IEEE Cat. No. 83CH1916-6 NPS

10th Symposium on

FUSION ENGINEERING

PROCEEDINGS

Volume 1

Pages 1-960

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Franklin Plaza Hotel

Philadelphia, Pennsylvania

December 5-9, 1983

CONSTRUCTION OF THE JFT-2M TOKAMAK (6)
DESIGN, FABRICATION AND TESTING OF NOISE PREVENTION AND GROUNDING SYSTEM

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Summary

The JAERI JFT-2M TOKAMAK experimental device produces high-frequency noise from heating devices such as ICRH/NBI and generates induction noise from the toroidal field/poloidal field (TF/PF) coil power supply and plasma. The coil power supply, control and instrumentation of the JFT-2M contain a number of low-voltage electronic circuits which are exposed to a high-noise environment. Accordingly, to prevent the possible erroneous operation of each unit resulting from noise, a preliminary test was conducted for the shielding system, wiring system, filter effects and grounding system. Design and manufacture of the device were completed based on the results of this test and then, various tests using the device were conducted in cooperation with JAERI.

1. Introduction

The JFT-2M contains noise-susceptible low-voltage electronic circuits and detectors, for which the measures described in the following sections of this paper have been completed,.

(1) Analog computer for plasma feedback control
(2) Digital computer for setting pre-program of PF coil current pattern
(3) Gate control circuit of thyristor rectifier for coil current control
(4) Detecting part for instrumentation signals and magnetic probes, etc. and gate integration circuit.
(5) Sequences for controlling the entire system
(6) Coil current detecting unit and control circuit
(7) Other instrumentation units

2. Preliminary Test on JFT-2 [3,7]

Prior to design and manufacture, to clarify the noise level in the JFT-2, the following preliminary test was conducted during the period from December 1981 to January 1982 at the conditions of 125 KA in plasma current, 0.8 MW in ICRH output and 1 MW in NBI output:

Using the current detecting unit and analog computer of the JFT-2M the effects of the shielding case, shielding tube, cable electric wire, wiring system, line filter and grounding system were measured with an oscilloscope in the noise environment of JFT-2. The measurement system is shown in Fig. 1.

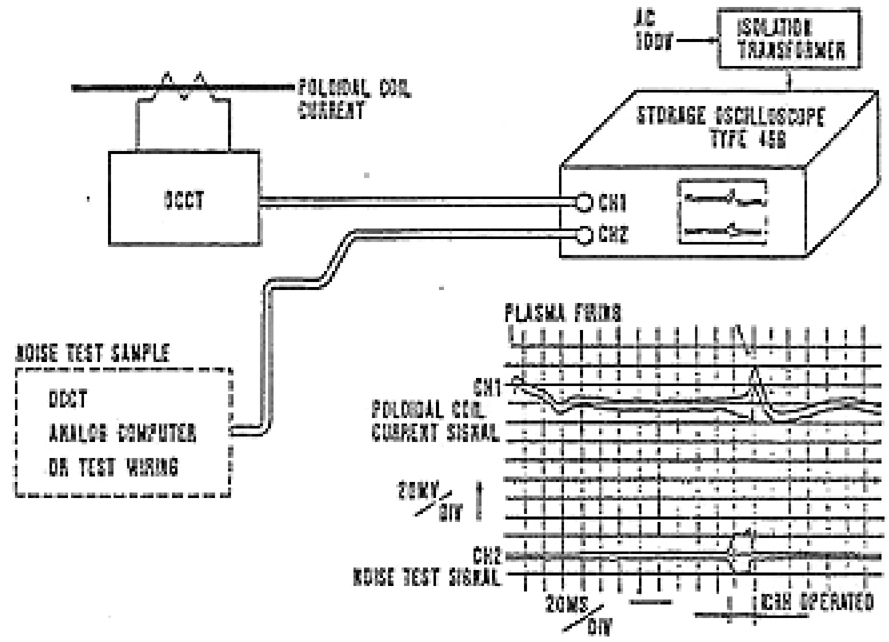

Fig. 1 Constitution of Noise Test Data Measurement

2.1 Noise screening for measurment

Since the environmental noise level is very high in the neighbourhood of nuclear fusion tests the oscilloscope (Sony's Tectro Storage Oscilloscope 466) must be screened against noise. If the oscilloscope is used without screening, a noise waveform is superimposed on the cathode-ray tube image due to power source noise and propagation noise. and therefore, the following measures were taken:

(1) The power source of the oscilloscope was isolated from the line power source with an insulating transformer.
(2) The wiring of probes was entirely shielded with aluminum foil, and the aluminum foil was connected to the common point of the oscilloscope.
(3) Clips and measurement terminals were shielded with aluminum foil.

