SSC DETECTOR SOLENOID DESIGN NOTE #27

TITLE: Axial Electromagnetic Forces on Coils for Various Failure Scenarios

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Note: The direction of the forces is incorrect in these calculations! will be new

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Axial Electromagnetic Forces on Coils for Various Failure Scenarios

Bob Wands

Introduction

The current solenoid design can allow any of the eight coil modules to vary in current independently of the other modules. In the worst case, a module could fail completely. This will result in axial magnetic forces which may be much greater than those encountered during normal magnet operation. This note presents the forces found for the cases of normal operation, and the simultaneous failure of module pairs symmetric about the solenoid midplane.

Approach

A two-dimensional, axisymmetric finite element model was created with the ANSYS program, using the vector potential magneto-static solution procedure. This model was also symmetric about the midplane of the magnet, and so includes only four modules. The finite element mesh and coil numbering are shown in Fig. 1. Infinite mu iron was assumed for simplicity. Each coil was given the same current density to represent normal operation. A failed coil was given a current density of zero.

The iron at the ends of the solenoid extends up to, but not past, the outer boundary of the first coil (non-reentrant iron).

Results

Five load cases were run.

1. All modules operational
2. Coil 1 failed
3. Coil 2 failed
4. Coil 3 failed
5. Coil 4 failed.

The coil failure cases actually represent the failure of two coils due to the midplane symmetry assumption.

Fig. 2 shows the central field for normal operation plotted from the outer boundary of coil 1 to the midplane of the solenoid. The current density was chosen to give a field of approximately 1.9 Tesla.

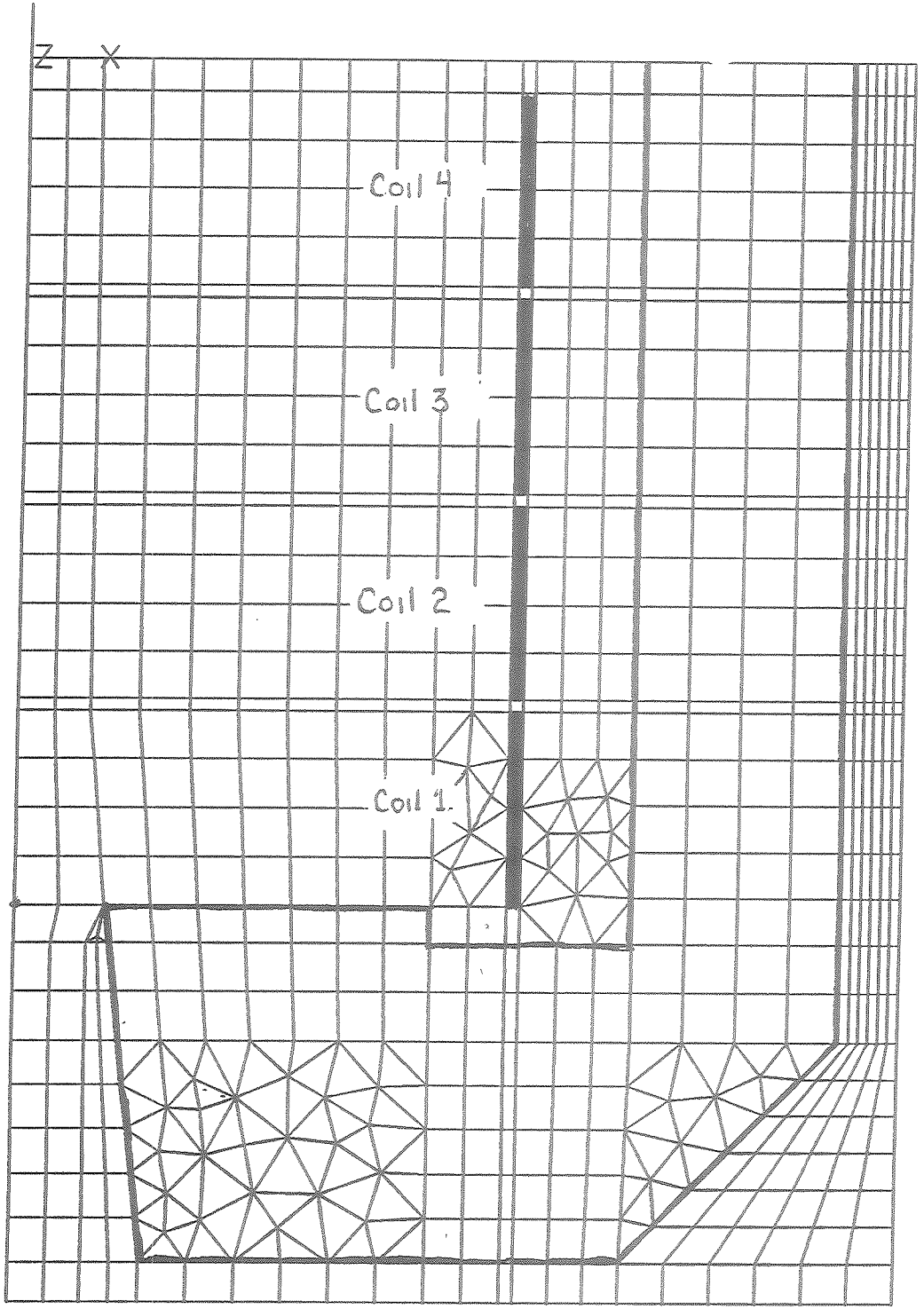
Fig. 3 shows the total axial force on the four coil modules in one-half of the solenoid. A positive force is directed toward the midplane of the solenoid. The axial force for normal operation is $3.6(10^6)$ lbs. The largest force occurs when the two innermost coils have failed, and is $16(10^6)$ lbs. The least force occurs with failure of coil 2 and it's symmetric partner, and is $-2(10^6)$ lbs. The largest force directed away from the center of the solenoid is $-12(10^6)$ lbs, and occurs when coil 1 and it's symmetric partner fail. This failure is particularly critical since it will put the axial support rods in compression.

