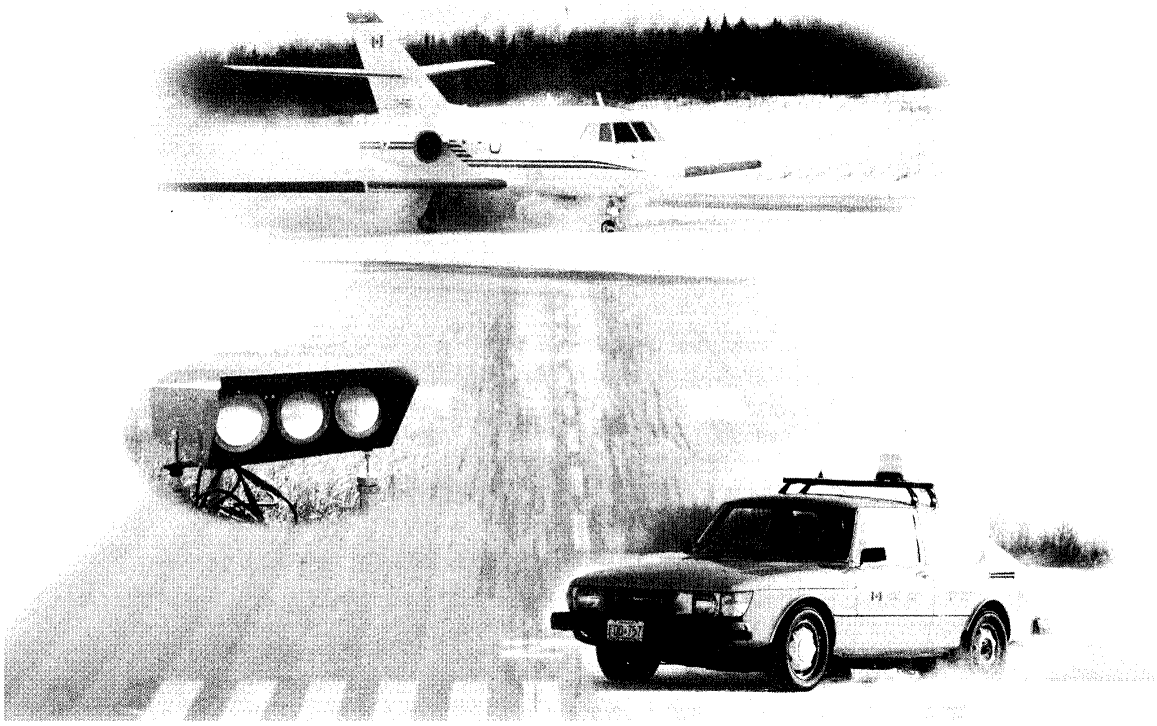
Transport Canada Transports Canada

TP 13706E
(01/1998)

Technical Evaluation Engineering Aerodrome Safety, Civil Aviation



TC-1001804

Canada

TP 13706E
(01/1998)

TC-1001804

TEST REPORT

Study of Frost /Dew Cover on Precision Approach Path Indicators (PAPI)

Contract No. 5115

AARME/E-98-13

TP 13706E

January 1998

Transport Canada Transports Canada

PUBLICATION DATA FORM

1. Transport Canada Publication No. NA	2. Project No.	3. Recipient's Catalogue No.
4. Title and Subtitle TEST REPORT Study of Frost/Dew Cover on Precision Approach Path Indicators (PAPI) Contract No. 5115		5. Publication Date 1998/01/01 6. Performing Organization Document No. AARME/E-98-13
7. Author(s) PMG Technologies Test and Research Centre		8. Transport Canada File No.
9. Performing Organization Name and Address Transport Canada, Civil Aviation Aerodrome Safety, Evaluation Engineering	Technical	10. PWGSC File No. 11. PWGSC or Transport Canada Contract No.
12. Sponsoring Agency Name and Address Aerodrome Safety Branch, Technical Evaluation Engineering 330 Sparks Street Tower C, Place de Ville, 7B Ottawa, Ontario, Canada K1A 0N8		13. Type of Publication and Period Covered 14. Sponsoring Agency Code
15. Supplementary Notes		16. Project Officer

17. Abstract

A study of frost was conducted on a number of designs of Precision Approach Path Indicator (PAPI) light units. The purpose of the study is to eliminate the possibility of a false signal being presented to aircrafts from a frosted PAPI, and thus to prevent a potential hazard. The study is split up into four parts along with photographs.

18. Key Words PAPI lights, minimal current test, Dew test, cold chamber	19. Distribution Statement For general or public distribution.

20. Security Classification (of this publication)	21. Security Classification (of this page)	22. Declassification (date)	23. No. of Pages 136	24. Price $0.00

02-0149E (0011-02)

Canada

TEST REPORT

STUDY OF FROST / DEW COVER ON PRECISION APPROACH PATH INDICATORS (PAPI)

Prepared by:
PMG TECHNOLOGIES
TEST AND RESEARCH CENTRE
100 rue du Landais
Blainville, (Quebec), J7C 5C9.

Contract N°: 98-5115

For:
TRANSPORT CANADA
CIVIL AVIATION
Technical Evaluation Engineering (AARME)
Ottawa, (Ontario)

The test results presented herein are proprietary to Transport Canada, and shall not in any fashion be duplicated or issued to others without the prior consent of Transport Canada, Civil Aviation, Aerodrome Safety, AARME, Ottawa.

Préparé par: Prepared by: **DIANE VACRI**	Date 15-6-98
Vérifié par: Verified by: **CLAUDE SAUVAGEAU**	Date 15-6-98
Approuvé par: Approuved by: **CLAUDE SAUVAGEAU**	Date 15-6-98

TABLE OF CONTENTS

Intentionally left blank

INTRODUCTION

Pursuant to a request from Transport Canada – Civil Aviation, a frost study was conducted on a number of designs of Precision Approach Path Indicator (PAPI) light units. The objective for the project is to eliminate the possibility of a false signal being presented to aircraft from a frosted PAPI, and thus to prevent a potential hazard. For more details, see terms of reference (Annex A).

The project is separated in 4 parts:

1. Determine the amount of operating time required to eliminate frost 1/16" (1.6 mm) from the PAPI lens or cover glass at different temperatures (-5, -10, -20, -30°C).
2. Determine the minimum current level for the PAPI lights to function with a partial frost accumulation on the lenses or cover glass at the same temperatures as in 1.
3. Determine the minimum current level for the PAPI lights to function without frost accumulation on the lenses or cover glass at the same temperatures as in 1.
4. Determine what is the effect of dew on PAPI signal at 0°C.

Intentionally left blank

TEST PROCEDURE

LABORATORY BOOK FOR
PRECISION APPROACH PATH INDICATOR (PAPI)

Name of PAPI: Date:

Test type: Time:

Test Amp.:

Test number:

Test temperature:

By (initials):

Before the test:

1. We ensured that the test equipment conformed to standards (Check for ISO stamp).
2. We obtained the materials required to conduct the test procedures as stipulated in Canada Motor Vehicle Safety Standard, (CMVSS) 103. (paint gun, pressure regulator, Hydra, timer Cra-Lab, video camera, digital camera).
3 We installed a white 8' x 8' panel to receive the projected signal from the PAPI'S.
4 We installed the PAPI units on a table at the other end of the chamber (the PAPI projected the signal onto the panel surface). The supply current for the PAPI light unit was set at 6.6 Amp.
5. We adjusted the distance of the table so that the emitted light beam just covered the width of the target panel.
6. We lowered the temperature of the cold chamber to test temperature and confirmed this using a thermocouple measuring device.
7. A sign identifying the test being performed was prepared.

DEFROSTING:

Note: For this test, it was necessary to measure the thickness of the applied frost when sprayed with water. The adopted technique was to install a measured metallic disc between the two PAPI lenses, to create frost by spraying water vapor from a paint gun equally onto the entire front surface of the PAPI unit under test, including the metallic disc. After completing the application of water, the disc was removed and the total thickness of the disc plus frost was measured using a dial caliper. The thickness of the frost was measured as the difference between the total thickness and the thickness of the metallic disc.

1. A pre-test photograph was taken of the equipment under test.
2. A means to measure the thickness of the frost applied on the PAPI surface was installed (metallic disc between the lenses).
3. Vaporized water was sprayed onto the front of the PAPI unit (entire surface of optical window) to form a 1/16" thickness of frost (0.175 ml/cm2)
4. The application of vaporized water was video-taped and a still picture was taken after the application.
5. The metal measuring disc was removed and the total thickness of the disc plus the frost deposit was measured.
6. The thickness of the frost was calculated.
7. A 30 minutes time period was allowed to elapse to allow, for temperature stabilization as specified in CMVSS 103.
8. The video camera was started, the PAPI was turned on and operated at 6.6 Amperes while simultaneously starting a timer.
9. The end of the test was acknowledged as the moment when the signal displayed on the screen was identical to the signal displayed when the PAPI light unit was operating without any frost cover.
10. The time required for the PAPI defrosting to the point of producing a signal the same as a PAPI without frost cover was noted.
11. A post-test still photograph was taken.

MINIMAL CURRENT TEST:

1. A thermocouple was attached to the centre of one of the two PAPI lenses or at the beam centre point for PAPI equipped with a cover glass.
2. A pre-test still photograph was taken of the equipment under test and the test identification sign.
3. The PAPI light unit was operated at the specified current test level.
4. The test was delayed until there was a stabilization of the lens or cover glass temperature (approximately 1 hour).
5. The lens temperature was recorded.
6. An attempt was made to apply a thin coat of vaporized water onto the lens surface or onto the portion of the cover glass without the thermocouple. This procedure was video-taped.
7. A verification was made to see if the frost melted immediately from the lens or cover glass.
8. The test was considered successful if the frost melted and was eliminated. If this did not occur and permanent frost remained, the test was repeated by raising the current to the next required level.
9. A post-test still photograph was taken with the test identification sign.

DEW TEST:

1. The temperature of the cold chamber was lowered to 0 degrees Celsius. A panel was installed.
2. The PAPI units were installed at 12' of the surface measuring the light intensity.
3. A supplied current of one PAPI was set up at 6.6 Amp.
4. It was left in soak for 1 hour.
5. A photograph of the intact signal was taken.
6. With a kettle, vapor was generated under the glass/lens to form dew.
7. The brightness of the signal and the width of the bundle were compared and quantified approximately.
8. The test was video-taped.
9. A photograph of the signal with dew was taken.

TEST RESULTS

DEW TEST AT 0°C

Test #	PAPI Manufacturer	Cover glass (Yes/No)	Signal reduction	RMS Current (Amp)	Comments
14	Siemens	No	100%	6.6 Amp	Color mismatch/ no signal
15	Siemens	Yes/Wired	50%	6.6 Amp	
16	Siemens	Yes/Antifog	30%	6.6 Amp	
17	Siemens	Yes/Regular	100%	6.6 Amp	No Signal
18	Cegelec	N/A	20%	6.6 Amp	
19	Crouse-Hinds	N/A	0%	6.6 Amp	Dew Evaporate

DEFROSTING TIME TEST AT -5°C *

Test #	PAPI Manufacturer	Cover glass (Yes/No)	Ice Thickness (inch)	RMS Current (Amp)	Defrosting time (min.)
1	Cegelec	No	.060	6.6	24 minutes
2	ADB/Siemens	No	.060	6.6	22 minutes
3	Crouse-Hinds	No	.055	6.6	6 minutes
4	ADB/Siemens	Yes/Wired	.053	6.6	32 minutes
5	ADB/Siemens	Yes/Antifog	.060	6.6	32 minutes
6	ADB/Siemens	Yes/Regular	.060	6.6	32 minutes

NOTES:* Application of water did ice instead of frost.

DEFROSTING TIME TEST AT -10°C

Test #	PAPI Manufacturer	Cover glass (Yes/No)	Ice Thickness (inch)	RMS Current (Amp)	Defrosting time (min.)
28	Cegelec	No	.060	6.6	30 minutes
29	ADB/Siemens	No	.053	6.6	26 minutes
30	Crouse-Hinds	No	.059	6.6	9 minutes 30 sec.
31	ADB/Siemens	Yes/Wired	.058	6.6	9 minutes
32	ADB/Siemens	Yes/Antifog	.056	6.6	18 minutes
33	ADB/Siemens	Yes/Regular	.065	6.6	17 minutes

DEFROSTING TIME TEST AT -20°C

Test #	PAPI Manufacturer	Cover glass (Yes/No)	Ice Thickness (inch)	RMS Current (Amp)	Defrosting time (min.)
94	ADB/Siemens	Yes/Regular	070	6.6	8 minutes
95	ADB/Siemens	Yes/Wired	.080	6.6	5 minutes
96	ADB/Siemens	Yes/Antifog	.075	6.6	7 minutes
97	ADB/Siemens	No/Glass	.065	6.6	14 minutes
98	Cegelec	No	.060	6.6	19 minutes
99	Crouse-Hind	No	.065	6.6	6.5 minutes

DEFROSTING TIME TEST AT -30°C

Test #	PAPI Manufacturer	Cover glass (Yes/No)	Ice Thickness (inch)	RMS Current (Amp)	Defrosting time (min.)
56	ADB/Siemens	No	.070	6.6	30 minutes/ uneven icing
57	Cegelec	No	.070	6.6	53.5 minutes
58	Crouse-Hinds	No	.065	6.6	15 min./ light icing at the top
59	ADB/Siemens	Yes/Regular	.066	6.6	10 min/10 sec. (donut)
60	ADB/Siemens	Yes/Wired	.068	6.6	8 min/40 sec. (donut)
61	ADB/Siemens	Yes/Antifog	.070	6.6	9 min/35 sec.

MINIMUM CURRENT TEST AT -5°C

Test #	PAPI Manufacturer	Cover glass (Yes/No)	RMS Current (Amp)	Lens/glass Temperature (°C)	Accumulation of frost (Yes/No)
7	ADB/Siemens	Yes/Regular	2.8	6.3	Yes
8	ADB/Siemens	Yes/Regular	3.4	16.3	Yes
9	ADB/Siemens	Yes/Regular	4.1	31.1	No
10	ADB/Siemens	Yes/Antifog	2.8	6.6	Yes
11	ADB/Siemens	Yes/Antifog	3.4	18.3	No
12	ADB/Siemens	Yes/Wired	2.8	7.3	Yes
13	ADB/Siemens	Yes/Wired	3.4	17.7	No
20	ADB/Siemens	No glass	3.4	6.4	Yes
21	ADB/Siemens	No glass	4.1	17.1	Yes
22	ADB/Siemens	No glass	5.2	38.9	No
23	Crouse-Hinds	No glass	2.8	1.4	Yes
24	Cegelec	No glass	2.8	3.6	Yes
25	Cegelec	No glass	3.4	11.4	Yes
26	Crouse-Hinds	No glass	3.4	6.4	No
27	Cegelec	No glass	4.1	22.5	No

MINIMUM CURRENT TEST AT -10°C

Test #	PAPI Manufacturer	Cover glass (Yes/No)	RMS Current (Amp)	Lens/glass Temperature (°C)	Accumulation of frost (Yes/No)
34	Cegelec	No	4.1	19.6	Yes
35	ADB/Siemens	Yes/Regular	4.1	21.3	Yes
36	ADB/Siemens	Yes/Regular	5.2	47.8	Yes
37	ADB/Siemens	Yes/Regular	6.6	94.5	No
38	ADB/Siemens	Yes/Antifog	4.1	28.5	Yes
39	ADB/Siemens	Yes/Antifog	5.2	61.3	Yes
40	ADB/Siemens	Yes/Antifog	6.6	116.9	No
41	ADB/Siemens	Yes/Wired	4.1	23.6	Yes
42	ADB/Siemens	Yes/Wired	4.8	44.4	Yes (donut)
43	ADB/Siemens	Yes/Wired	5.2	56.4	Yes small donut
44	ADB/Siemens	Yes/Wired	5.5	66.3	Yes light frost
45	ADB/Siemens	Yes/Wired	6.6	102.3	No
46	ADB/Siemens	No Glass	4.1	12.3	Yes total frost
47	ADB/Siemens	No Glass	4.8	26.3	Yes total frost
48	ADB/Siemens	No Glass	5.2	36.6	Yes donut signal partial
49	ADB/Siemens	No Glass	5.5	43.7	Yes + glass donut
50	ADB/Siemens	No Glass	6.6	78.5	No
51	Cegelec	No	4.8	38.2	Yes donut
52	Cegelec	No	5.2	51.5	No small 5 mm around
53	Crouse-Hinds	No	3.4	2.2	Yes complete frost
54	Crouse-Hinds	No	4.1	10.5	No
55	ADB/Siemens	No glass	4.8	28.6	No
78	ADB/Siemens	Yes/Regular	5.5	70.6	Yes donut
79	ADB/Siemens	Yes/Antifog	5.5	92.1	Yes donut

MINIMUM CURRENT TEST AT -20°C

Test #	PAPI Manufacturer	Cover glass (Yes/No)	RMS Current (Amp)	Lens/glass Temperature (°C)	Accumulation of frost (Yes/No)
80	ADB/Siemens	Yes/Antifog	4.8	43.0	Yes
81	ADB/Siemens	Yes/Antifog	5.2	60.5	Yes
82	ADB/Siemens	Yes/Antifog	5.5	70.4	Yes
83	ADB/Siemens	Yes/Antifog	6.6	115.8	Yes
84	ADB/Siemens	Yes/Regular	5.5	58.4	Yes
85	ADB/Siemens	Yes/Regular	6.6	96.5	Yes
86	ADB/Siemens	Yes/Wired	5.5	55.6	Yes
87	ADB/Siemens	Yes/Wired	6.6	91.3	Yes
88	ADB/Siemens	No/Glass	6.6	61.1	Yes
89	Cegelec	No	4.8	17.3	Yes
90	Cegelec	No	5.2	29.9	Yes
91	Cegelec	No	5.5	40.0	Yes
92	Cegelec	No	6.6	71.5	Yes
93	ADB/Siemens	No	4.8	29.2	No

MINIMUM CURRENT TEST AT -30°C

Test #	PAPI Manufacturer	Cover glass (Yes/No)	RMS Current (Amp)	Lens/glass Temperature (°C)	Accumulation of frost (Yes/No)
62	ADB/Siemens	No	5.5	35.1	Yes
63	ADB/Siemens	No	6.6	59.6	Yes
64	ADB/Siemens	Yes/Antifog	5.5	63.5	Yes
65	ADB/Siemens	Yes/Antifog	6.6	101.3	Yes (donut)
66	ADB/Siemens	Yes/Regular	5.5	50.8	Yes
67	ADB/Siemens	Yes/Regular	6.6	94.0	Yes (donut)
68	ADB/Siemens	Yes/Wired	5.5	53.9	Yes (donut)
69	ADB/Siemens	Yes/Wired	6.6	106.1	Yes (donut)
70	Cegelec	No	5.2	31.5	Yes
71	Cegelec	No	5.5	29.2	Yes
72	Cegelec	No	6.6	61.2	Yes
73	Crouse-Hinds	No	4.1	-3.9	Low temperature
74	Crouse-Hinds	No	4.8	10.5	Yes
75	Crouse-Hinds	No	5.2	22.4	Yes
76	Crouse-Hinds	No	5.5	32.1	Yes
77	Crouse-Hinds	No	6.6	63.9	No

DEFROSTING TEST SUMMARY

Temperature PAPI	**-5°C**	**-10°C**	**-20°C**	**-30°C**
CROUSE-HINDS	Test #3 **6 min.** Complete defrosting	Test # 30 **9.30 min.** Complete signal, a little frost on edge.	Test #99 **6.5 min.** Small donut hole, waterdrops, complete signal. *(5113)* Test #13 – **8 min.**	Test #58 **15 min.** Light frost on top section.
CEGELEC	Test #1 **24 min.** Good signal ± 10 min.	Test #28 **30 min.** Good signal ± 20 min. Donut hole large.	Test #98 **19 min.** Donut hole, waterdrops, complete signal *(5113)* Test #1 – **56 min.**	Test #57 **53.5 min.** Light signal ± 10min/ Good signal ± 20min/ Complete ±30 min. Donut hole, poor defrosting of lens
SIEMENS NO GLASS	Test #2 **22 min.** Total signal with 1 cm of ice around lens on 5cm long (Good signal ± 10 min)	Test #29 **26 min.** Donut hole – Complete signal.	Test #97 **14 min.** Donut hole, waterdrops, complete signal. (5113) Test #14 – **30 min.**	Test #56 **30 min.** Donut hole – Signal OK at ± 15 min.
SIEMENS REGULAR	Test #6 **32 min.** Donut hole – Complete signal around ± 20 min.	Test #33 **17 min.** Complete signal – Donut hole	Test #94 **8 min.** Donut hole, water drops, correction, with cover glass, complete signal	Test #59 **10.10 min.** Donut hole, complete signal.
SIEMENS WIRED	Test #4 **32 min.** Good signal ± 20 min. Donut hole	Test #31 **9 min.** Donut hole, complete signal.	Test #95 **5 min.** Donut hole, water drops, complete signal *(5113)* Test #4 – **3 min.**	Test #60 **8.40 min.** Donut hole, complete signal.
SIEMENS ANTIFOG	Test #5 **32 min.** Good signal ± 10 min. Donut hole.	Test #32 **18 min.** Large donut hole, complete signal.	Test #96 **7 min.** Large donut hole, complete signal *(5113)* Test #2 – **25 min.**	Test #61 **9.35 min.** Donut hole, complete signal.

Note: Each cell contains test #, defrosting time at 6.6 Amp. and comments.

MINIMUM CURRENT TEST SUMMARY (PARTLY DEFROSTED)

This table contains minimum current test results where the ice on the lens/cover glass begins to melt. (A donut shape of ice remains around the lens)

TemperaturePAPI	**-5°C**	**-10°C**	**-20°C**	**-30°C**
CROUSE-HINDS	Test #23 **2.8 Amps** Complete frosting 2.8 no melting 1.4°C	Test #53 **3.4 Amps** Complete frosting no melting 2.2°C	Test #15 *(5113)* **4.1 Amps** No. ref. 8.1°C	Test #76 **5.5 Amps** Complete frosting and defrosting 32.1°C
CEGELEC	Test #25 **3.4 Amps** Light frost melting 11.4°C	Test #57 **4.8 Amps** Low signal ± 10min/ good signal ± 20min/ complete ± 30 min Donut hole, poor defrosting of lens. 38.2°C	Test #90 **5.2 Amps** Small donut, low signal 29.9°C	Test #72 **6.6 Amps** Donut hole, low signal 61.2°C
SIEMENS NO GLASS	Test #20 **3.4 Amps** Yes slowly 6.4°C	Test #48 **5.2 Amps** Yes, donut hole, partial signal 36.6°C	Test #19 **5.2 Amps** Yes slowly 17.0°C	Test #63 **6.6 Amps** Yes complete frosting No melting 59.6°C
SIEMENS REGULAR	Test #8 **3.4 Amps** Donut hole, defrosting 16.3°C	Test #35 **4.1 Amps** Donut hole 21.3°C	Test #84 **5.5 Amps** Yes, donut hole with water drops, low signal 58.4°C	Test #67 **6.6 Amps** Donut hole, water drops 94.0°C
SIEMENS WIRED	Test #12 **2.8 Amps** Light frost, very light melting 7.3°C	Test #41 **4.1 Amps** Yes, donut hole 23.6°C	Test #86 **5.5 Amps** Yes, donut hole, water drops, low signal 55.6°C	Test #68 **5.5 Amps** Yes, donut hole, light frost 53.9°C
SIEMENS ANTIFOG	Test #10 **2.8 Amps** Light frost, water drops, defrosting, donut 6.6°C	Test #38 **4.1 Amps** Donut hole 28.5°C	Test #80 **4.8 Amps** Yes, donut hole, water drops 43.0°C	Test #64 **5.5 Amps** Yes, light defrosting 63.5°C

Note: Each cell contains test #, minimum current, lens temperature and comments.

MINIMUM CURRENT TEST SUMMARY (FULLY DEFROSTED)

This table contains minimum current test results where the ice on the lens/cover glass completely melts.

Temperature PAPI	-5°C	-10°C	-20°C	-30°C
CROUSE-HINDS	Test #26 **3.4 Amps** 6.4°C	Test #54 **4.1 Amps** 10.5°C	Test #17 *(5113)* **4.8 Amps** 23.5°C	Test #77 **6.6 Amps** Almost all clear, very light frost on edge 63.9°C
CEGELEC	Test #27 **4.1 Amps** 22.5°C	Test #52 **5.2 Amps** 51.5°C	Test #92 **4.8 Amps** No defrost Large donut hole, water drops, low signal 6.6 Amps – 71.5°C *(5113)* Test #11 17.7°C	Test #72 **6.6 Amps** No defrost Donut hole, low signal 61.2°C
SIEMENS NO GLASS	Test #55 **4.8 Amps** 28.6°C	Test #50 **6.6 Amps** 78.5°C	Test #88 **6.6 Amps** No defrost Yes, no donut hole, very low signal 61.1°C	Test #63 **6.6 Amps** No defrost Yes, complete frosting 59.6°C
SIEMENS REGULAR	Test #9 **4.1 Amps** 31.1°C	Test #37 **6.6 Amps** 94.5°C	Test #85 **6.6 Amps** No defrost Yes, donut hole with water drops, low signal 96.5°C	Test #67 **6.6 Amps** No defrost Donut hole, water drops 94.0°C
SIEMENS WIRED	Test #13 **3.4 Amps** Donut hole 17.7°C	Test #45 **6.6 Amps** 102.3°C	Test #87 **6.6 Amps** No defrost Yes, donut hole, water drops, low signal 91.3°C	Test #69 **6.6 Amps** No defrost Yes large donut hole, light frost 106.1°C
SIEMENS ANTIFOG	Test #11 **3.4 Amps** 18.3°C	Test #40 **6.6 Amps** 116.9°C	Test #83 **6.6 Amps** No defrost Yes, donut hole, water drops 115°C *(5113)* Test #12 4.8 Amps – 7.2°C	Test #65 **6.6 Amps** No defrost Yes, donut hole 101.3°C

CONCLUSIONS

DEFROSTING TESTS:

Most of the PAPI took a longer time to defrost at -5°C and -10°C than at -20°C. This can be explained by the type of ice. At -5°C and -10°C, the ice is clear, at -20 °C, the ice is white.

The best average performance was achieved by Crouse-Hinds PAPI.

The best defrosting time was achieved by Siemens PAPI with wired cover glass at -20°C in 5 minutes.

The most energy efficient PAPI is the Crouse-Hinds.

MINIMUM CURRENT TESTS:

What was simulated during this test is a snow storm or ice storm depending on test temperature, on a PAPI already energized. We obtained three types of results: The ice is not melting at all, the lens defrosts partially or the lens defrosts instantly.

We did two summary tables (completely and partly defrosted) because even if the lense is partly defrosted, the signal can be considered complete based on our criteria. It is to be noted that even if we consider the signal to be complete during the tests at 12' from the receiving panel, it does not necessarily means that the signal will be complete in the “real world” (at 1 mile).

Only Crouse-Hinds PAPI can meet the completely clear lens requirement at every temperature that we tested.

Siemens and Cegelec PAPI can meet the completely defrosted lenses at temperature above -10°C. At temperature below -10°C, there is always ice remaining on the edges of the lenses.

For partly defrosted lenses, the minimum current vary from 5.5 Amps to 6.6 Amps at -30°C.

RECOMMENDATIONS:

We recommend that other tests in the field be made to confirm the above conclusions which would also consider other parameters, such as the cooling effect of the wind, the effect of the sun on the observation of the output signal from distances greater than the 12 foot laboratory distance, the “real world” frost deposit thickness and deposit rate of, as well as other meterological conditions. We also need to establish a scientific way of calculating the degradation of the PAPI to what would be considered as a false signal, from a true signal.

Based on these tests results, the PAPI must be energized at least 53.5 minutes before any airplane landing or remain energized at 6.6 Amp at all time.

Intentionally left blank

APPENDIX "A"

TERMS OF REFERENCE

Study of PAPI Frost Tests
(Final)

Transport Canada – Civil Aviation
Aerodrome Safety
Technical Evaluation Engineering (AARME)
Aerodrome Electrical Systems

Intentionally left blank

1.0 OBJECTIVE

1.1 The objective of this study in relation to frost and the Precision Approach Path Indicator (PAPI) is in parts:

Phase 2:

Part 1 For purpose of standards development, to test 4 PAPI designs to determine the minimum time period for frost removal from moment of energization of the units. The question to be answered is, what is the minimum time required for the PAPI light units to eliminate its frost cover.

Part 2 To determine the brightness level (current level) setting required to prevent the accumulation of frost when the PAPI units are operated on a continuous basis.

Phase 3:

The results of the phase 2 study and discussions with experts in the field of meteorology and examination of lab facilities t to duplicate such things as snow, sleet, ice, and wind may result in initiating further investigation over a series of operational variables at a later date, the specifics of which will be detailed later.

2.0 BACKGROUND

The occurrence of frost on the front cover glass of Siemens' PAPI light was reported by Quebec Region of Transport Canada. Testing subsequently took place at Blainville to evaluate the time period for removal of this frost once the light unit has been turned on.

The PAPI light units are to be tested as supplied. They may have heaters or be without cover glasses

The PAPI light units are of the 5 step series circuit type. As a general practice, this form of design involves operation at 5 brightness levels, related to the RMS current value to the lamps.

TABLE 1: OUTPUT CURRENT VERSUS INTENSITY STEPS – 5 STEP REGULATORS

Brightness Level	Intensity (percent)	Current (rms amperes)	Allowable Range
5	100	6.6	6.40 – 6.70
4	25	5.2	5.04 – 5.36
3	5	4.1	3.98 – 4.22
2	1	3.4	3.30 – 3.50
1	0.2	2.8	2.72 – 2.88

Some PAPI may be supplied through a 3 step series circuit. The levels are as follows:

TABLE 2: OUTPUT CURRENT VERSUS INTENSITY STEPS – 3 STEP REGULATORS

Step	Nominal Output (amperes rms)	Intensity (percent)	Allowable Range
3	6.6	100	6.40 – 6.70
2	5.5	30	5.33 – 5.67
1	4.8	10	4.66 – 4.94

The PAPI, for 5 step regulators are normally installed so that they operate at only the steps 3,4, and 5. The current level of 4.1 amperes is most critical, as this the level at which the PAPI would be first turned on by pilots. For the case of PAPI for 3 step regulators there is a higher current level for the first step which is 4.8 amperes. We can assume that the 5 step (5.2 amperes) and the 3 step (5.5 amperes) should have the same effect. However, to determine the time period to defrost, we would have four separate tests at 6.6, 5.2, 4.8 and 4.1 amperes.

It is of importance during this testing that the PAPI units have an equal thickness of frost. Thus the need for a precise method of measurement.

It is to be noted that during the time at which frost is present on the PAPI, the resulting white color indicates a flydown signal. If the presence of this signal is considered unacceptable for any period of time, then the alternative of continuous operation will have to be considered. Part 2 of the objective is to determine at what brightness level or current value the light unit can be maintained warm enough to prevent frost from forming in the first place. Since this would involve a continuous operation of the PAPI, or at least for some length period, it would be of interest to know at what would be the lowest level at which frost is prevented. Thus, the test should look at the lower 5 step regulator settings of 2.8, 3.4 and 4.1 amperes. It is assumed that if the unit is maintained free of frost at or less than 4.1 amperes, then this should be sufficient for the case of the lower step of 4.8 amperes of the 3 step regulator. However, if the PAPI cannot maintain itself free of frost at a lower value, it would be necessary to check the higher levels of 4.8, 5.2 and 6.6 amperes.

The second part of the testing requires a possible 6 sets of tests to address all the indicated current levels. However, once result of prevention of frost is reached for a current level for a particular PAPI design, then it is not necessary to continue testing at the higher levels. It is entirely possible that one specific level can be sufficient for all units and this would then become the standard.

Since the Contractor may not have 3 step or 5 step regulators, the test can be performed with a current feed which is at the required RMS value.

Arrangements will be made by the Client for provision of the PAPI units to the Consultant.

3.0 GENERAL

3.1 "Client" means the Department of Transportation represented by the Director, Aerodrome Safety, Civil Aviation, Transport Canada, Place de Ville – Tower C, Ottawa, Ontario, K1A 0N8.

3.2 The project will be carried out under the direction of the Mr. A. Mazur, Chief, Technical Evaluation Engineering (613) 990-1424. The designated project manager for this project and will be Mr. E. Alf, Navaids Electrical Systems Engineer (613) 998-2999 who will manage it on a day-to-day basis.

4.0 TECHNICAL REQUIREMENTS / SCOPE OF WORK

4.1 Arrange for a preliminary Consultant/Client meeting to discuss the scope of work.

4.2 Use the Canada Motor Vehicle Safety Standard, No. 103, "Windshield Defrosting and Defogging", 24 January 1995, for application of frost. Use this standard and the dimensions of the Siemens cover glass, to find the thickness of frost that would be applied at a temperature of minus 20 degrees Celsius. This thickness will bb the thickness of frost to be applied to all PAPI units.

1/16", Telecon with F. Mangano 16-12-97

4.3 Proceedure for Part 1, for the following 4 specific temperatures:
-30, -10, -5, and 0 degrees Celsius

1. Soak the PAPI units in a cold chamber to the specified temperature.
2. Provide visual isolation barriers to ensure that there is no signal interference between the units during the test
3. Arrange the units so that their signal is projected onto a white diffuse screen at a distance of at least 3 m.
4. Apply an equal layers (thickness) of frost on the front of each PAPI light unit.
5. Using video recording, determine the time to defrost after turning the units on at brightness level 5 at 6.6 amperes. The time shall be measured from the moment of lamp energization to the moment when the projected signal has returned to a distinctive red/white display.

6. In addition to the above temperatures, perform the above test at -20 degrees Celsuis for the siemens PAPI unit without cover glass and with normal cover glass.

4.4 Proceedure for Part 2, for the following 4 specific temperatures: -30, -10, -5, and 0 degrees Celsius

(a) Place the light units in a cold chamber, at the select temperature.

(b) Place a thermocouple device on one of the lenses or on the middle of the cover glass to monitor the temperature during the test.

(c) Energize the light units at 2.8 amperes and allow the units to operate until they are thermally stabilized.

(d) Attempt to apply frost to the front of each light unit, determining whether the warmth of the units are preventing frost accumulation.

(e) If the unit is not maintained free of frost at 2.8 amperes, then repeat this test at each supply current level of 3.4, 4.1, 4.8, 5.2 and 6.6 amperes ,stopping at the supply level at which frost free operation is reached.

(f) Ensure that the thermal stability of the unit is achieved between each current change. The temperature of the lens/cover-glass shall be monitored and recorded continuously throughout the testing.

(g) In addition to the above temperatures, perform the above test at -20 degrees Celsuis for the siemens PAPI unit without cover glass and with normal
cover glass.

4.5 Deliverable: Prepare a report of the work done and submit to the Client maximum two weeks after the completion of the test for review and comment. One week after reception of Client comments, finalize the report and submit as the deliverable of this project. Submit the final version of the report to the Client, both as a hard copy printout and an electronic file. The report shall fully detail the testing and make conclusion as to achievement of the objectives.

4.6 The text of the report shall be prepared using a word processing programs whose files are retrievable with Microsoft Word, version 7.0. The diagram shall be prepared in a format retrievable by CorelDraw, version 7.0.

5.0 CODES, STANDARDS, AND REFERENCES

5.1 Work in accordance with Department of Transport's policies, standards and guidelines. For visual aids standards, the Contractor will be informed by the Client as to the source of reference.

6.0 SPECIAL REQUIREMENTS

6.1 Intellectual Property. All ownership and intellectual property rights for the deliverables (i.e. the technical circular) of this contract shall reside with Transport Canada.

7.0 COMMENCEMENT AND COMPLETION DATES

7.1 The work of this project will commence immediately upon award of contract.

7.2 The project is to be completed not later than 30 December 1997.

8.0 MODIFICATION, ADDITION TO, OR REDUCTION OF WORK

8.1 If modification, additional to or reduction of the scope of work is required the Client shall notify the Contractor in writing.

9.0 FEES AND DISBURSEMENTS

9.1 The fee for Professional Services, Associated Costs (long distance calls, telex, fax, courier, reproduction costs, etc.) shall be an all-inclusive fixed lump sum.

9.2 No fee payment will be made by the Department of Transport to remedy errors or omissions for which the Contractor is responsible, and which the Contractor shall remedy and correct as appropriate.

9.3 Invoices, supported by time sheets, receipts, and vouchers, shall be submitted in duplicate and itemized to permit proper audit.

9.4 Invoices, shall be submitted at the 50 percent and 100 percent completion milestones, upon acceptance of work completed by the Client.

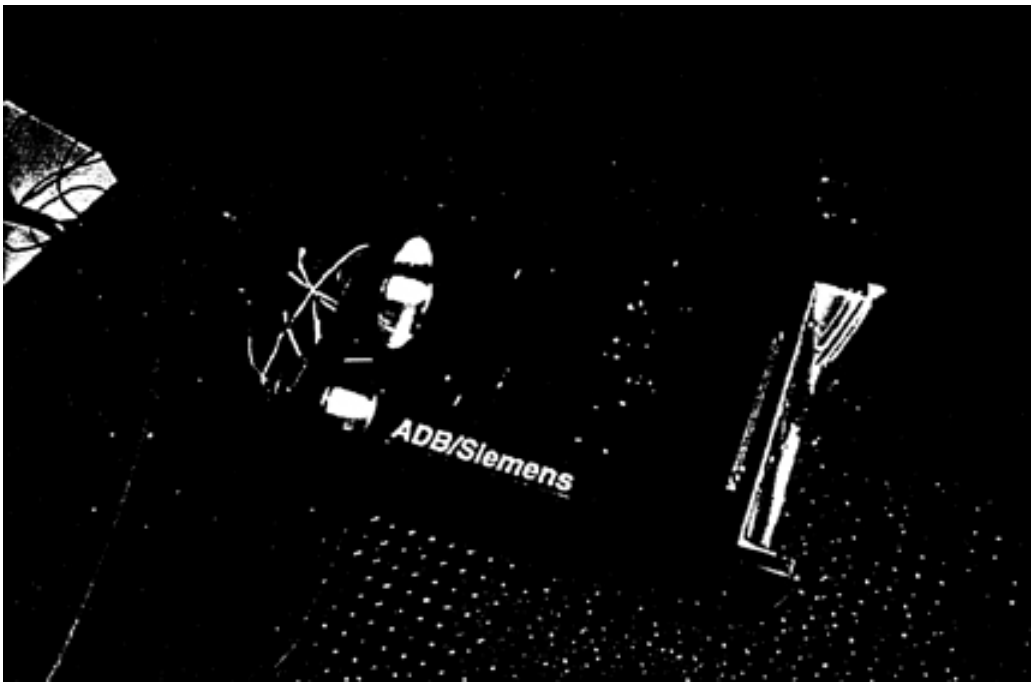
Intentionally left blank

APPENDIX A

DEFROSTING TEST AND MINIMUM CURRENT TEST PHOTOGRAPHS

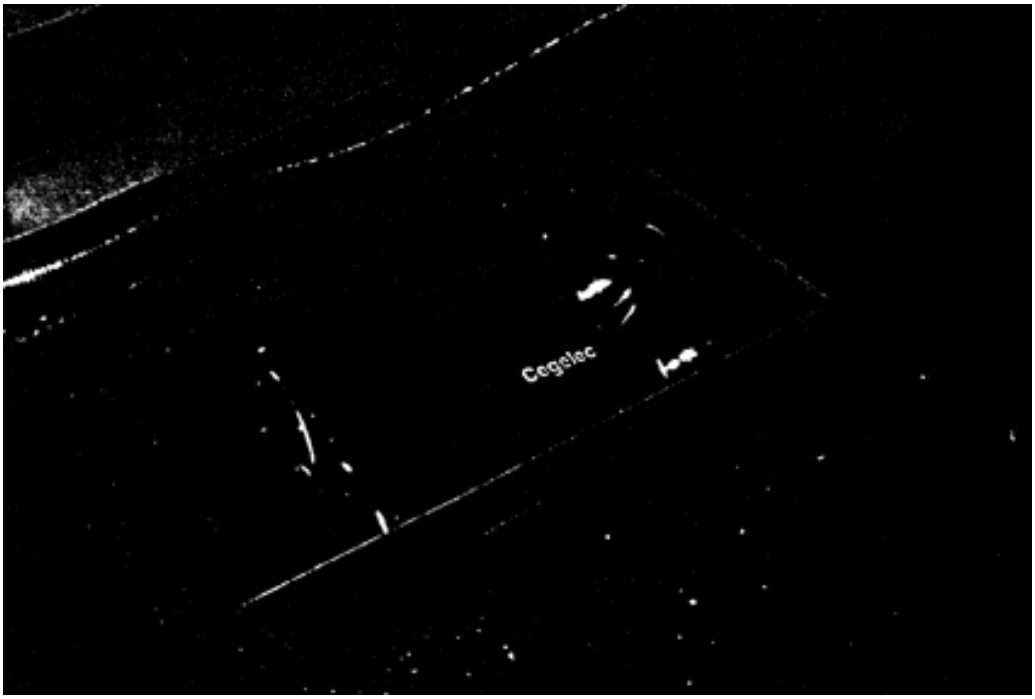
Intentionally left blank

1. ADB/Siemens Papi.

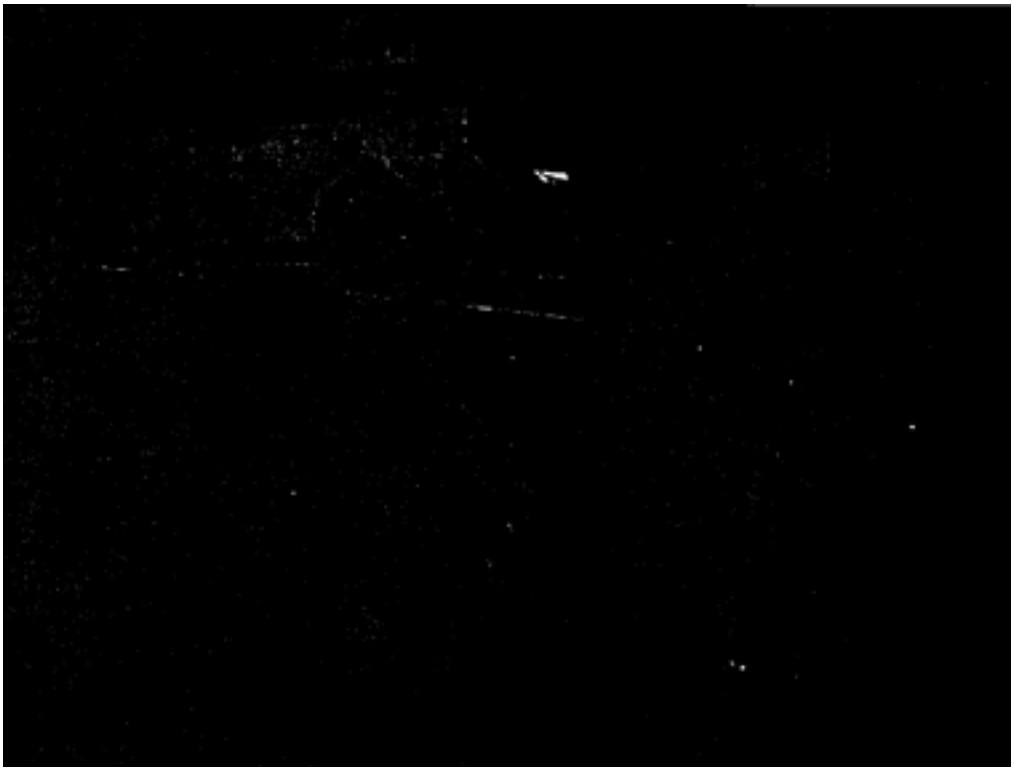


2. Inside view of ADB/Siemens.

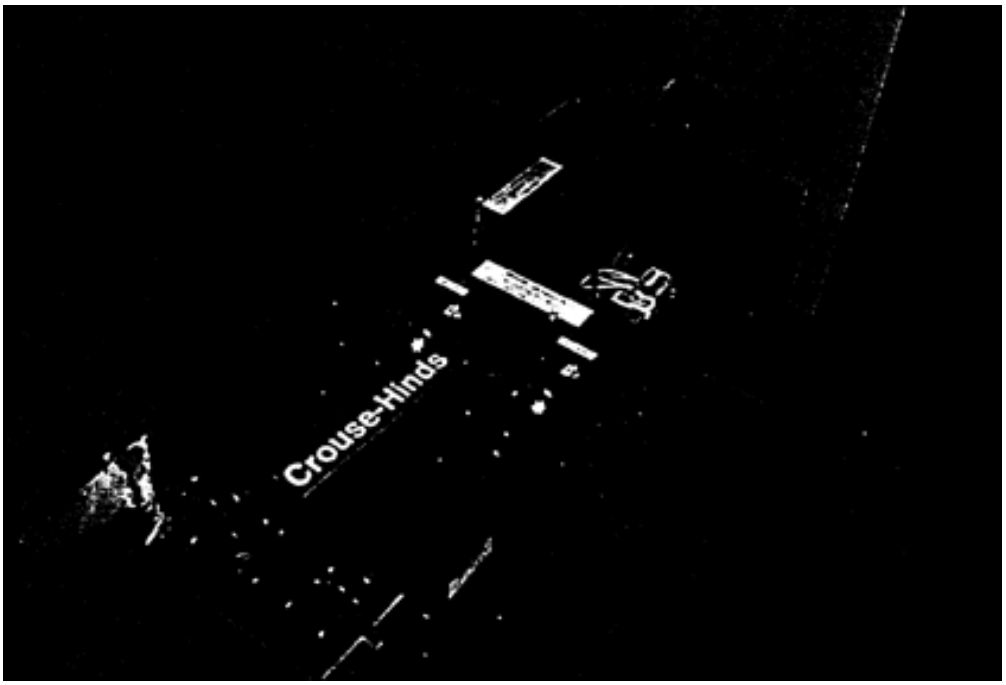
3. Cegelec Papi.



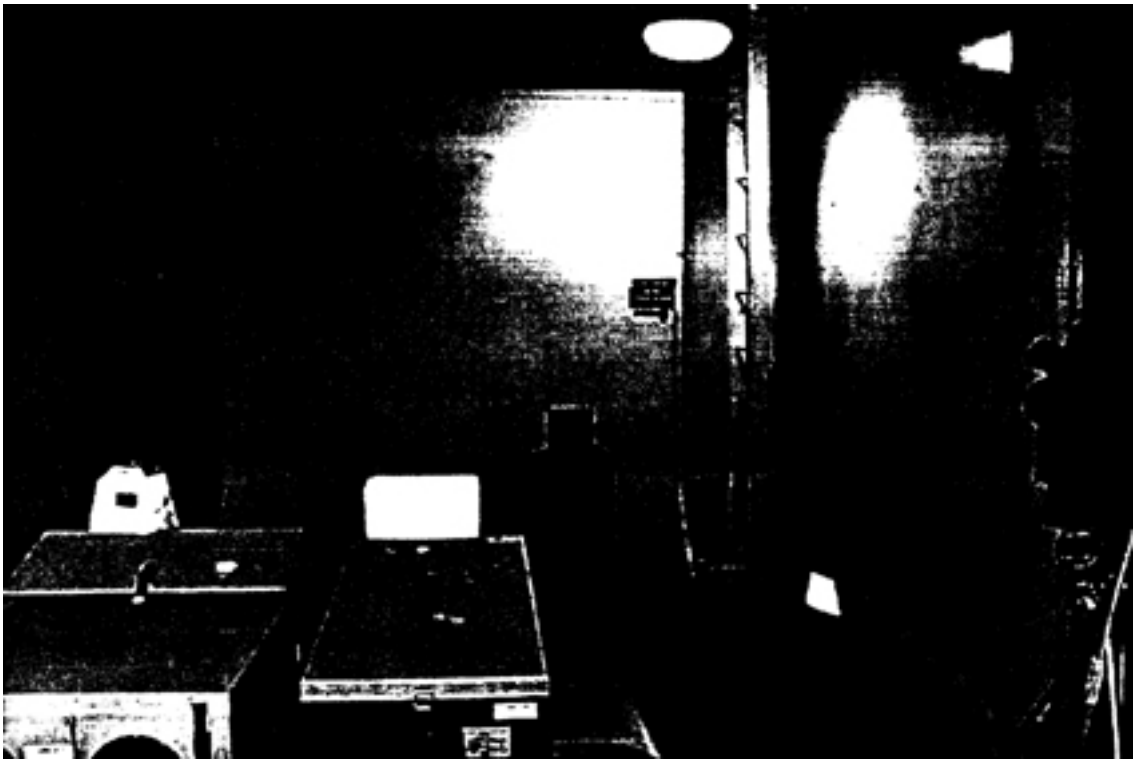
4. Inside Cegelec.



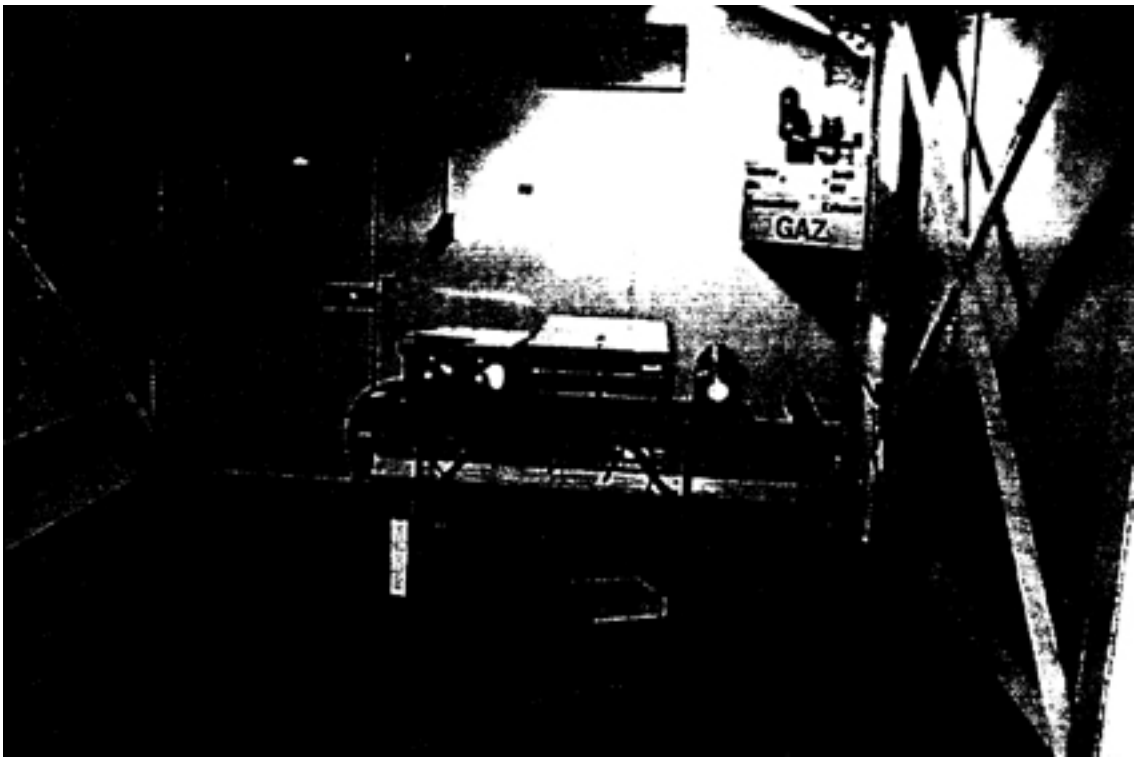
5. Crouse-Hinds.



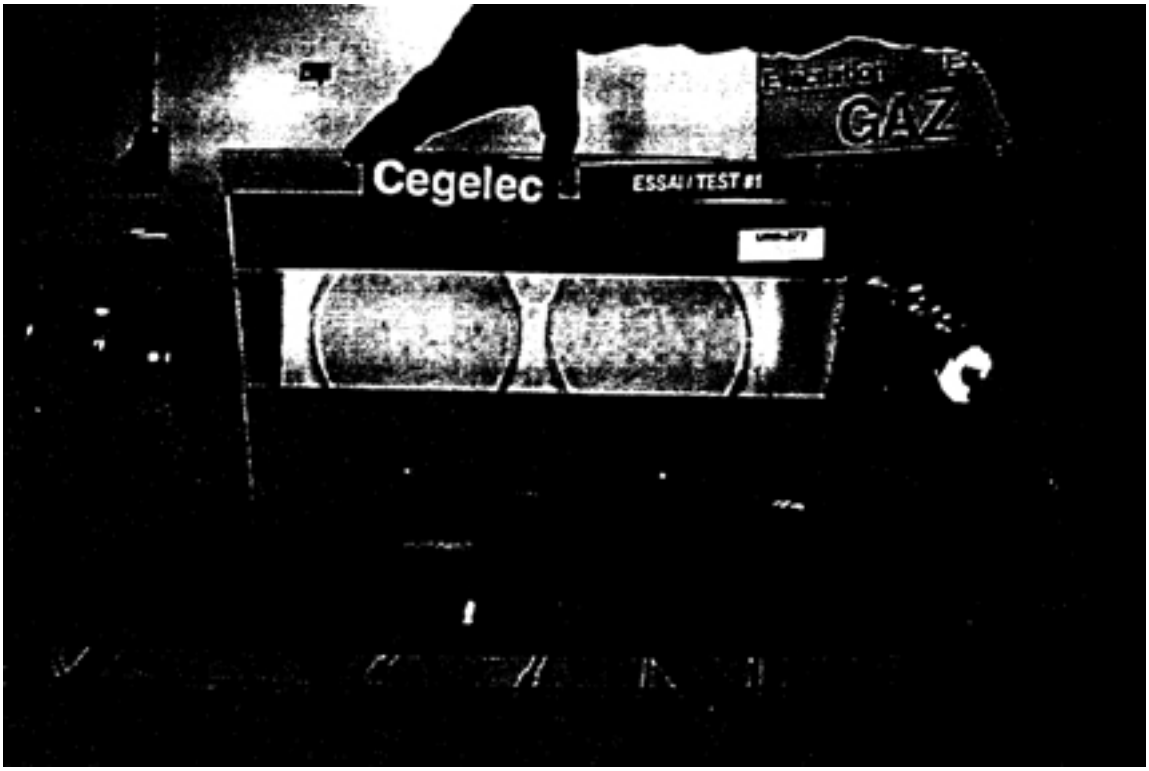
6. Inside Crouse-Hinds.



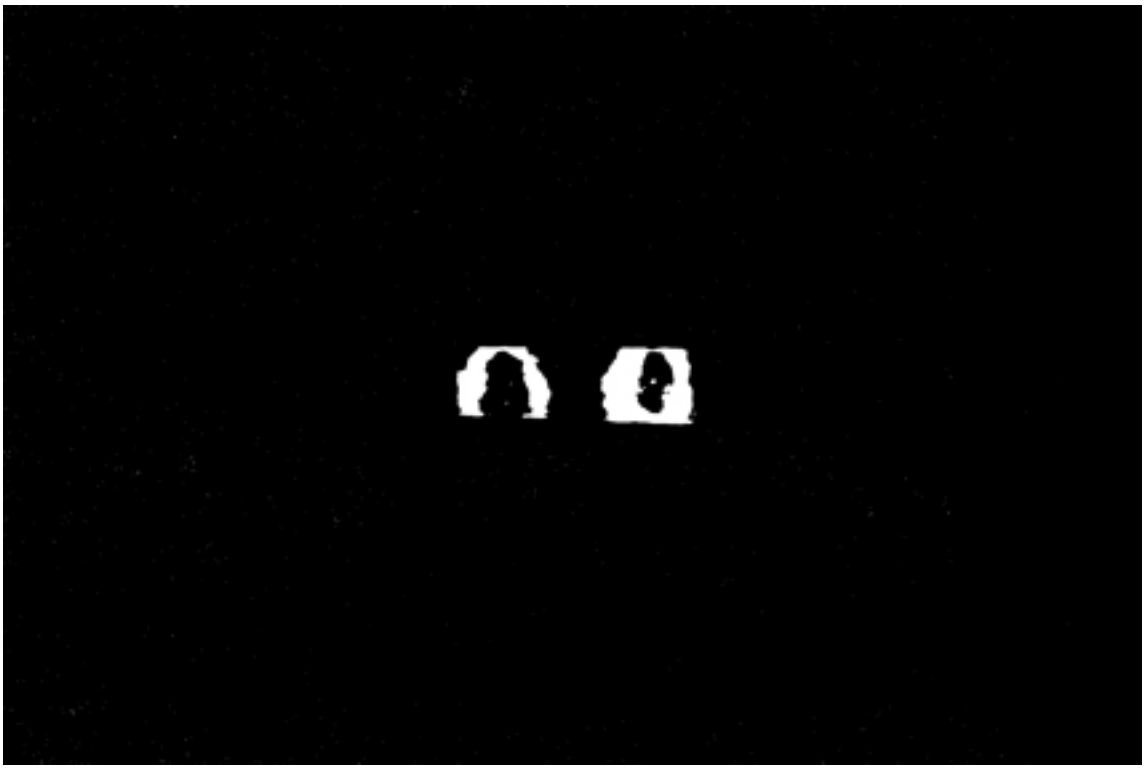
7. General view of the test set-up.



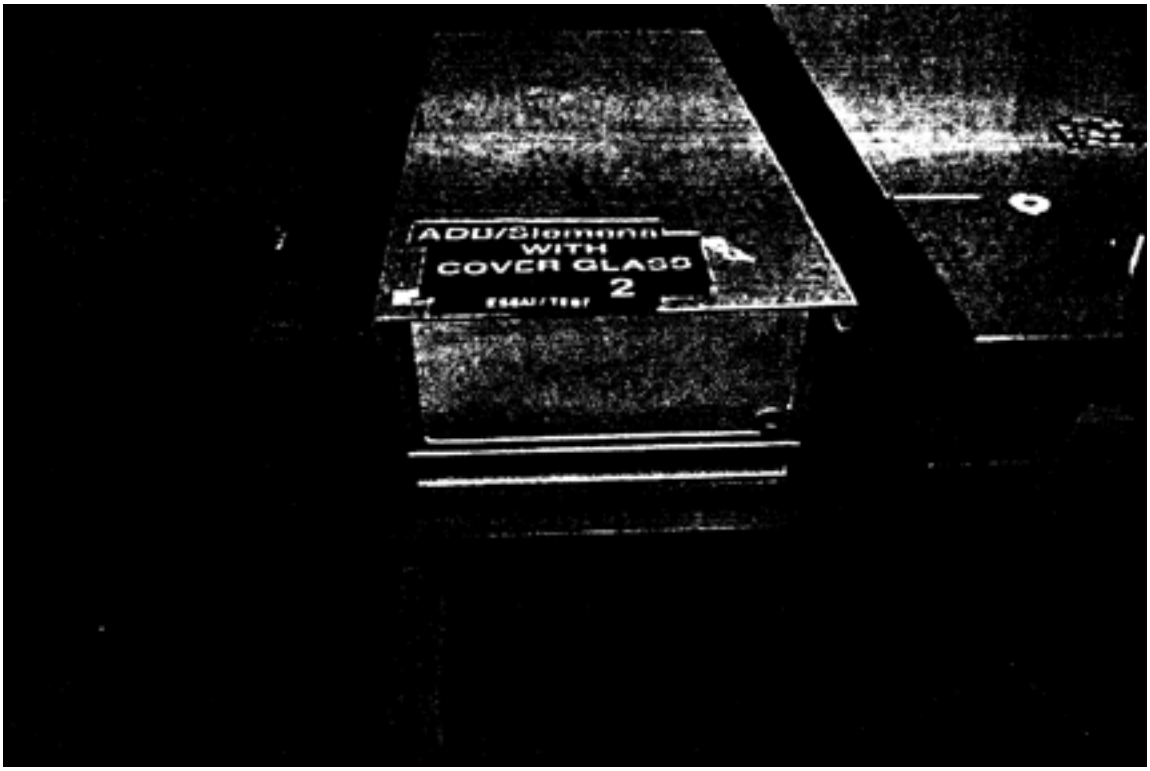
8. Papi installation.



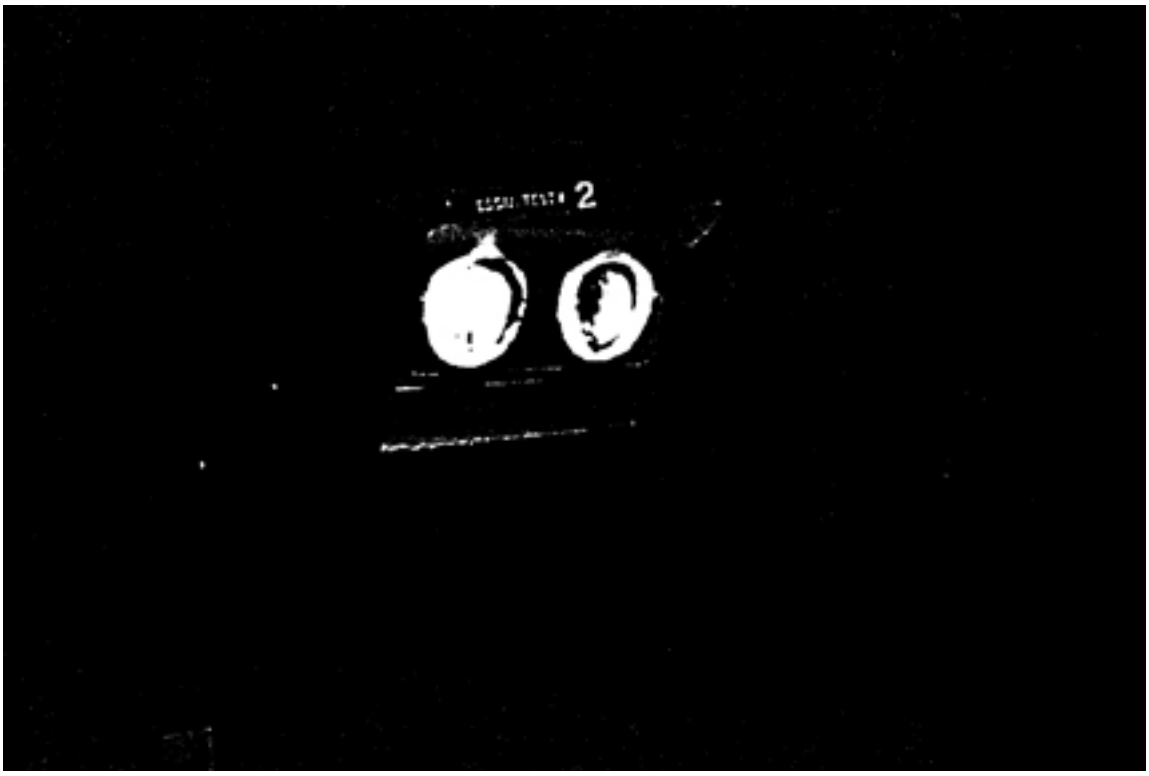
9. Test #1, pre-test.



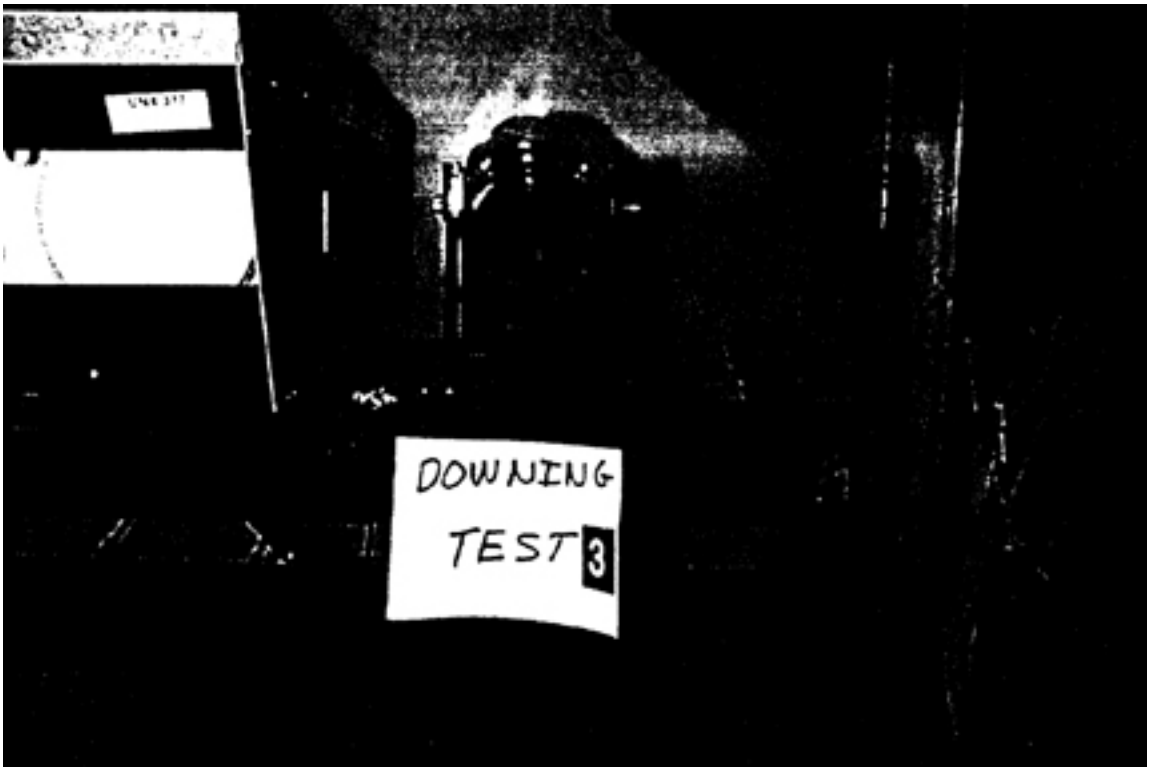
10. Test #1, post-test.