The details are shown in Fig. 2.

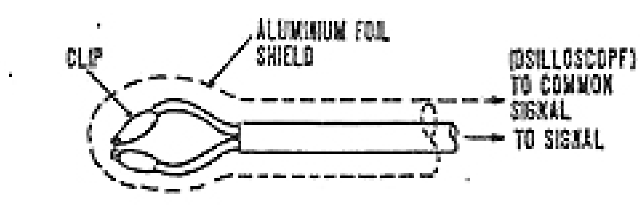

Fig. 2 Shielding of Probe's Clip

After taking measures (1) through (3) the noise voltage became 0 mV. However, the noise voltage became 50 mV following implementation of measures (1) and (2) and 5 mV following (1) and (3).

2.2 Shielding case and line filter

To check the effects of the shielding case and line filter, comparison tests using the copper and steel shielding cases were conducted using the current detecting unit and analog computer as the subject. The external apperance of the shielding case used for the test is shown in Fig. 3. Table 1 shows the case test results when the current detecting unit is the object and Table 2 for the analog computer. In either case, the comparison was made on the assumption that the noise ratio is "1" in the case of No. 1 in Tables 1 and 2.

Both the copper and steel shielding cases were effective. Therefore, in consideration of future increases in the power level of noise sources, of the JFT-2M and the high cost of copper, the aluminum shielding case was adopted.

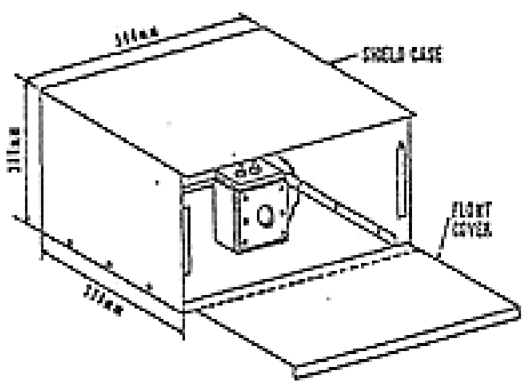

Fig. 3 Appearance of Shielding Case

Table 1 Effects of the shielding case when using the current detecting unit as the subjects

No.	Specification of Shielding Case	Line Filter ZAG 2220-11 (TDK)	Noise Ratio
1.	None.	None	1
2.	Made from 1.2 mm thick steel sheet	Provided	0
3.	Made from 1.2 mm thick copper sheet	Provided	0
4.	Made from 1.6 thick perforated steel sheet	Provided	0.1

Table 2 Effects of the shielding case when using the analog computer as the subject to be tested

No.	Specification of Shielding Case	Noise Ratio
1.	Made from 1.2 mm thick steel sheet	1
2.	Made from 1.6 mm thick steel sheet	0.7
3.	Made from 1.2 mm thick copper sheet	0.6

2.3 Cabling

To determine the most noise-resistant cable, a comparison test was conducted for two-core twisted wire, coaxial cable (single core) and two-core shielded wire. All the tests were conducted with an impedance of 10-ohm on the signal-transmitting side and 50-ohm on the signal-receiving side, and the cable was 12 meters to measure the noise level superimposed on the cable. The results are shown in Table 3.

Table 3 Types and Effects of Cable

No.	Shielding Case of Cable	Noise Ratio
1.	Two-core twisted cable (600V heat-resistant vinyl cable; 0.9 mm² (35/0.18))	1
2.	Coaxial cable (RG-58 A/U)	0.3
3.	Two-core shielded cable (HKIV-ST2-D)	0.07

2.4 Connection of shielding

To check differences in connection methods to the shielding copper tube and signal common point, the comparative test was conducted for different connection methods using two-core shielded wire as the subject. Each connection method and the respective noise ratio are shown in Fig. 4. A twelve-meter long cable was used in each casé. A Ten-ohm resistor on the detector side and a fifty-ohm resistor on the signal-reception side were shielded with aluminum foil.

