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A Novel Method of Aligning ATF-1 Coils

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OPERATED BY
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FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes—Printed Copy: A02; Microfiche A01

ORNL/TM-8791
Dist. Category UC-20 b,f,g

Fusion Energy Division

A NOVEL METHOD OF ALIGNING ATF-1 COILS

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Date Published - August 1983

Prepared by the
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Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
U. S. DEPARTMENT OF ENERGY
under Contract No. W-7405-eng-26

ABSTRACT

The coils for the Advanced Toroidal Facility (ATF-1) torsatron may be easily aligned before the machine is placed under vacuum. This is done by creating nulls in the magnetic field by energizing the coils in various configurations. All of the nulls in $|\vec{B}|$ occur on the z-axis. When the nulls coincide, the coils are properly aligned.

Proper alignment of the inner and outer vertical field (VF) coil sets for the Advanced Toroidal Facility (ATF-1) is crucial in reducing magnetic field errors. Once they are built, the helical field (HF) coil sets will be immutable. Thus, we must find the axis of the HF coil set (the z-axis) and the up-down ($z = 0$) symmetry plane. Then the VF coils must be aligned so that they are concentric with and perpendicular to the z-axis.

We propose a procedure for doing this that can be easily performed as soon as the coils are assembled, even before the machine is under vacuum. In Fig. 1, the ATF coil configuration is shown, together with the coordinate system used in this memorandum.

First, we must determine the location of the z-axis with respect to the HF coil set. If the HF coils are connected in a stellarator configuration (opposing currents in the two coils), a line null in $|\vec{B}| \equiv B$ is created as shown in Fig. 2. To measure this easily, the coils should be energized with alternating current to eliminate the effect of the earth's magnetic field. This line null determines the z-axis, which can then be marked with a string or a laser beam.

