The Magnetic Iron-Core Model and Stray Field Measurements for PULSATOR I and their Relevance to JET

J. Gernhardt, G. Herppich, F. Werner

IPP 4/117
IPP III/11 February 1974

MAX-PLANCK-INSTITUT FÜR PLASMAPHYSIK
GARCHING BEI MÜNCHEN

MAX-PLANCK-INSTITUT FÜR PLASMAPHYSIK

GARCHING BEI MÜNCHEN

The Magnetic Iron-Core Model and Stray Field Measurements for PULSATOR I and their Relevance to JET

J. Gernhardt, G. Herppich, F. Werner

IPP 4/117
IPP III/11 February 1974

The contents of this report were presented at the "Workshop on the Technical Aspects of the JET-Assembly" held at Culham on Thursday and Friday, Feb. 28 and March 1, 1974

Die nachstehende Arbeit wurde im Rahmen des Vertrages zwischen dem Max-Planck-Institut für Plasmaphysik und der Europäischen Atomgemeinschaft über die Zusammenarbeit auf dem Gebiete der Plasmaphysik durchgeführt.

IPP 4/117

IPP III/11

The Magnetic Iron-Core Model and Stray Field Measurements for PULSATOR I and their Relevance to JET.

J. Gernhardt, G. Herppich, F. Werner

Abstract:

Results of the measurements at the Pulsator I iron core magnetic model are compared with the stray field measurements at the original core. Special regard is given to the plasma simulation. Outlines for a JET model are presented.

The Magnetic Iron-Core Model and Stray Field Measurements for PULSATOR I and their Relevance to JET

J. Gernhardt; G. Herppich; F. Werner

The subject is treated in three parts:

1) The magnetic iron-core model of PULSATOR I
2) The stray field measurements at the original transformer of PULSATOR I
3) Some Aspects of a JET model

1. Magnetic iron-core model of PULSATOR I [1]

At Garching we adapted two different approaches in designing and studying the behaviour of the iron-core transformer of PULSATOR I.

In Fig. 1 a schematic illustration of the tokamak assembly is given. All the windings and the vacuum chamber are sited around the central iron core with its eight symmetrically arranged return yokes. A cold rolled transformer plate with a thickness of o.3 mm was used. The core flux at 15 kG is o.42 Vs, and with premagnetization to lo kG it is o.7 Vs. The total flux of o.77 Vs at 15 kG in the return yokes is necessary because of the short-circuit performance of the transformer.

According to SHAFRANOV the relation between the permissible plasma shift and the stray field is

$$\Delta = b \frac{B_{stray}}{B_s} ;$$

$$B_s = B_\vartheta \frac{a}{b} = \frac{\mu_o J}{2\pi b} ;$$

$$B_{stray} = \frac{\Delta}{b} \cdot \frac{\mu_o J}{2\pi b} ;$$

J being the plasma current, b the distance from the plasma centre to the copper shell radius.

For the plasma current of 3oo kA in the PULSATOR experiment this means that for a plasma drift smaller than 2 mm the stray field has to be less than 3o G. (q = 1)

The arrangement, the number of coils, and the amp-turns requirements were calculated with aid of the "nutcracker" computer program. Since the resolution of the calculated stray field was just 25 G, in order to get more information about the stray field distribution we decided to build a scaled model.
In scaling such a model one condition has to be satisfied.

$$B' = B$$

The magnetic flux density should be the same as in the original. With s being the scale factor the model parameters are

Length	$l' = l \cdot s$
Flux density	$B' = B$
Current	$J' = J \cdot s$
Flux	$\phi' = \phi \cdot s^2$
Inductance	$L' = L \cdot s$
Current density	$S' = \frac{S}{s}$

This means a linear scaling for all geometric dimensions of the transformer.
The scaling factor for the model was chosen as 1:5. To get the same conditions in the model, we used transformer iron plates with magnetization behaviour nearly identical to that of the original.

