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# INVESTIGATION OF A HIGH VOLTAGE BREAKDOWN PROBLEM THAT OCCURRED DURING INSTALLATION OF THE NEW 750 kV HIGH GRADIENT ACCELERATING TUBE I N THE COCKCROFT-WALTON PIT

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December 1968

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**Brookhaven National Laboratory**

**U.S. Department of Energy**

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AGS DIVISION TECHNICAL NOTE

No. 58

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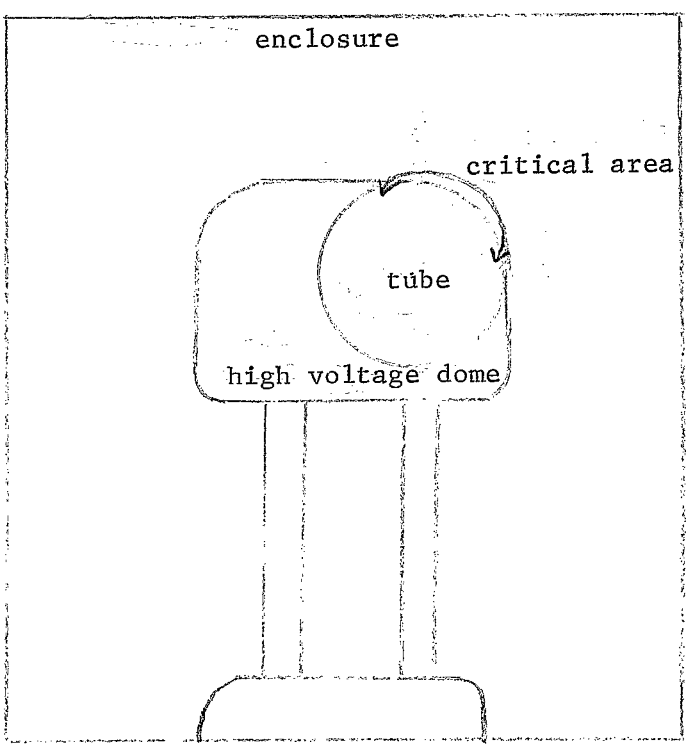
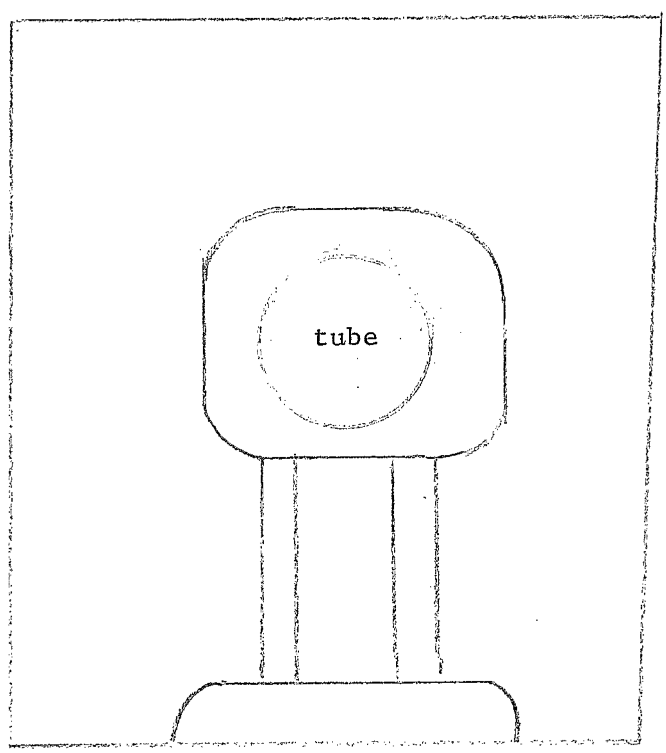
# INVESTIGATION OF A HIGH VOLTAGE BREAKDOWN PROBLEM THAT OCCURRED DURING INSTALLATION OF THE NEW 750 kV HIGH GRADIENT ACCELERATING TUBE IN THE COCKCROFT-WALTON PIT

An unexpected rejection of the new high gradient accelerator by the Cockcroft-Walton generator enclosure occurred during the 1968 October shutdown.

The cause of the trouble became obvious after several days of conditioning the tube. Figure 1 shows respectively cross-sections of the column and its enclosures in the test area and in the present location of the pit. Figure 2 shows the actual column installed in the pit.




"Non-symmetrical" Location of Tube in the 750 kV Cockcroft-Walton Pit.




"Symmetrical" Location of Tube in a Comparable Test Area.

The column conditioned properly before serious arcing occurred at 670 kV. Our diagnostic equipment (simultaneous recording of a) high voltage micro-discharges b) tube vacuum and c) polaroid photographs from stategic locations around the column) made it clear that the outside of the column was the limitation. All photographs showed arcing in the area indicated as "critical area" in Fig. 1. Arcing also initiated from very much the same spot, i.e., the second corona-ring nearest to the high voltage dome. Figure 3 is a photograph of such a typical discharge, initiated from above mentioned corona-ring.