Figs. 4-7 show the individual distribution of forces on the coils for the various failure scenerios. Figs. 8-11 show the axial magnetic fields resulting from the failures.

Conclusion

The largest total force occurs when the two innermost modules fail, and is in the same direction and about four times greater than the force during normal operation. This force will determine the tensile requirements of the axial support rods. Compressive requirements are determined by the failure of the two outer most coils.

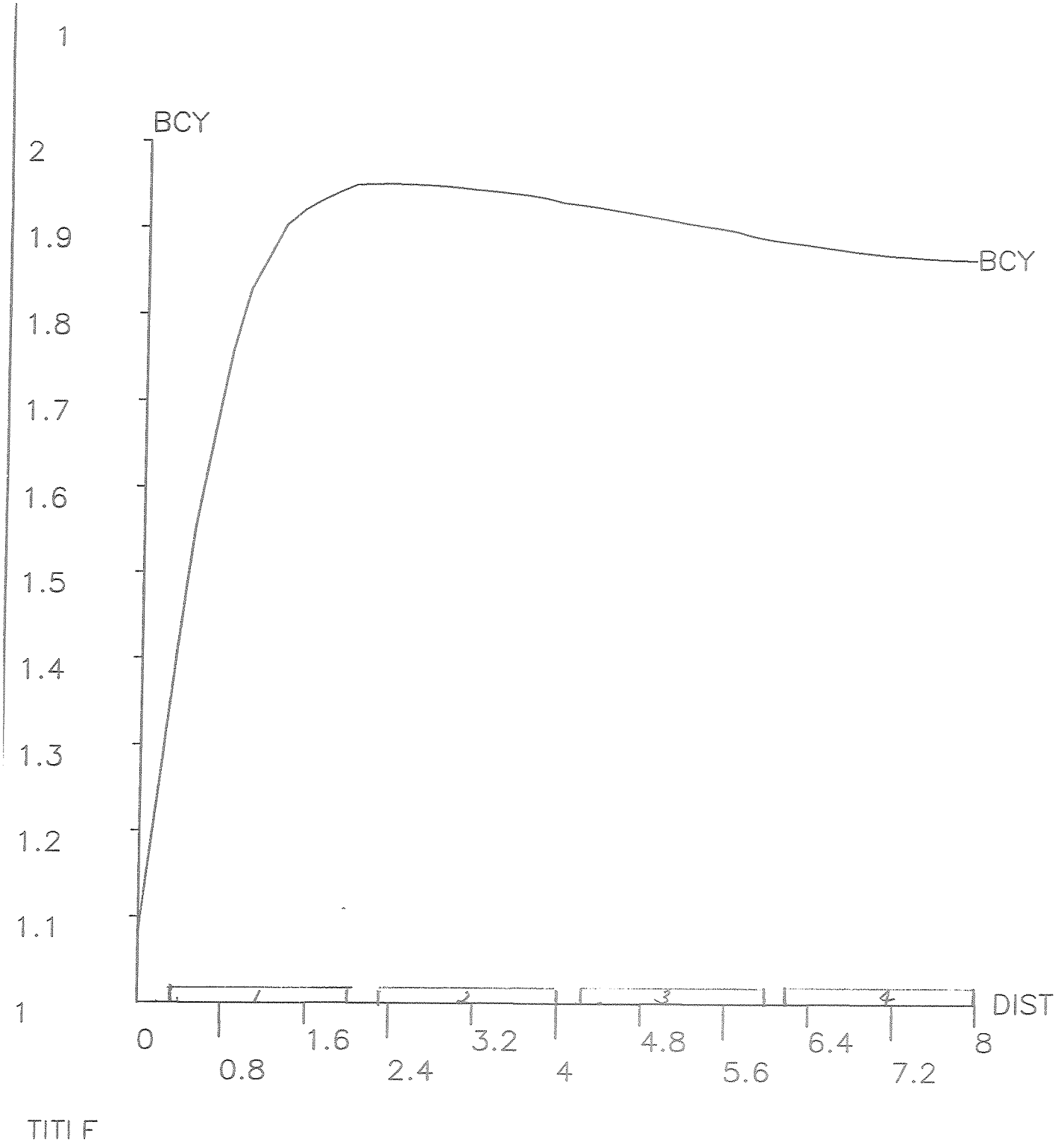
The individual coil force distributions can be used to examine the load carrying requirements of coil module interconnections.



ANSYS 4.3A
OCT 28 1988
8 03 54
PLOT NO. 1
POST1 ELEMENTS

ZV =1
DIST=6.394
XF =4.25
YF =-5.813

Fig.1, Finite Element Mesh



ANSYS 4.3A
OCT 26 1988
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ITER=1
PATH PLOT
NOD1=160
NOD2=624
BCY

