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A 1,000 MVA, 13.8 KV

MAGNETIC "DE-ION" AIR CIRCUIT BREAKER

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INTRODUCTION

Magnetic air circuit breakers as a general class give the user the maximum economy in installation, maintenance, and flexibility of operation. These qualities are particularly desirable in distribution substations. As the size of these substations increases, the advantages of the magnetic type of interrupter become still more apparent. The fast growth of metropolitan substations thus led to the recent development of the 750 MVA 13.8KV magnetic breaker for use in metal clad switchgear. (1)

The previous maximum interrupting rating of 500 MVA remained the maximum available magnetic air breaker rating in metal clad switchgear for many years. In the short period of approximately 2 years, the 750 MVA rating has become inadequate to meet the still increasing needs of the industry. Consequently a 1,000 MVA 13.8KV magnetic air breaker has been developed.

This statement in itself need convey no surprise or particular sense of technical accomplishment. It is relatively easy to build an air circuit breaker for any conceivable interrupting rating, both as to MVA and voltage, provided that no particular space limitations be imposed on the design. The essence of the science, and we must say, art, of circuit breaker development consists essentially in designing to meet economically acceptable space requirements.

Thus, it is in the sense of space requirements that this development of a 1,000 MVA magnetic air circuit breaker is here presented as a technological advance.

The breaker to be described fits into an indoor metal clad cell of the same width and height as that required for the previously developed 13.8 KV ratings of magnetic breakers (1); and an increase of only 4 inches in depth is required for the breaker over the depth of the 750 MVA rating. This is true for both of the continuous current ratings of 1200 and 3000 amperes.

RATING FACTORS

This breaker has been put in the same class as to insulation level, minimum KV for rated interrupting MVA and rated interrupting time as in the existing standards rating tables. The complete rating characteristics are as follows:

Rated KV.	13.8
Maximum Design KV	15.0
Minimum KV for rated MVA	11.5
Three Phase MVA	1,000
Continuous Amperes	1200 and 3000
Momentary Amperes	80,000
Four - Second Amperes	50,000
Amperes at Rated KV.	42,000
Maximum Interrupting Amperes	50,000
KV. 1 minute Withstand	36
KV. Impulse Withstand	95
Rated Interrupting Time	8 cycles

As will be shown below, the actual interrupting time of the new breaker is less than its rated interrupting time of 8 cycles, as in the case of previously available magnetic breakers.

DESCRIPTION OF THE BREAKER

GENERAL

This new breaker is not a remodeled version of a previous design. Because of the large increase in interrupting, momentary and continuous current requirements over previous 13.8KV designs, the most advisable policy was to develop a basically new design in respect to all major components such as frame, operating mechanism, contacts, main bushings and interrupters. The new design was, however, coordinated with the development of a 4.16KV. 350 MVA breaker, described in a separate paper (2) before the Institute, because the ampere rating characterics for the 350 MVA 4.16KV rating are nearly the same as for the 1,000 MVA 13.8KV. rating. The result is that most of the breaker contact details and many of the operating linkage details are common to the two designs.

In line with established practice, this breaker is applied in metal clad switching equipment. It is designed as a complete horizontal drawout unit, apractice established more than 25 years ago by the company with which the authors are associated.

Fig. 1 shows the new breaker completely assembled. Fig. 2 shows the breaker with the 3-section main barrier removed. The insulating inter phase barriers are made of a special flame retardent grade of glass mat polyester resin material.

Fig. 3 shows the hinged arc chutes being raised for inspection. The chute lifter consists of 2 lightweight channels with adapter plates and a rod, inserted through the 3 arc chutes. The adapter plates are fastened to the levering-in device arms with one bolt. The regular levering in crank is then rotated to raise the arc chutes. The breaker can thus be prepared for inspection in a few minutes.

The basic structural arrangement is similar to previous magnetic breakers of this manufacture. The operating mechanism is below the live parts of the breaker. The air puffer is of a recent design first introduced on a 50/75 MVA breaker previously described before the institute by Frink and Kozlovic. (3) It has no piston but the air is displaced by bellows action of a silicone rubber diaphragm. The bellows extends across the width of the breaker and exhausts through nozzles directly under the breaker contacts.

The secondary contacts, as on previous designs, are automatically disconnected when the breaker is withdrawn to the test position but may be reconnected instantly for test purposes.

The breaker as shown is equipped with a conventional type solenoid mechanism which, in line with standard practice can be energized either from d-c or a rectified a-c source. This breaker also can be equipped with a motor operated spring stored energy closing mechanism which is interchangeable within the breaker with the solenoid mechanism.

ARC INTERRUPTER

The most fundamental new requirement of the new breaker is of course the interrupting ability. In order to avoid a great increase in space requirements, a new concept in interrupters was required. However, the material used for the main interrupter elements is still the zircon refractory ceramic developed approximately 18 years ago for this purpose by the company with which the authors are associated. This material still gives the best possible results as to basic requirements such as minimum gas formation and high heat shock resistance at arc temperatures, high dielectric strength and low moisture absorbtion.

