SDC-91-00005

SDC
SOLENOIDAL DETECTOR NOTES

EFFECTS ON THE MAGNETIC INDUCTION DUE TO THE GAPS WIHIN THE SDC MUON TOROID

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January15, 1991

SDC-91-00005

UM High Energy Physics Memorandum Jan. 15, 1991

TO: SDC collaboration

FROM: Seong J. Hong

SUBJECT: Effects on the magnetic induction due to the gaps within the SDC muon toroid.

This note describes effects on the magnetic induction due to the gaps within the SDC muon toroid. The effects were studied using simplified configurations of the SDC muon toroid and the POISSON program in Ref. 1 which has been used for many years to calculate 2-dimensional magnetic induction problems at SLAC.

The SDC muon toroid is assumed to be 0.10% carbon steel whose magnetization curve is shown in Fig. 1. The SDC muon steel assembly is shown Fig. 2 which also shows the definition of gap 1 and gap 2. Here, gap 2 is greatly exaggerated. Figures 3 and 4 show simplified 2-dimensional configurations to study the effects on the magnetic induction due to the gaps. In Fig. 3, octagonal symmetry has been assumed to calculate the magnetic induction. No symmmetry has been assumed in Fig. 4 and magnetic inductions at the left and right boundaries may not be useful for our purpose. A current of 4×10^4 ampere-turns for each point coil has been applied in Fig. 3 to produce a field of about 1.8 tesla in the toroid. But for the leakage of the magnetic flux in Fig. 4, a current of 1.07×10^5 ampere-turns for each point coil would also result in about 1.8 tesla of the magnetic induction in the toroid. Figures 3 and 4 also show the size of the toroid and the position of the coil.

Figures 5, 6 and 7 show the total magnetic induction in the toroid for 0.0, 0.4 and 0.6 cm gap 1's, respectively. These figures show that the gap does not affect much the uniformity of the magnetic induction. The magnetic flux for the 0.4 cm gap is shown in Fig. 8. Fig. 9 shows mesh points to calculate the magnetic induction. Two gaps are shown in Fig. 4; gap 1 is the same gap shown in Fig. 3 and gap 2 is a gap between layers of the toroid. Because of the leakage of the magnetic flux in figures 10-15, the total magnetic induction in figures 10-15 is lower than in figures 5-7. In figures 10-15, we are not interested in the absolute value but in the uniformity of the magnetic induction. Figures 10, 11 and 12 show the total magnetic induction for (gap 1, gap 2) = (0.2, 0.0), (0.4, 0.0) and (0.0, 0.4) cm, respectively. These figures again show that the gap does not affect much the uniformity of the magnetic induction, independent of the sizes of the gaps. Figures 13, 14 and 15 show the total magnetic induction for (0.4, 0.4), (0.6, 0.6) and (0.1, 0.2) cm gaps. Even for the smallest gap of (0.1, 0.2) cm, the uniformity of the magnetic induction is disturbed. Figures 16, 17 and 18 show the magnetic flux line for the (0.4, 0.0), (0.0, 0.4) and (0.4, 0.4) cm gaps, respectively.

In conclusion, what really deteriorates the uniformity of the magnetic induction is the combined effect of gap 1 and gap 2. The magnetic induction stays uniform regardless of the size of the gap if there is only one gap (gap 1 or gap 2) and if the size of the gap is not bigger than 0.6 cm. The magnetic induction stays uniform up to 20 cm from the gap if there is only gap 1. Finally, it is important to study effects on the momentum resolution due to these gaps after the structure of the muon toroid steel is determined.

Acknowledgement

This work was initiated with R. Thun's suggestion and wouldn't be completed without R. A. Early's help.

References

1. R. A. Early, PEP-NOTE-326 R, Aug 10, 1984.

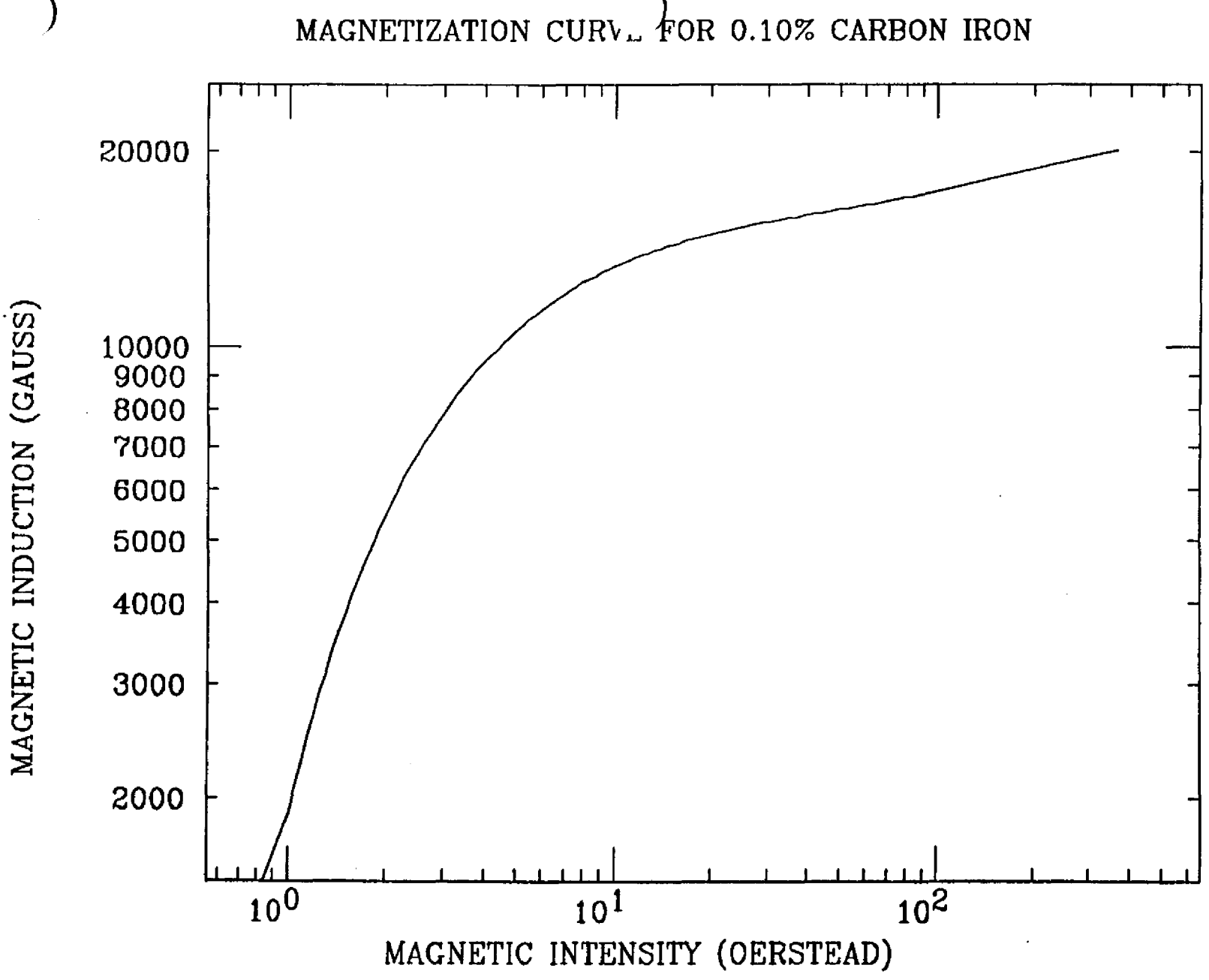

Fig. 1. Magnetization Curve for 0.10% Carbon Steel.