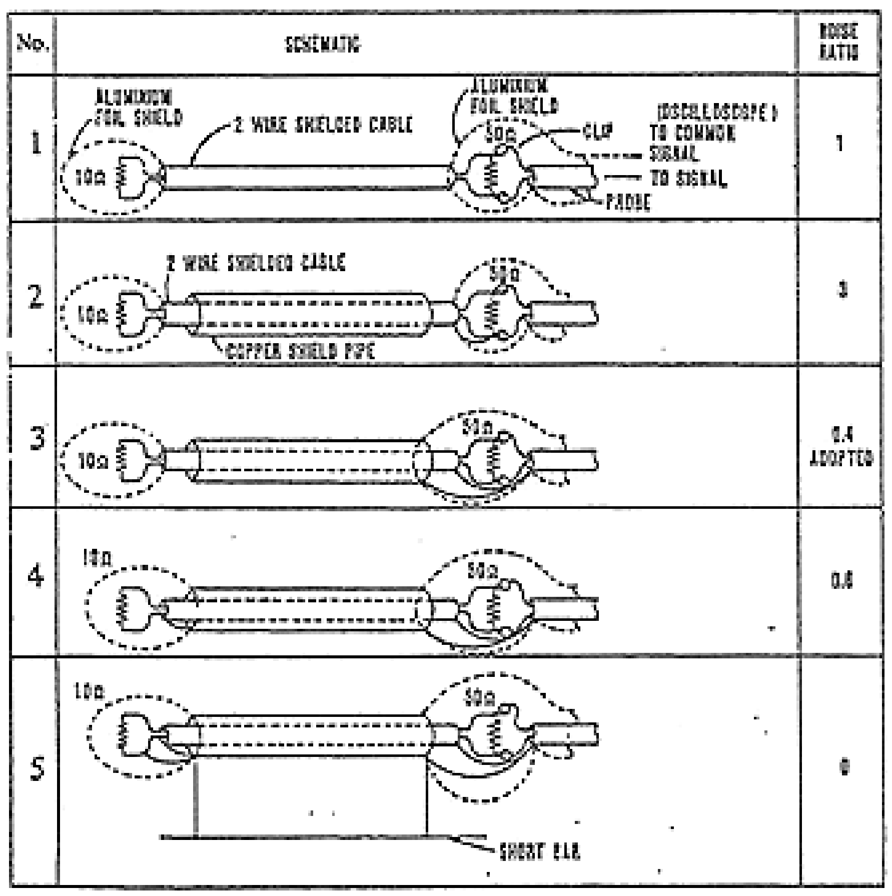

Fig. 4 Effects of each connection method on shielding the copper tube and signal common point

In Fig. 4, No. 1 is the case when a copper tube is not used. The noise ratio in No. 1 was assumed to be "1". In No. 2, the cable was inserted into the shielding copper tube, which is not connected to any part to keep the potential isolated. In this case, the noise ratio became "3" indicating that the shielding effect was worse than that using no copper tube. No. 3 is the case when the signal-reception terminal of the copper tube is connected to the common point of the oscilloscope. The shielding effect improved in this case. In No. 4, both the detecting terminal and signal-receiption terminal of the copper tube were connected to the common point. This resulted in two-point grounding and a shielding effect inferior to that in No. 3. In No. 5, the ends of the copper tube were short-circuited directly to simulate the multi-point grounding. This provided the best noise ratio. Since it is not practical to apply No. 5, for the actual equipment from the standpoint of the building space and installation cost, it was decided to employ, No. 3 for the JFT-2M.

2.5 Line filter and wiring route

To check the shielding effect for each location on the line filter and wiring route, the comparative test was conducted using the current detector contained in the shielding for each wiring route between equipment when the line filter is connected and not connected. Equipment configuration and noise ratio for each case is shown in Fig. 5. 1.2 mm thick copper sheets were used for the shielding cases.