The basic interrupter consists of two groups of spaced zircon plates located symmetrically in an H shaped blowout magnet, similar to the general arrangement in a 750 MVA previously described before the Institute (1). There are two major points of novelty about the new interrupter. The individual plates have a new arrangement of inverted V shaped slots which divide the arc into two parallel paths in portions of the arc chamber. The second point of novelty is the use of leakage suppressors in the blowout magnet structure, as described in a paper by A.P. Strom (4), being presented at this meeting of the Institute.

In developing the parallel arc structure, elementary tests were first made by drawing arcs in small holes in spaced refractory plates. With oscillograph probes in these and in another set of small holes nearby, it was possible to determine if or when and at what current values 2 parallel arcs would exist in the structure. Since these tests showed the definite possibility, more realistic structures were built in which the principle was further demonstrated.

The interrupter plates as used in the 1,000 MVA interrupter are shown on Fig. 4. Here it is seen that one plate has 2 inverted V slots offset symmetrically about the center line and another plate has a single inverted V slot on the centerline. These plates are alternated in the assembly. Fig. 4 shows plates removed from an interrupter which had been subjected to a series of interrupting tests. The path which was taken by the arc can be seen from the slight glazing and discoloration of the plates. However, these plates are good for considerably more interrupting duty.

Other arrangements were investigated, such as one in which each plate had 2 slots, which were alternated so that an arc could and did exist in each of the four channels of each pair of plates. However, the design as shown in Fig. 4 gave better results, largely because the overall effect is to expose more of the arc stream to a greater area of relatively cold material.

CONTACTS

Fig. 5 shows a close-up looking toward the stationary contacts of the breaker. This contact design was first developed for use on a 4.16KV 350 MVA breaker described in another paper (2) being presented at this meeting. The main contacts consist of 5 pairs of parallel path fingers engaging the movable contact at an angle. This gives the assembly a high momentary and continuous current carrying ability because of the increase in pressure with current and because of the multiplicity of contact points in parallel.

INTERRUPTING TESTS

As is to be expected in a present day development of this magnitude hundreds of interrupting tests have been made. These tests are made not only to develop the desired maximum interrupting ability but also to demonstrate the durability of parts usually regarded as expendable. As an illustration of this, refer to Table I and Fig. 6. The table shows the results of a series of thirty-two 3 phase interrupting tests made on an experimental breaker without replacement or maintenance of any kind on the contacts.

In addition to the 3 phase tests shown on Table I, there were 92 single phase tests made on the center pole. Fig. 6 shows a laboratory photograph of the breaker contacts after these tests. The pitting visible on the main contact fingers is very light and causes no deterioration of continuous or momentary performance.

A series of tests illustrating interrupting performance as such is shown by the data given in Table II. In this table, the last two operations are significant in illustrating the margin of interrupting ability built into the new breaker. These two tests average approximately 1,300,000 KVA interrupted, one being slightly over and the other slightly under. (Oscillograms of these tests are shown as Figures 7 and 8) It is the opinion of the authors that this gives the breaker sufficient margin for a nominal interrupting time of 5 cycles and contact opening time of 3 cycles for satisfactory operation with fast relaying on any system that will be encountered.

It is also noteworthy that in the last test shown in Table II, the breaker closed successfully against an rms current in the most asymmetrical phase of 81,000 amperes measured at the 1st crest. This is more than the momentary current of the breaker and illustrates the obtaining of tests of 3 rating values, momentary, making current and interrupting current in a single operation. It is also noteworthy that these tests were obtained on a 1200 ampere breaker.

OTHER TESTS

In the development of practically any size circuit breaker, the arc interrupter receives the primary attention of the development engineer. However, the development program for this new breaker has included all tests deemed necessary for assurance of dependable performance in the field. Included are, 4 second current carrying, temperature rise, impulse for 95 KV b.i.l., and mechanical endurance.

SUMMARY

The development of the first magnetic air breaker to be rated at 1000 MVA 13.8 KV has been described in this paper. It fulfills an industry need for a 13.8 KV breaker to perform the switching requirements of the presently largest 13.8 KV metropolitan substations.

"LIST OF ILLUSTRATIONS"

Fig. 1 (Negative No. 356832)
1,000 MVA., 1200 ampere, 13.8KV Magnetic Air Circuit Breaker completely assembled for insertion into metal clad switchgear cell.

Fig. 2 (Negative No. 356824)
1,000 MVA. breaker as shown on Fig. 1, with main barrier removed.

Fig. 3 (Negative No. 356827)
1,000 MVA. breaker with arc chutes being raised with chute lifting attachment. Crank being used is regular levering in device crank attached to regular levering in device shaft.

Fig. 4 (Negative No. 357309)
New design interrupter plates developed for the 1,000 MVA. breaker. These plates have been cutout from an arc chute which had been subjected to a series of interrupting tests. Plates are of zircon refractory ceramic material as developed for magnetic air breakers in 1939.

Fig. 5 (Negative No. 354565)
Close up of contacts for 3000 ampere breaker. Parallel fingers carry main current. Intermediate, lower center, and arcing contacts upper center, are 3 members in parallel and flexibly mounted with respect to each other.