After installation of stainless steel 1-in. diameter corona-rings (removed originally for practical reasons) the high voltage reached a new level of 720 kV*. This improvement can be explained by the lower maximum gradient around the corona-rings (see Appendix 1).

It became more and more evident that the field strength was too large around the top quadrant, closest to the dome which has not the "protection" of an adequate spinning due to the asymmetric location of the beam center-line with respect to the dome center. Small modifications of the position of the first two corona-rings improved the operating level to 750 kV.

R. Clipperton plotted potential distributions of several configurations in an electrolytic tank to verify above modifications, but mainly to find possible improvements: As long as arcing is not erratic, but prevails to trigger in the section mentioned above, lower field strength in that area with slight modifications should be possible. This is still the case.

Figures 4 and 5 shows the electrolytic tank and automatic plotter several years ago built by A. Soukas and R. Clipperton (unpublished). The accuracy of the plotter is mainly determined by the diameter of the pen (.020"). We are mainly interested in relative measurements.

*It should be noted that the tube in the test area could operate up to at least 760 kV.

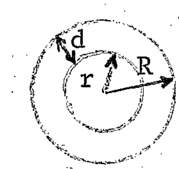
Figure 6 shows the general potential distribution in the vertical plane of the C-W pit. Close-ups (half scale) are made of various potential distributions around the critical corona-rings numbered 11 to 15.

TABLE 1

| Configuration | Figure | Field Strength (kV/cm)* | | | | |
|---|---|---|---|---|---|---|
| | | #15 | #14 | #13 | #12 | #11 |
| Original Layout | 7 | 35.5 | 42.6 | 33.6 | | |
| Present Layout | 8 | 37.7 | 37.7 | 35.5 | | |
| Gradual Recess of 12, 13 & 14 Corona-Rings | 9 | 35.5 | 35.5 | 33.6 | 33.6 | 32.5 |
| $2\frac{1}{2}$" o.d. Corona-Ring 12 cm Extended From #11 | 10 | 33.6 | 30.3 | 30.3 | 28.8 | 27.1 |

The maximum field strength around them has been approximated by a simple formulae assuming concentric equipotentials:

$$E_{max} = \frac{\Delta V}{d} \frac{R}{r} \text{ kV/cm}$$




with $\Delta V = 25$ kV.

Figure 7 shows the distribution when we reached 720 kV and Fig. 8 (with respectively recessed and raised rings #14 and 15) for 750 kV. The analysis is summarized in Table 1. The improvement around disk #14 is clear: <u>The field strength is about equalized around the first three rings</u>.

Along this way of reasoning a further improvement can be expected by a gradual recess of the corona-rings starting from disk #12. This is demonstrated in Fig. 9. The maximum field strength is improved about 20%. This solution, however, requests machining of disk #14 which is not too practical.

*Note: 30 kV/cm field strength is mostly used as practical upper limit in air.

Other configurations were checked, such as raising of the high voltage dome with some inches. However, a clear improvement was not so evident. J.G. Cottingham suggested to replace and extend the corona-ring on disk #11 or 12 for a much larger corona-ring, relieving the electrical stress further around the original critical region.* Figure 10 shows a more or less optimized location of such a ring and a comparison with the previous results seems indeed to suggest an interesting reduction of field strength in the present critical area. More details of this possibility using a computer program is under investigation by J.G. Cottingham and R. Lockey.

Finally a potential plot was made of the 810 kV high gradient column located symmetrical in the new pit of the 200 MeV linac (see Fig. 11). It is obvious that no high stresses occur around the rings close to the high voltage dome.

## Conclusion

The operational voltage of the high gradient column is around 750 kV. Further improvement can still be expected with the extended large corona-ring.

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AGS Division Staff
Conversion Division Staff

*See memorandum to Th. Sluyters from J.G. Cottingham on the subject, Electric Field High Gradient Column, dated November 13, 1968.

## APPENDIX 1

The maximum electrical strength (gradient) between parallel cylinders can be compared by using the following practical formulae (M. von Ardenne: Tabellen der Elektronenphysik, Ionenphysik und Ubermikroskopie, Band II):

$$E_{max}\ (\mathrm{kV/cm}) = \frac{.9\,\Delta V}{2.3\ r\,\mathrm{lg}\,\frac{r + .5d}{r}}$$

$\Delta V$ = potential difference between conductors (in kV)

r = radius of the cylinder (cm)

d = distance between the cylinders (cm)

For 1/2-in. o.d. corona-rings and 2-in. distances, the maximum gradients are 18.7 kV/cm, while for 1-in. o.d. corona-rings and 1-1/2-in. distances between them the maximum gradient is smaller; 17.0 kV/cm. This reduction improved the voltage hold-off significantly (+ 50 kV).