11. Test #2, pre-test.



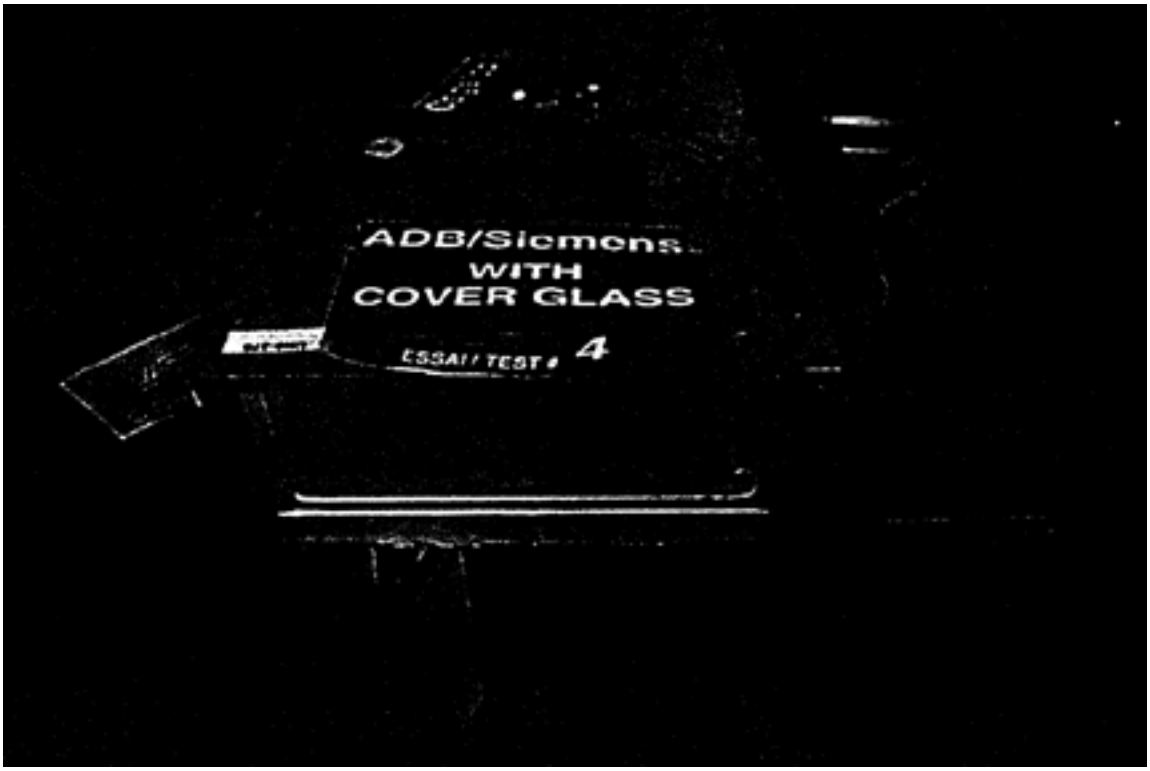
12. Test #2, post-test.



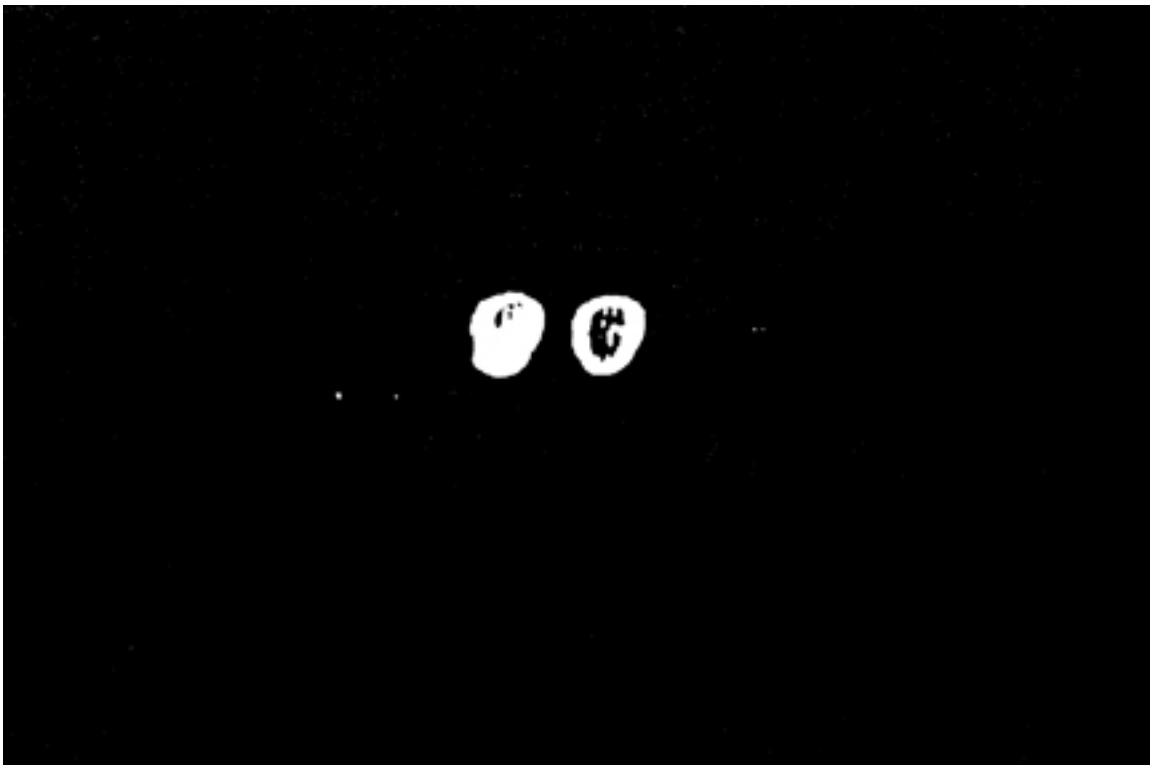
13. Test #3, pre-test.

IDEM AS PRE-TEST

14. Test #3, post-test.



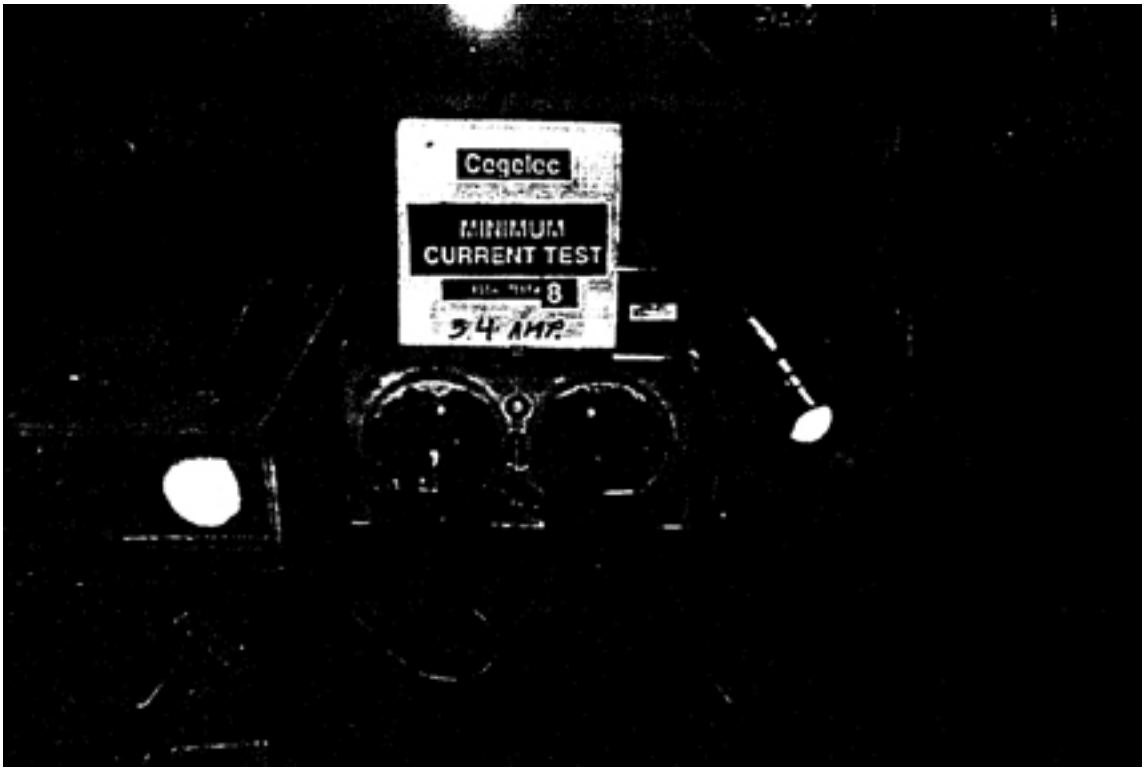
15. Test #4, pre-test.



16. Test #4, post-test.

17. Test #7, pre-test.

18. Test #7, post-test.

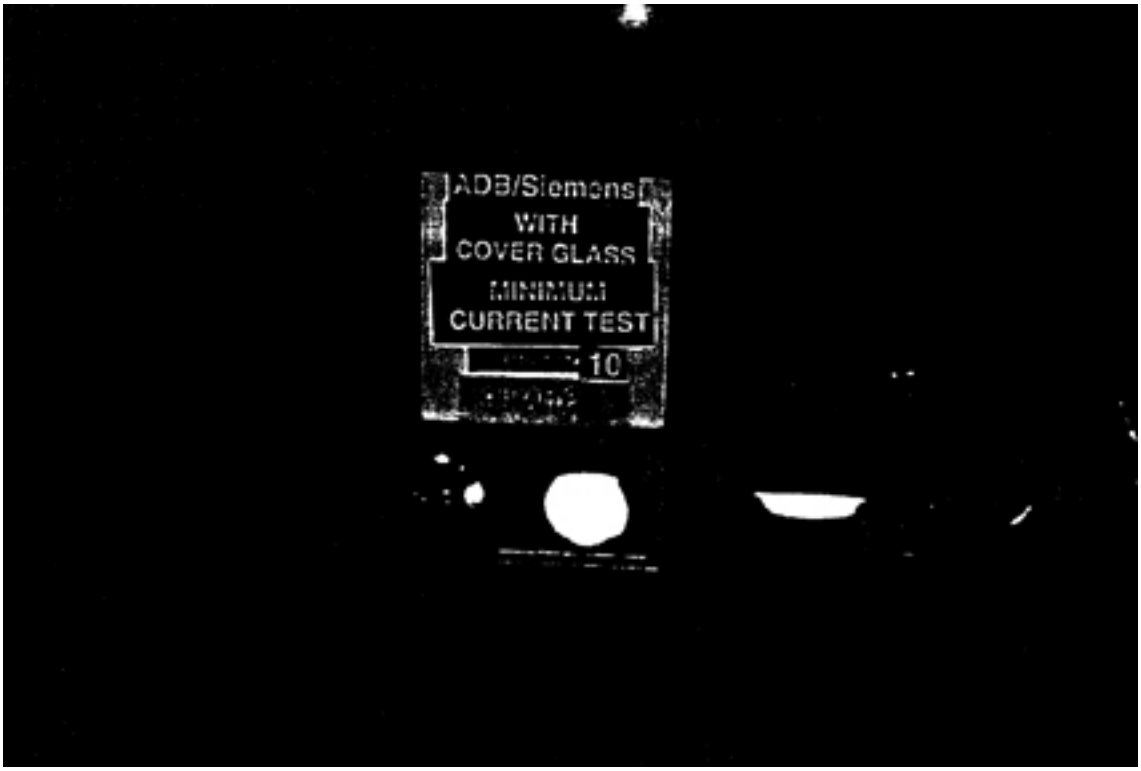


19. Test #8, pre-test.

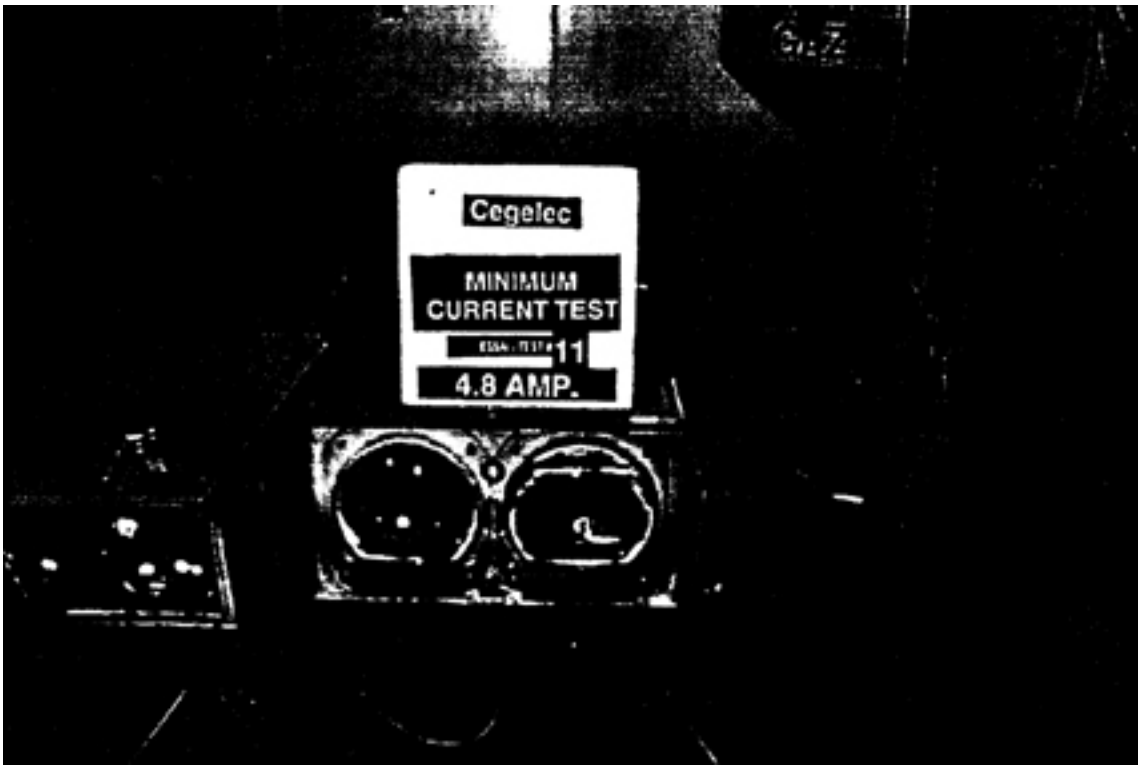
20 Test #9, pre-test.

21. Test #9, post-test.

22. Test #10, pre-test.

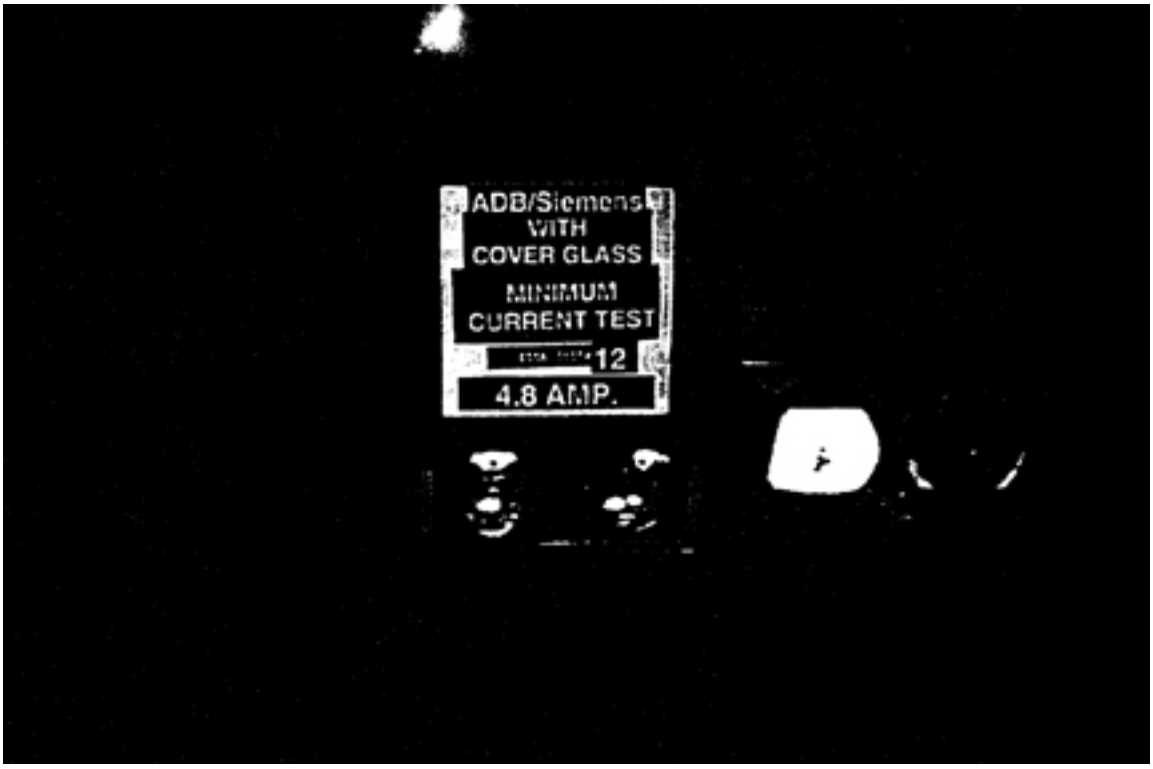


23. Test #10, post-test.

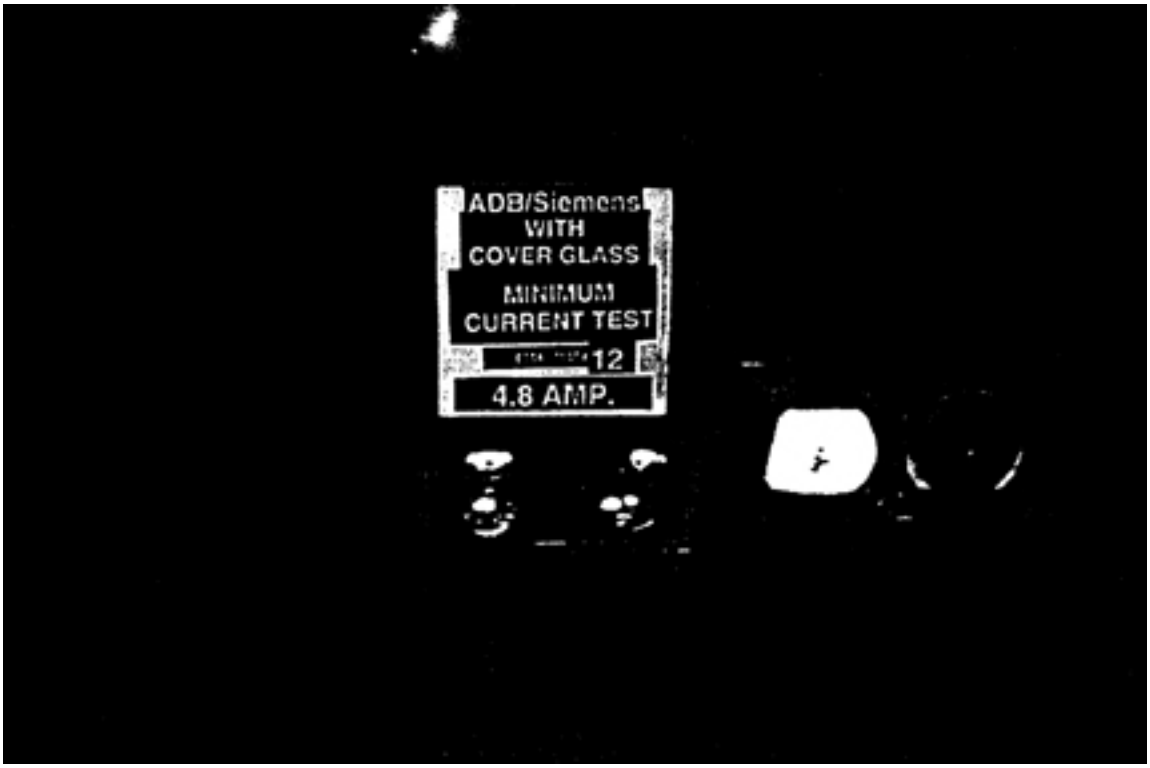


24. Test #11, pre-test.

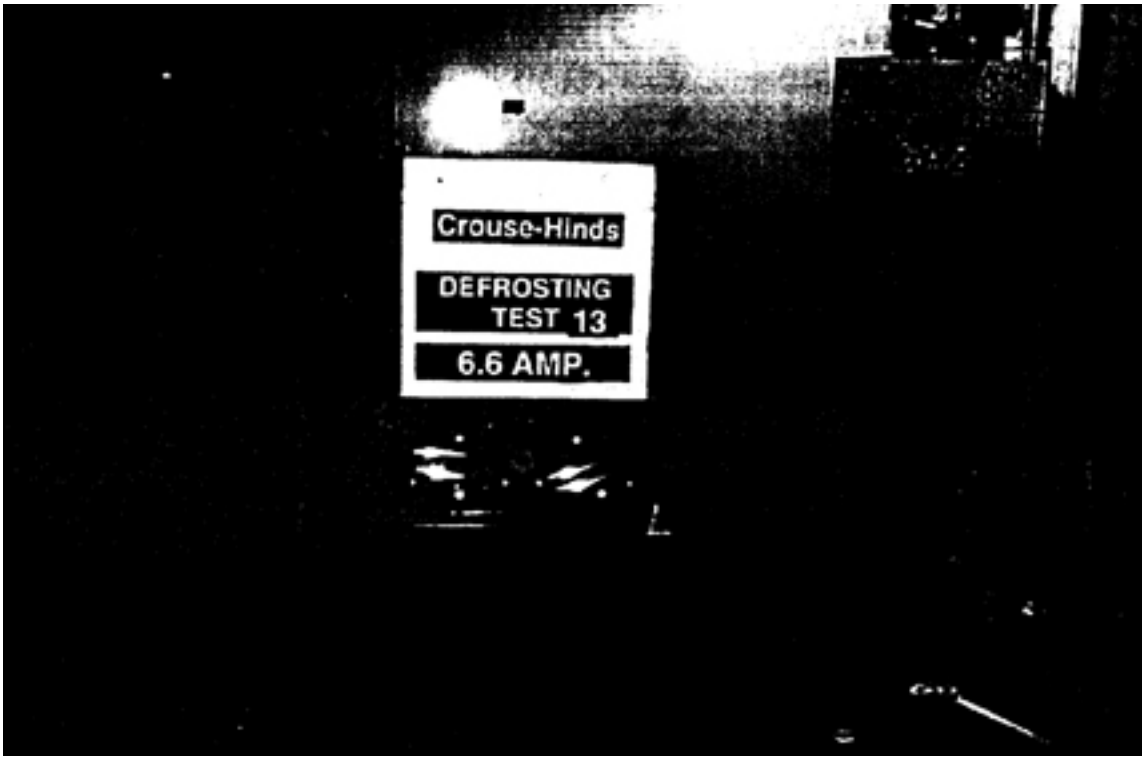
25. Test #11, post-test.



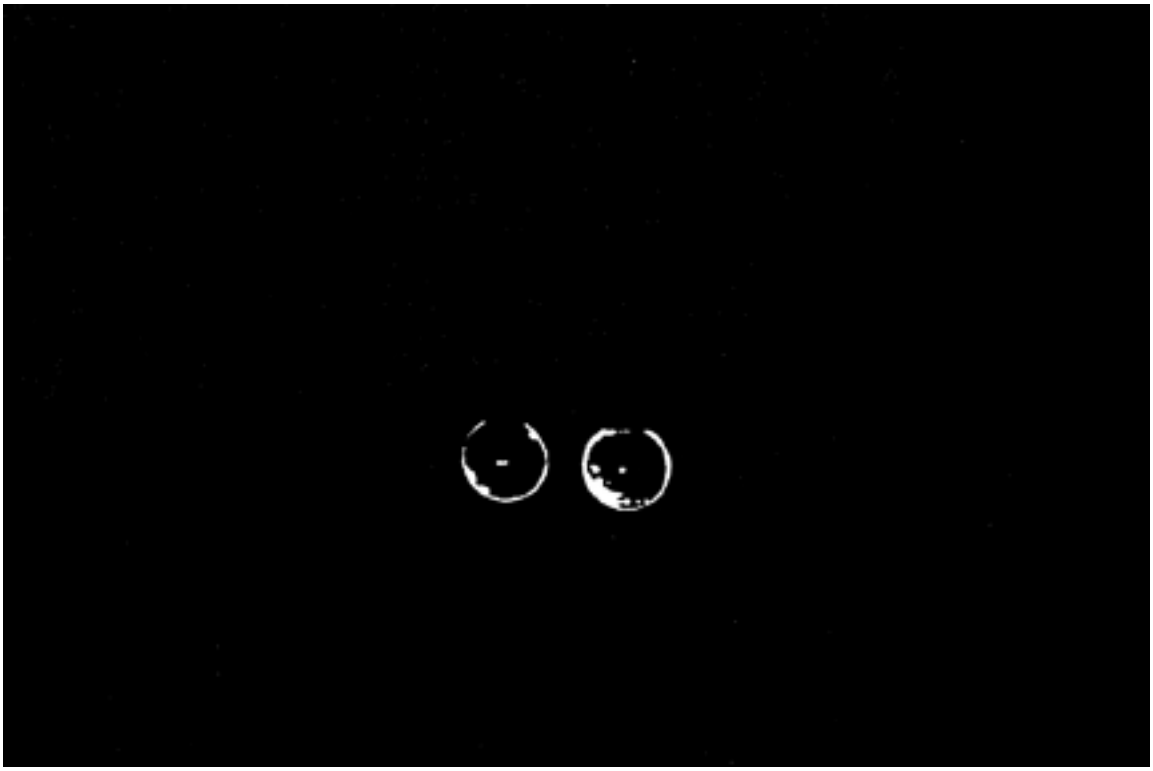
26. Test #12, pre-test.



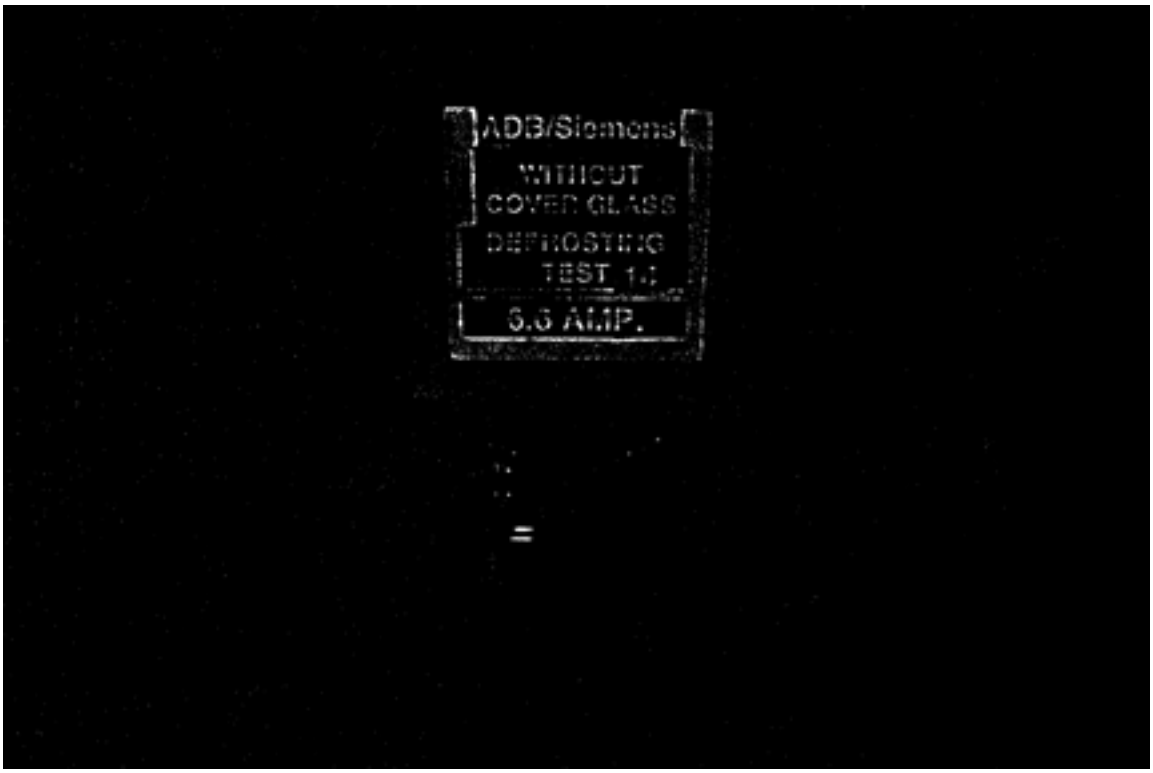
27. Test #12, post-test.



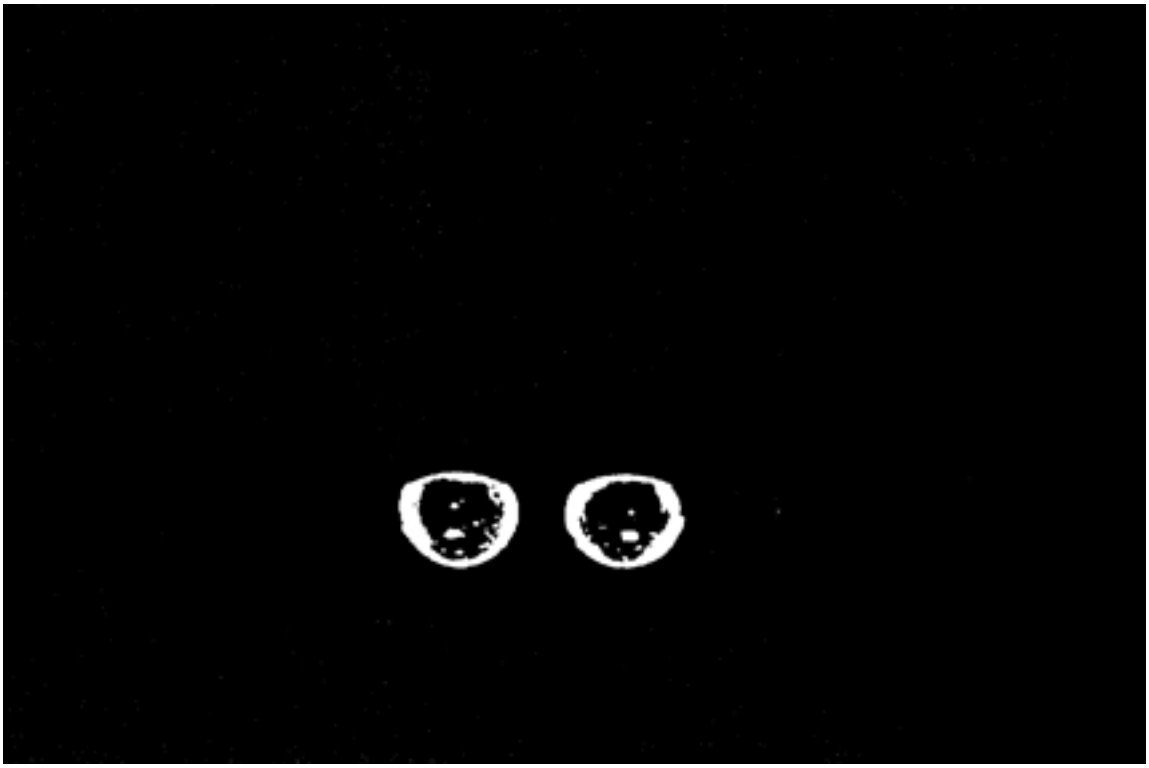
28. Test #13, pre-test.



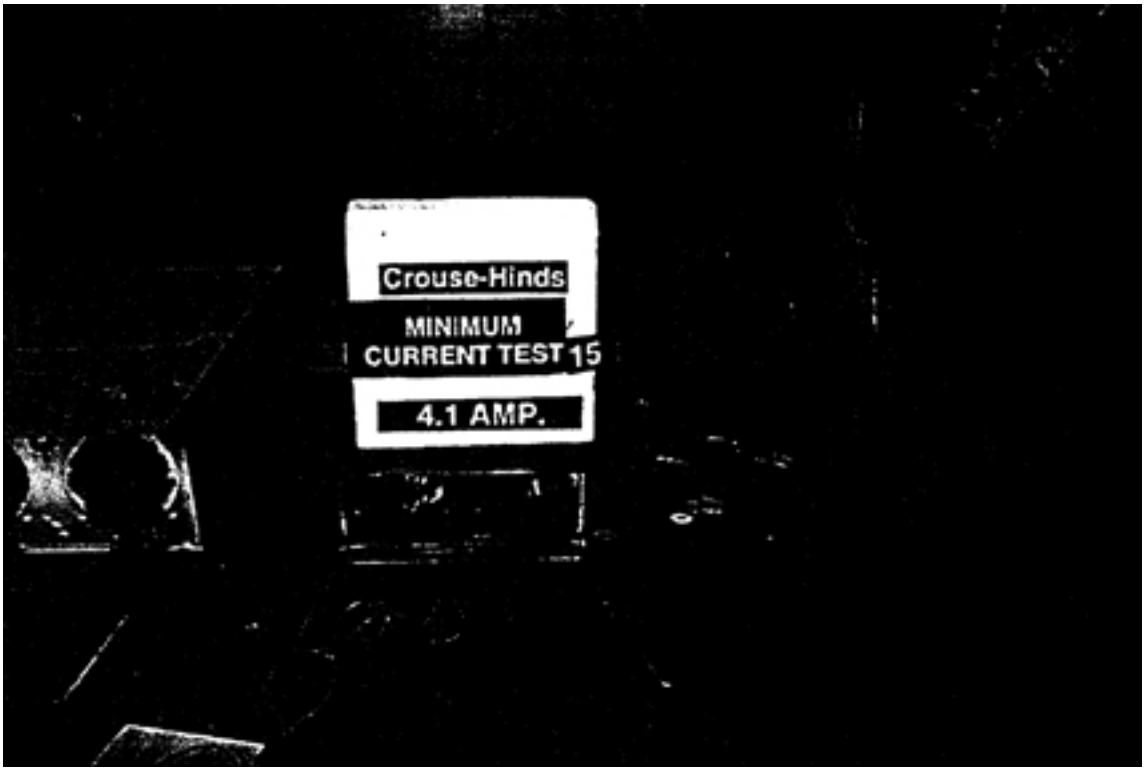
29. Test #13, post-test.



30. Test #14, pre-test.



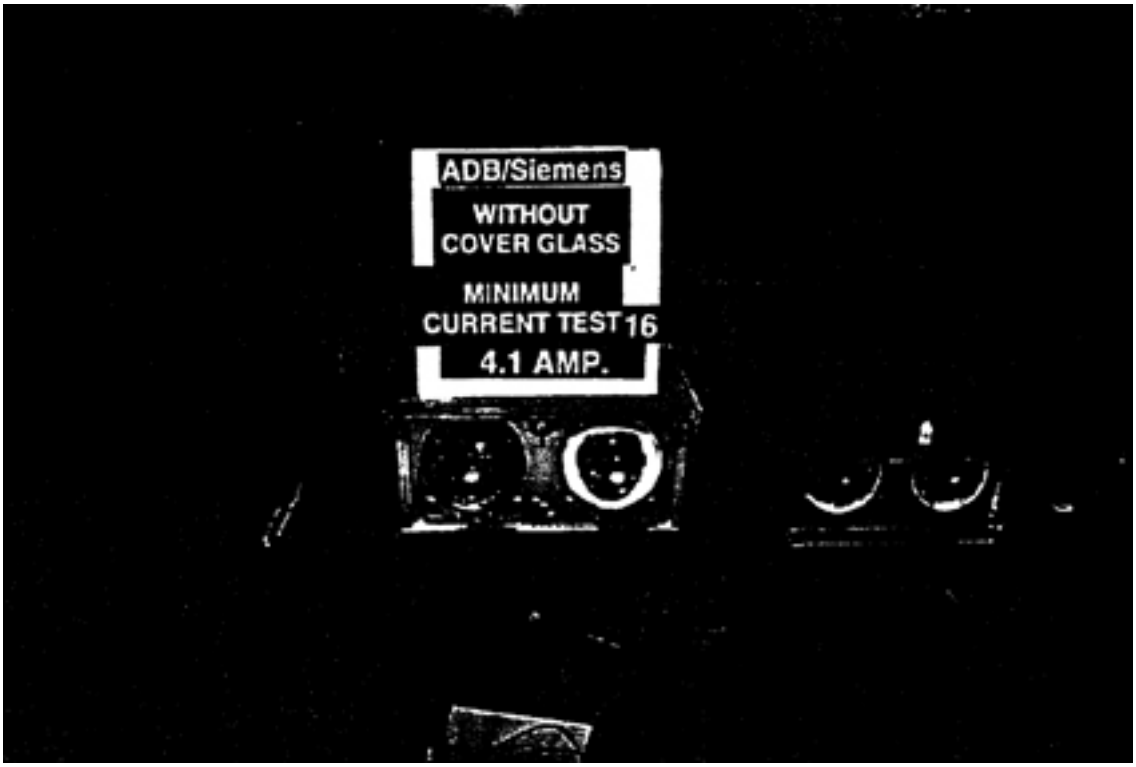
31. Test #14, post-test.



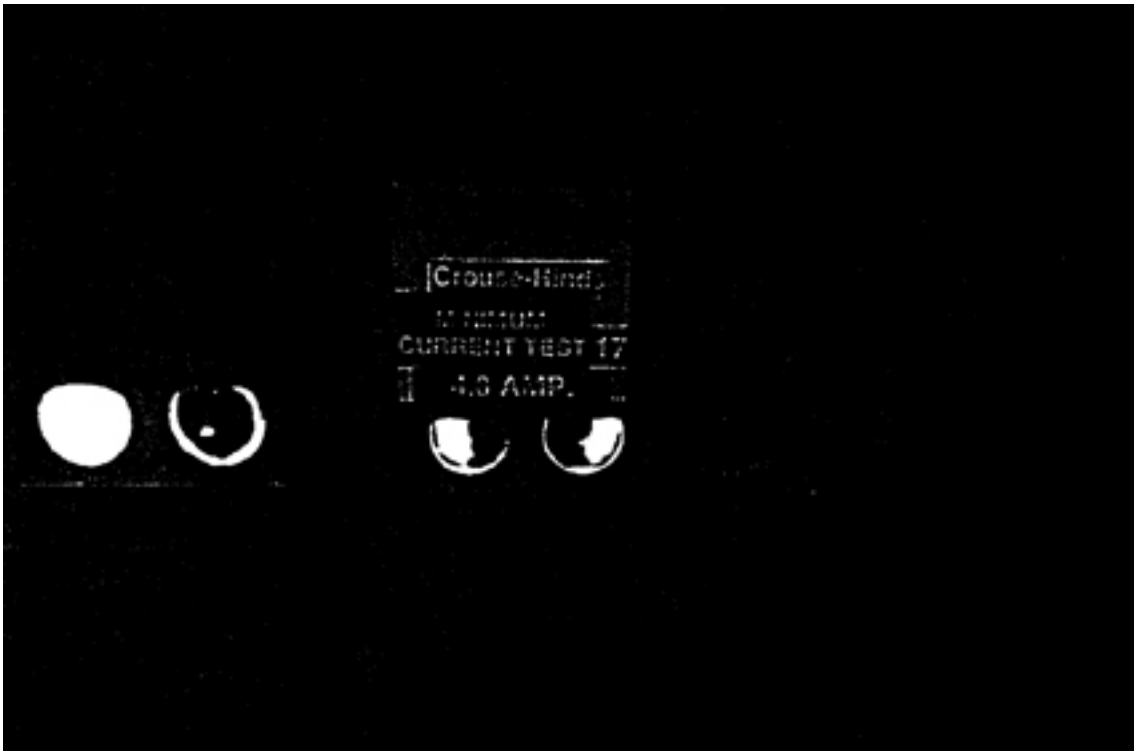
32. Test #15, pre-test.

33. Test #15, post-test.

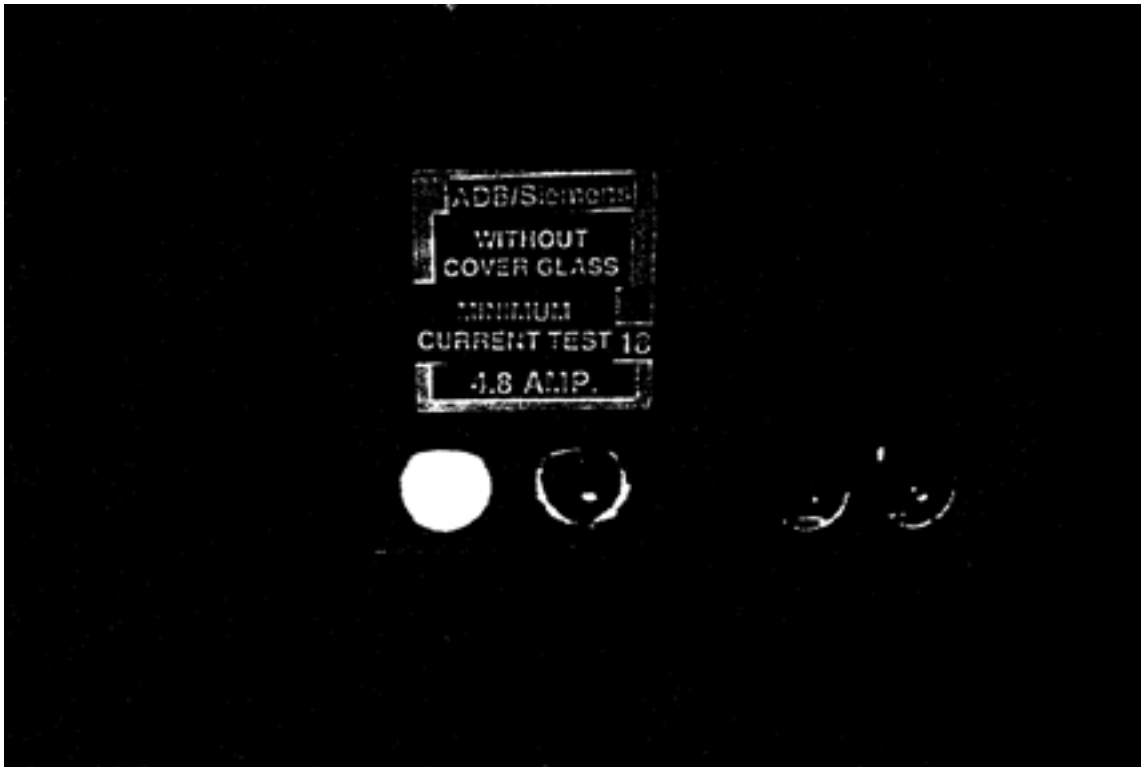
34. Test #16, pre-test.



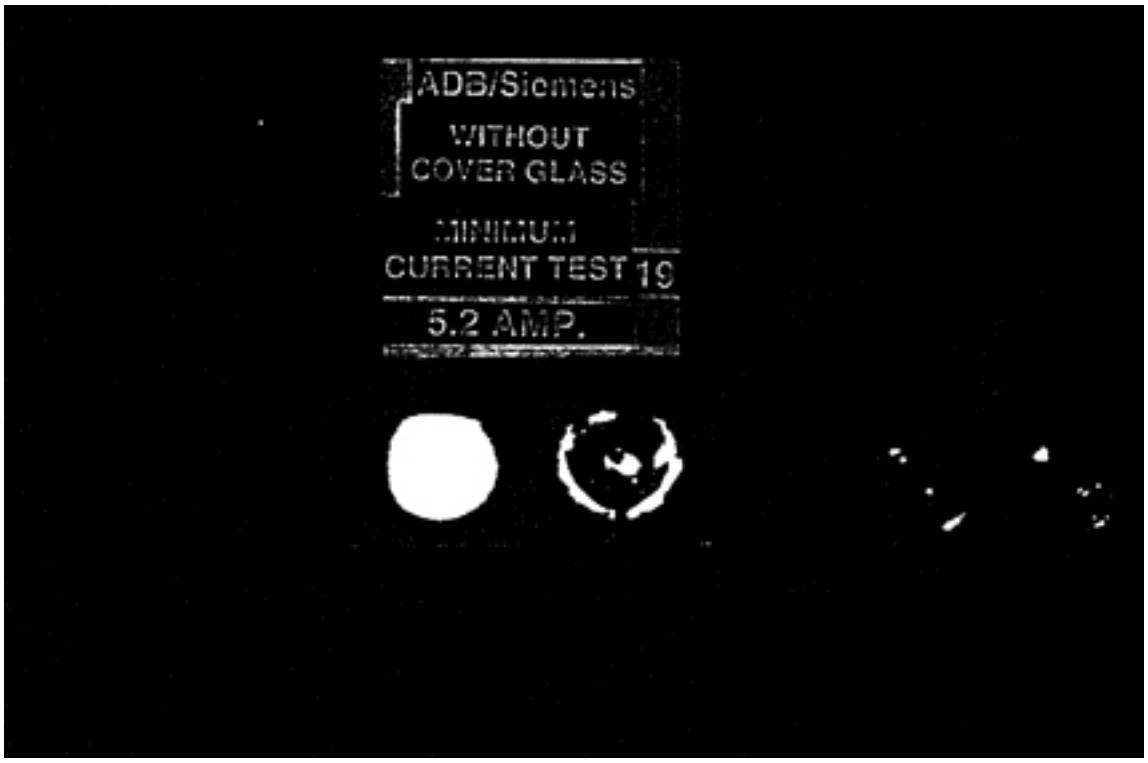
35. Test #16, post-test.



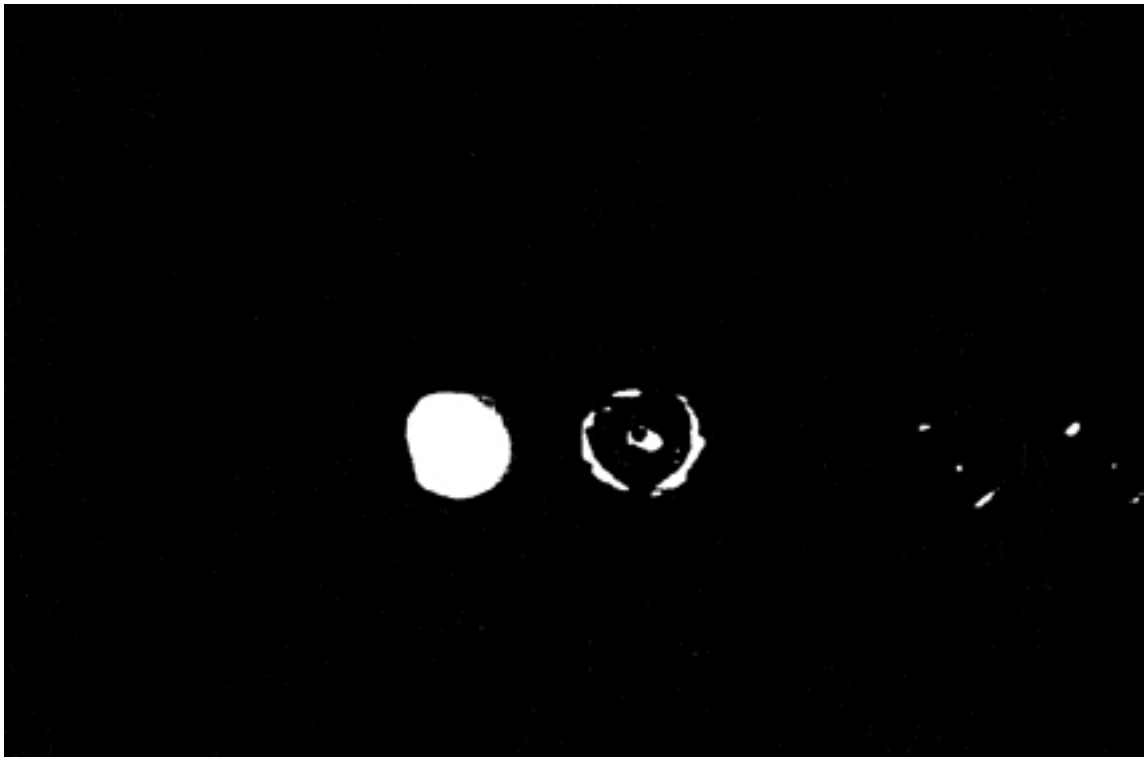
36. Test #17, pre-test.



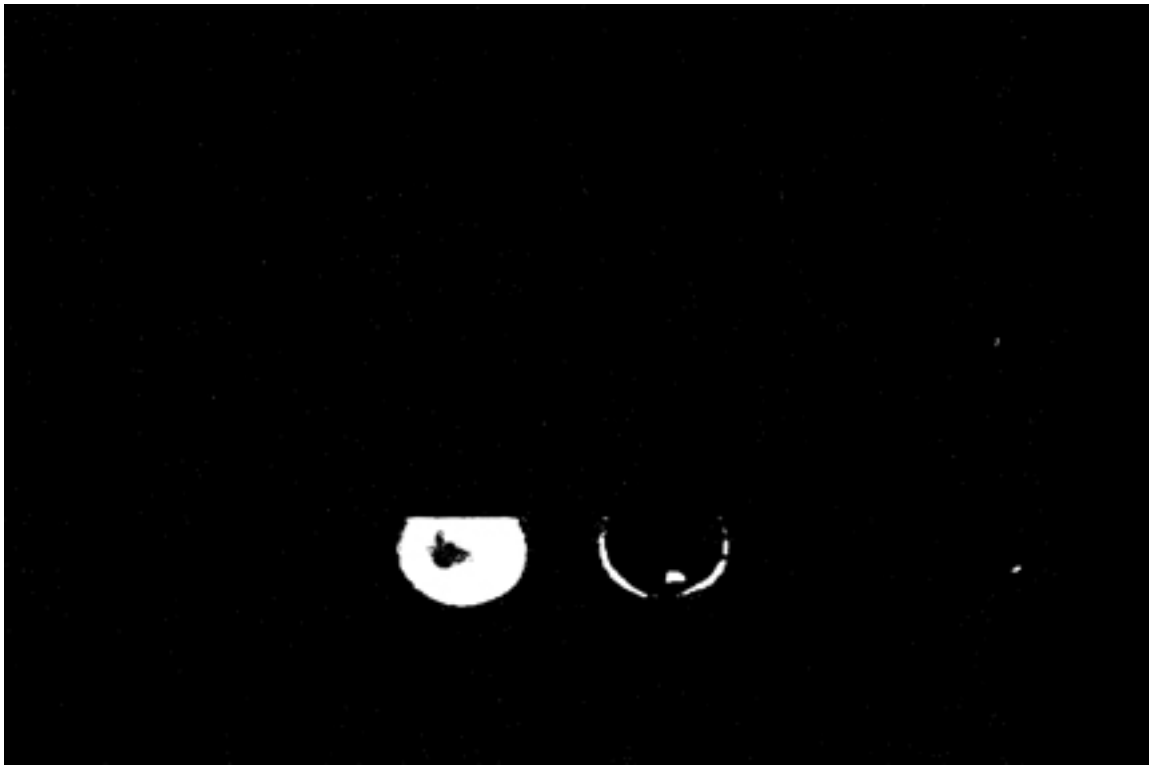
37. Test #18, pre-test.



38. Test #19, post-test.



39. Test #19, post-test.

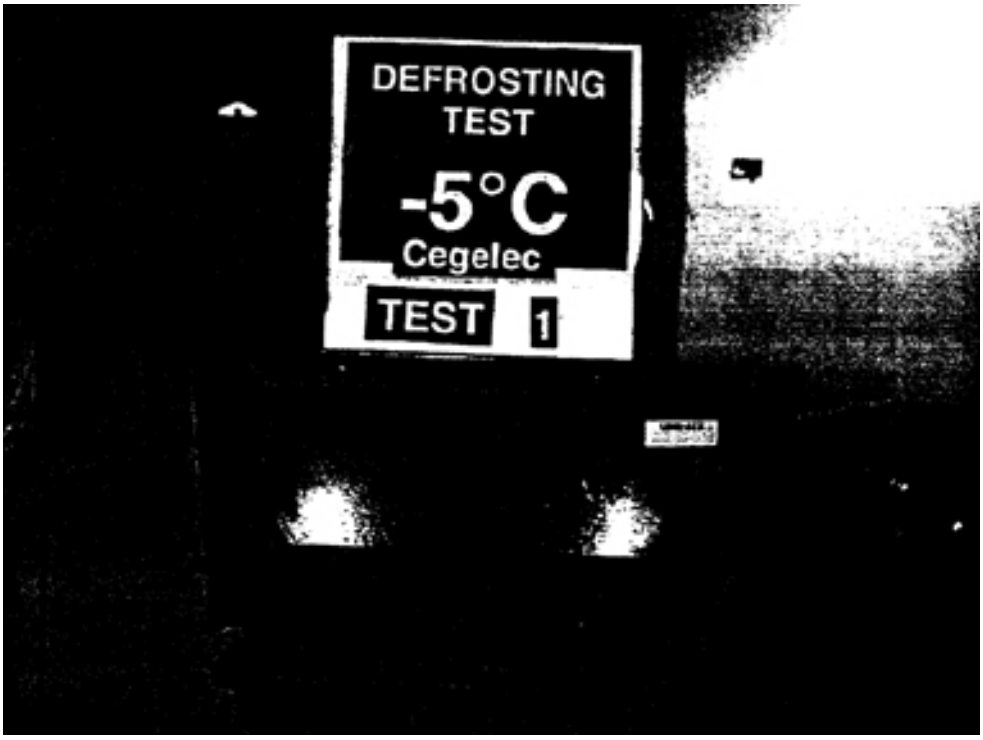


40. Test #20, post-test.

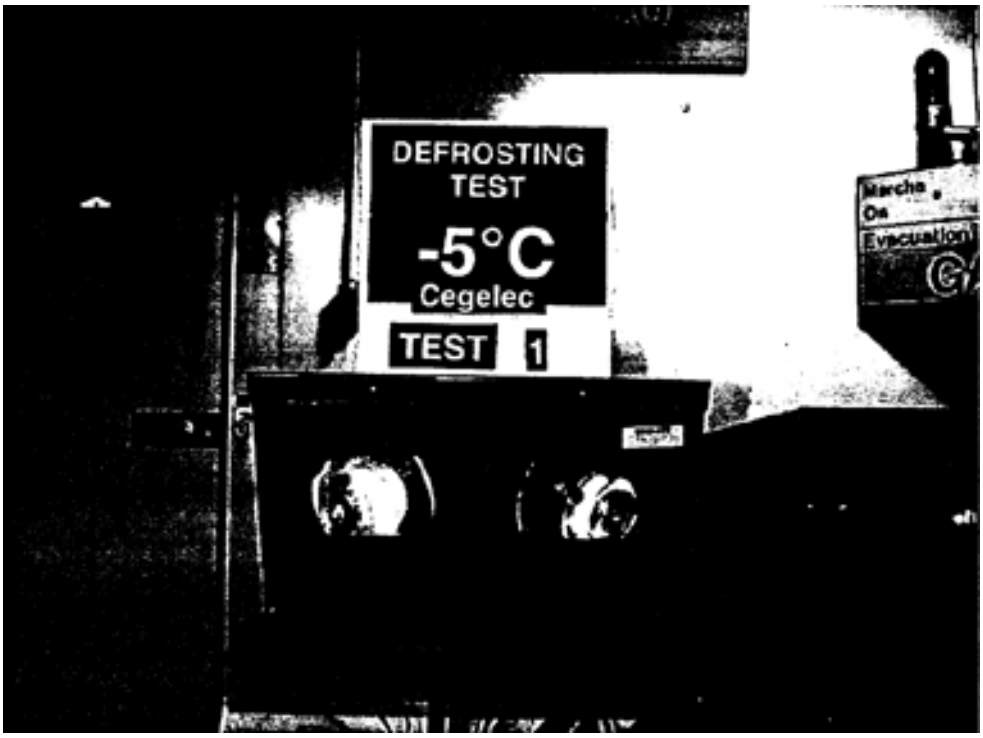
APPENDIX B

TEST PHOTOGRAPHS

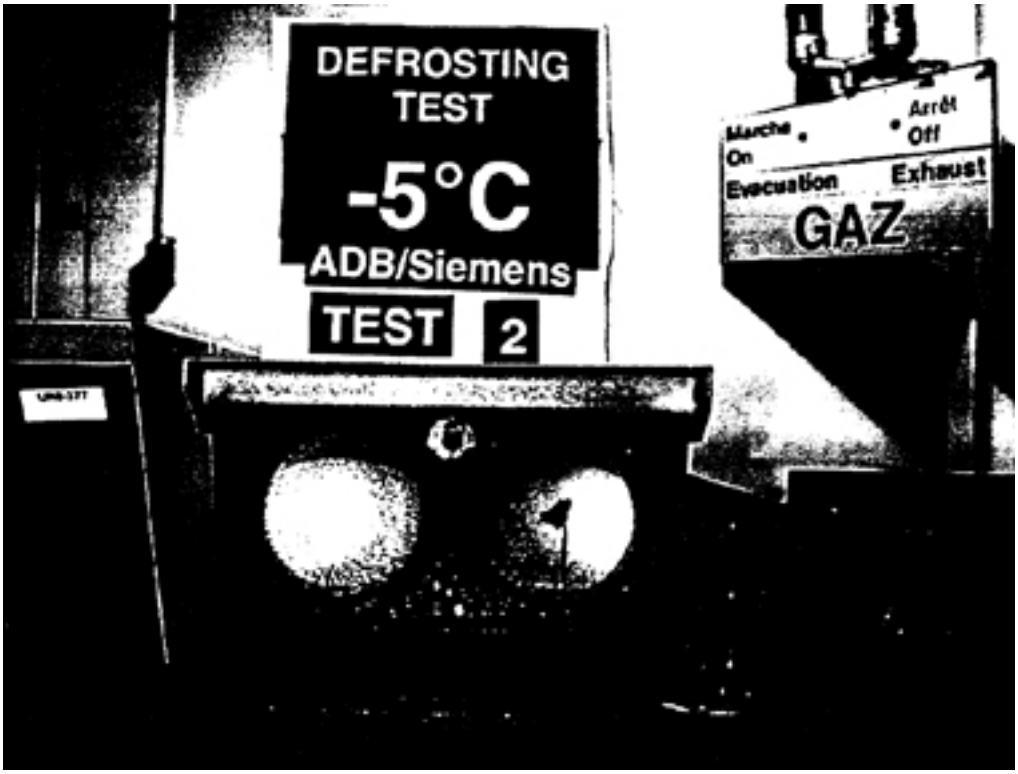
Intentionally left blank



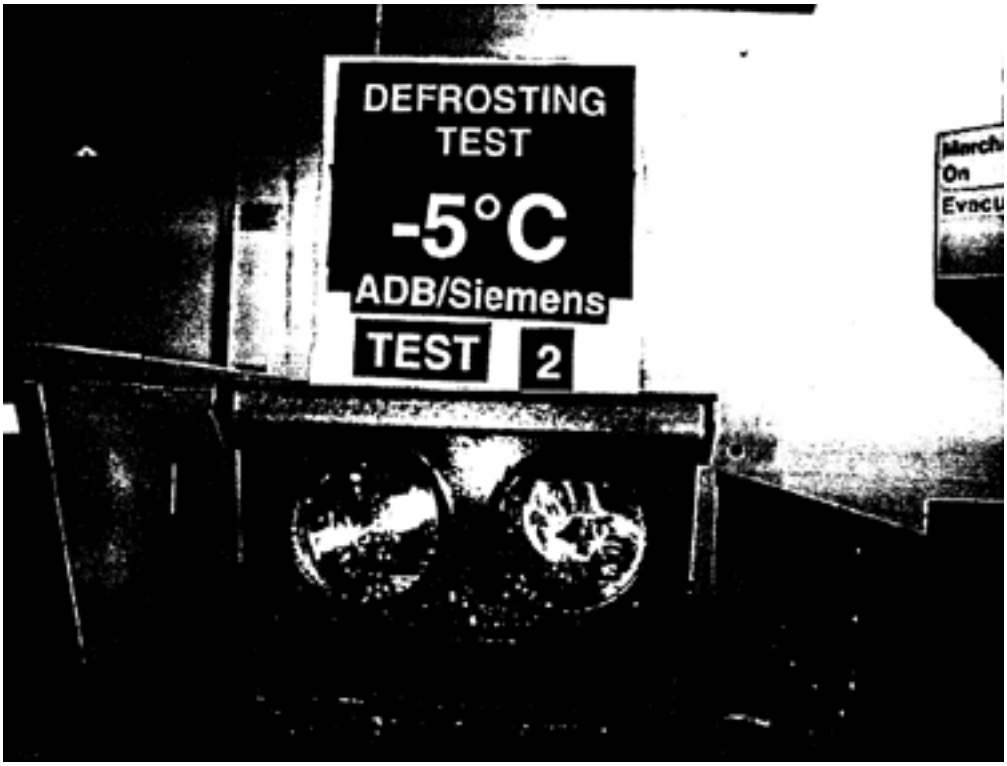
1. Test #1, pre-test.



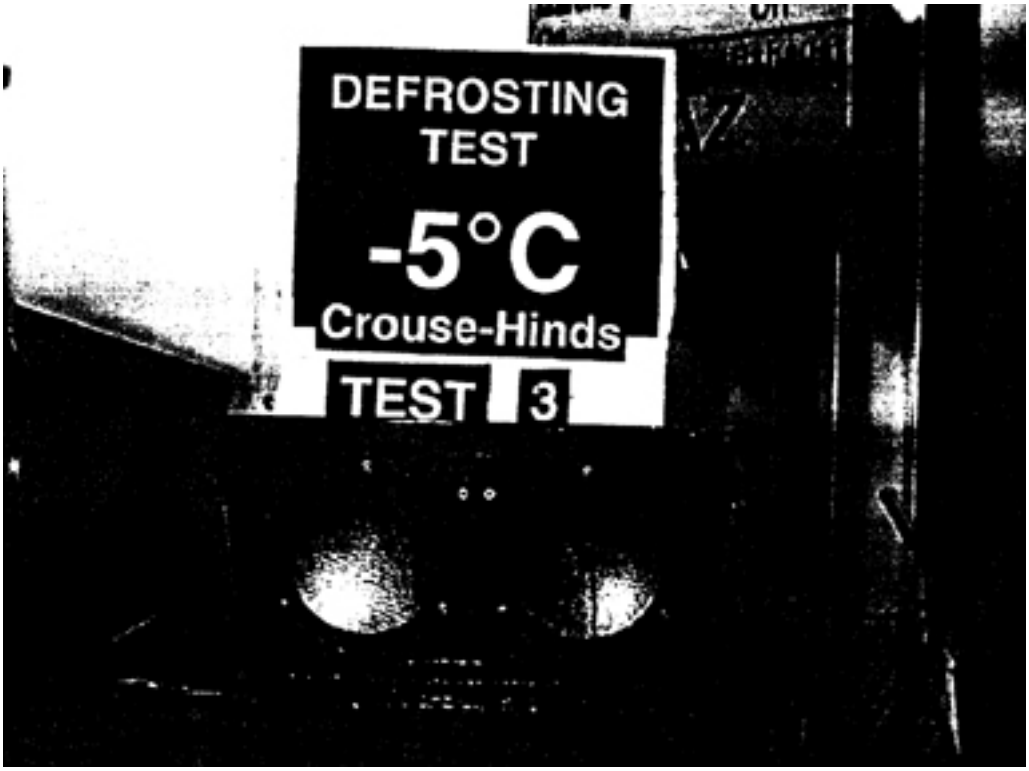
2. Test #1, post-test.