The scaled electrical data are:

Max. induction for the model $B' = B = 17$ kG

Model currents $J' = \frac{J}{5}$

Model flux $\phi' = \frac{\phi_{org}}{25}$

Fig. 2 shows the PULSATOR I model with the iron core and the eight return yokes. The iron core is surrounded by a plasma simulator and by the primary and vertical field windings. The problems of the copper plasma simulator will be discussed later. The windings are fed by a small capacitor bank with power crowbar. The bank was switched with ignitrons and was designed to produce a pulse equal in rise time and pulse length to the original.

First we measured the transformation ratio of the transformer with calibrated Rogowski coils, which was about 19:1 for 24 primary windings. Secondly we measured the stray field in the plasma region with small calibrated coil probes. The probes were about o.8 mm in diameter and 1 mm in length and have 24 windings. The stray field of the transformer in the plasma region was smaller than 2o G for an original plasma current of 3oo kA. ($q = 1$)

2. Stray field measurements at the original transformer of PULSATOR I with plasma simulator [2]

2.1 Stray field measurements

To measure the stray field which was produced by the primary winding in the plasma region, the plasma current had to be simulated.

For this purpose a copper ring with square-shaped profile was made, so that field measurements on the inside of the square-shaped profile could be carried out. The plasma simulator surface was made identical to the plasma surface in order to obtain the same stray field at a certain distance from the plasma centre with the plasma simulator, as later with the plasma.

The ohmic resistance of the plasma simulator and the plasma were of the same order. A plasma temperature of 1 keV was estimated.

The plasma simulator shown in fig. 3 was fed with 3o kA by an outside power supply. With a three-dimensional ball probe the field could be measured inside the profile of the simulator in the vertical, radial and tangential directions. At the position where the ball probe is installed one could adjust the field signal of the ball probe with the signal of the Rogowski coil (current signal). The compensated output signal at the potentiometer was integrated and adjusted to zero. The potentiometer position was then marked. These was done several times at different positions. After these measurements the plasma simulator was short-circuited and rigidly installed in the transformer. The ball probe was installed at a given position and the potentiometer position adjusted accordingly. The field, produced by the plasma simulator, was compensated by the compensating circuit and only the field part produced by the primary windings of the transformer was measured. During these experiments the vertical, radial and tangential stray field components below and between the return yokes were determined. All results were below 3o G.

2.2 Stray field influence on the plasma-behaviour of PULSATOR I

No influence on the plasma by the stray fields could be observed. During the experiments the plasma could be kept stabilized for a time of 14o ms.

3. Some aspects of a JET model

The questions to be answered with the aid of the model should be about the same as they were for PULSATOR I, namely the stray field distribution (rotational symmetry), the stray flux to net flux relation, and the amounts of circulation currents needed.

The most accurate way to evaluate the parameters wanted would surely be to simulate the whole current program from the beginning of stage a to the end of stage e, which calls for almost the whole circuitry to be modelled. In this case we think the power supply and switching problems would be almost similar, even at a lower level, to those occuring in the original assembly [3]. An additional difficulty would exist in closing the plasma simulator ring with a low impedance switch ($\mu\Omega$ range) at the beginning of stage b. Simulation of the exact current program would involve a lot of technical effort, so that as a compromise the simulation of the conditions of stage e should be more effective. Owing to the shape of the central core the flux swing has to be simulated up to ϕ_{max}.

Based on the data available from the preliminary description of JET [3] with a geometrical scale factor chosen of $s = \frac{1}{2o}$ the main model parameters would be:

