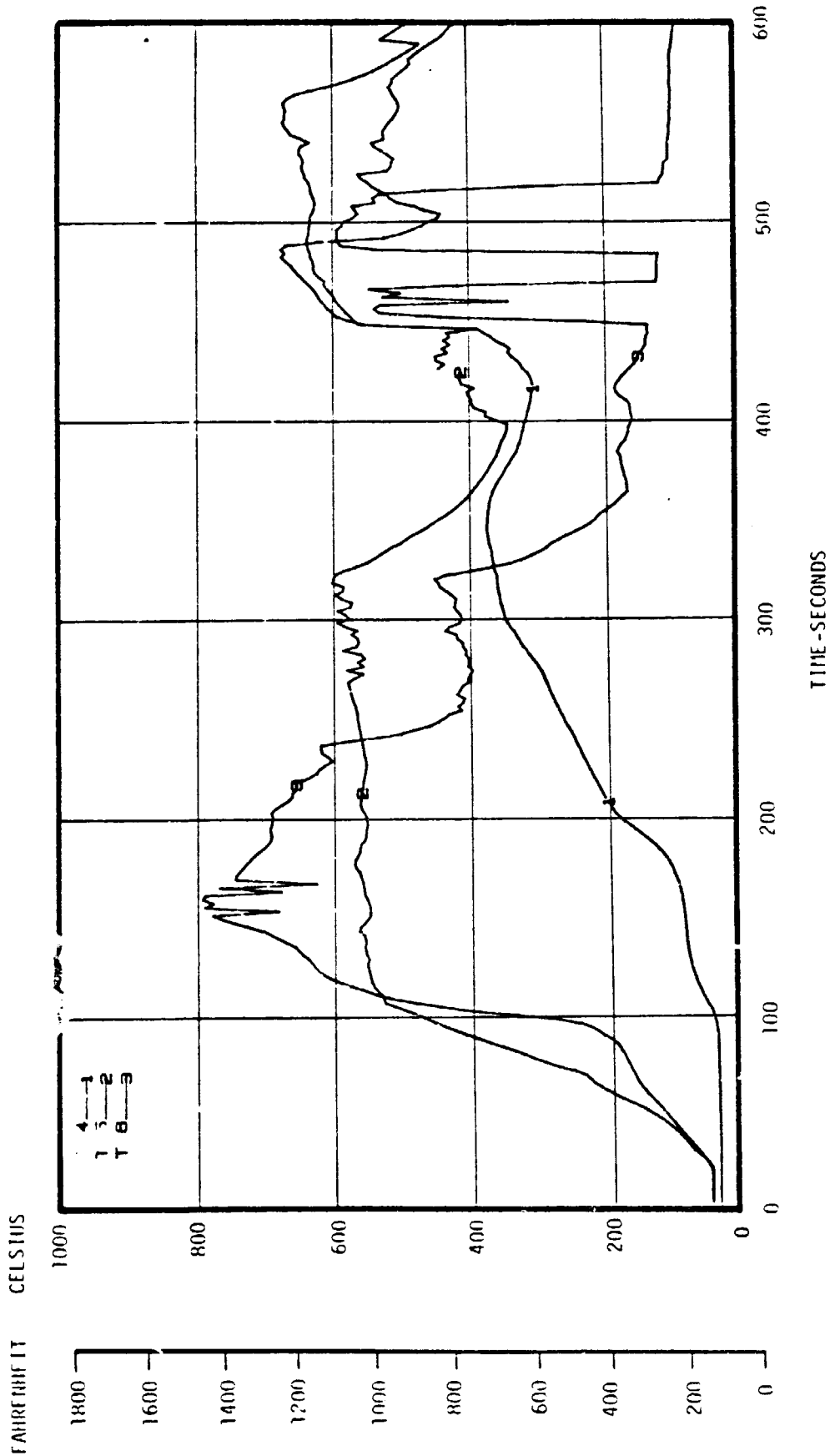
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SEAT CUSHION TEMPERATURES