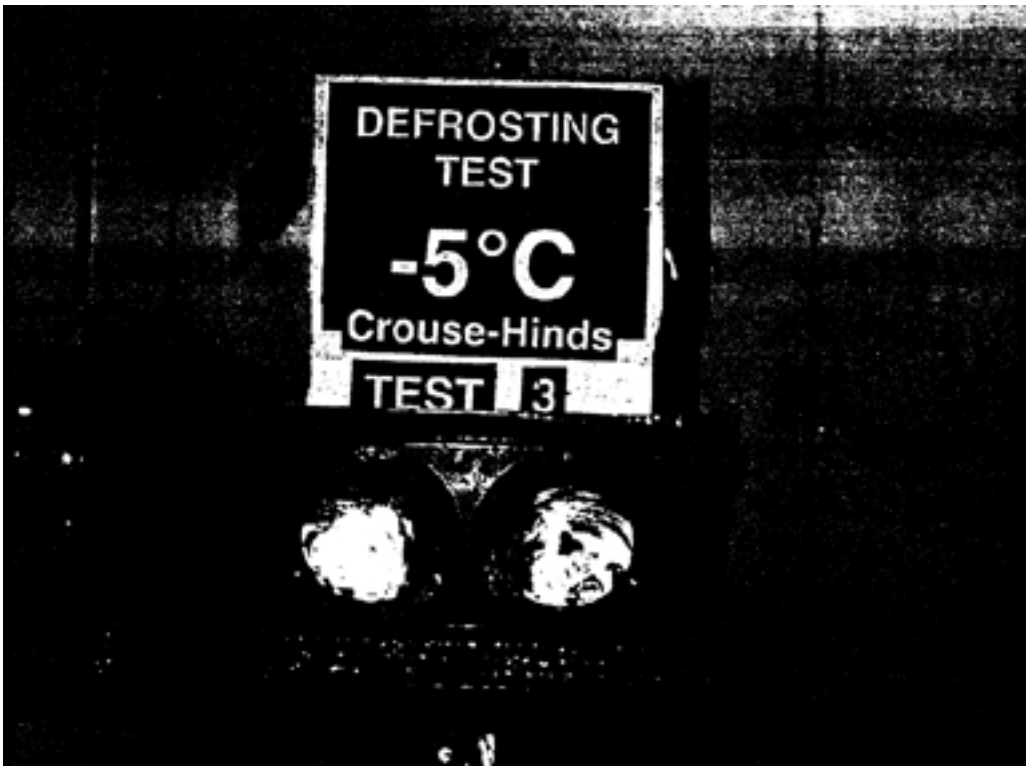
3. Test #2, pre-test.



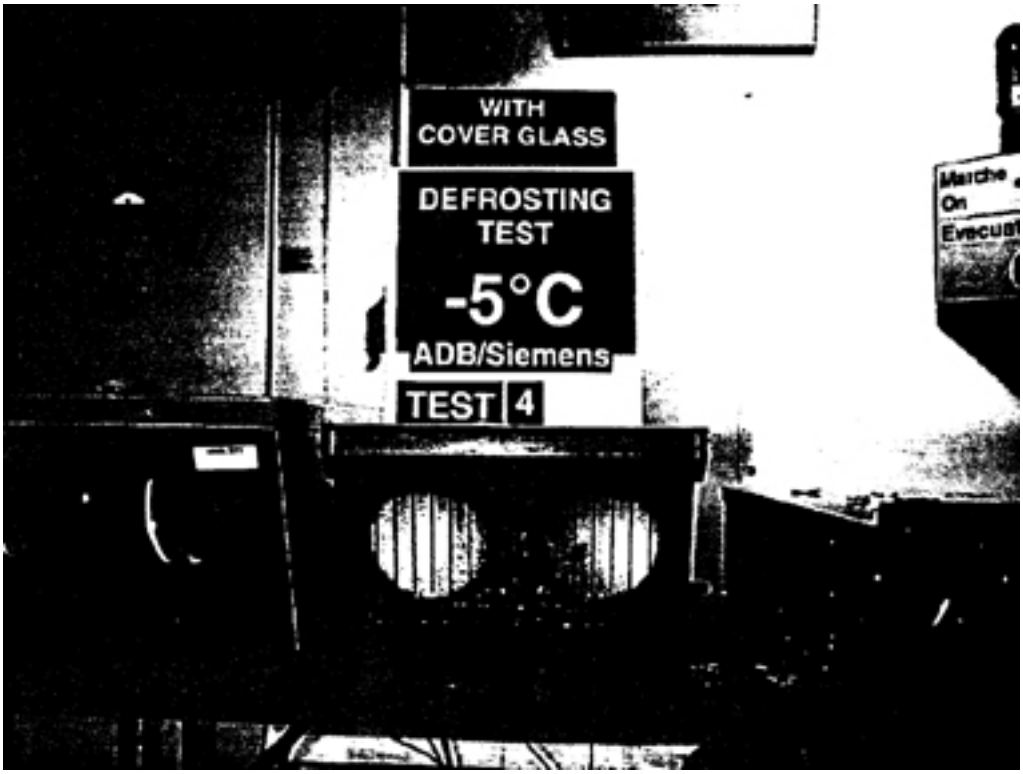
4. Test #2, post-test.



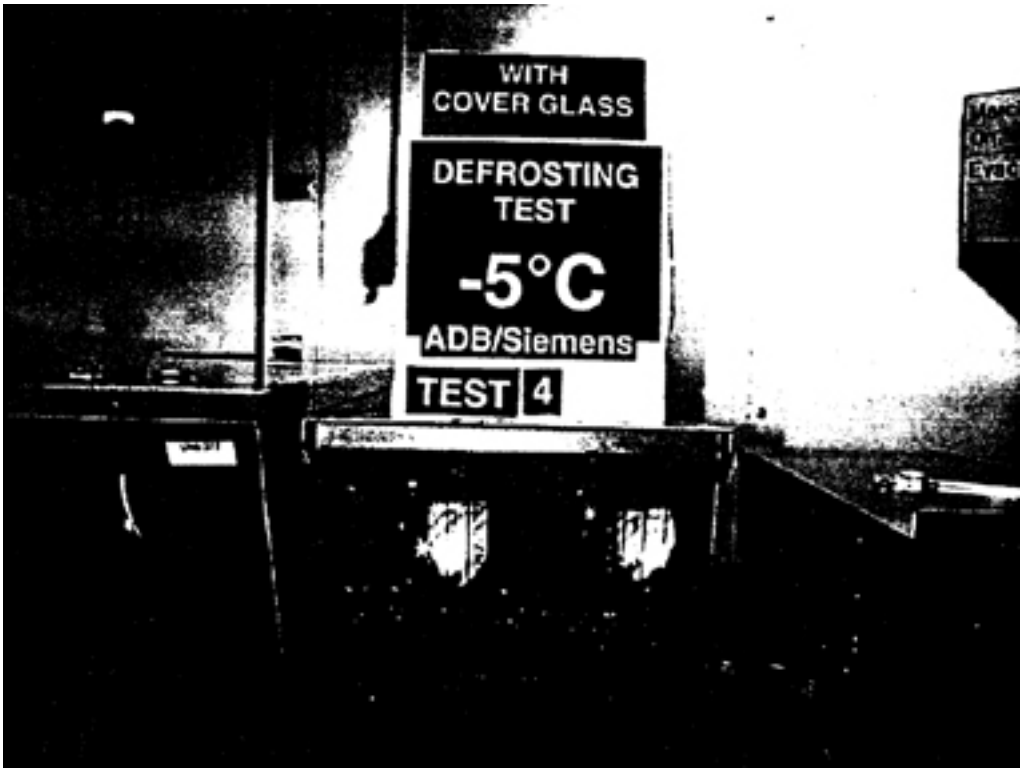
5. Test #3, pre-test.



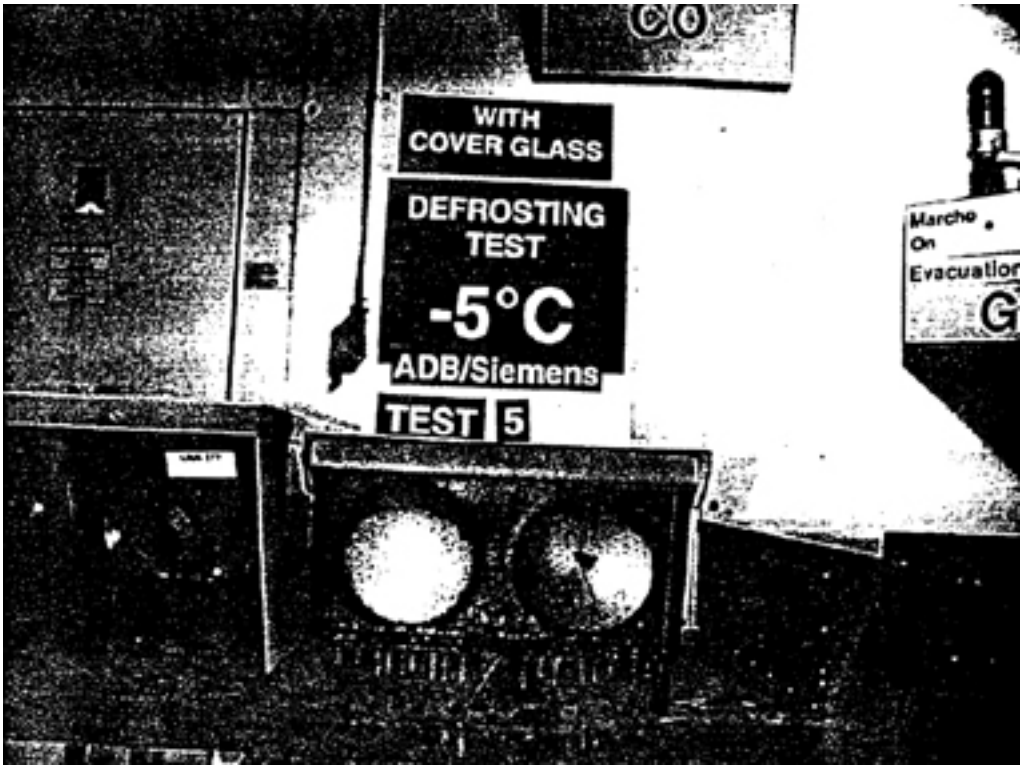
6. Test #3, post-test.



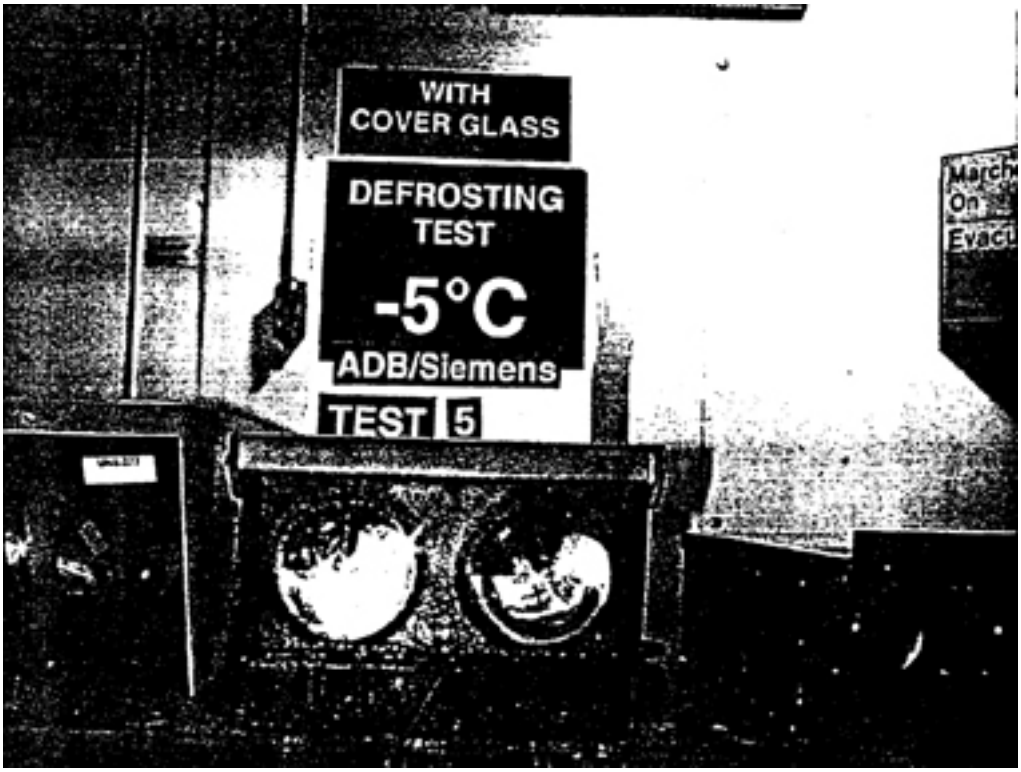
7. Test #4, pre-test.



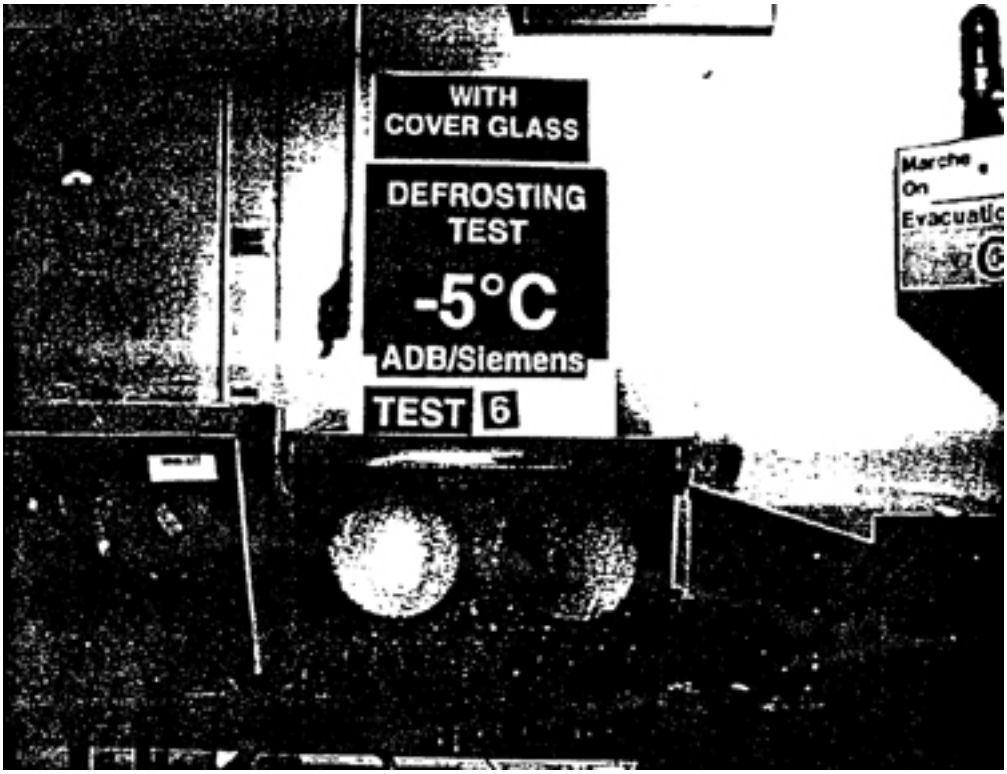
8. Test #4, post-test.



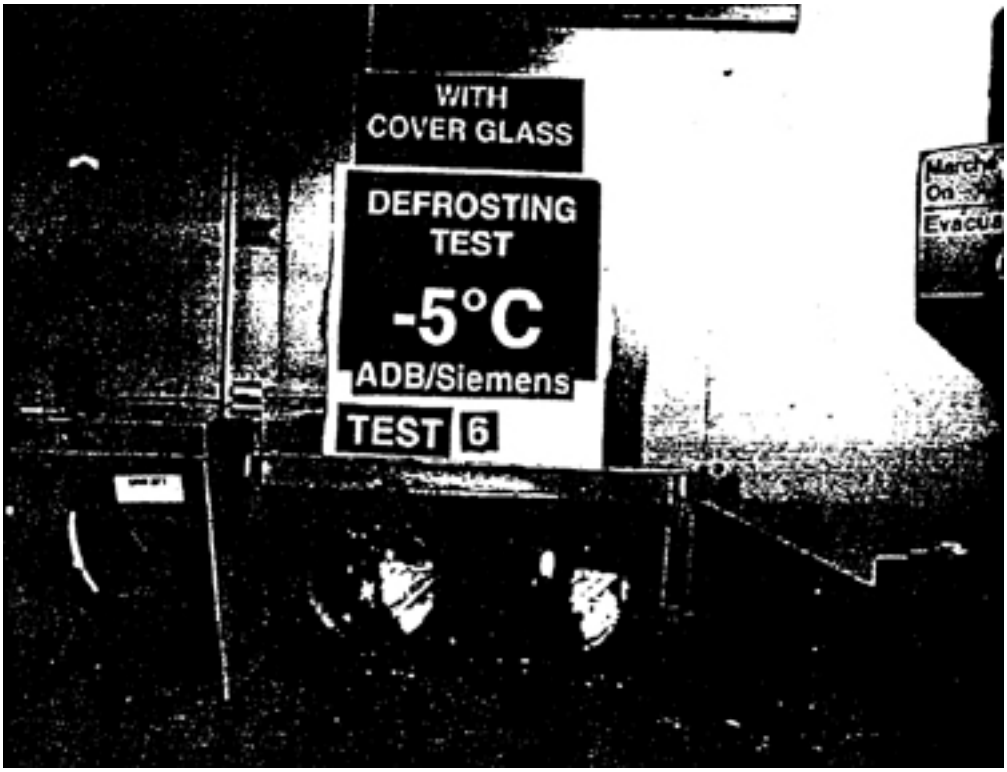
9. Test #5, pre-test.



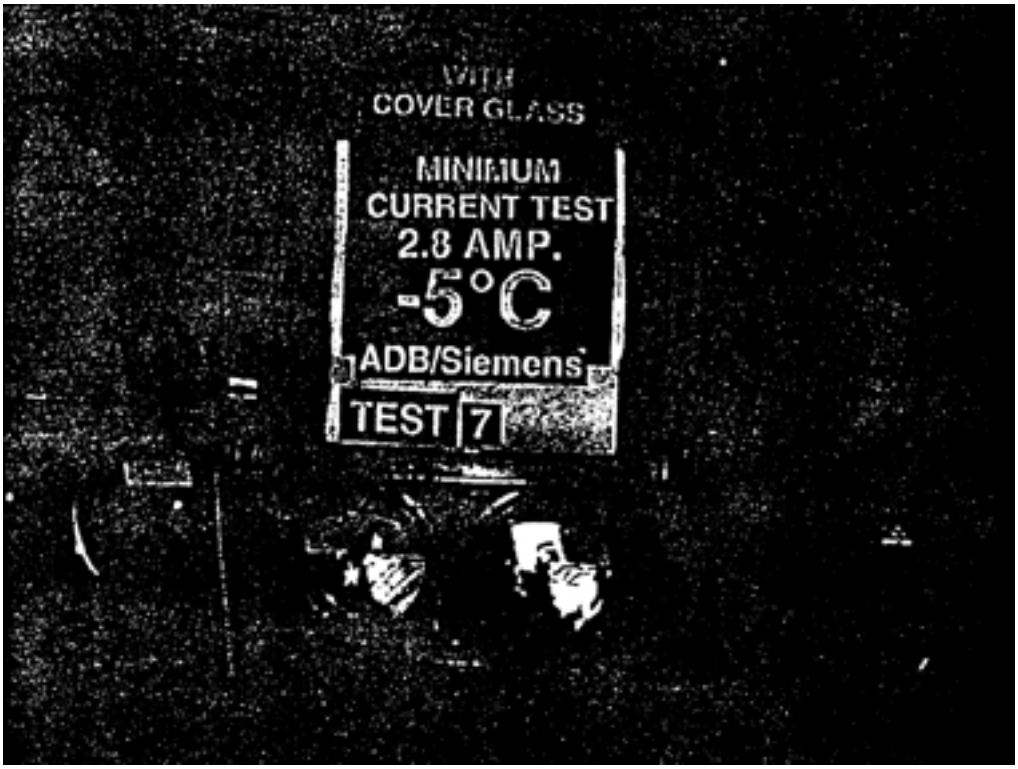
10. Test #5, post-test.



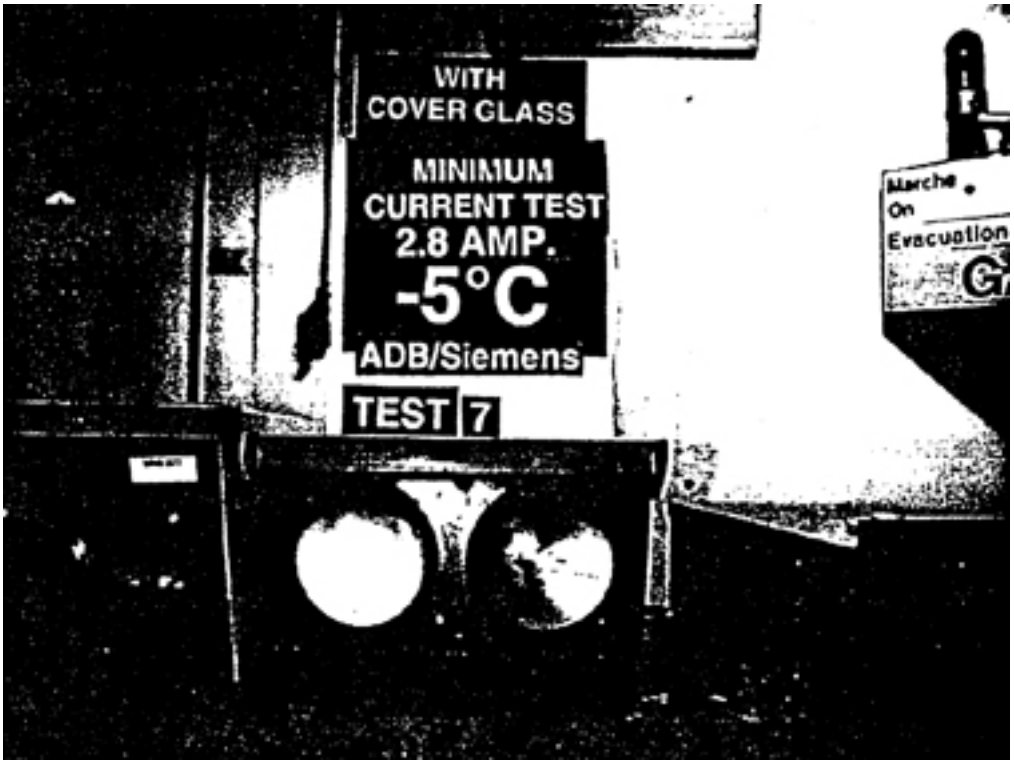
11. Test #6, pre-test.



12. Test #6, post-test.

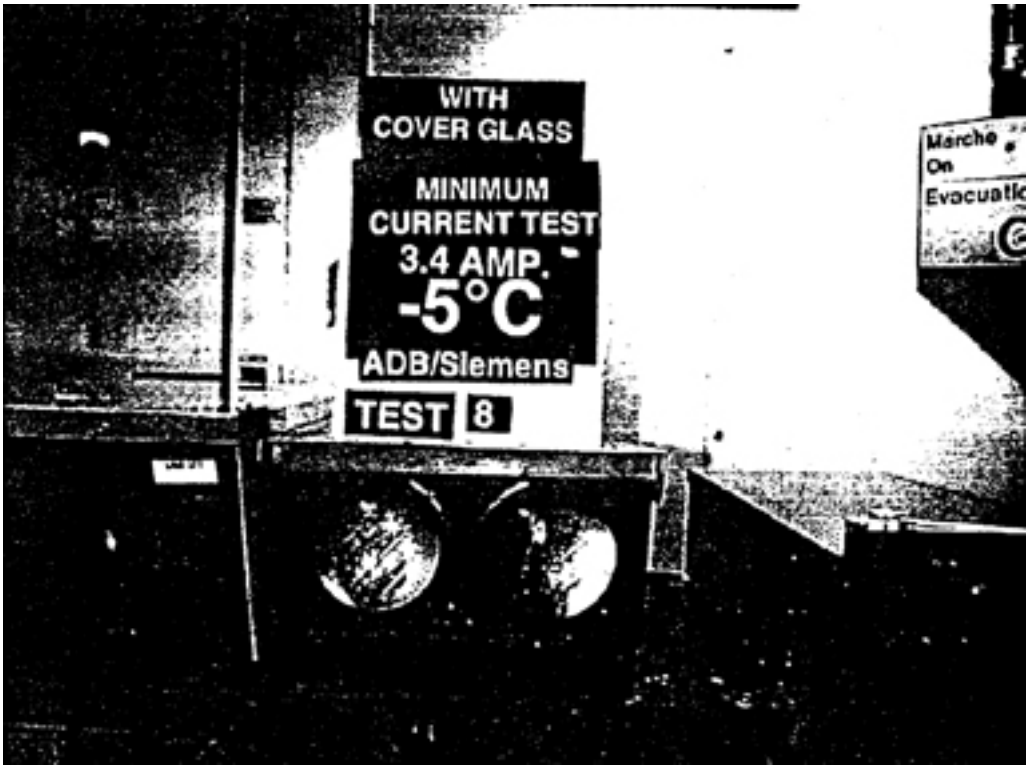


13. Test #7, pre-test.

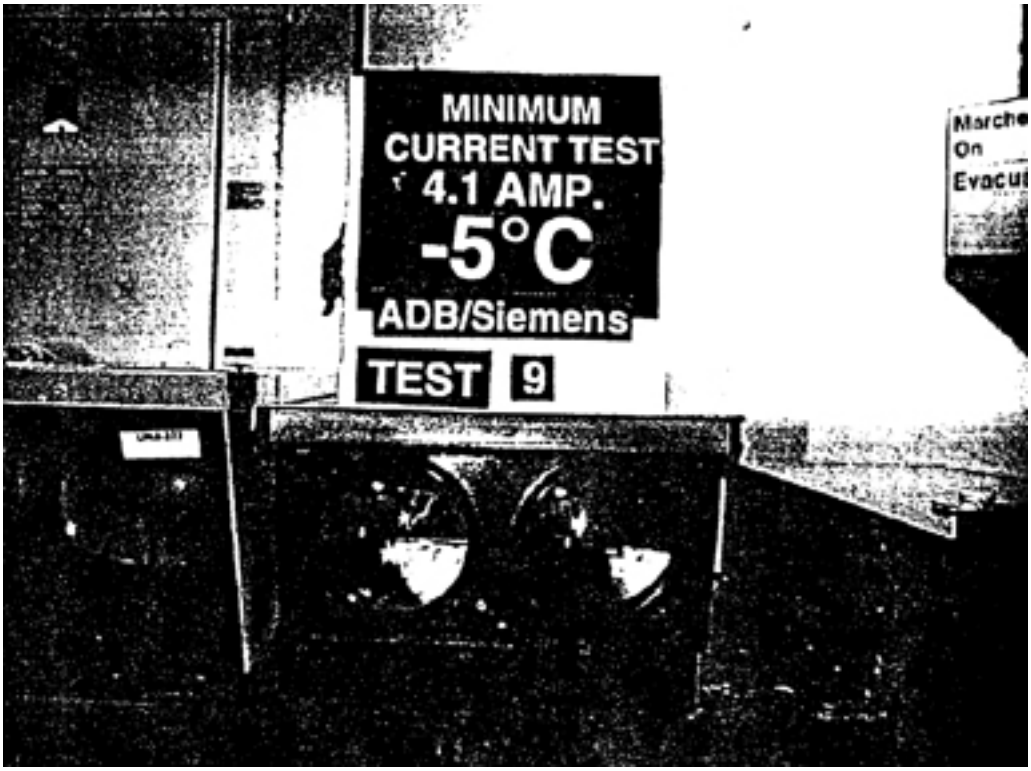


14. Test #7, post-test.

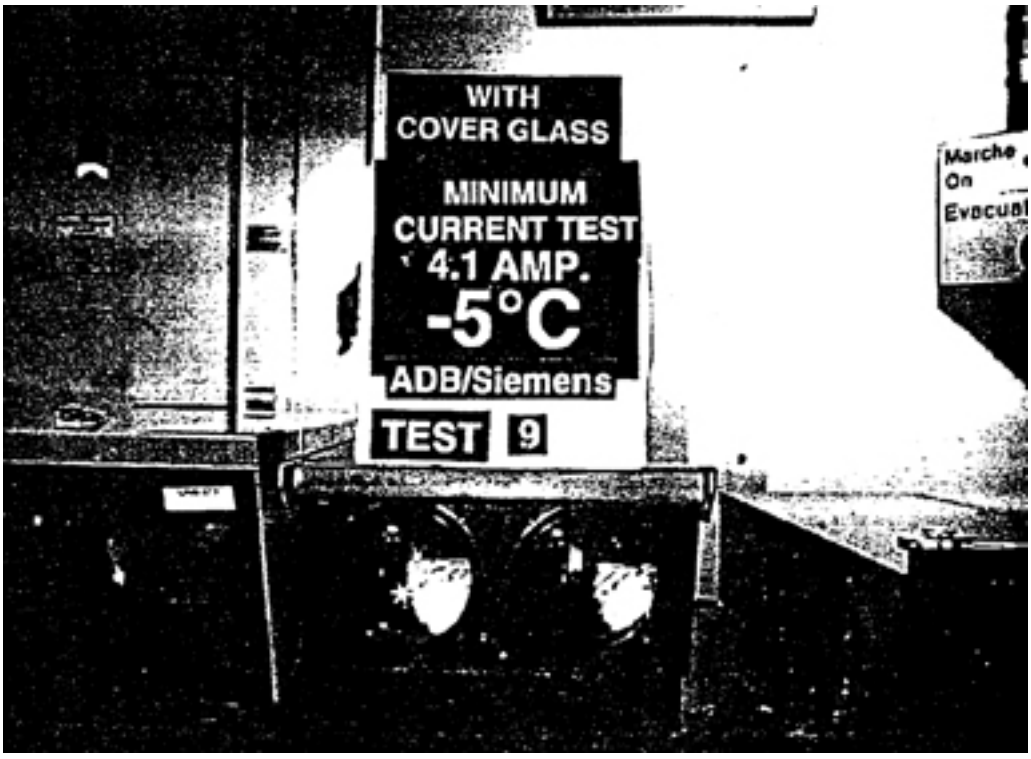
15. Test #8, pre-test.



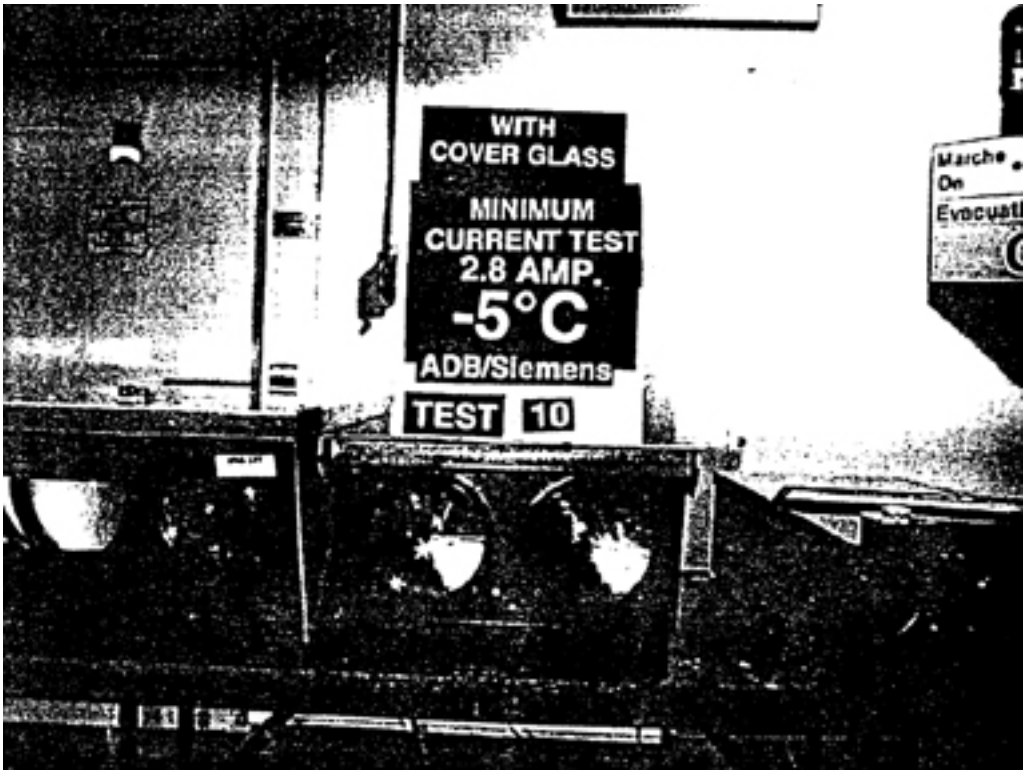
16. Test #8, post-test.



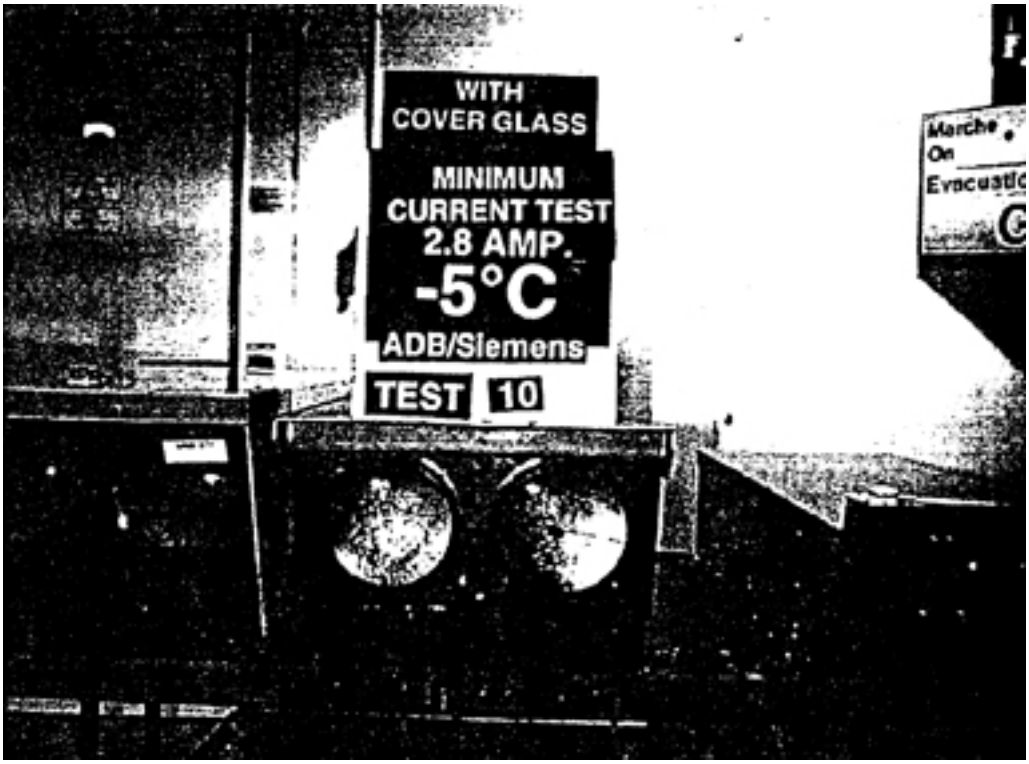
17. Test #9, pre-test.



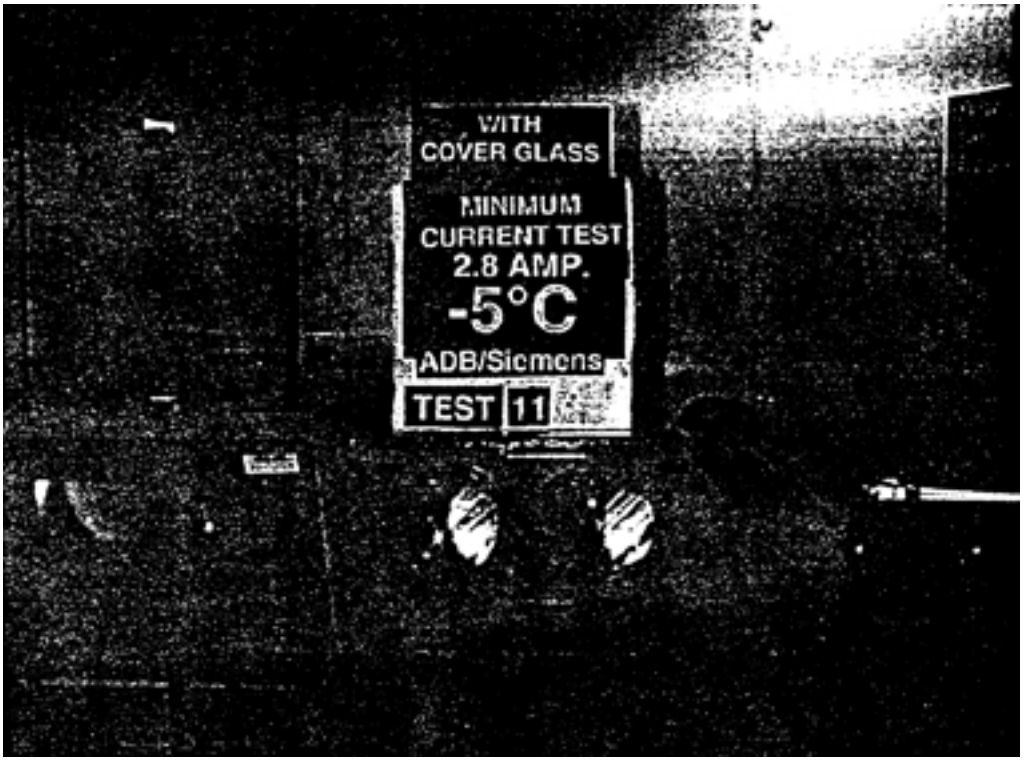
18. Test #9, post-test.



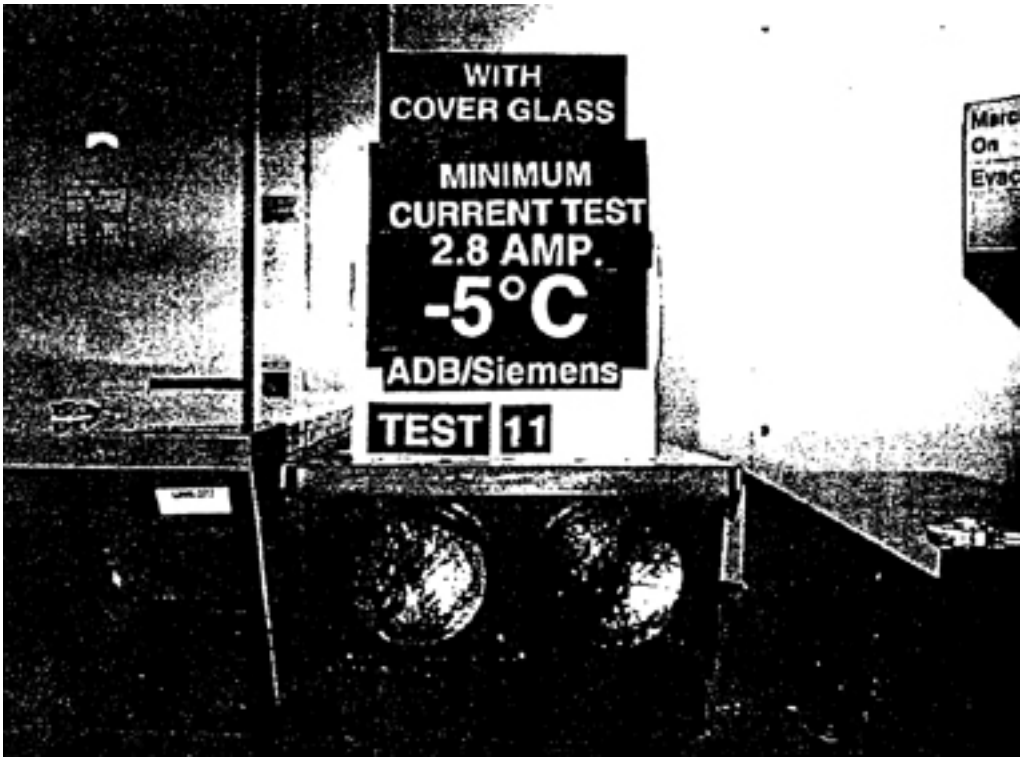
19. Test #10, pre-test.



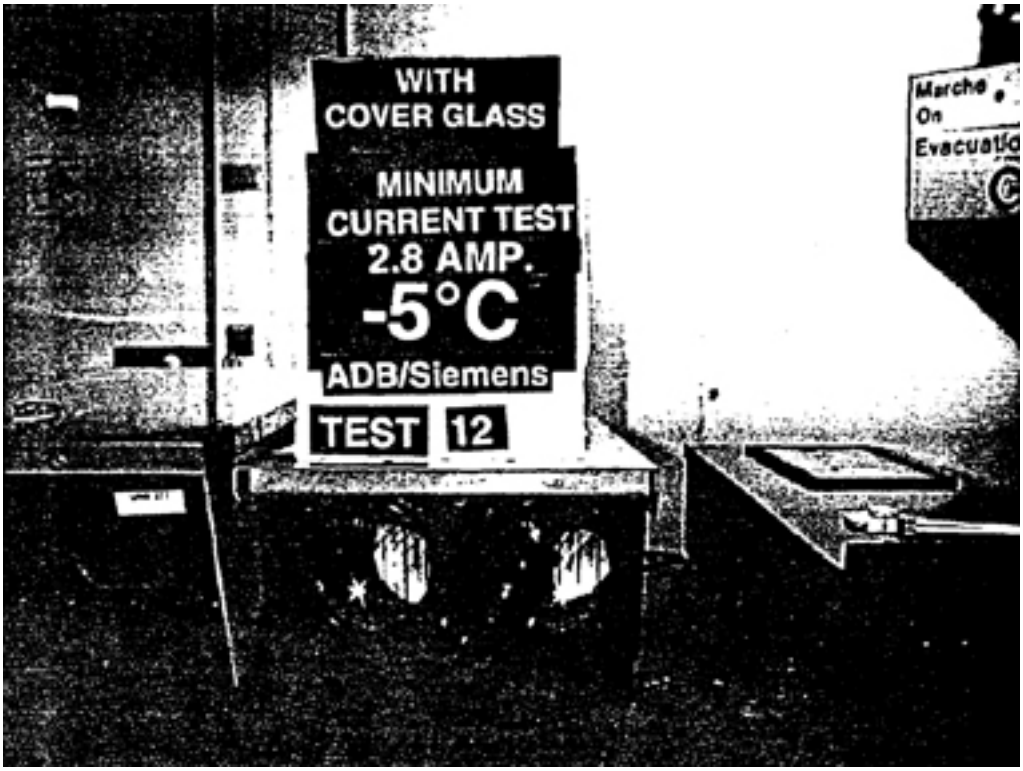
20. Test #10, post-test.



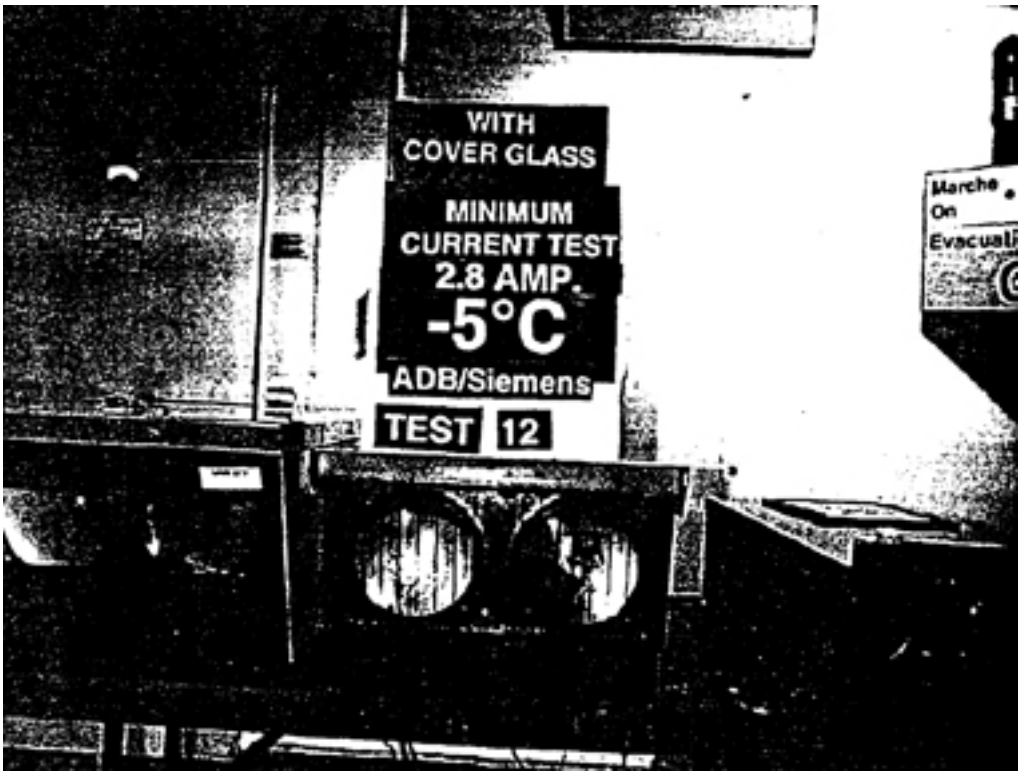
21. Test #11, pre-test.



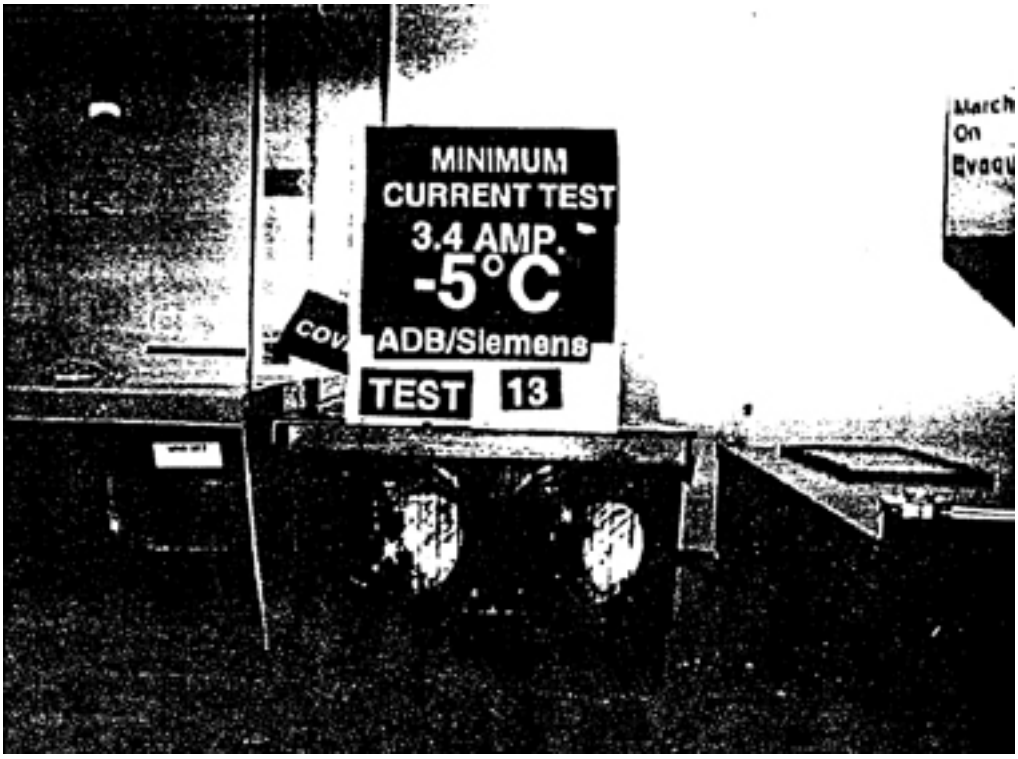
22. Test #11, post-test.



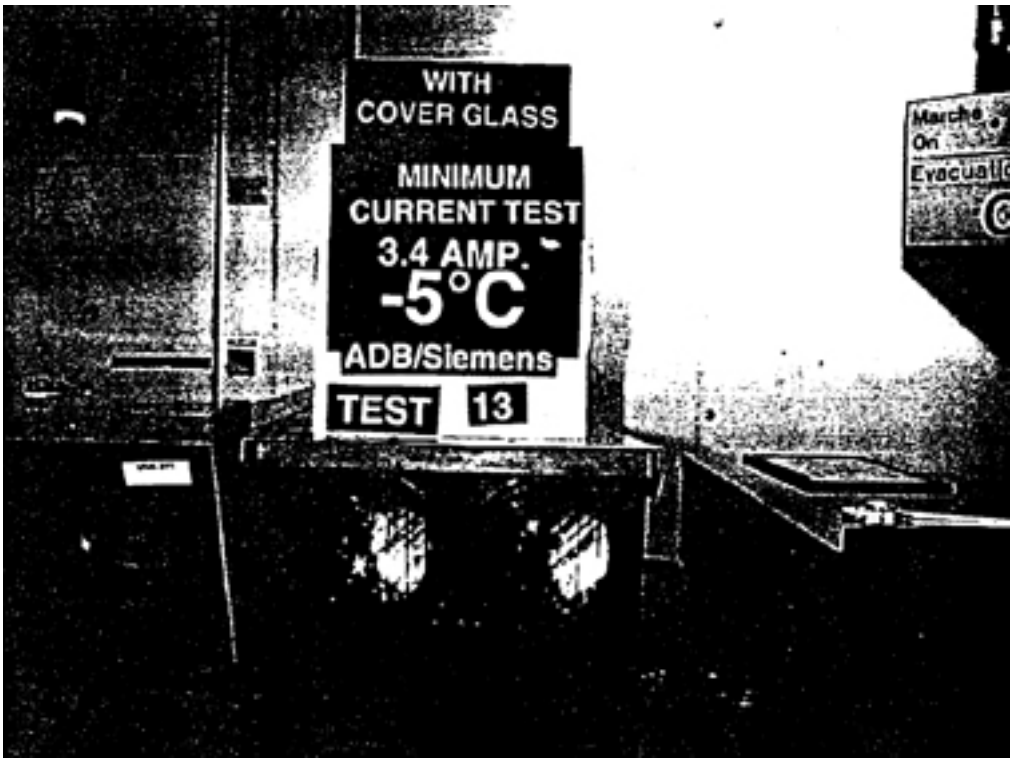
23. Test #12, pre-test.



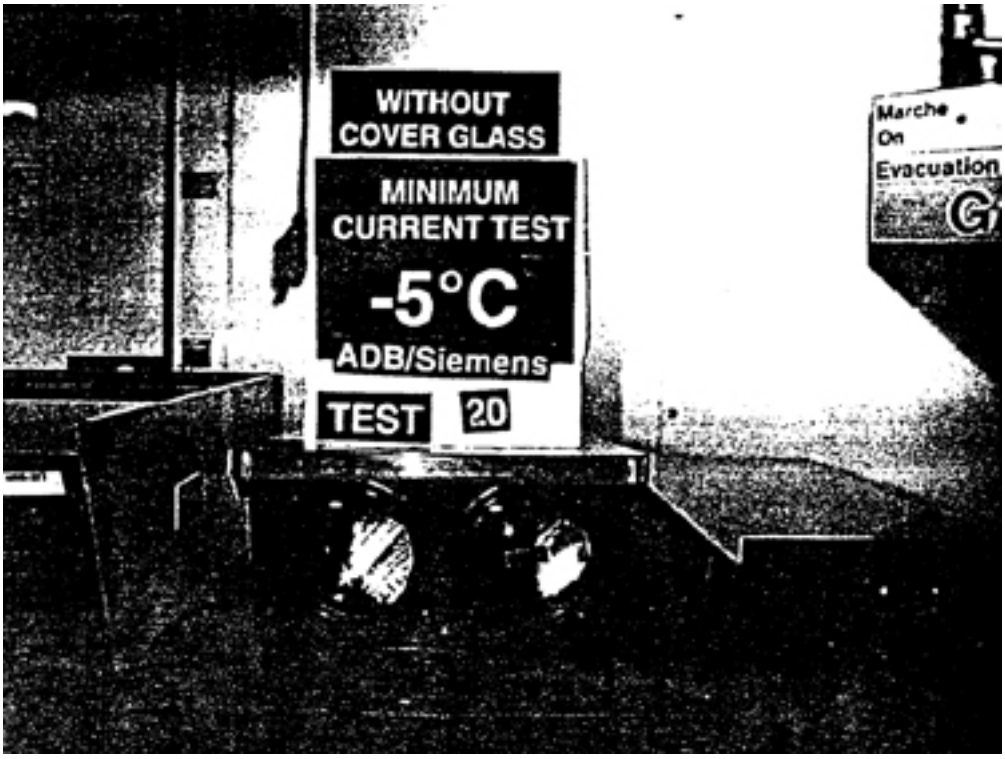
24. Test #12, post-test.



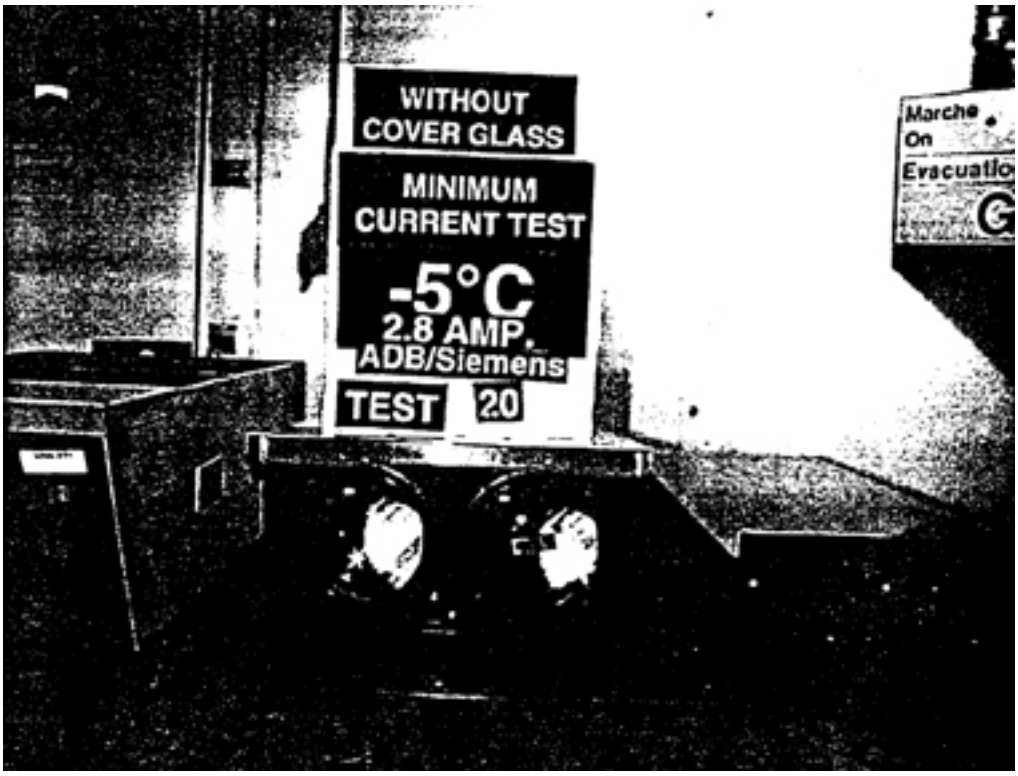
25. Test #13, pre-test.



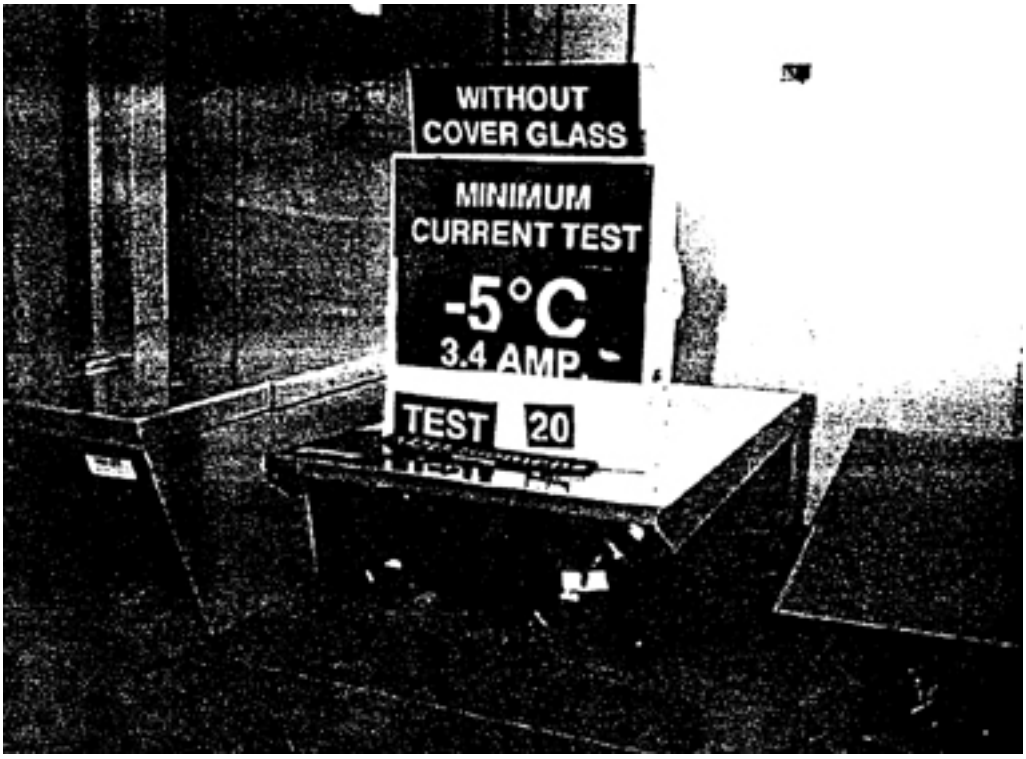
26. Test #13, post-test.



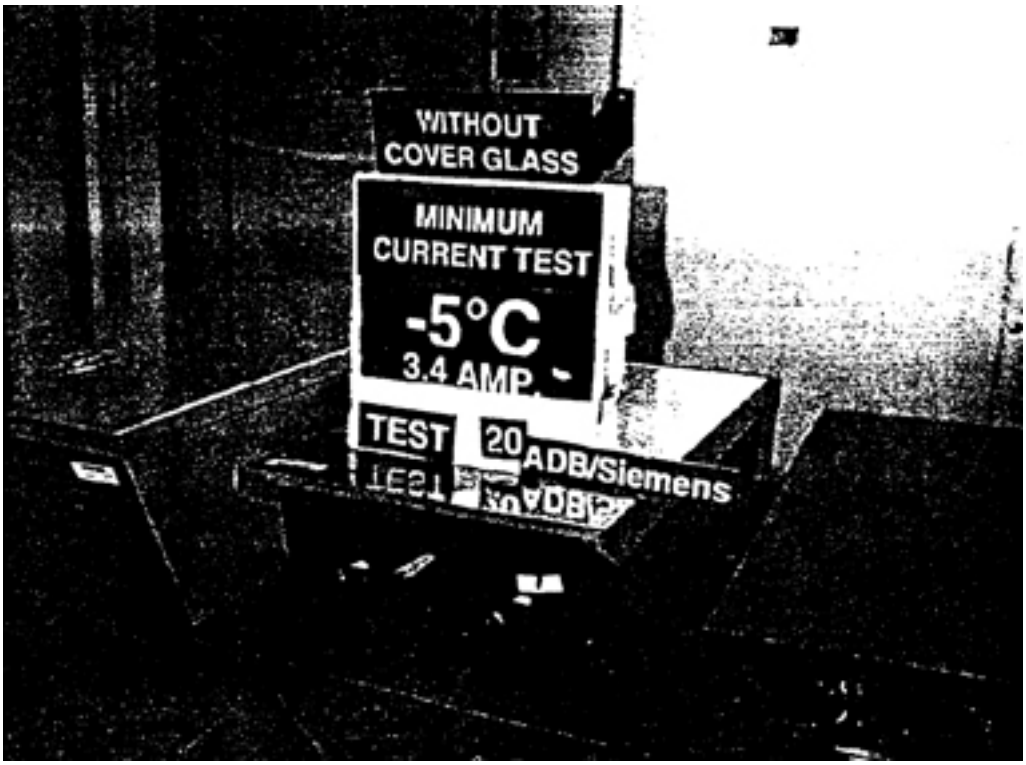
27. Test #20, pre-test.



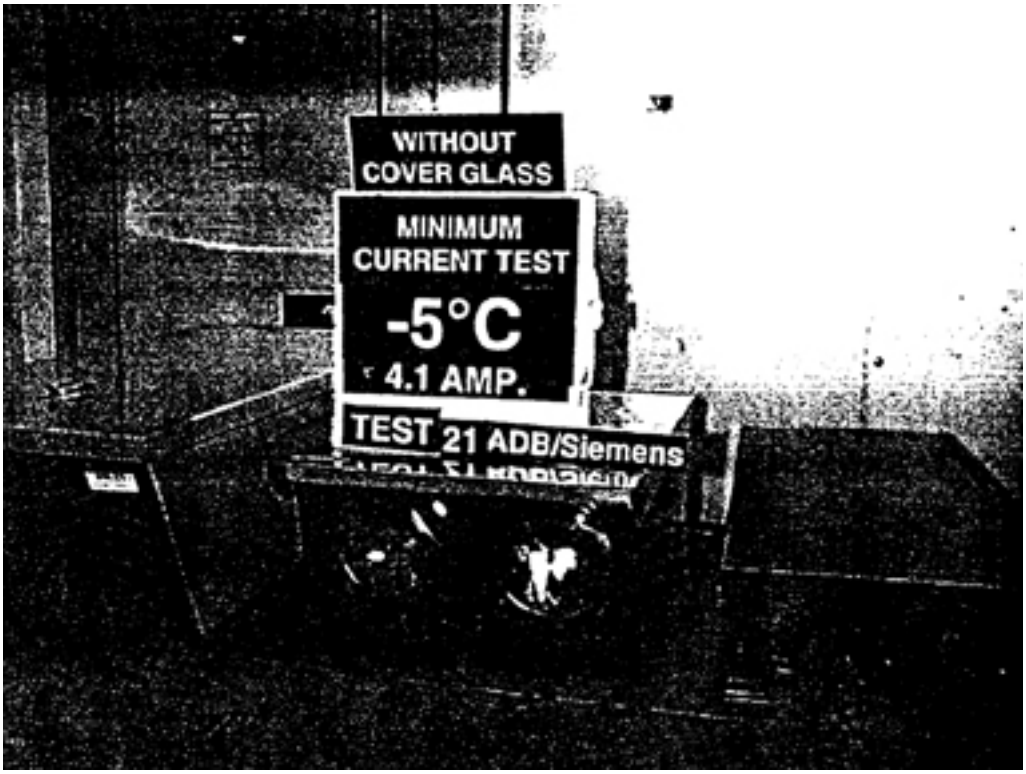
28. Test #20, post-test.



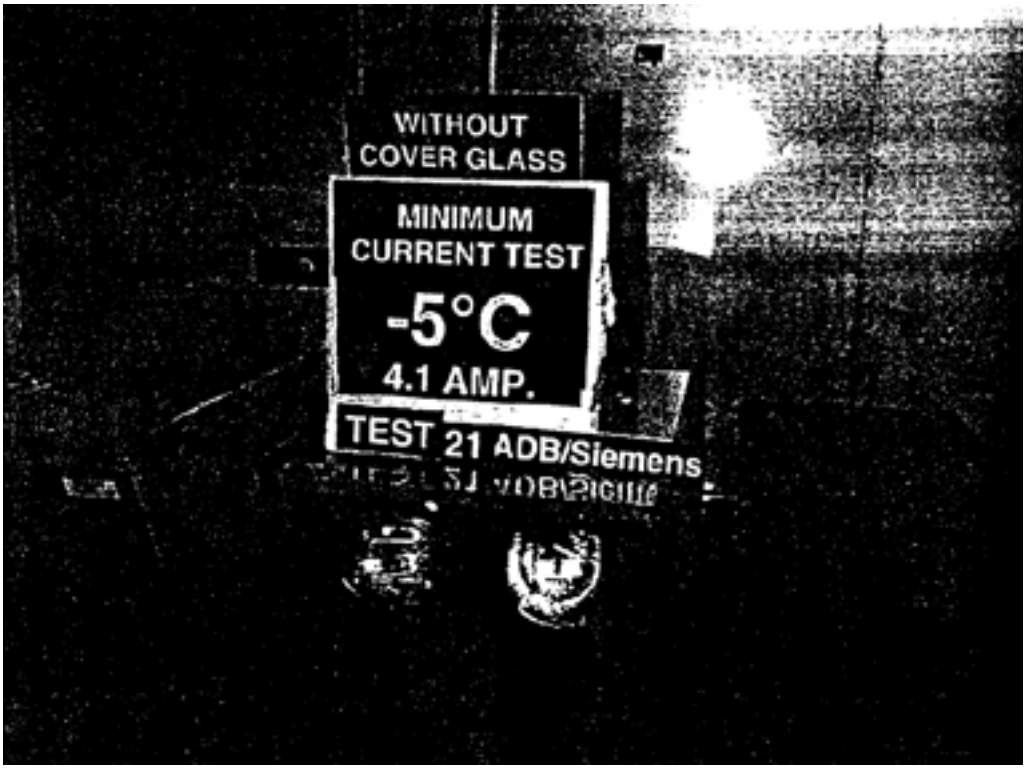
29. Test #20-B, pre-test.