Fig. 6 (Negative No. 357804)
Photograph of contacts of a 1,000 MVA breaker after being subjected to the tests shown in Table I. There was no contact maintenance or replacements during the tests.

Fig. 7 Oscillogram of close-open operation showing breaker closing 74,000 amperes and opening 56,100 amperes at 13.2 KV.

Fig. 8 Oscillogram of close-open operation showing breaker closing 81,100 amperes and opening 57,300 amperes at 13.2 KV.

"REFERENCES"

(1) A Magnetic "De-ion" Air Breaker for 750 MVA., 13.8 KV, Russell Frink and J. M. Kozlovic, AIEE CP57-225, January, 1957.

(2) A Magnetic Air Circuit Breaker for 350 MVA, 3000 ampere and 4.16 KV. Russell Frink and J. M. Kozlovic, AIEE CP58-130, January, 1958.

(3) A new 5 KV, 50,000 KVA "De-ion" Air Circuit Breaker, Russell Frink and J. M. Kozlovic, AIEE CP55-721, January, 1955.

(4) Suppression of Leakage Flux in Magnetic Air Breakers, A. P. Strom AIEE CP58-21, January, 1958.

"TABLE I"

GEN. VOLTAGE	INTERRUPTED AMPERES PHASE 1	PHASE 2	PHASE 3	INT. TIME	MVA
13.2	3,000	3,700	2,970	4.9	84.5
13.2	10,500	12,700	13,500	3.8	308
13.2	20,900	20,200	24,400	3.8	557
13.2	2,930	3,760	3,390	4.9	86.
13.2	19,600	25,000	31,400	3.8	717
13.2	29,800	32,800	35,700	3.8	815
13.2	33,300	40,000	39,200	4.2	914
13.2	3,200	2,600	4,040	5.7	92.4
13.2	28,600	20,700	24,400	3.8	653
13.2	34,600	34,600	45,800	4.2	1050
13.2	4,640	3,640	3,090	3.2	106.
13.2	10,000	13,450	11,800	4.0	306
13.2	20,500	21,700	26,000	3.8	594
13.2	33,800	31,200	29,600	4.8	772
13.2	3,260	3,120	4,040	6.6	92.4
13.2	12,100	10,150	10,800	4.5	276
13.2	21,000	20,700	26,000	4.7	594
13.2	3,260	3,990	3,330	4.7	89
13.2	31,600	31,800	37,600	3.2	860
13.2	35,000	36,400	39,400	3.1	900
13.2	3,200	4,400	3,110	4.5	100
13.2	3,880	3,060	4,100	4.5	93.6
13.2	26,200	24,100	25,500	3.4	598
13.2	29,400	36,600	41,400	3.3	945
13.2	33,100	47,700	44,600	3.3	1090
13.2	2,990	3,760	3,980	4.8	91
13.2	21,500	22,700	28,600	3.3	653
13.2	3,920	3,440	4,000	4.2	91.4
13.2	8,650	6,480	8,460	3.5	197.5
13.2	18,750	15,400	18,750	3.2	465
13.2	30,800	27,400	34,200	3.3	780
13.2	36,250	36,500	44,500	2.9	1020

"TABLE II"

GEN. VOLTAGE	INTERRUPTED AMPERES PHASE 1	PHASE 2	PHASE 3	INT. TIME	MVA
13.2	3,400	2,430	3,210	4.2	77.6
13.2	3,880	2,260	3,030	4.9	88.5
13.2	8,090	6,360	8,620	4.1	197
13.2	20,800	19,950	14,850	3.2	460
13.2	33,000	33,800	25,500	3.4	773
13.2	43,600	43,300	33,200	3.4	995
13.2	45,200	45,900	32,300	2.9	1050
13.2	45,200	47,600	36,600	3.0	1090
13.2	8,450	8,340	6,370	4.0	193
13.2	18,750	19,650	14,850	3.2	449
13.2	34,200	33,100	25,500	4.7	781
13.2	34,800	35,800	25,300	3.1	816
13.2	41,400	41,500	32,200	3.2	946
13.2	45,200	47,500	36,600	3.4	1085
13.2	23,000	21,200	18,700	3.1	525
13.2	44,700	36,200	36,800	3.2	1020
13.2	48,000	42,700	40,200	2.9	1095
13.2	2,720	3,760	3,680	3.8	86
13.2	56,100	46,200	45,300	2.7	1283 *
13.2	44,400	44,800	57,300	2.7	1310 *

* Close-open operations. Oscillograms of these test shown as Figs. 7 & 8.

