DEVELOPMENT OF THE IN-CORE FISSION CHAMBER

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TOKYO SHIBAURA ELECTRIC CO., LTD.

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The In-Core fission chamber for LMFBR is under development. The latest model of the detector developed in 1973 was 10mmϕ. It is successfully operating at KNK. Development efforts are now focussed on smaller size detector, suitable as a "JOYO" Mark II fuel assembly for an instrumented fuel assembly.

Two of the smaller size detectors were designed and fabricated for performance testing. Tests were conducted under conditions of 600 °C, 10^{10} nv thermal neutron flux. The trial operation tests on a thermal research reactor are satisfactory.

Detectors design and fabrication

The design of the detector is based on the experimental data gained from the former detector development program and adjusted for "JOYO" operating conditions. The design concepts are as follows:

Maximum temperature	:	600 °C
Neutron sensitivity	:	1mA at JOYO 100 MW (thermal)
Gamma sensitivity	:	Less than 1% of neutron signal
Dimensions	:	Small enough to match the fuel pin size
Leakage current	:	Less than 1% of signal current

Following the design requirement, the engineering design and test manufacturing of the detector proceeded apace.

For high temperature resistance, careful considerations are paid to both the structure and the material. The tri-axial cable construction is chosen for guarded signal current. Alumina, sapphire and beryllia are selected for different sections of the chamber. As shown in Fig. 1, the electrodes supporting insulators are sapphire and beryllia. One is used for the detector end support and the other for the vacuum sealed signal wire penetration. Beryllia has better ceramic to metal seal material characteristics. Sapphire is known as a good insulation material for high temperatures. The metals for the detectors are SS316 for the outer casing and Fe-Ni alloy for seal parts and cathode.

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The designed detector specifications are as follow.

Neutron sensitivity	:	3.7×10^{-19} A/nv (above 100 keV)
Gamma sensitivity	:	1×10^{-14} A/hr
Insulation resistance	:	2.7×10^{7} at 600 °C
Outer dimension	:	6.3mϕ x 118mm
Neutron converter	:	U-235 (90% enriched)
Chamber gas	:	Pure Argon
Cable	:	Tri-axial alumina insulated stainless steel cable, 3.2mmϕ

The detectors are fabricated as shown in photograph 1.

Detector Operation Tests

The purpose of the tests is to evaluate the operational characteristics of the fabricated detectors. The tests we electrical test, gamma test and reactor operation test. During those tests to evaluate the detector performance, measurement method is typical direct current measurement. Figure 2 shows the experimental set up testing diagram.

Electrical resistivity test. The detectors are tested for electrical resistivity in high temperature up to 600 °C. A portion of the cable and the detectors are placed in the electrically heated furnace.

Leakage currents are measured with 100 volts bias across the electrodes. The results are values of 10^{6} ohms at 600 °C. The reason for the larger leakage current, compared to the designed value, is considered to be the surface leakage current of the chamber insulators.

Gamma flux irradiation tests. Using 5,700 Curie of Co^{60} gamma source, the gamma sensitivity of the detectors are measured. 2.86×10^{5} R/hr is the gamma field where the detectors are placed. Chamber output currents during gamma irradiation were measured. Figure 3 shows the bias-current characteristics of the detector. For each chamber, the gamma sensitivity ($S\gamma$) is calculated as

$$S\gamma = 4.1 \times 10^{-14} \text{ A/R/hr} \quad (\#1 \text{ detector})$$
$$2.6 \times 10^{-14} \text{ A/R/hr} \quad (\#2 \text{ detector})$$

The measured values are satisfactory, but a little larger than the designed values. The reasons for the difference are considered to be a chamber construction problem and/or contribution of gamma current other than from the chamber itself.

Reactor performance tests. The detectors are put into the electrical furnace and placed in the vicinity of the TTR-1 reactor core. The furnace is a specially designed irradiation facility for detectors. It can be electrically heated up to 600 °C with neutron flux up to 5×10^{10} nv. The detectors are irradiated in dry nitrogen atmosphere. During the irradiation, the output signal currents of the detectors are measured at the cold end of the detectors. Figure 4 shows the measured plateau characteristics of the detector for different temperatures. At high temperature, the measured current is increased. By increasing the bias voltages, the detector current is increased. This shows the effects of leakage current due to high temperature. The phenomena observed on this performance test is much more emphasized due to the small neutron flux of TTR-1. In the case of "JOYO", 10^{-3} A of the signal current is expected, compared to the TTR's 10^{-6} Amp. Thus, the error current at "JOYO" is expected to be less than 1%. The output linearity tests, whose results are shown in Figure 5, also show the effect of high temperature as was expected. But, in the "JOYO" core, the effect will be negligible, for the same reason as mentioned above.

Results

Performance test results are satisfactory. As shown in Table 1, the measured values are slightly different from the designed values of the detector performance, but it is considered that the detectors showed the capability of operation under operating LMFBR conditions. However, the reliability and the study of long term irradiation effects are future detector development program subjects.