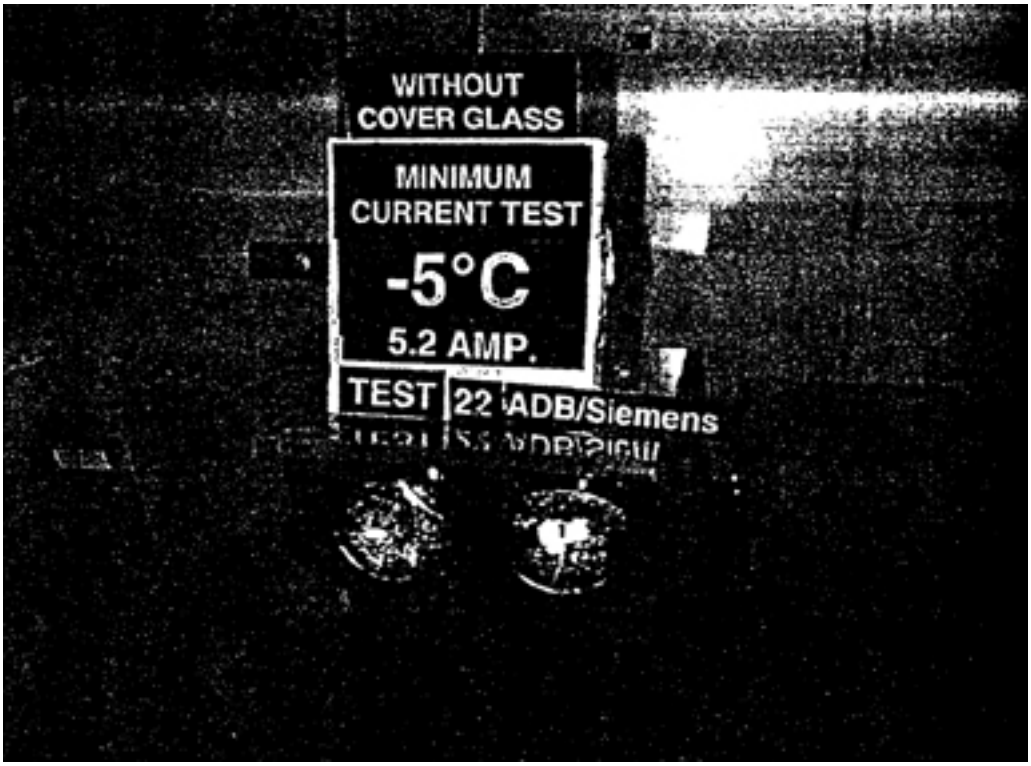
30. Test #20-B, post-test.



31. Test #21, pre-test.

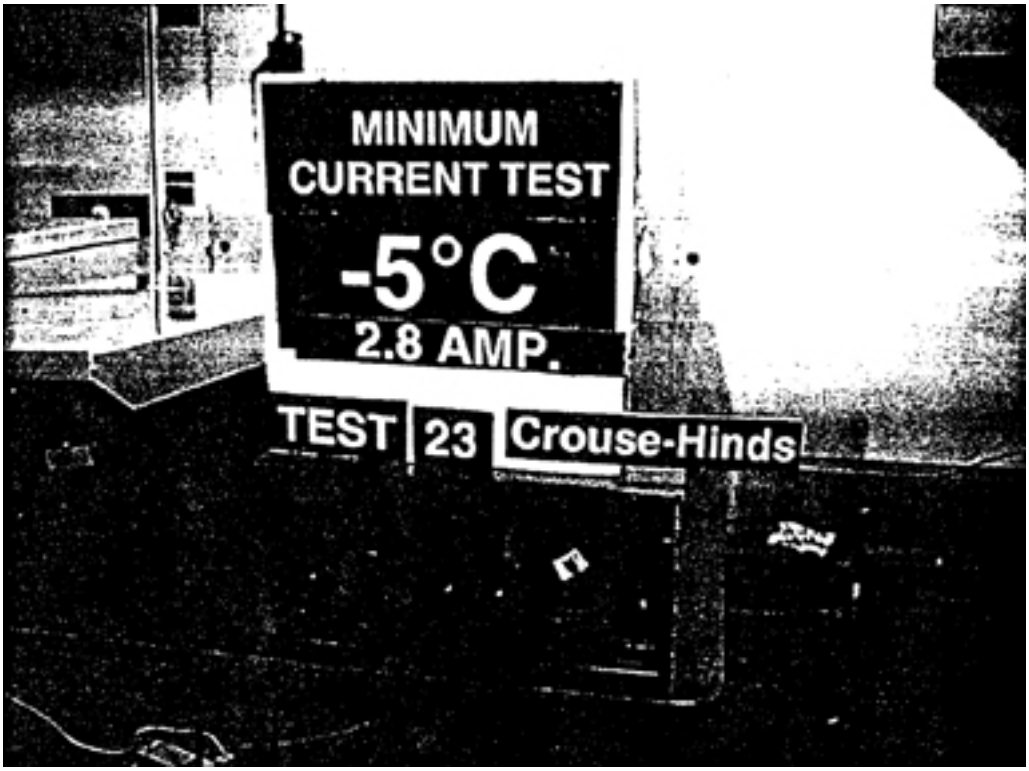


32. Test #21, post-test.

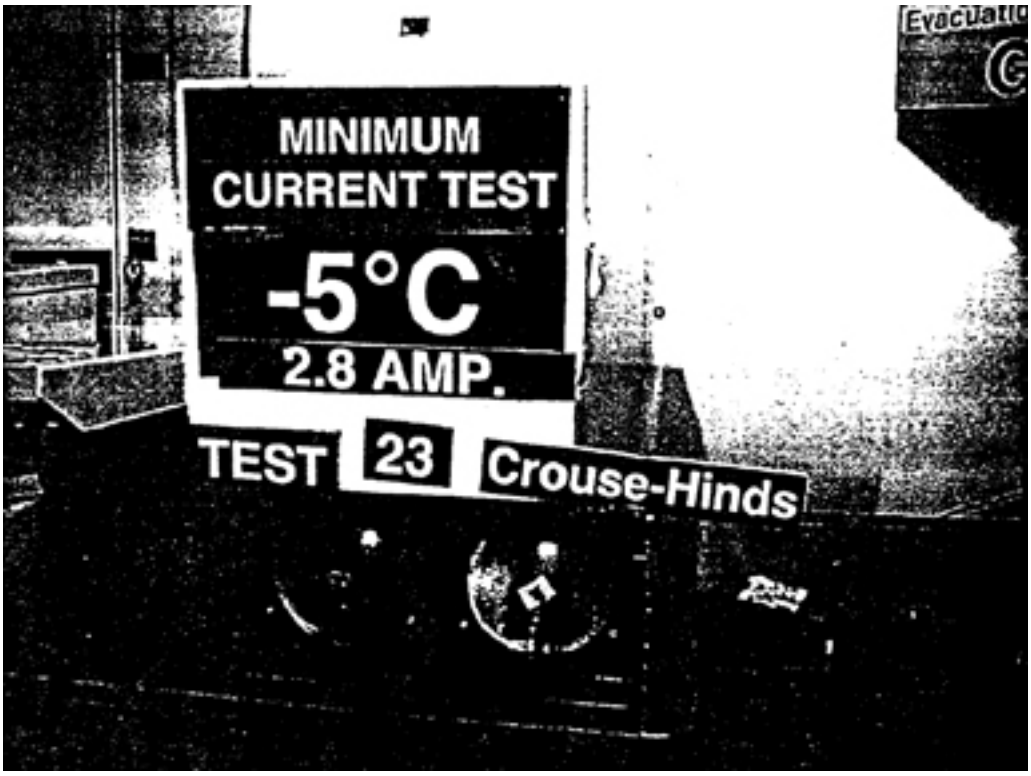


33. Test #22, pre-test.

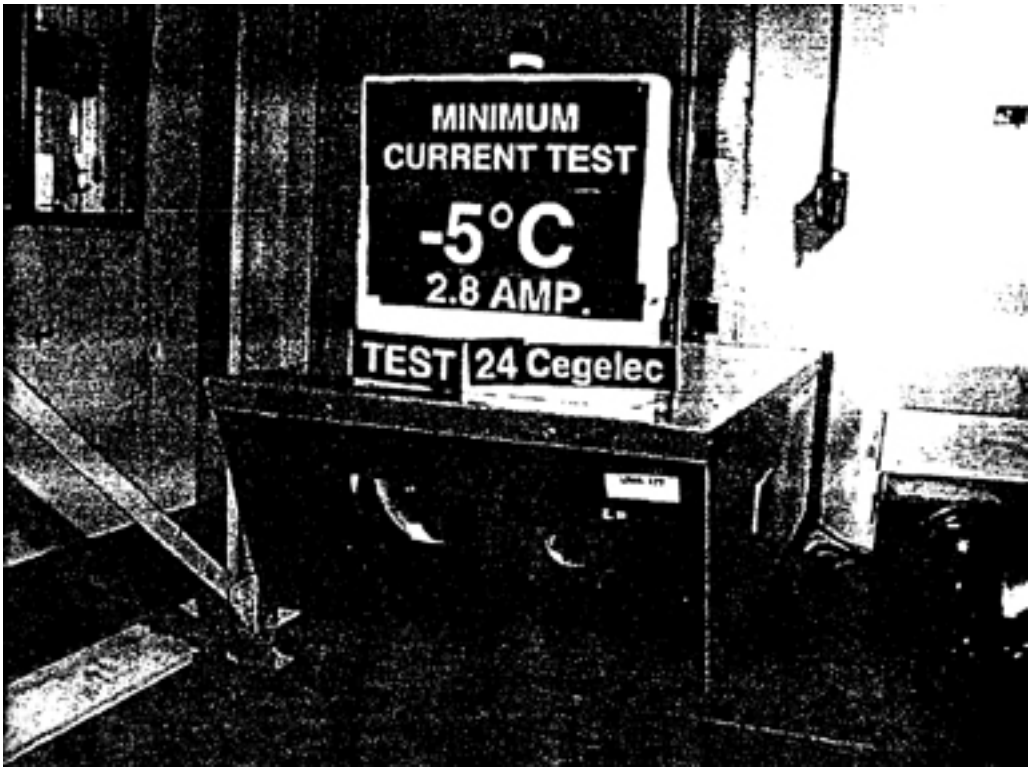
34. Test #22, post-test.



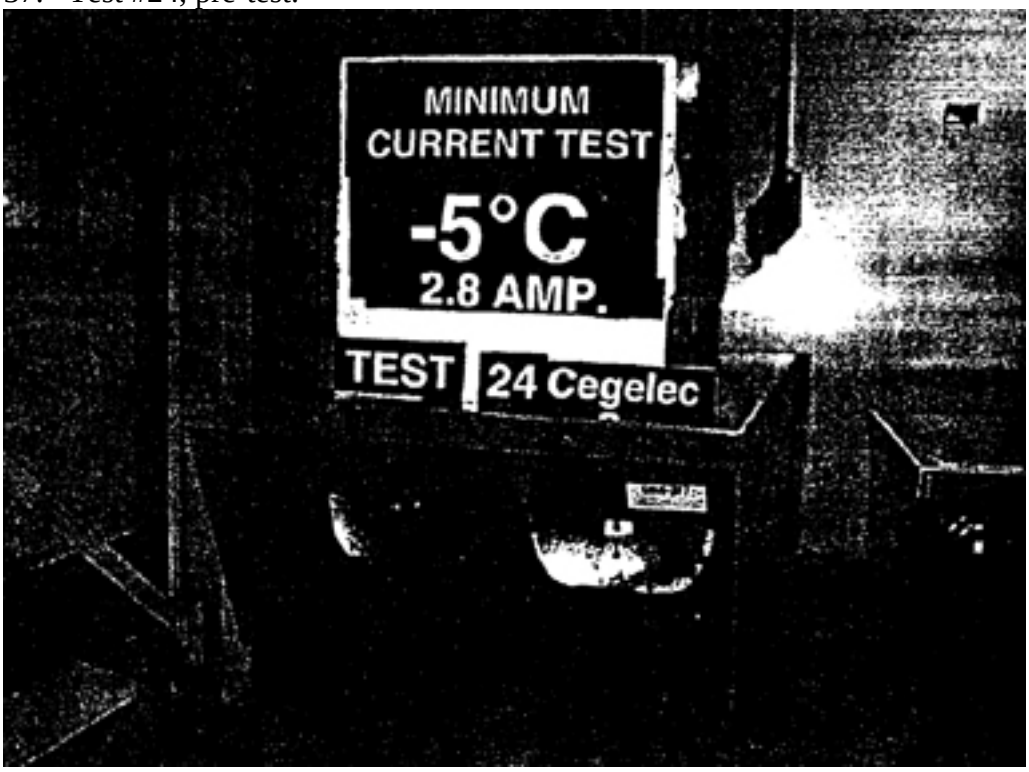
35. Test #23, pre-test.



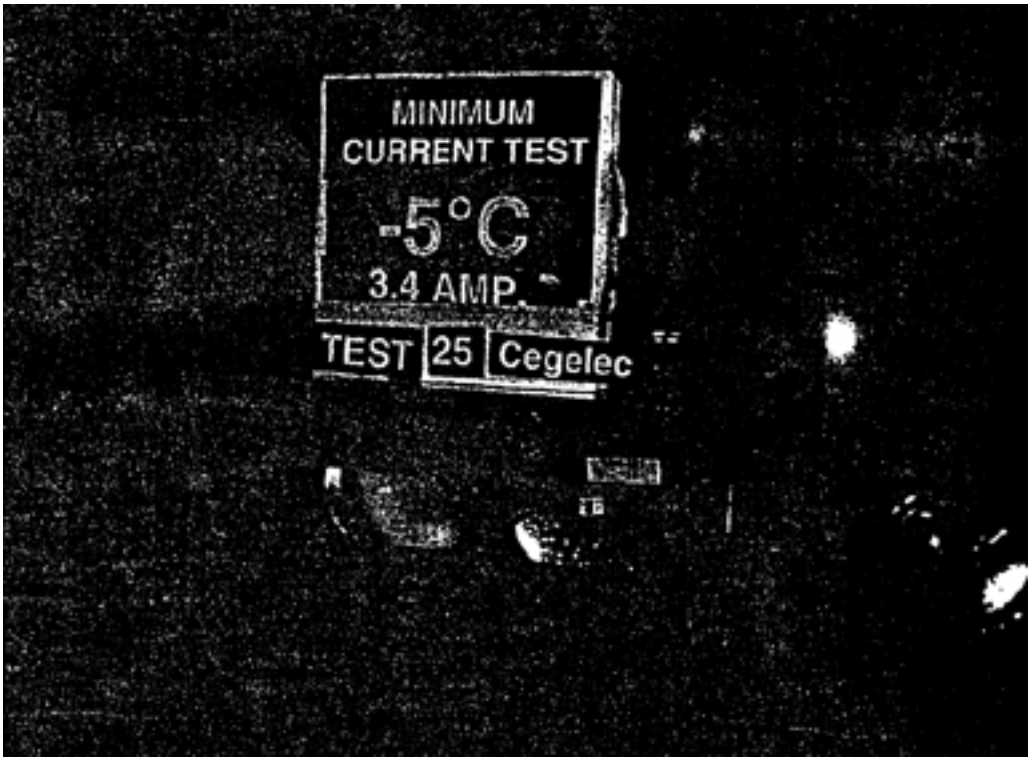
36. Test #23, post-test.



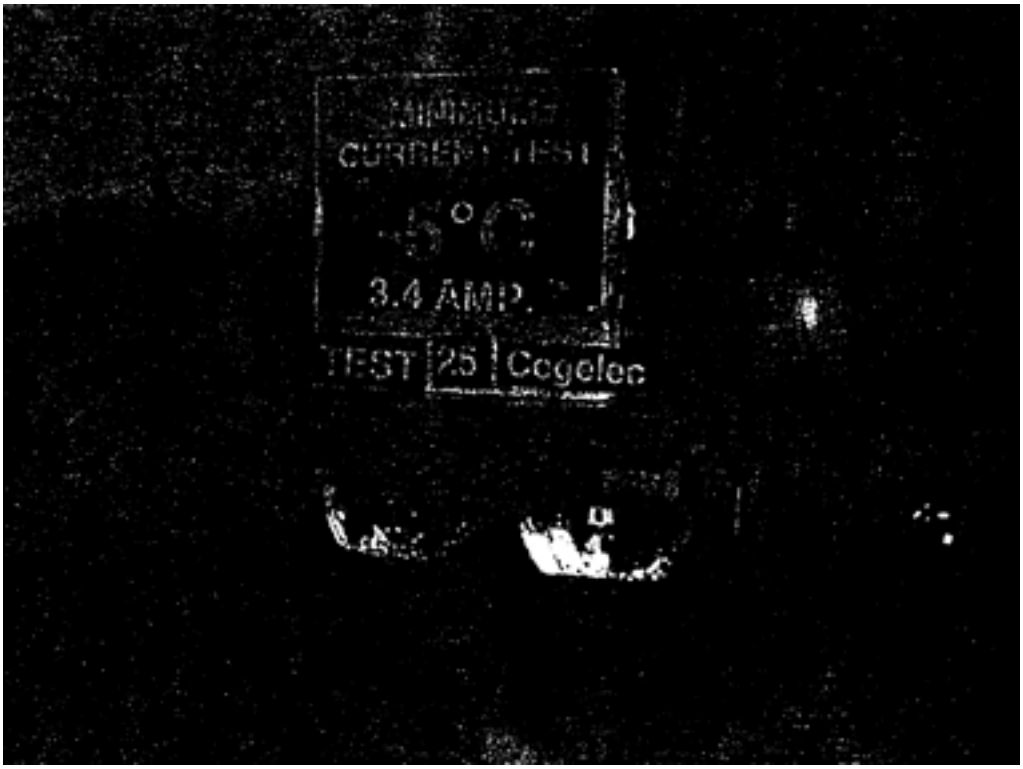
37. Test #24, pre-test.



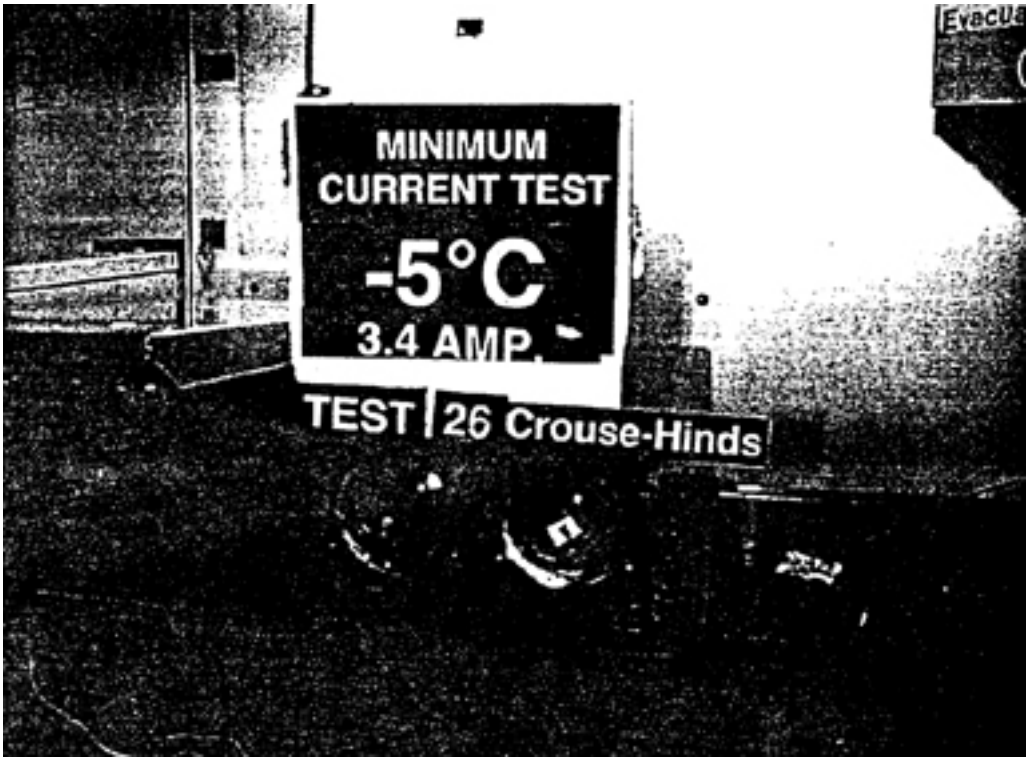
38. Test #24, post-test.



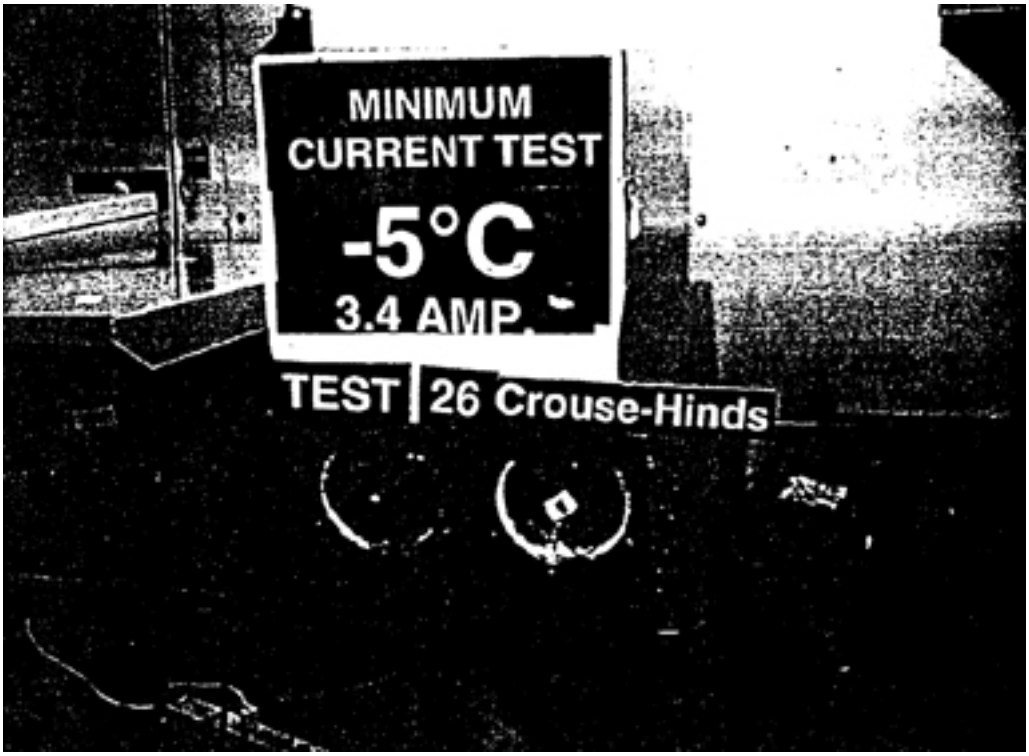
39. Test #25, pre-test.



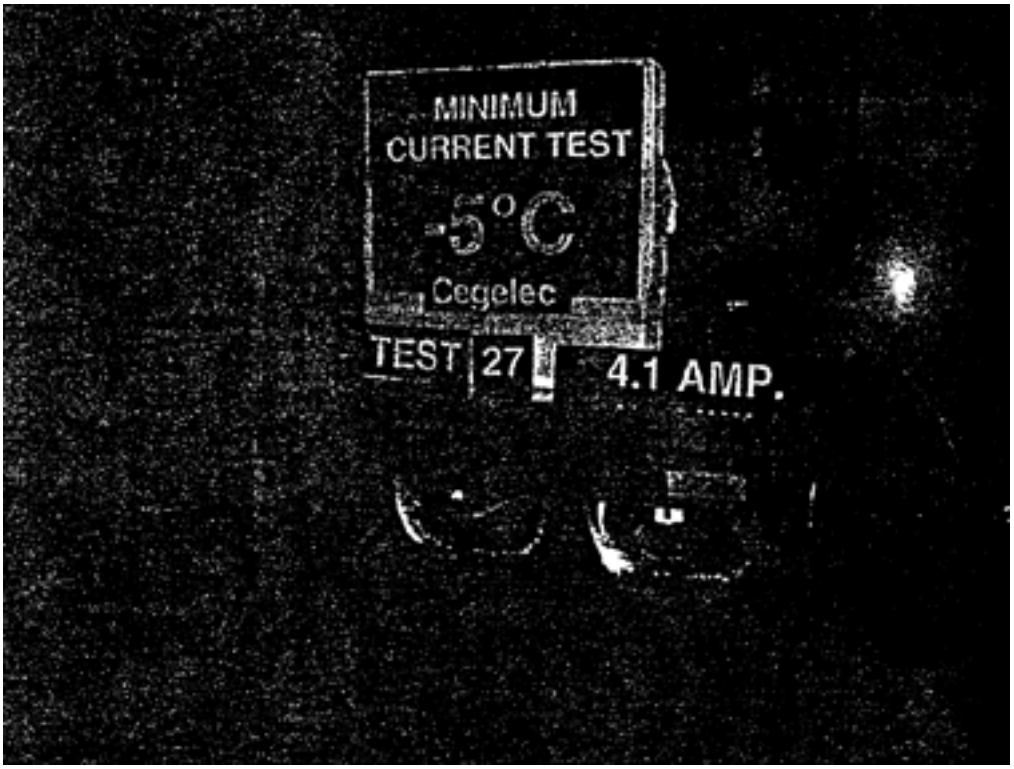
40. Test #25, post-test.



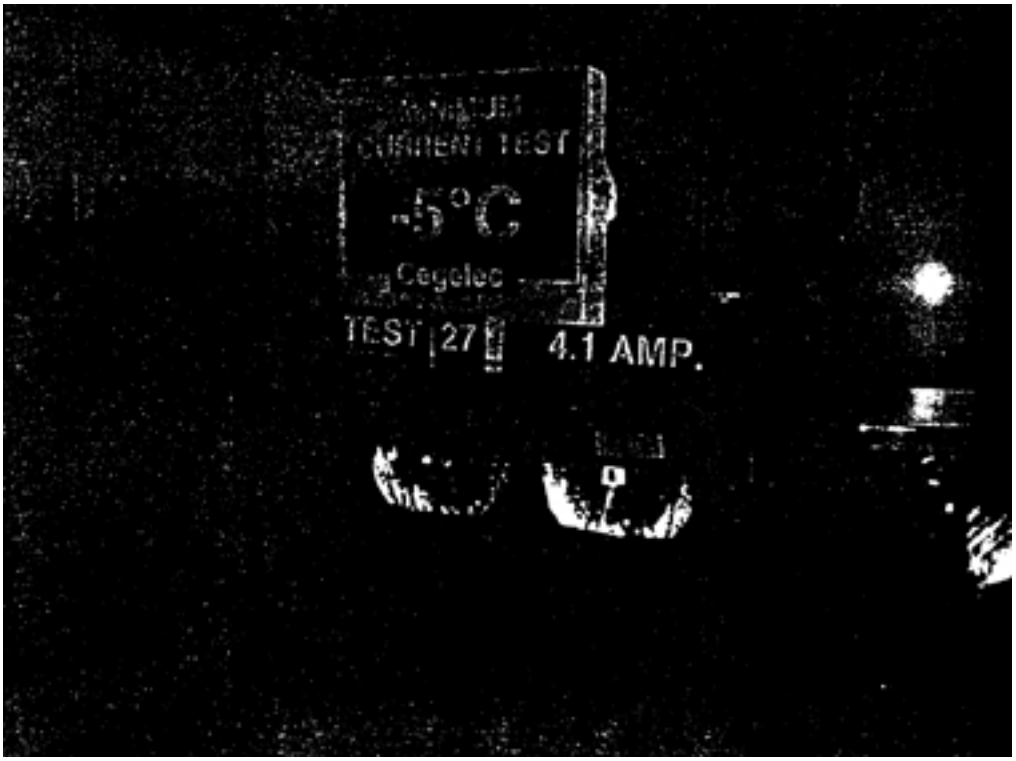
41. Test #26. post-test.



42. Test #26, post-test.



43. Test #27, pre-test.

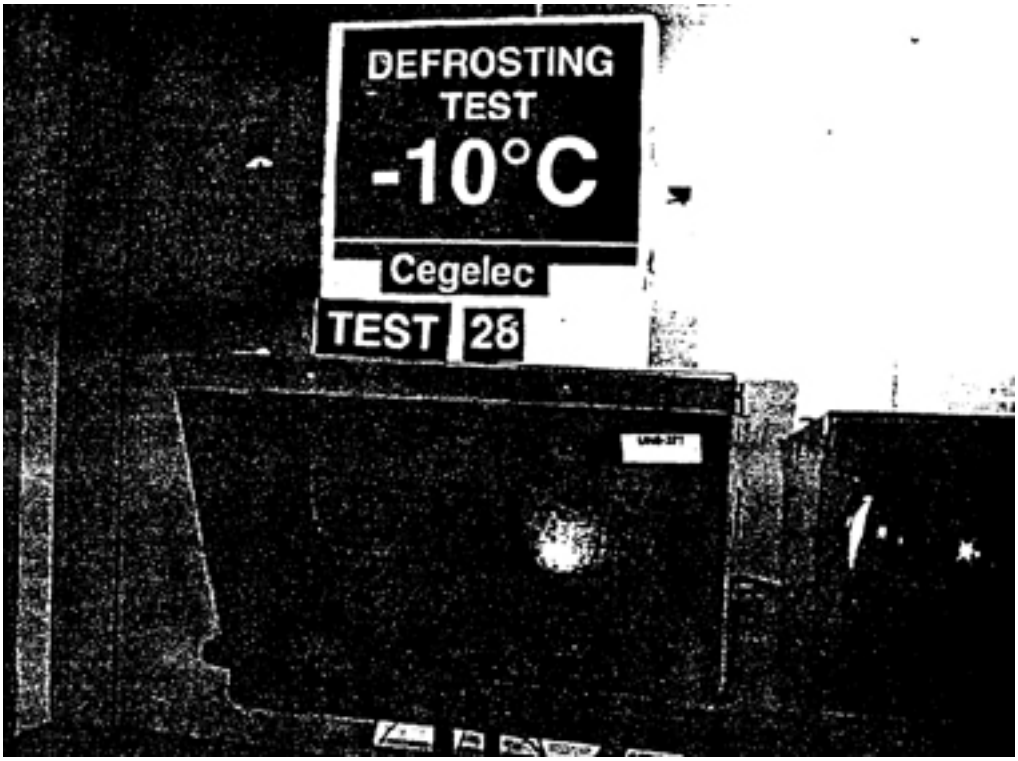


44. Test #27, post-test.

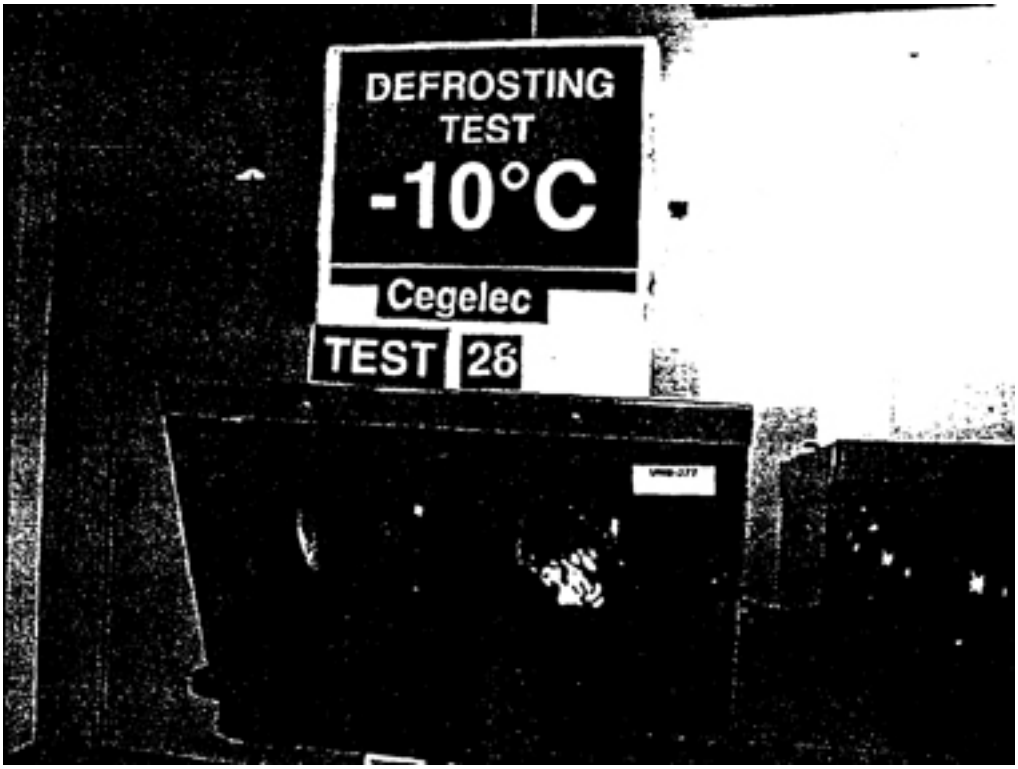
APPENDIX C

TEST PHOTOGRAPHS

Intentionally left blank



1. Test #28, pre-test.

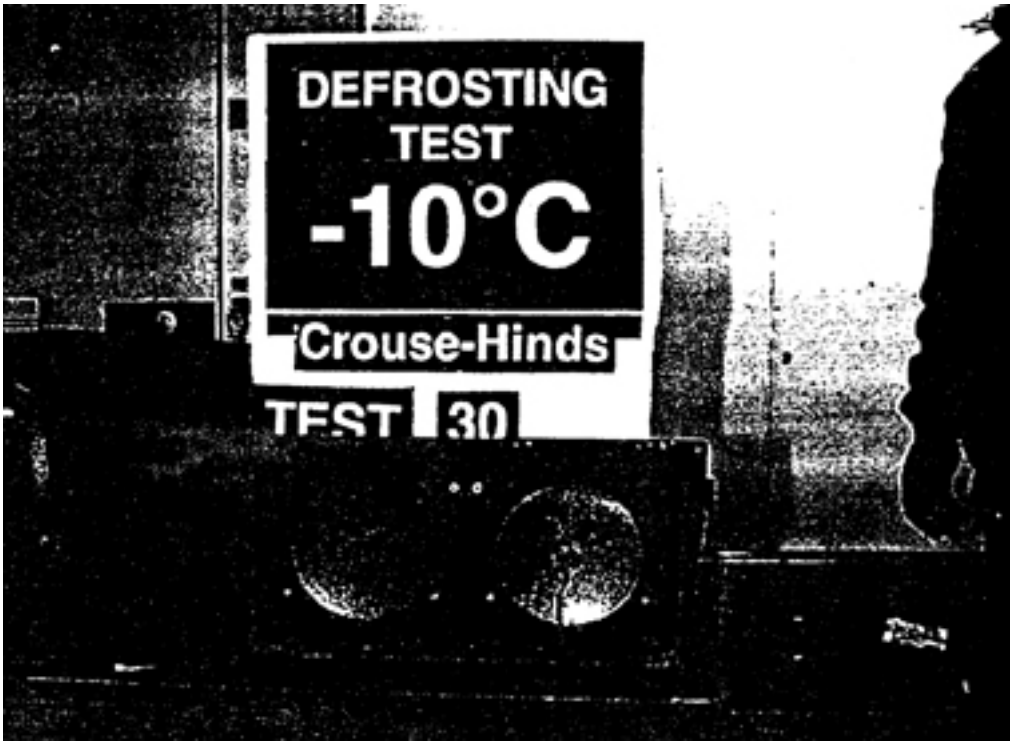


2. Test #28, post-test.

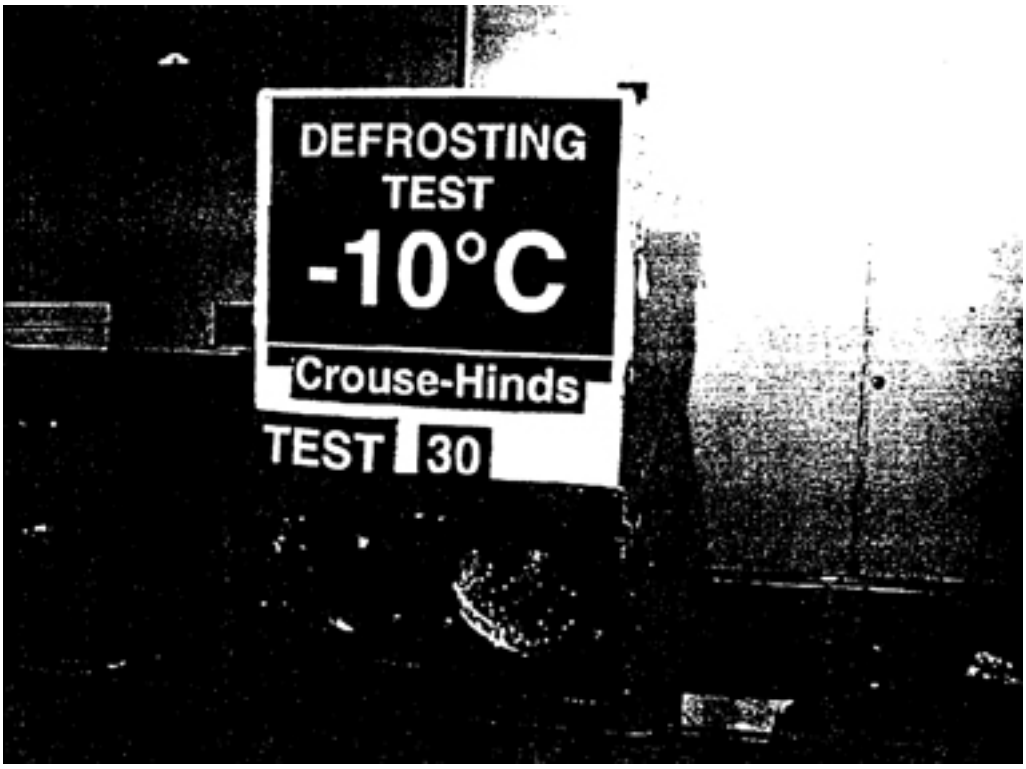
N/A

3. Test #29, pre-test.

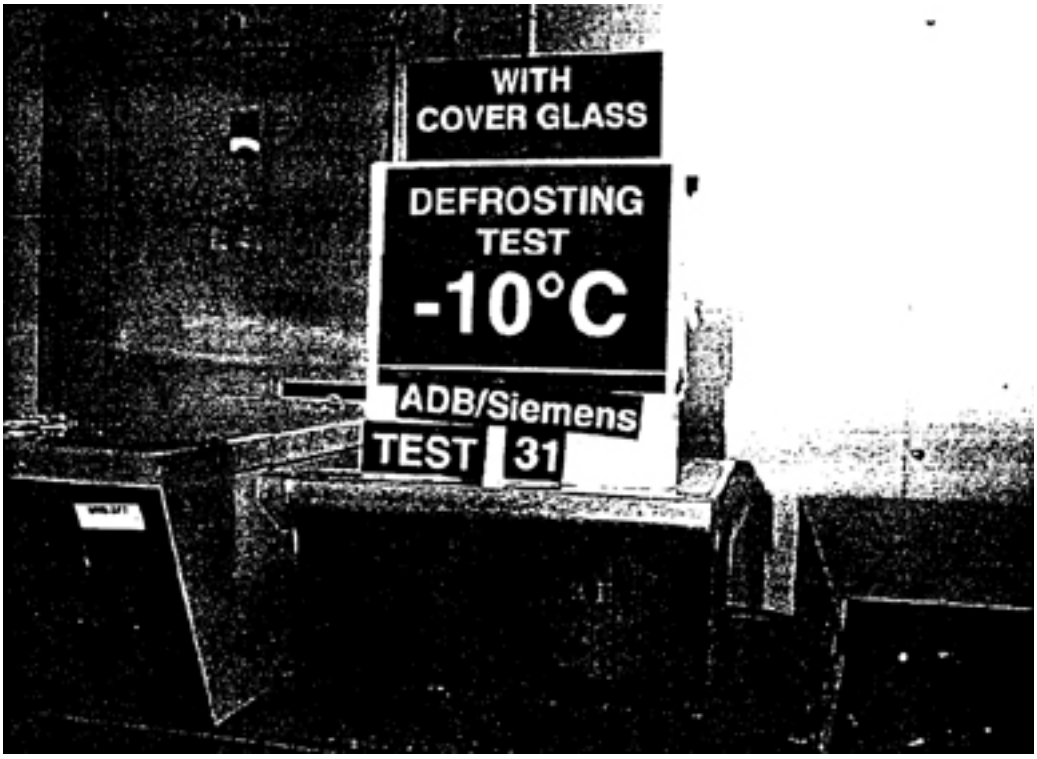
4. Test #29, post-test.



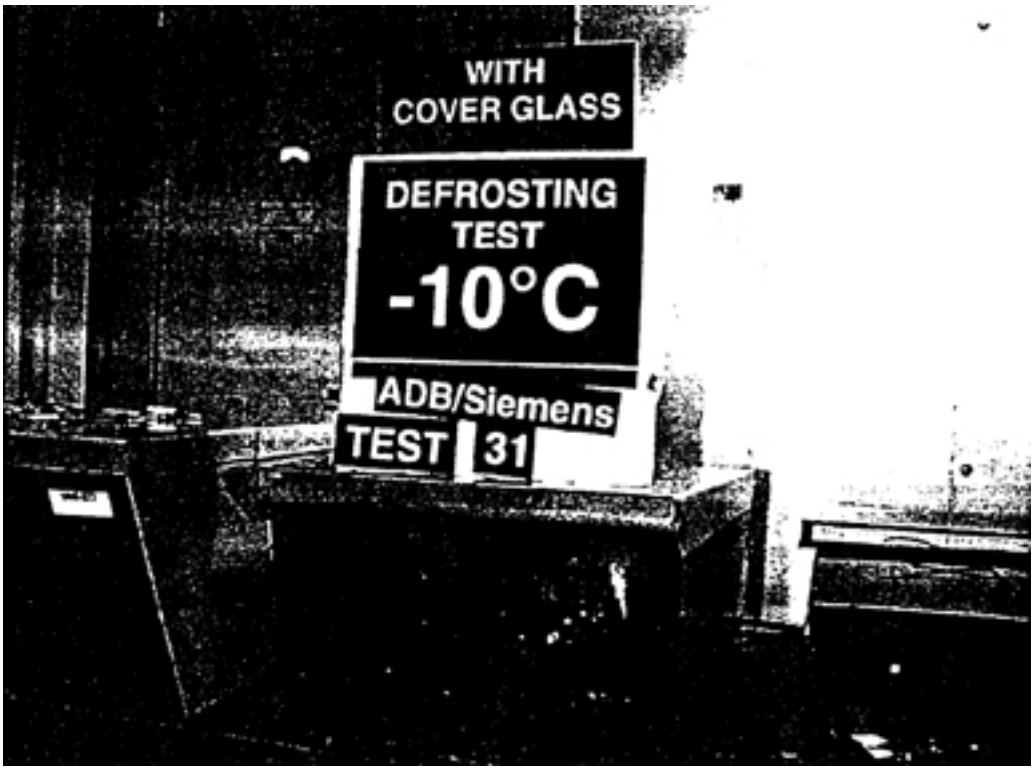
5. Test #30, pre-test.



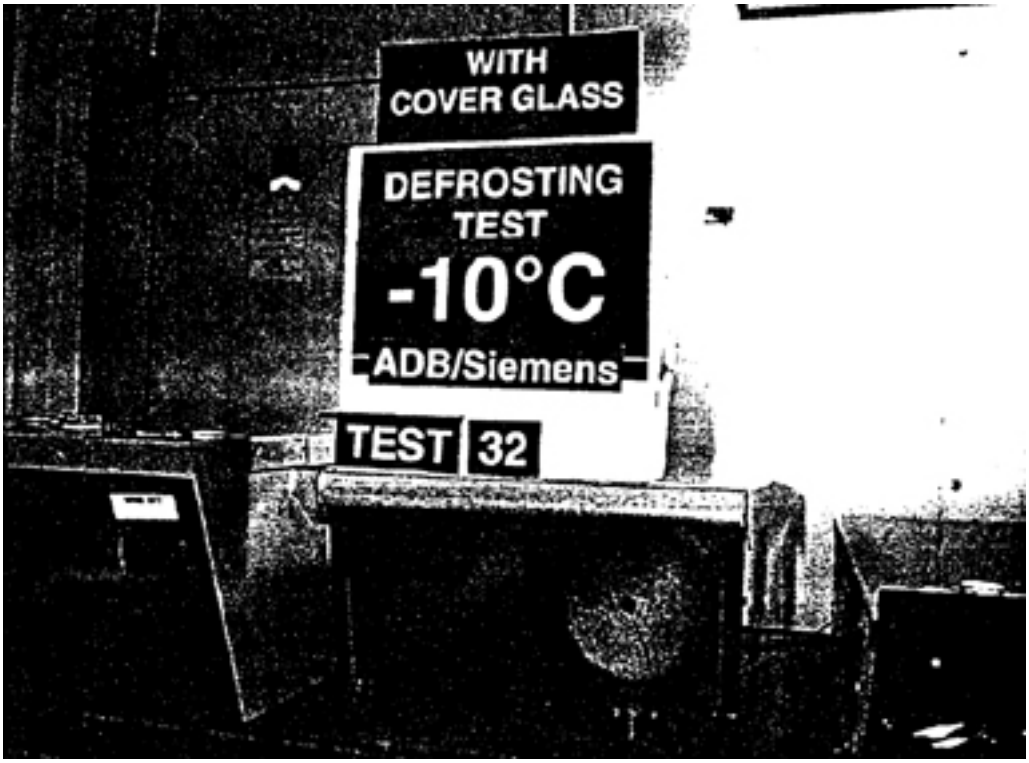
6. Test #30, post-test.



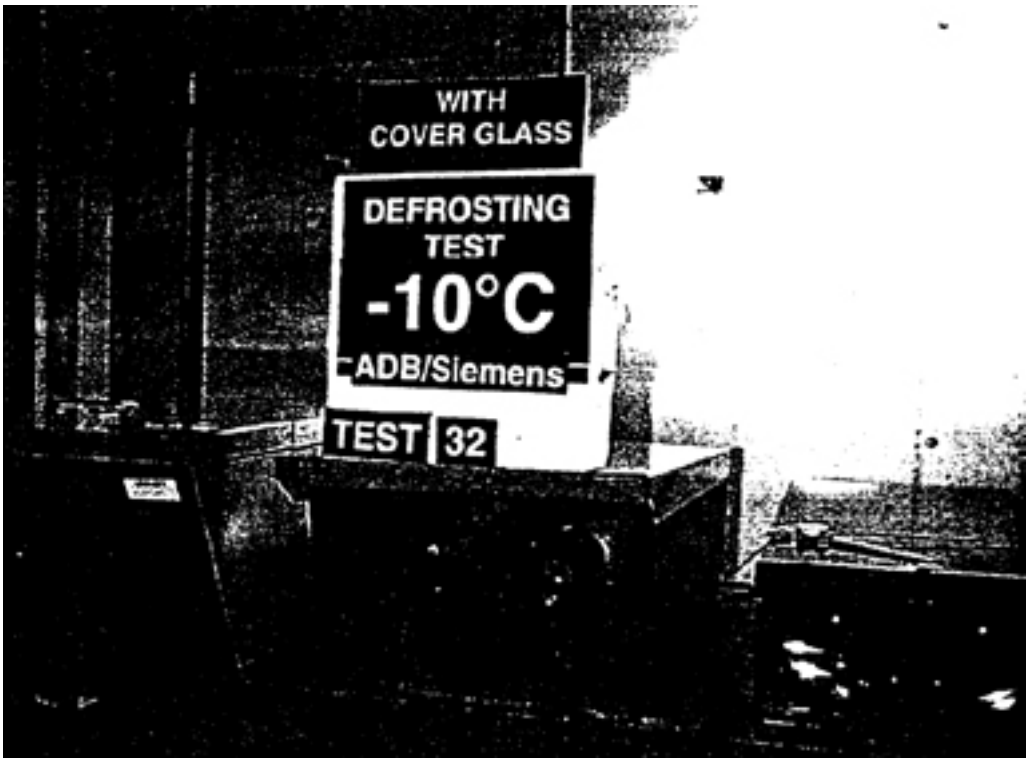
7. Test #31, pre-test.



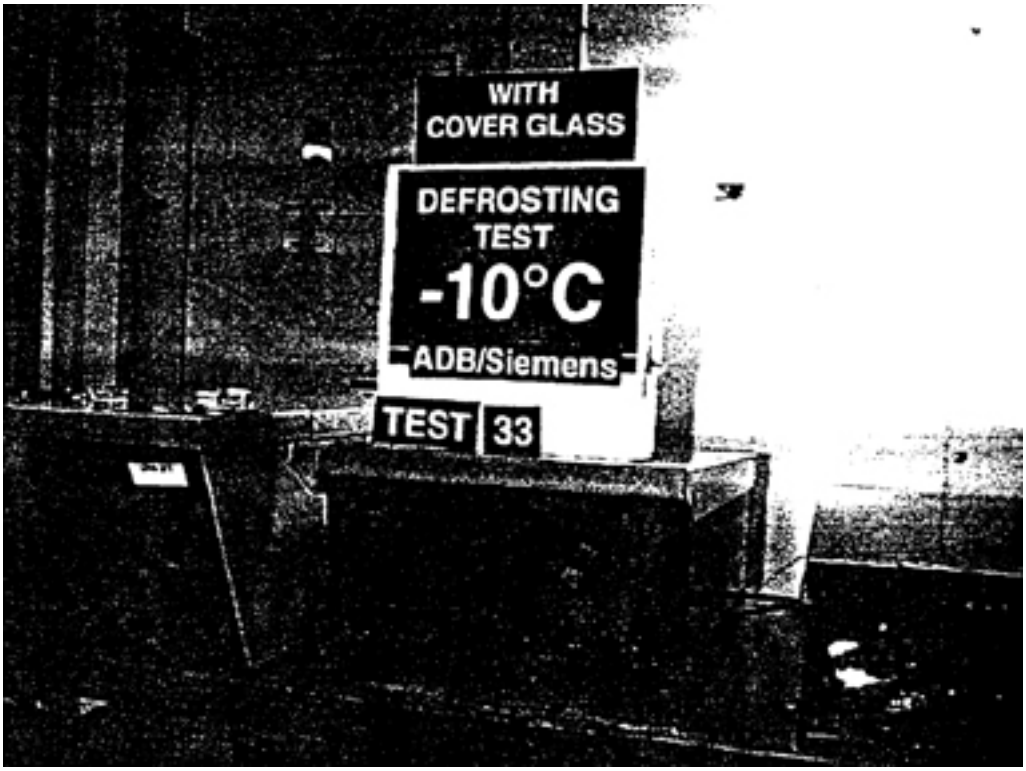
8. Test #31, post-test.



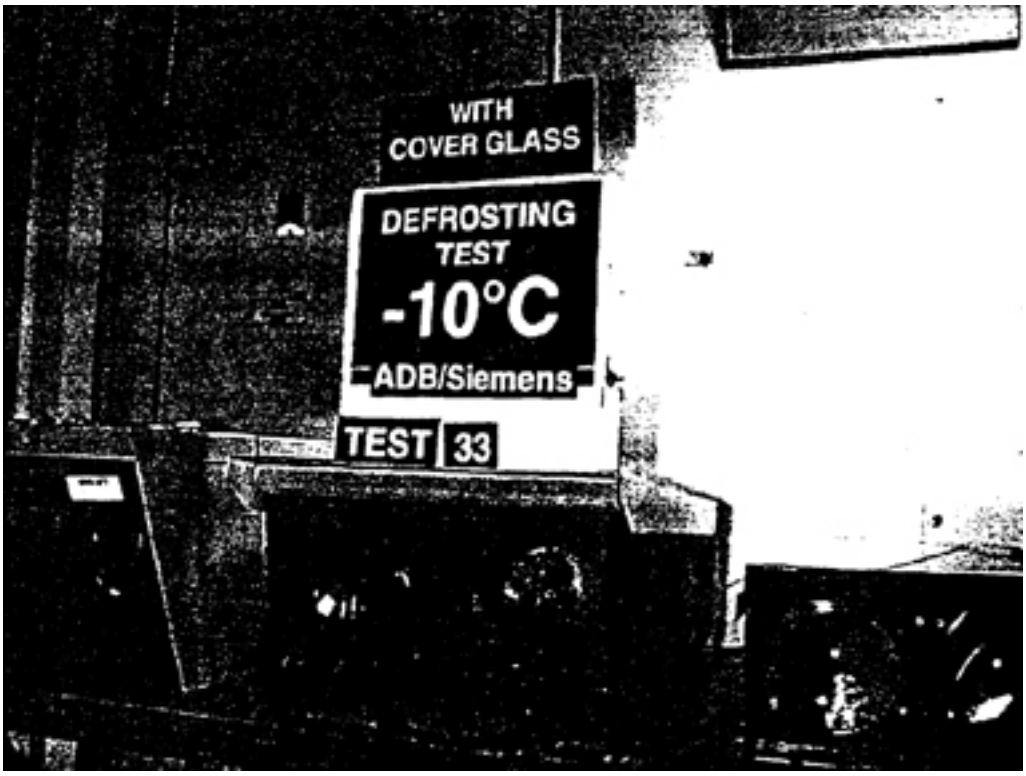
9. Test #32, pre-test.



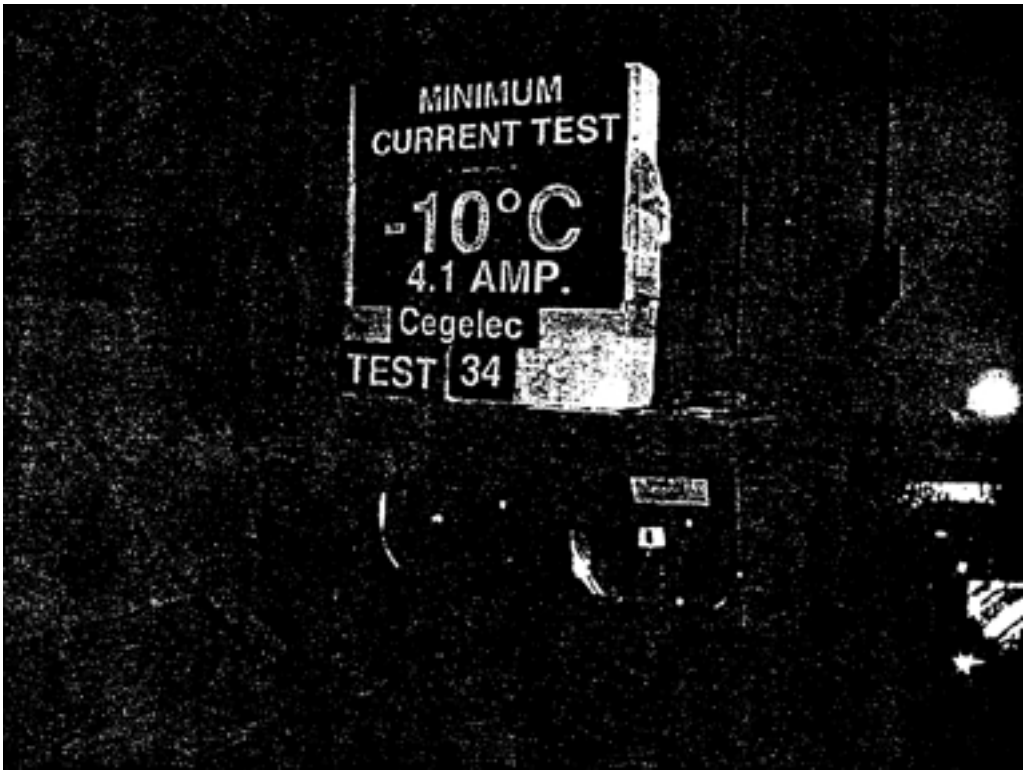
10. Test #32, post-test.



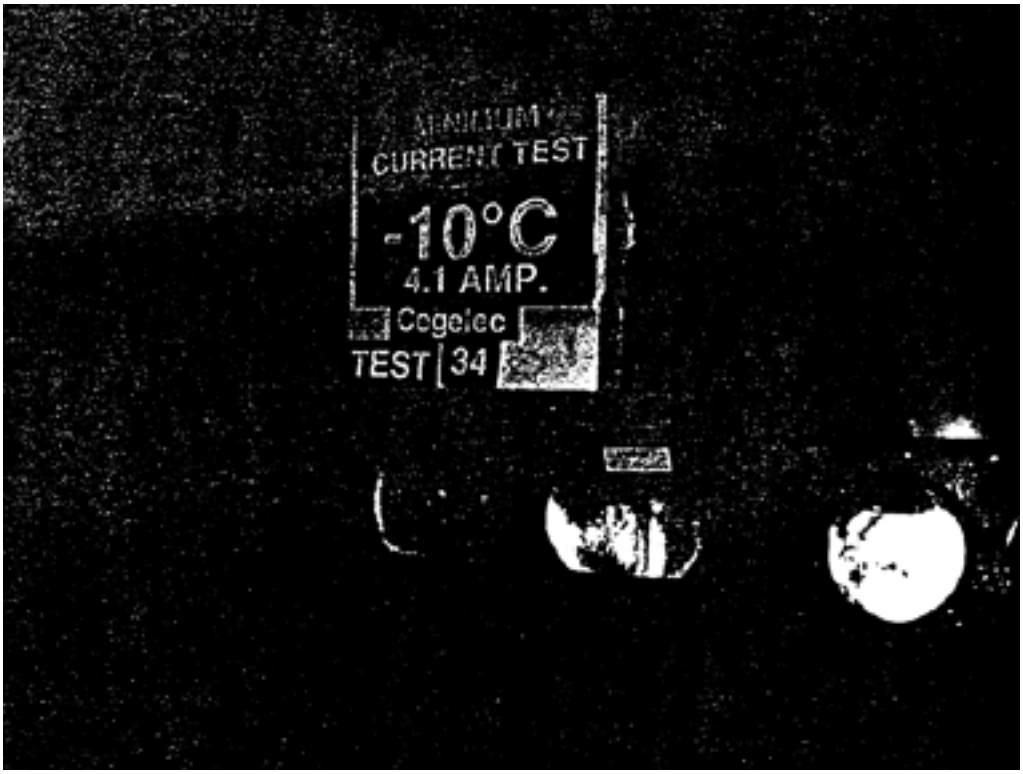
11. Test #33, pre-test.



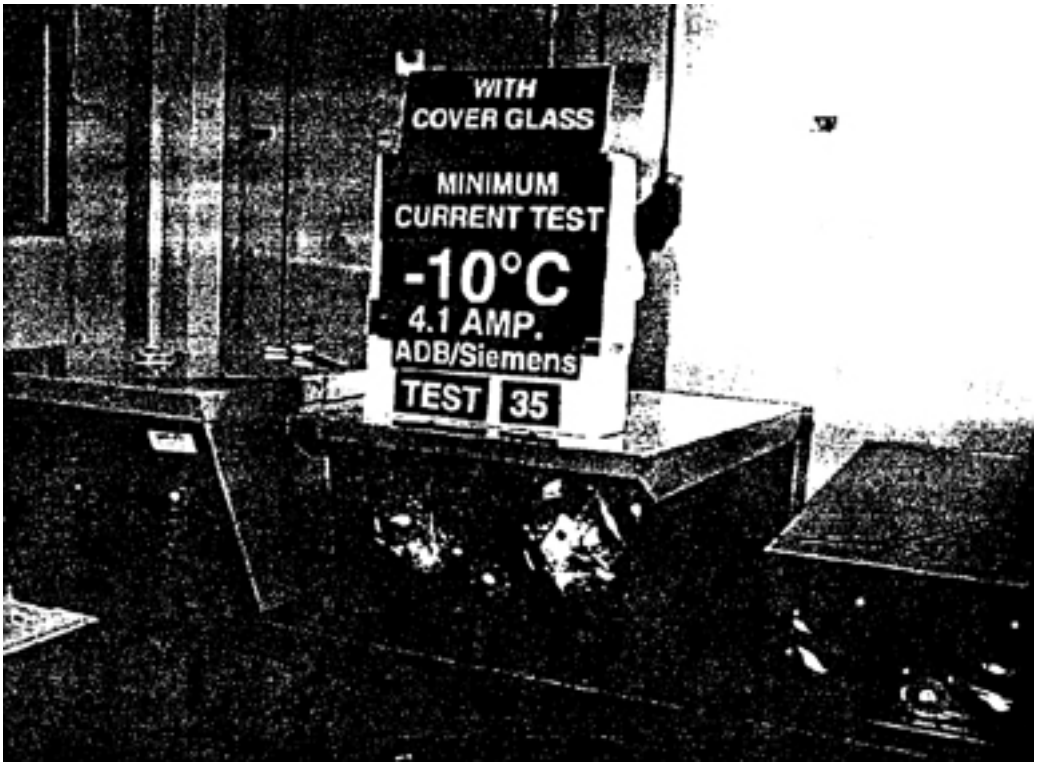
12. Test #33, post-test.



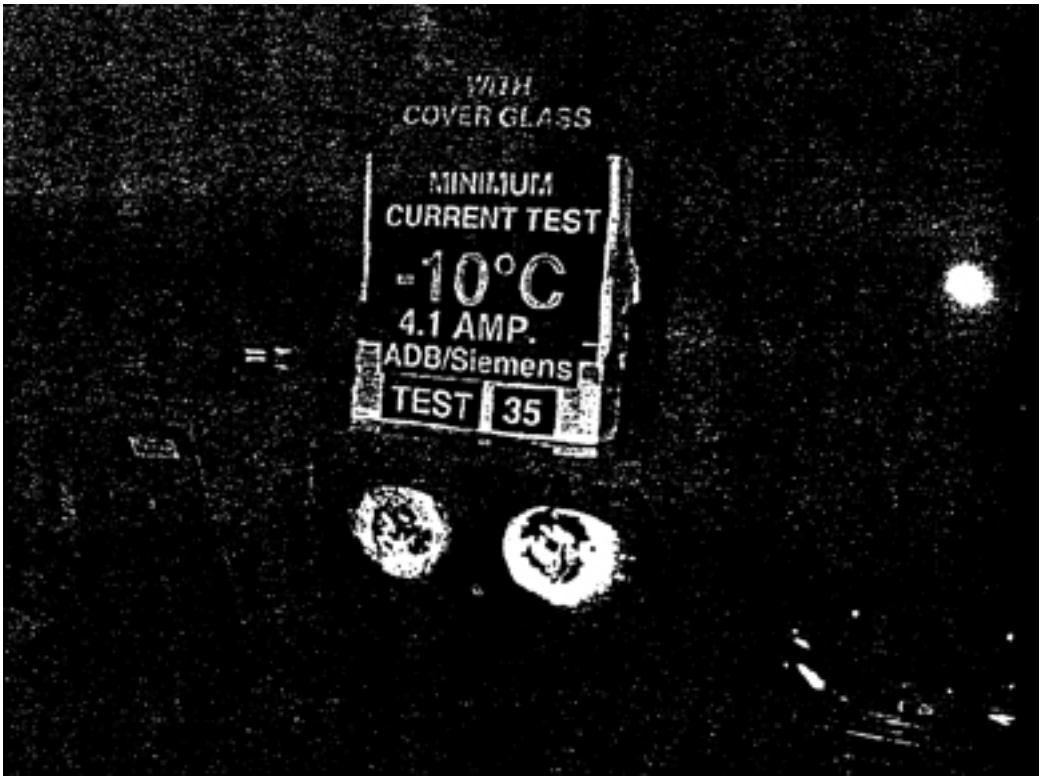
13. Test #34, pre-test.



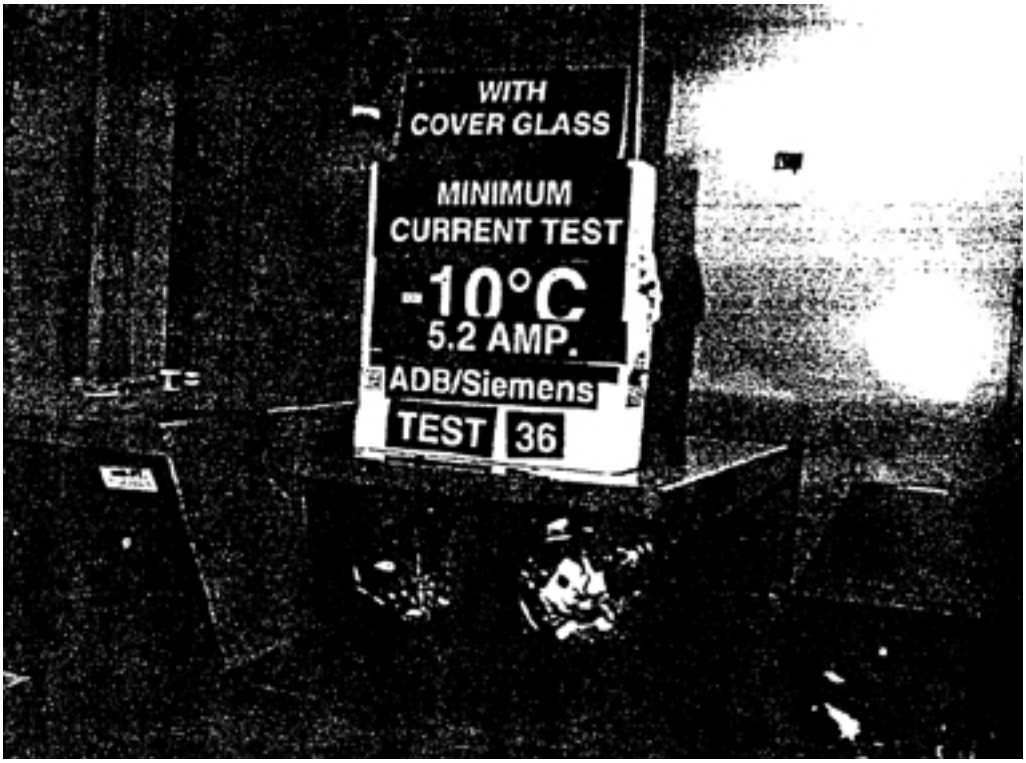
14. Test #34, post-test.