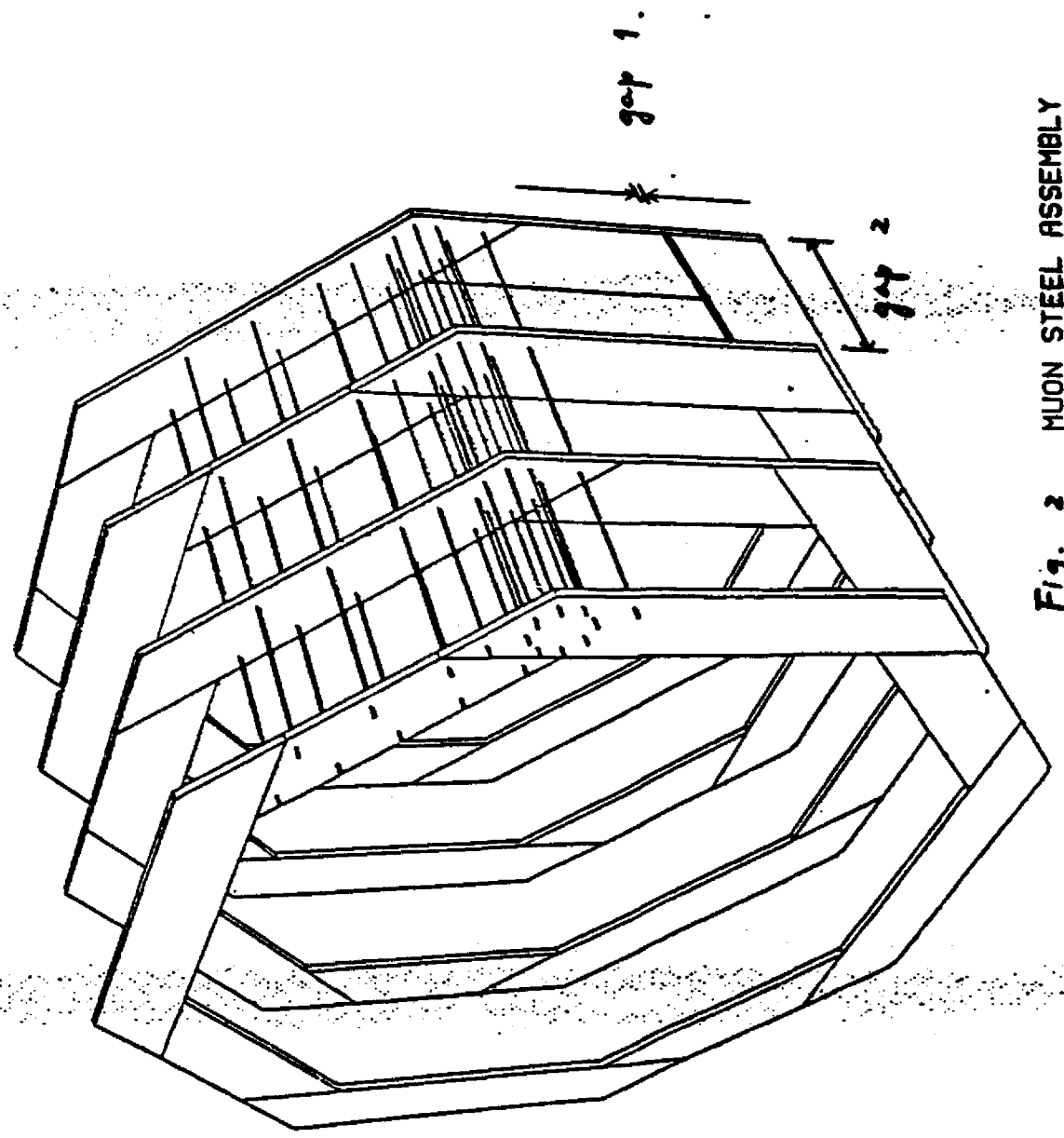

Fig. 2 MUON STEEL ASSEMBLY
RTK 7-18-90

EOI TYPE S SOLENOID
MUON STEEL PLATES

SK#2

SDC031 – 0.40CM CRACK

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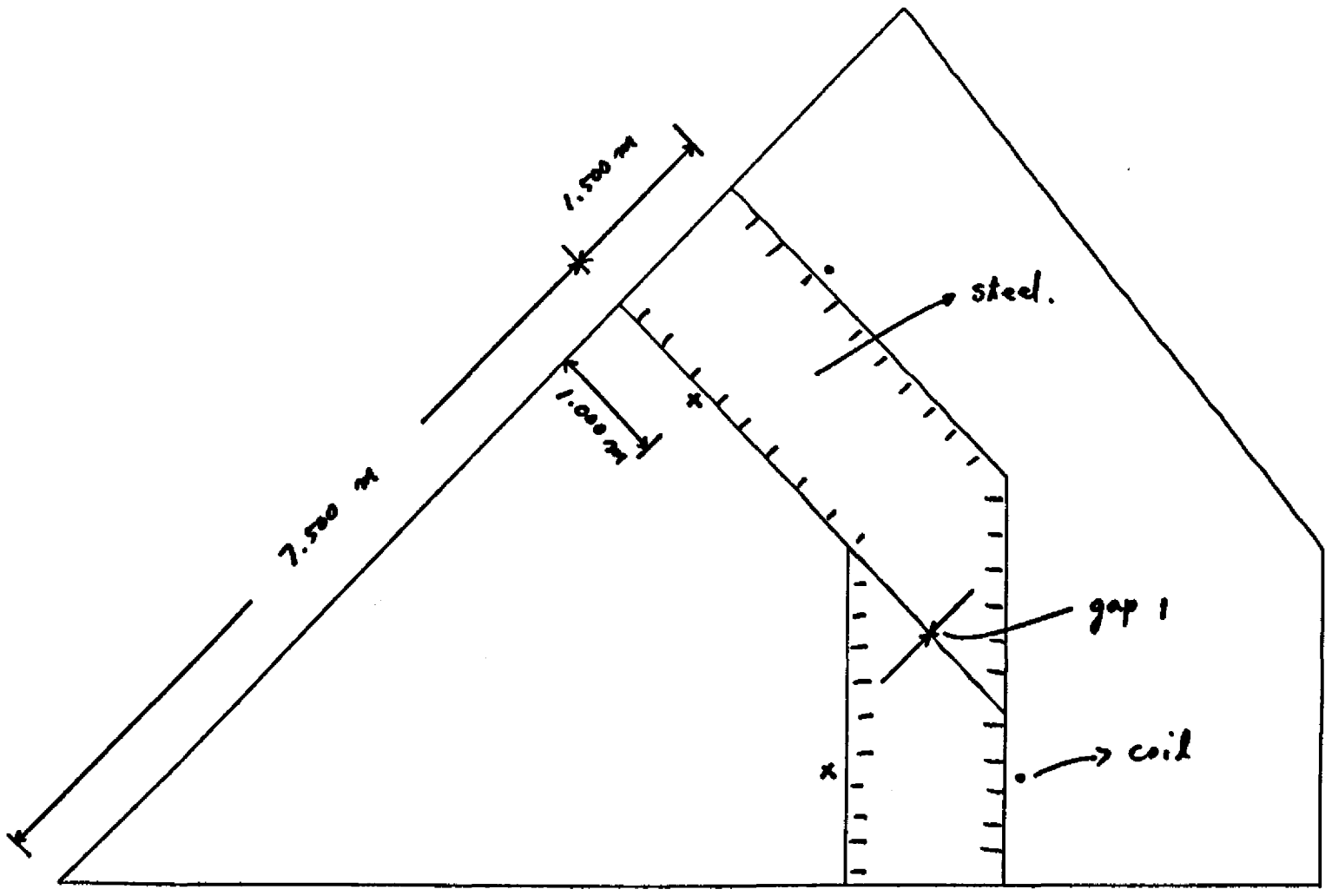
Fig. 3. Simplified 2-D mean toroid configuration (Front View)



