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SYNOPSIS OF INSULATION PROBLEMS AT YELLOWTAIL POWERPLANT

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16. ABSTRACT

A synopsis of insulation problems at Yellowtail Powerplant is presented along with the dissection results of a faulted portion of a coil from the powerplant.

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SYNOPSIS OF INSULATION PROBLEMS AT YELLOWTAIL POWERPLANT

by
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October 1983

Power and Instrumentation Branch
Division of Research and Laboratory Services
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Denver, Colorado

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UNITED STATES DEPARTMENT OF THE INTERIOR ★ BUREAU OF RECLAMATION

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INTRODUCTION AND CONCLUSIONS

On November 19, 1980, unit 3 at Yellowtail Powerplant "relayed off" (shut down) with a line-to-ground fault on phase A. Through subsequent testing, the fault was located on the line end coil of one of the parallel groups. The faulted portion of the coil was removed and a half-coil splice was made by Westinghouse personnel.

Dissection of the faulted portion of the coil and subsequent testing revealed deterioration of strand binder, a condition that was probably prevalent throughout all of the machines in the powerplant due to the manufacturing process used when these coils were made.

ORIGINAL FAILURE AND DISSECTION

The faulted portion of the coil was sent to the Power and Instrumentation Branch, Division of Research and Laboratory Services, E&R Center, Denver, Colo. for dissection.

This was the first Bureau line-to-ground insulation failure of a hard insulation system where the unit had provided a relatively long and successful period of service. The coils in this machine had not become loose and had not been subjected to external mechanical abrasion. This failure was unusual because it did not result from an internal turn-to-turn fault, or an external mechanical wedging problem typical of many "hard" insulation systems.

Examination of the coil prior to dissection revealed the following:

1. When the coil was pulled from the slot, a pronounced bend occurred at the point of fault.

2. The fault was located about 300 mm (12 in) down from the top of the steel on the left side of the boreside turn.

3. The coil sounded hollow when the outside of the insulation was tapped with a piece of metal.

The coil was dissected by using a sharp knife to peel off the layers of mica one at a time.

The following conditions were found during removal of the groundwall and turn insulation (figs. 1 and 2):

1. The binder used to hold the mica together was dry and dark yellow to brown in color (fig. 3). It had apparently deteriorated, because the layers of mica were peeled apart very easily, as compared to the force required to peel the comparative sections of a portion of the spare coil (fig. 4).

2. The final two strands of the boreside turn were distorted and misplaced about 3 mm (1/8 in). The distorted strands had formed an angle at their interface which had created a sharp knife-like edge. The outer edge had worn through the turn insulation and four to five layers of the groundwall insulation. In the area of the fault, there was evidence of extensive corona activity under the groundwall and throughout the badly deteriorated turn insulation. None of the binder was intact, and only brown dust was found. Through the first two turns, the strand insulation had completely decomposed into dust (fig. 5). In the third turn, the strand insulation was intact but no binder could be found.

THEORY OF FAILURE

The failure mode was primarily mechanical. The outer strands of the boreside turn are subject to tangential mechanical forces created by the flux entering the front of the slot. If these strands are not well bonded to the remainder of the strands in the first turn, they can vibrate and move with respect to the rest of the strands in the turn. This vibration could cause strand-to-strand faults resulting in higher temperatures and accelerated deterioration of the binder that holds the mica insulation in place. The dissection of the unit 3 fault revealed conditions which coincide closely with this explanation of the cause of failure. The vibrating strands wore through the turn and groundwall insulation, and eventually resulted in electrical failure. The misplaced strands were examined and found to have lost 20 percent of their original weight due to vibration-induced abrasion.

The dry and discolored binder found throughout the coil sample was probably due to overheating caused by the strand-to-strand fault and degraded thermal conduction properties. This condition probably exists throughout the coil, including the back half of the coil which is still in the machine. The bend which occurred when the coil was removed was due to lack of rigidity of the groundwall insulation in the vicinity of the fault.

PREVIOUIS TESTING

Routine "ramped" (gradually increasing) d-c absorption tests [1][1] were run on unit 3 of the four generators at Yellowtail Powerplant on September 17, 1980. The easiest way to disconnect

[1]Numbers in brackets refer to items in the Bibliography.

these units from the isolated phase bus and generator switchgear for testing was to unbolt the flexible braid connectors on the isolated phase bus between the generator and the generator switchgear. This left about 3 m (10 ft) of isolated phase bus which had to remain connected to the generator during the tests. The connector that was originally bolted to the flexible braids was wrapped with plastic for corona suppression. The generator neutral leads were also electrically isolated and corona shielded in a similar manner.