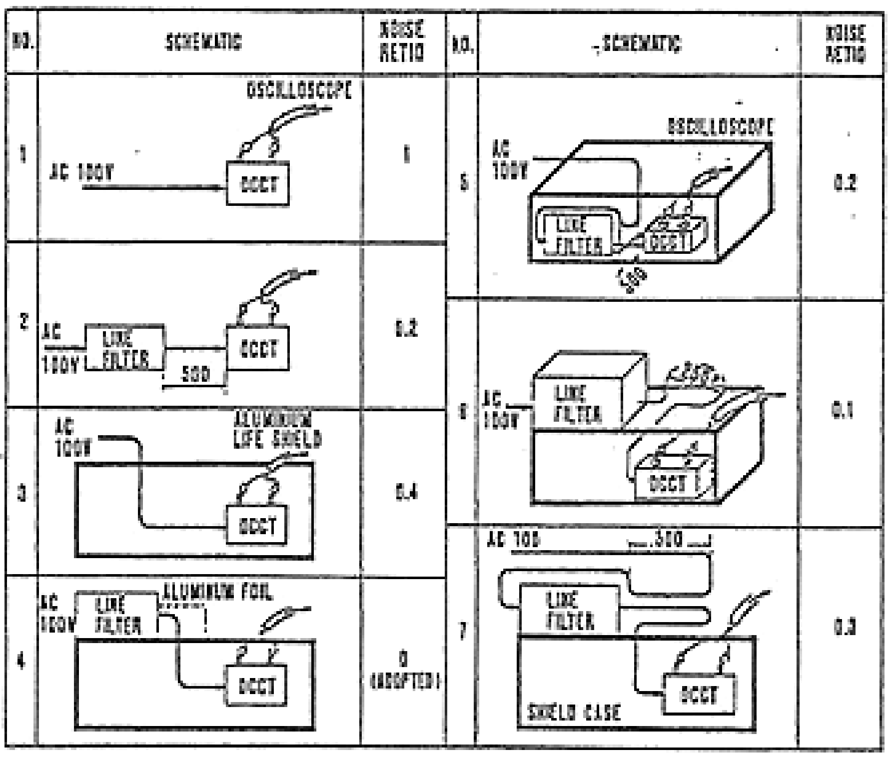

Fig. 5 Effects for each Location on Line Filter and Wiring Route

In No. 1, both the line filter and shielding case were not used, and the noise ratio was assumed to be "1". In No. 2, only the line filter was used. In No. 3 only the shielding case was used. No. 4 is the ideal wiring set-up in which both line filter and the shielding case were used. No. 5 thru No. 7 show unsatisfactory examples of wiring. In No. 5, the input cable and the output cable of the line filter are parallel with each other in the shielding case. This results in noise reception. In No. 6, the cable, having passed through the line filter, forms a loop outside the shielding case. This results in noise reception. In No. 7, the input wire and the output wire of the line filter were parallel with each other outside the shielding case. This results in noise reception. From these results, it was decided to employ No. 4 for the JFT-2M.

2.6 Results

The aforementioned results are summarized as follows:

(1) Two-core shielded cable provided better noise-resistance than two-core twisted cable and coaxial cable (single core).

(2) Either a copper or iron shielding case was effective.

(3) When the two-core shielded wire is inserted into a shielding copper tube, if the copper tube is not connected to the common point of the oscilloscope, it is liable to receive more noise than an exposed two-core shielded wire. Connecting the signal-reception side of the shielding copper tube to the common point is effective.

(4) Connection of a line filter is effective.

(5) The most effective results are achived when the subject equipment is put into the shielding case, the line filter is installed directly onto the shielding case, the input cable of the line filter is arranged outside the shielding case and the output cable is arranged inside the shielding case.

(6) The input and output cables of the line filter must not be parallel with each other.

(7) The output cable of the line filter must not be outside the shielding case.

3. Design and Manufacture for Noise Prevention

On the basis of the results of the preliminary test for the JFT-2, this equipment (JFT-2M) has been provided with noise-preventing measures for its shielding structure, copper sheet sections, wiring and copper tube shielding, and details of which are follows:

Fig. 6 shows the external appearance of the plasma control panel. Fig. 7 shows the aluminum shielded case of the plasma control panel and the wiring diagram for grounding. Fig. 8 shows the plasma monitoring system, the grounding of measuring signals and the shielding structure.