SDC219 - 0.6CM GAP1, 0.6CM GAP2

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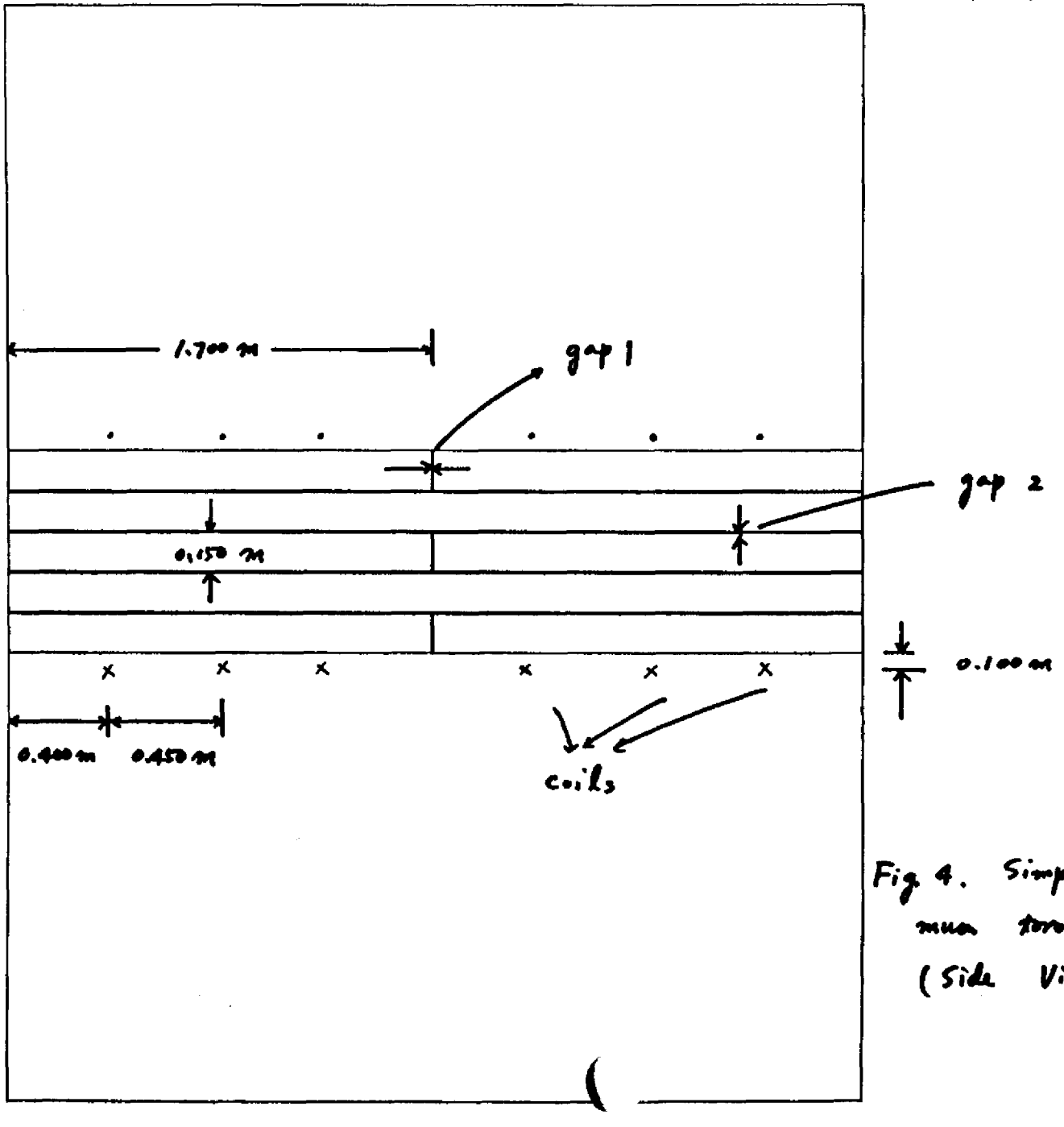

Fig 4. Simplified 2-D muon toroid configuration (Side View)

Fig. 5. SDC091 – NO CRACK

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Current : 4×10^4 ampere - turns.

Magnetic Induction (Tesla)