1. Geometric dimensions

Outer diameter (given by the return yokes) .... 66 cm

Height of the core .... 45 cm

Major diameter of the plasma simulator .... 28 cm

2. Electromagnetic parameters (peak values)

Induction B' .... 9o kG

Flux ø' .... 31 mVsec

Current in the windings J' .... 2.5 kA

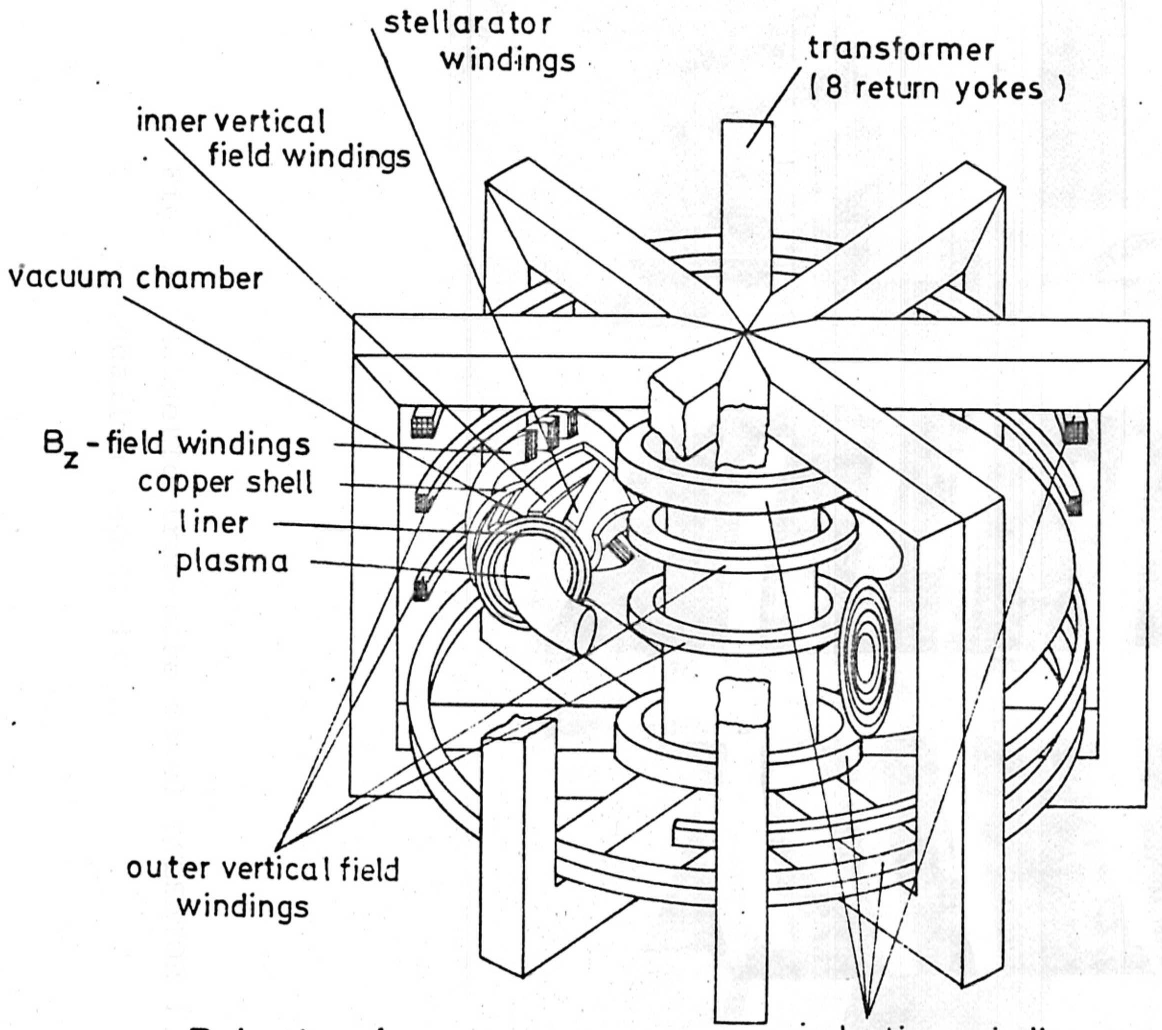
As the current density in the windings increases with $\frac{1}{s}$ probably a larger scaling factor has to be chosen.