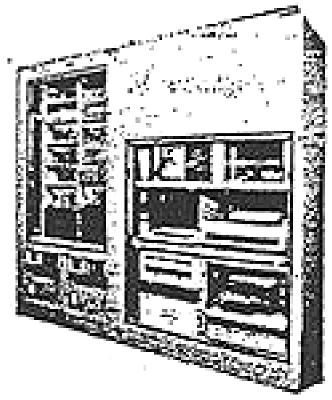

Fig. 6
External appearance of plasma control panel

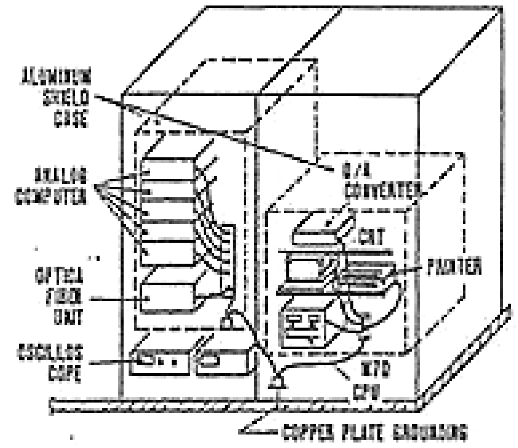

Fig. 7
Aluminum shielding case for plasma control panel and schematic diagram for grounding wire

As shown in Fig. 8, the AC power source is input into the panel through the insulating transformer and the line filter, and the wiring carrying the measuring signal is fed through shielded copper tubing in each control panel. Signals to or from other equipment are transmitted or received through optical fiber cable to insure complete insulation from the other grounding and to prevent leakage of the grounding current from the high voltage system into this grounding system.

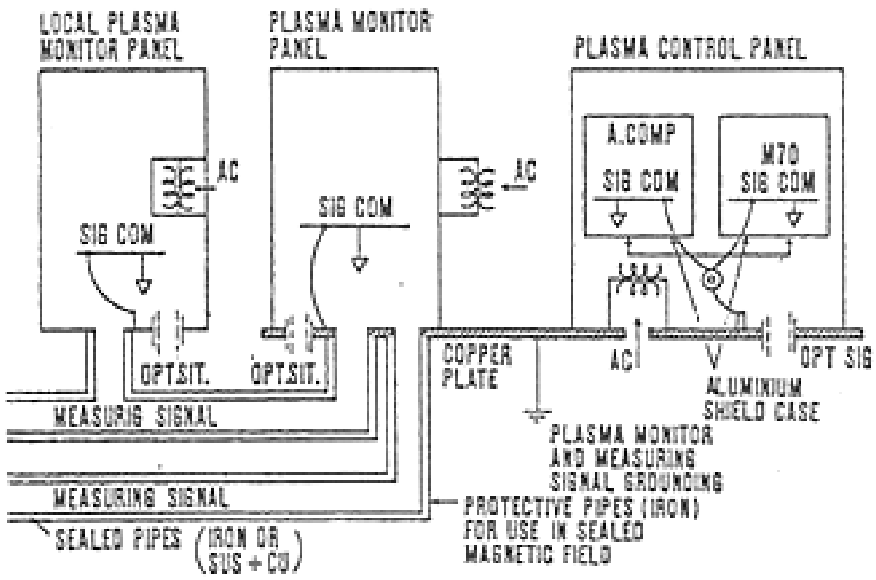

Fig. 8 Grounding system for plasma monitoring and measuring signals and shielding structure

The analog computer and the digital computer shown in Fig. 7 are housed in an aluminum shielding case. Common signal common points are brought together in the shielding case and grounded to the copper sheet. The copper sheet is placed under the control panel as shown in Figs. 7 and 8 to shield high-frequency noise from ICRH. Fig. 9 shows how of the plasma control panel is mounted on the copper sheet. The bottom surface of the panel and base stand and the base stand and copper sheet are bolted together while keeping plane contact. To keep the potential constant between these parts and to prevent the copper sheet from making an unsatisfactory connection with other grounding poles through structures, the copper sheet is placed on a rubber sheet on a concrete slab. The base stand and the concrete slab are bolted together through insulating washers to insure complete insulation. By taking these measures, the grounding point of the plasma monitoring & measuring equipment is completely isolated from other grounding systems.