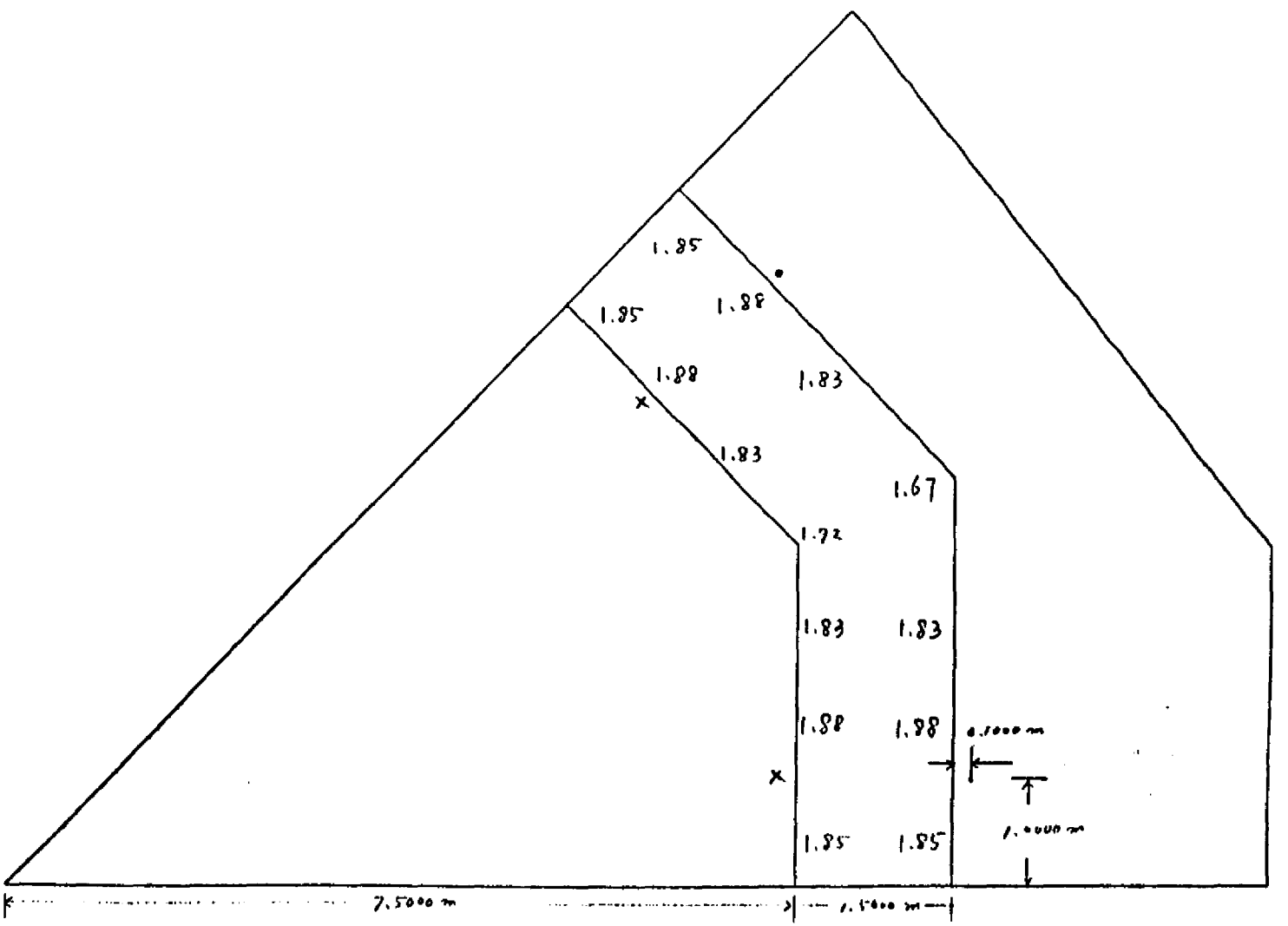

Fig. 5

FIG 6. SDC031 – 0.40CM CRACK

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current : 4×10^4 ampere-turns.

Magnetic Induction (Tesla)

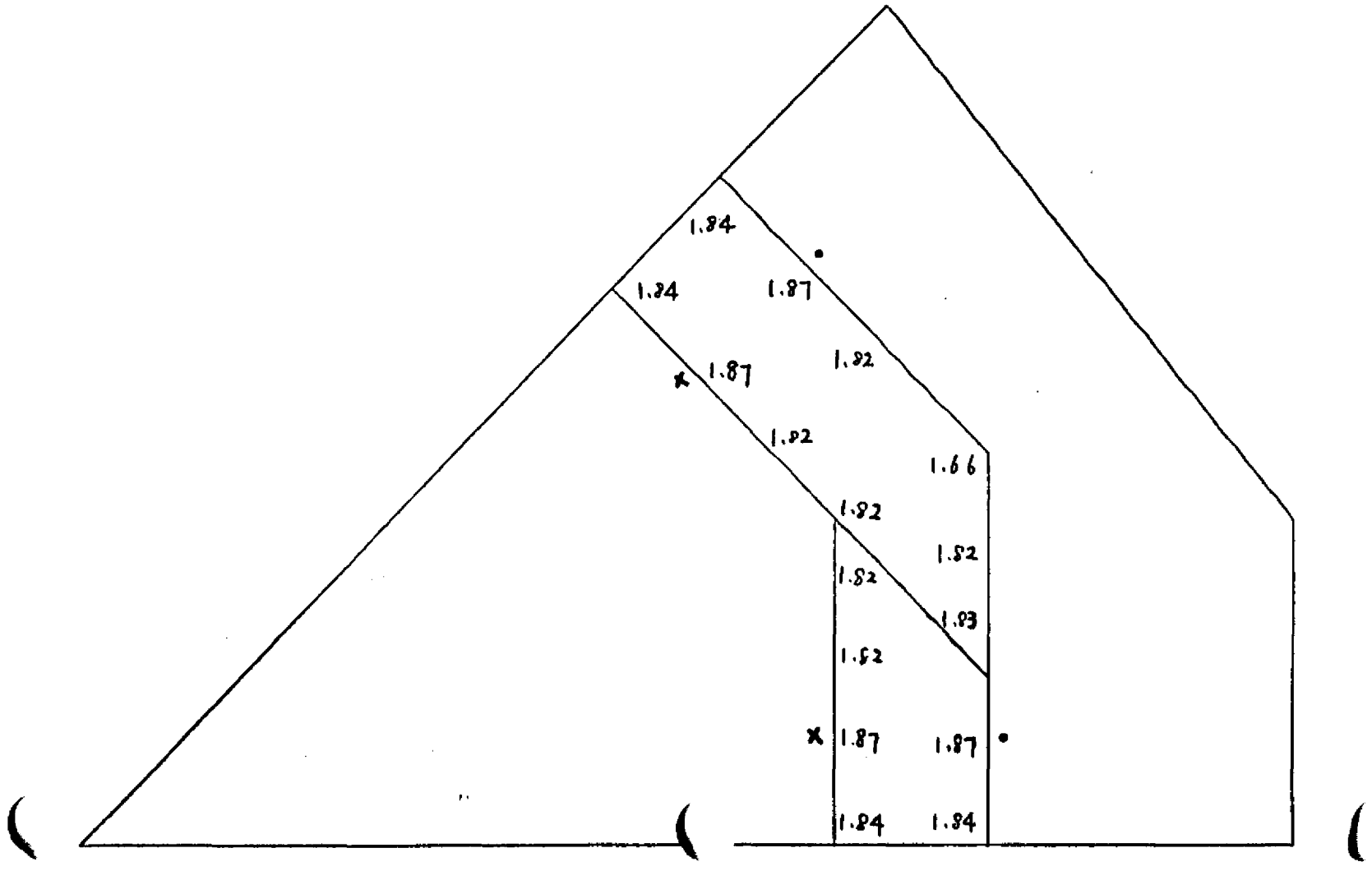

FIG SDC021 – 0.60CM CRACK

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Magnetic Induction (Tesla)