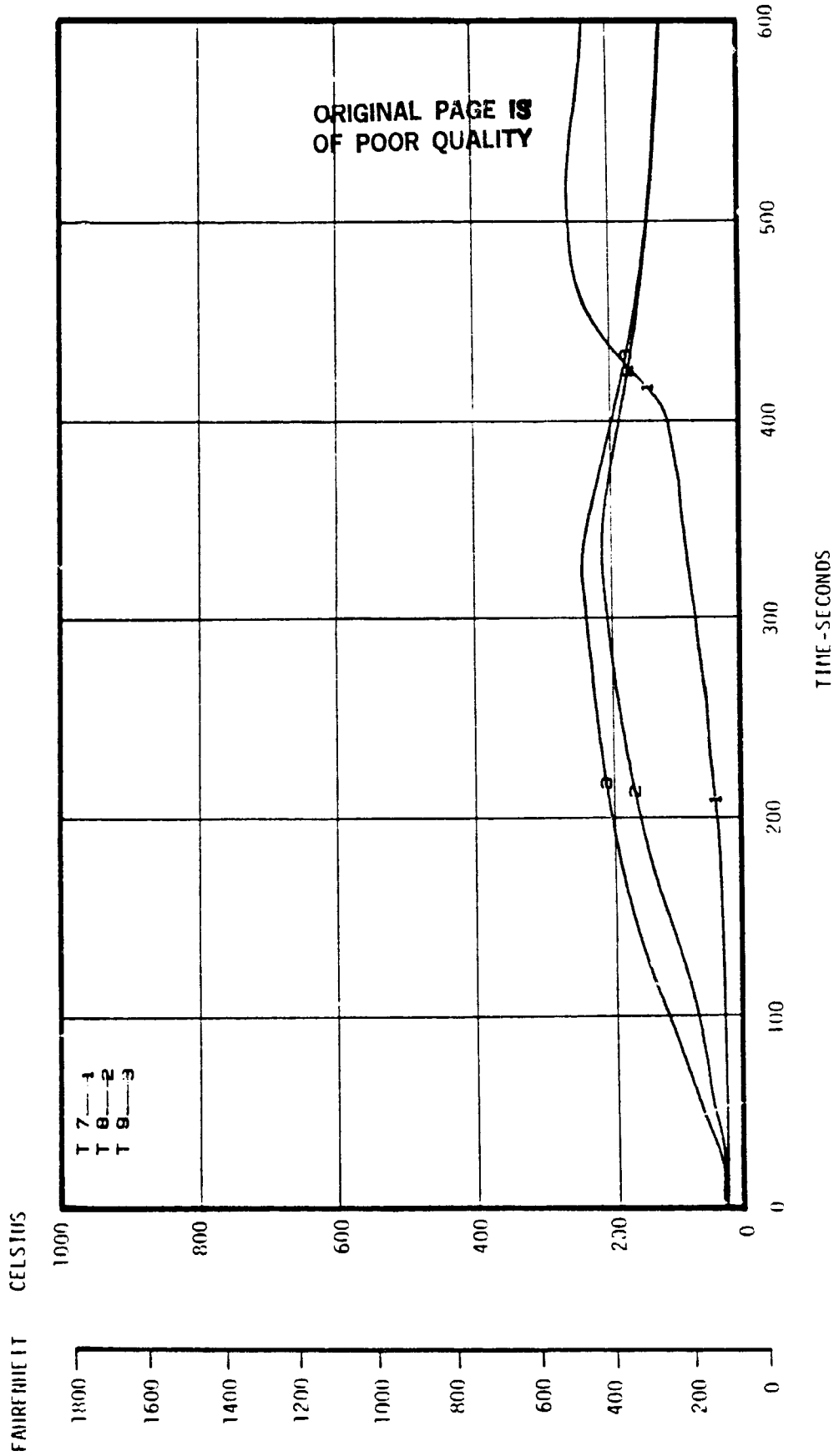


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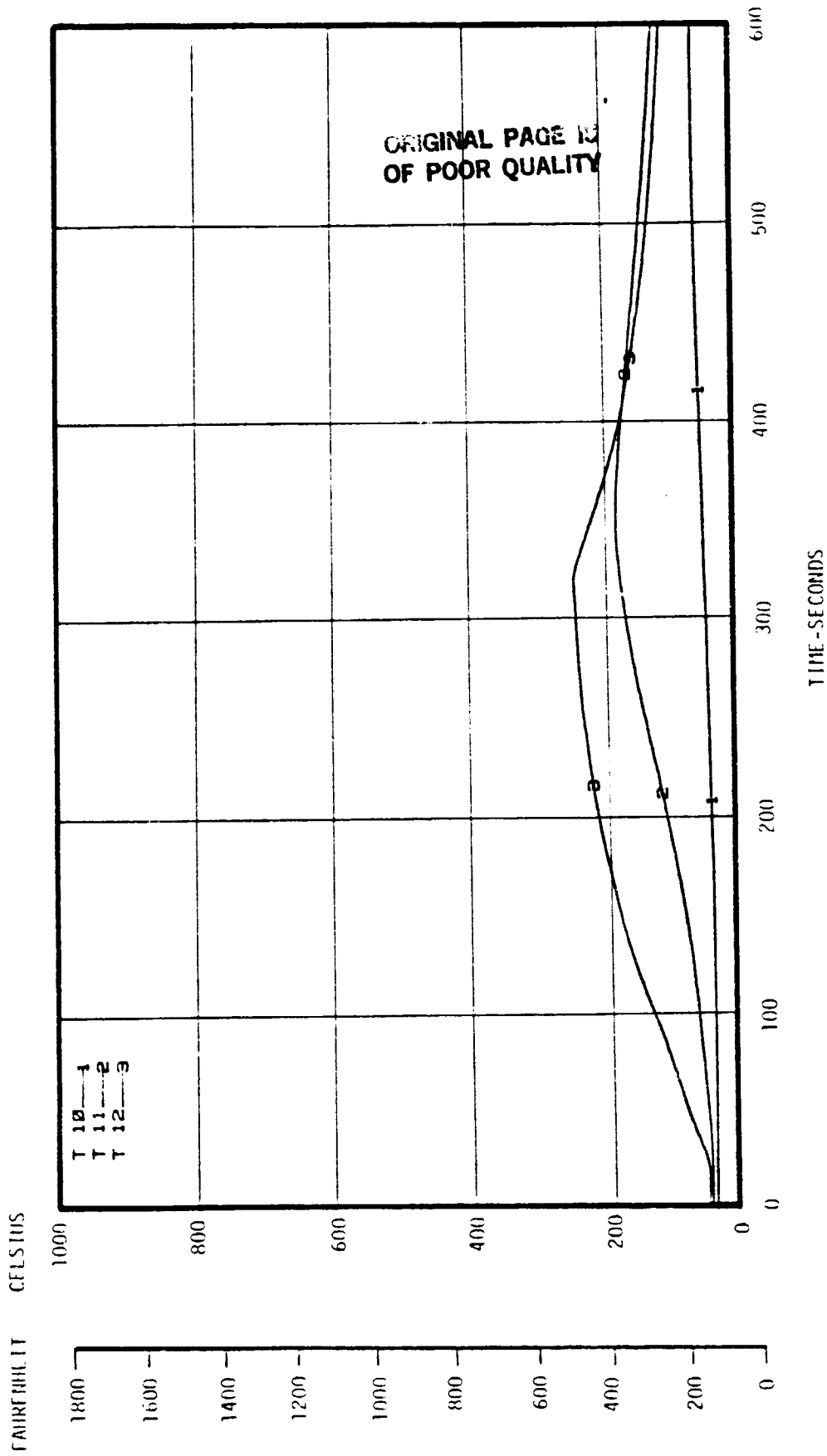
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SEAT CUSHION TEMPERATURES



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/18/82 13.42
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SEAT CUSHION TEMPERATURES