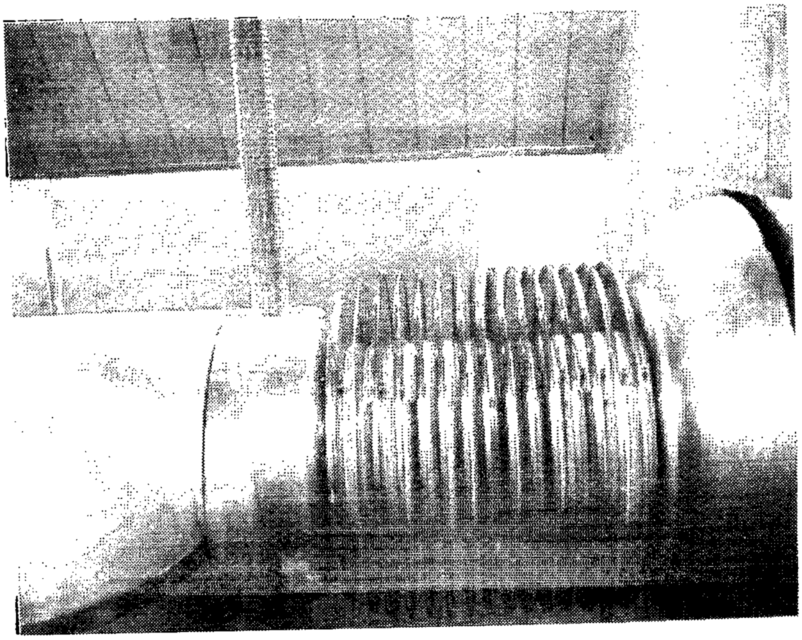

Fig. 2 High Gradient Column Installed in the Linac

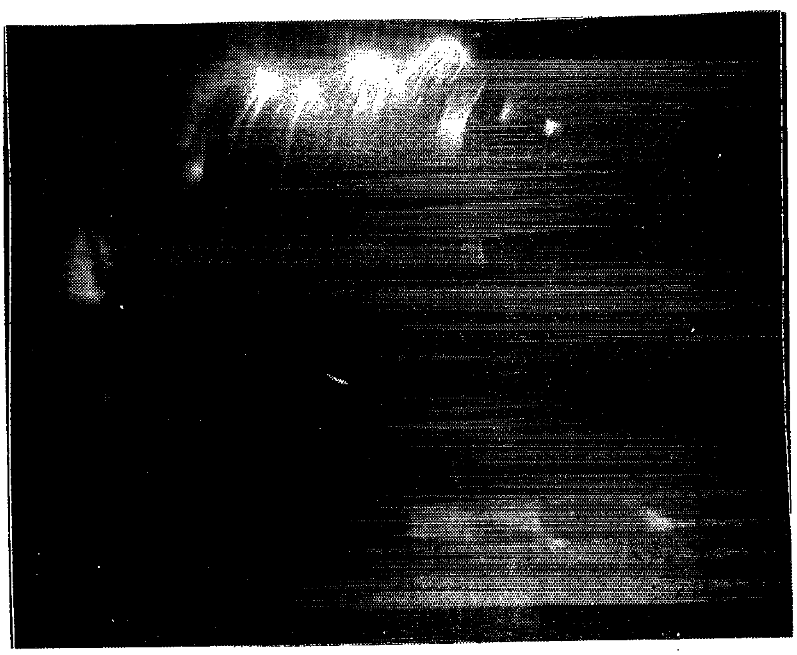

Fig. 3 A Typical Arc Across the Column

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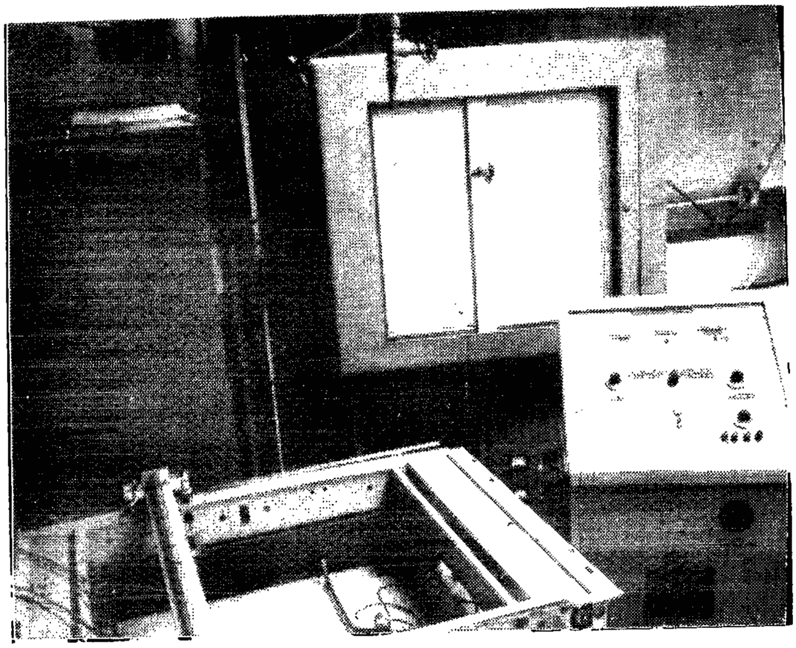