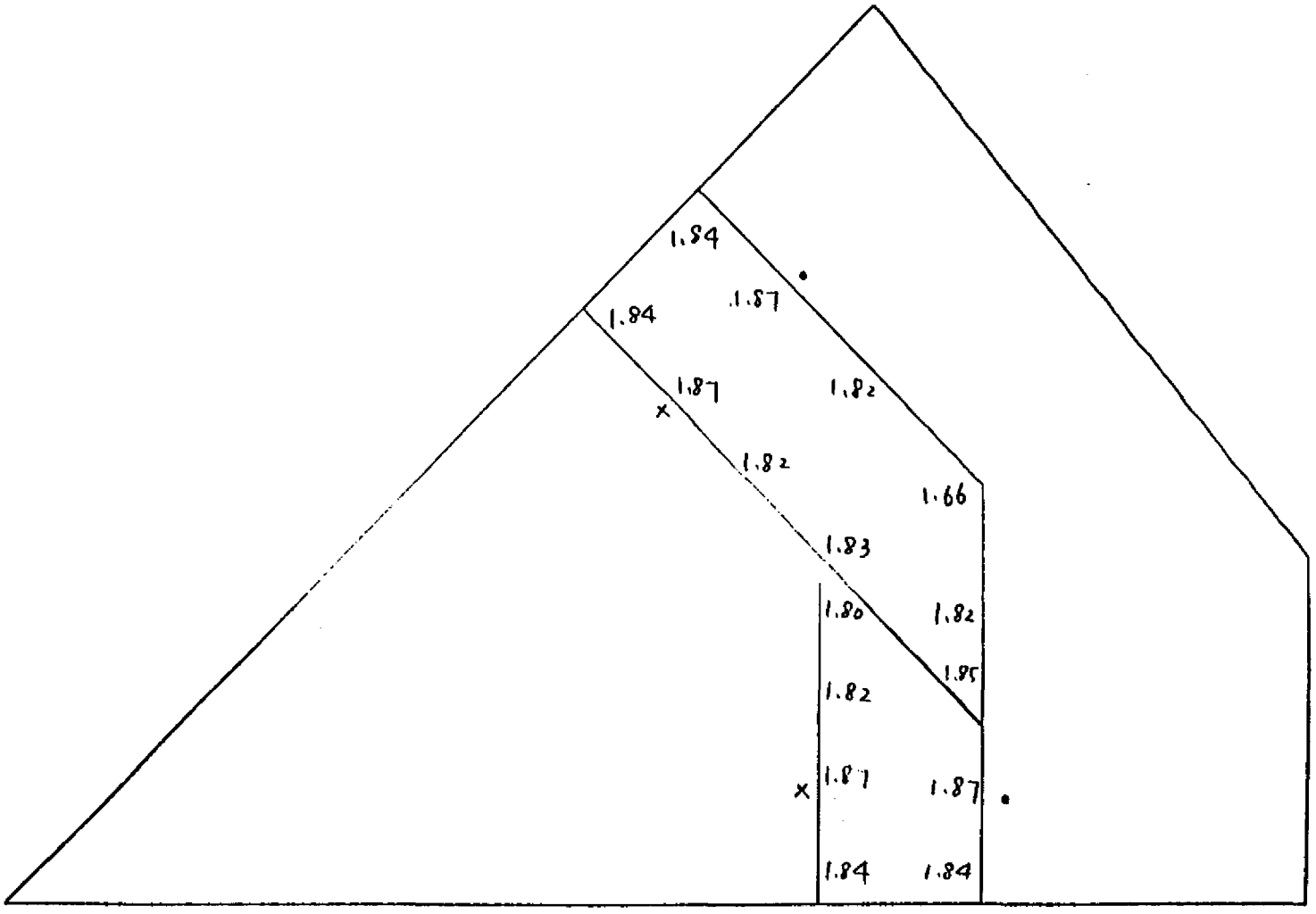

FIG 8. SDC031 - 0.40CM CRACK

MAGNETIC FLUX

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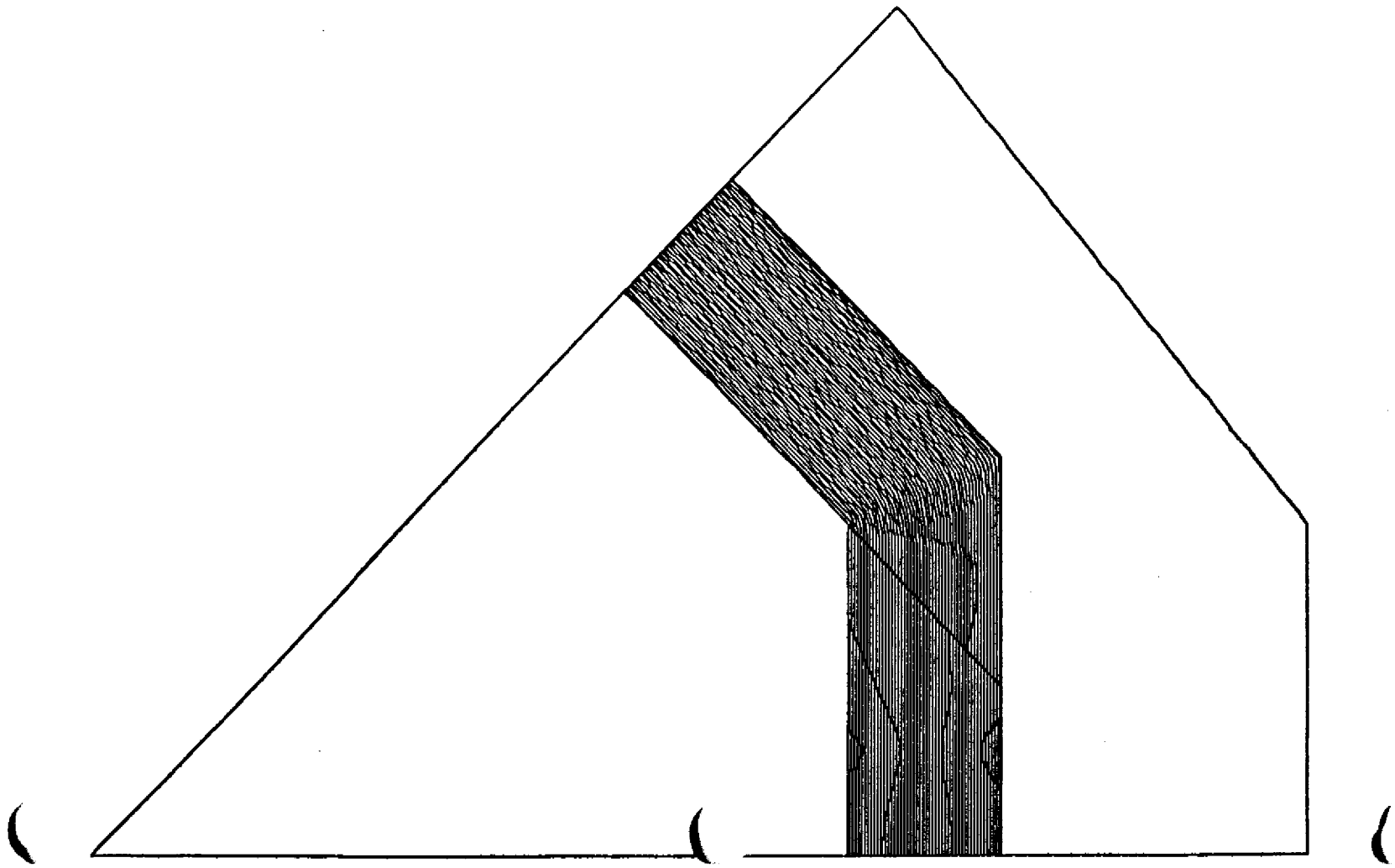