ZV =1
DIST=0.6666
XF =0.5
YF =0.5
ZF =0.5

Fig 2.
Central Fish - Normal operation

Total Axial Force on Coils

for various failure conditions

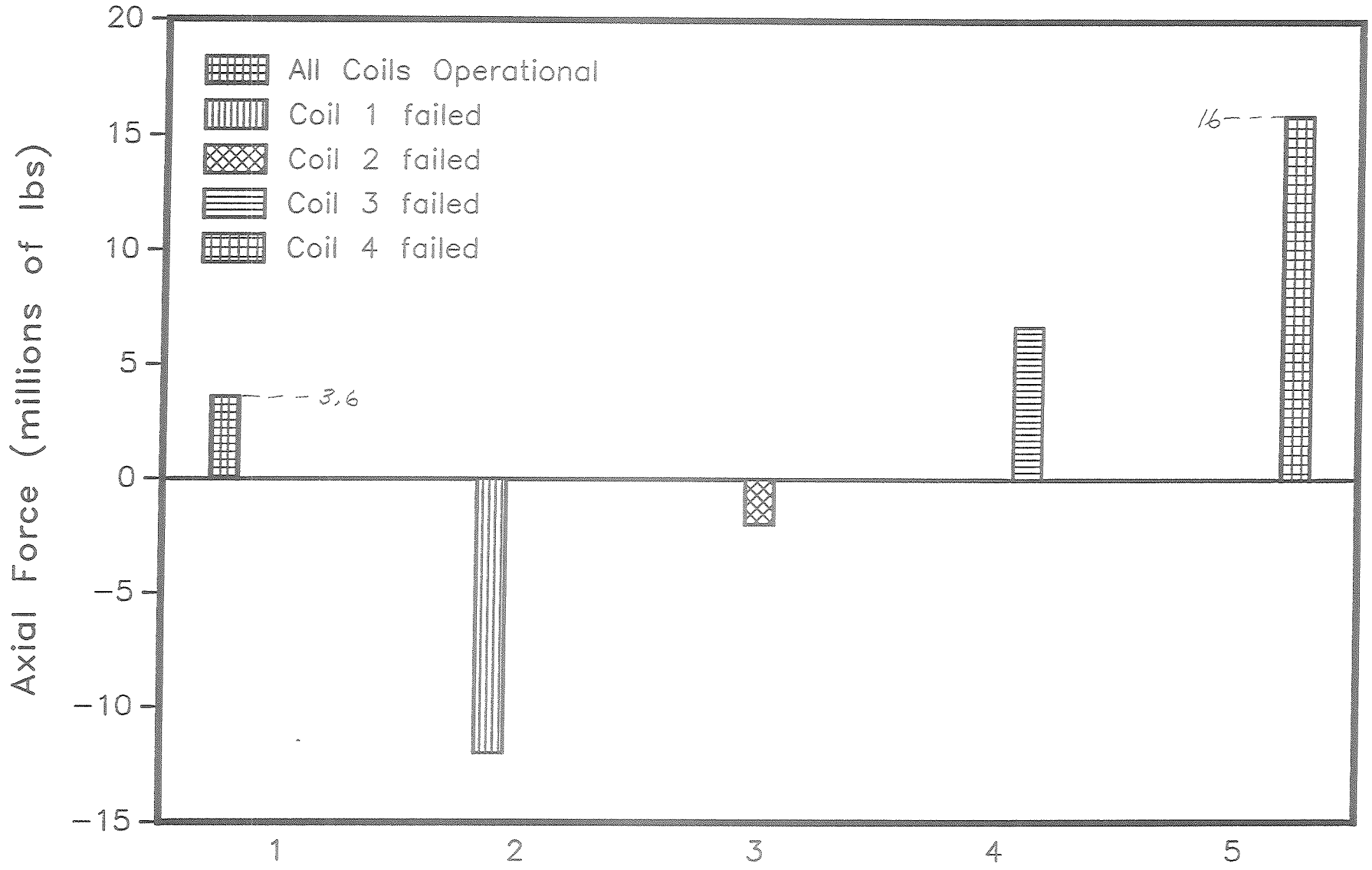


Fig 3.