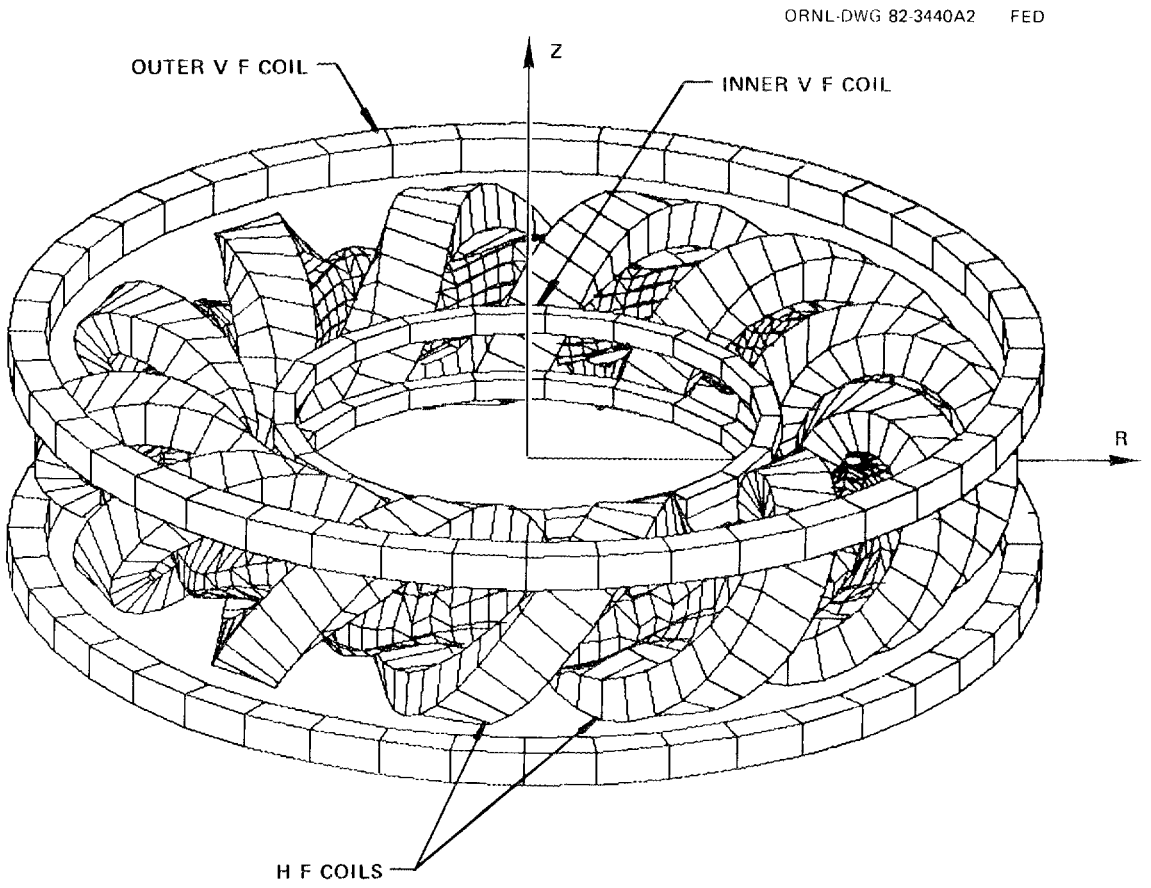

Fig. 1. The ATF-1 coil configuration and the coordinate system used in this report.

The most difficult thing to do is to measure the location of the z = 0 plane. We will do this in several ways. If the HF coils are energized in the torsatron configuration, B is a maximum at z = 0 along the z-axis. However, this is a saddle point and the maximum is quite broad. A further check on this measurement will be introduced later.

Next, each VF coil set is aligned. By running oppositely directed (and equal) currents in the two VF coils, a sharp point null in B is introduced at the origin (Fig. 3). The coils should be aligned so that

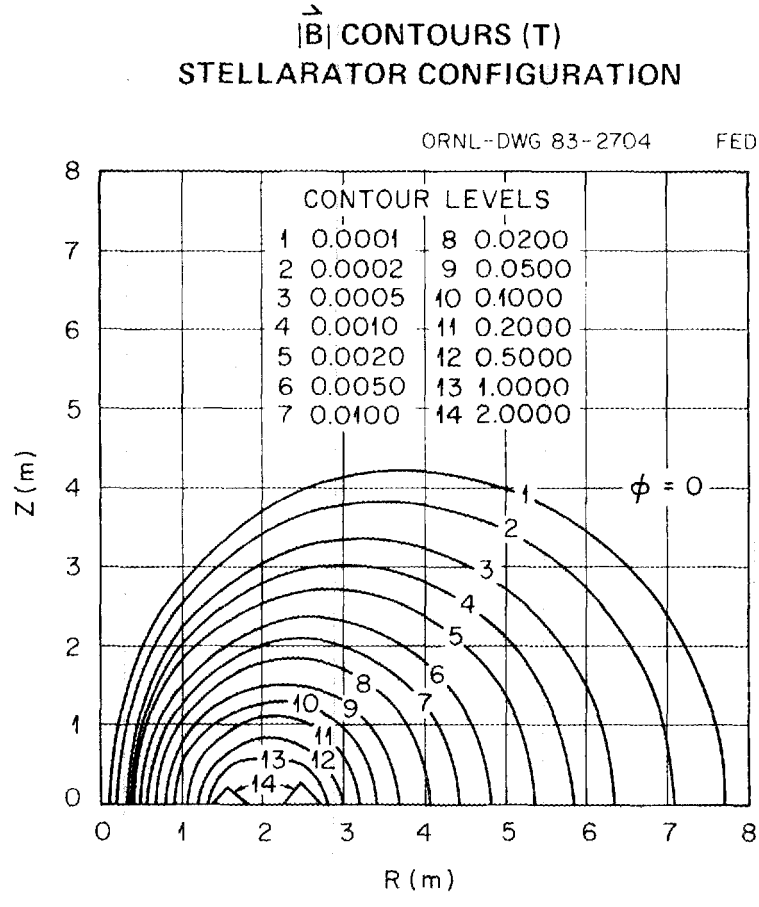

Fig. 2. Line null in $|\vec{B}| \equiv B$, created by connecting the HF coils in a stellarator configuration (opposing currents in the two coils).

this corresponds to the origin determined from the HF coil measurements. If the current in one coil is increased by a small amount, this null runs up along the z-axis, if the coils are concentric and not tilted. For example, in Fig. 4, the current in the lower coil was increased so that it is 1.4 times the current in the upper coil. In this case, the null appears about 3 m up the z-axis. This must, of course, coincide with the z-axis of the HF coil set.