The results of these tests showed that, on phases B and C, the V-I curve did not have any discontinuities or sudden current increases (figs. 6 and 7). This indicated good quality insulation. On phase A, the V-I curve (fig. 8) was linear up to 23 kV, at which point the current suddenly increased and went off scale. The quality of the corona suppression was questioned, more plastic tape added, and the phase retested. This time the current increased and went off scale at 23.7 kV (fig. 9). We now suspect that arc-overs occurred in the isolated phase bus during these tests. The remaining portion of the isolated phase bus was disconnected from the generator leads, the generator leads insulated from the isolated phase bus by use of micarta blocks, and the unit retested on September 22, 1980. The V-I curve for phase A showed a moderate tip-up[2] starting at 21.5 kV (fig. 10). Another test was made with the same results, except the tip-up started at 22 kV (fig. 11). For this test, it appeared that the insulation was serviceable and that the moderate knee observed on phase A was apparently due to insufficient corona shielding on the winding terminals. Therefore, it was assumed that the V-I curves indicated acceptable quality insulation and the unit was returned to service.

We now conclude that the arc-overs that occurred during testing on September 17, 1980, may have overstressed the already weakened groundwall insulation on the coil that eventually failed. This is further reinforced by the fact that the ramp test run after the faulted half-coil was replaced (fig. 12) did not have the tip-up that was present on the last ramp test run on September 22, 1980 (fig. 11).

SUBSEQUENT TESTING

After the dissection revealed a problem that could have been caused by the coil manufacturing process and could affect the coils in the rest of the machine, it was decided that corona probe tests be conducted on unit 3. At this time, the unit was disassembled and being rewedged. This presented an opportune time to perform the corona probe tests.

Corona probe tests were conducted on unit 3 on December 14, 1981. Table 1 is a list of the higher readings recorded and the specific locations:

Table. 1—*Results of corona probe tests on unit 3*

Slot No.	Coil (In top of slot)	Reading
101	C3-3	80
102	C3-2	150
103	C3-1	280
104	B2-17	60
108	C2-17	70
109	C2-18	55
146	A2-3	75
149	C2-4	270
155	C2-3	95

Wedges were removed from slots 101, 102, 103, 146, 149, and 155, and a close physical inspection was conducted. Coils were checked for soundness by tapping with a coin. Hollow-sounding areas were found on the coils in slots 101, 102, 103, 146, and 149. The high readings in slots 108, 109, and 155 were probably due to the discharges being generated in slots 102, 103, and 149, respectively.

Arrangements were made to have the front half-coils in slots 102, 103, 146, and 149 removed and dissected. A detailed description of the dissection of these coils is given in a report by Richard Dye of the Regional Office in Billings, Montana. The dissection of the coils removed from slots 103 and 149 revealed extremely deteriorated binder, voids, evidence of overheating, lose strands, and internal insulation damage due to vibrating strands. The coils removed from slots 102 and 146 had voids, deteriorated binder, and showed signs of overheating. Spare coils were used to replace the coils removed. The contractor encountered great difficulty making the half-coil splices because of the deteriorated condition of the insulation on the back-half of the coils that had remained in the machine.

Since the dissection confirmed our diagnosis that there would be more coils in the machine with internal insulation deterioration and that we could detect these deteriorated coils with the corona probe, we suggested that corona probe tests be conducted on the other three units at the powerplant. We also decided to corona probe test unit 3 again to determine if the repairs had

[2]Tip-up is a gradually increasing rate of rise in the measured current.

reduced the corona level in the slots that we suspected were giving high readings due to cross coupling from the bad coils.

Corona probe tests were conducted on unit 4 with the rotor in the bore on April 21, 1982. Test results indicated only two slots with moderately high readings, slot 194 with a reading of 64 and slot 200 with a reading of 58. Since these were only moderate readings, it was concluded that no major deterioration had occurred in unit 4.

Corona probe tests were conducted on unit 3 on April 26, 1982. The areas where the half-coil splices were made showed a marked decrease in corona probe readings; however, several areas that were not involved in the repairs had increases, although none were as high as in December 1981. Table 2 shows a comparison of the readings of both tests.

Table 2.—*Comparison of readings from two corona probe tests on unit 3*

Slot No.	Coil (In top of slot)	Readings 12/81	Readings 4/82
43	B4-2	8	50
47	C4-3	10	46
78	B3-9	10	52
87	A3-5	50	130
88	C3-7	12	88
93	A3-2	14	82
95	C3-4	21	50
119	A2-12	5	48
133	A2-7	6	50
140	A2-4	40	94
141	A2-5	12	110
146	A2-3	50	90
147	A2-2	20	48
148	A2-1	16	64
159	B1-18	10	64
160	A1-16	8	60
167	A1-13	8	70
173	A1-12	8	62

As with the first test, the second test indicated that some of the high readings are probably due to cross coupling, as in the case of slots 140, 141, 146, 147, and 148; and slots 167 and 173. These coils are all physically connected in series. The high frequency discharges detected by the corona probe are coupled into adjacent coils through the copper coil jumpers. Although there are no coils with high readings above 150, there are 15 coils with moderate readings between 50 and 150 that should be monitored closely to forewarn of an increased rate of deterioration.

Corona probe tests were conducted on unit 1 on April 27, 1982; results are given in table 3.