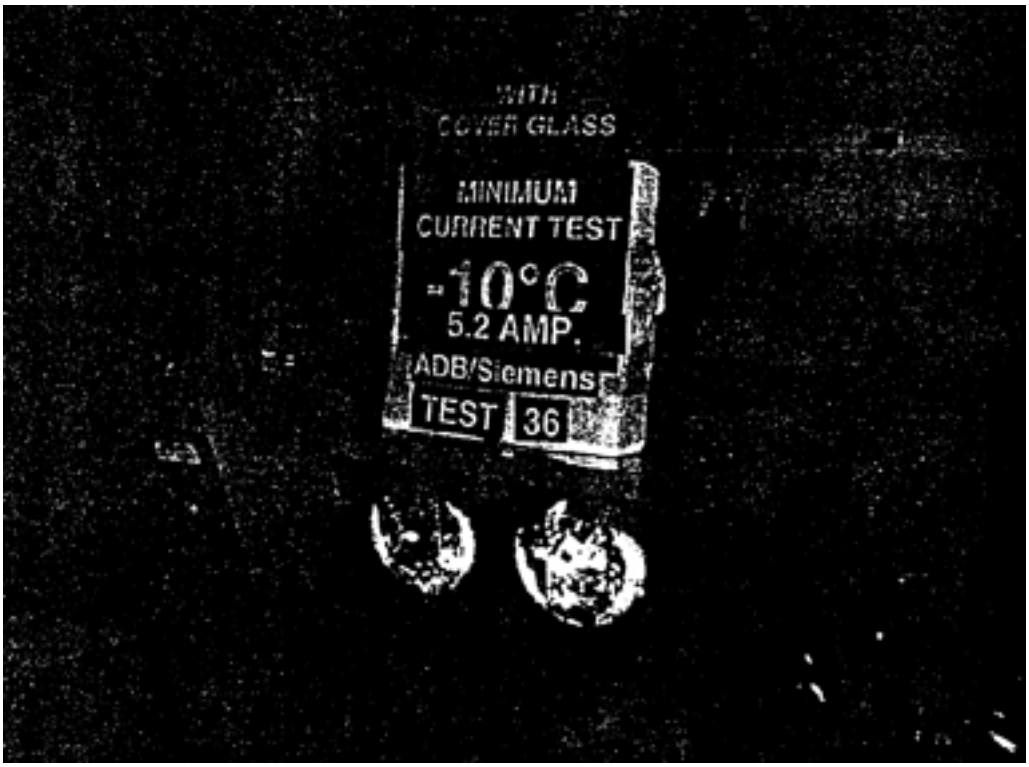
15. Test #35, pre-test.



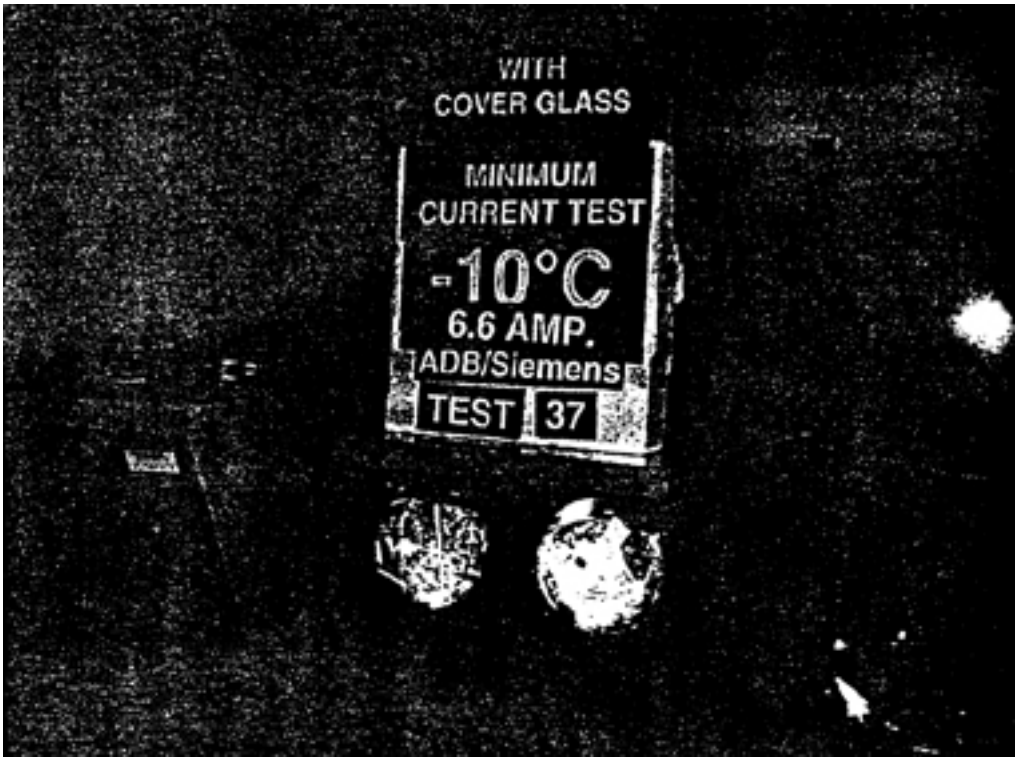
16. Test #35, post-test.



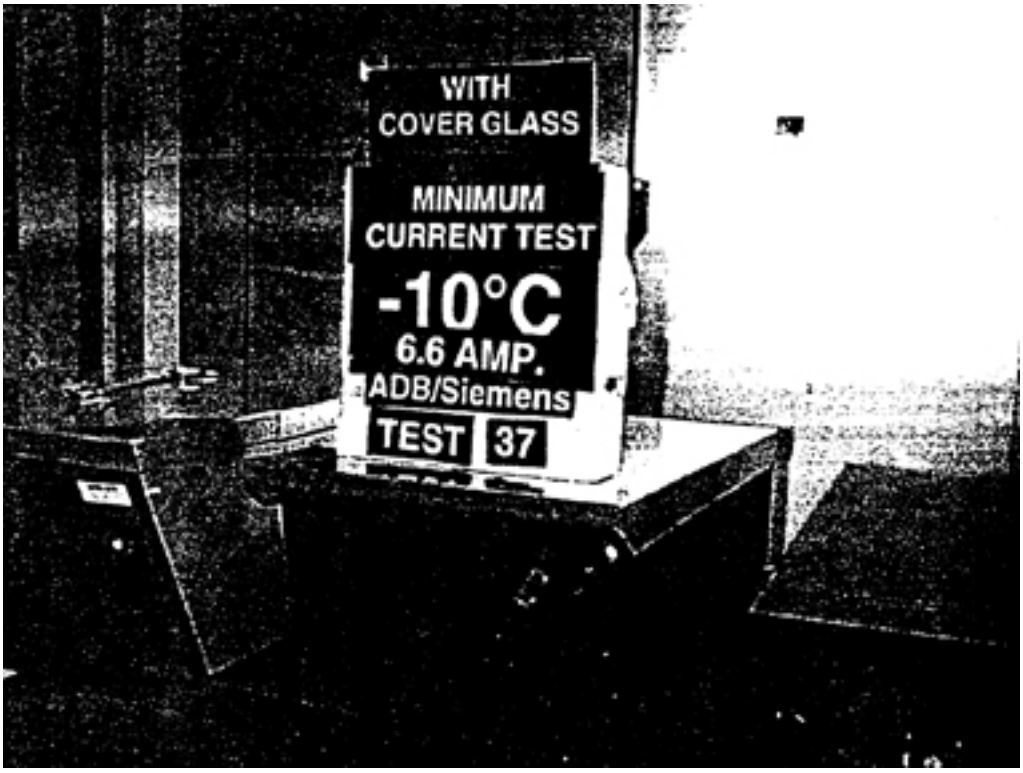
17. Test #36, pre-test.



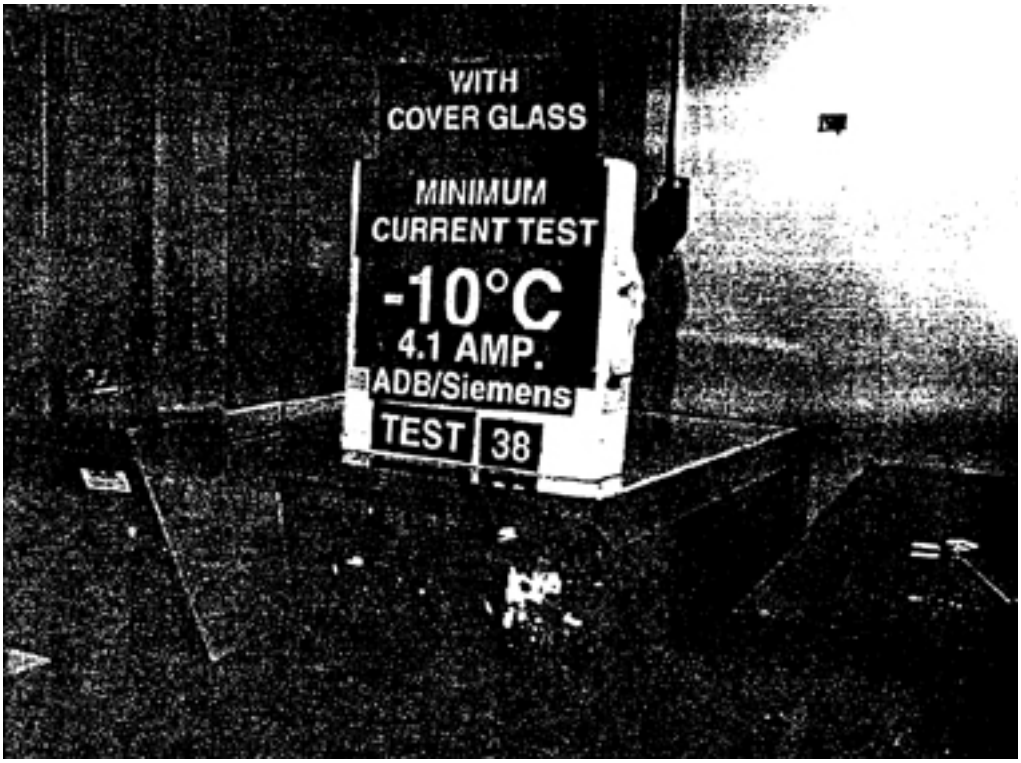
18. Test #36, post-test.



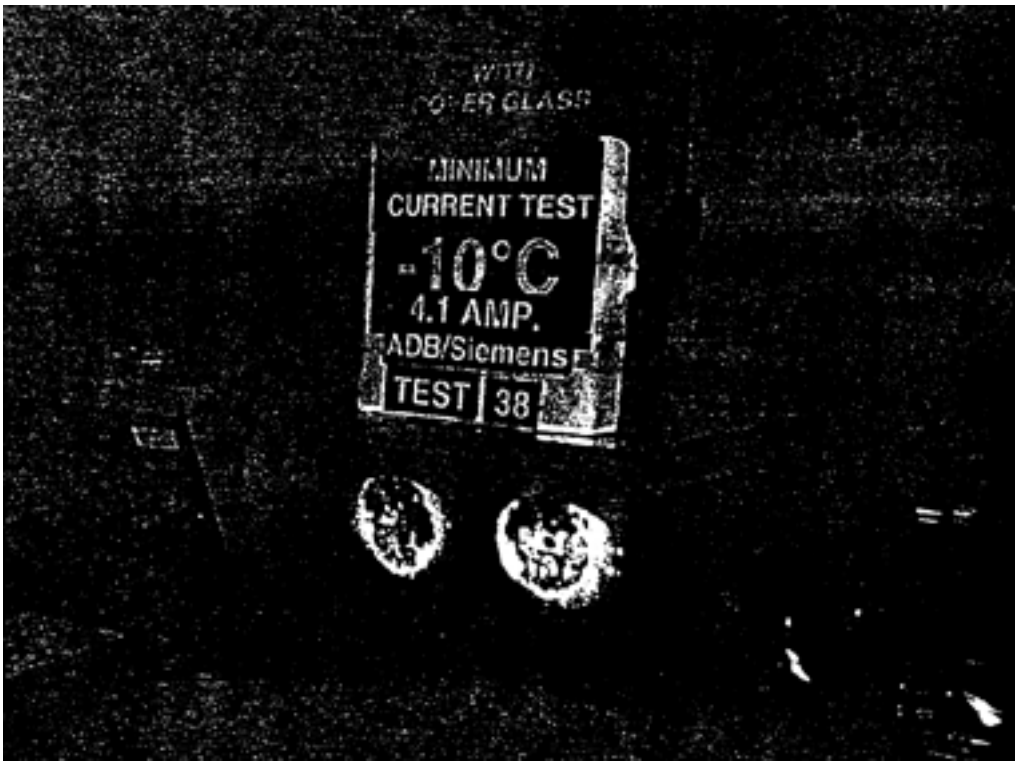
19. Test #37, pre-test.



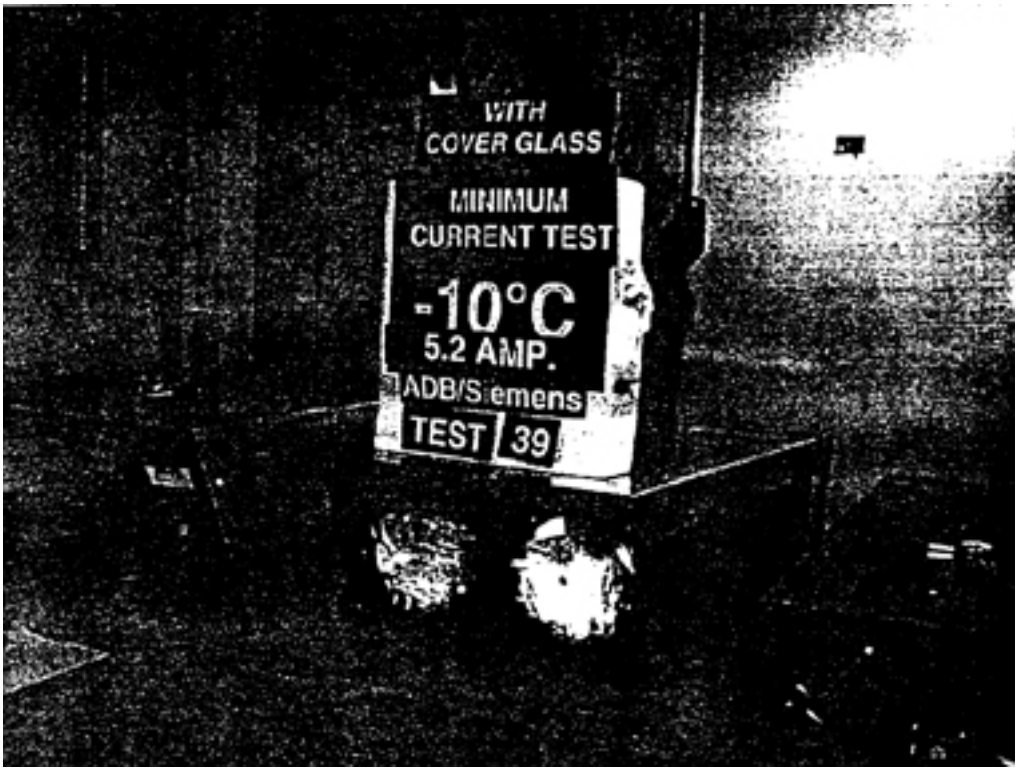
20. Test #37, post-test.



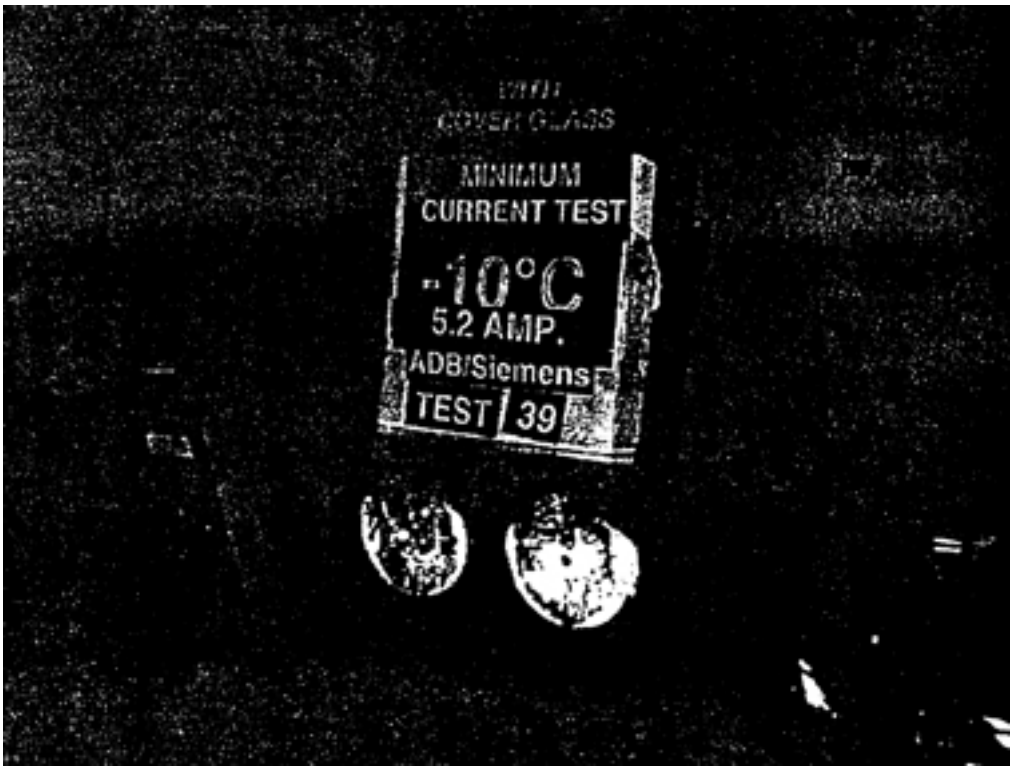
21. Test #38, pre-test.



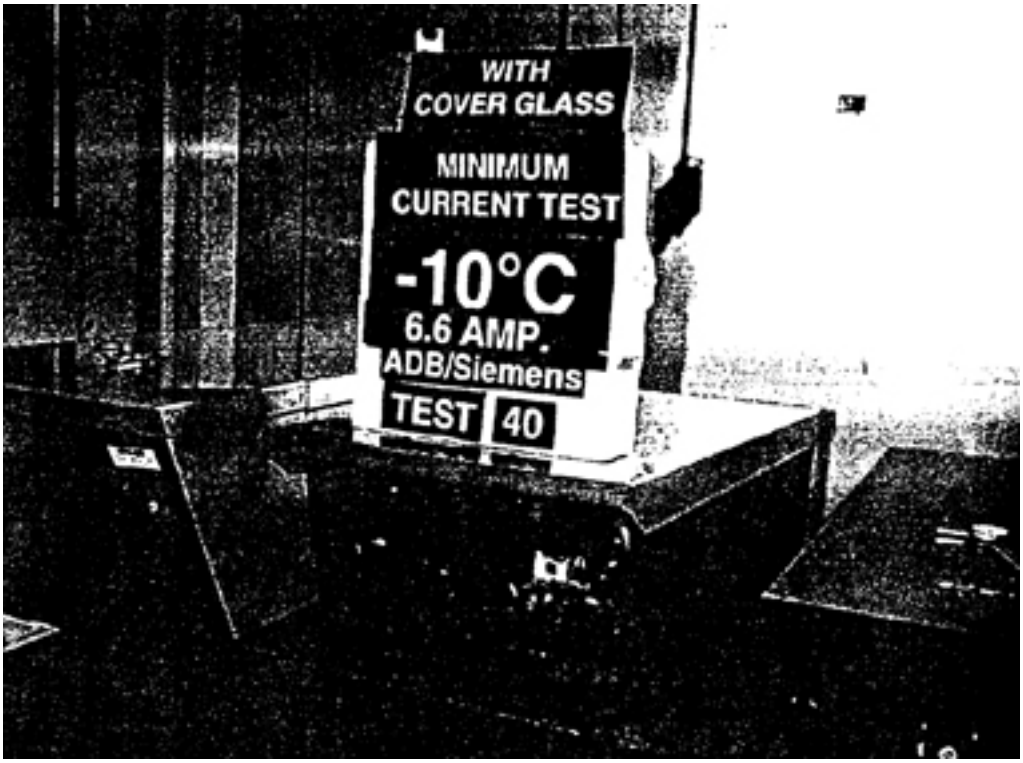
22. Test #38, post-test.



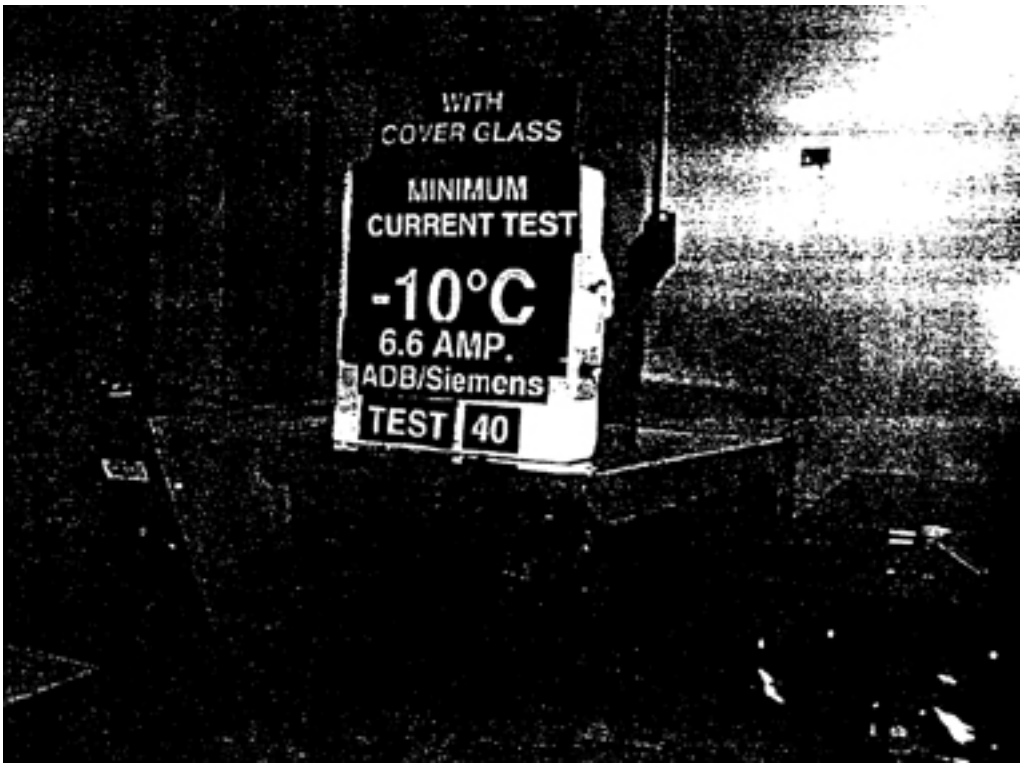
23. Test #39, pre-test.



24. Test #39, post-test.



25. Test #40, pre-test.



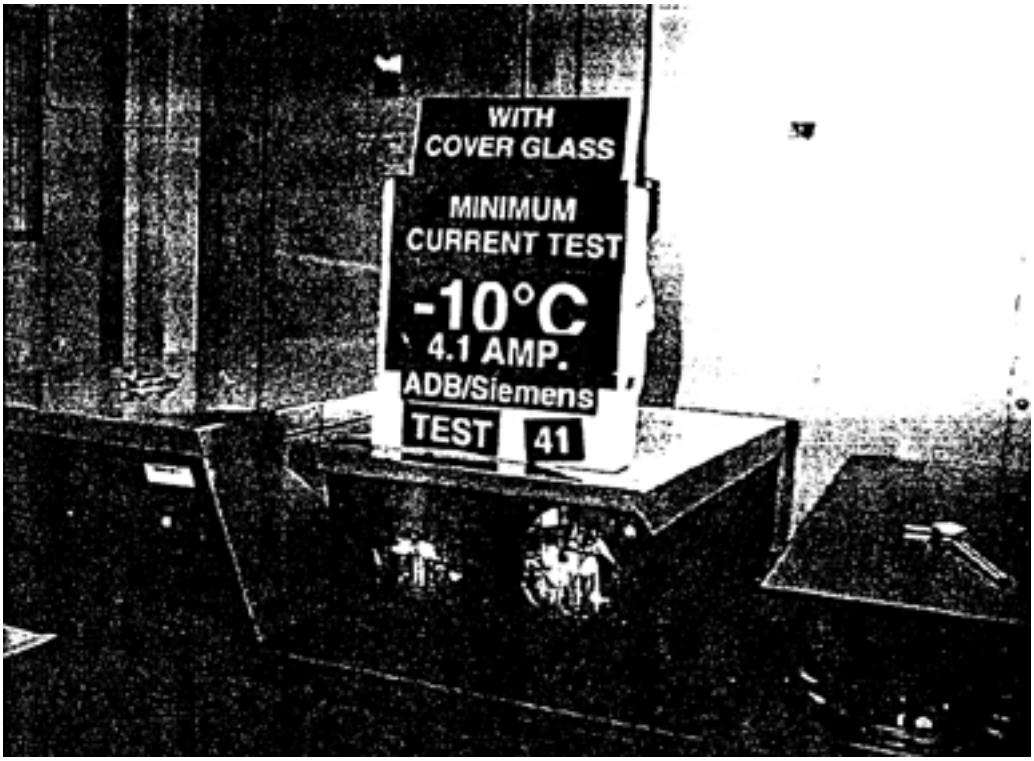
26. Test #40, post-test.

Intentionally left blank

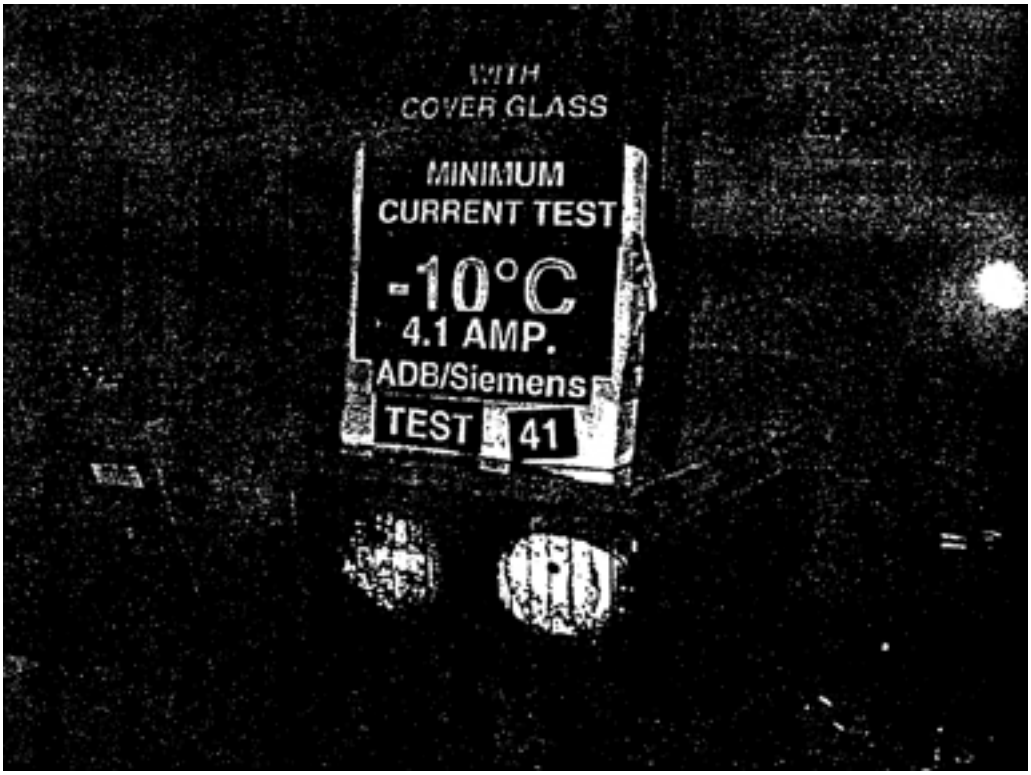
APPENDIX D

TEST PHOTOGRAPHS

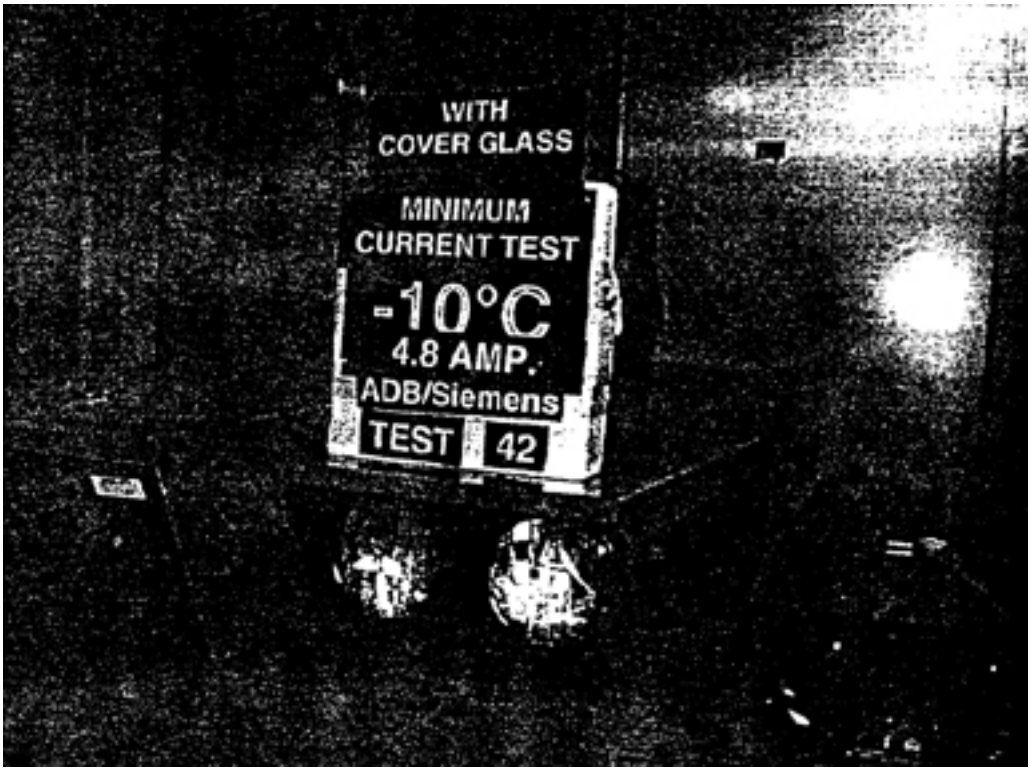
Intentionally left blank



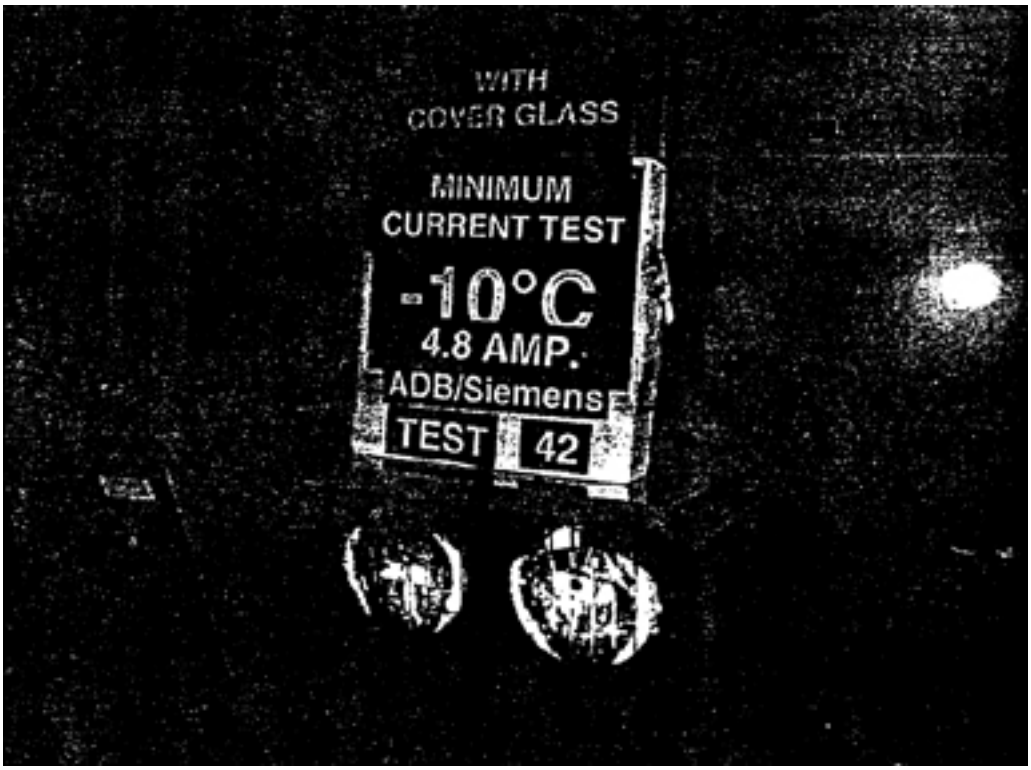
1. Test #41, pre-test.



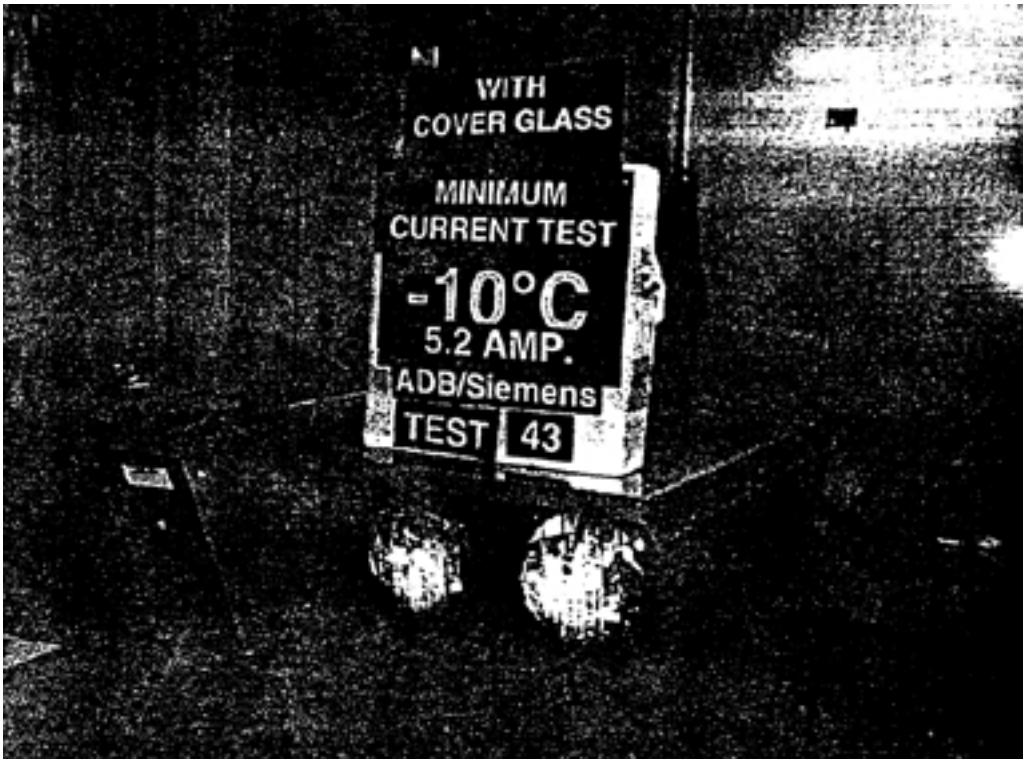
2. Test #41, post-test.



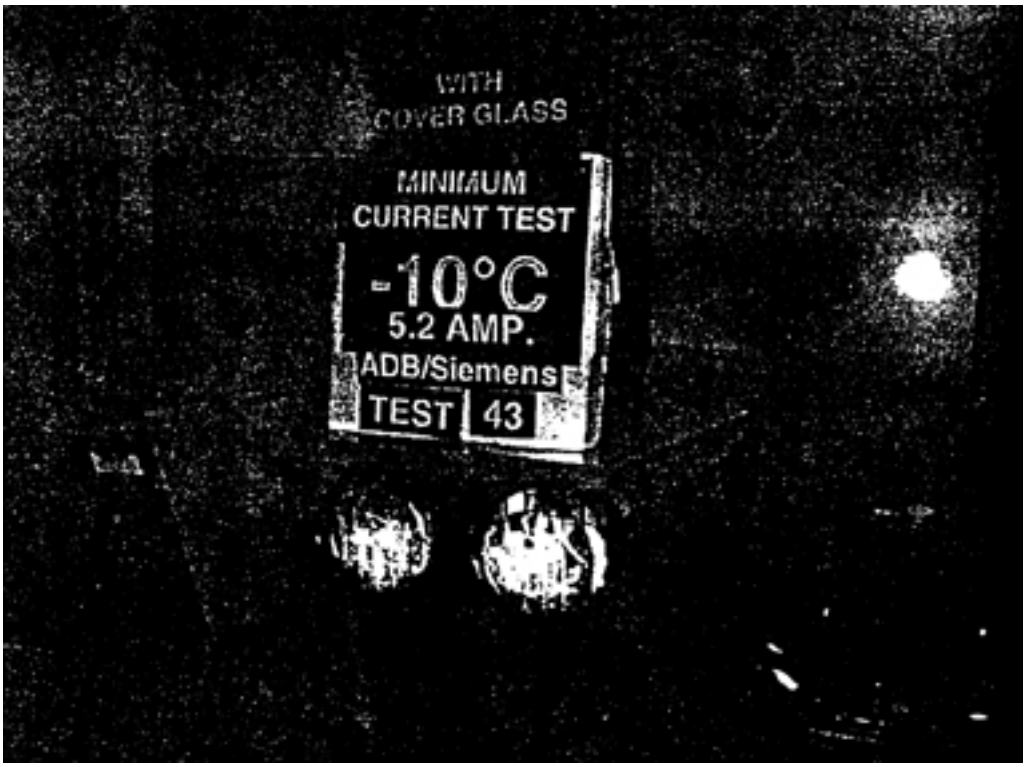
3. Test #42, pre-test.



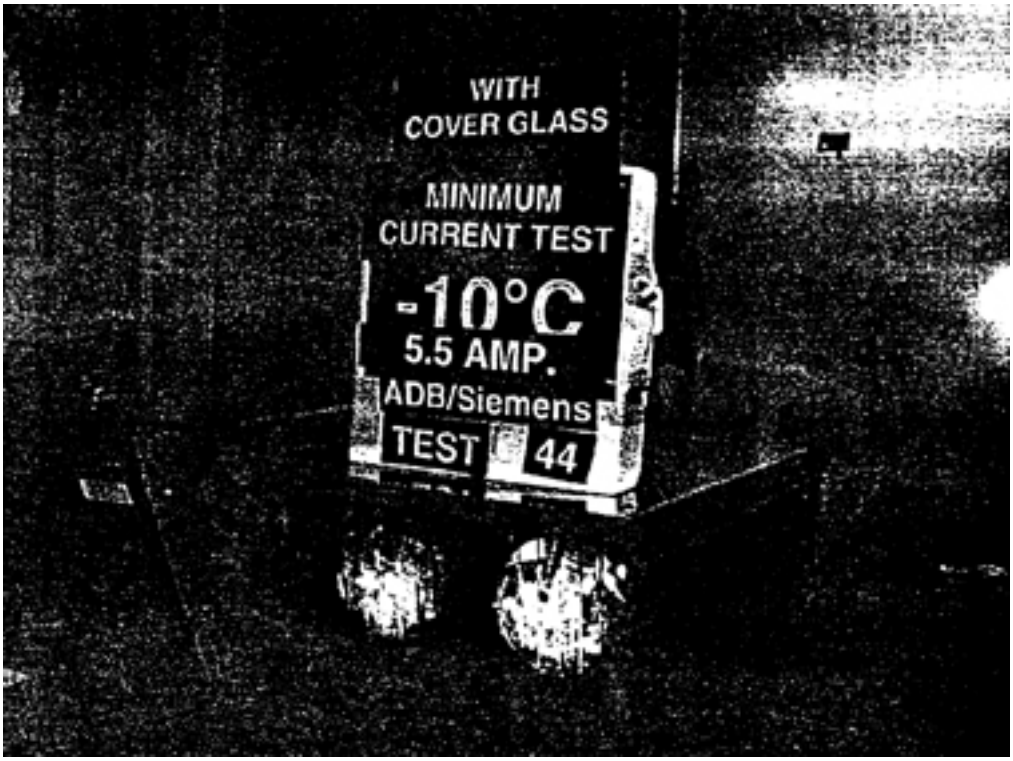
4. Test #42, post-test.



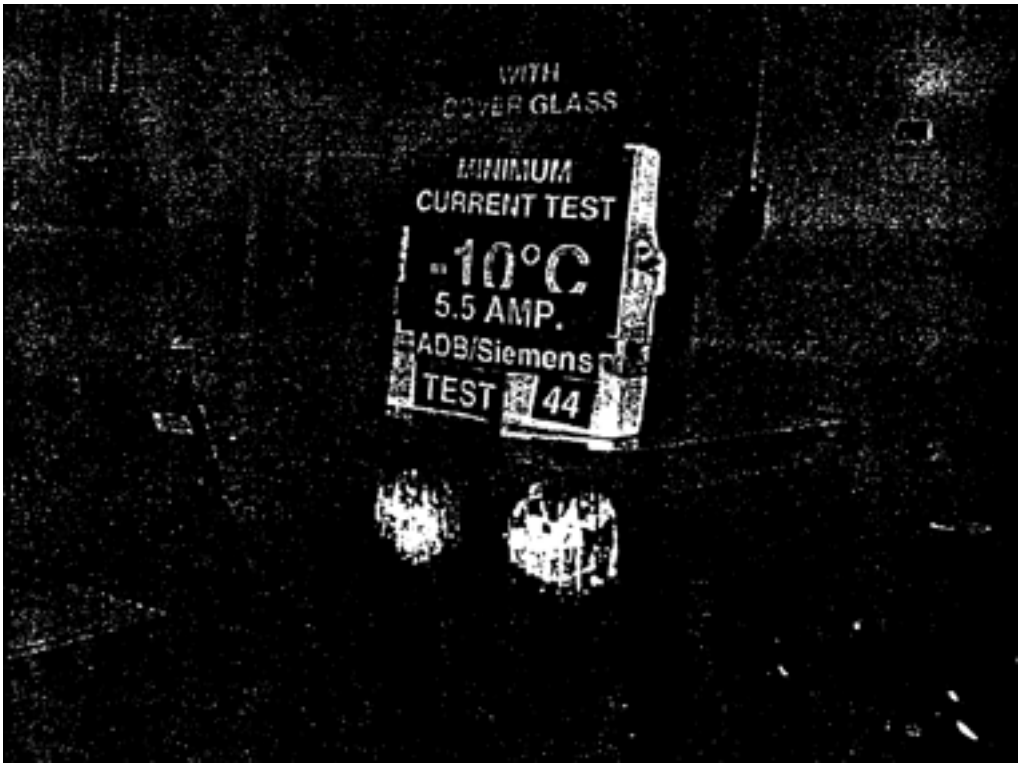
5. Test #43, pre-test.



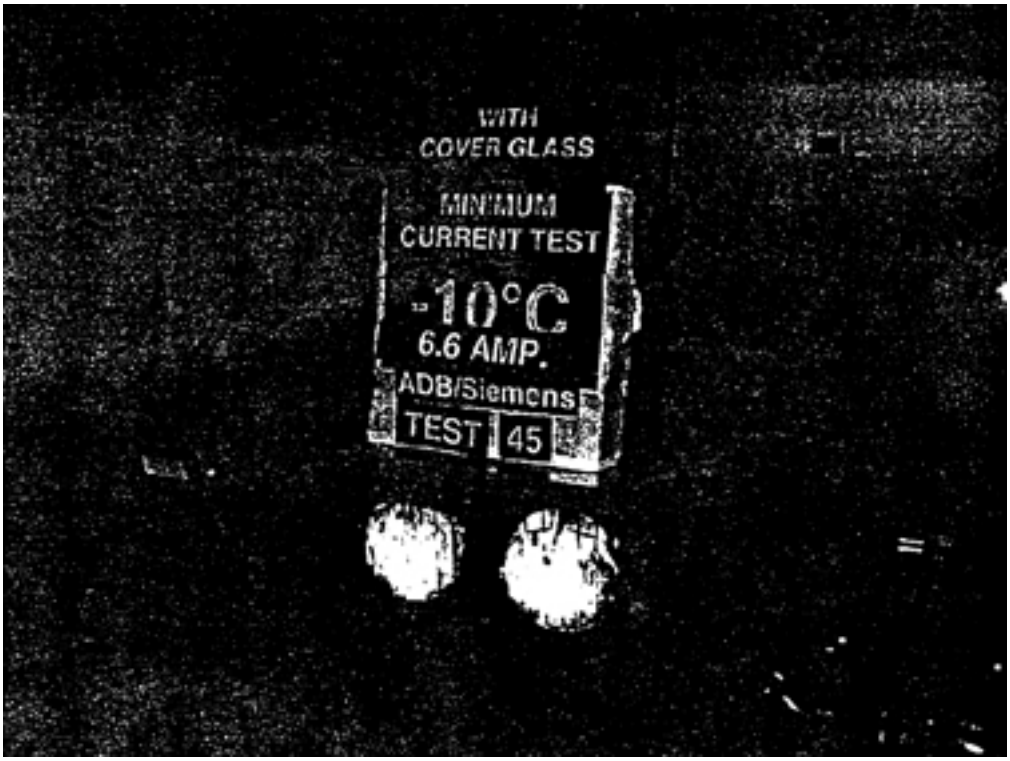
6. Test #43, post-test.



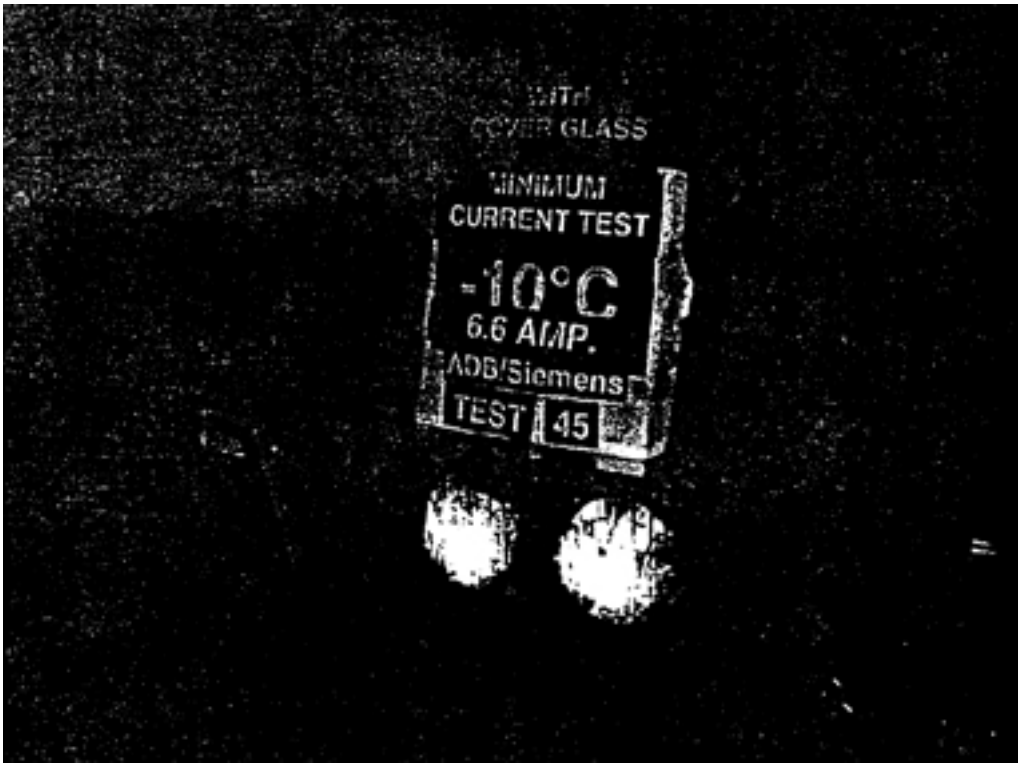
7. Test #44, pre-test.



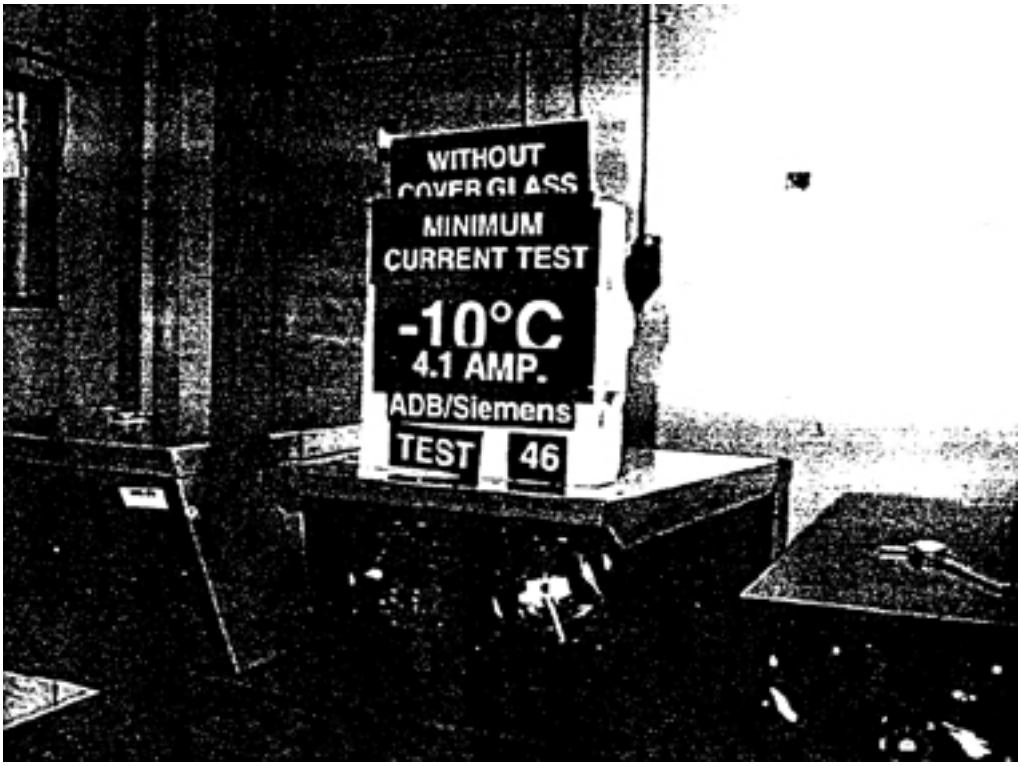
8. Test #44, post-test.



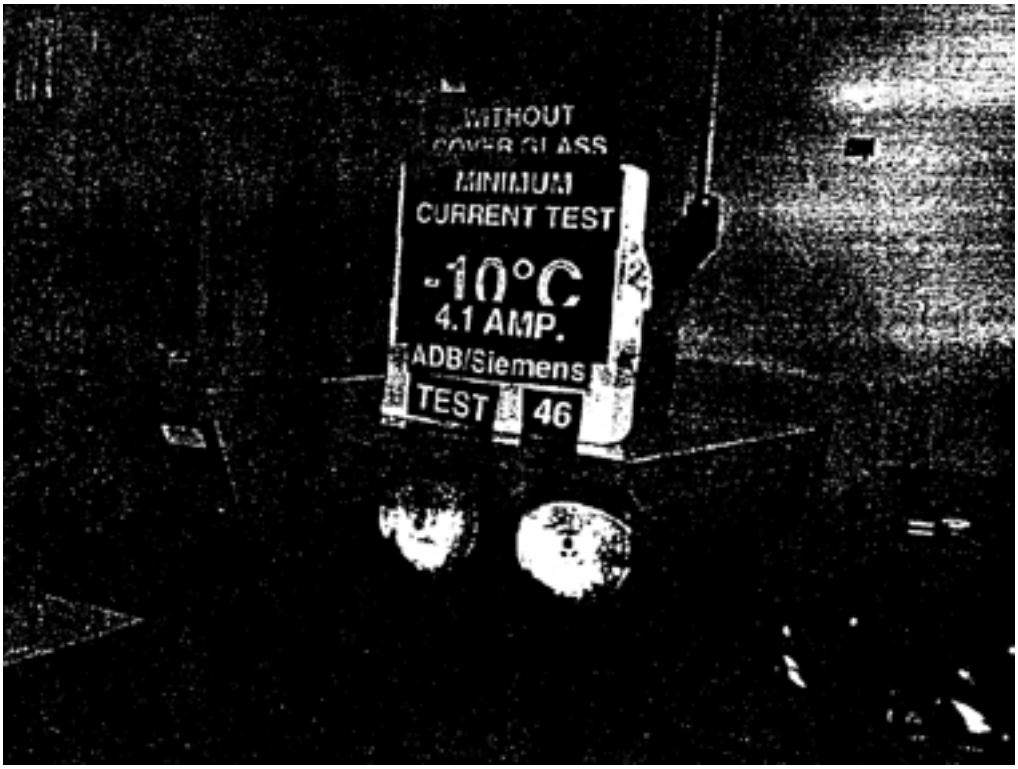
9. Test #45, pre-test.



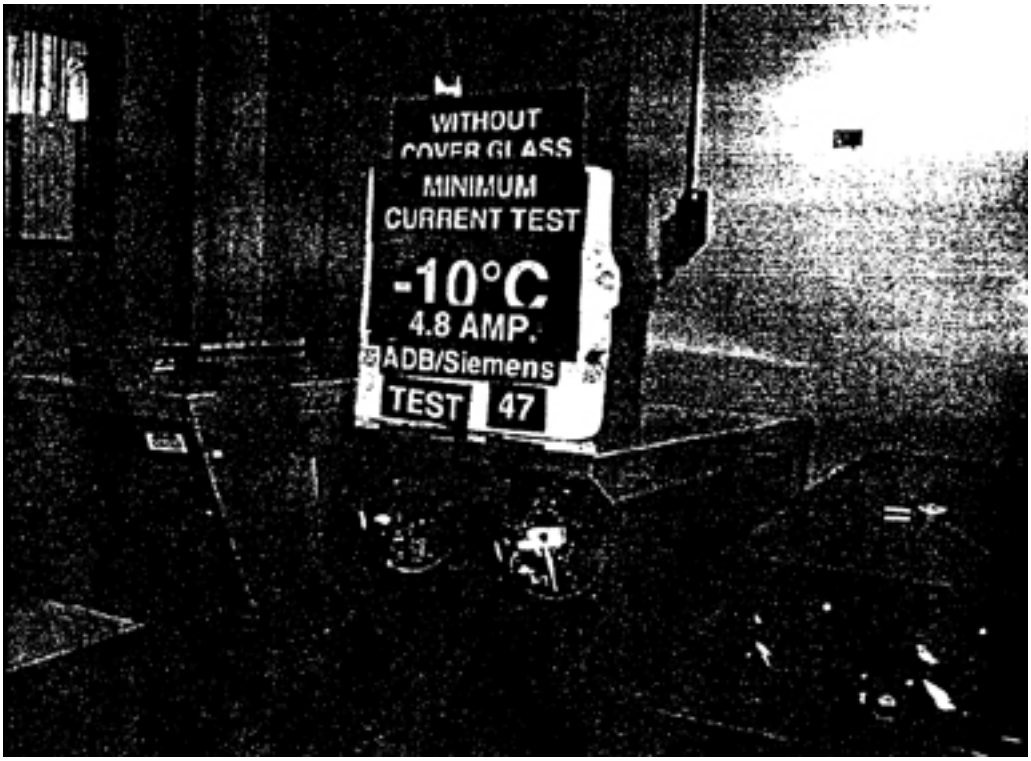
10. Test #45, post-test.



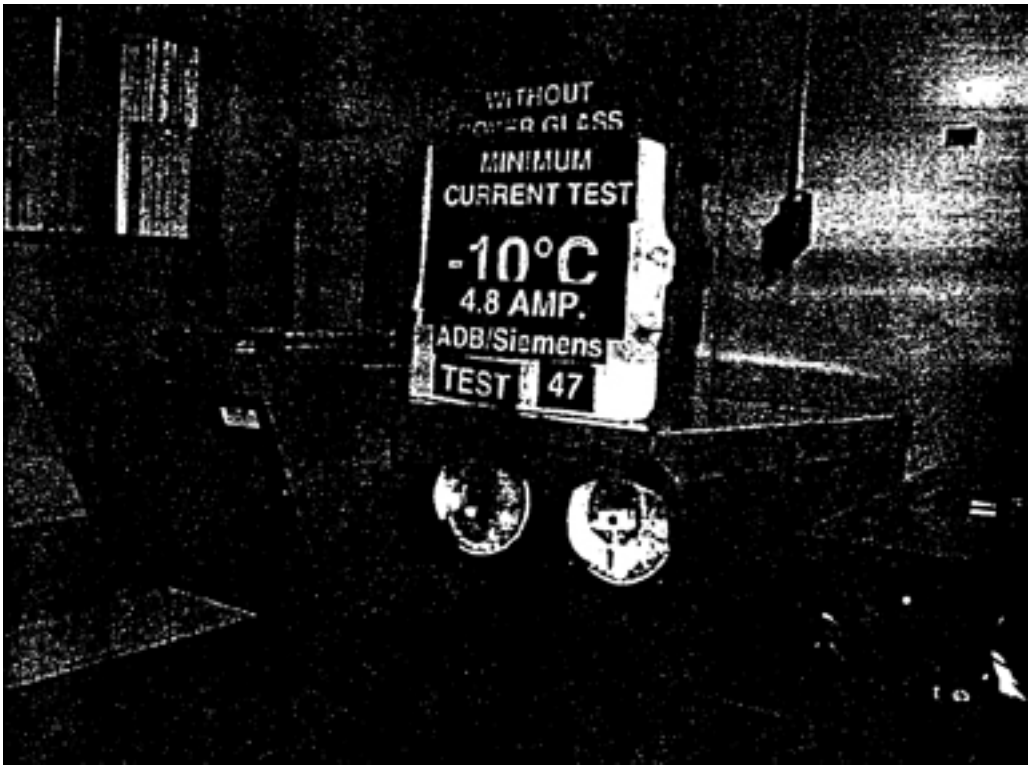
11. Test #46, pre-test.



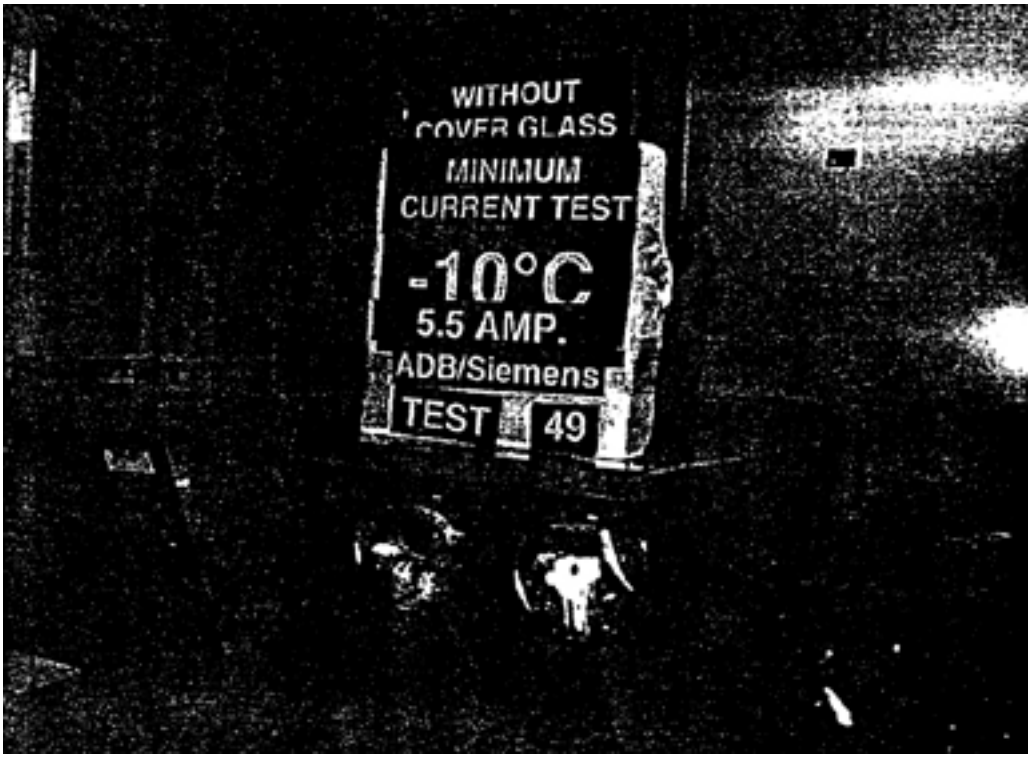
12. Test #46, post-test.



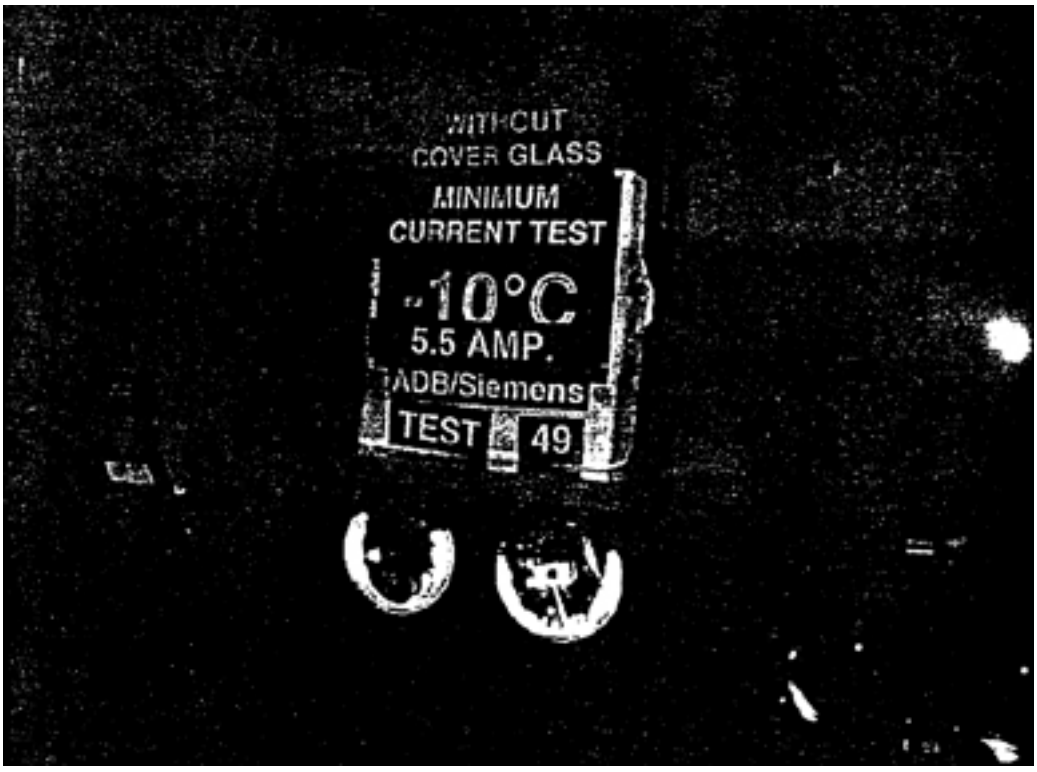
13. Test #47, pre-test.