Fig. 4 Electrolytic Tank, Plotter and Control Panel

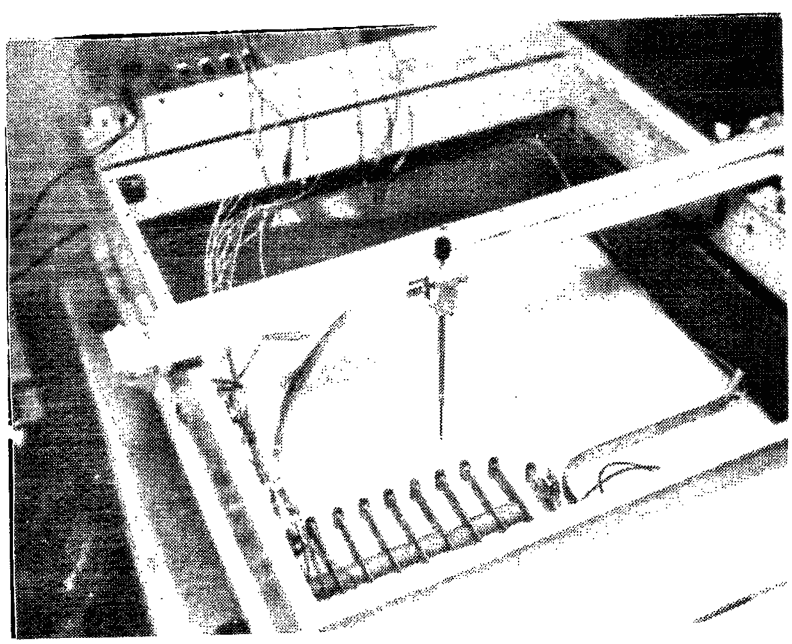

Fig. 5 Electrolytic Tank

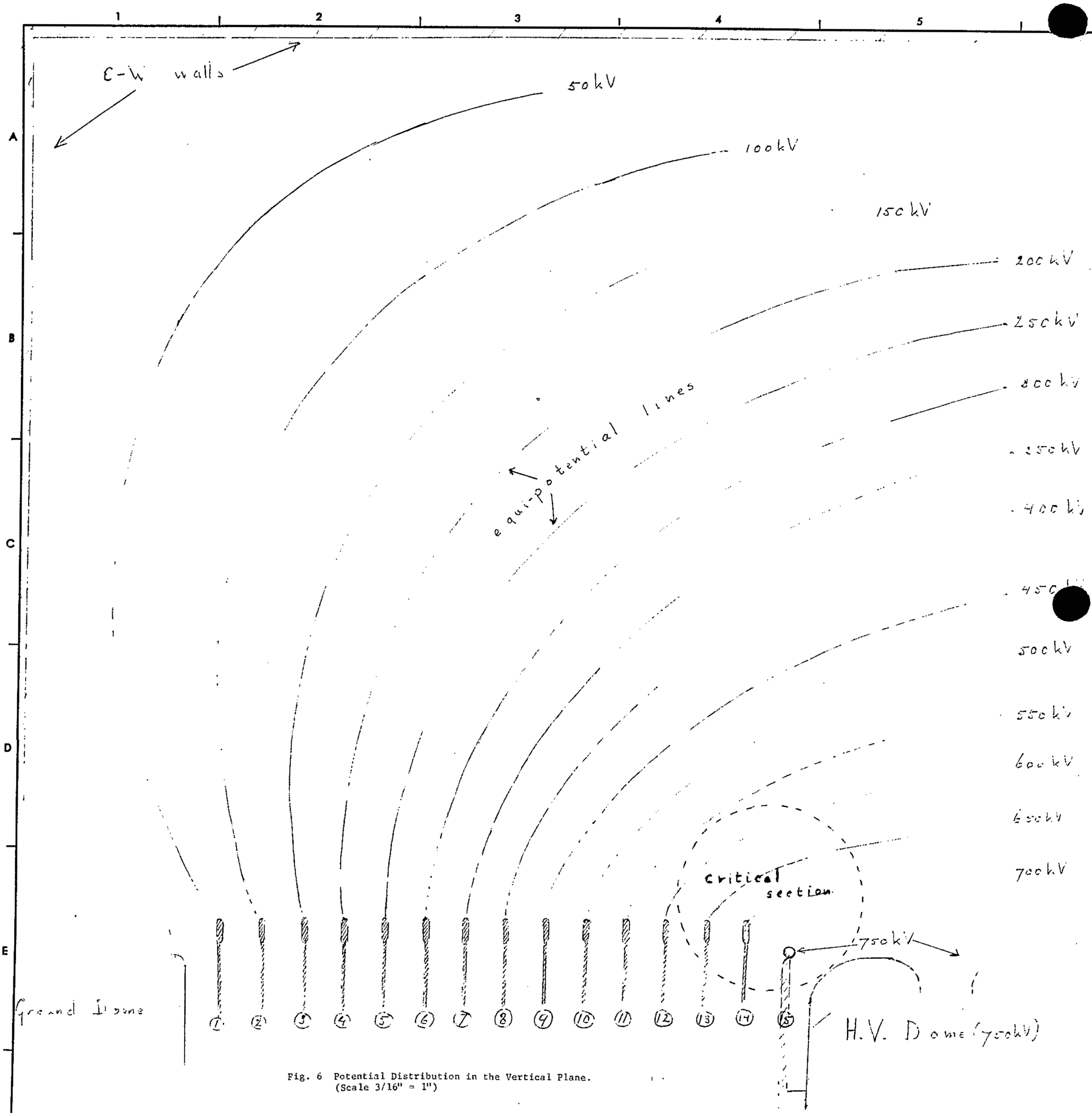


Fig. 6 Potential Distribution in the Vertical Plane.
(Scale 3/16" = 1")