Table 3.—*Results of corona probe tests on unit 1*

Slot No.	Coil (In top of slot)	Reading
62	C3-15	50
69	C3-14	74
91	B3-4	76
95	C3-4	78
97	B3-2	54
98	B3-1	140
101	C3-3	50
183	C1-11	50
193	B1-5	60
194	A1-4	100
195	A1-5	52
197	C1-6	63
198	B1-3	730
199	B1-4	240
200	A1-3	110
203	C1-4	130
204	C1-5	120
205	B1-2	270
206	B1-1	100
210	C1-2	56
211	C1-1	80
214	A4-16	60
216	C4-17	82

High readings due to coupling appeared in the following slot sequences: 62-69, 91-97-98, 95-101, 194-195-200, 193-198-199-205-206, 197-204-203, and 210-211. This unit appeared to have several coils with badly deteriorated insulation, and minor deterioration in the remainder of the coils with moderate readings between 50 and 150.

Corona probe tests were conducted on unit 2 on May 4, 1982; results are given in table 4.

Table 4.—*Results of corona probe tests on unit 2*

Slot No.	Coil (In top of slot)	Reading
7	C4-16	62
8	C4-15	56
9	B4-12	62
10	B4-13	66
11	A4-12	54
12	A4-11	61
14	C4-13	90
20	C4-12	72
21	C4-11	60
146	A2-3	85
147	A2-2	62
150	C2-5	55
152	B2-1	60
153	A1-17	80
174	A1-11	78
182	C1-12	58
183	C1-11	50
186	B1-9	53

There were no coils with high readings in unit 2.

After collecting all of the corona probe data, the following conclusions were reached on the condition of the insulation systems:

1. Unit 1 had the highest corona probe reading of 730 and may be in danger of failure. Coils removed from unit 3 had readings of 280 and were in a very deteriorated and dangerous condition.

2. The insulation in unit 3 was generally in a more deteriorated condition than the insulation in units 2 or 4, but was not in danger of imminent failure.

All four units had a problem with the stationary turbine wear rings. The rings on units 3 and 4 were replaced when the units were rewedged in 1979.

Because of the condition of the insulation systems, the reliability of the units was questionable and a decision was made to rewind the generators. It was decided to rewind unit 1 first because it had severely deteriorated coils and also needed a new stationary turbine wear ring. Unit 2 was selected as the second one to be rewound because it also needed a new stationary turbine wear ring. This is predicated on the condition of the unit 3 insulation. If, for some reason the unit 3 insulation starts deteriorating at a faster rate, unit 3 may have to be rewound before unit 2. If not, unit 3 would be rewound third and unit 4 last.

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[1] Milano, B. and R.C. Arbour, *A Portable Ramped D-C Test Set for Electrical Insulation Testing,* Bureau of Reclamation Report No. GR-80-2, E & R Center, Denver, Colo. June 1980.