Axial Force on Individual Coils

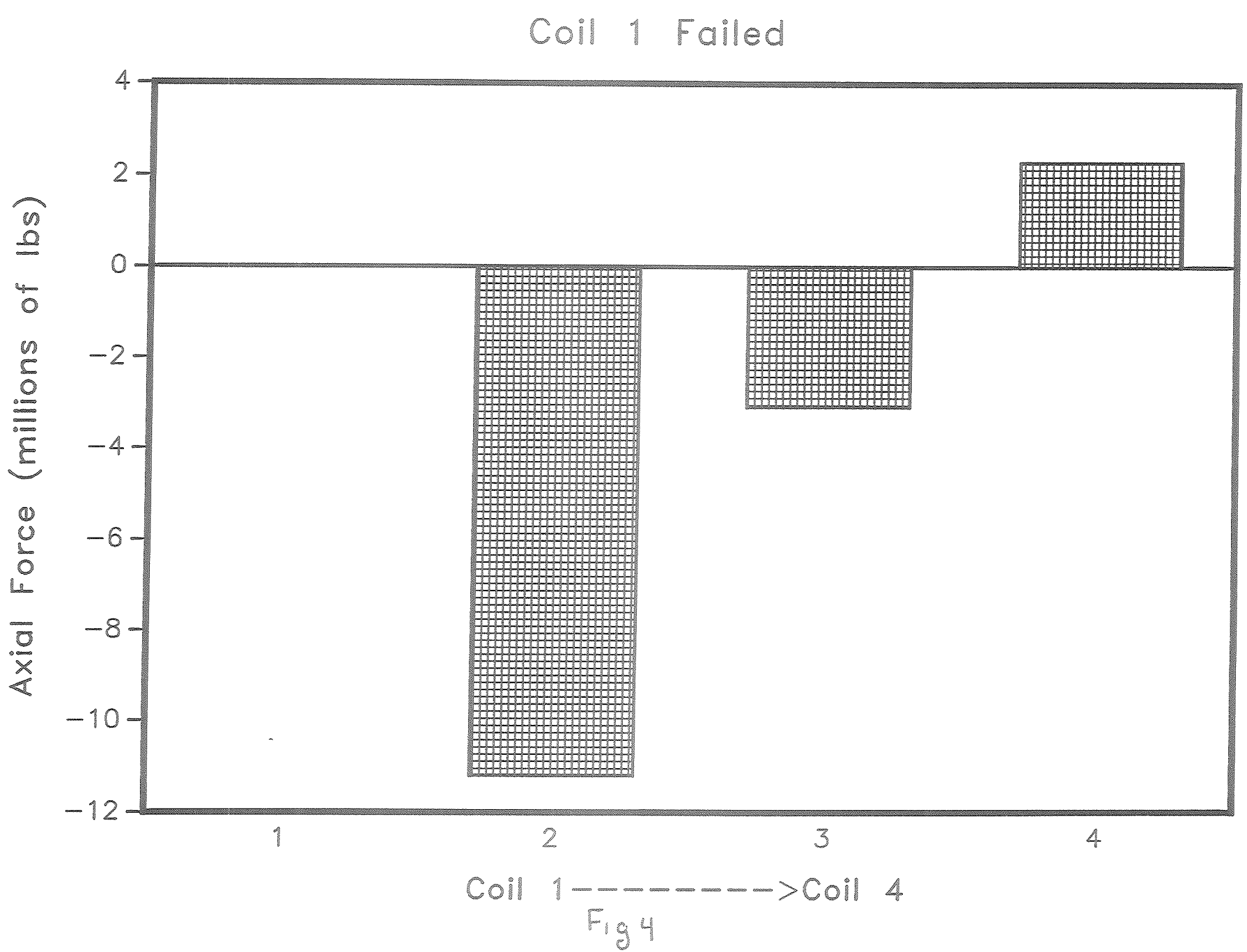


Fig 4

Axial Force on Individual Coils

Coil 2 Failed