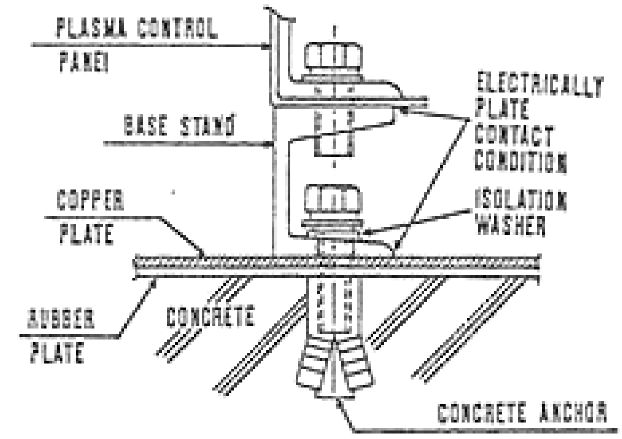

Fig. 9 Mounting of plasma control panel on copper sheet

To minimize the influence of noise between cables, the cable trays are divided as follows:

(1) High-voltage cable tray (3.3 kV high-voltage cable, TF/PF power supply cable, etc.)

(2) Control low-voltage cable tray (AC 100/200V, electromagnetic valve, relay contact signal cable, etc.)

(3) Instrumentation cable tray (Analog signal, thermo-couple, magnetic probe and thyristor gate pulse signal cable, etc.)

For transmissions through the optical fiber cable, the analog link (FFL-I001A; Voltage level; –2V to +2V, Band; DC-300 kHz (–6 dB); Non-linearity: ±1%, below of F.S.) is used for coil current standard signals, plasma measuring signals and magnetic probe signals. The digital link (OPM-T/R510A; Band: DC-1mb/S) is used for coil current start signals, Pre-program waveform start signals and other timing signals.

4. Design and Installation of Grounding System [4, 5, 6]

The vacuum vessel, iron core, the supports and the lower parts of the supports are all insulated from each other. All measuring instruments and auxiliary systems mounted on the vacuum vessel are insulated from the vacuum vessel and grounded independently. The objective of the insulation is to keep the potential of each equipment constant and the prevent electric discharges between equipment, and to ensure the safety of personnel. The vacuum vessel and the support are divided toroidally into two sections. The four divided semitori are insulated from each other and grounded to the grounding pole of the main device of the equipment through the 10 m-ohm grounding resistor. This prevents toroidal loop current and possible voltage rise due to grounding resistance. As this grounding resistor is connected in parallel with the plasma, it has a sufficiently large value compared with the plasma resistance.

Since the grounding pole protects every part from noise and surge generated from the plasme, coil magnetic field and heating unit, it is divided into five grounding poles and each item of equipment is connected to the most suitable grounding pole. Fig. 10 is a block chart of the equipment connected to each grounding pole of JFT-2M.

(1) Main device grounding pole: This is the grounding pole for the main device, TF/PF power supplies and other peripheral equipment.

(2) Control signal grounding pole: This is the grounding pole for the electronic control device of the PF power supply and operation control equipment.

(3) Plasme monitoring & measuring signal grounding pole: This is the grounding pole for the analog and digital computers for plasma measuring signals and plasma control. The copper sheet at the lower part of the control panel is connected to this grounding pole.