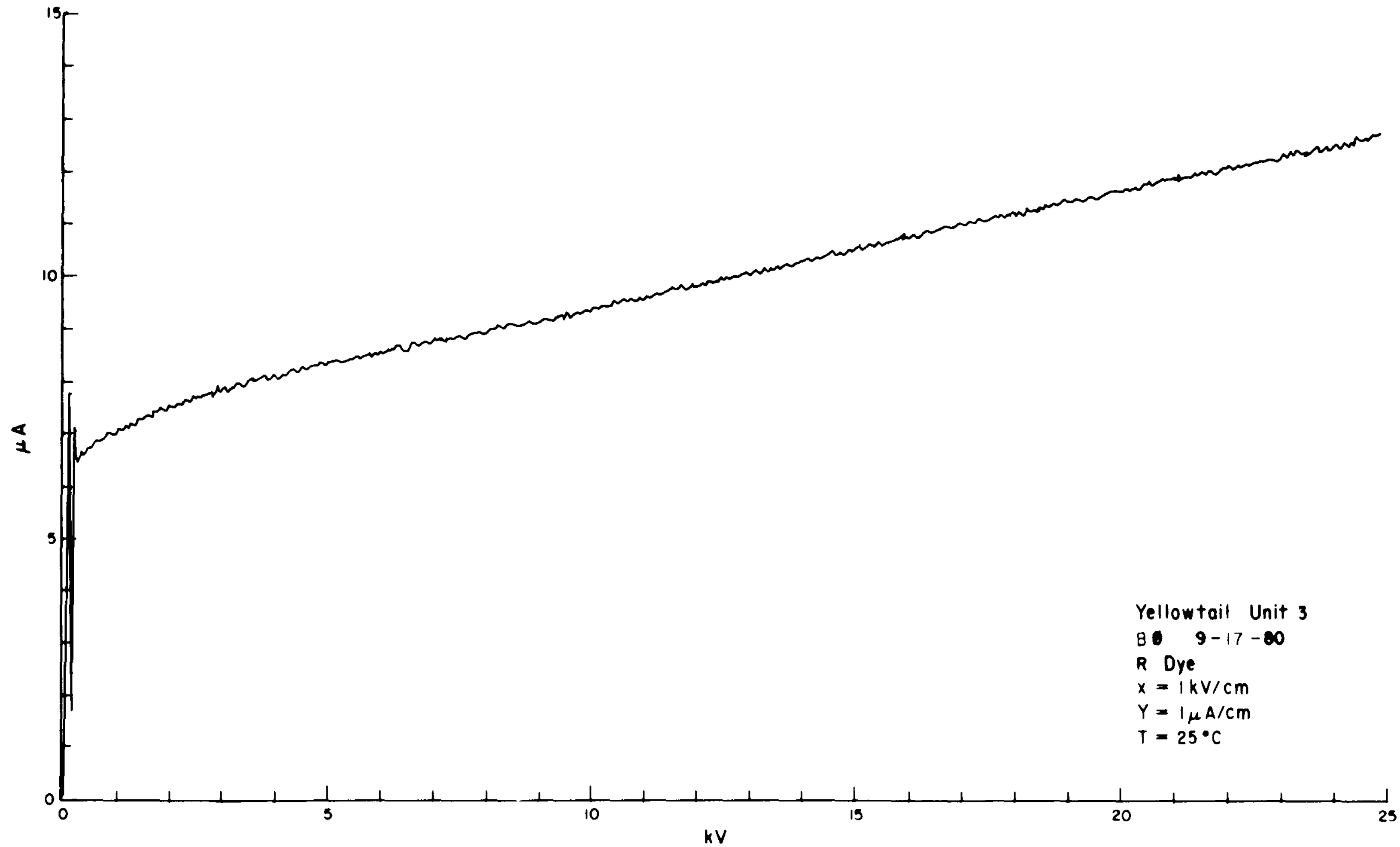

Figure 1.—Ramped d-c absorption test V-I curve, B phase.

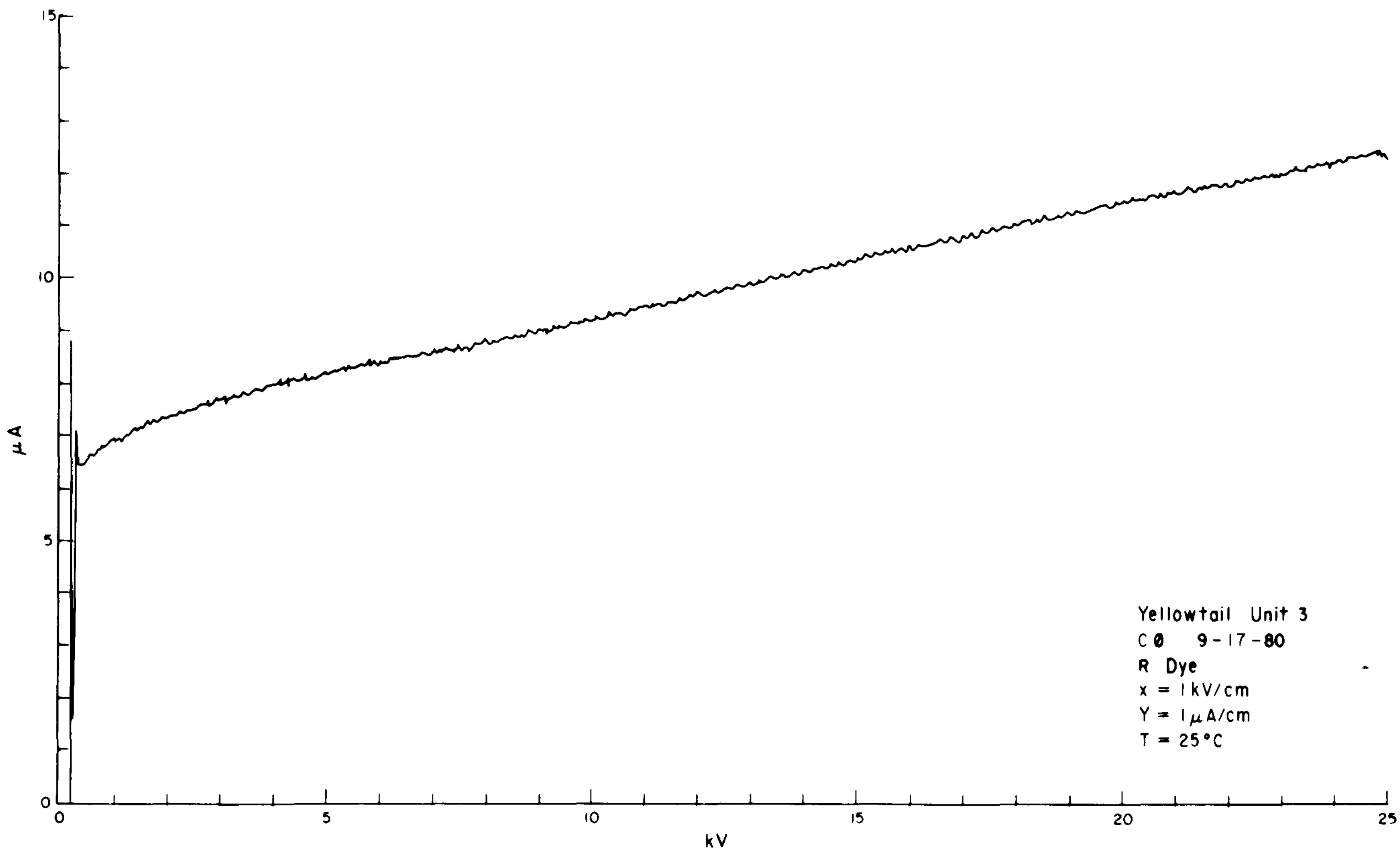

Figure 2.—Ramped d-c absorption test V-I curve, C phase.