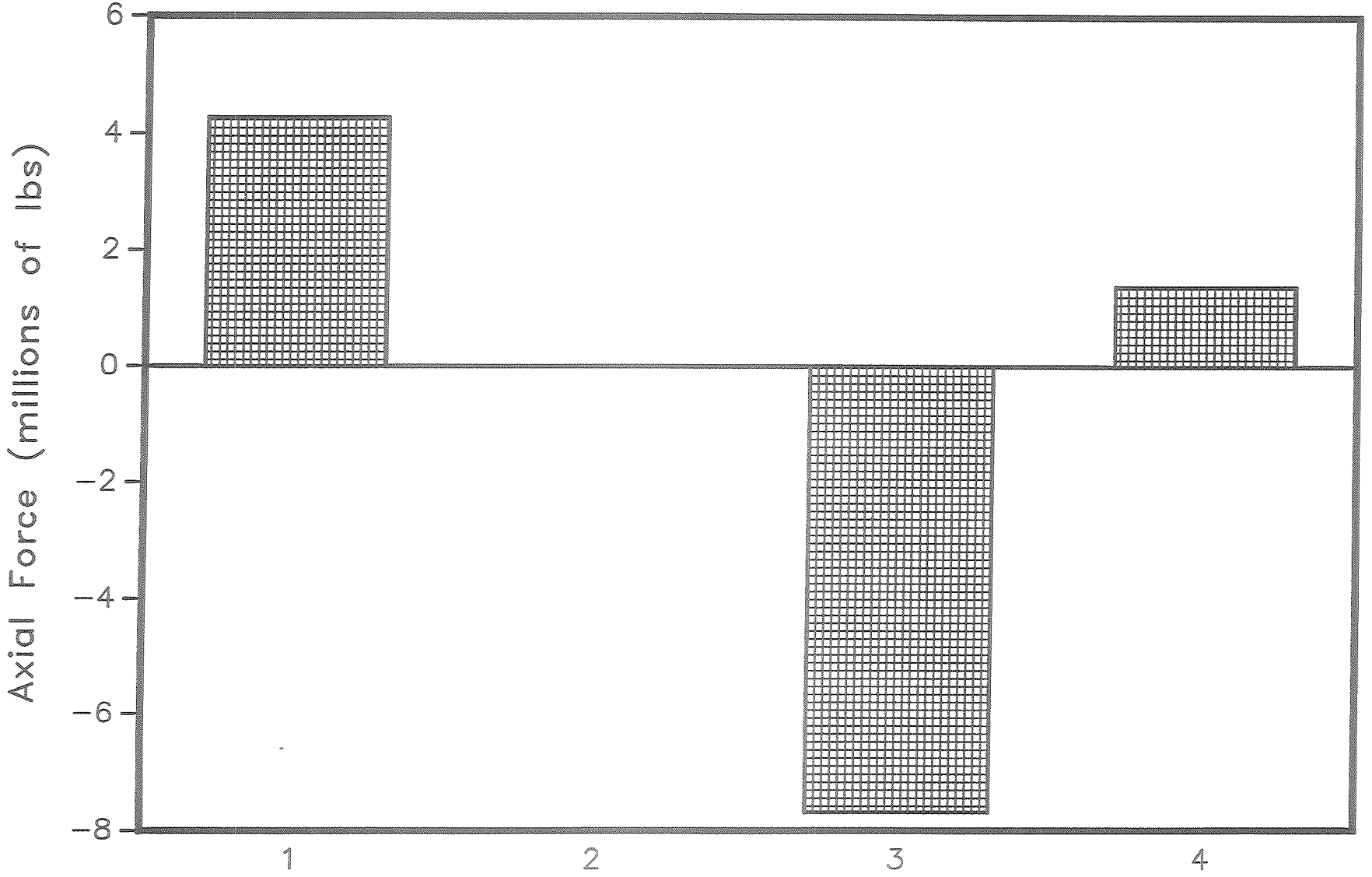


Fig 5

Axial Force on Individual Coils

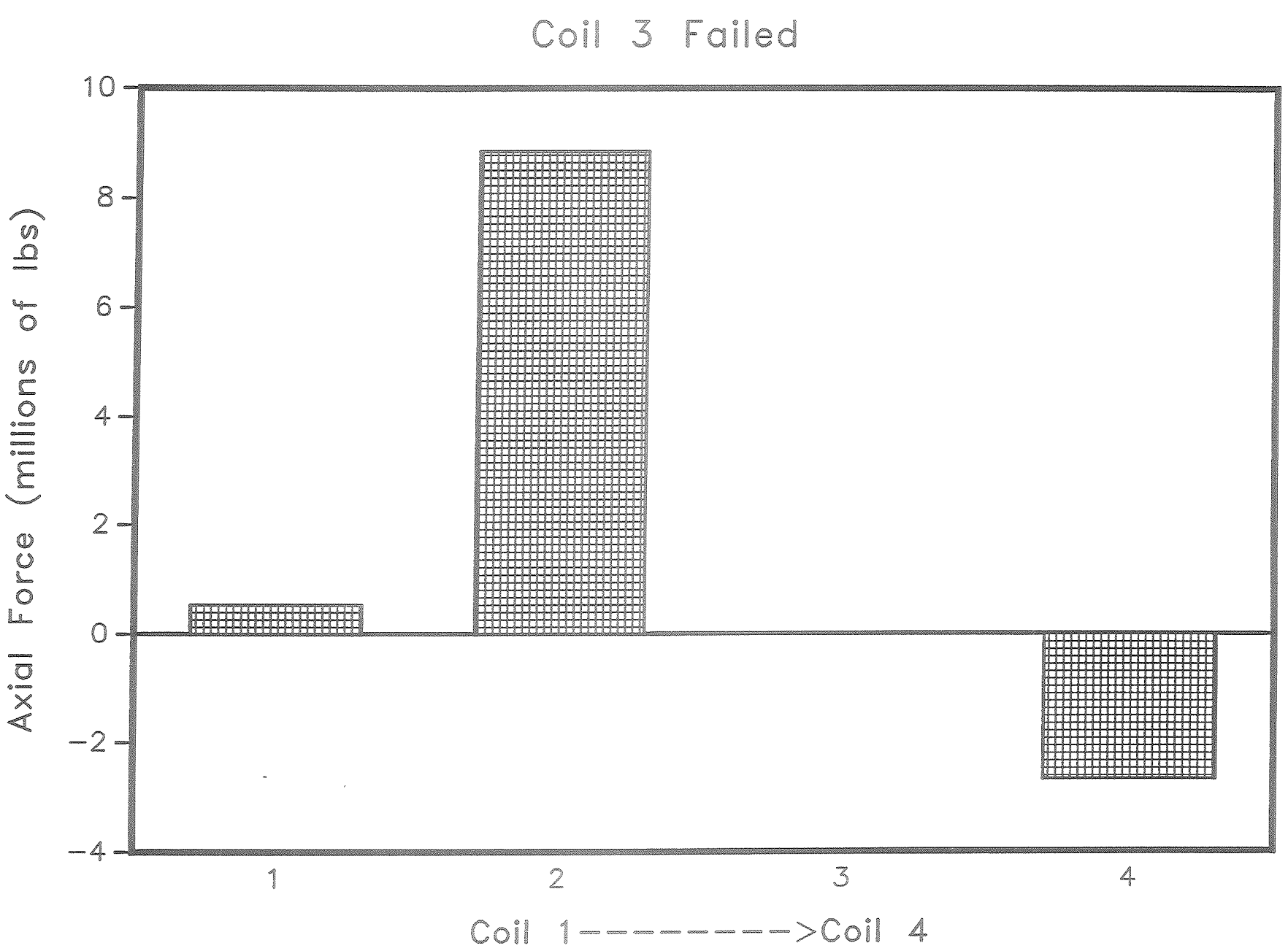