Fig 7. SDC031 - 0.40CM CRACK

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MESH POINTS

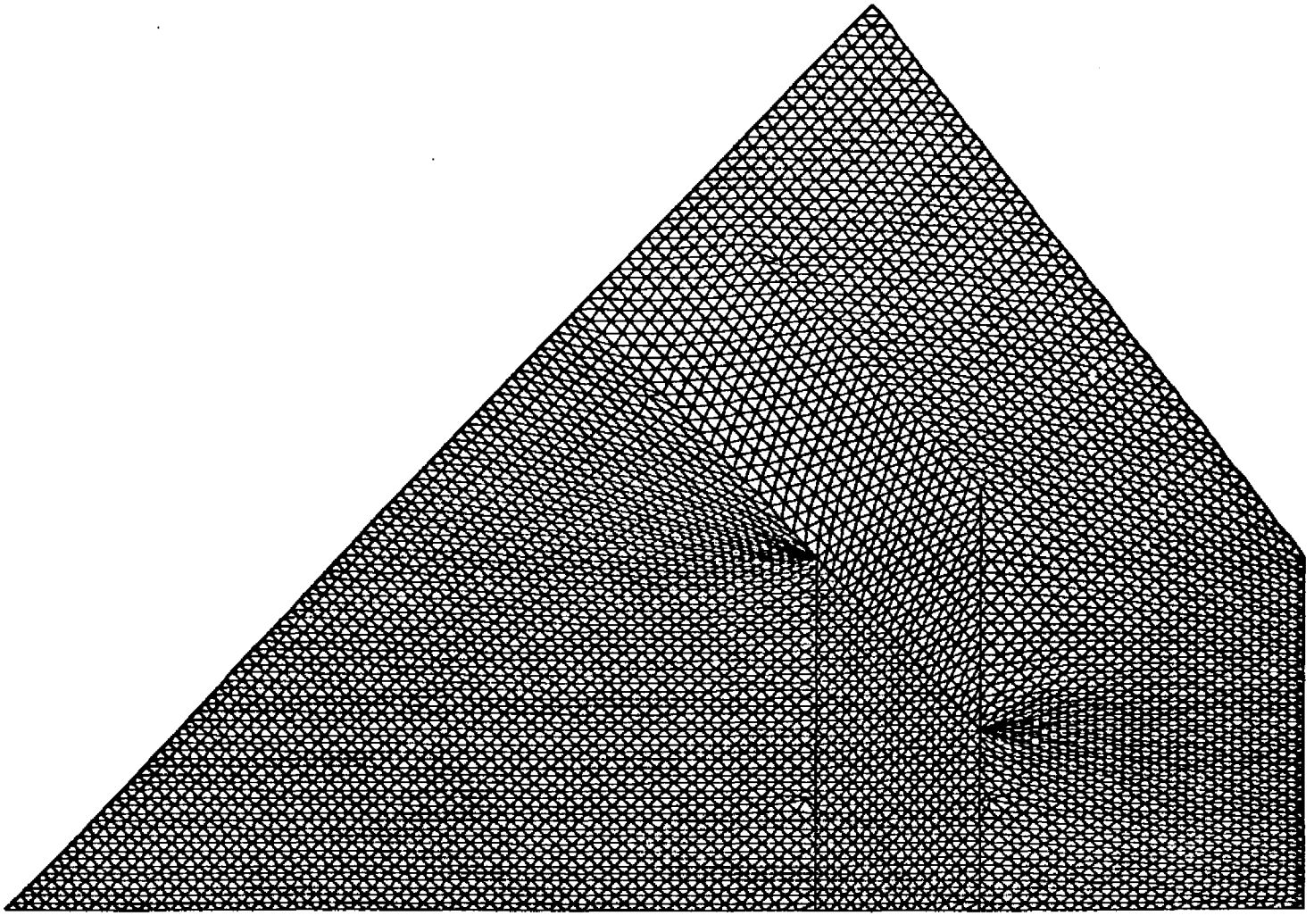

FIG 10. MAGNETIC INDUCTION

Unit : Tesla

SDC 0200 – 0.2 CM GAP 1, 0.0 CM GAP 2, 6-COILS ($3.2 \times 10^5/3$ ampere – turns each)

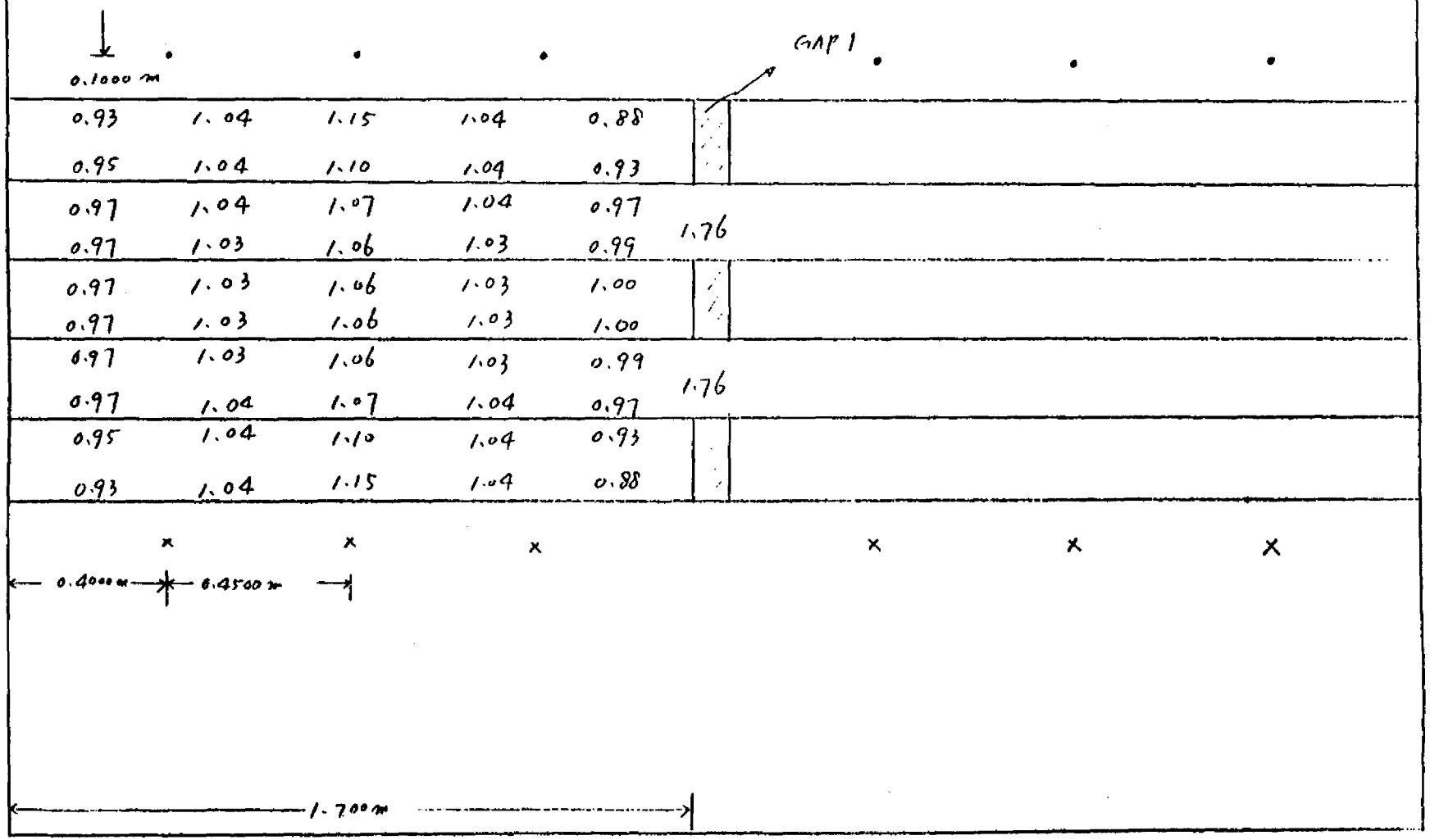

FIG 11. MAGNETIC INDUCTION

Unit : Tesla

SDC 0 400 — 0.4CM GAP 1, 0.0 CM GAP 2

0.93	1.04	1.05	1.04	0.88		
0.95	1.04	1.10	1.04	0.92		
0.96	1.04	1.07	1.04	0.97	1.85	
0.97	1.03	1.06	1.03	0.99		
0.97	1.03	1.06	1.03	1.00		
0.97	1.03	1.06	1.03	1.00		
0.97	1.03	1.07	1.03	0.99	1.85	
0.96	1.04	1.08	1.04	0.97		
0.95	1.04	1.10	1.04	0.92		
0.93	1.04	1.05	1.04	0.87		

FIG 12. MAGNETIC INDUCTION

Unit : Tesla

0.0 CM GAP1. 0.4 CM GAP2

0.86	1.08	1.21	1.02	0.81
0.88	1.08	1.17	1.04	0.93
1.01	1.02	1.03	1.02	1.01
1.01	1.02	1.03	1.02	1.01
1.01	1.02	1.02	1.02	1.02
1.01	1.02	1.02	1.02	1.02
1.01	1.02	1.03	1.02	1.01
1.01	1.02	1.03	1.02	1.01
0.88	1.08	1.17	1.04	0.93
0.86	1.08	1.21	1.02	0.81

GAP2

FIG 13. MAGNETIC INDUCTION

Unit : Tesla

SDC 214 – 0.4 CM GAP1, 04 CM GAP 2, 6 coils

6 coils – $3.2 \times 10^5/3$ ampere – turns.