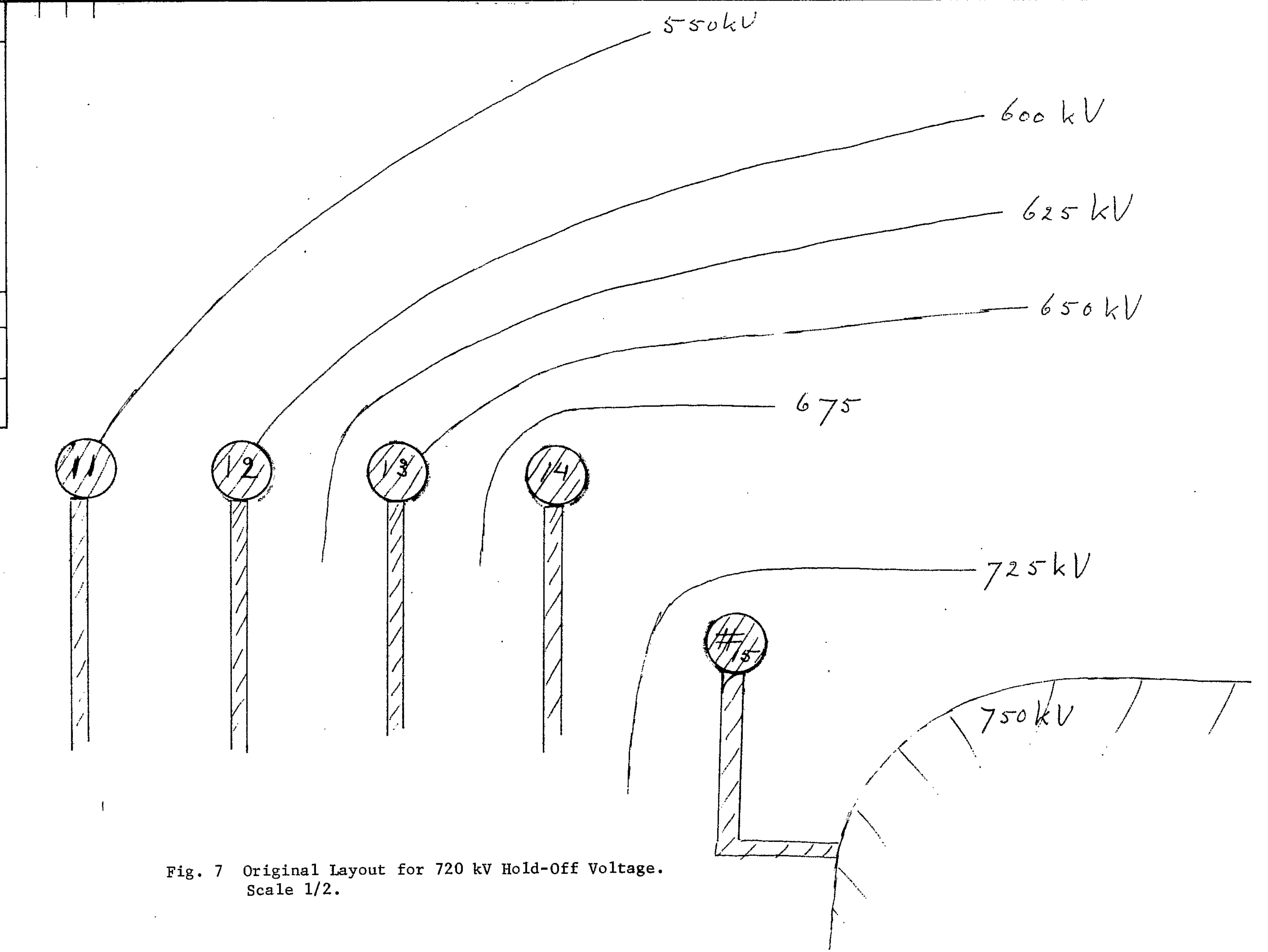


Fig. 7 Original Layout for 720 kV Hold-Off Voltage.
Scale 1/2.