Fig 6

Axial Force on Individual Coils

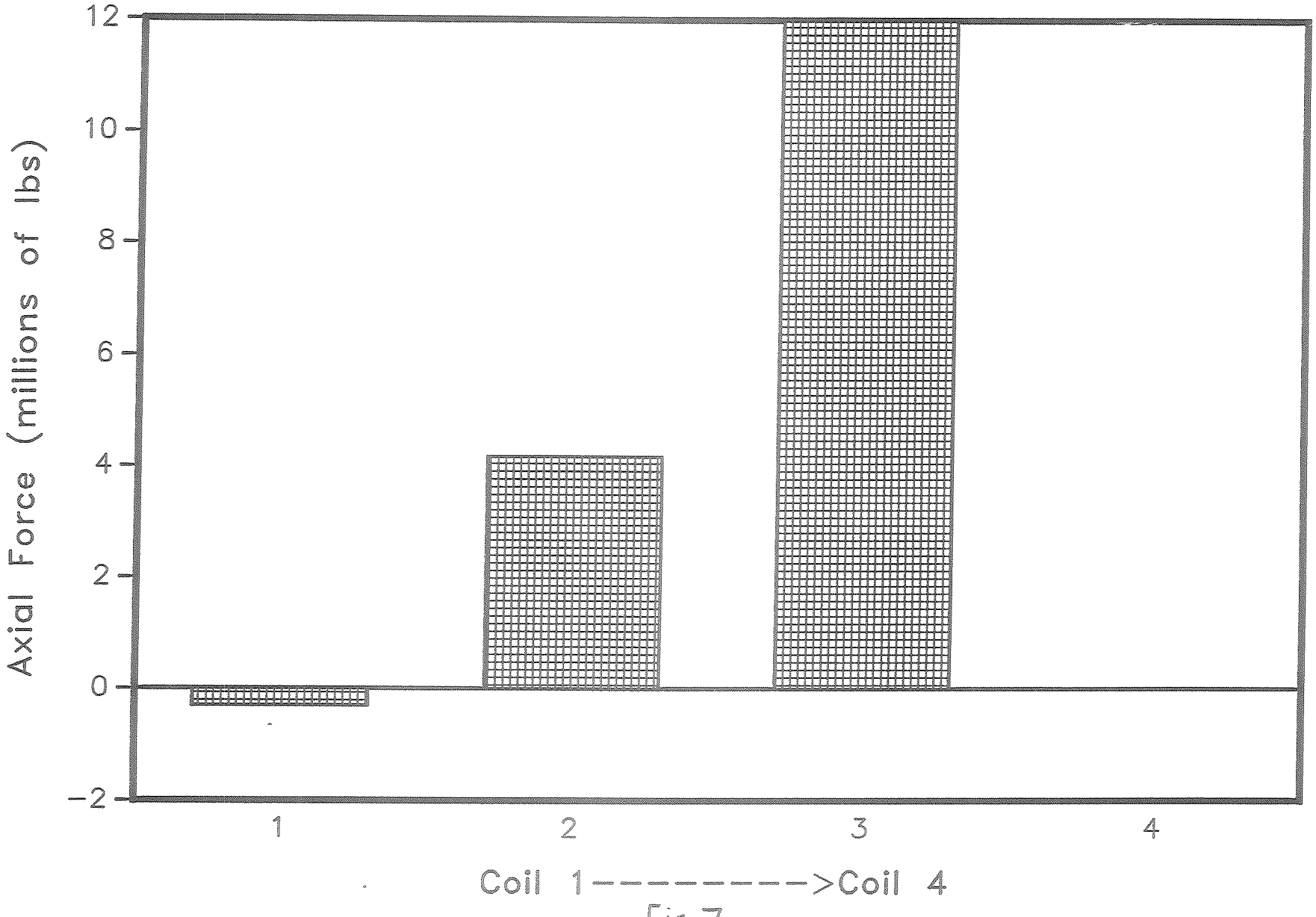
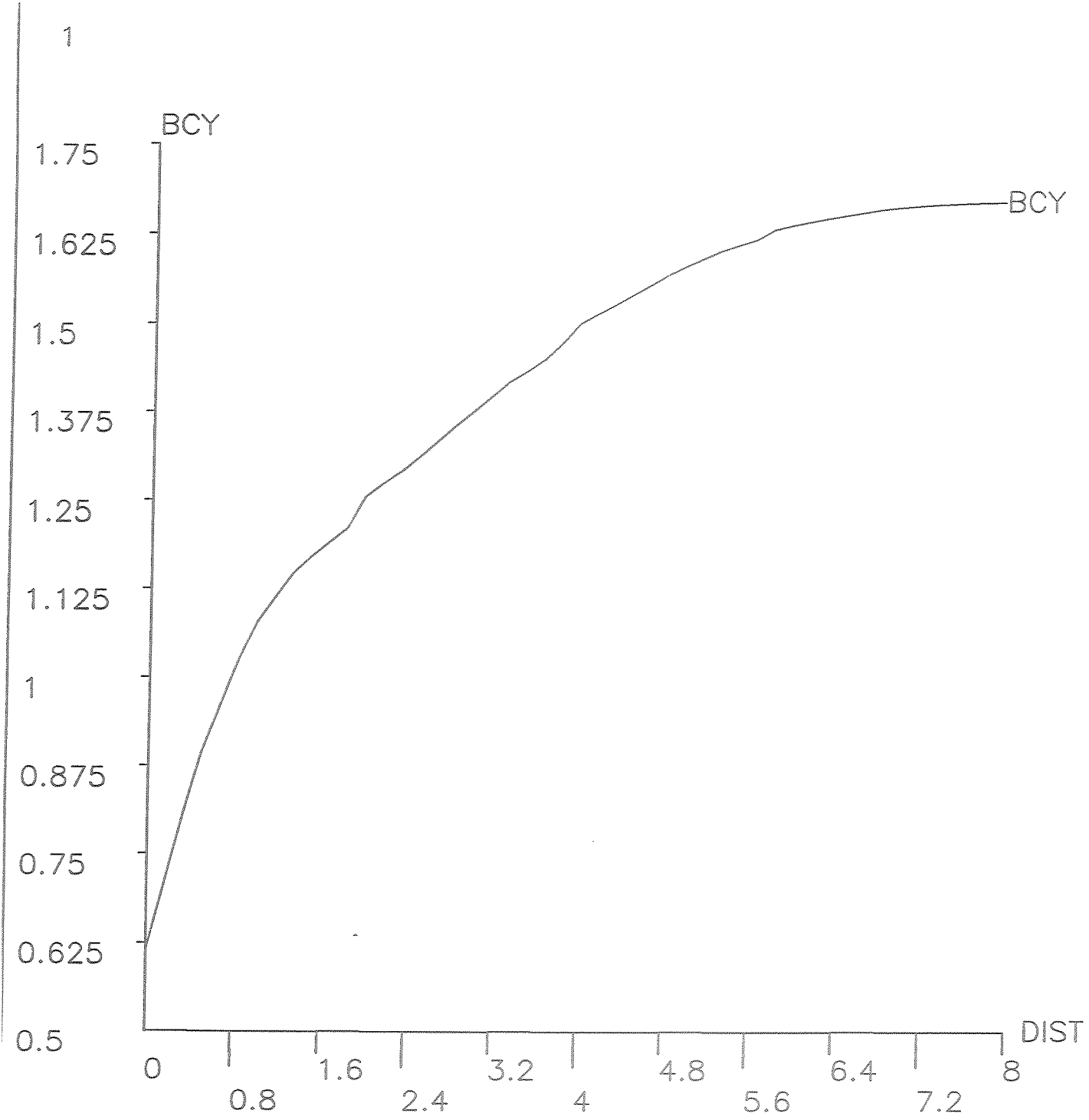