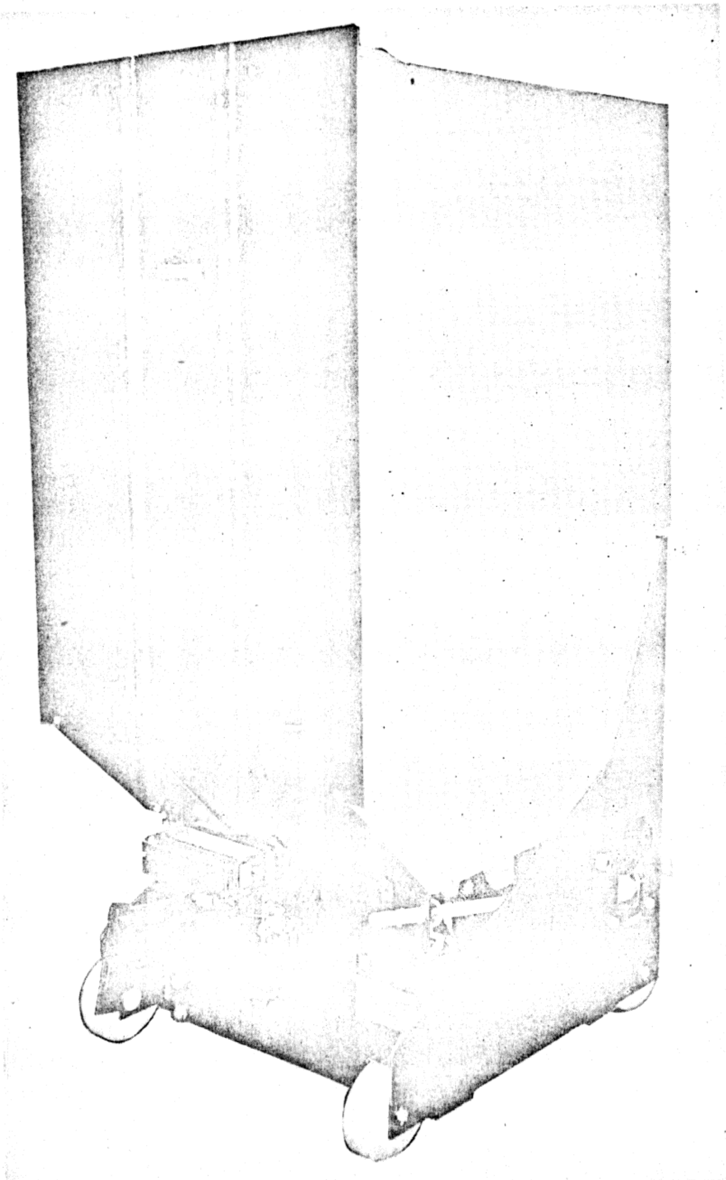

FIG. 1. 1,000 MVA, 1200 Ampere, 13.8 KV Magnetic Air Circuit Breaker Completely Assembled for Insertion into Metal-Clad Switchgear Cell.

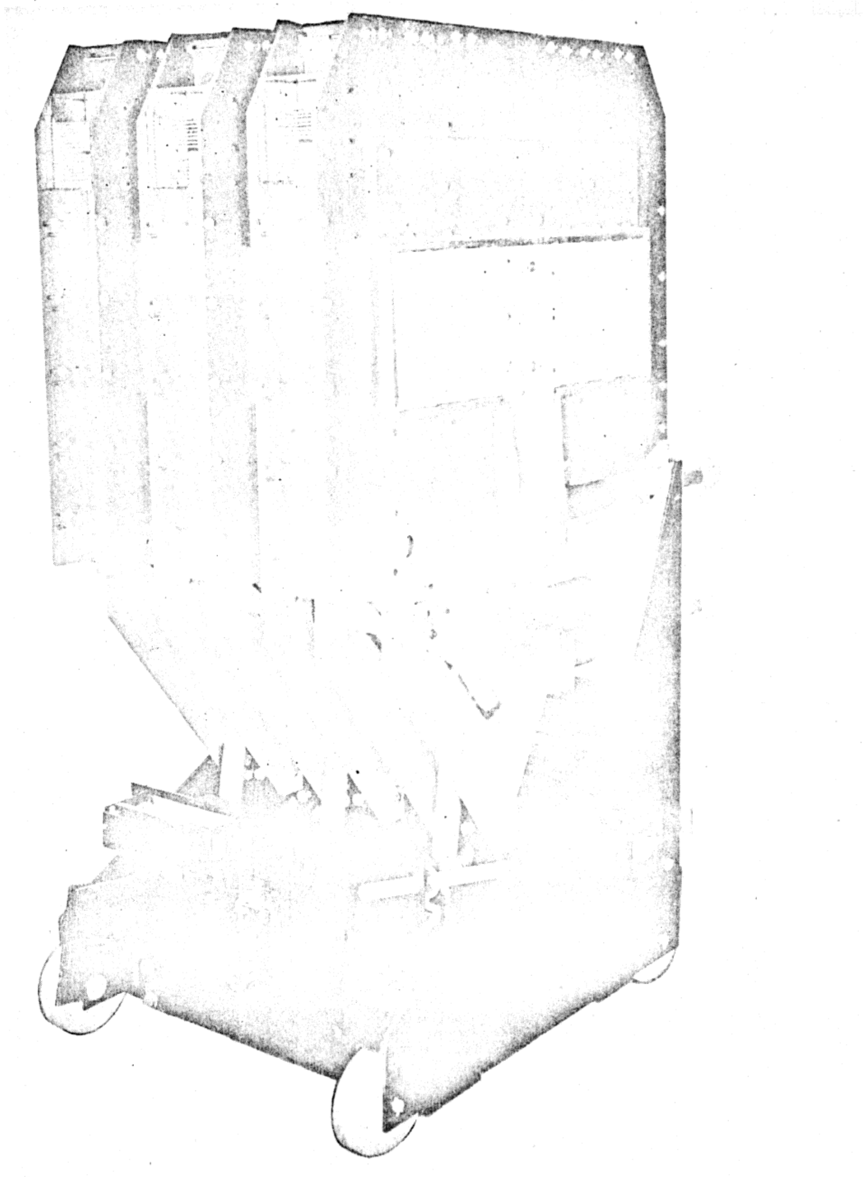

FIG. 2. 1,000 MVA Breaker as Shown in Fig. 1, with Main Barrier Removed.