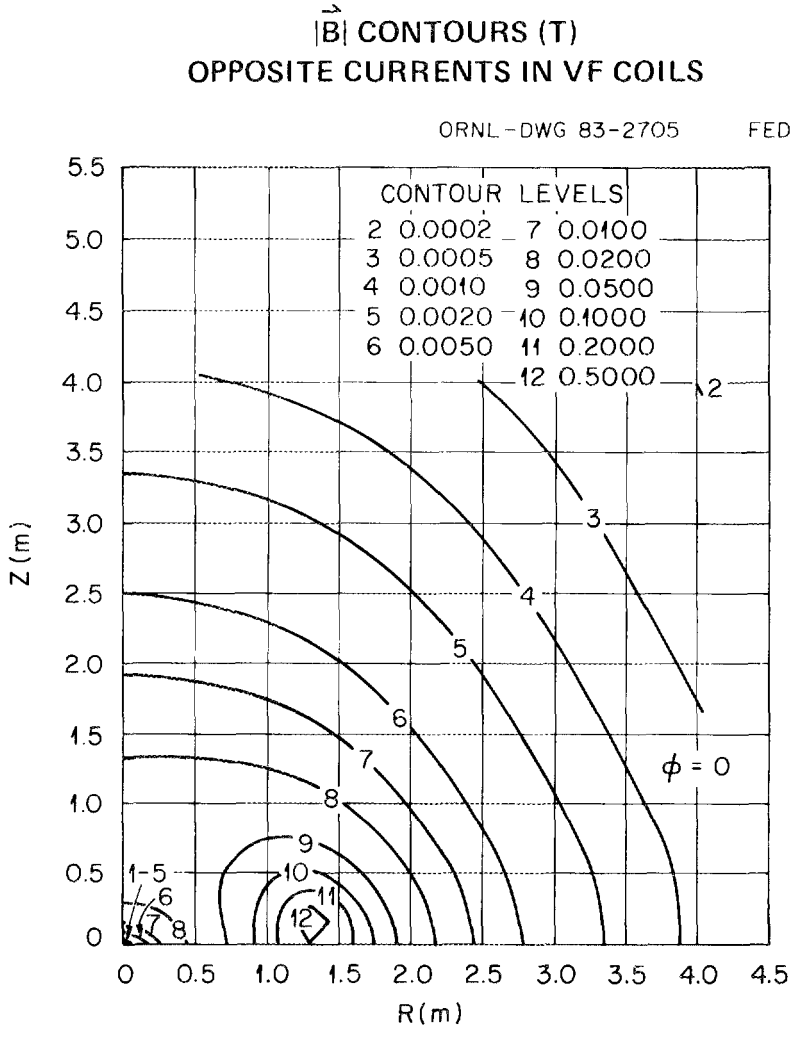

Fig. 3. Point null in B, created by running oppositely directed, equal currents in the two VF coils.

Finally, we recheck the symmetry of the VF coils with respect to the $z = 0$ plane of the HF coils. For example, if we run the helix in its torsatron configuration and put -1.45 times the HF current into the inner VF coils, we create two sharp minimia in B at about $z = \pm 2.1$ m. When the $z = 0$ planes of the HF and VF coils coincide, the strengths of