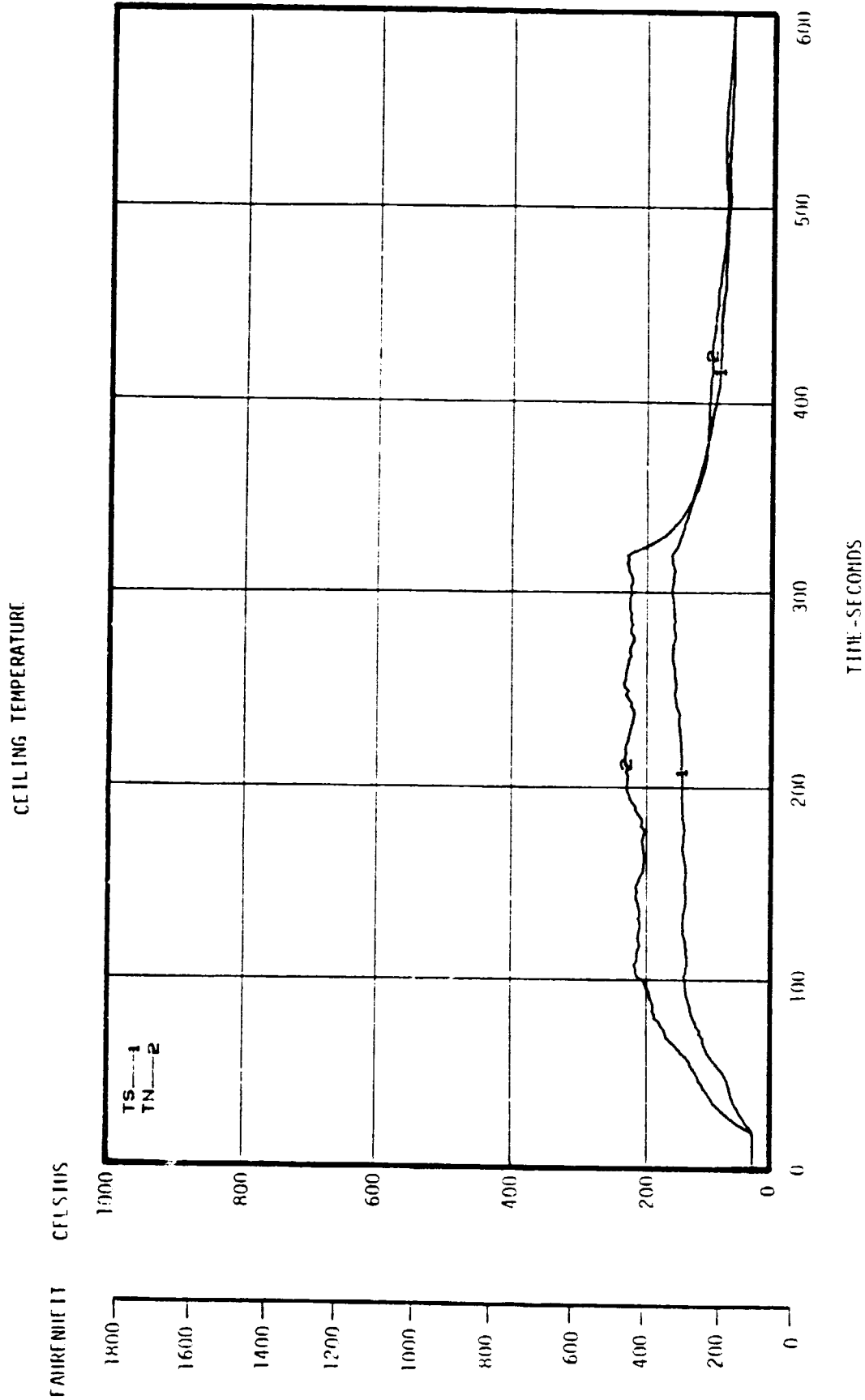


DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/10/62 13.42

NASA-AMES FULL SCALE CUSHION BURH TEST NUMBER 22

CUSHION CONSTRUCTION NUMBER 13.0