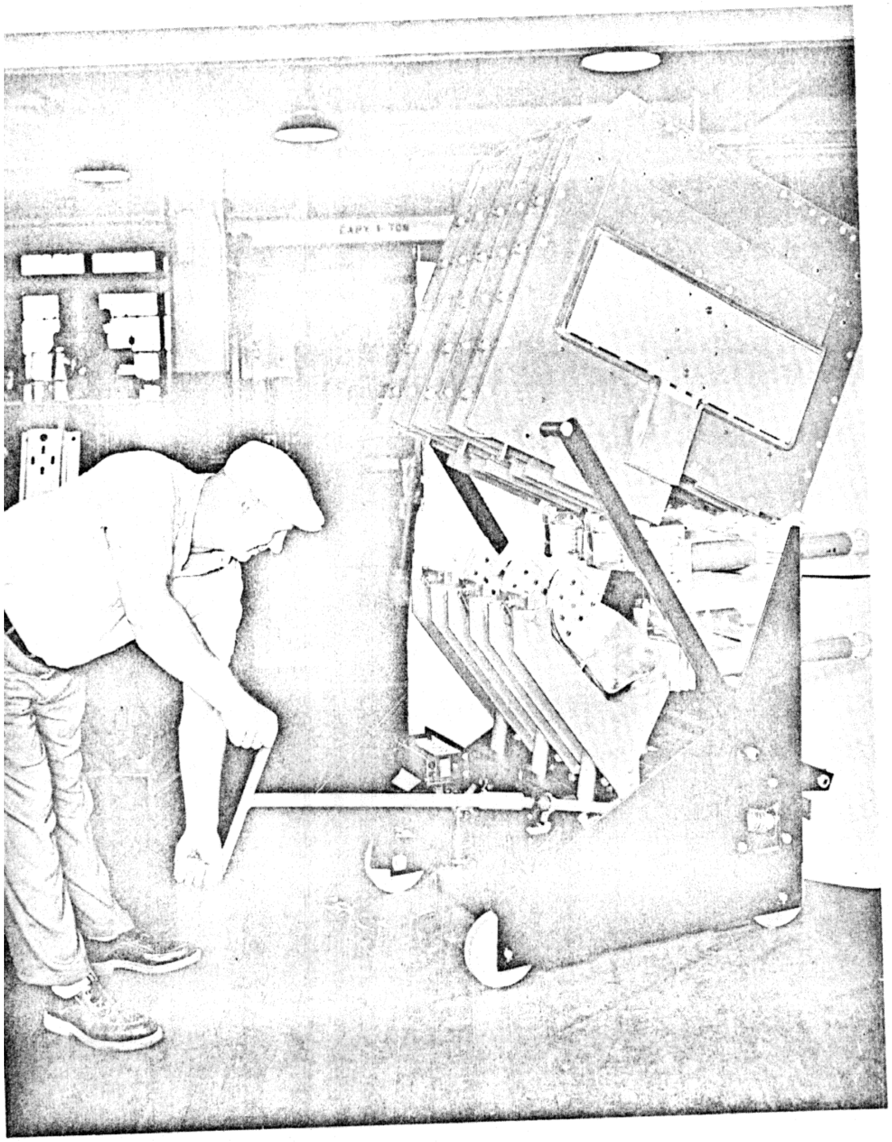

FIG. 3. 1,000 MVA Breaker with Arc Being Raised with Chute Lifting Attachment. Crank being used is regular levering in device crank attached to regular levering in device shaft.