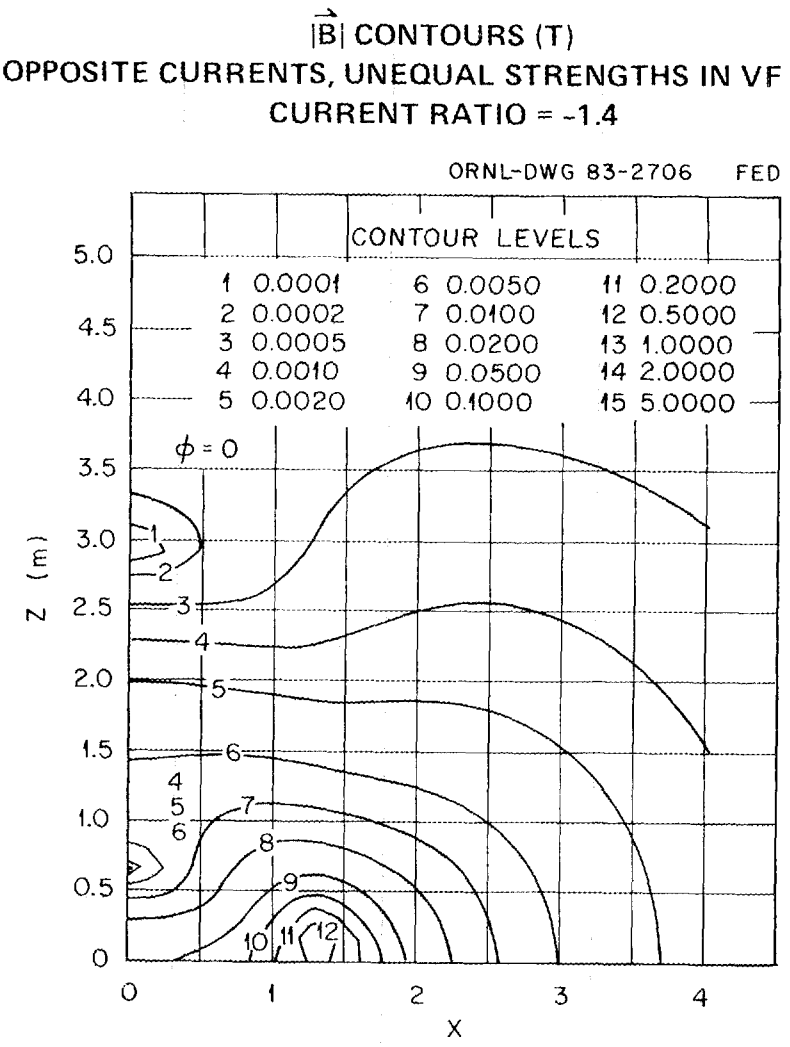

Fig. 4. Displacement of point minimum in B, created by running oppositely directed, unequal currents in the two VF coils. Here, the current in the lower coil is 1.4 times that in the upper coil.

these two minima will be equal and the z = 0 plane will lie halfway between them. This configuration is shown in Fig. 5.

This procedure should yield the best possible location for the various ATF-1 coils if they were all built perfectly. However, there will be imperfections in them. In this event, the nulls in B will

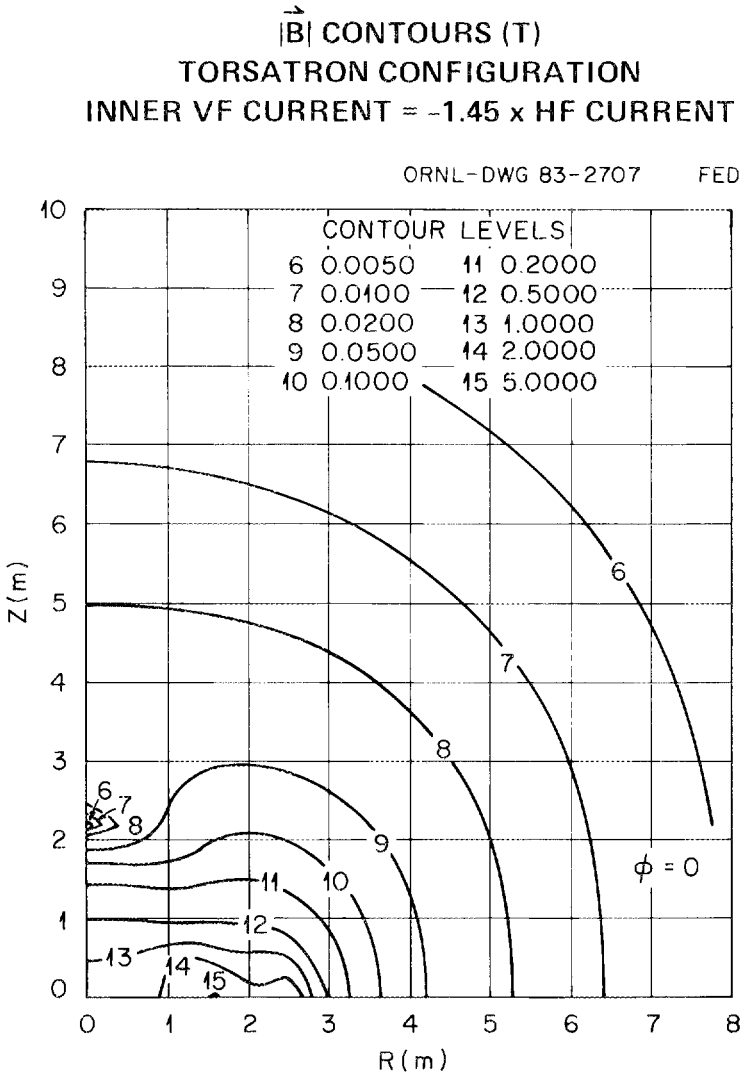

Fig. 5. Torsatron configuration. The current in the inner VF coil is -1.45 times that in the HF coils.

become minima. Nonetheless, this procedure should still yield the optimum coil configuration because it is based upon aligning the axes of all the dipole moments. Coil imperfections will show up as higher moments and may have to be eliminated by using additional error correction coils.

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