14. Test #47, post-test.

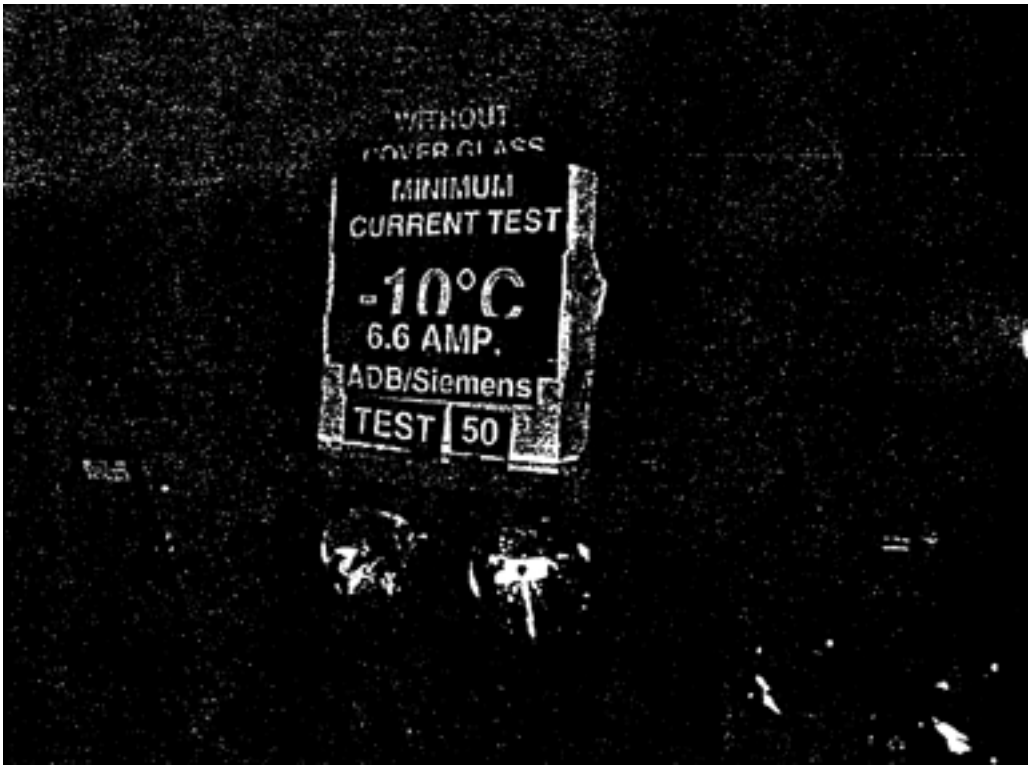


15. Test #49, pre-test.



16. Test #49, post-test.

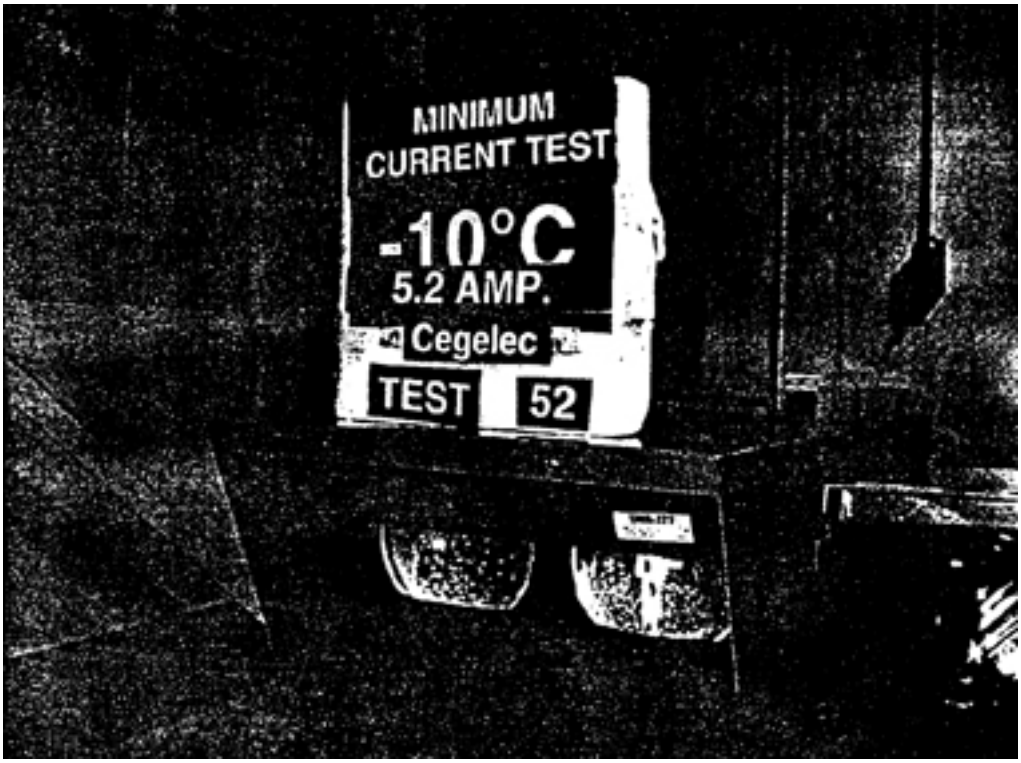
17. Test #50, pre-test.



18. Test #50, post-test.

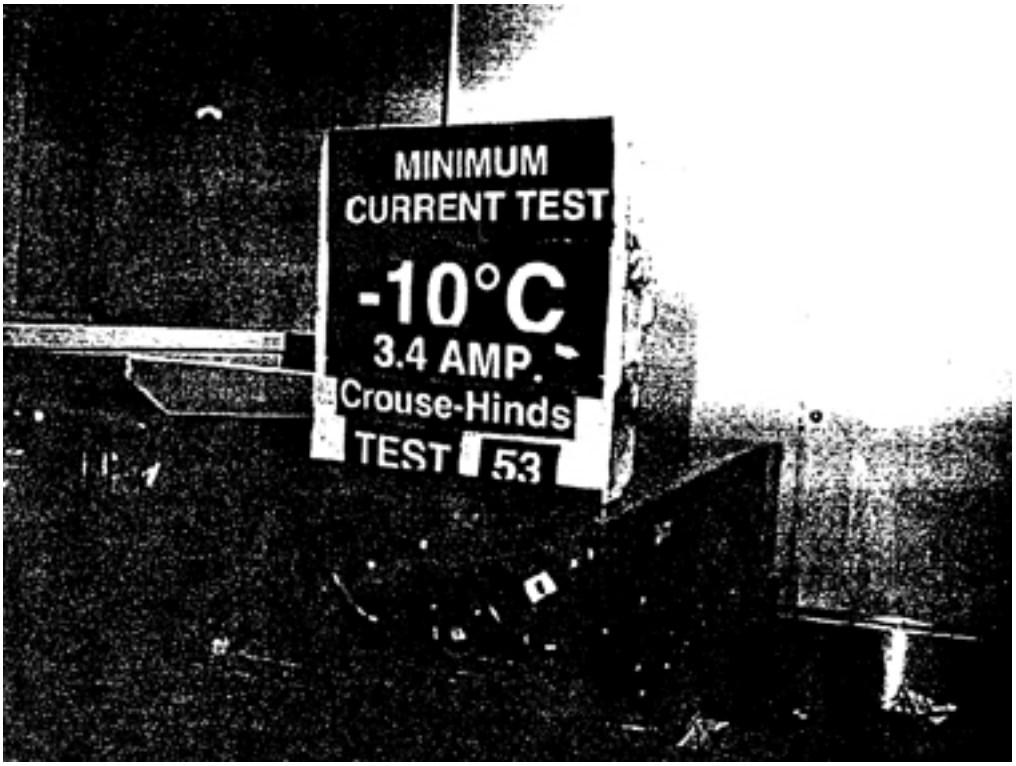
19. Test #51, pre-test.

20. Test #51, post-test.

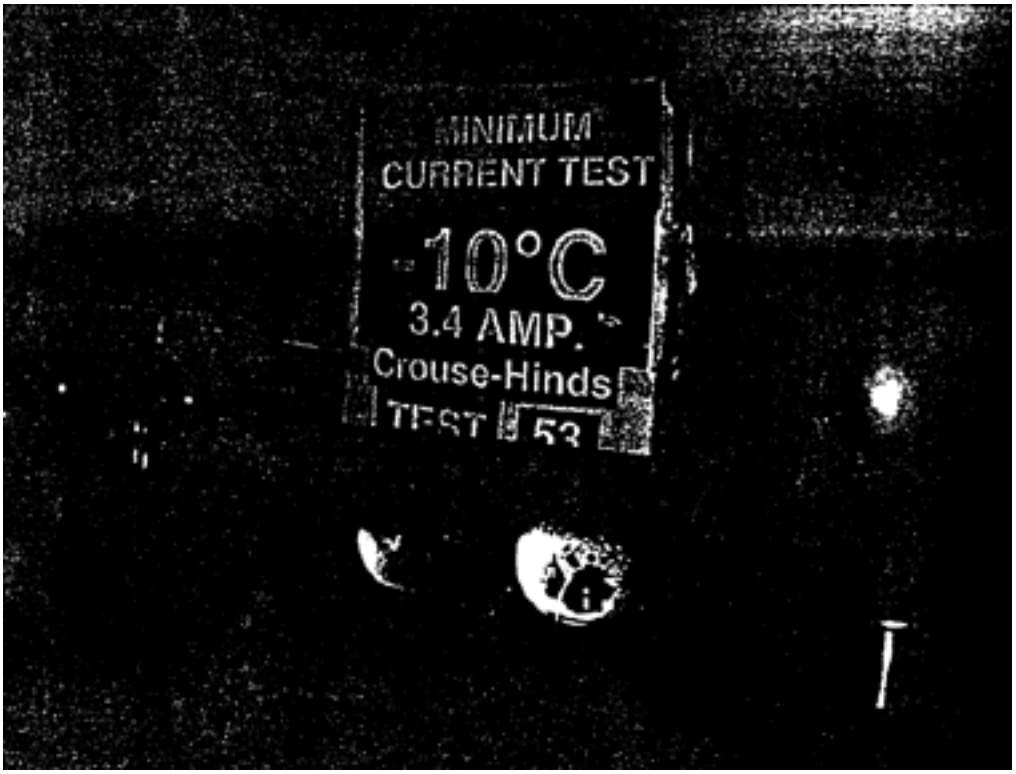


21. Test 52, pre-test.

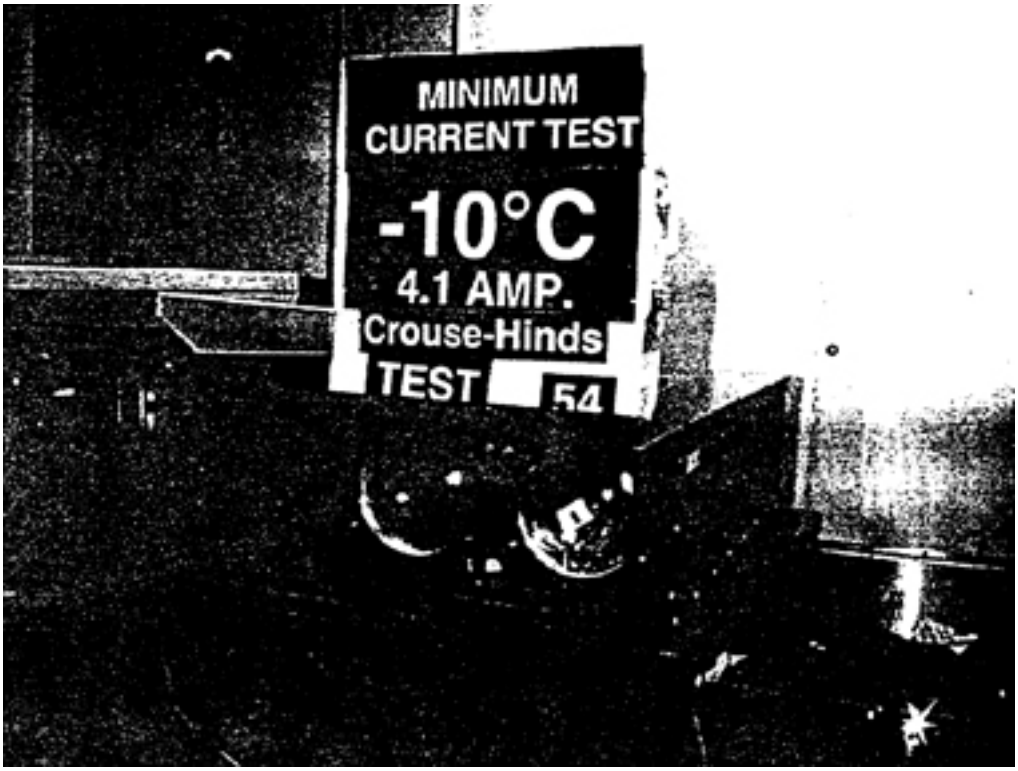
22. Test #52, post-test.



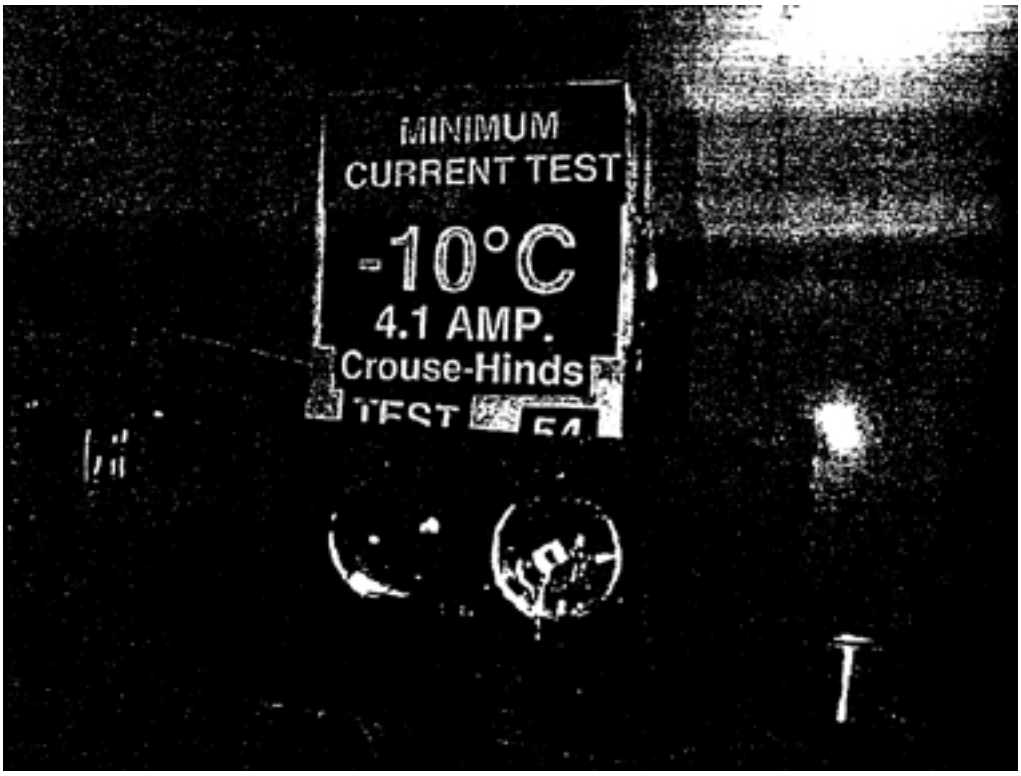
23. Test #53, pre-test.



24. Test #53, post-test.



25. Test #54, pre-test.



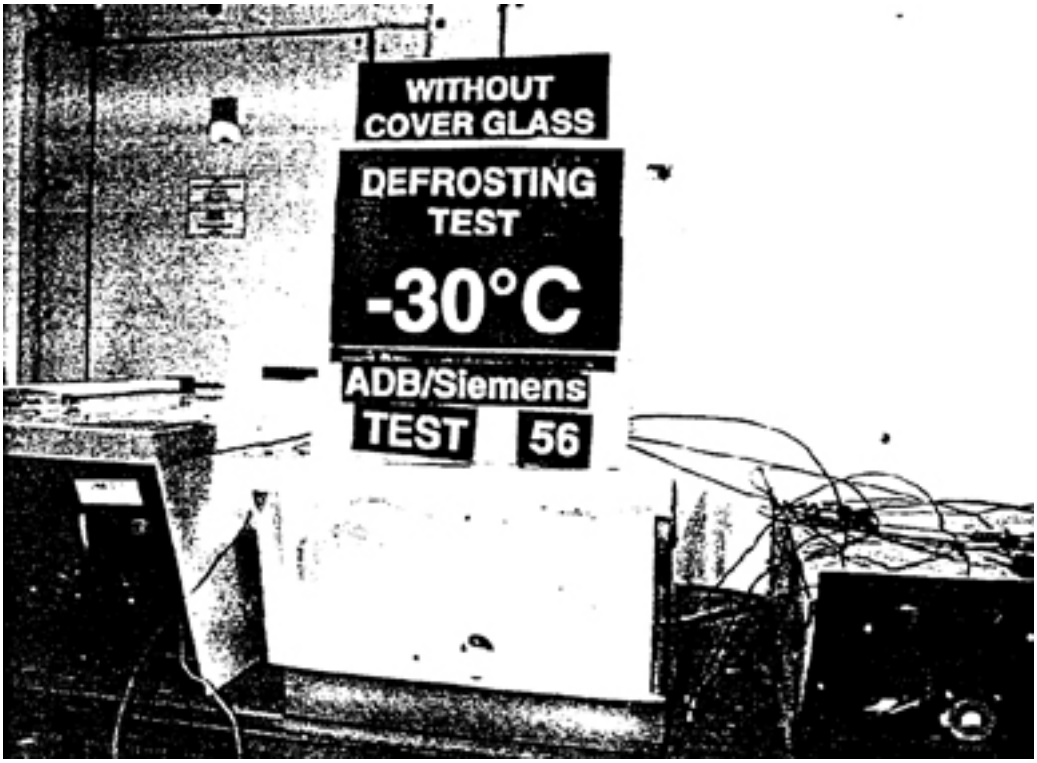
26. Test #54, post-test.

Intentionally left blank

APPENDIX E

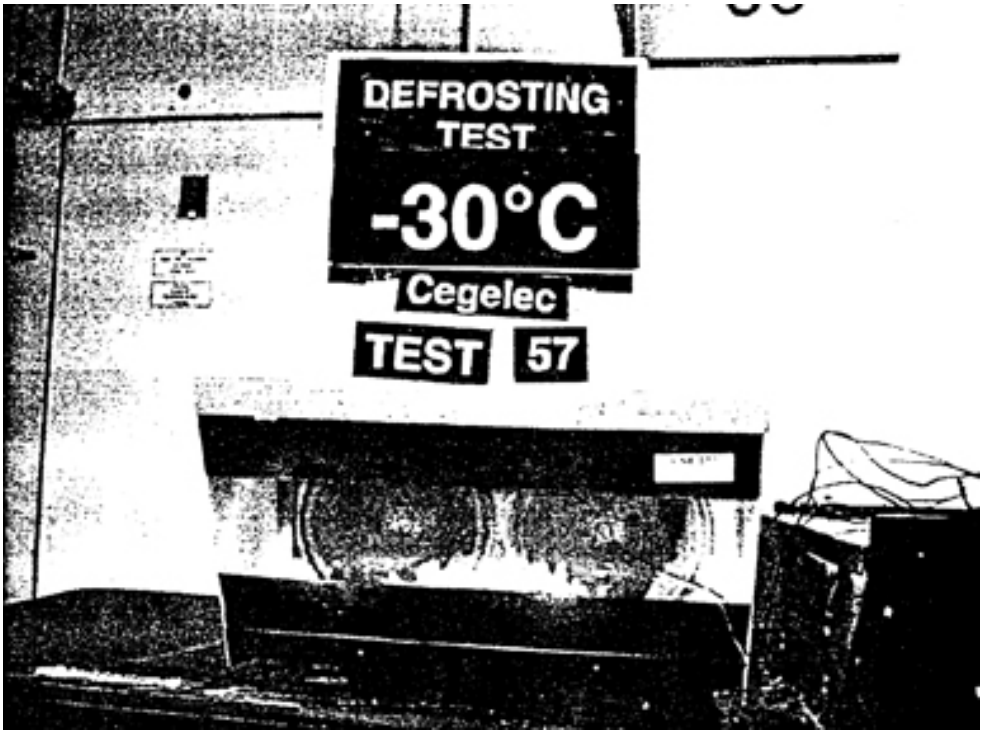
TEST PHOTOGRAPHS

Intentionally left blank

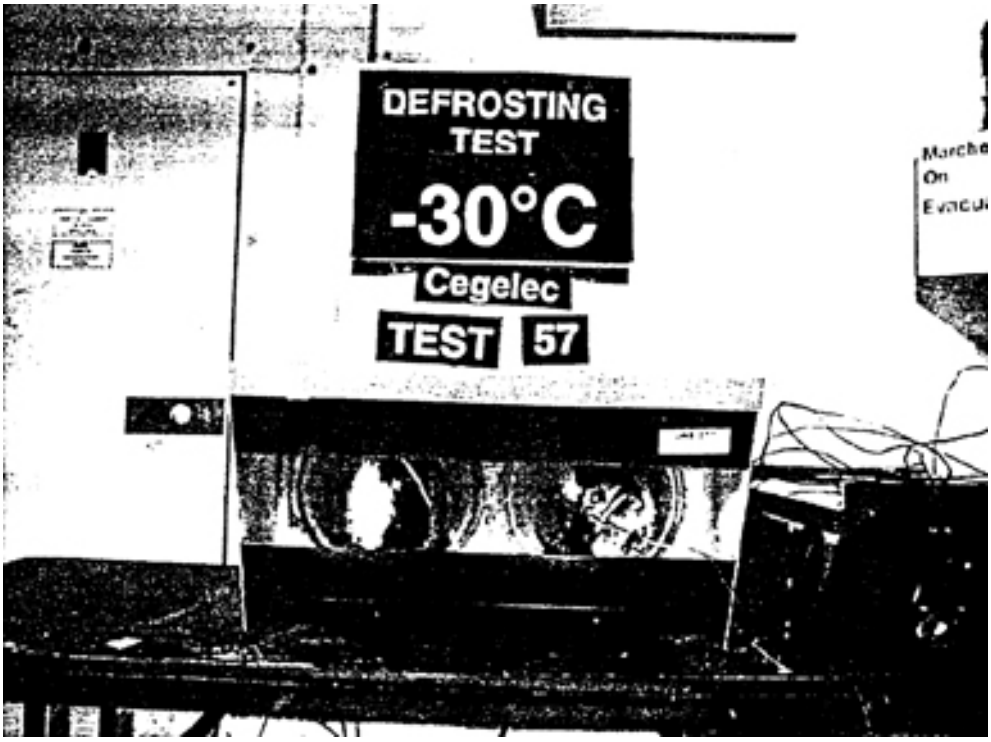


1. Test #56, pre-test.

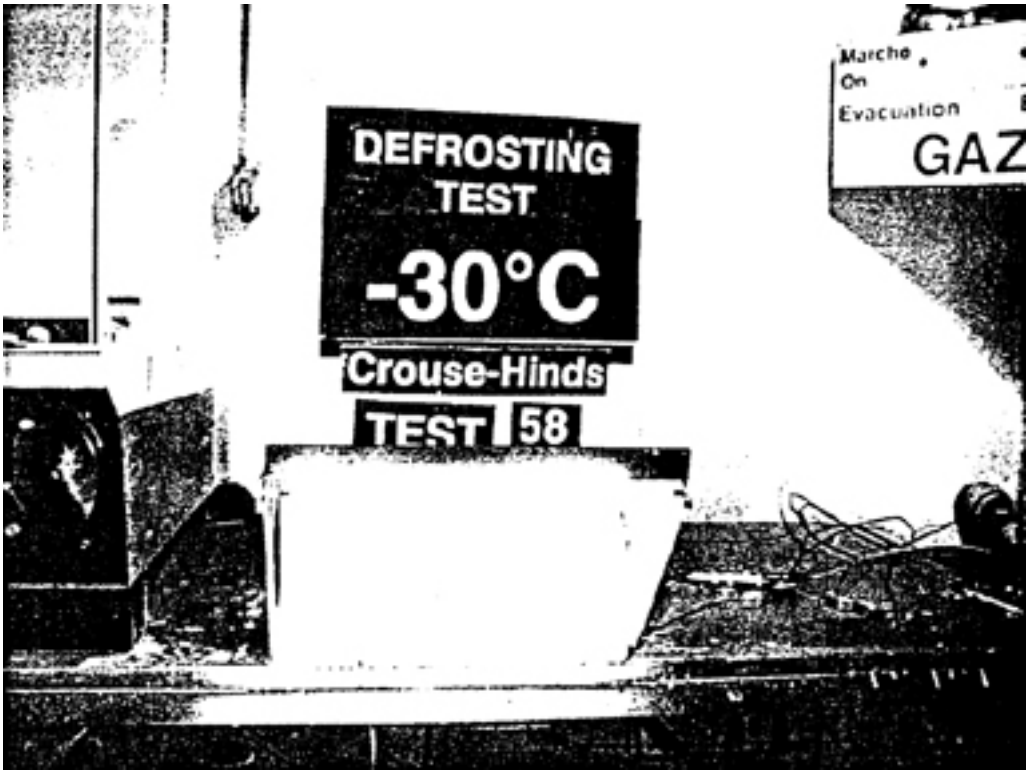
2. Test #56, post-test.



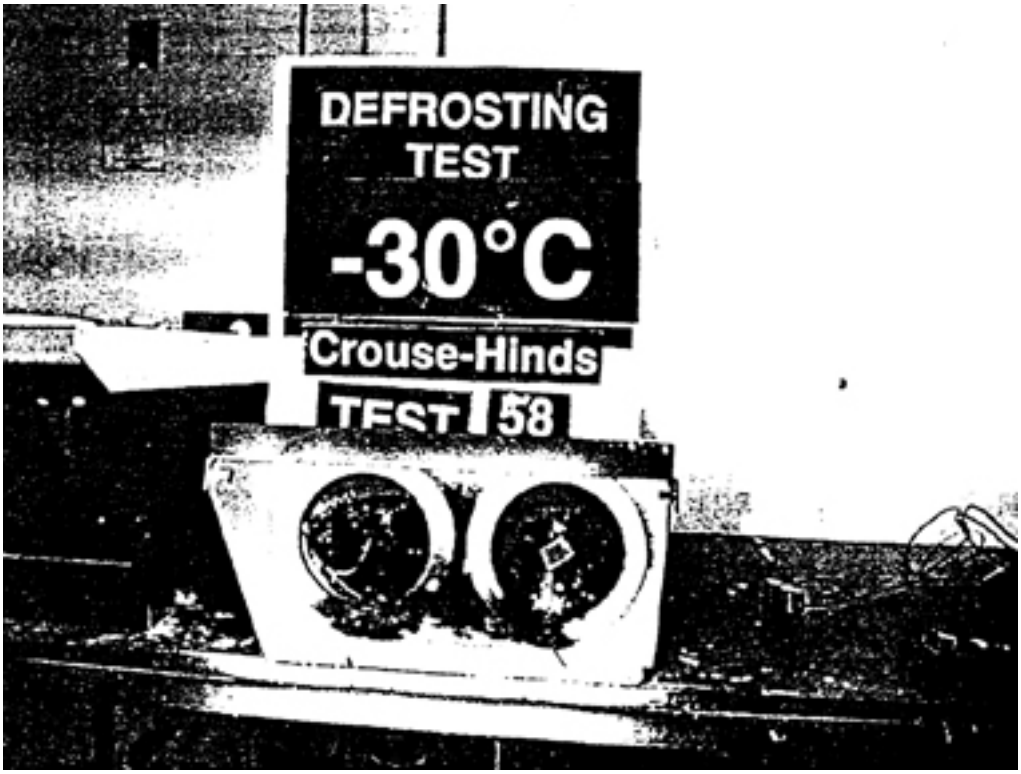
3. Test #57, pre-test.



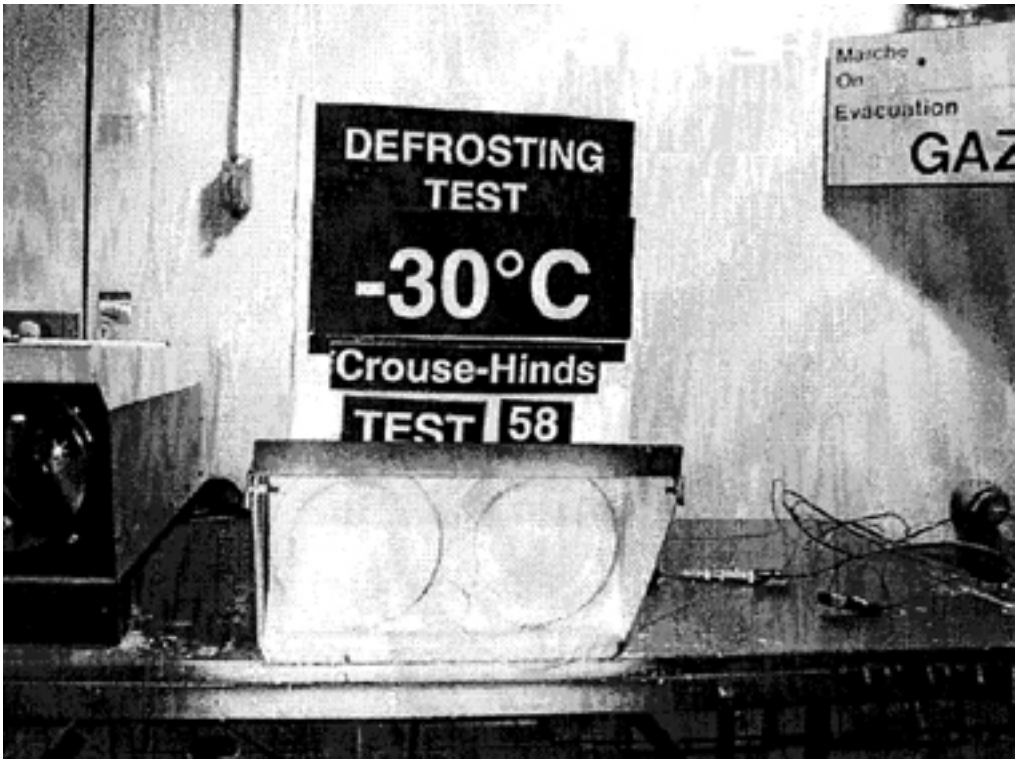
4. Test #57, post-test.



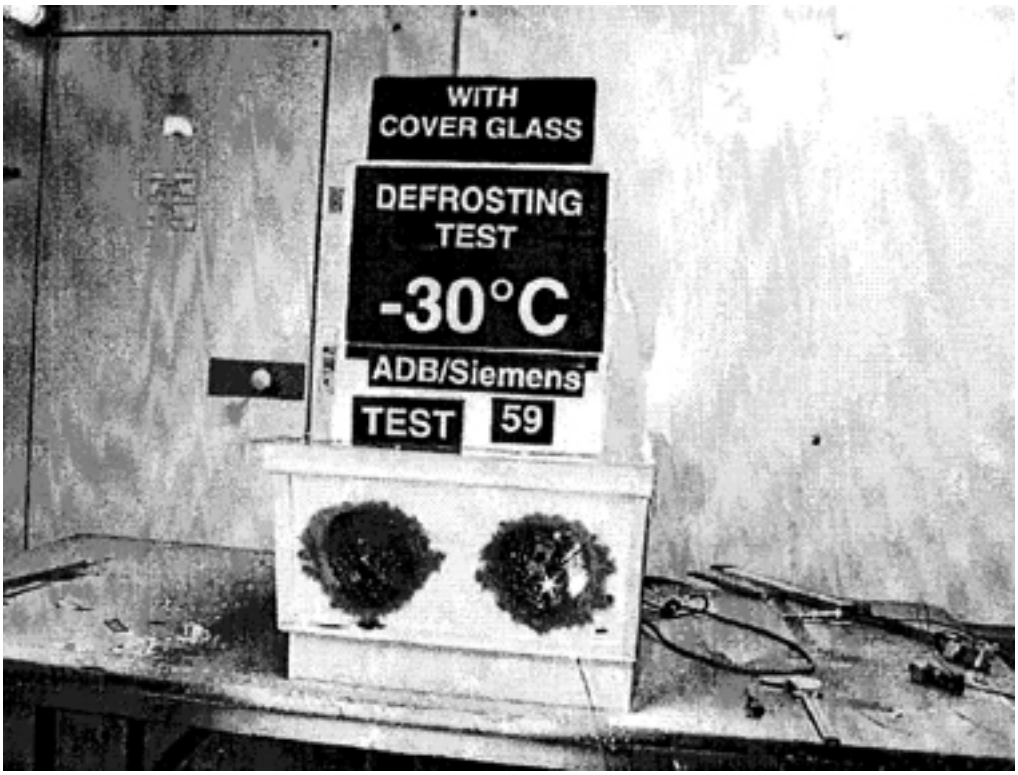
5. Test #58, pre-test.



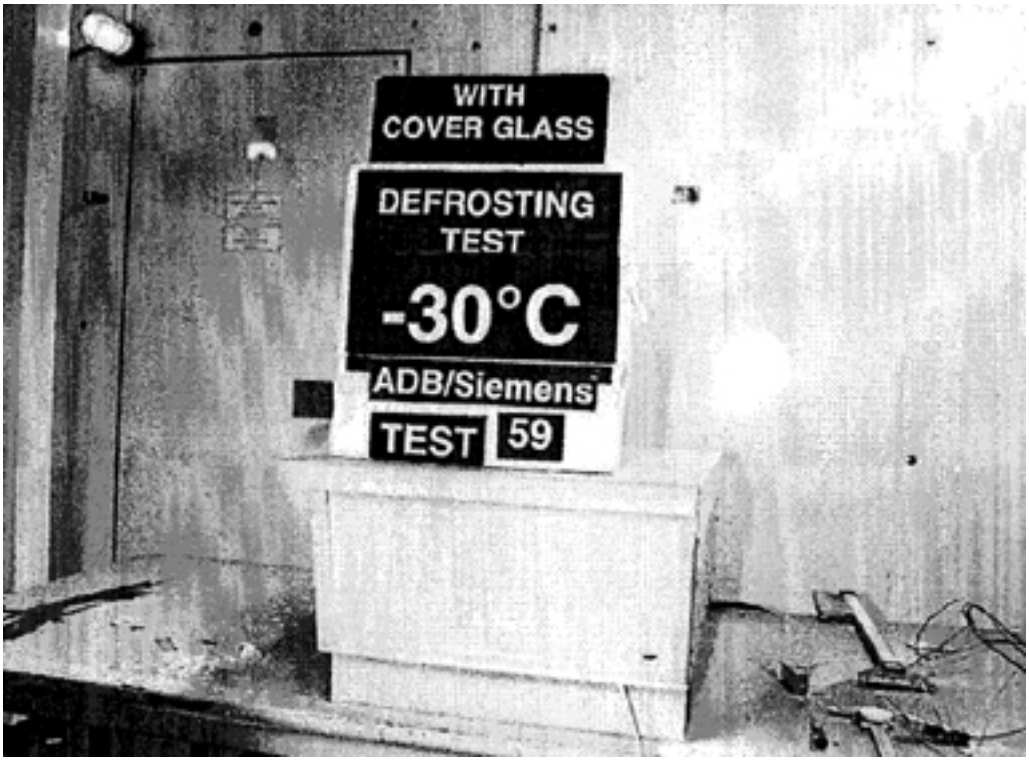
6. Test #58, post-test.



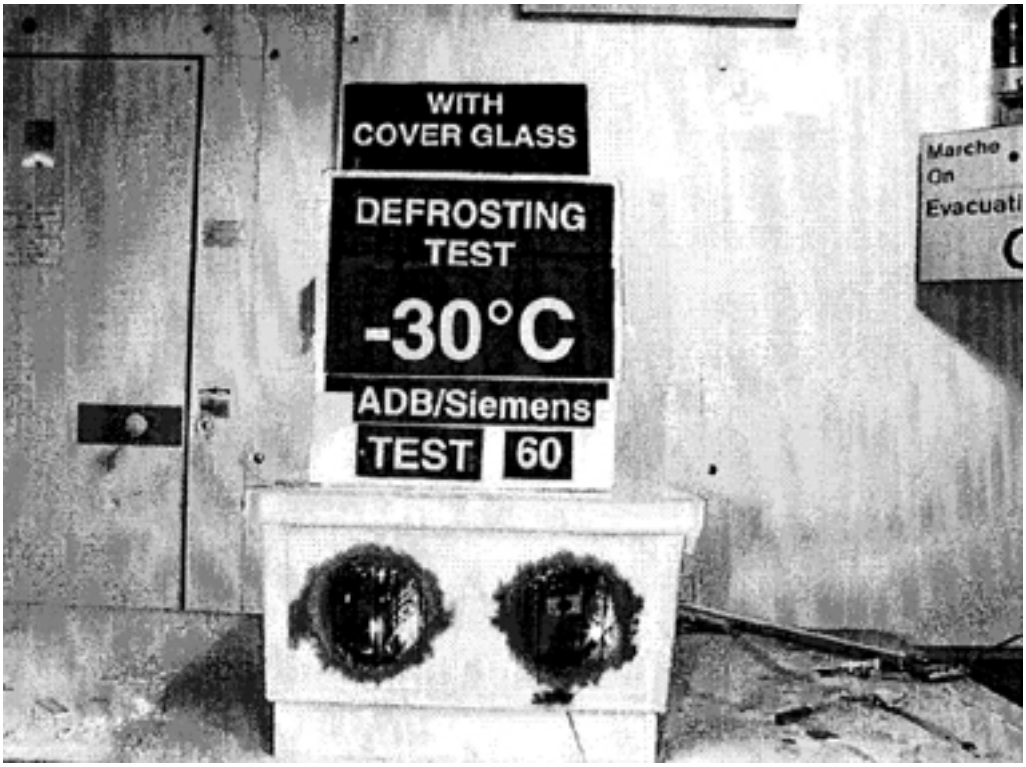
7. Test #59, pre-test.



8. Test #59, post-test.

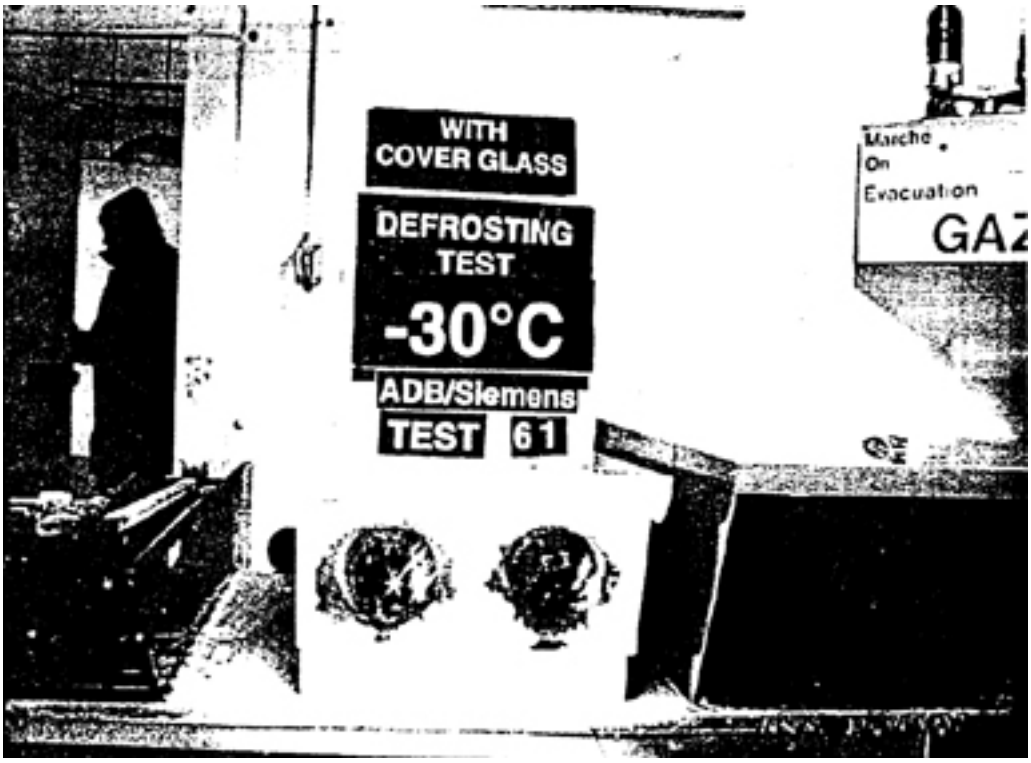


9. Test #60, pre-test.

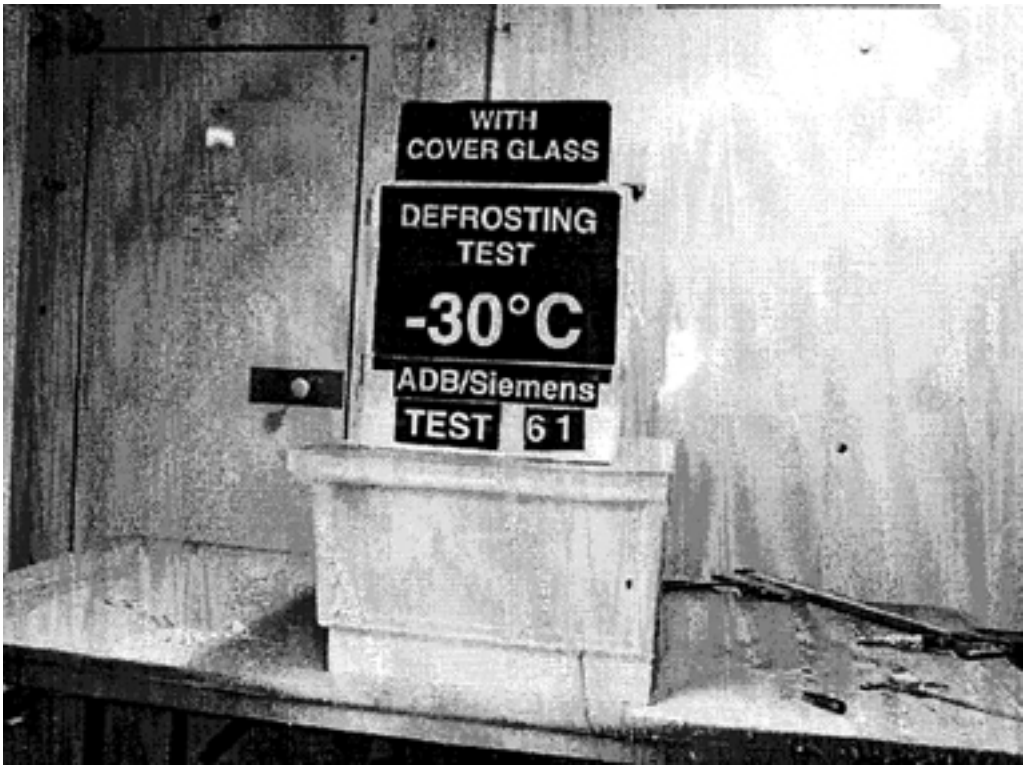


10. Test #60, post-test.

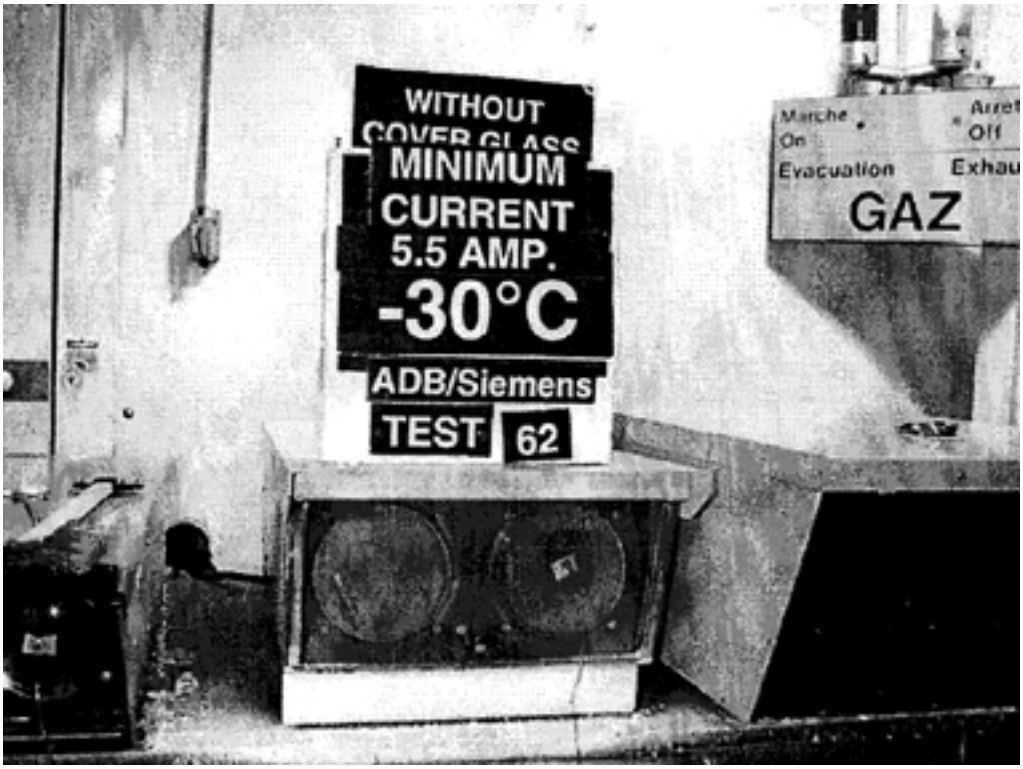
11. Test #61, pre-test.



12. Test #61, post-test.

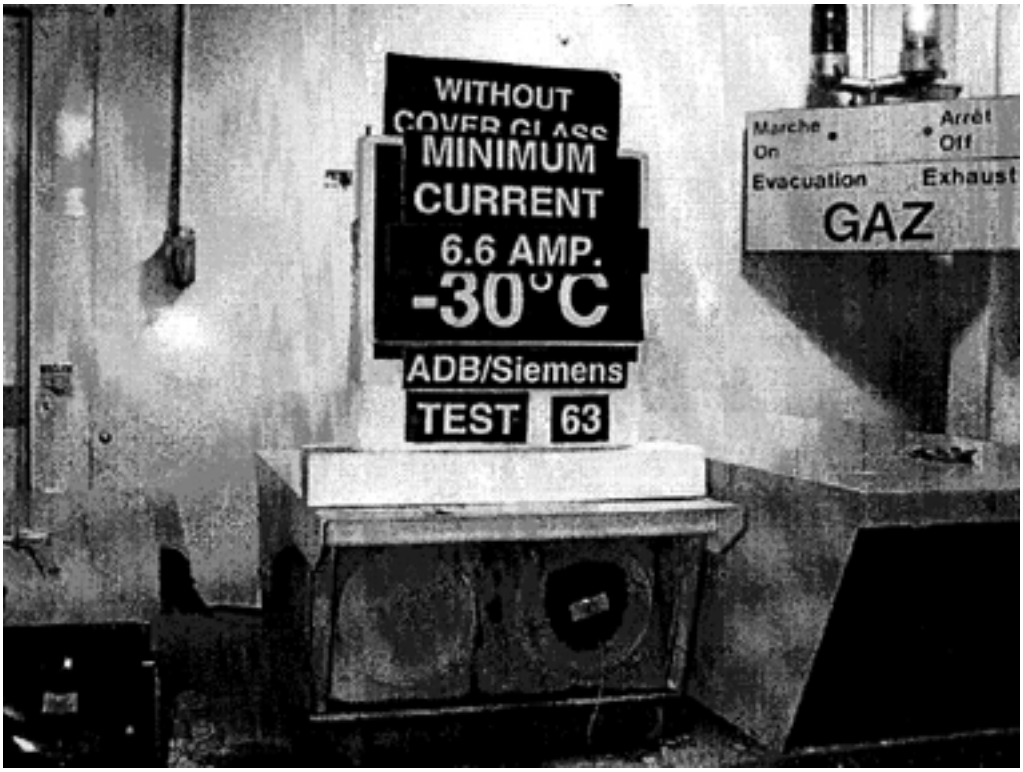


13. Test #62, pre-test.

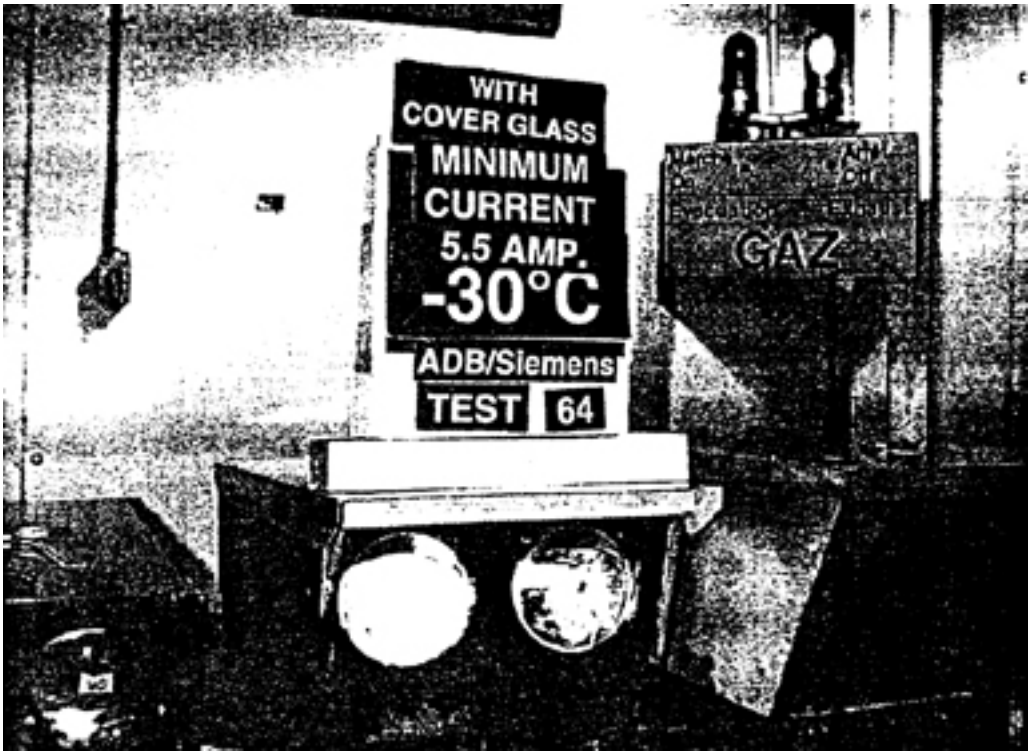


14. Test #62, post-test.

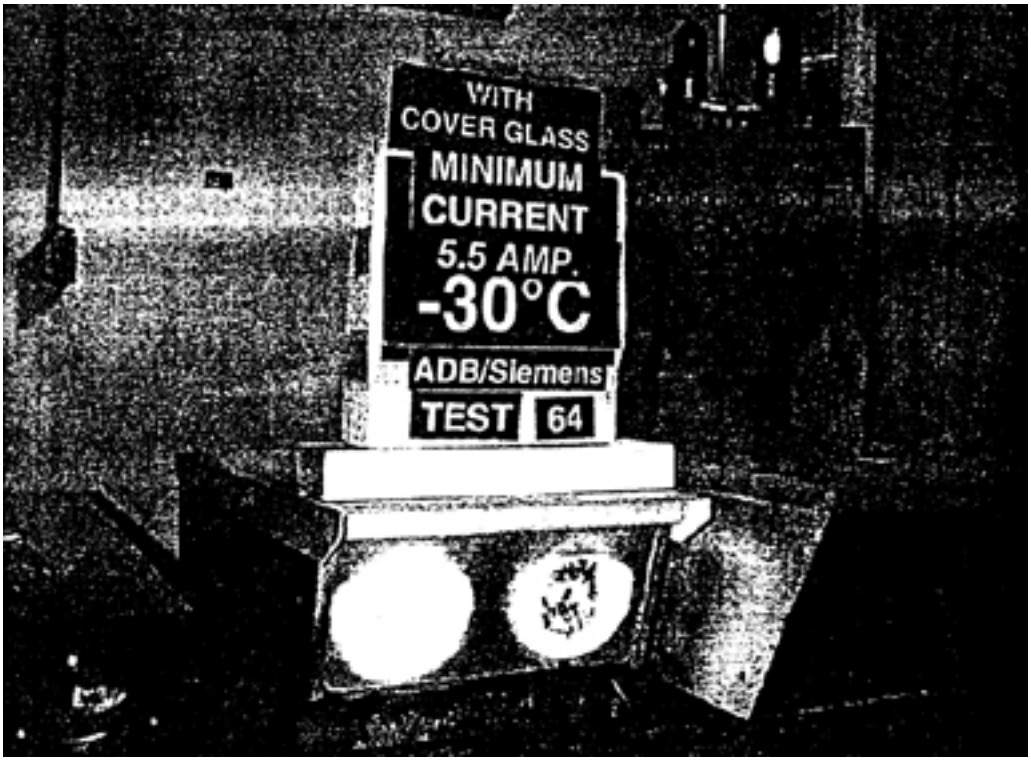
15. Test #63, pre-test.



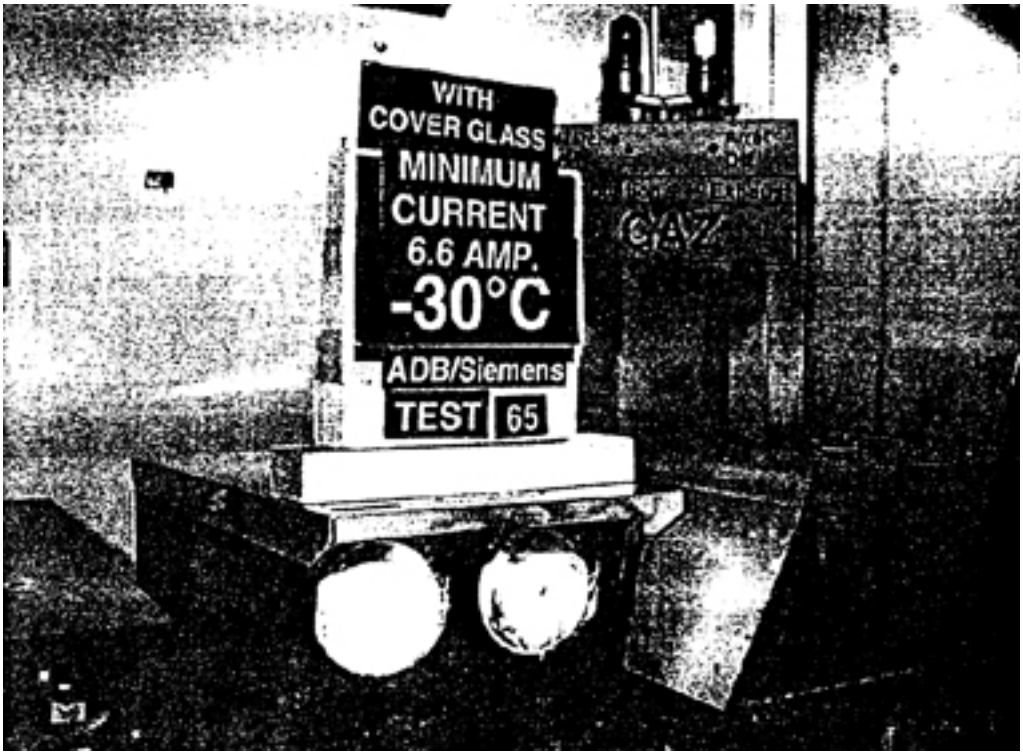
16. Test #63, post-test.



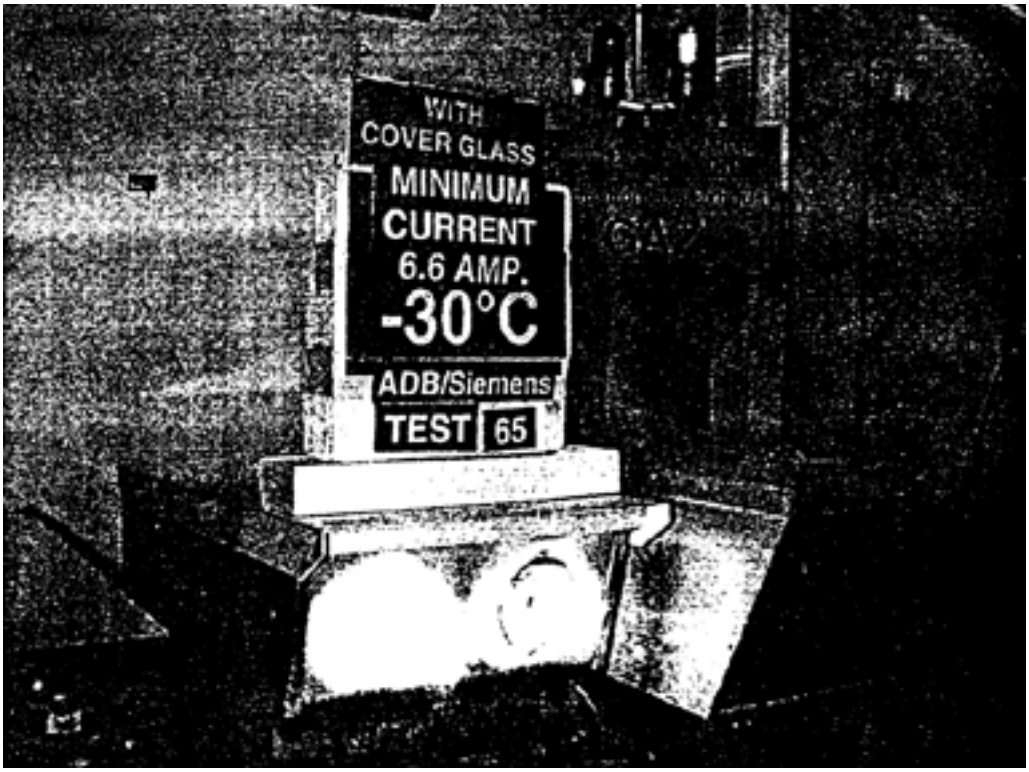
17. Test #64, pre-test.



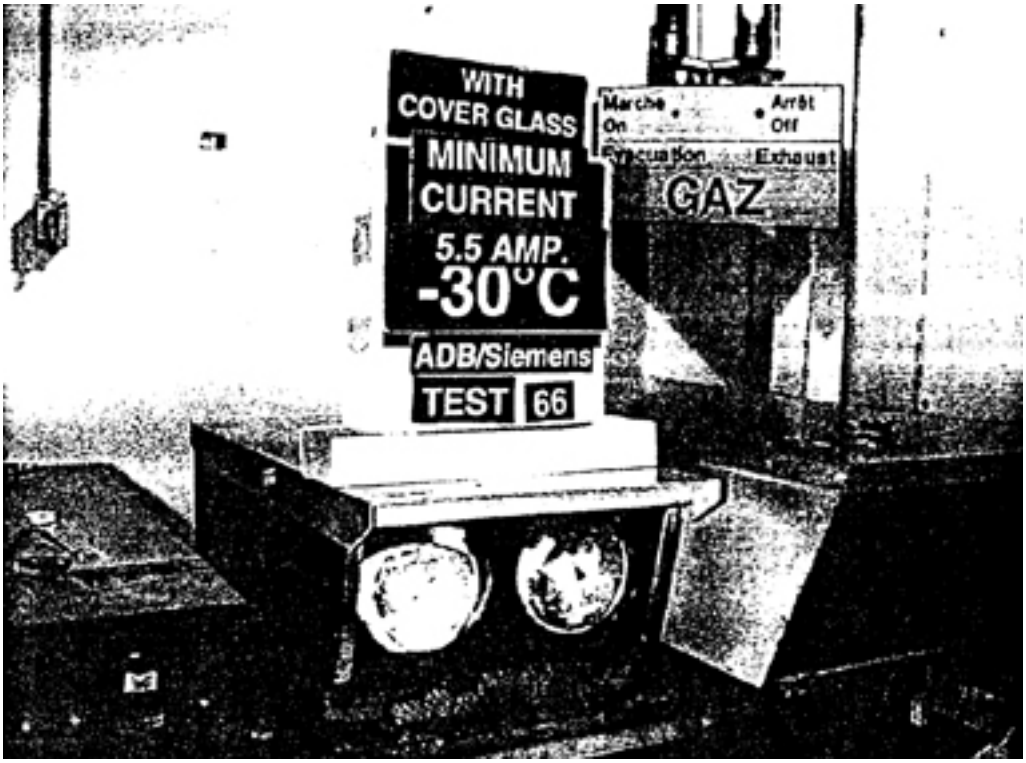
18. Test #64, post-test.



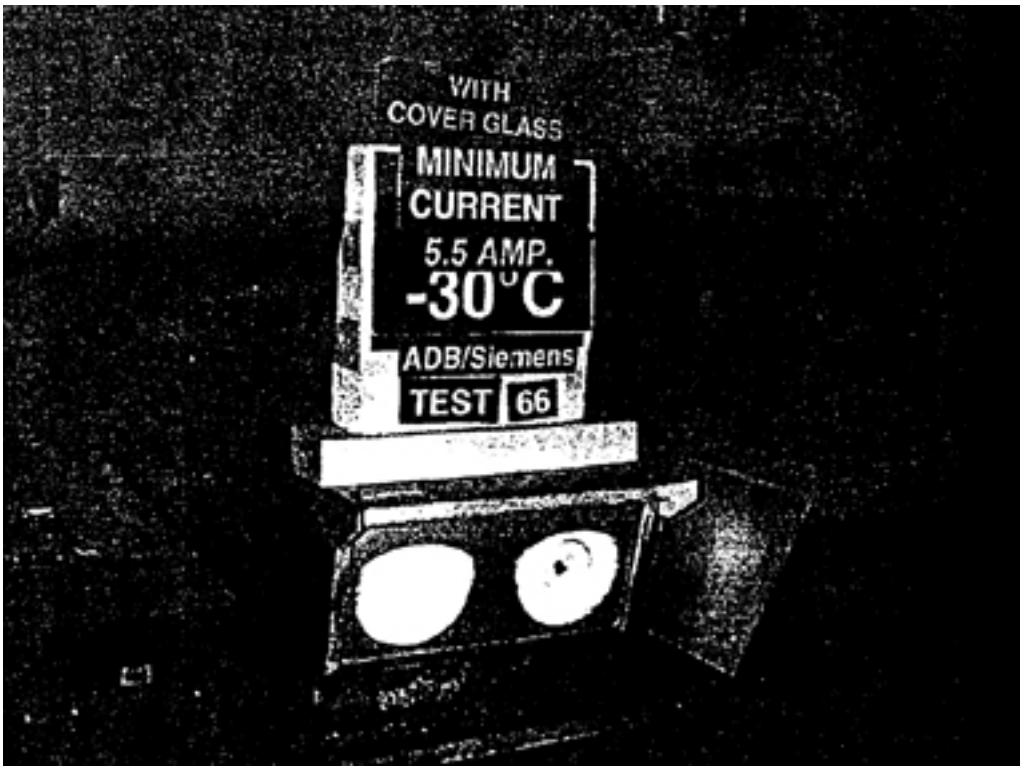
19. Test #65, pre-test.



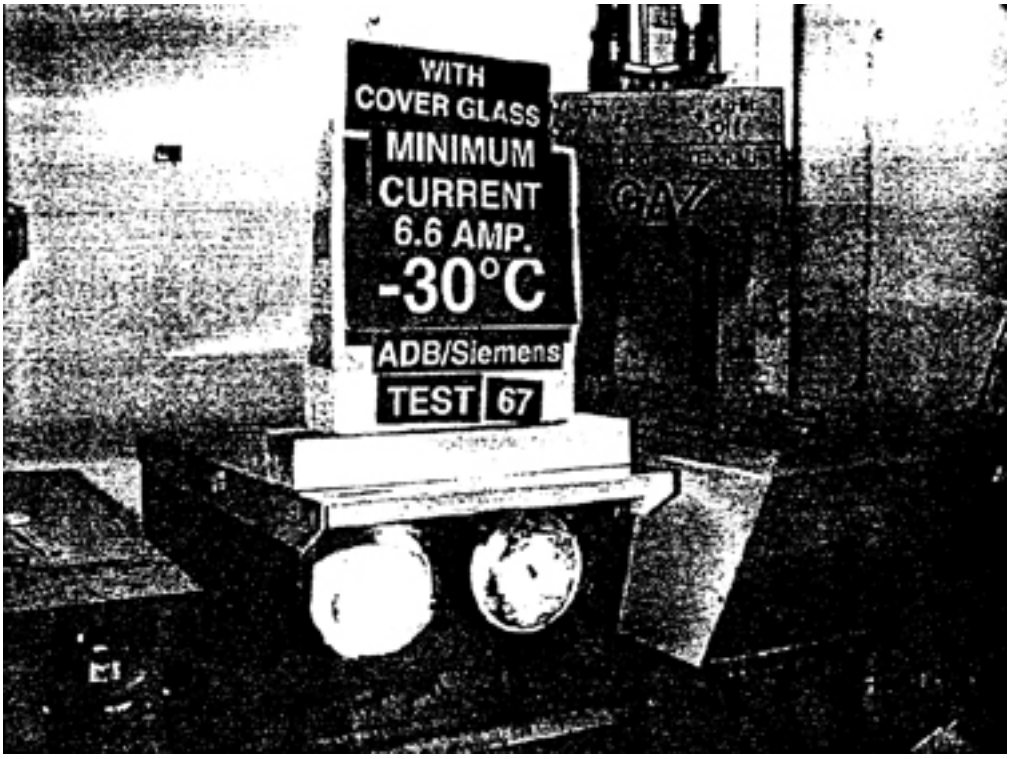
20. Test #65, post-test.