0.84	1.02	1.14	0.94	0.63		0.63	0.95	1.14	1.04	0.84
0.85	1.02	1.10	0.94	0.65		0.65	0.95	1.10	1.04	0.85
1.03	1.06	1.11	1.20	1.37	1.62	1.37	1.20	1.10	1.06	1.03
1.03	1.06	1.11	1.20	1.37		1.37	1.20	1.10	1.06	1.03
1.02	1.01	0.97	0.86	0.66		0.66	0.86	0.96	0.99	1.00
1.02	1.01	0.97	0.86	0.66		0.66	0.86	0.96	0.99	1.00
1.03	1.06	1.11	1.20	1.37	1.62	1.37	1.20	1.10	1.06	1.04
1.03	1.06	1.11	1.20	1.37		1.37	1.20	1.10	1.06	1.04
0.85	1.02	1.10	0.94	0.65		0.65	0.95	1.10	1.04	0.86
0.84	1.02	1.14	0.94	0.63		0.63	0.95	1.14	1.04	0.85

0.4020

1.7020

FIG 14. MAGNETIC INDUCTION

Unit : Tesla

0.6 CM GAP 1, 0.6 CM GAP 2

	•	•	•			•	•	•
0.82	1.01	1.12	0.92	0.60				
0.84	1.01	1.08	0.92	0.62				
1.06	1.09	1.14	1.24	1.42	1.66			
1.06	1.09	1.14	1.24	1.42				
0.99	0.98	0.93	0.82	0.62				
0.99	0.98	0.93	0.82	0.62				
1.06	1.09	1.14	1.24	1.42	1.66			
1.06	1.09	1.14	1.24	1.42				
0.84	1.01	1.08	0.92	0.62				
0.82	1.01	1.12	0.92	0.60				
	×	×	×			×	×	×

FIG 15. MAGNETIC INDUCTION

Unit : Tesla

SDC 298 – 0.1 CM GAP 1, 0.2 CM GAP 2 – 6 coils

0.85	1.05	1.17	1.01	0.73			
0.87	1.05	1.13	1.01	0.76			
1.01	1.02	1.05	1.11	1.23	1.40		
1.01	1.02	1.05	1.11	1.23			
1.04	1.02	0.99	0.92	0.76			
1.04	1.02	0.99	0.92	0.76			
1.01	1.02	1.05	1.11	1.23	1.40		
1.01	1.02	1.05	1.11	1.23			
0.86	1.05	1.14	1.01	0.76			
0.85	1.05	1.19	1.01	0.73			

SDC0400 - 0.4CM GAP1, 0.0CM GAP2, 6-COILS

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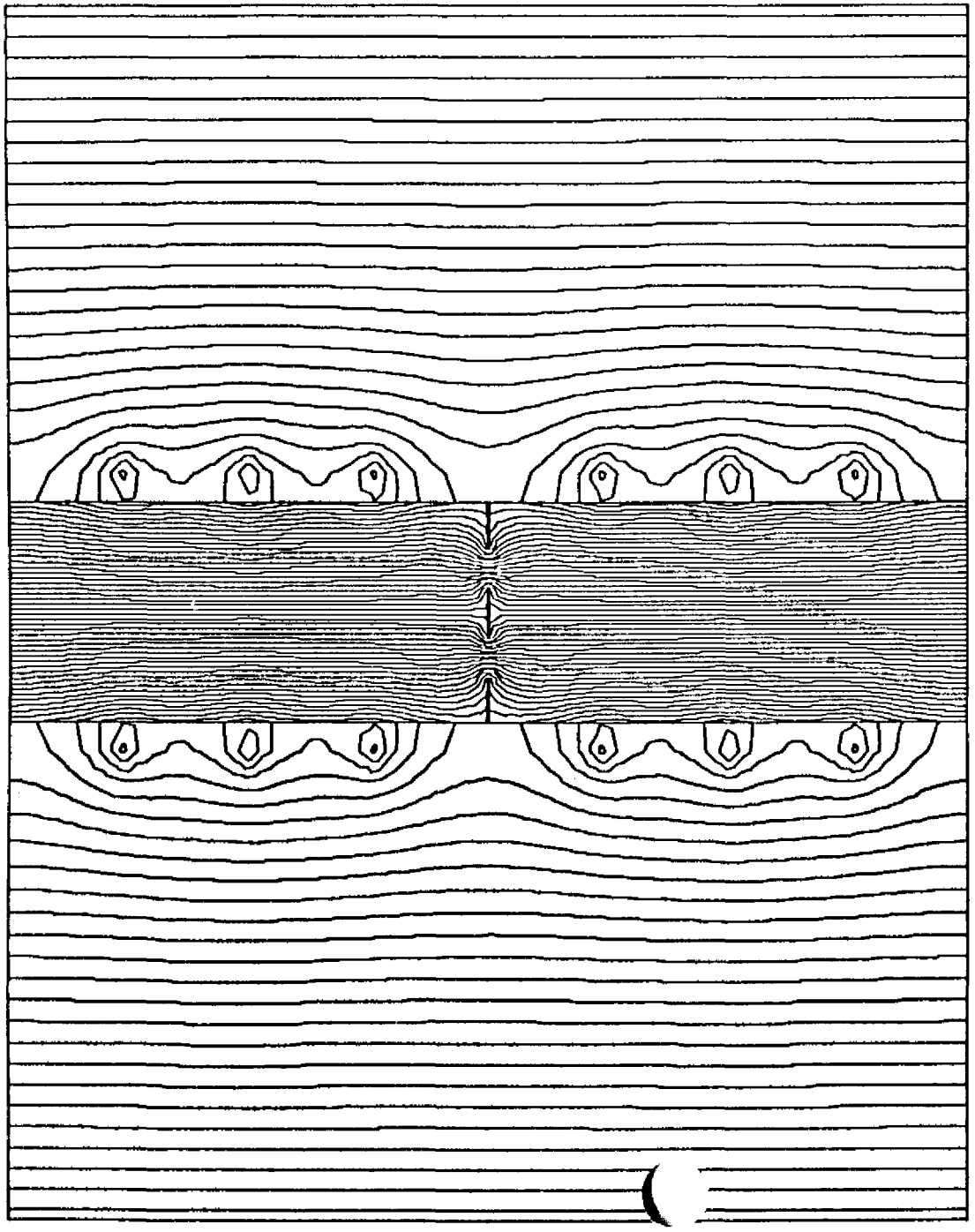