References

[1] G. HERPPICH, A. KNOBLOCH, G. NÜTZEL
Model of PULSATOR I not published (1972)

[2] J. GERNHARDT, O. KLÜBER
Stray field measurements of PULSATOR I
not published (1972)

[3] The JET Project, Preliminary Description
EUR-JET-R1 November 1973



Pulsator 1

Fig.1

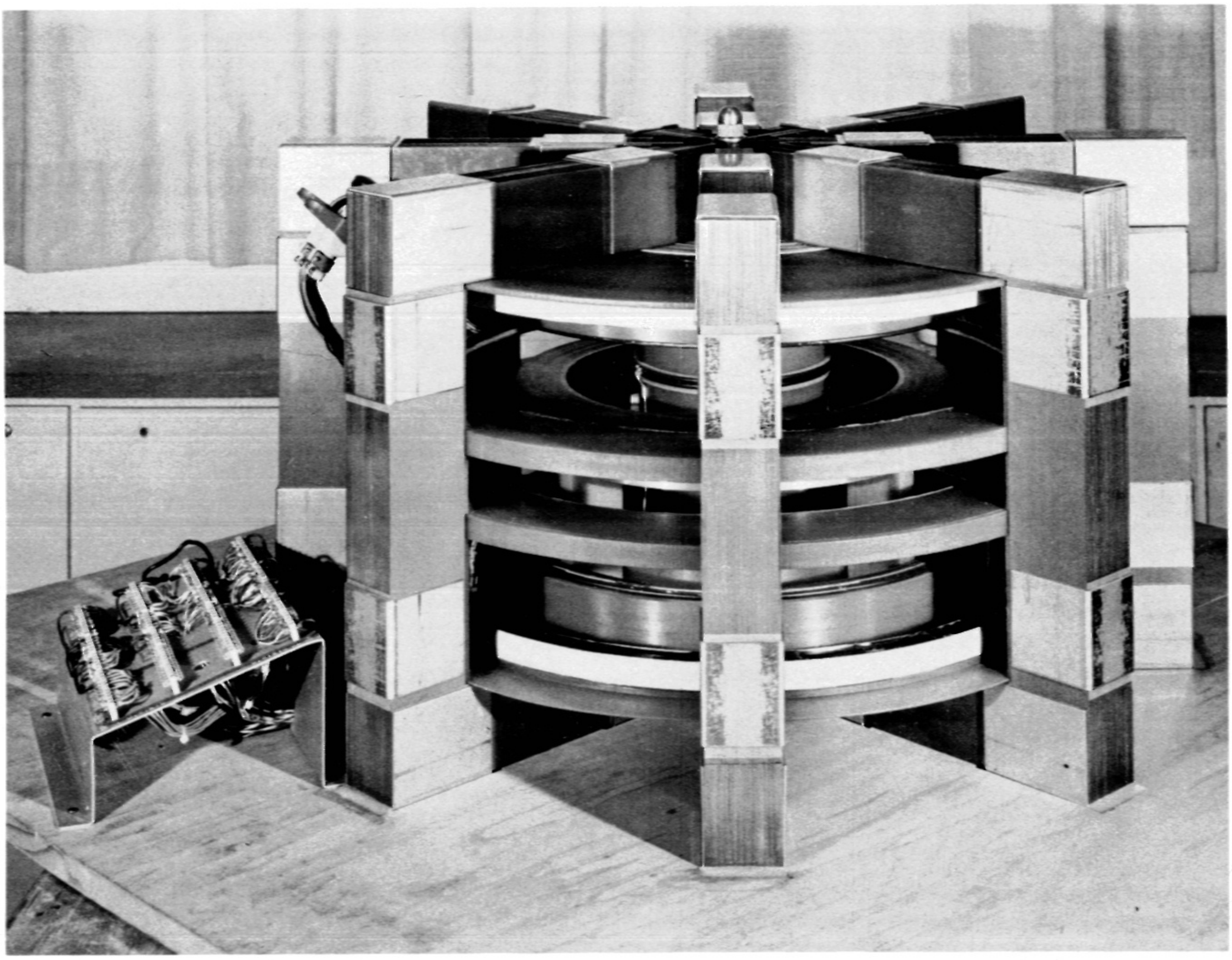
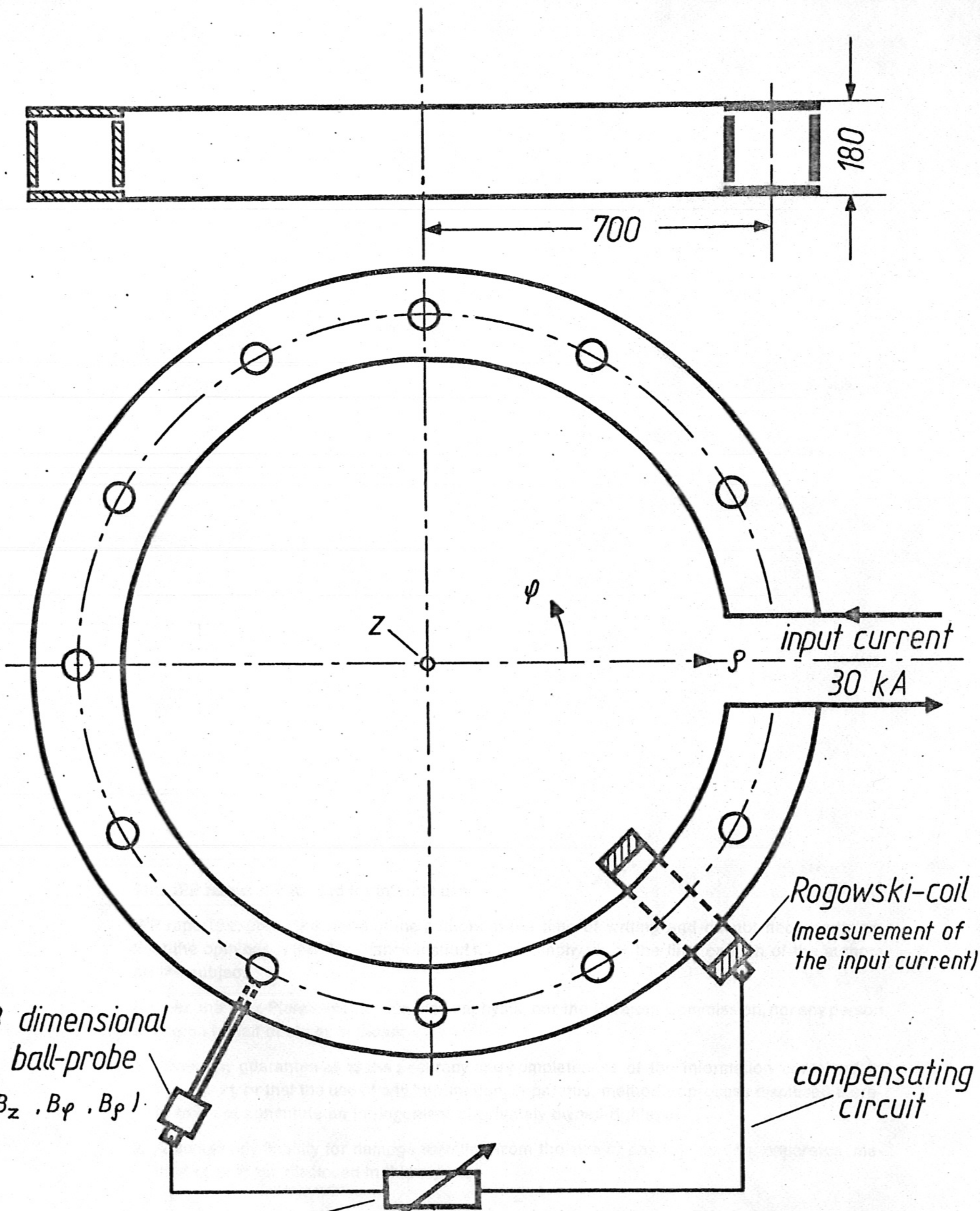


Fig. 2 Magnetic iron-core model PULSATOR I
scaling factor 1:5



plasma-simulator with compensation-circuit

Fig. 3