21. Test #66, pre-test.

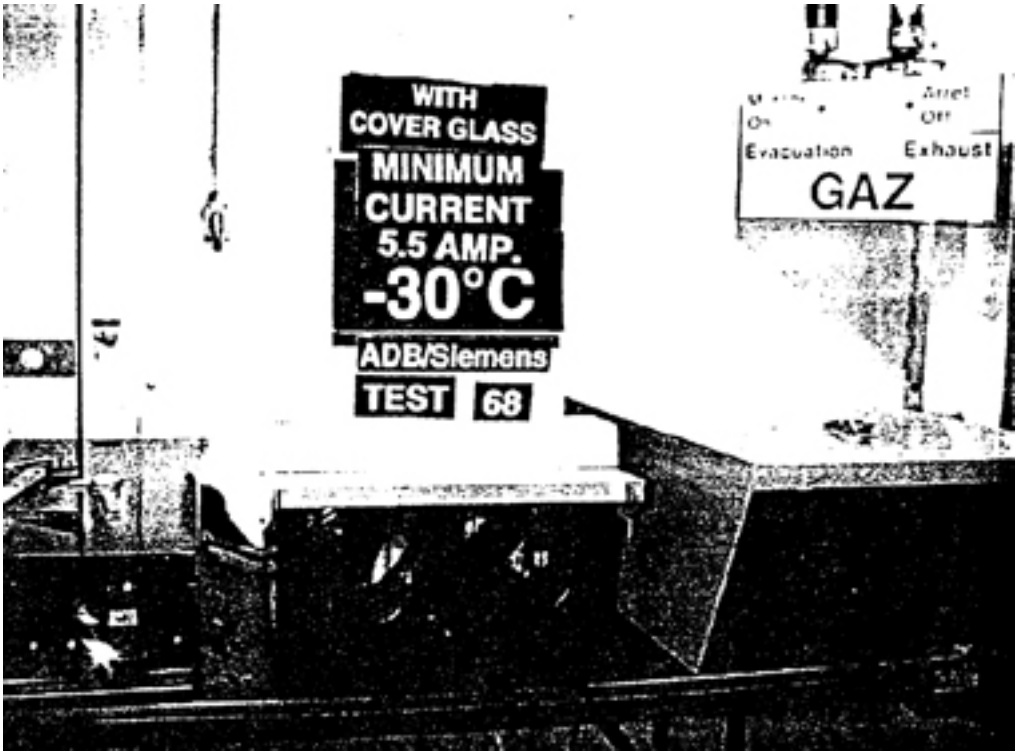


22. Test #66, post-test.

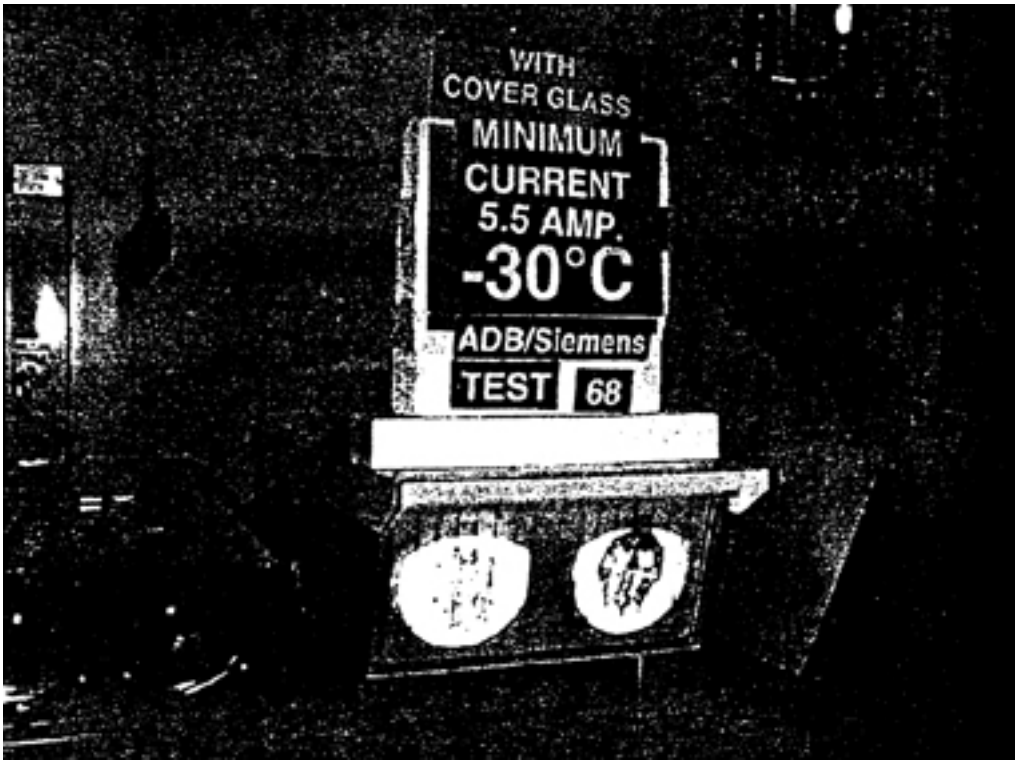


23. Test #67, pre-test.

24. Test #67, post-test.



25. Test #68, pre-test.



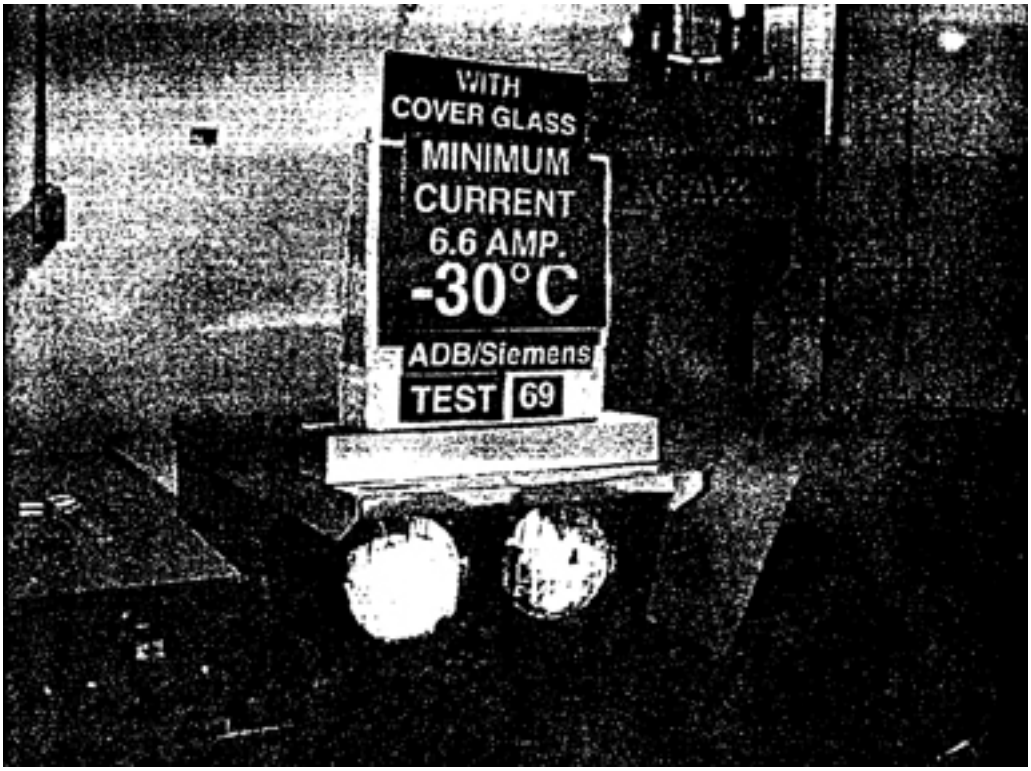
26. Test #68, post-test.

Intentionally left blank

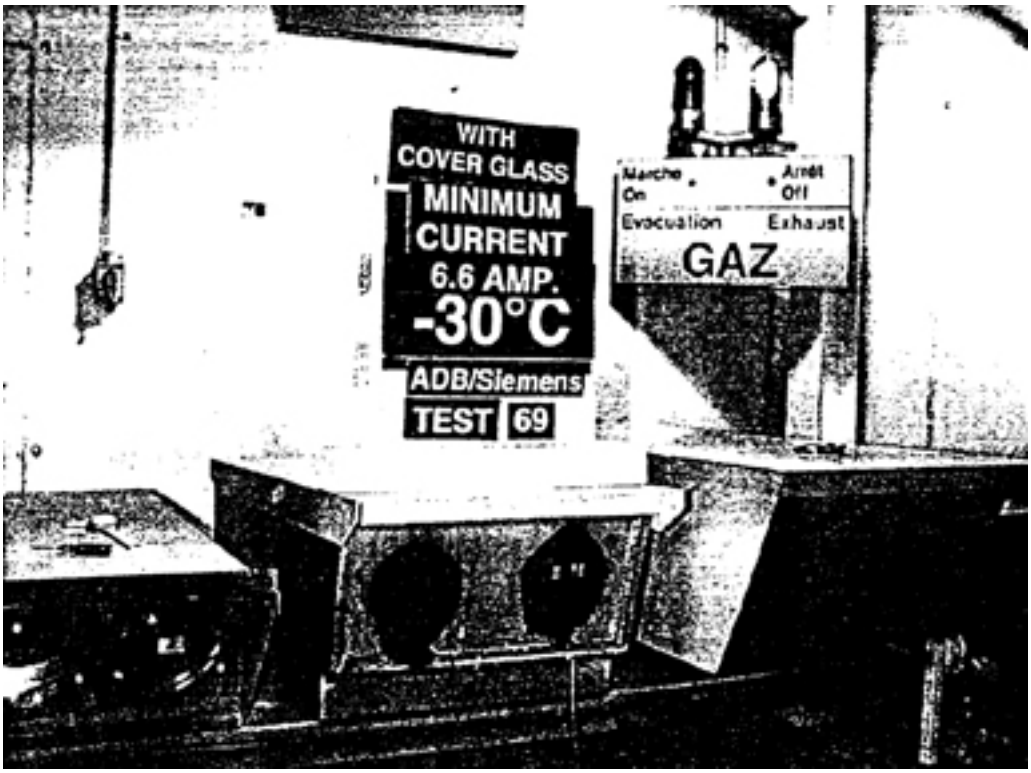
APPENDIX F

TEST PHOTOGRAPHS

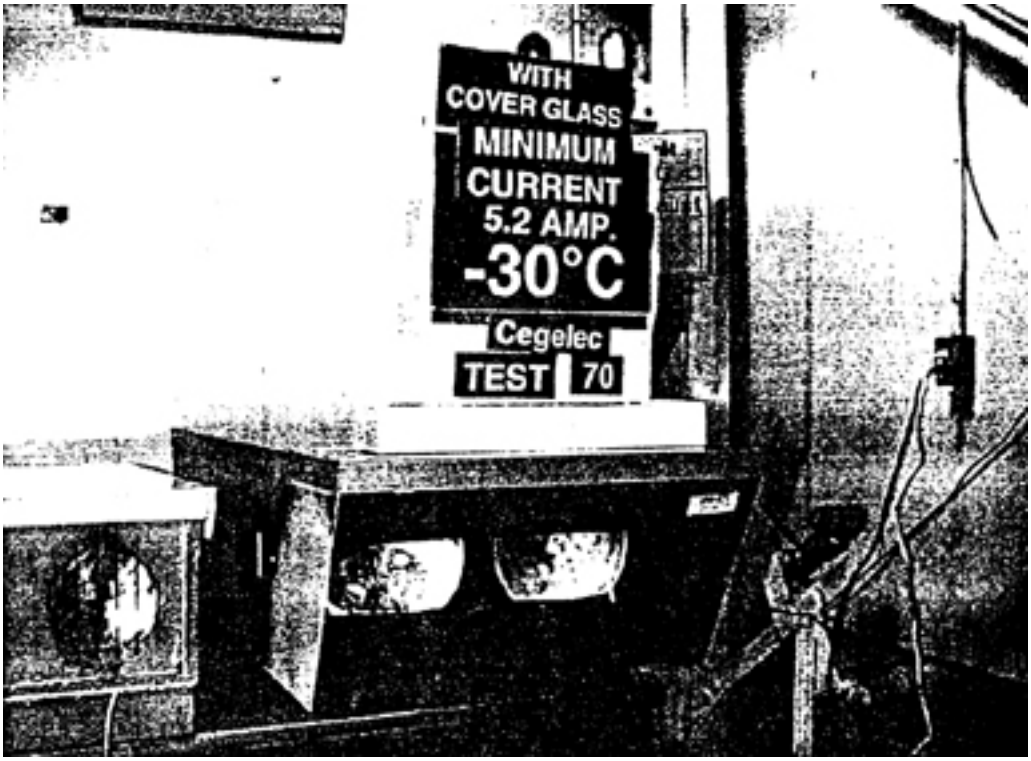
Intentionally left blank



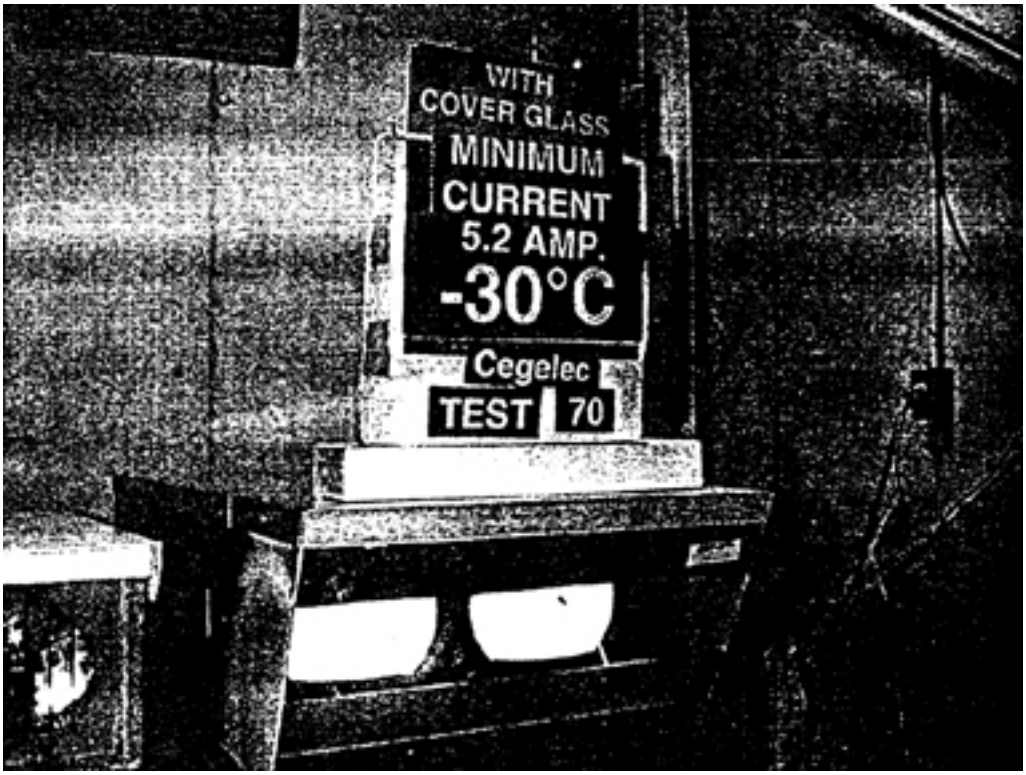
1. Test #69, pre-test.



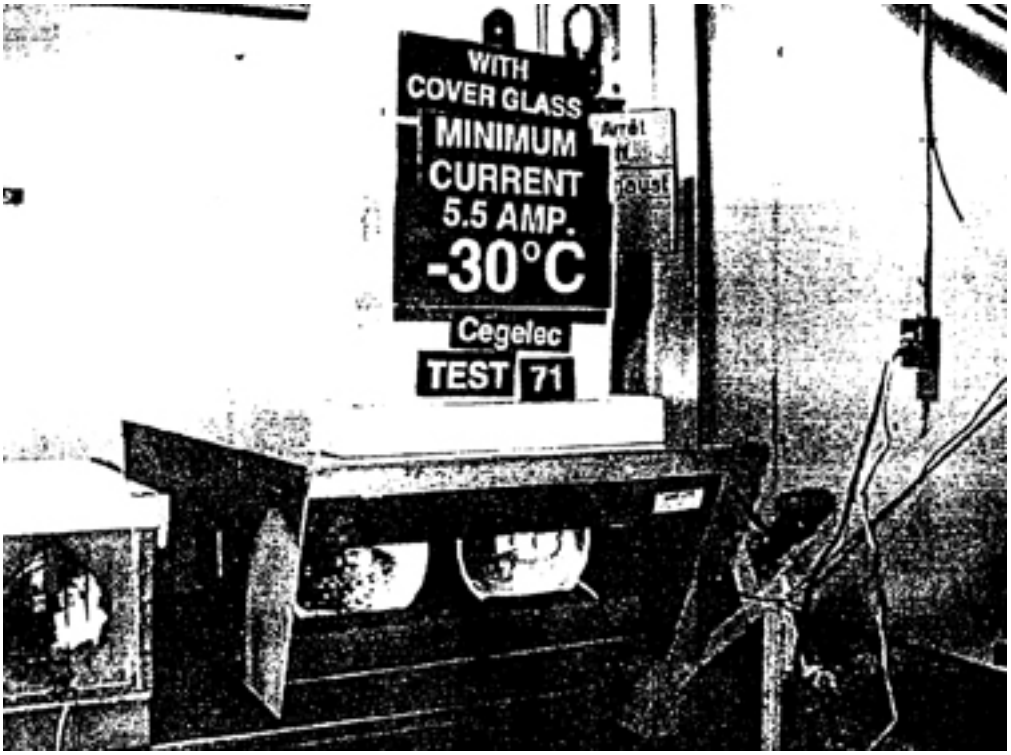
2. Test #69, post-test.



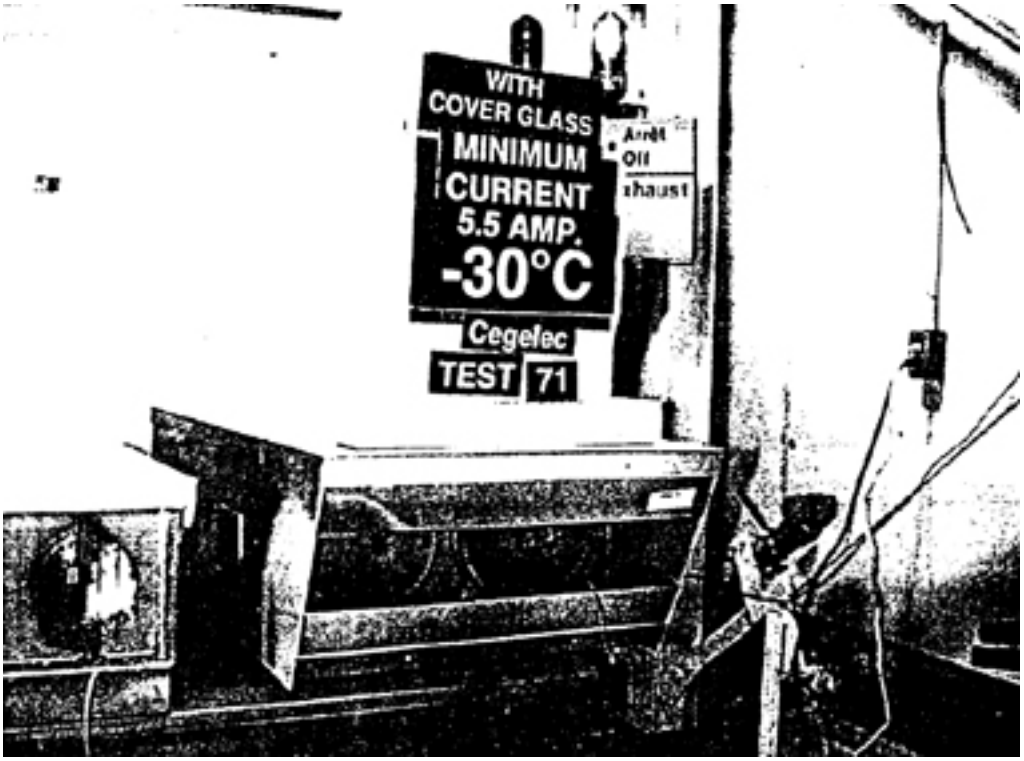
3. Test #70, pre-test.



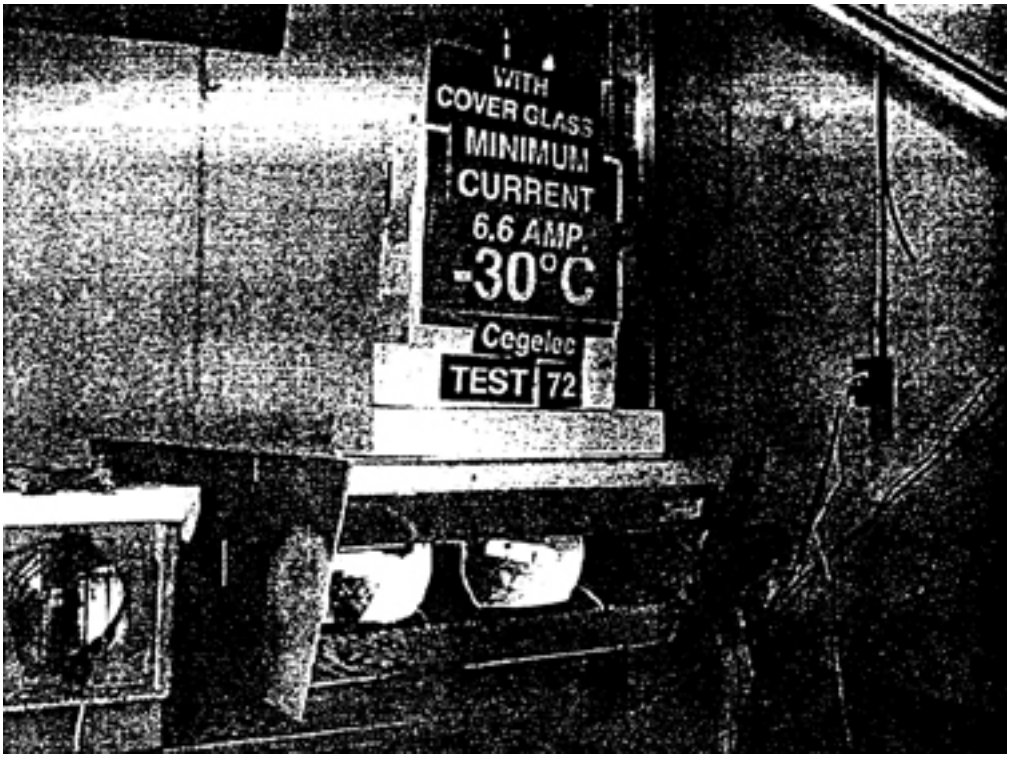
4. Test #70, post-test.



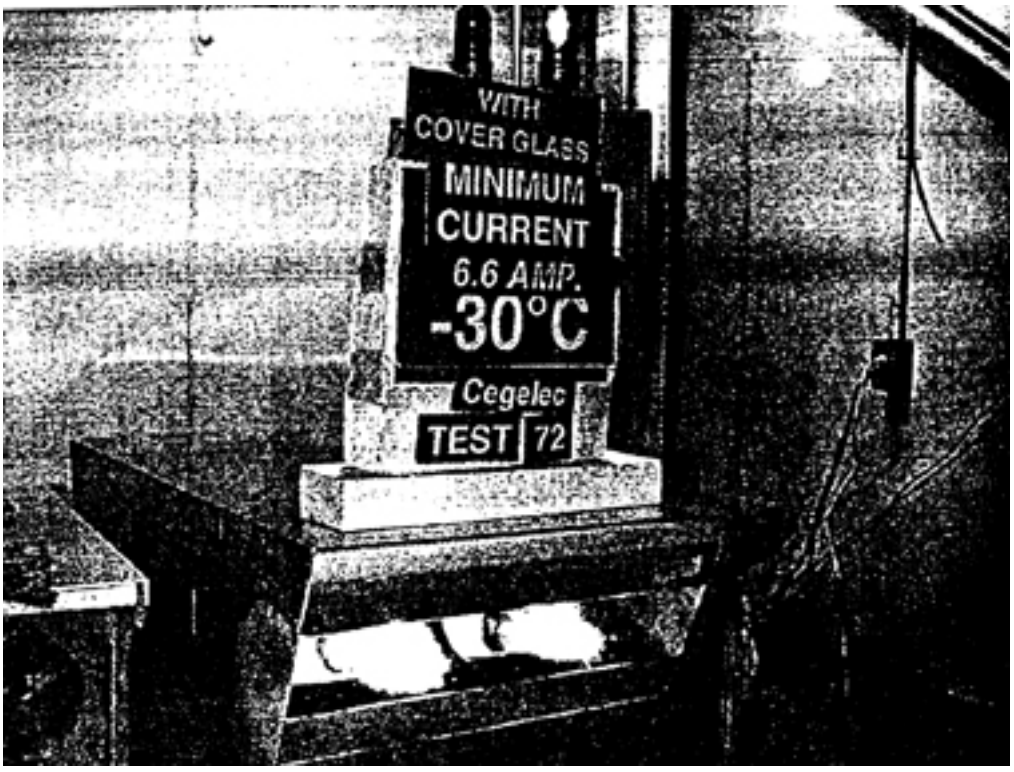
5. Test #71, pre-test.



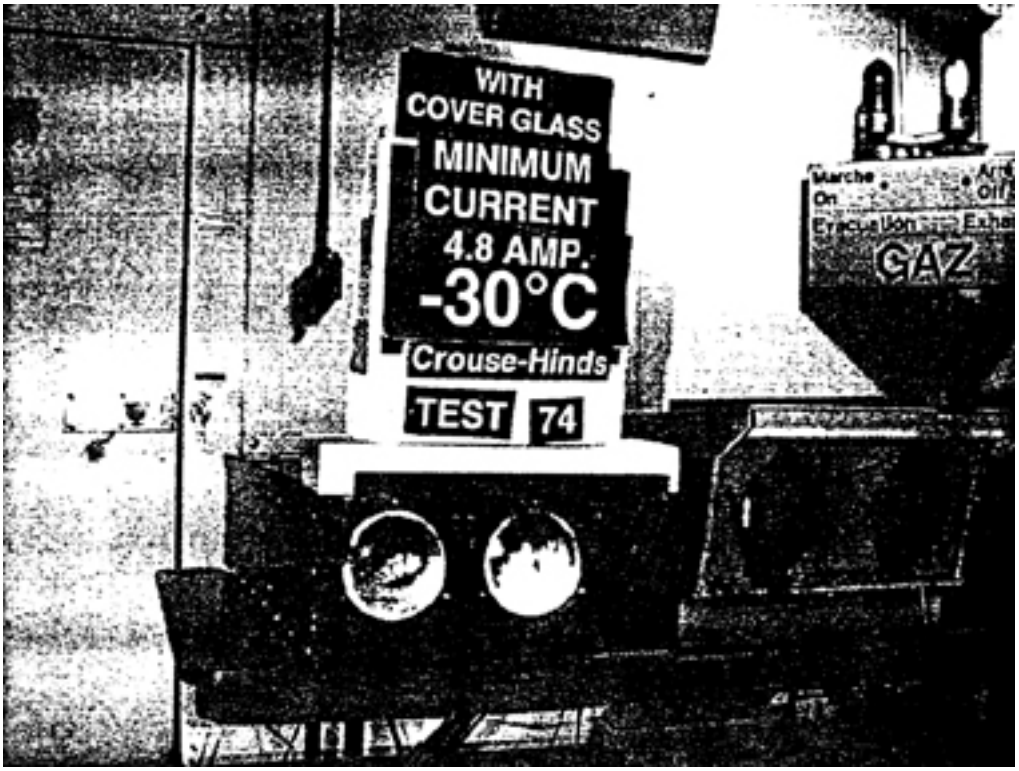
6. Test #71, post-test.



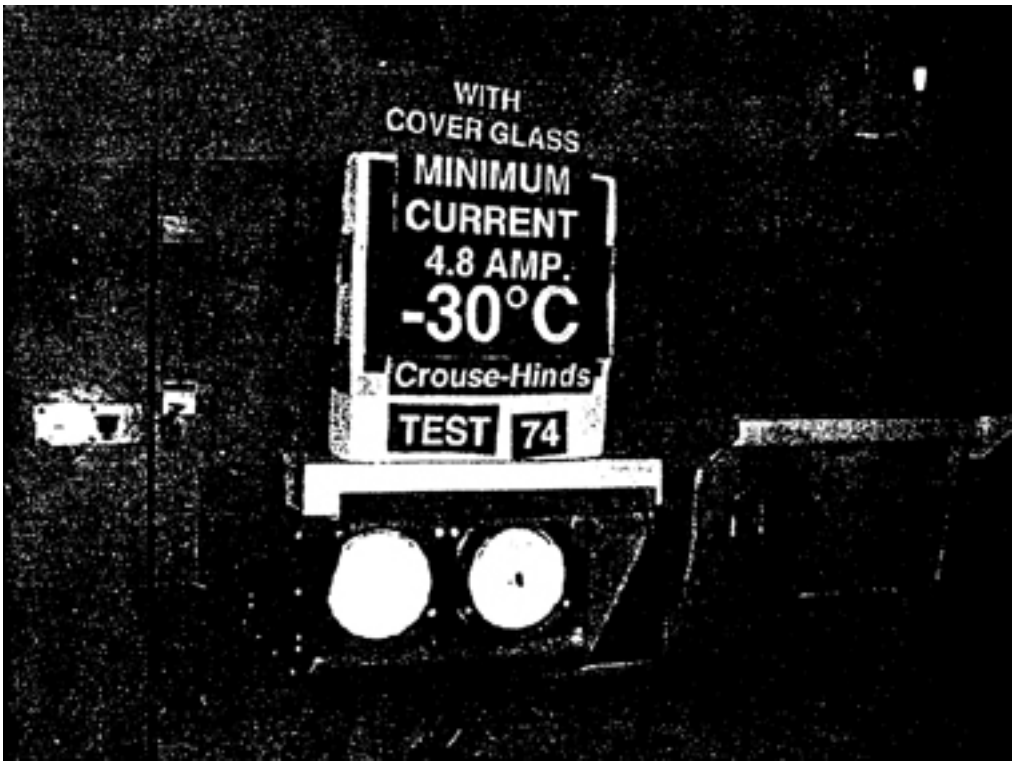
7. Test #72, pre-test.



8. Test #72, post-test.

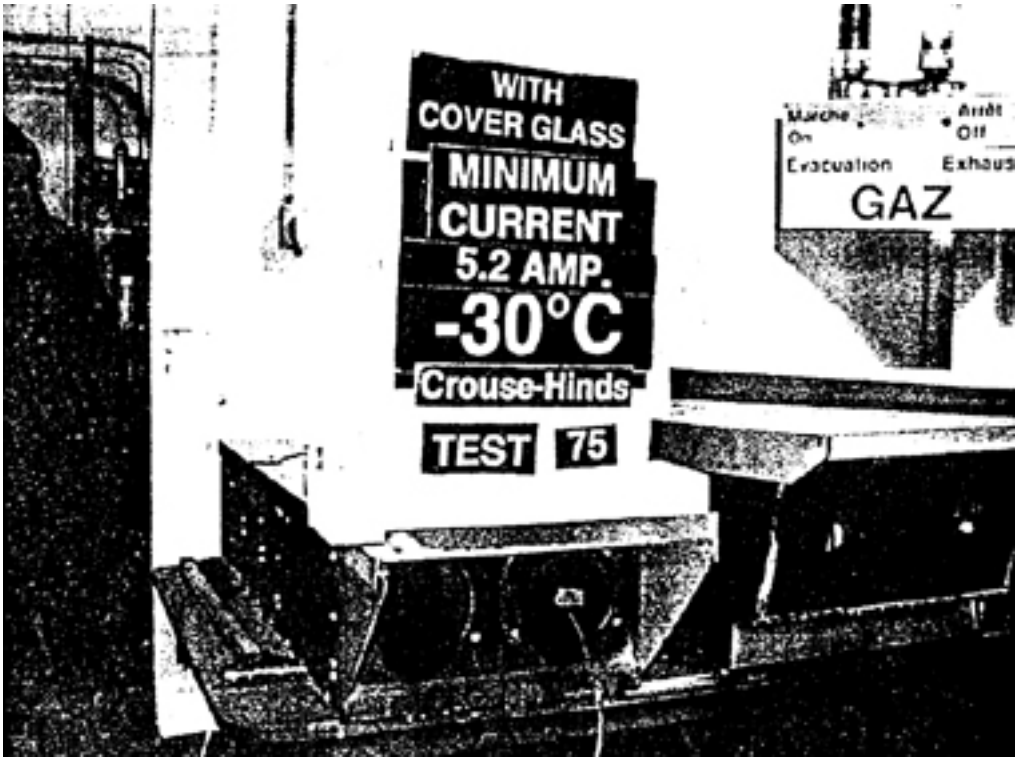


9. Test #74, pre-test.

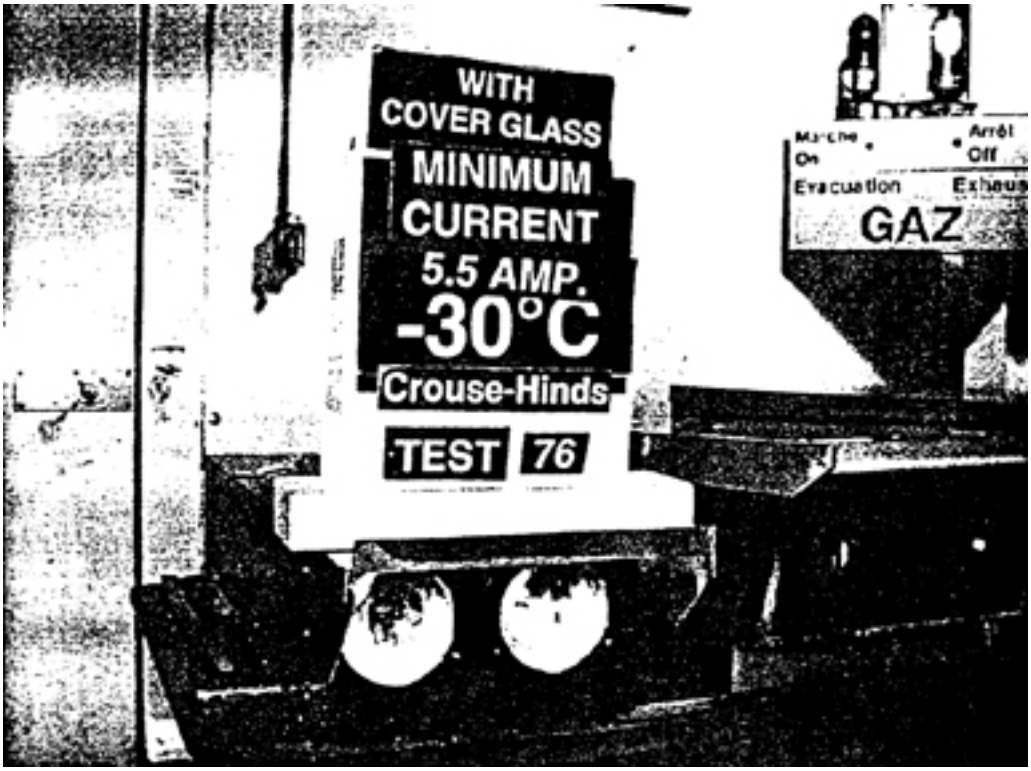


10. Test #74, post-test.

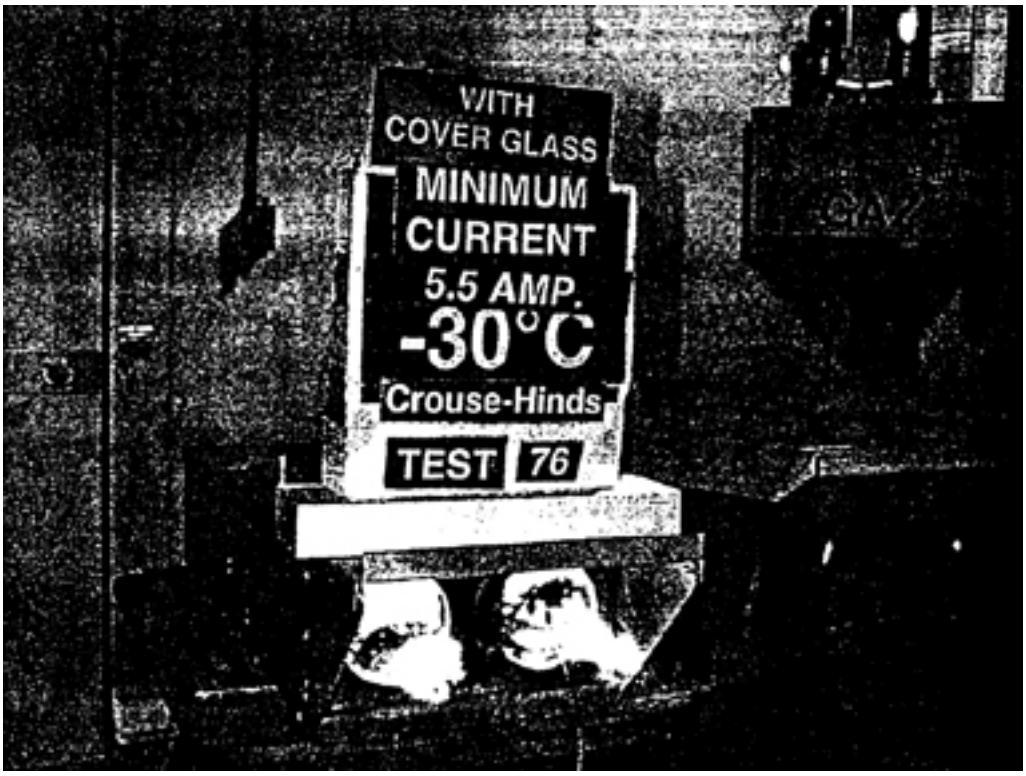
11. Test #75, pre-test.



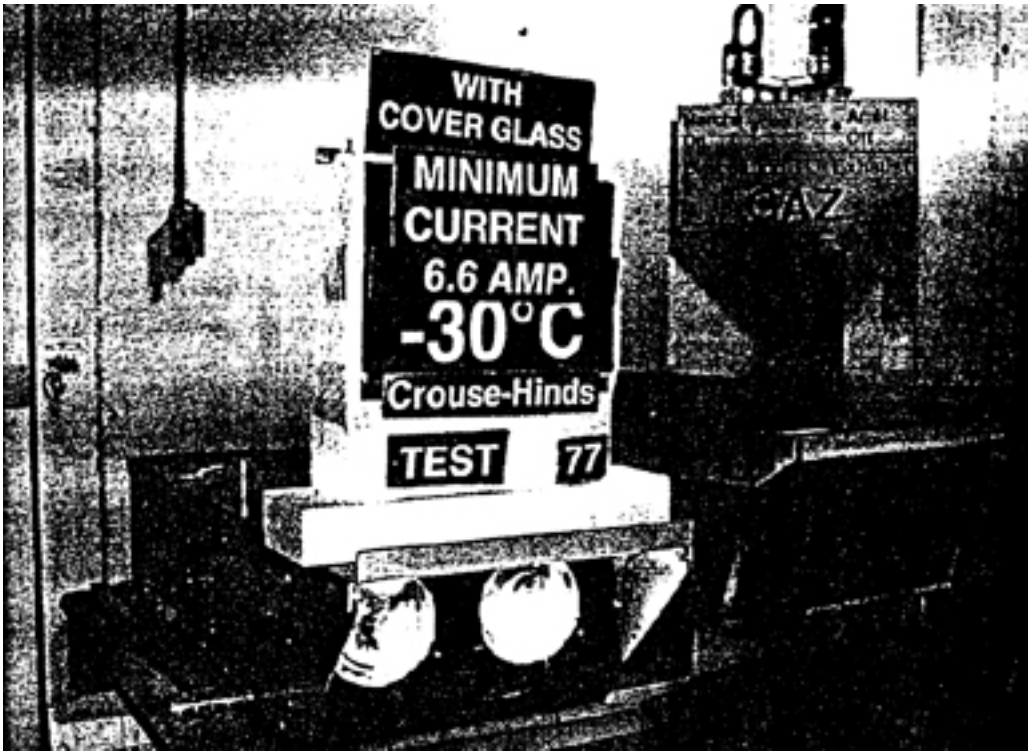
12. Test #75, post-test.



13. Test #76, pre-test.

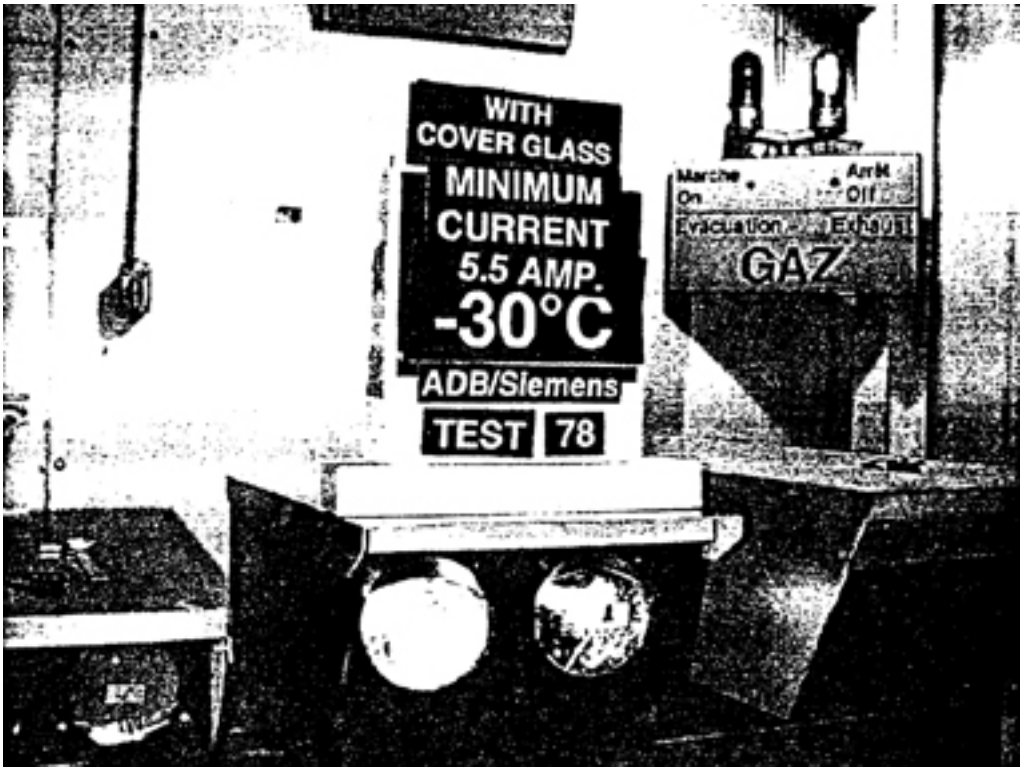


14. Test #76, post-test.

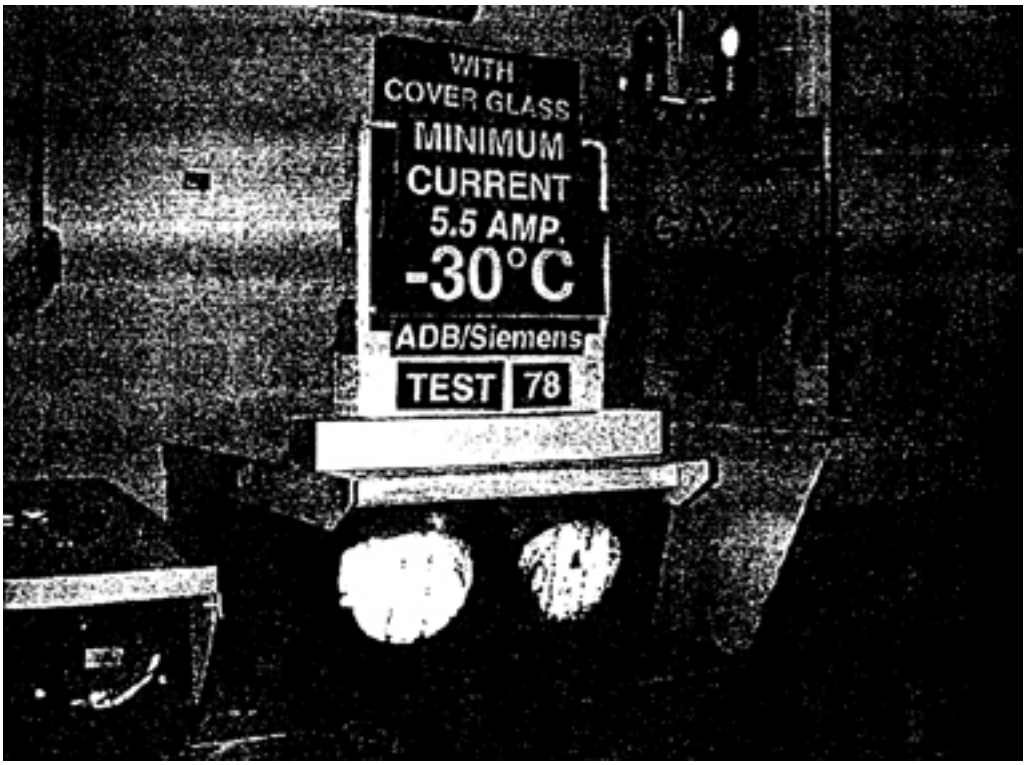


15. Test #77, pre-test.

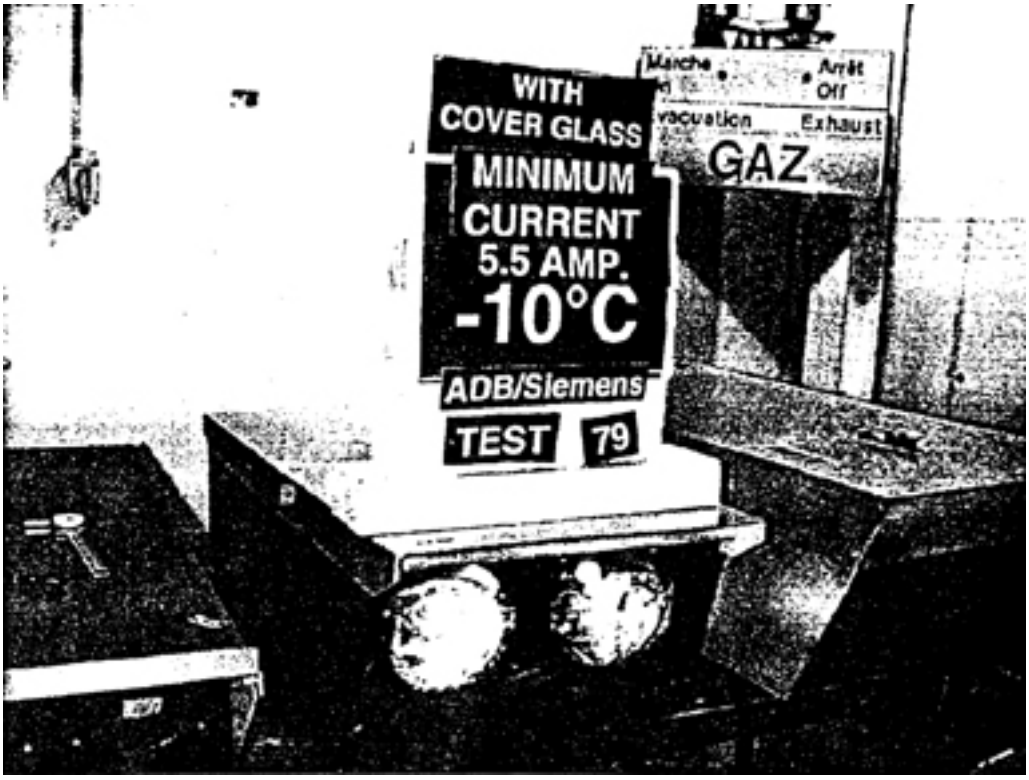
16. Test #77, post-test.



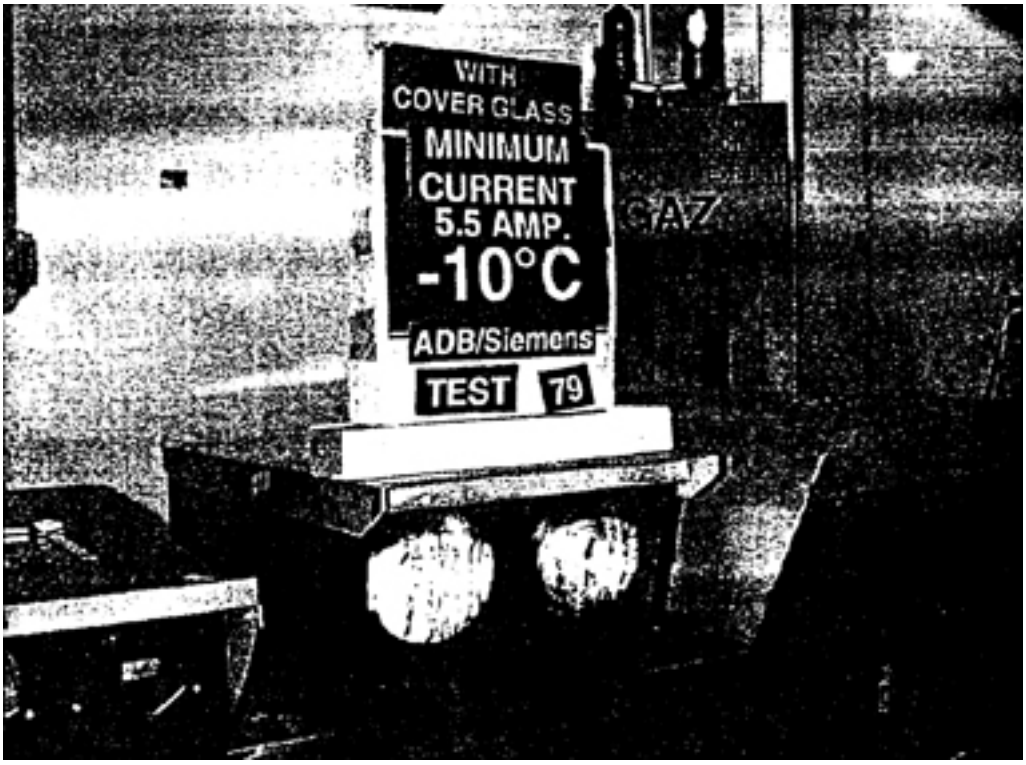
17. Test #78, pre-test.



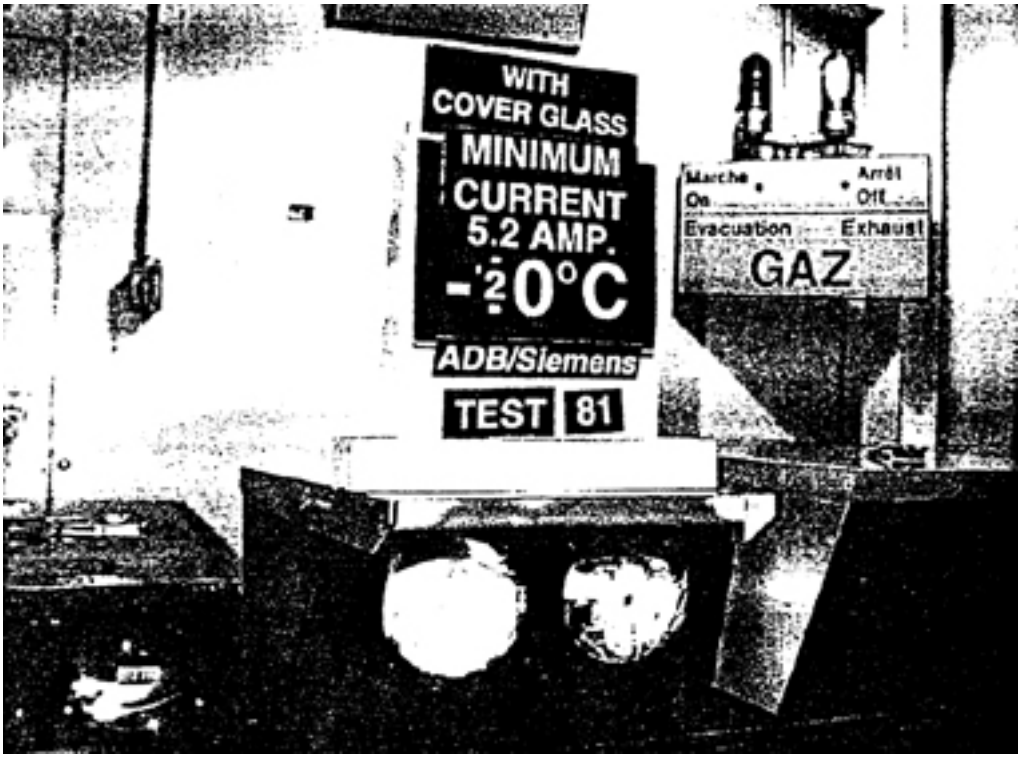
18. Test #78, post-test.



19. Test #79, pre-test.

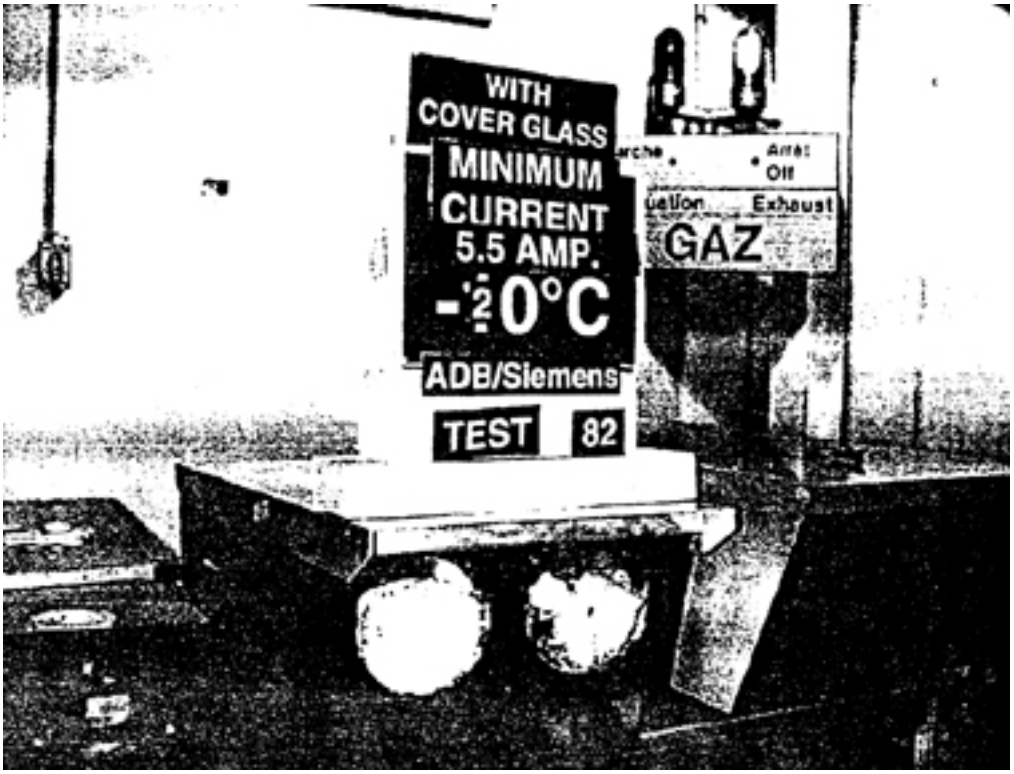


20. Test #79, post-test.

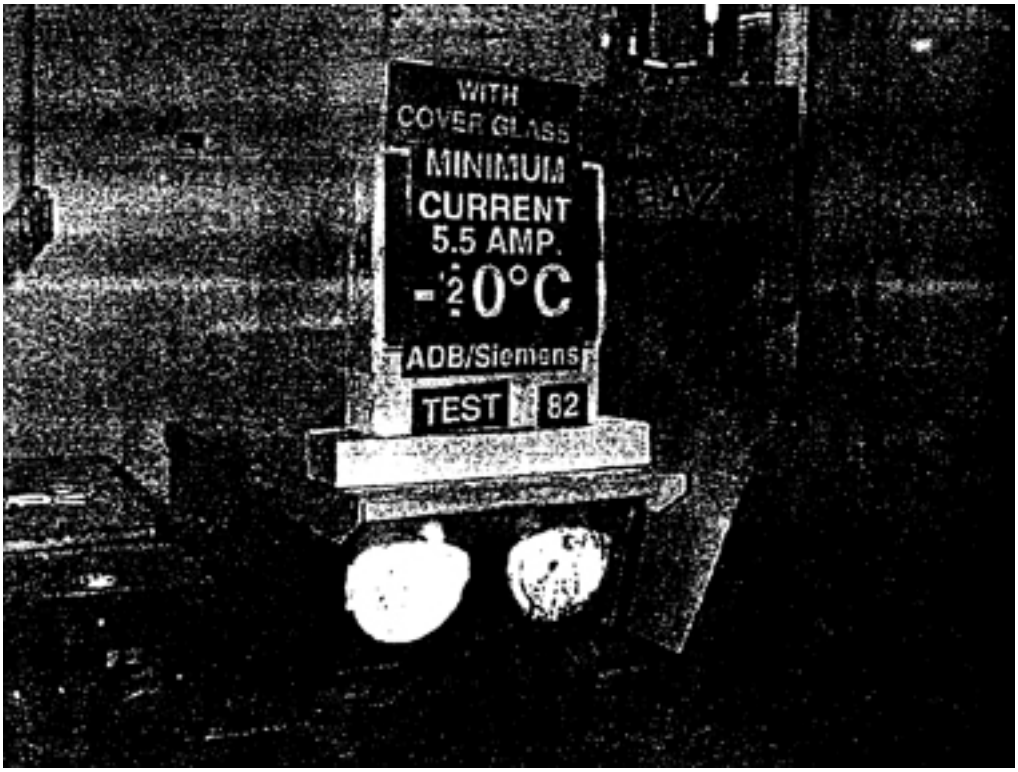


21. Test #81, pre-test.

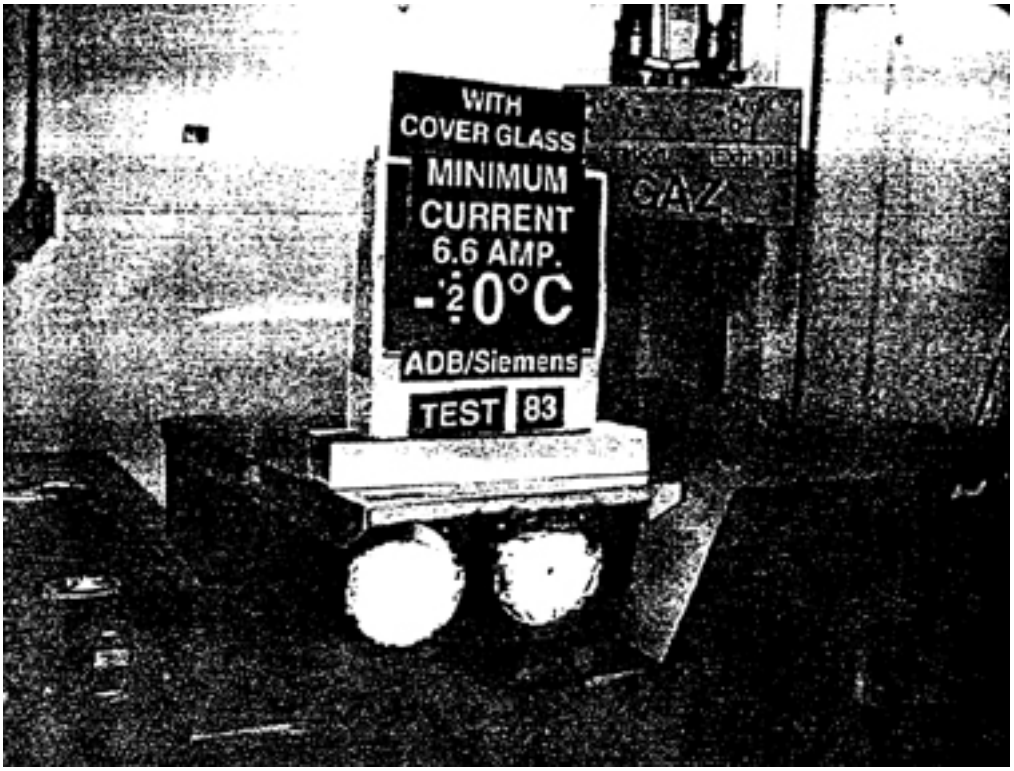
22. Test #81, post-test.



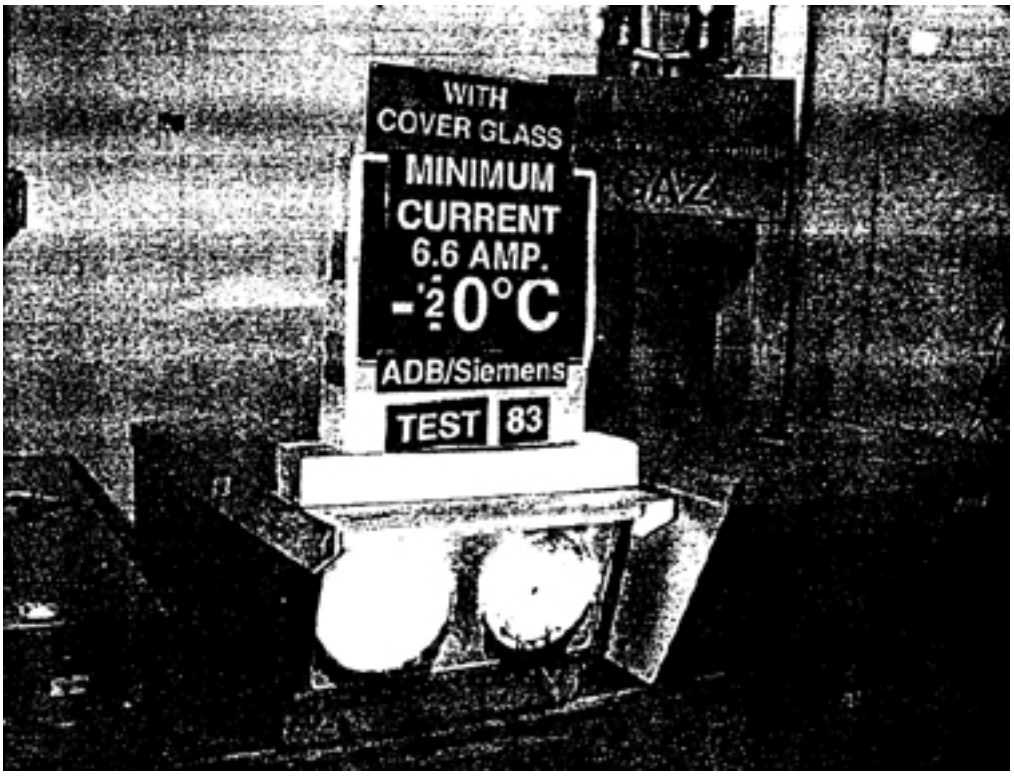
23. Test #82, pre-test.