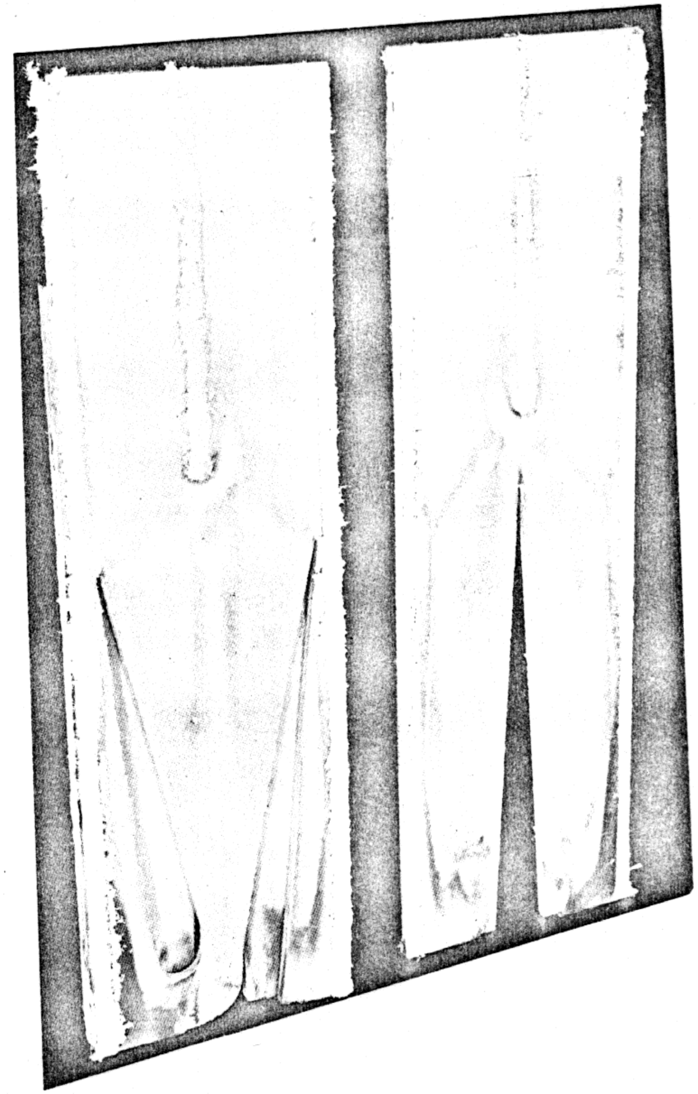

FIG. 4. New Design Interrupter Plates Developed for the 1,000 MVA Breaker. These plates have been cutout from an arc chute which had been subjected to a series of interrupting tests. Plates are of zircon refractory ceramic material as developed for magnetic air breakers in 1939.

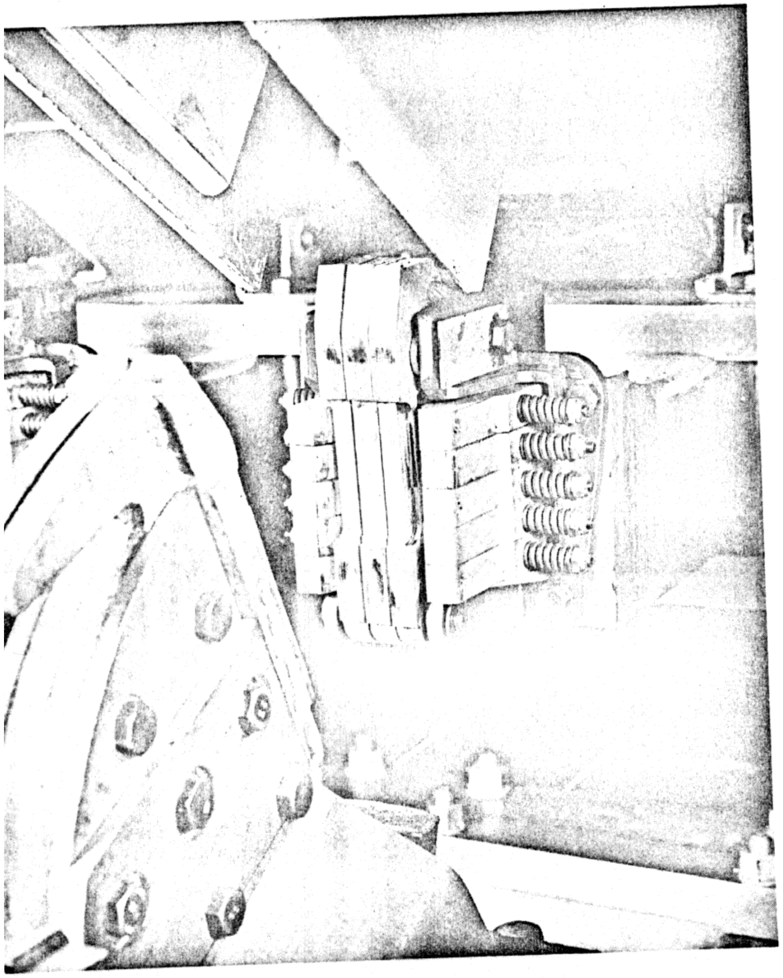

FIG. 5. Close Up of Contacts for 3000 Ampere Breaker. Parallel fingers carry main current. Intermediate, lower center, and arcing contacts upper center, are 3 members in parallel and flexibly mounted with respect to each other.