FIG 16. MAGNETIC FLUX

SDC141 – 0.0CM GAP1, 0.4CM GAP2

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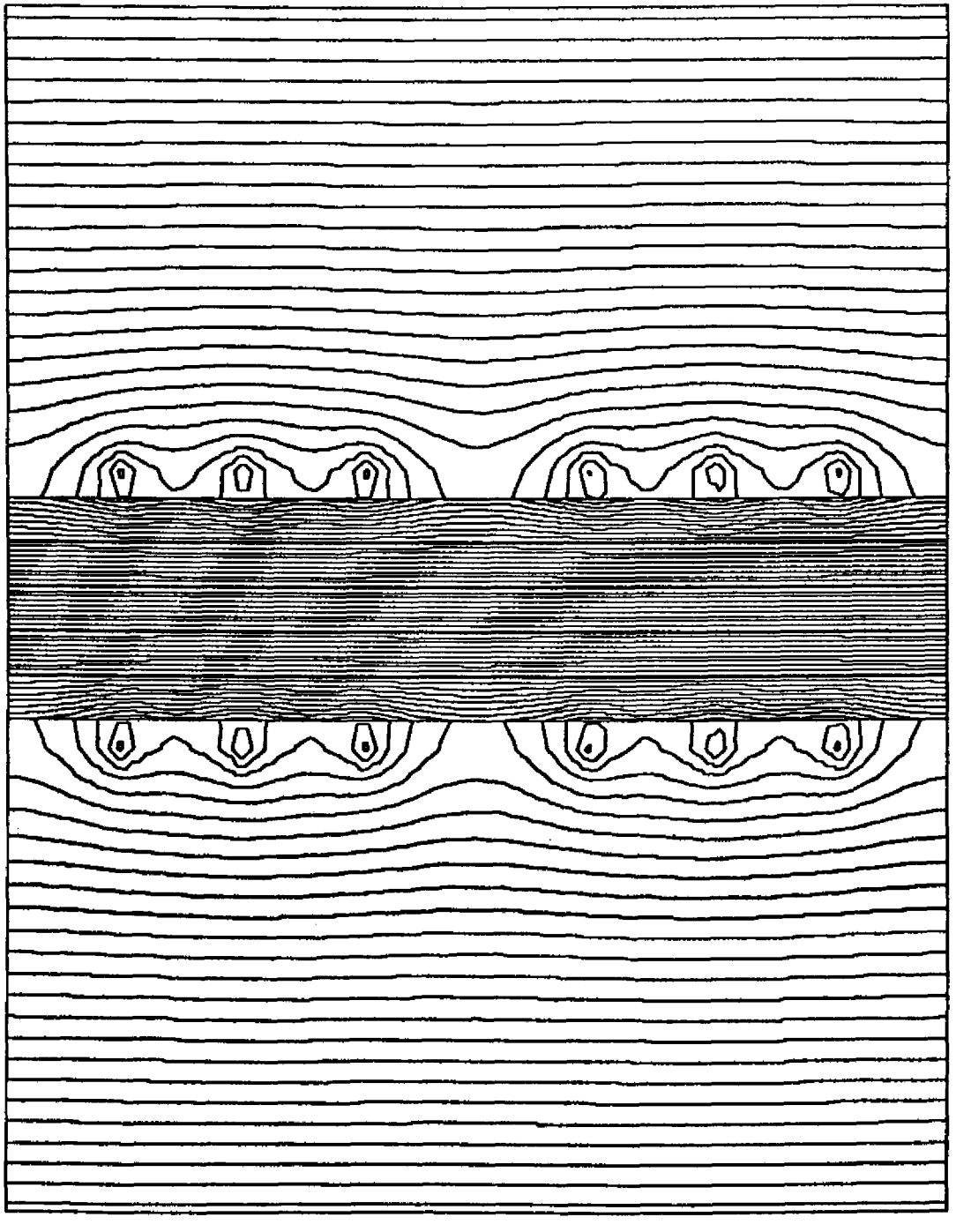

FIG 17. MAGNETIC FLUX

SDC214 – 0.4CM GAP1, 0.4CM GAP2

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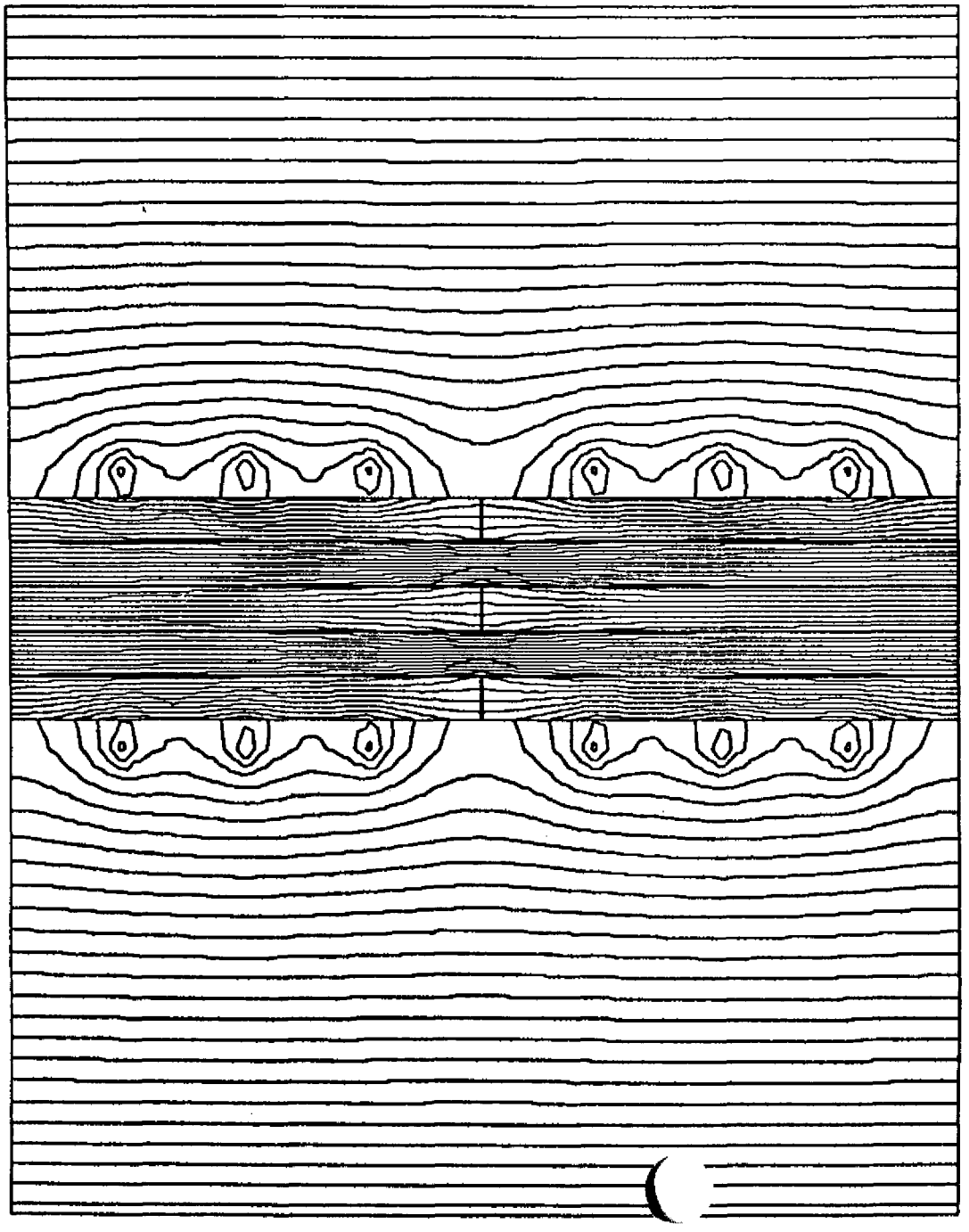

FIG 18. MAGNETIC FLUX