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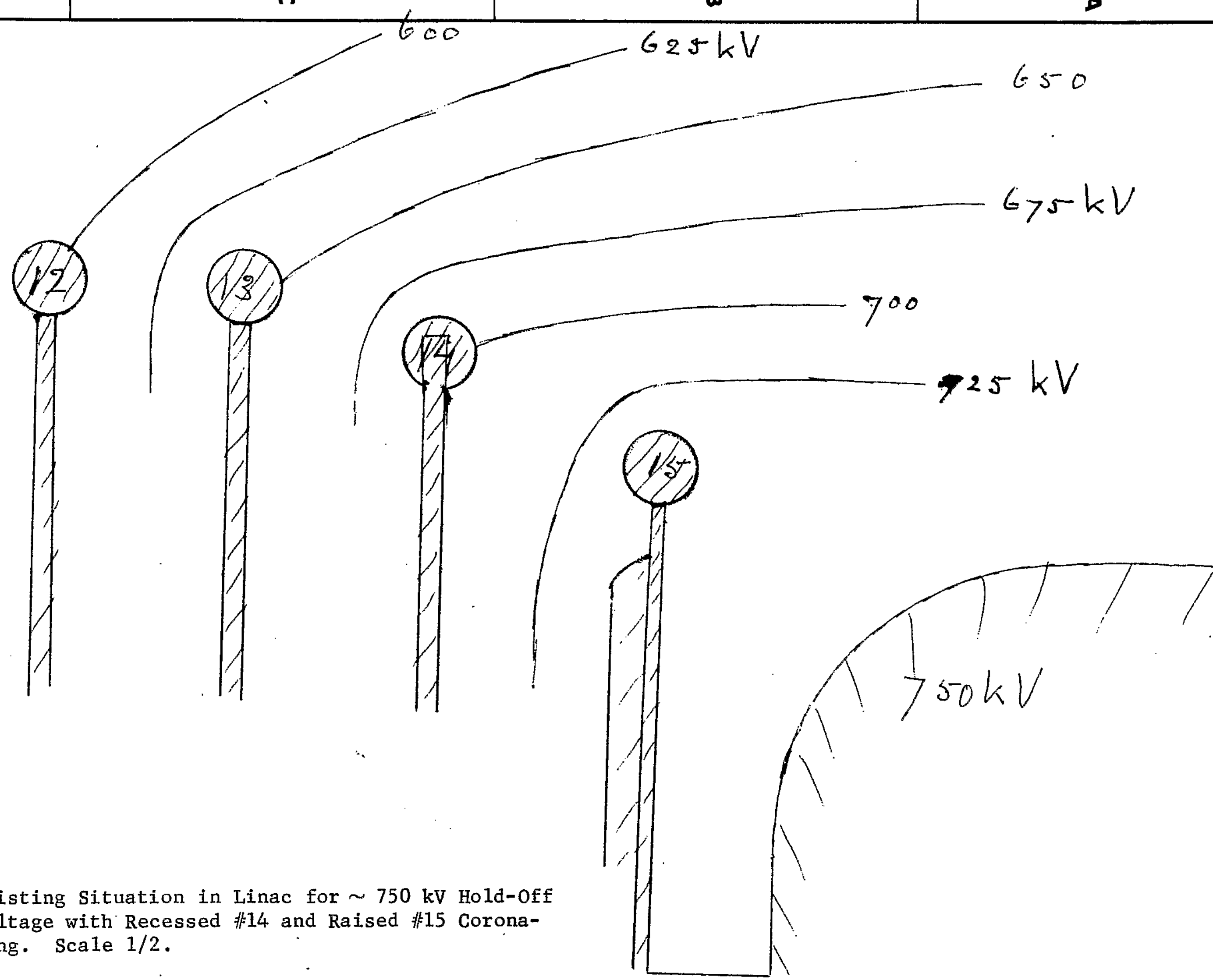


Fig. 8 Existing Situation in Linac for ~ 750 kV Hold-Off Voltage with Recessed #14 and Raised #15 Corona-Ring. Scale 1/2.