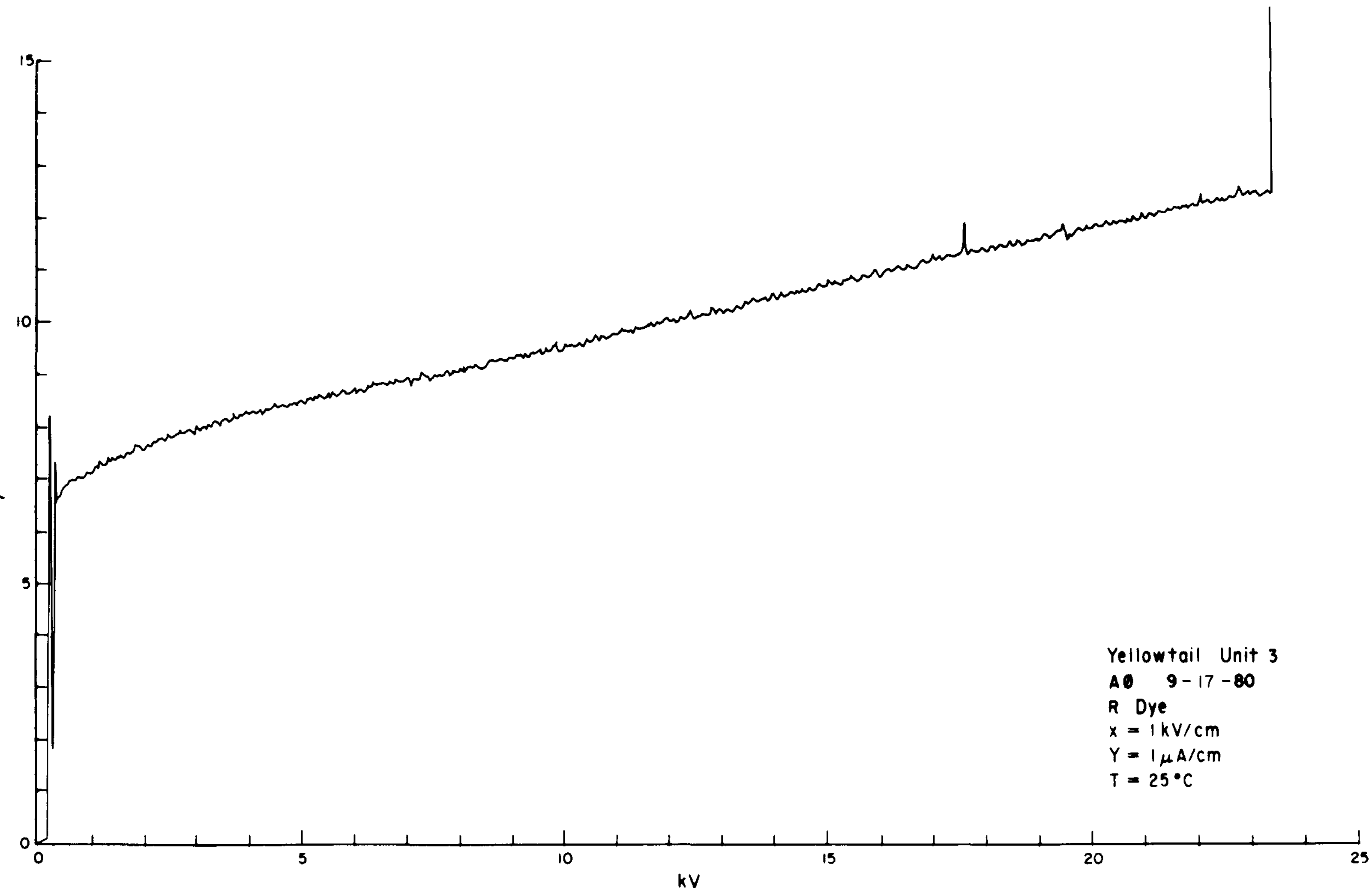

Figure 3.—Ramped d-c absorption test V-I curve, A phase, (flashover).