24. Test #82, post-test.



25. Test #83, pre-test.



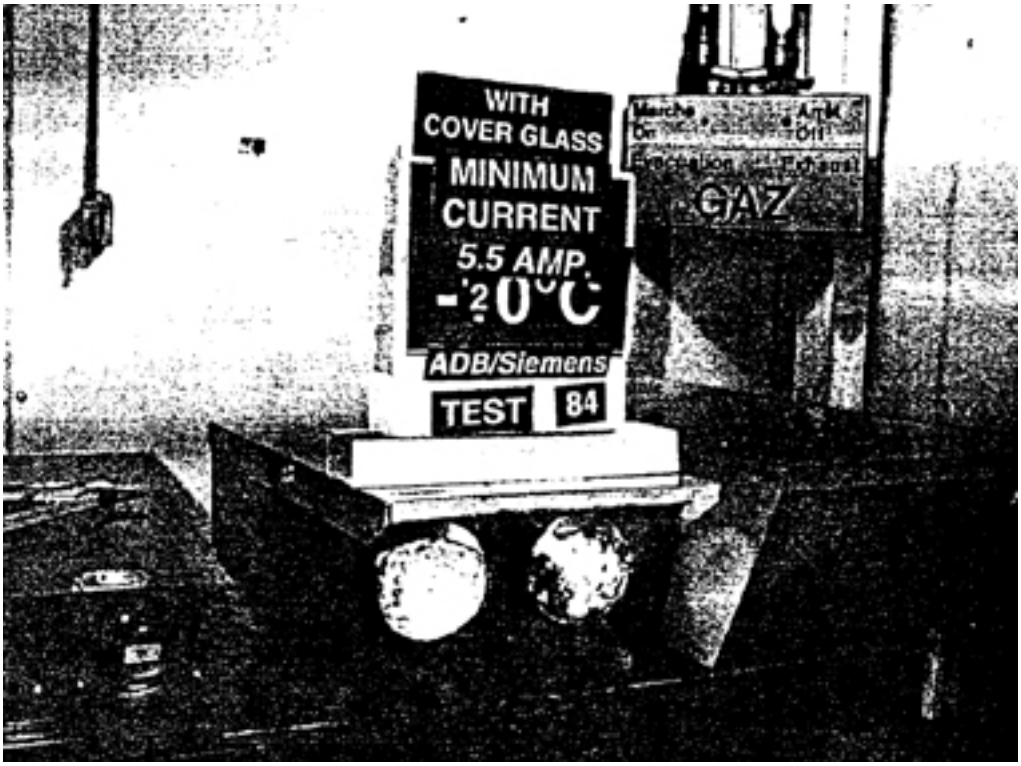
26. Test #83, post-test.

Intentionally left blank

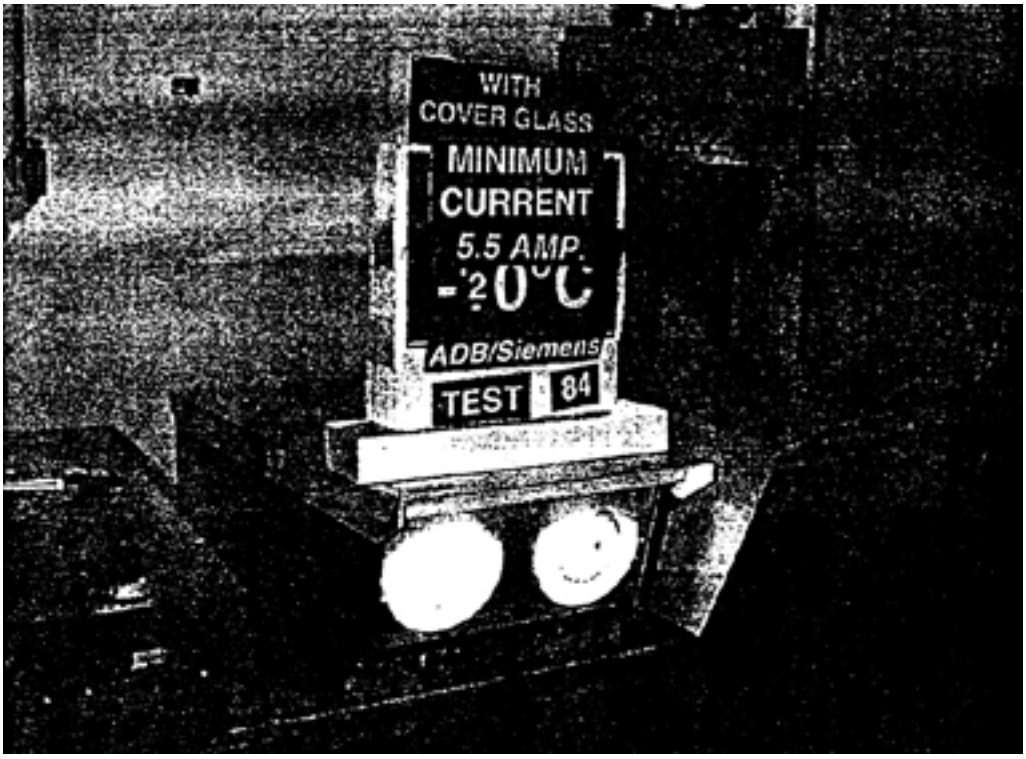
APPENDIX G

TEST PHOTOGRAPHS

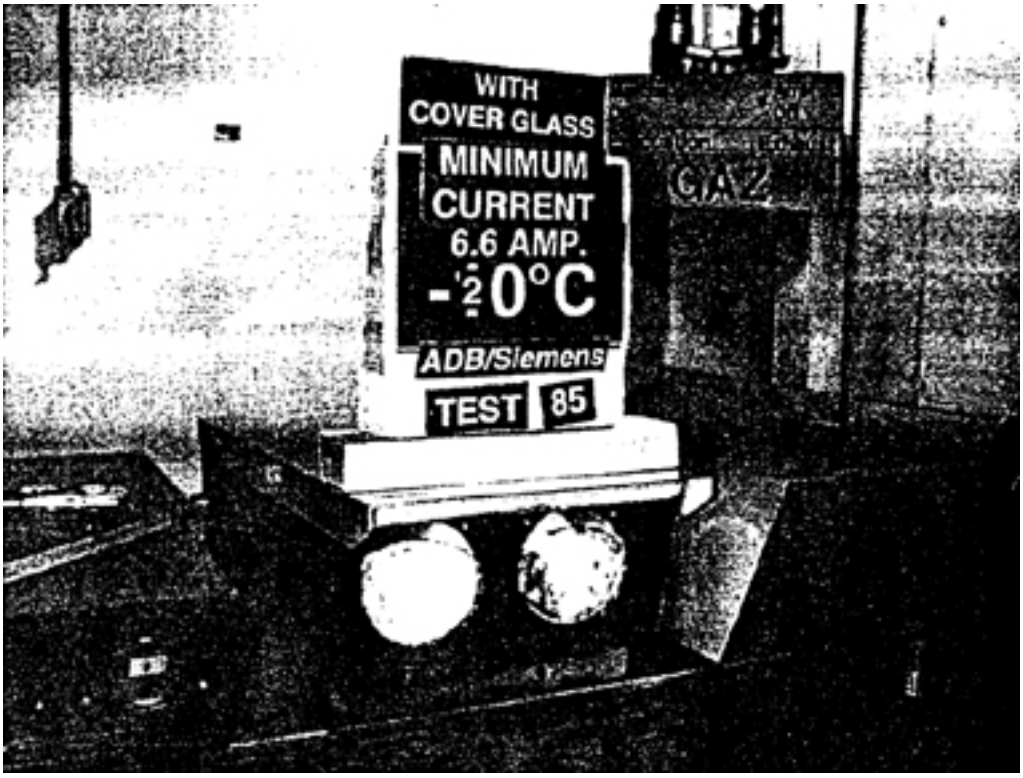
Intentionally left blank



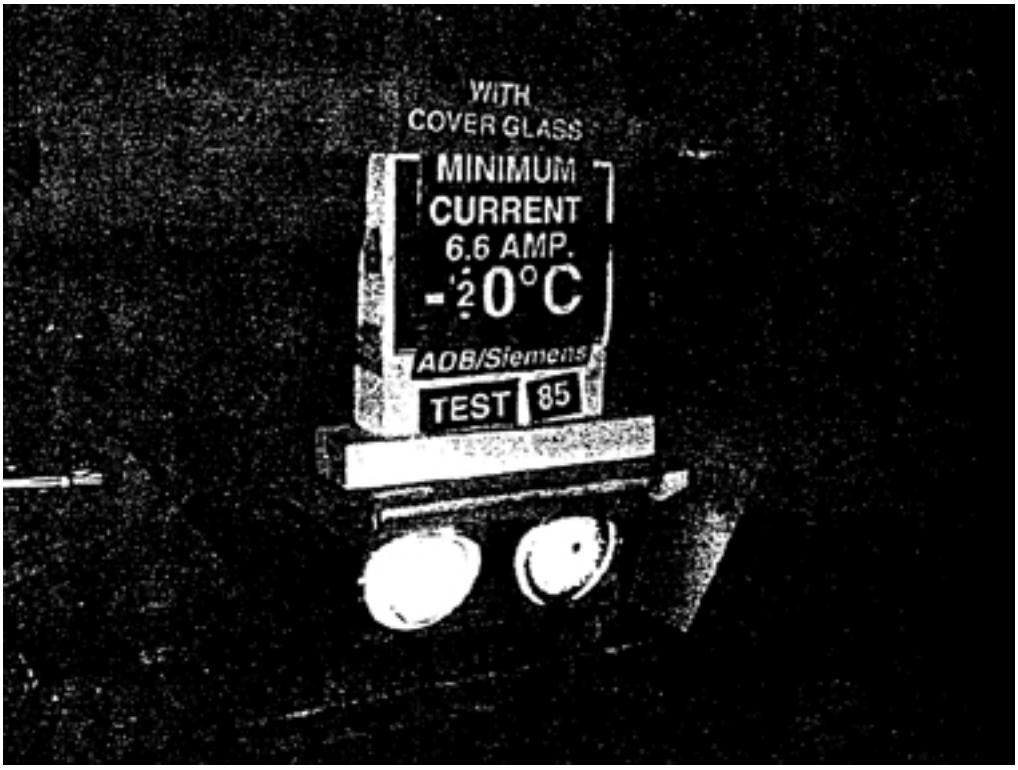
1. Test #84, pre-test.



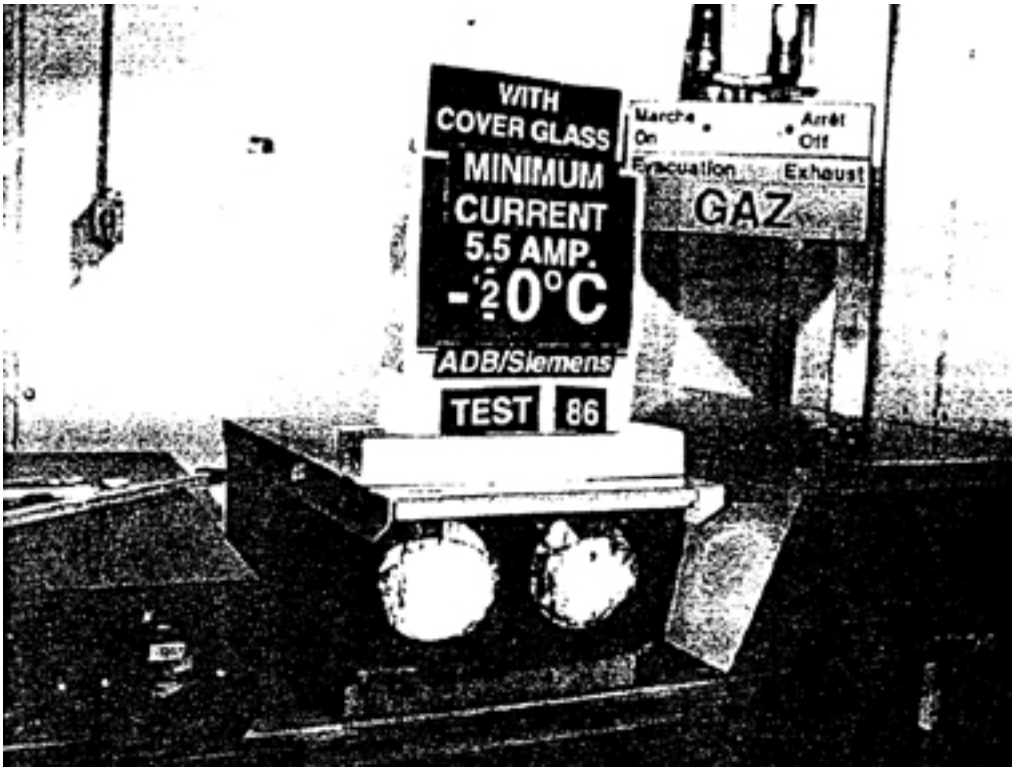
2. Test #84, post-test.



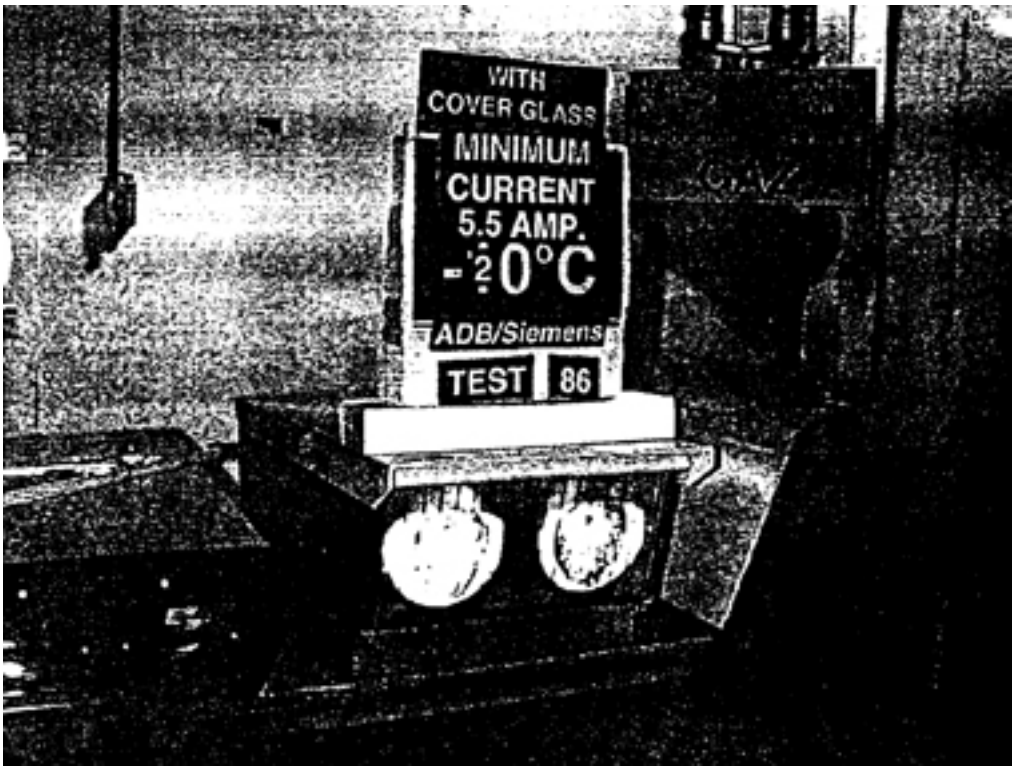
3. Test #85, pre-test.



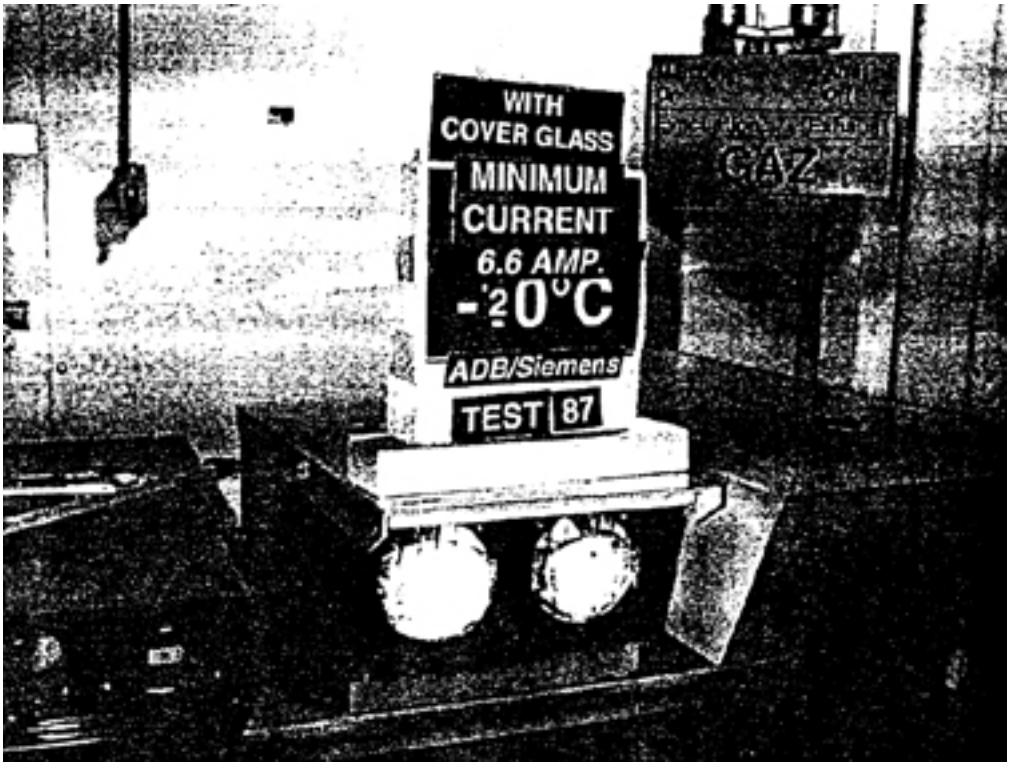
4. Test #85, post-test.



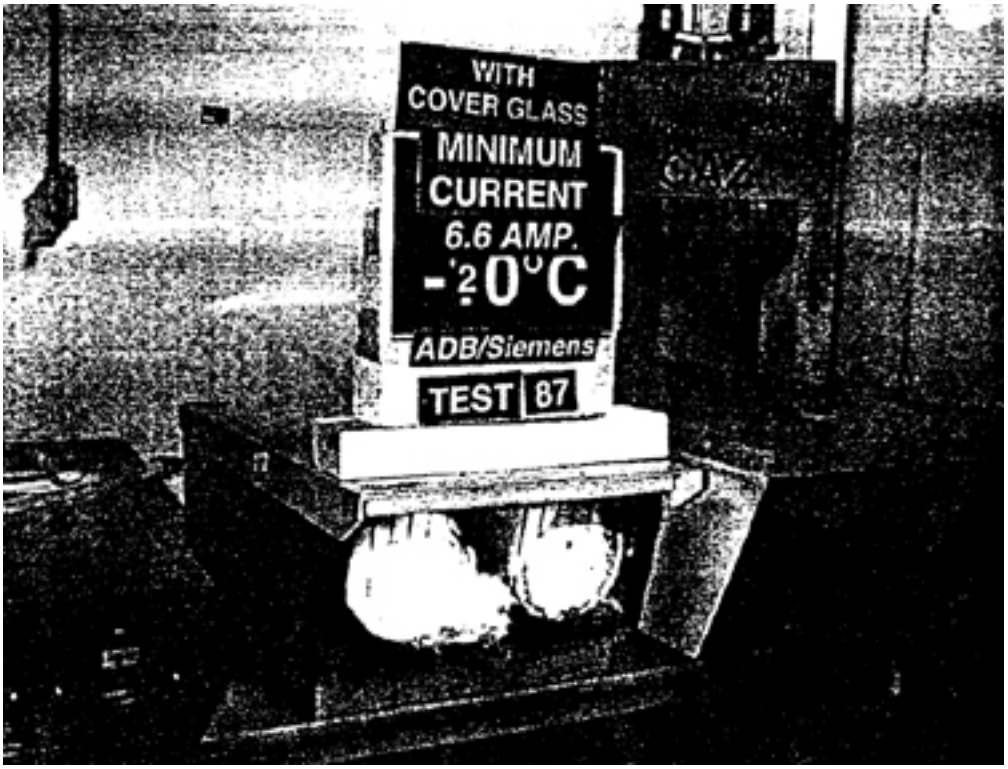
5. Test #86, pre-test.



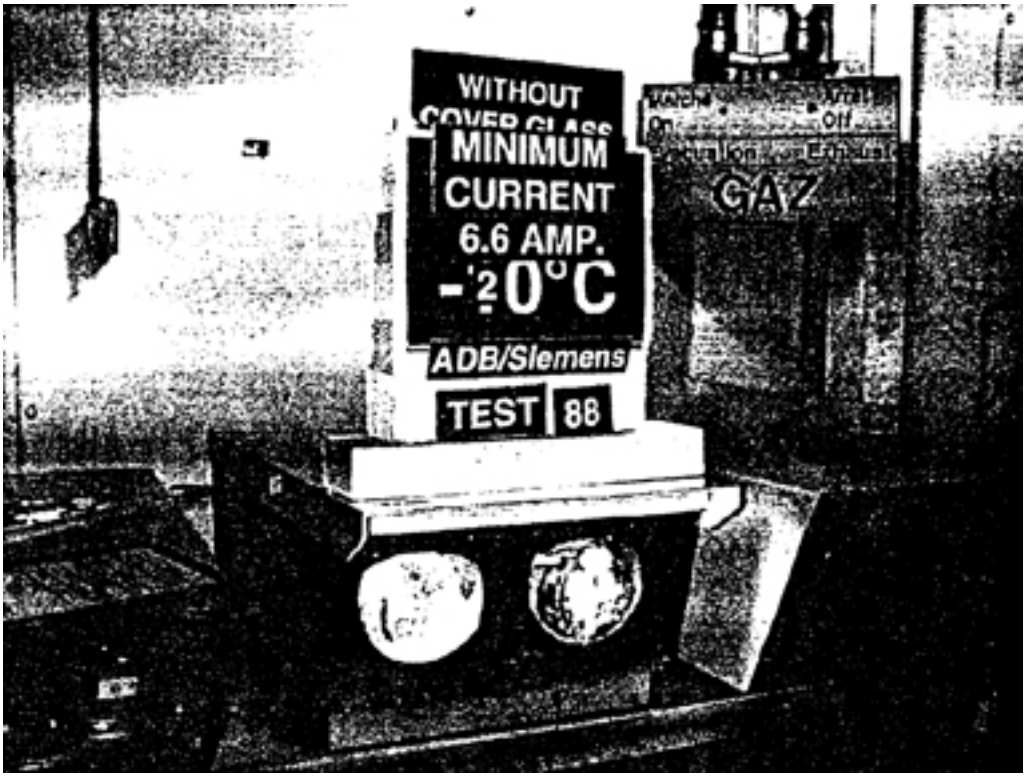
6. Test #86, post-test.



7. Test #87, pre-test.

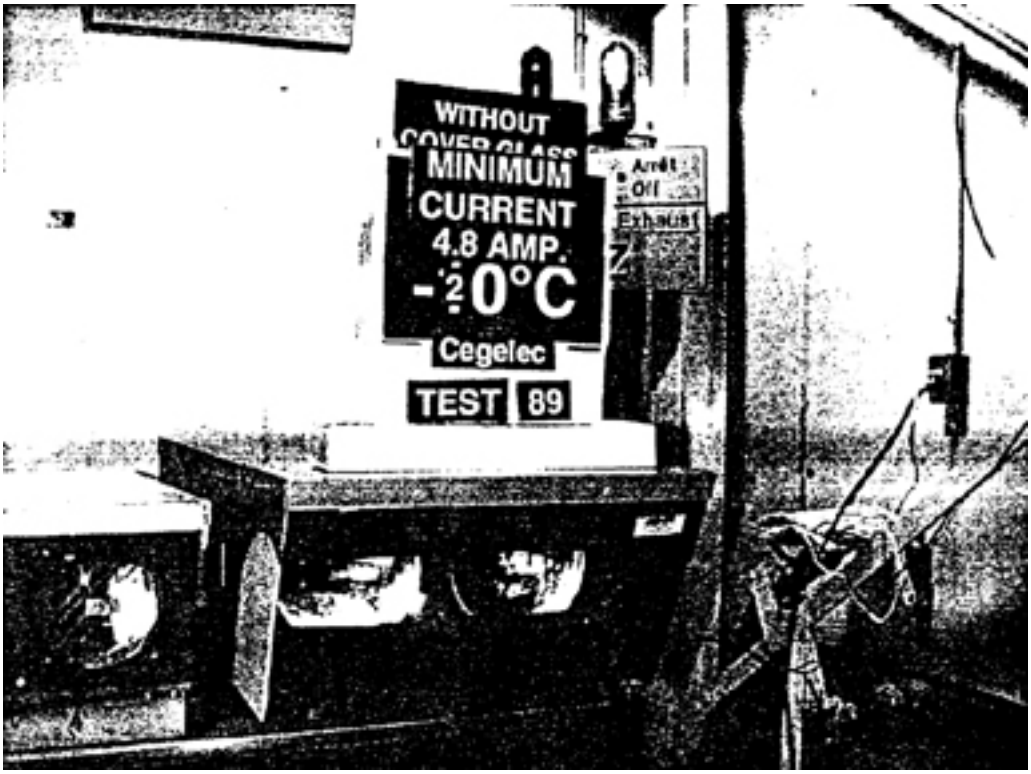


8. Test #87, post-test.

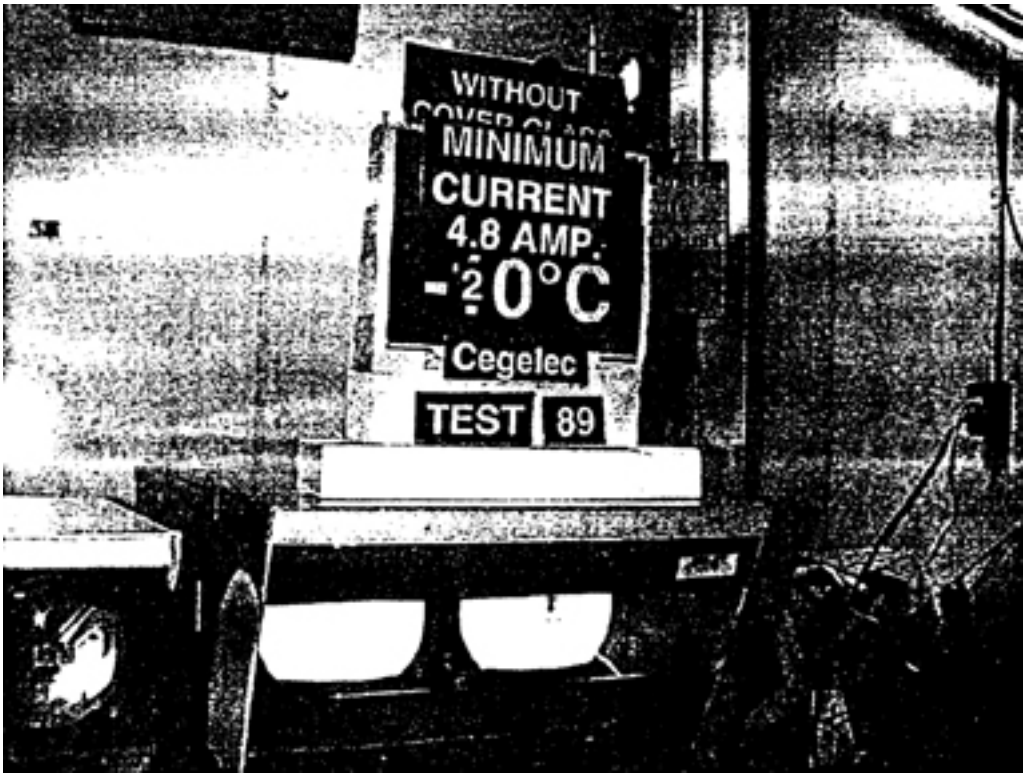


9. Test #88, pre-test.

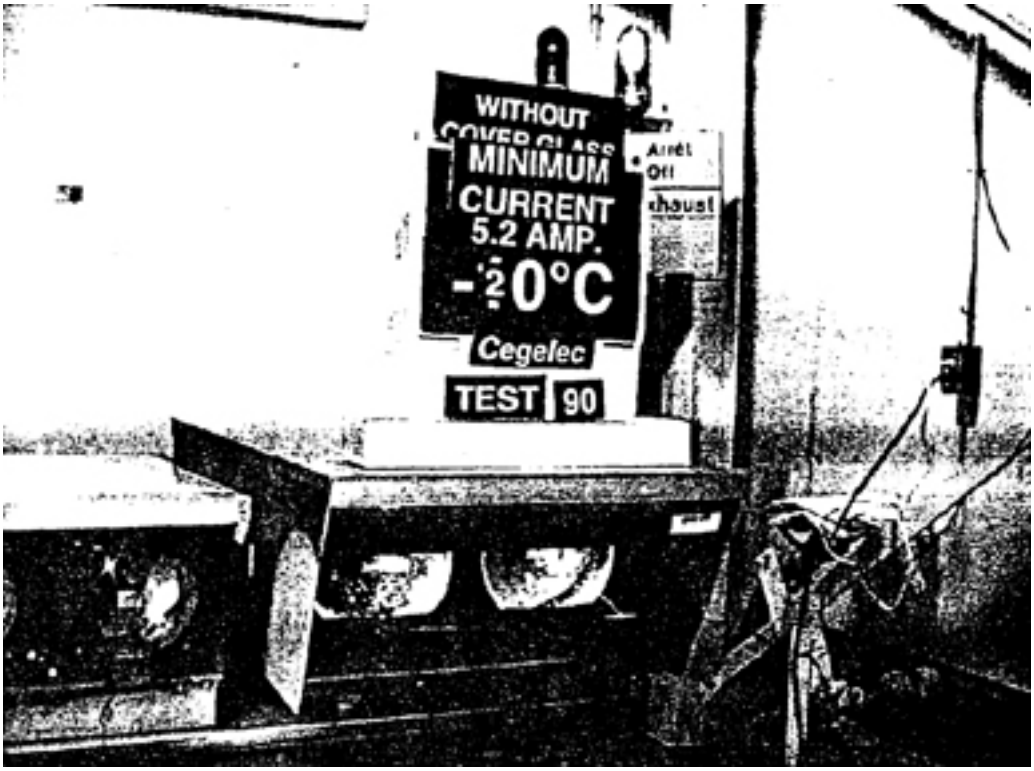
10. Test #88, post-test.



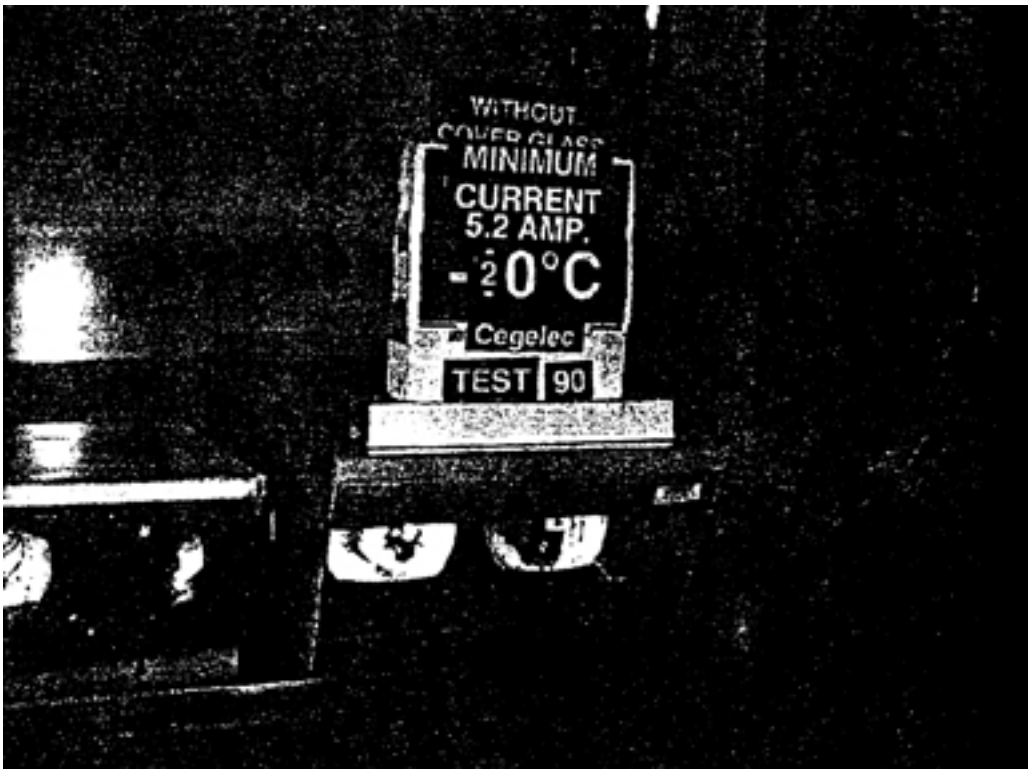
11. Test #89, pre-test.



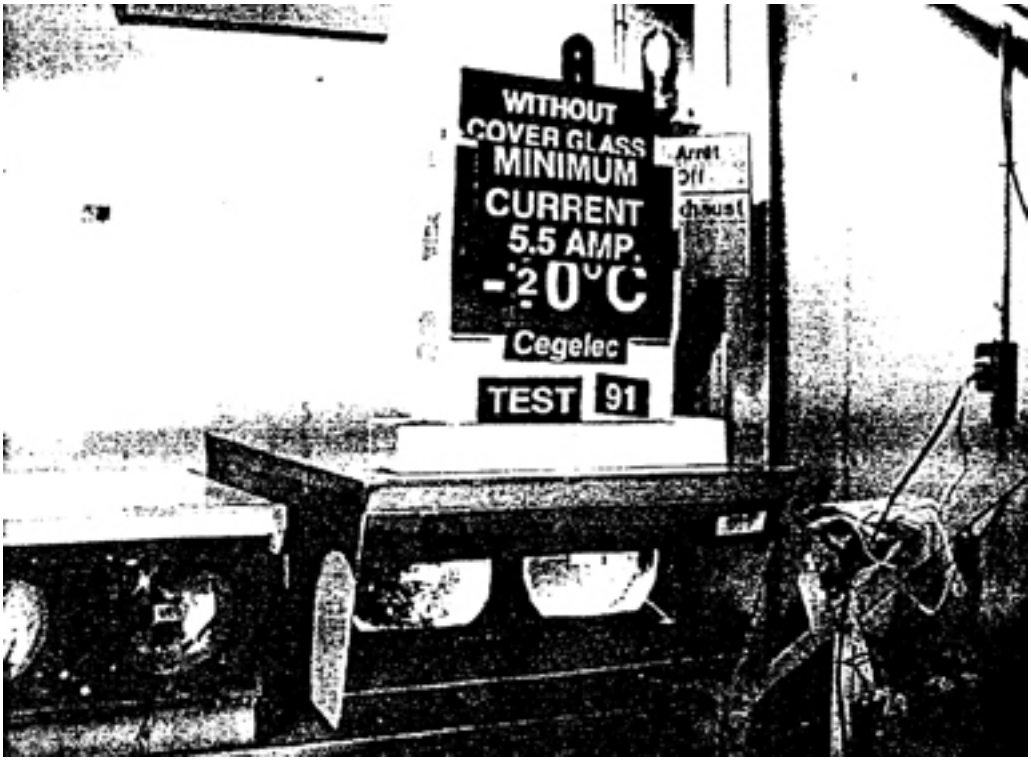
12. Test #89, post-test.



13. Test #90, pre-test.

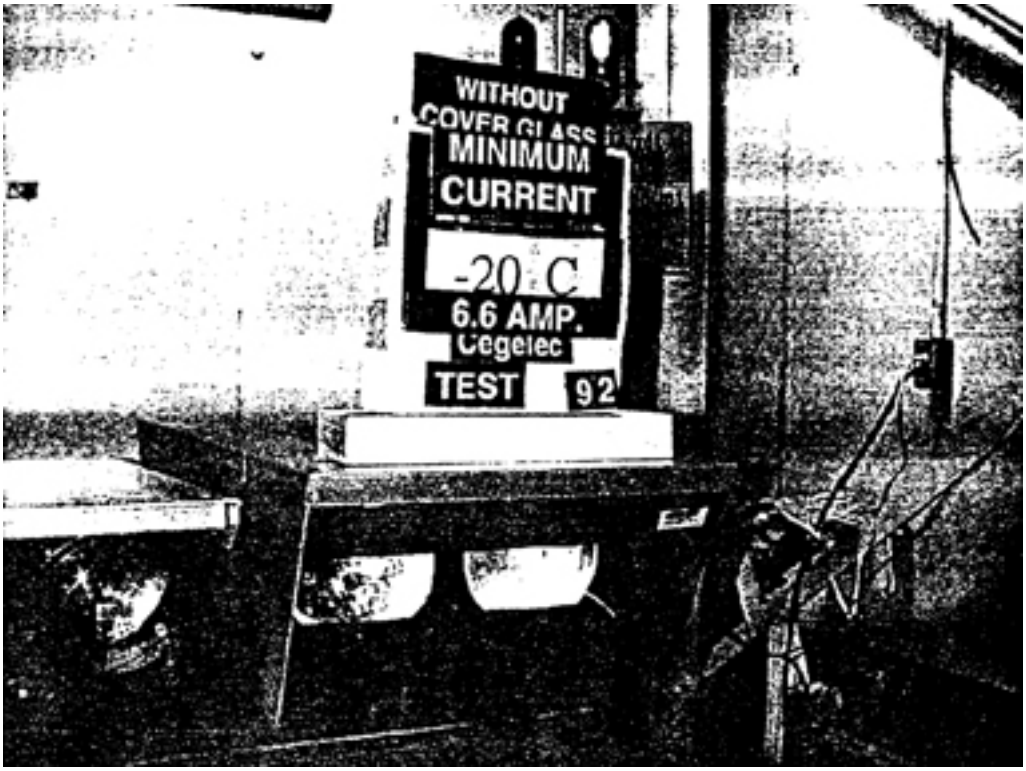


14. Test #90, post-test.

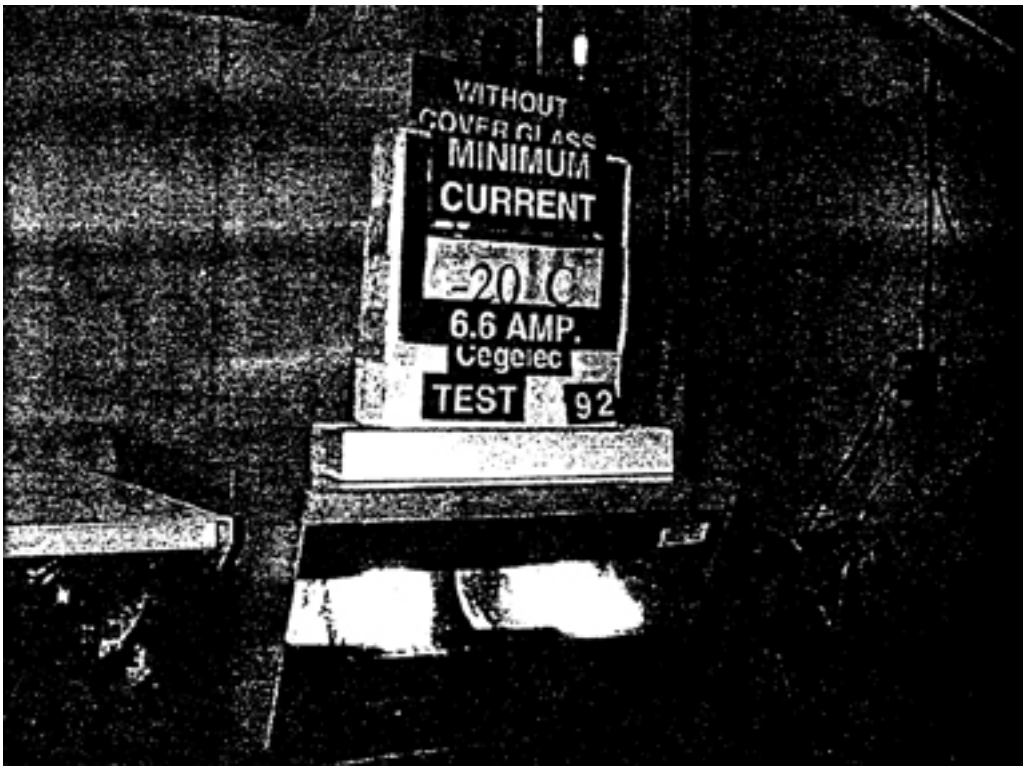


15. Test #91, pre-test.

16. Test #91, post-test.

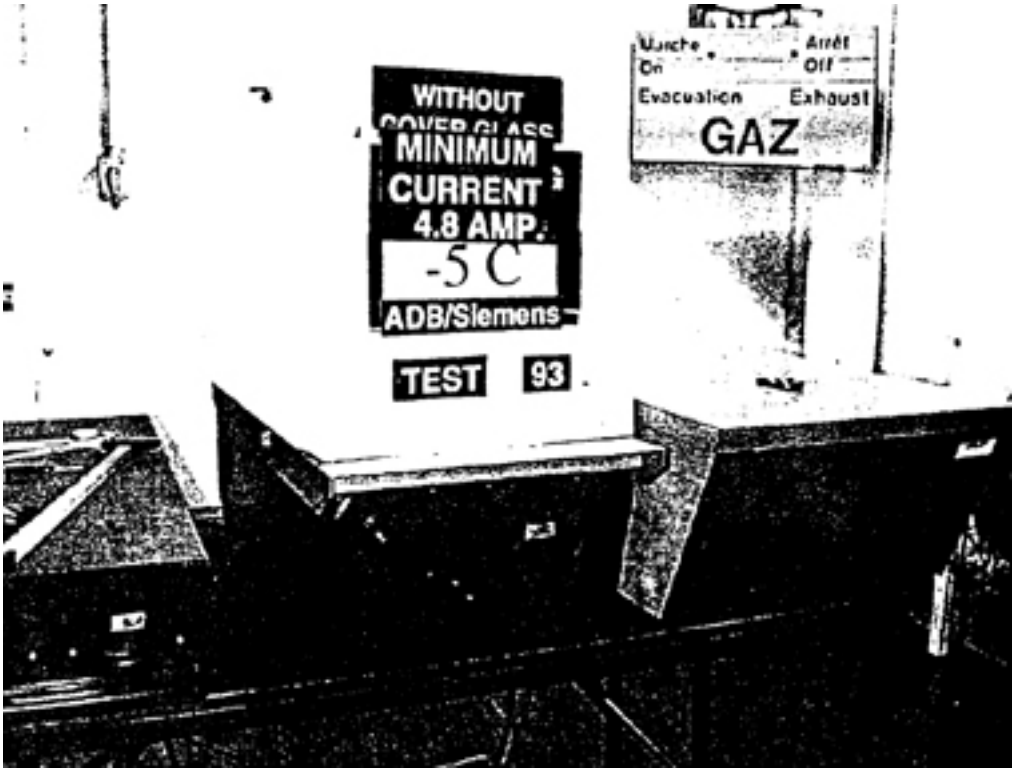


17. Test #92, pre-test.

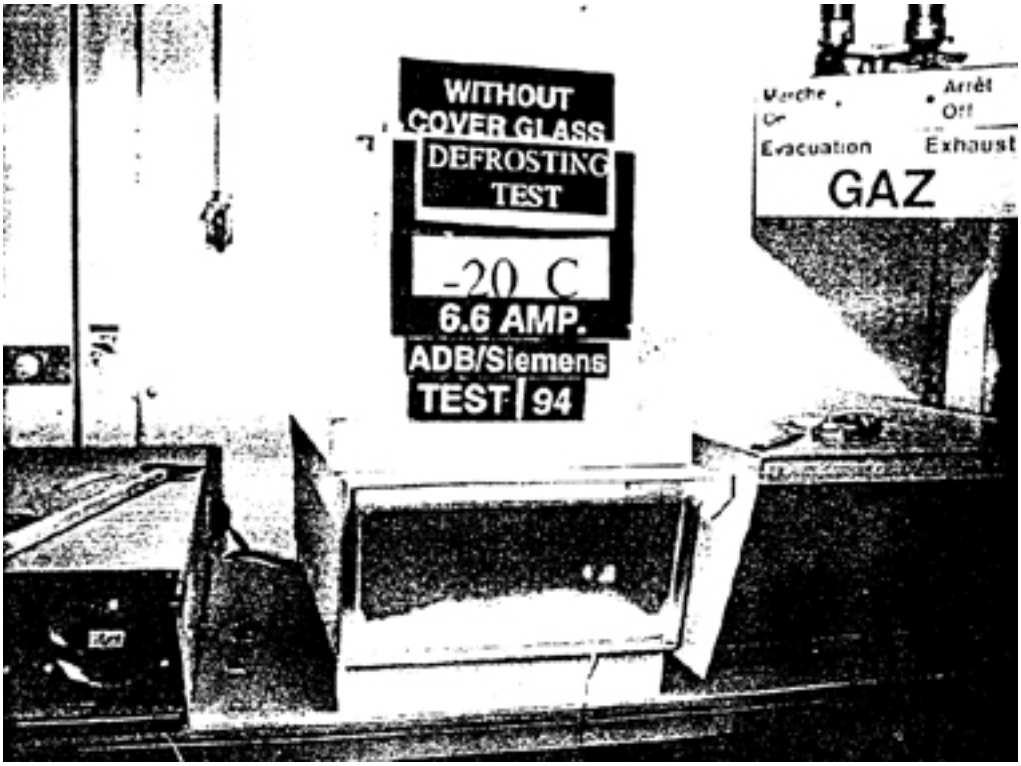


18. Test #92, post-test.

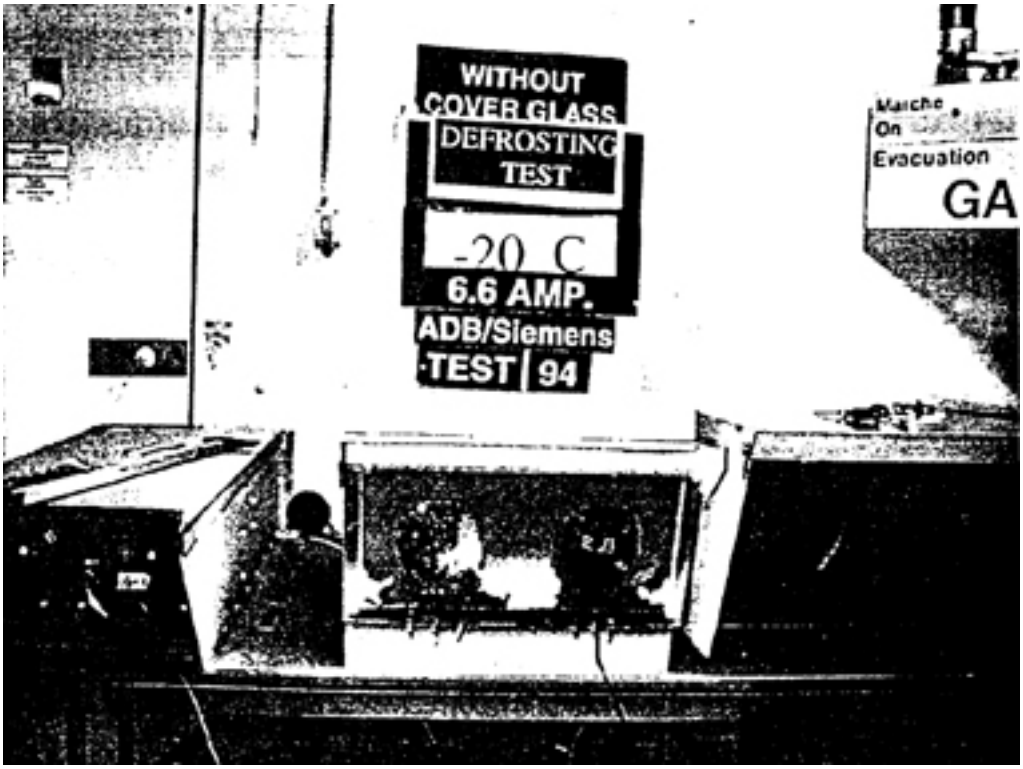
19. Test #93, pre-test.



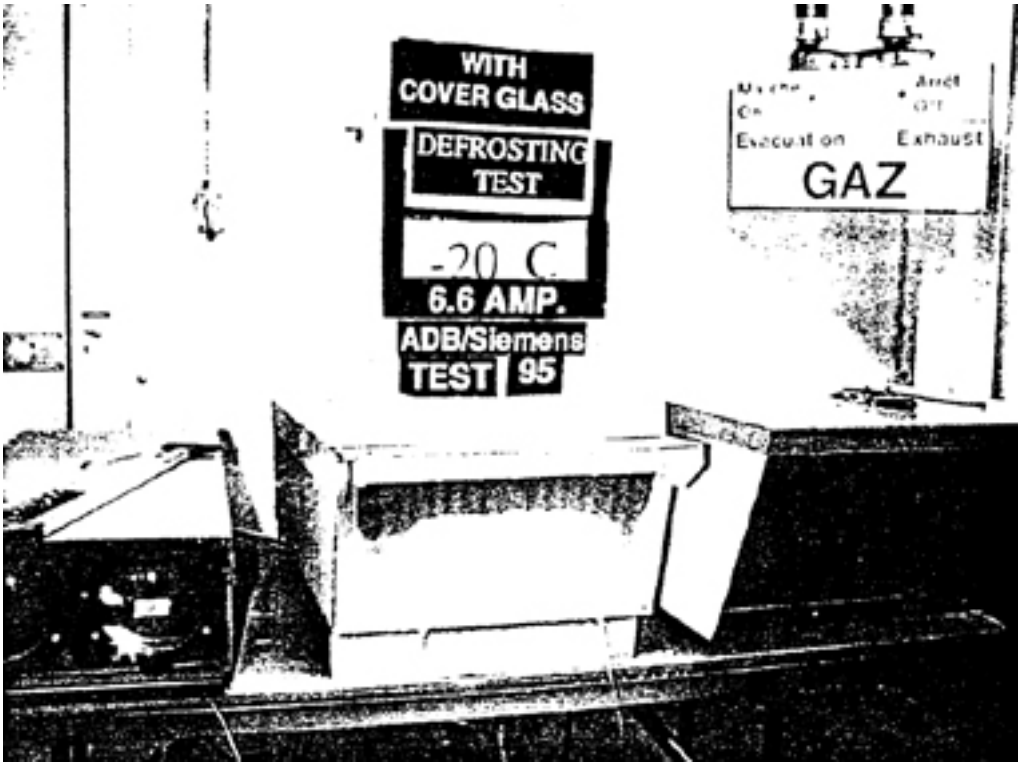
20. Test #93, post-test.



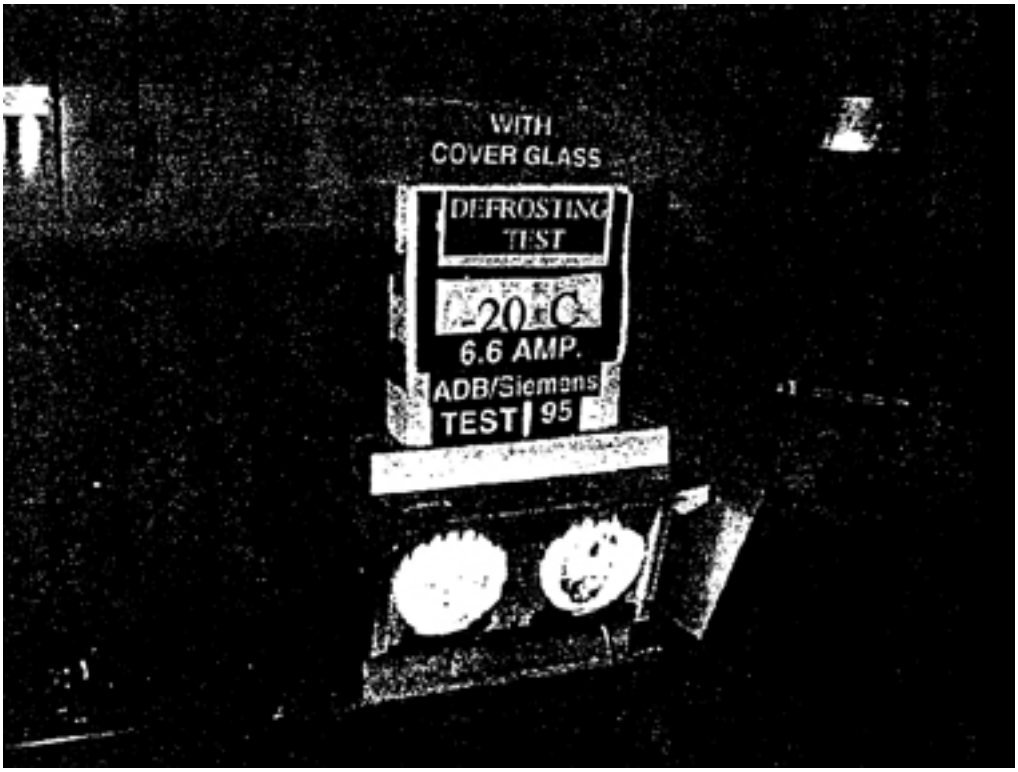
21. Test #94, pre-test.



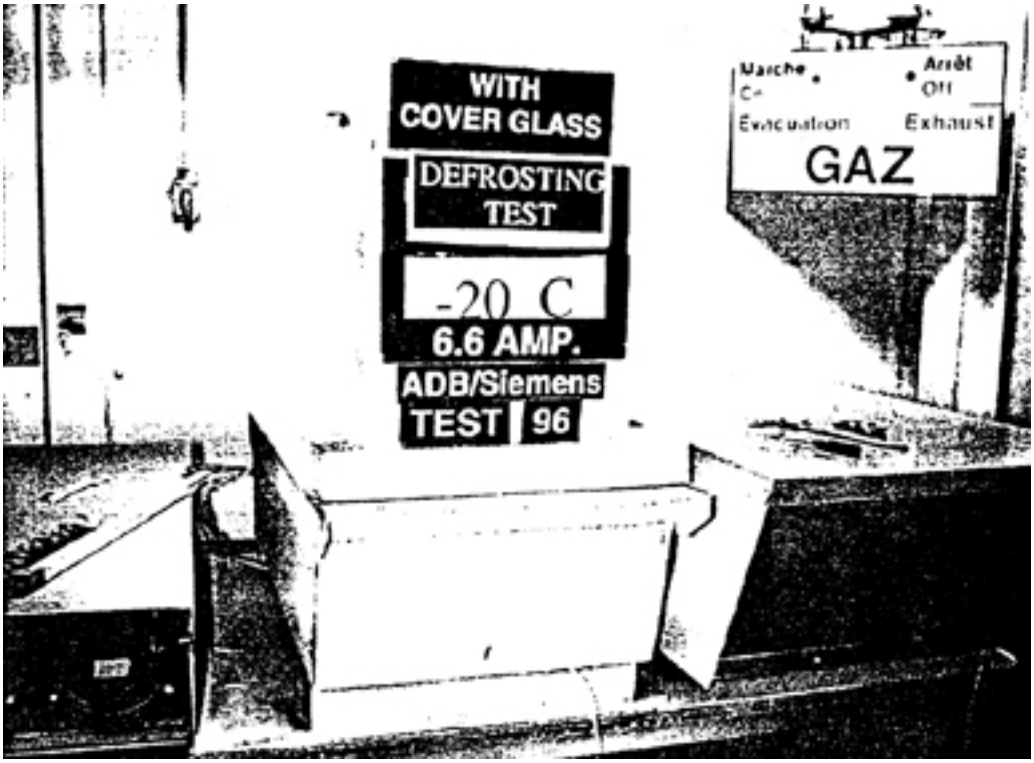
22. Test #94, post-test.



23. Test #95, pre-test.

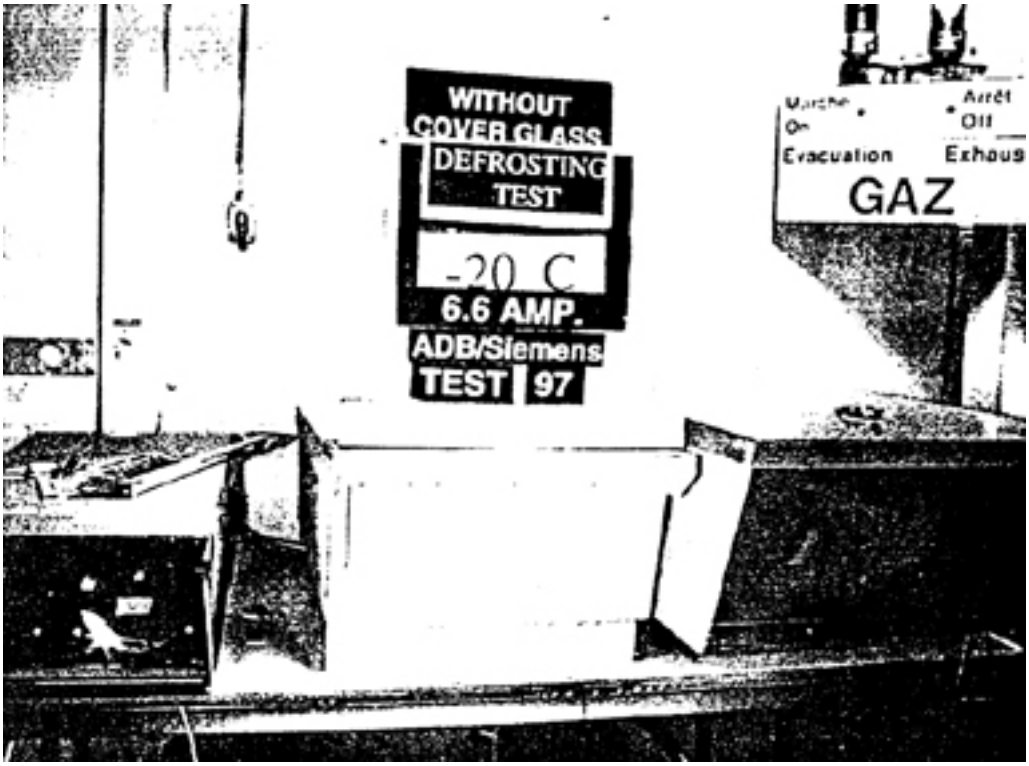


24. Test #95, post-test.

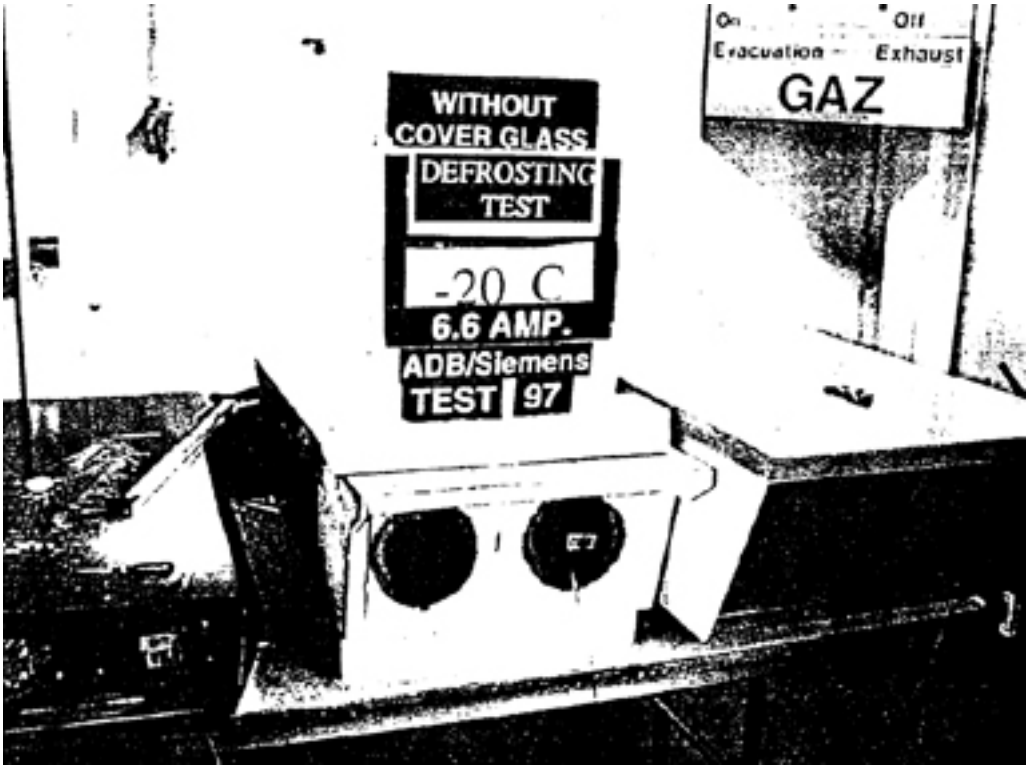


25. Test #96, pre-test.

26. Test #96, post-test.

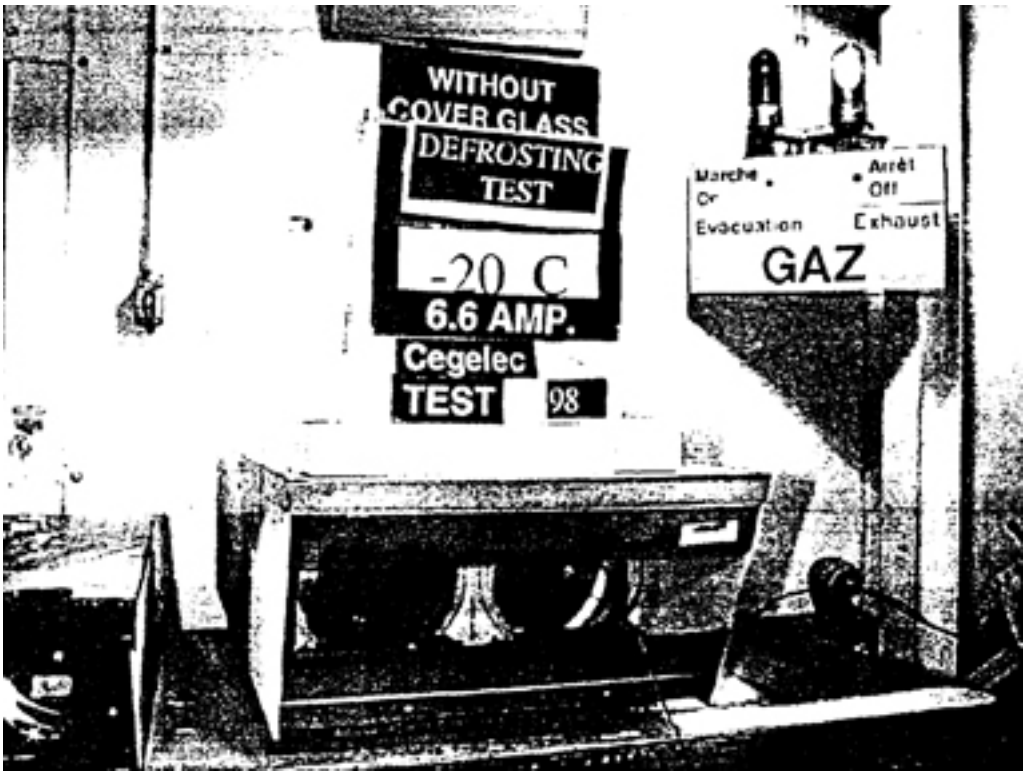


27. Test #97, pre-test.

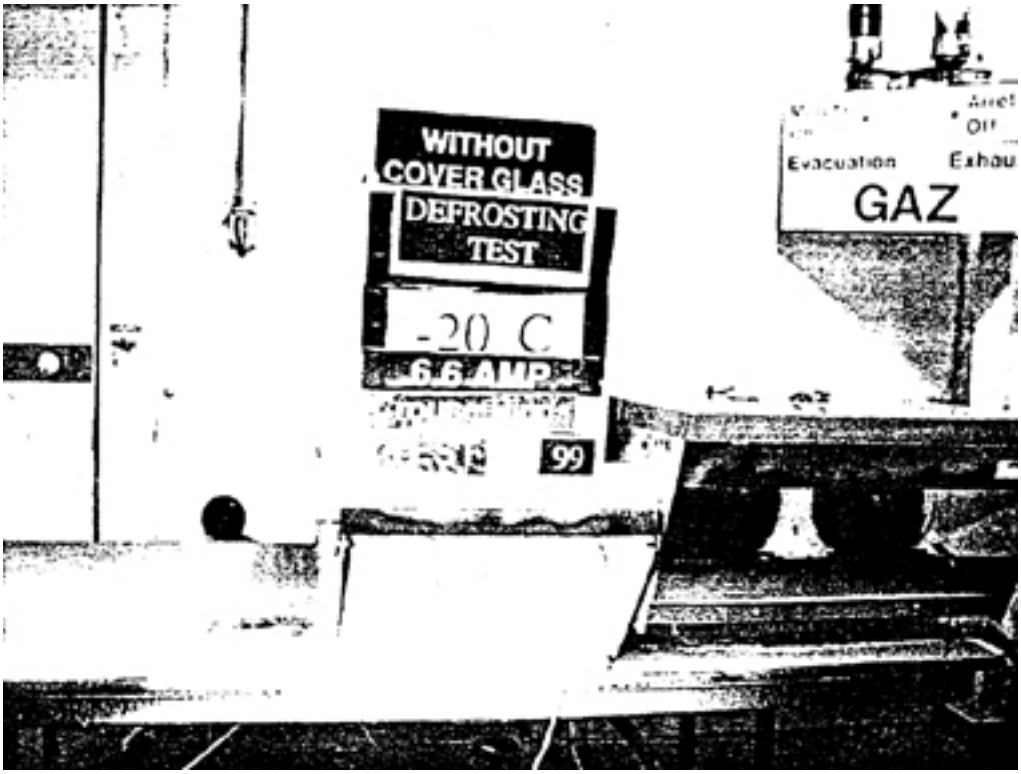


28. Test #97, post-test.

29. Test #98, pre-test.



30. Test #98, post-test.



31. Test #99, pre-test.

32. Test #99, post-test.