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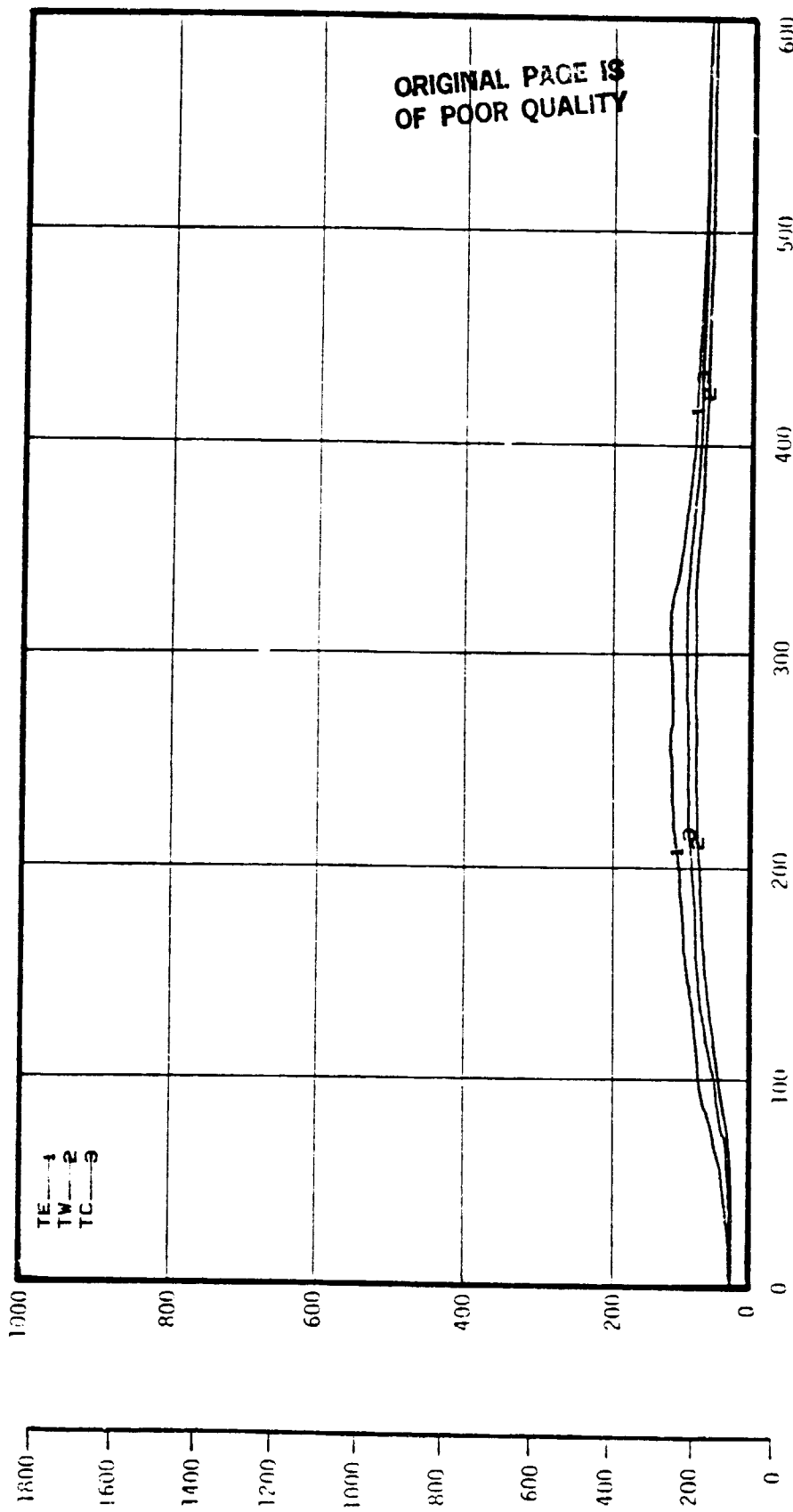
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NASA-AMES FULL SCALE CUSHION BURN TEST NUMBER 22