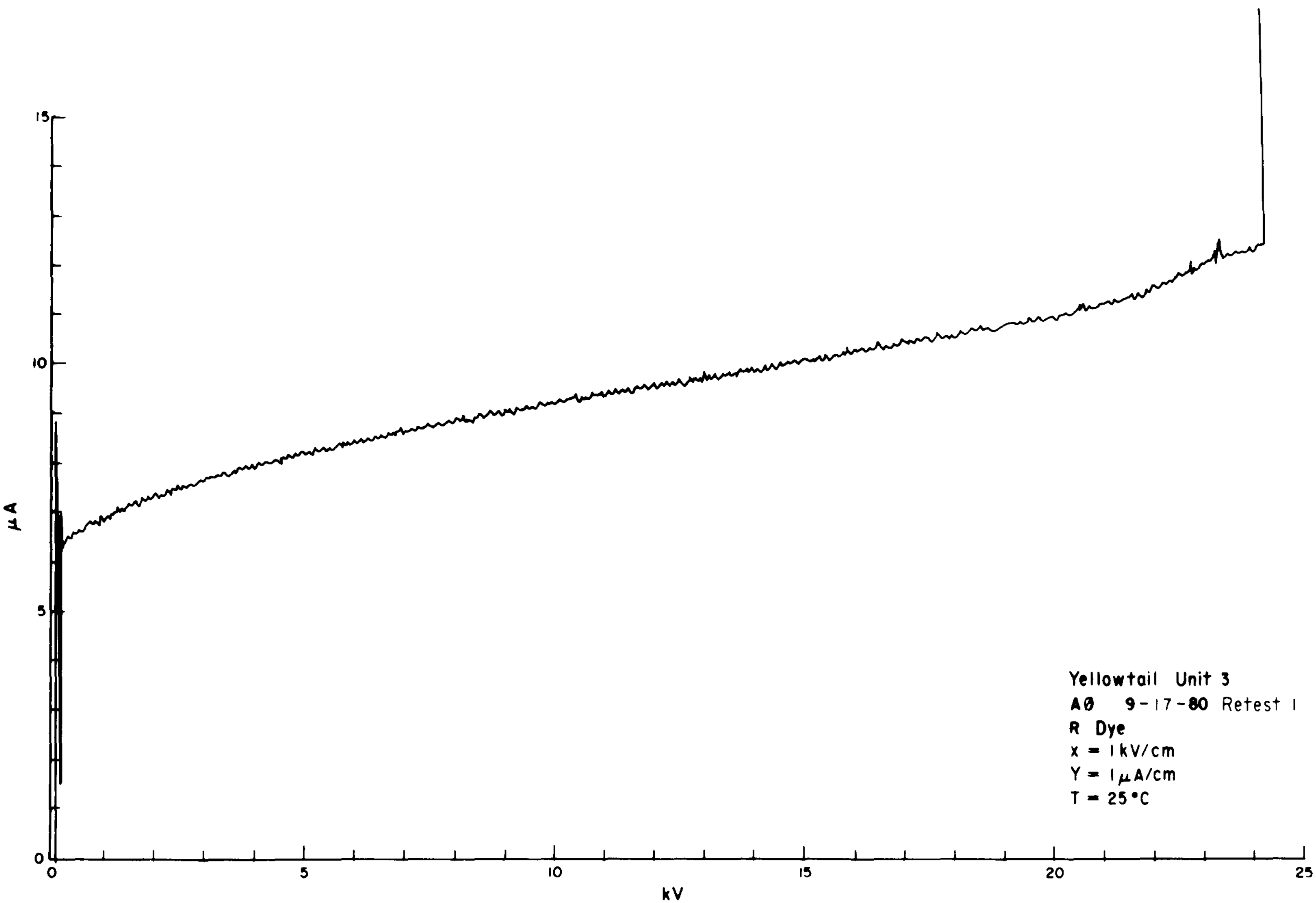

Figure 4.—Ramped d-c absorption test V-I curve, A phase, retest (flashover).