(4) NBI grounding pole

(5) ICRH grounding pole

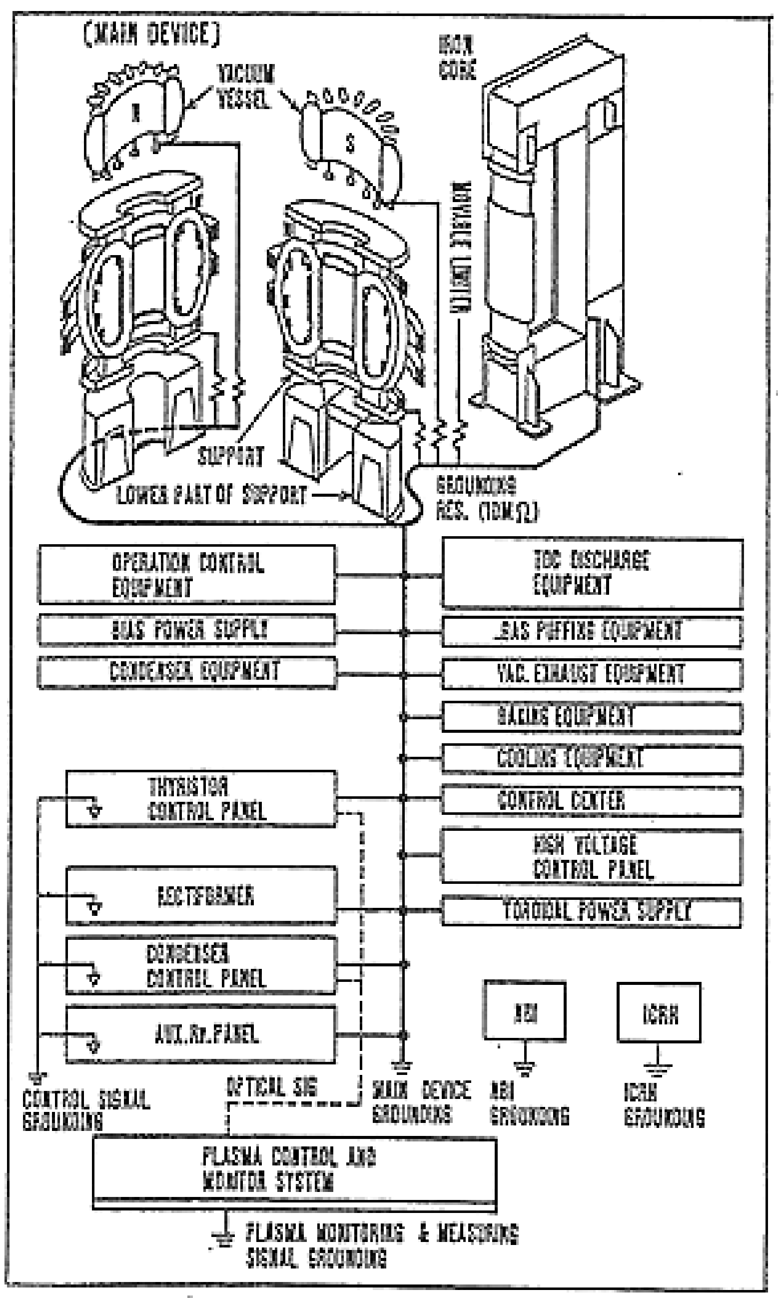

Fig. 10 Equipment connected to each grounding pole of JFT-2M and block chart of equipment

5. JFT-2M Noise Test

The JFT-2M, after being completed in April 1983, achived maximum plasma current of 300 kA, NBI output of 2 MW and ICRH output of 38 MHz 0.8 MW at the test by JAERI. [1, 2] In this noise environment, the JFT-2M's plasma control system for the analog and digital computers, the measuring systems for the plasma measuring unit and the gate integrator, and the thyristor control system for the poloidal coil power supply have been operating normally and the effectiveness of the noise-preventing measures have been proved.

The difference in potential between the main device grounding pole and the plasma monitoring & measuring signal grounding pole was 4 Vp-p. The grounding current to the main device grounding pole was approximately 6A and that to the control signal grounding pole and the plasma monitoring & measuring signal grounding pole was 0.2A to 0.6A. This shows that the difference was too small to adversely effect the operation.

The author would like to acknowledge the close cooperation received from JAERI in conducting this experiment which provided us with useful suggestions for the design and manufacture of the JFT-2M.

References

[1] T. Shoji, A. Funahashi, et. al., "Results from the JFT-2M Experiments" Proc. of the 11th Europ. Conf. on Controlles Fusion and Plasma Physics (Aachen) Vol. 1, 1983, pp.55–58.

[2] T. Shoji, K. Odajima, et. al., "An Outline of the JFT-2M Device, Design, Construction, Test" JAERI-M83–0194, 1983.

[3] Henry W. Ott, "Noise Reduction Techniques in Electronics Systems" 1976 by Bell Telephone Laboratories Inc.

[4] K. Arakawa, R. Shimada, H. Kishimoto, et. al., "Study of Grounding System of Large Tokamak Device JT-60", Denki Gakkai, June 1982, Vol.102–6, pp.41–48.

[5] U. Schwarz, C. Neumeyer, "The Grounding of TEXTOR" in proceeding of 11th SOFT 1980 pp.921–926.

[6] K. Kamahara, "Earthing Equipment of Electric Railway", Denki Hyoron, Vol.174, 30th June 1981, pp.619–625.

[7] D. Naile, "Elimination of Noise in Low-Level Circuits", ISA Journal, August 1965, pp.59–68