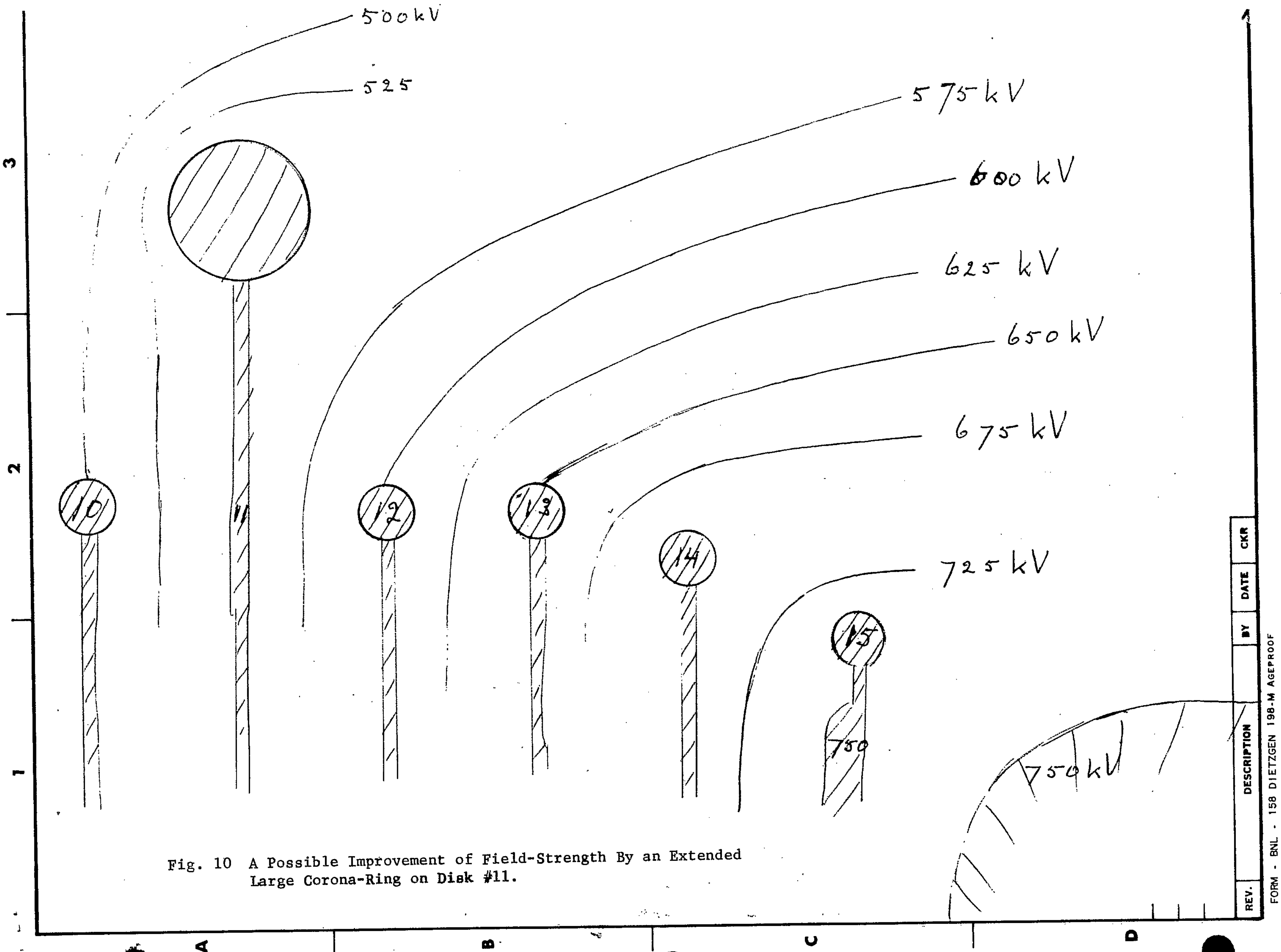


Fig. 10 A Possible Improvement of Field-Strength By an Extended Large Corona-Ring on Disk #11.