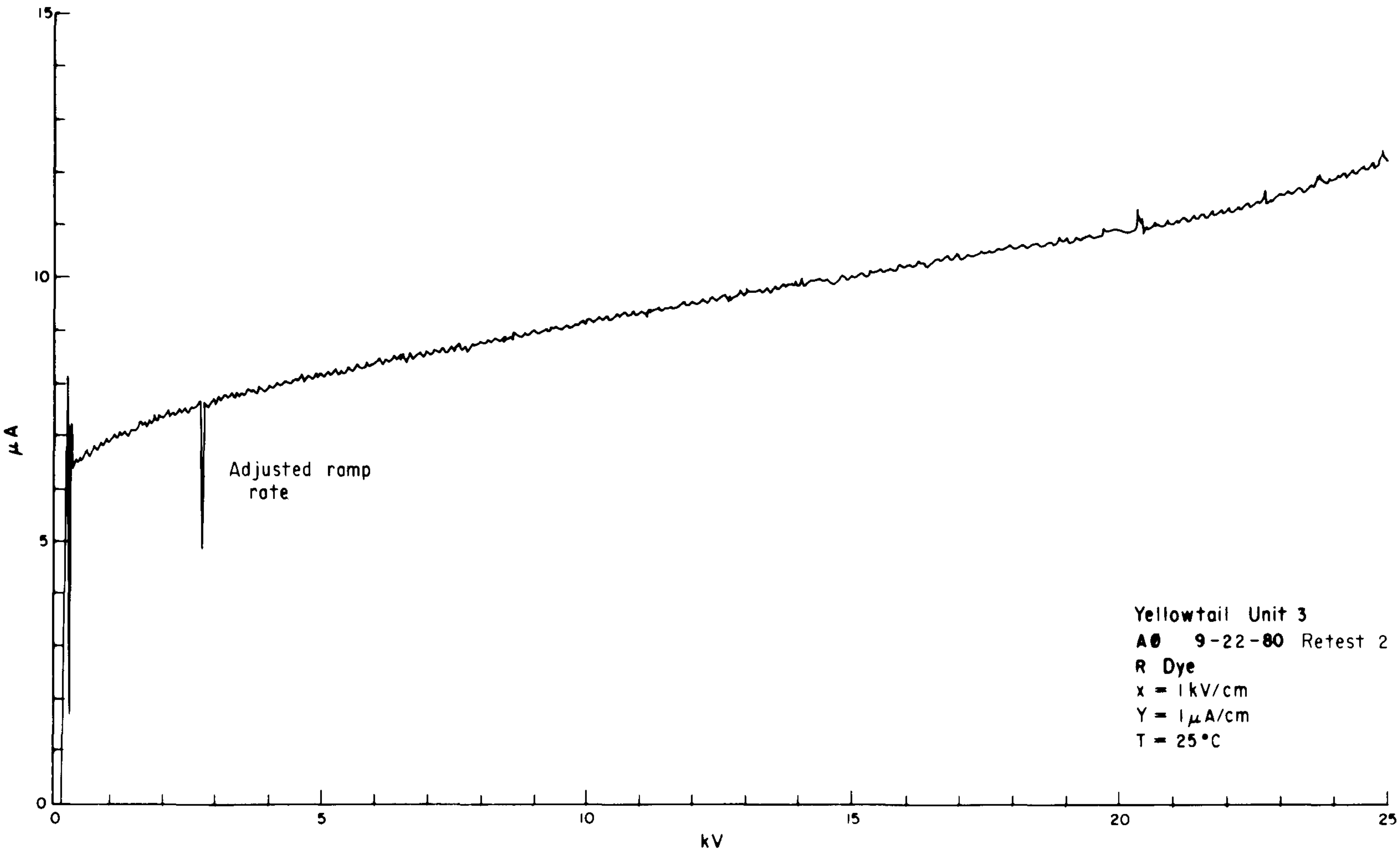

Figure 5.—Ramped d-c absorption test V-I curve, A phase (retest 2).

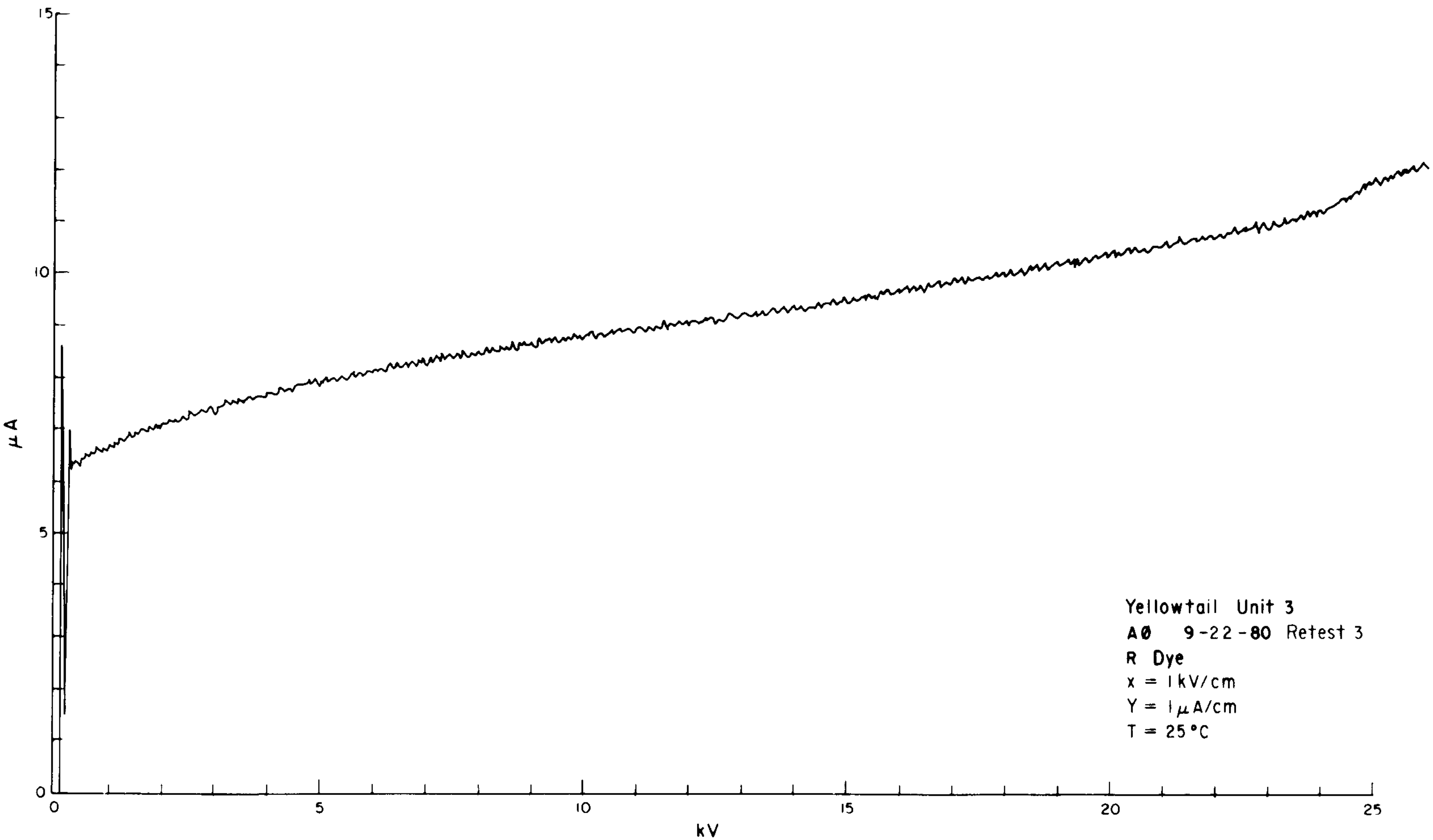

Figure 6.—Ramped d-c absorption test V-I curve, A phase (retest 3).