Fig 7



ANSYS 4.3A
OCT 24 1988
13 28 20
PLOT NO. 1
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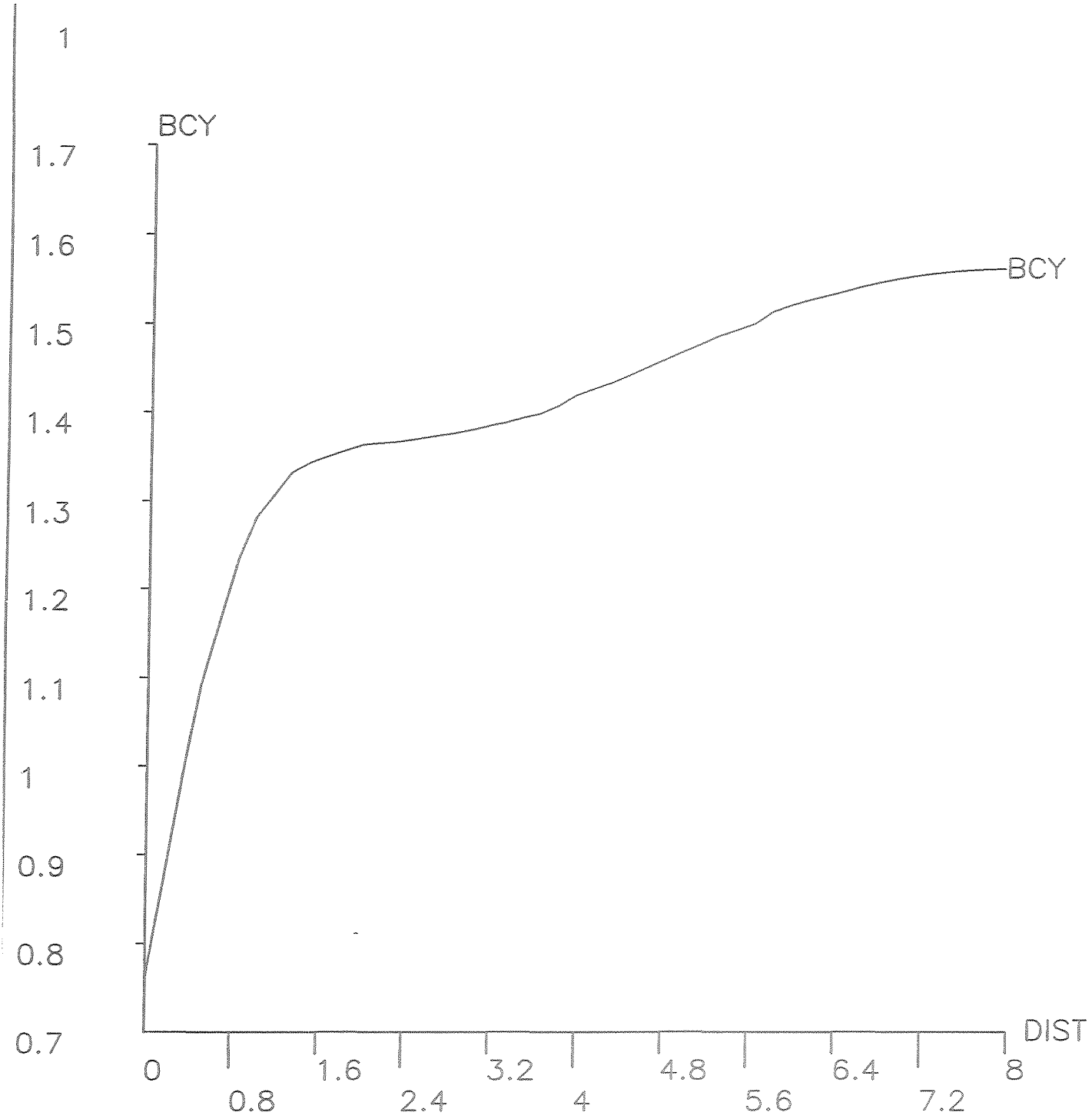
STEP=1
ITER=1
PATH PLOT
NOD1=160
NOD2=624
BCY