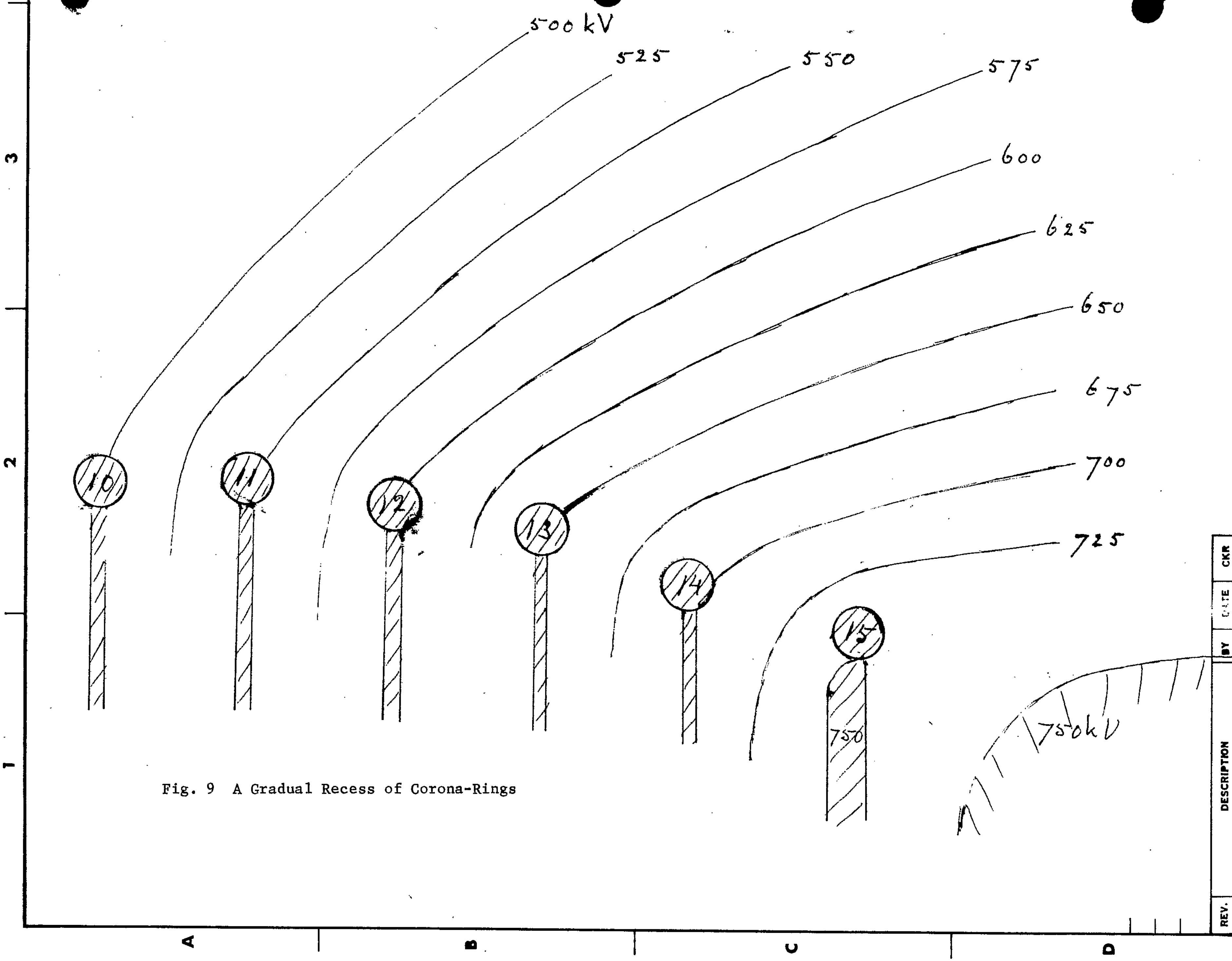


Fig. 9 A Gradual Recess of Corona-Rings

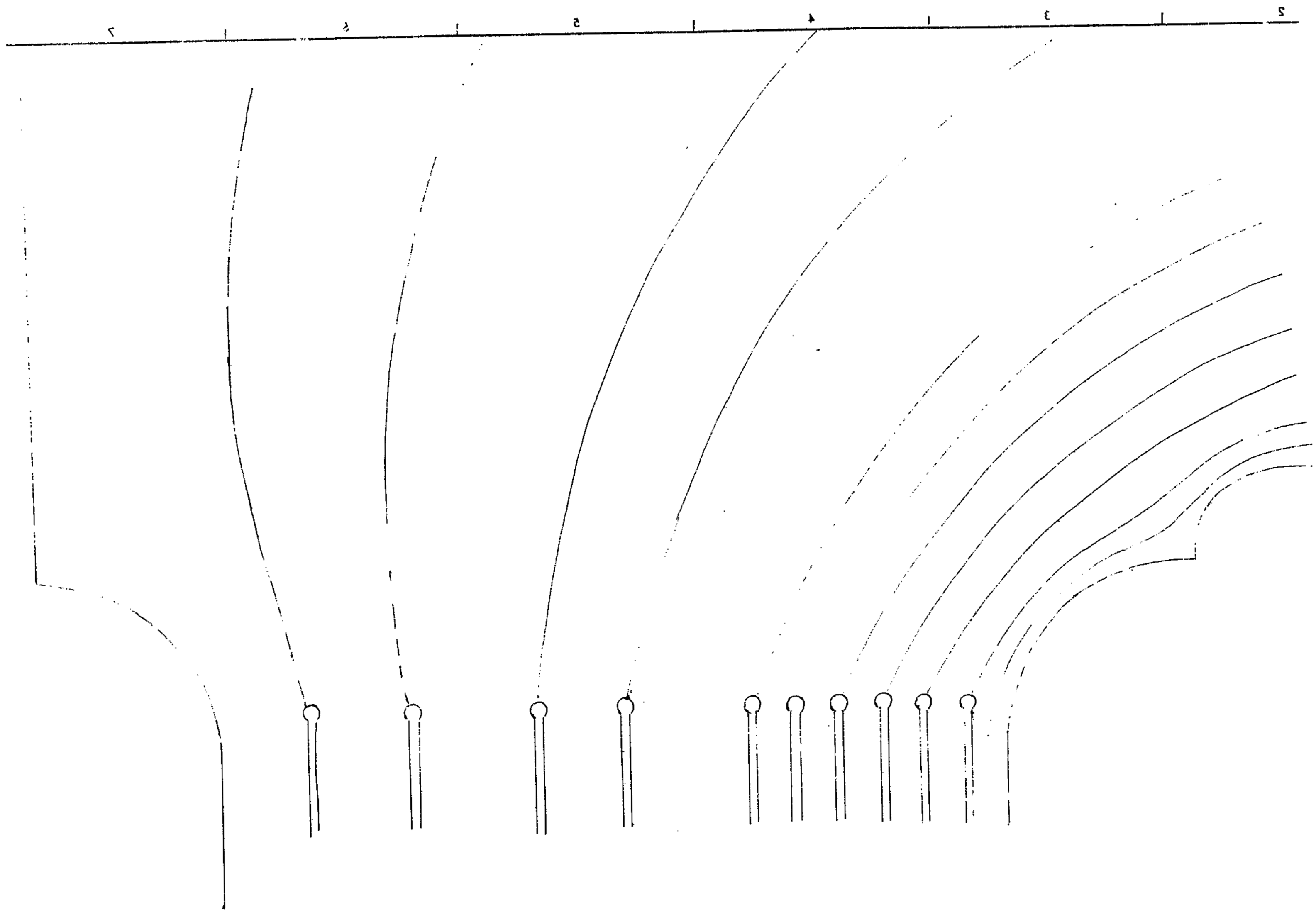

Fig. 11 Potential Distribution Around the Conversion Column.
(Scale 3/16" = 1")