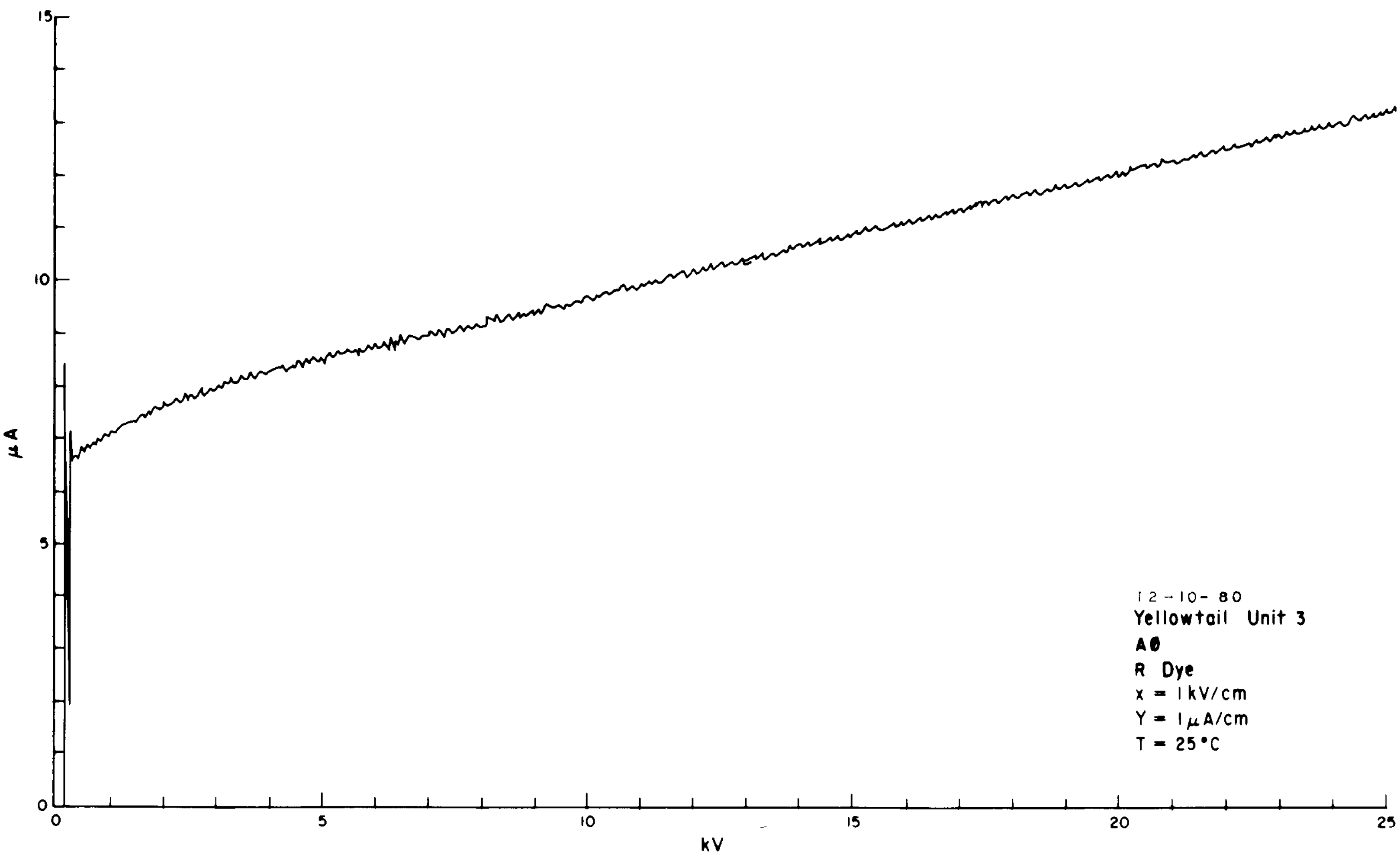

Figure 7.—Ramped d-c absorption test V-I curve, A phase after repairs.

Figure 8.—Dissected coil prior to removal of all groundwall and turn insulation. P801-D-79795.

Figure 9.—Closeup view of dissected coil prior to removal of all groundwall and turn insulation P801-D-79796.

:igure 10.—View showing discoloration of binder material. P801-D-79797.

Figure 11.—Groundwall and turn insulation removed from coil. P801-D-79798.

Figure 12.—Portion of unused spare coil showing normal color of binder. P801-D-79799.

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