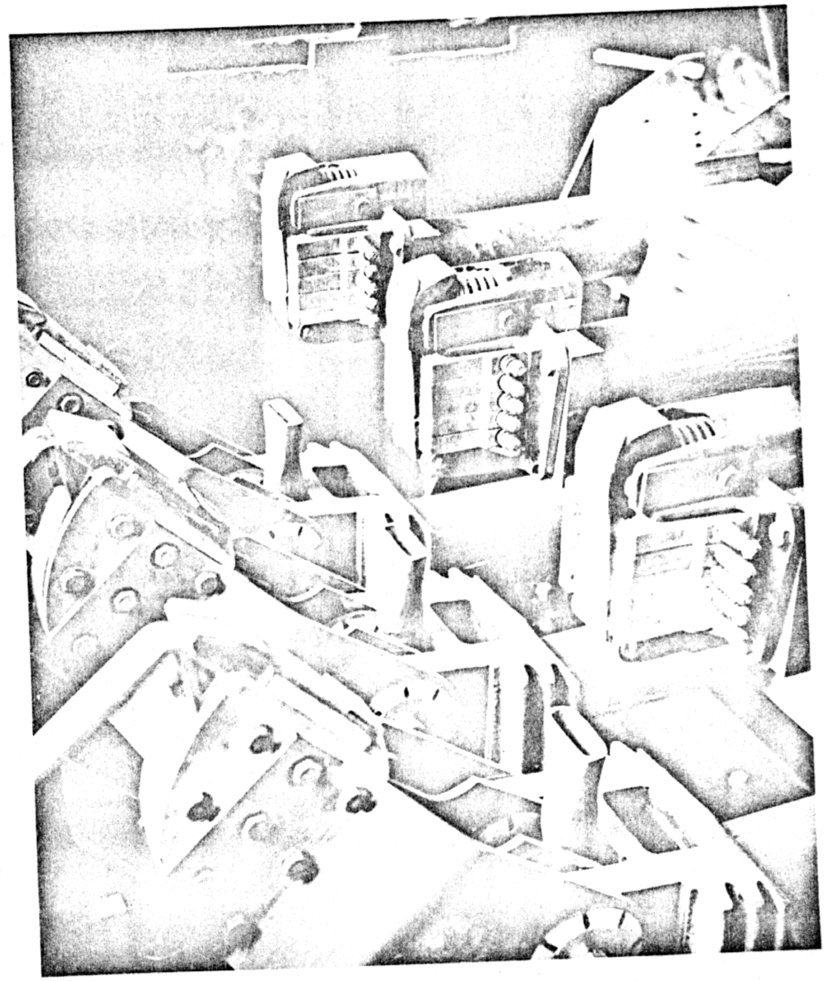

FIG. 6. Contacts of a 1,000 MVA Breaker after being Subjected to the Tests Shown in Table II. There was no contact maintenance or replacements during the tests.