CUSHION CONSTRUCTION NUMBER 13.0

CEILING TEMPERATURE

FAHRENHEIT CELSIUS

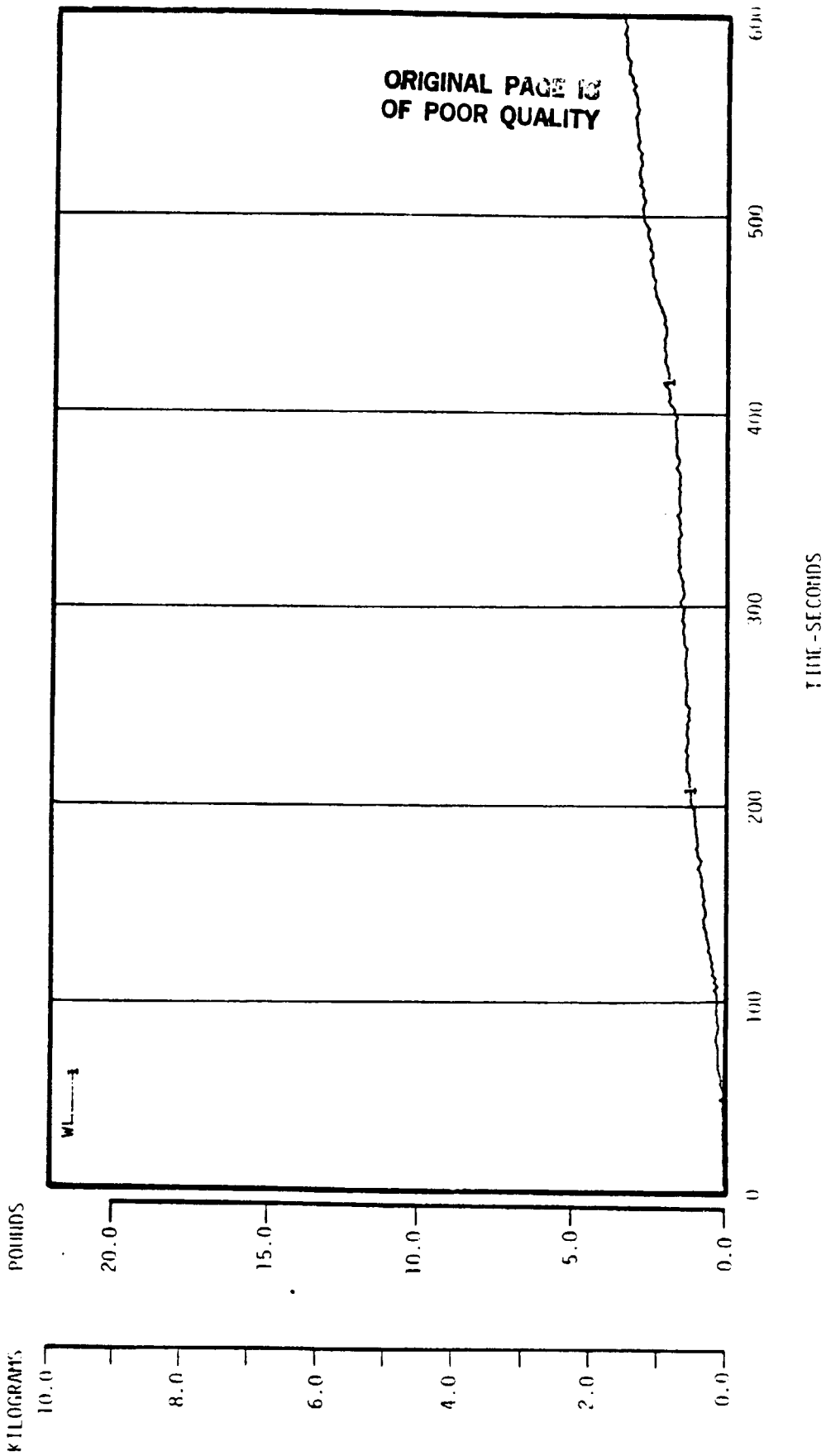


DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 03/18/82 13.42

NASA-AMES FULL SCALE CUSHION BURR TEST NUMBER 22

CUSHION CONSTRUCTION NUMBER 13.0

WEIGHT LOSS



DOUGLAS AIRCRAFT CABIN FIRE SIMULATOR 09/18/62 13.42

NASA-Mu 5 FUEL SCALP COSSION BURR TEST NUMBER 22

VISUATOR CONSTRUCTION NUMBER 13.0