ZV =1
DIST=0.6666
XF =0.5
YF =0.5
ZF =0.5

Fig 8. Axial Magnetic Field - Coil 1 failed

Coil 1

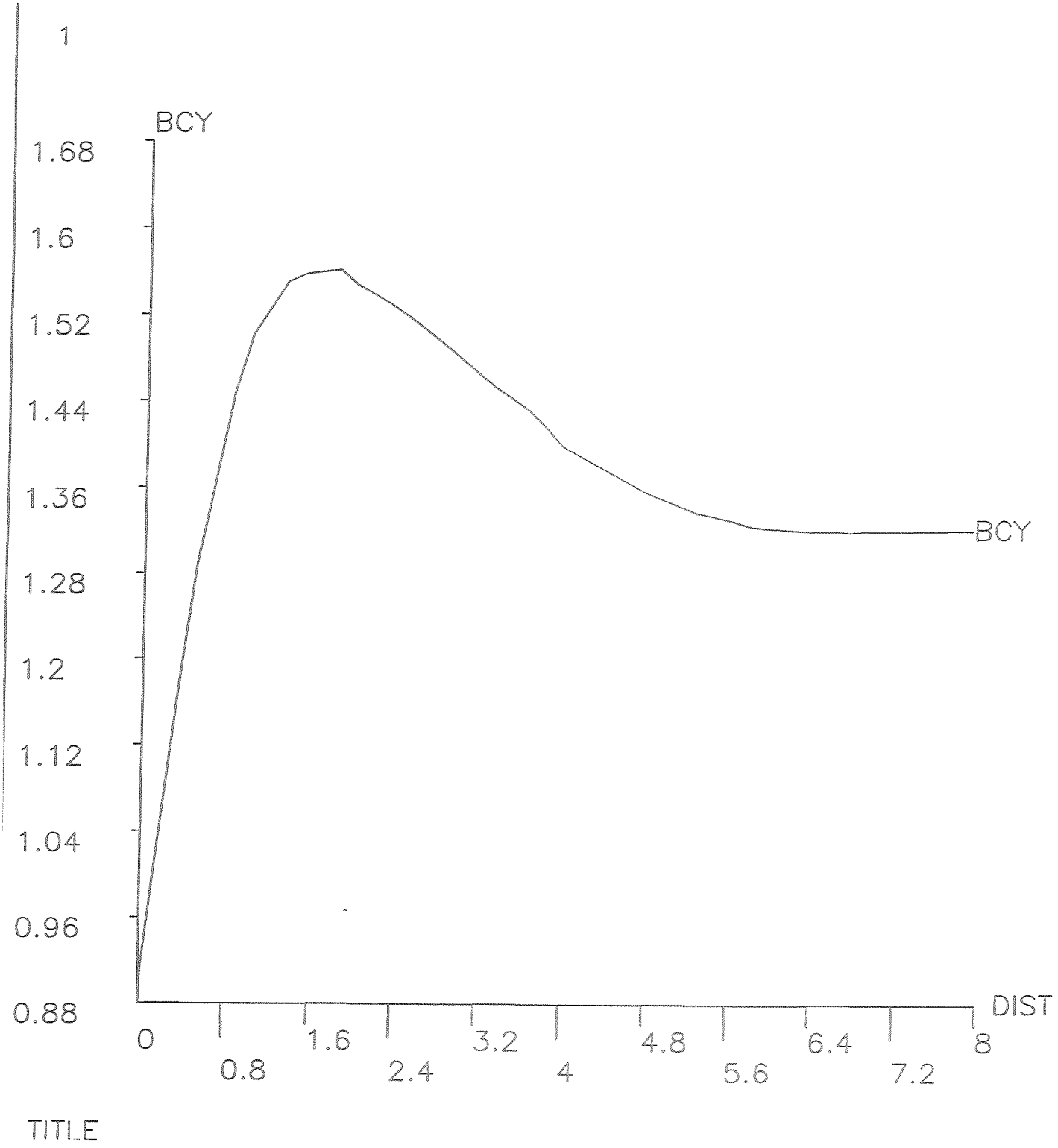


ANSYS 4.3A
OCT 24 1988
13 43 20
PLOT NO. 1
POST1
STEP=1
ITER=1
PATH PLOT
NOD1=160
NOD2=624
BCY

ZV =1
DIST=0.6666
XF =0.5
YF =0.5
ZF =0.5

Fig 9. Axial Magnetic Field - Coil 2 Failed

Coil 2



ANSYS 4.3A
OCT 24 1988
13 55 28
PLOT NO. 1
POST1
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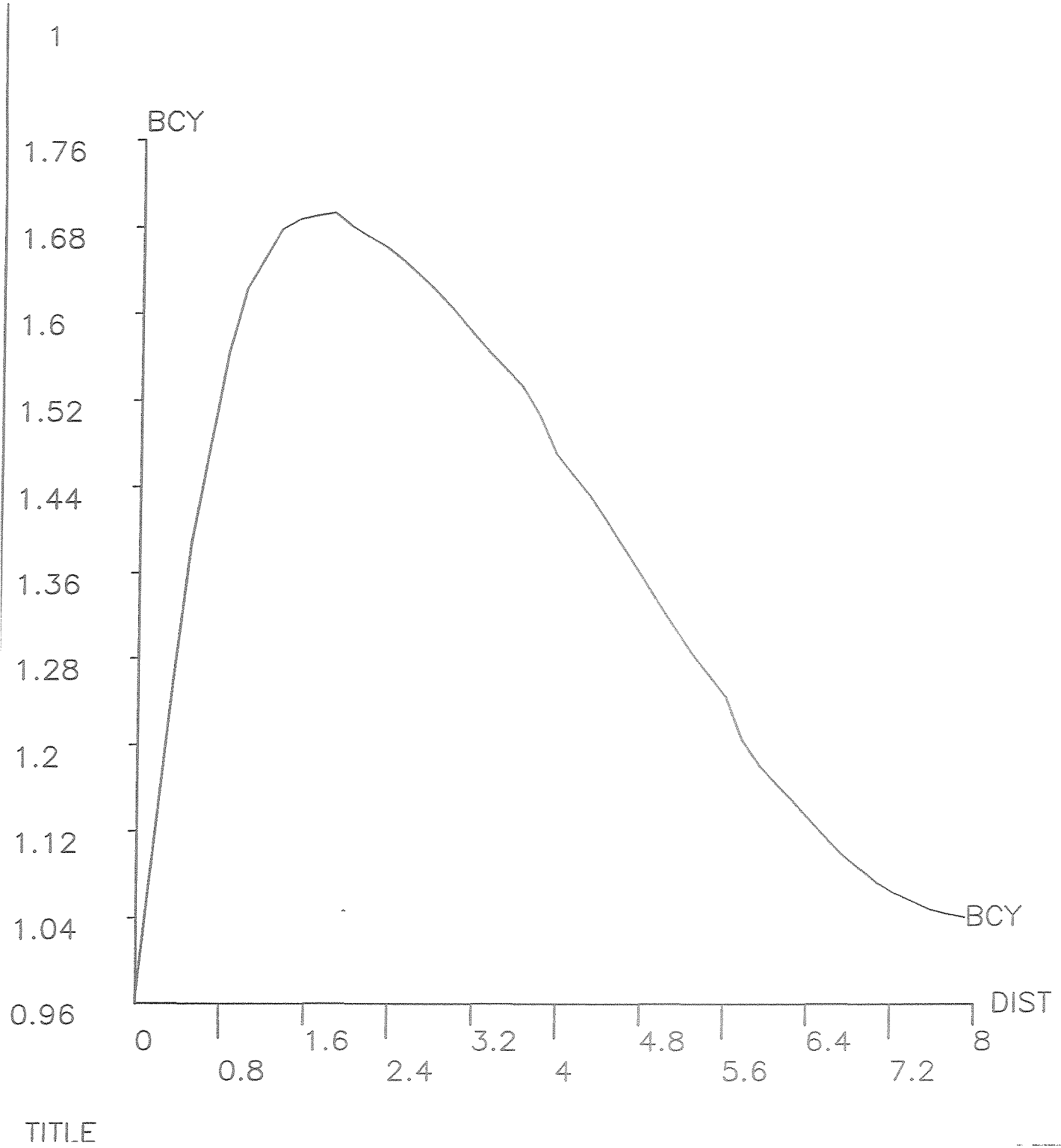
ITER=1
PATH PLOT
NOD1=160
NOD2=624
BCY

ZV =1
DIST=0.6666
XF =0.5
YF =0.5
ZF =0.5

Fig 10. Axial Magnetic Field-Coil 3 Failed

Coil 3



ANSYS 4.3A
OCT 24 1988
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PLOT NO. 1
POST1
STEP=1
ITER=1
PATH PLOT
NOD1=160
NOD2=624
BCY

ZV =1
DIST=0.6666
XF =0.5
YF =0.5
ZF =0.5

Fig 11, Axial Magnetic Field - Coil 4 failed

Coil 4