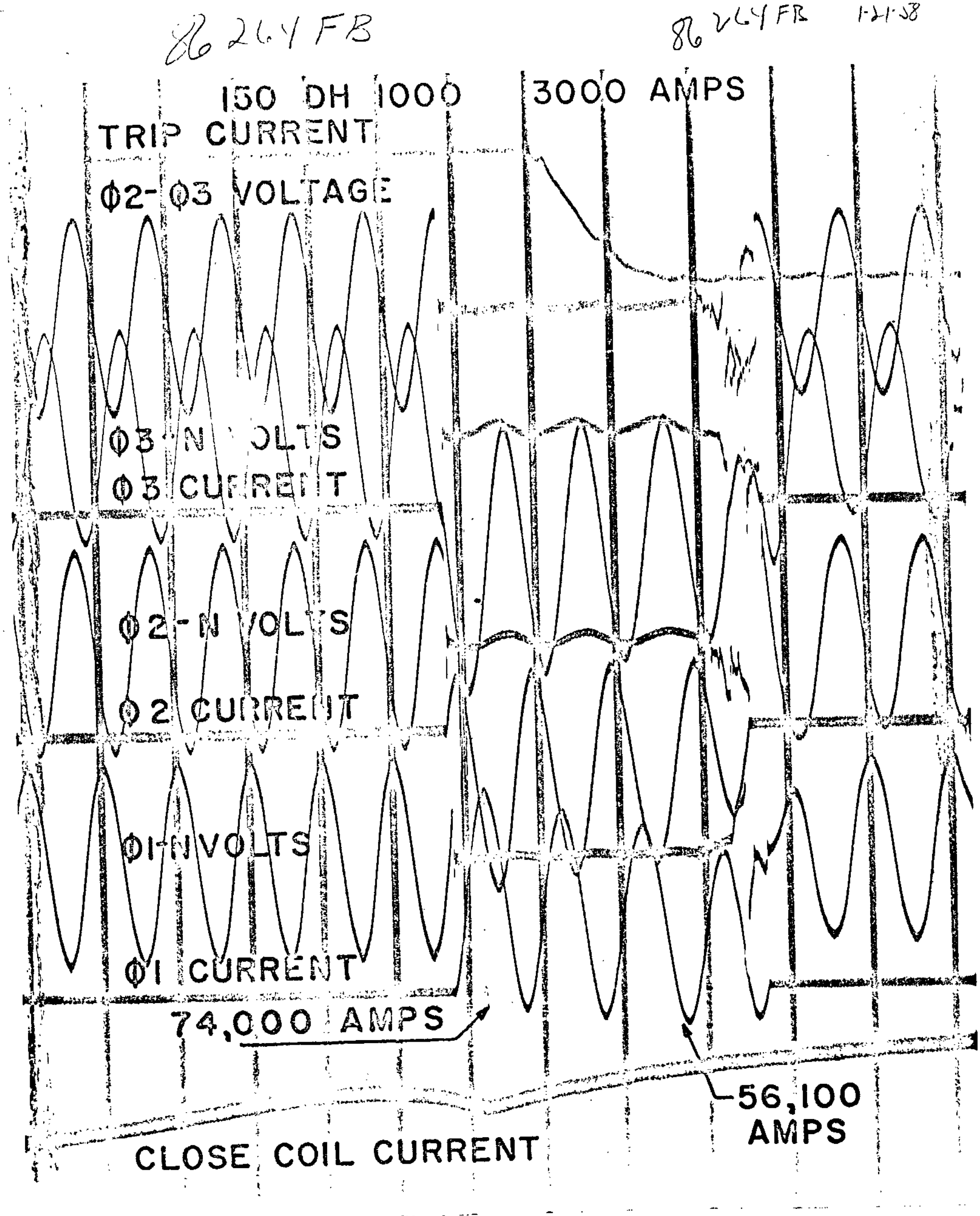

Fig. 7. Oscillogram of close-open operation showing breaker closing 74,000 amperes and opening 56,100 amperes at 13.2 KV.

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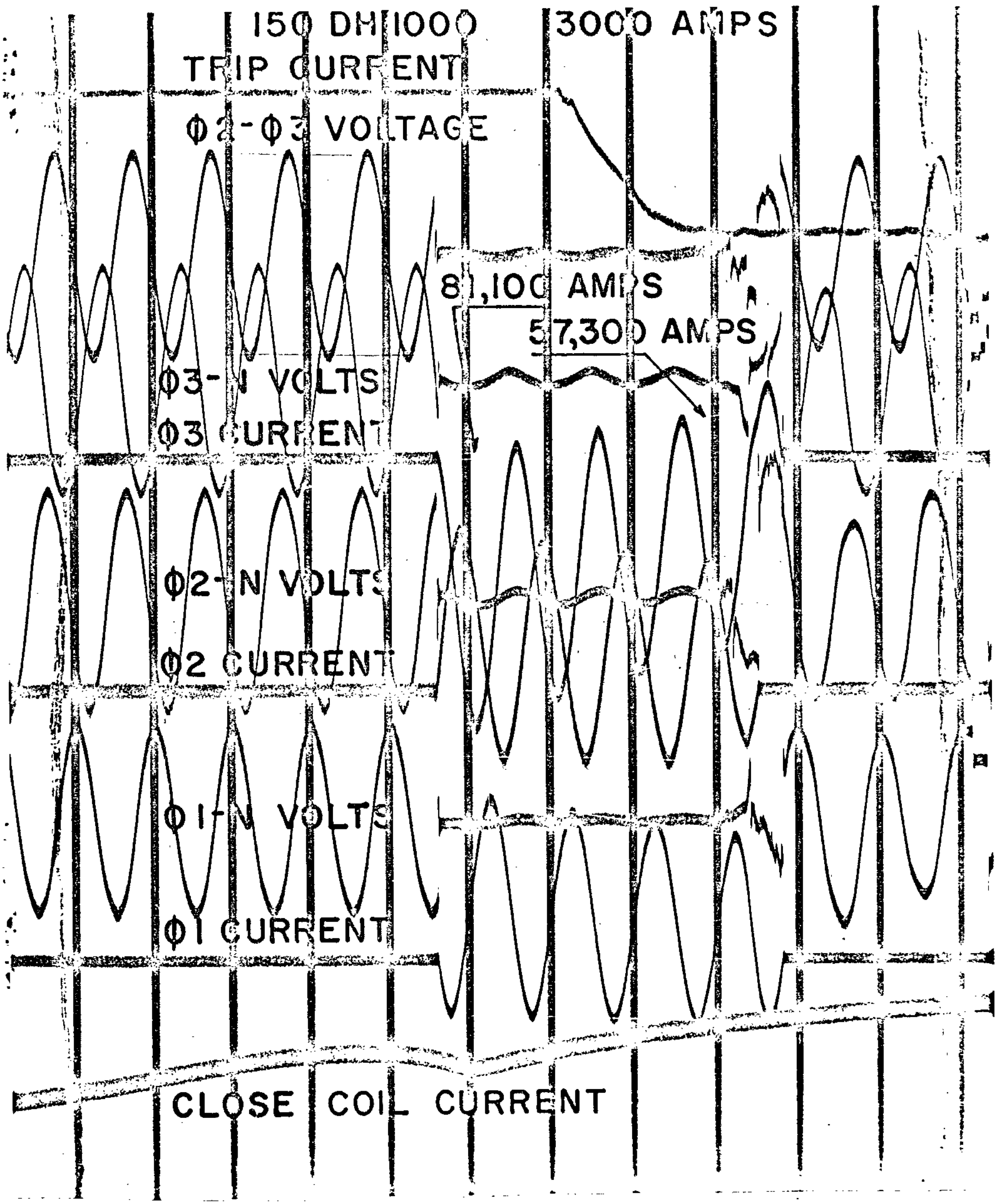

Fig. 8 Oscillogram of close-open operation showing breaker closing 81,100 amperes and opening 57,300 amperes at 13.2 KV