Table 1. Results of Characteristic Test

		Design Value	FBRS-28-1	FBRS-28-2
Thermal Neutron Sensitivity		8.2×10^{-17}	9.67×10^{-17}	6.28×10^{-17}
Insuration	Room Temperature	1×10^{12}	1×10^{13}	1×10^{13}
Resistance	600 °C	1.2×10^{7}	0.32×10^{7}	0.22×10^{7}
Gamma Sensitivity (A/R/Hr)		1×10^{-14}	4.1×10^{-14}	2.6×10^{-14}

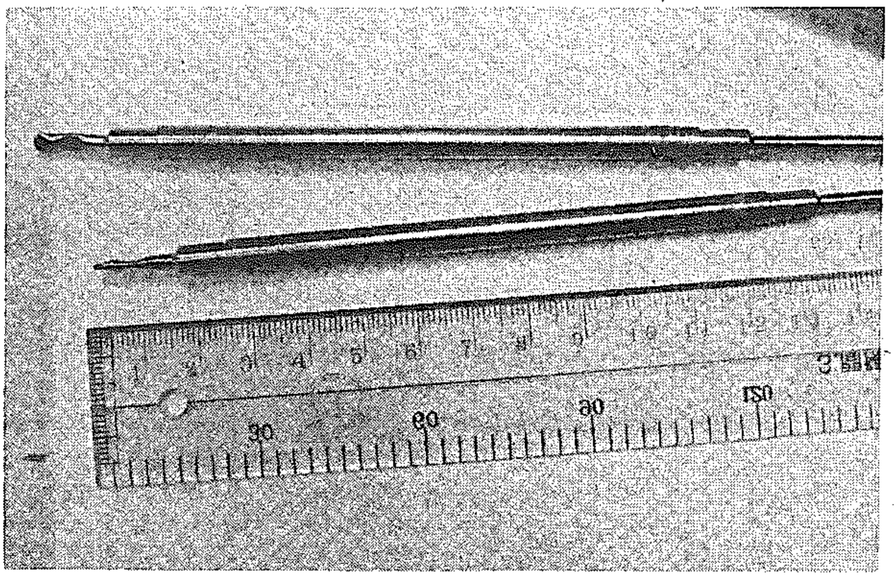

Photo 1(a) Close-up of the Detector-Head

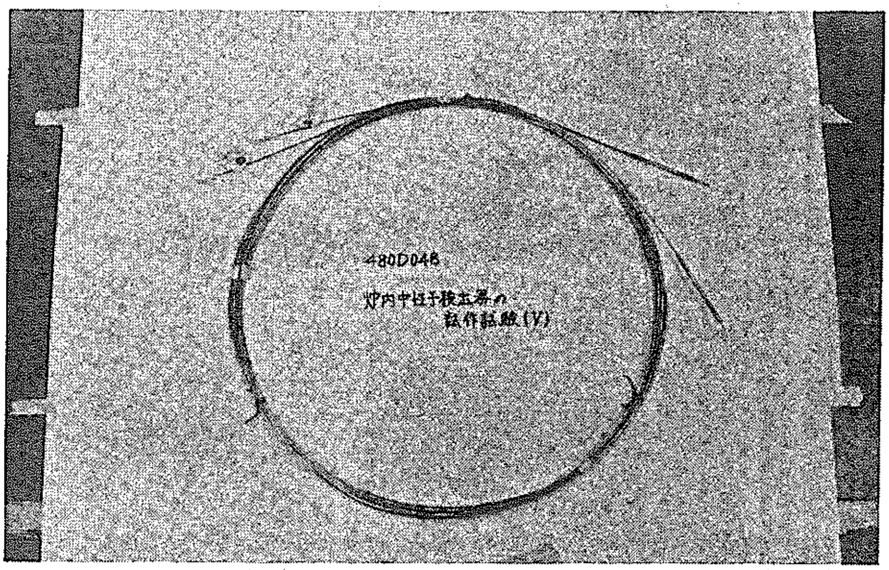

Photo 1(b) Fabricated Trial Detectors

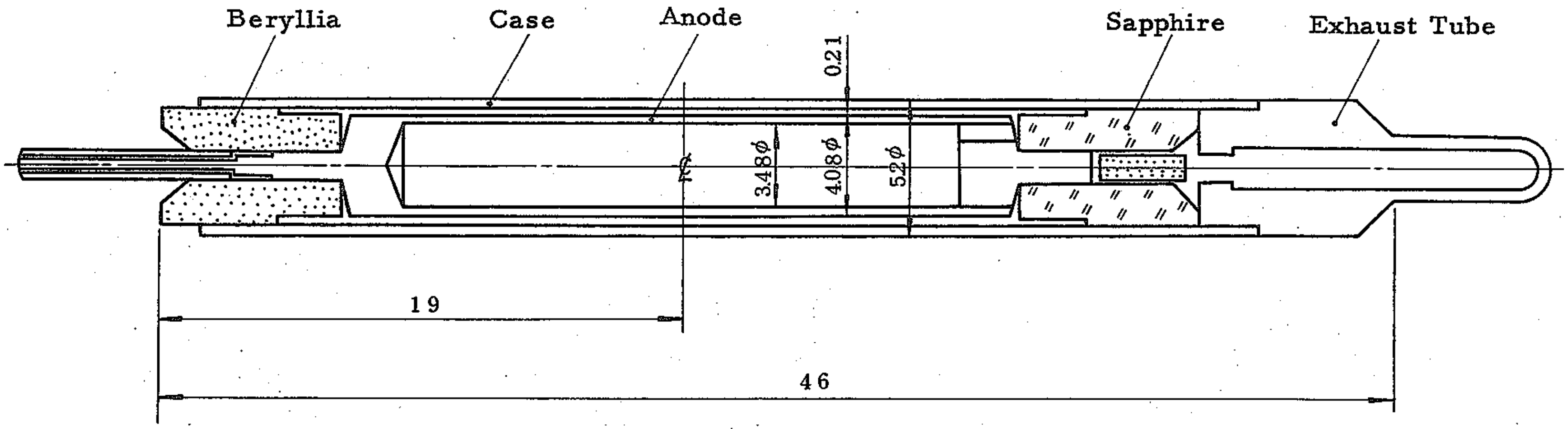

Fig. 1 The structure of chamber

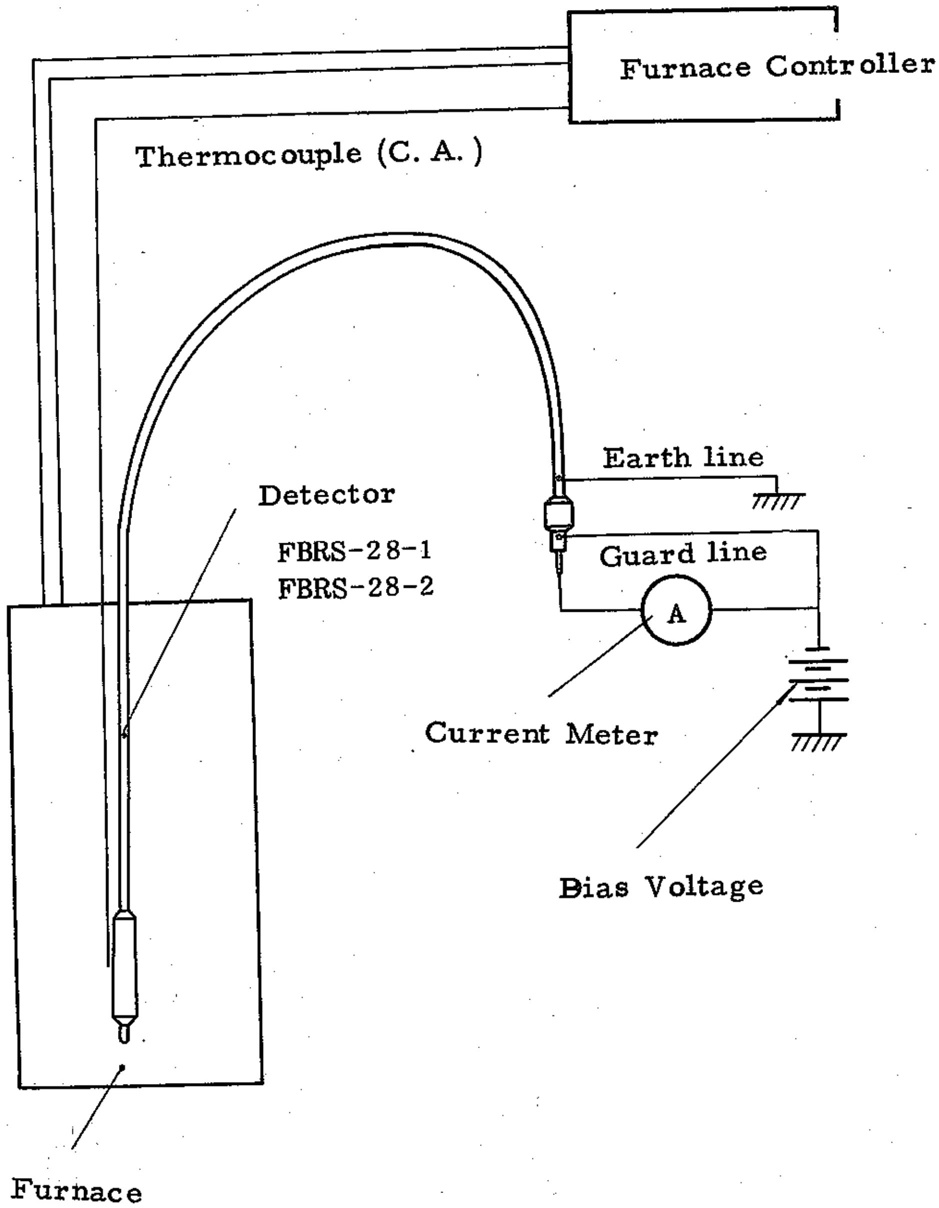

Fig. 2 Testing diagram

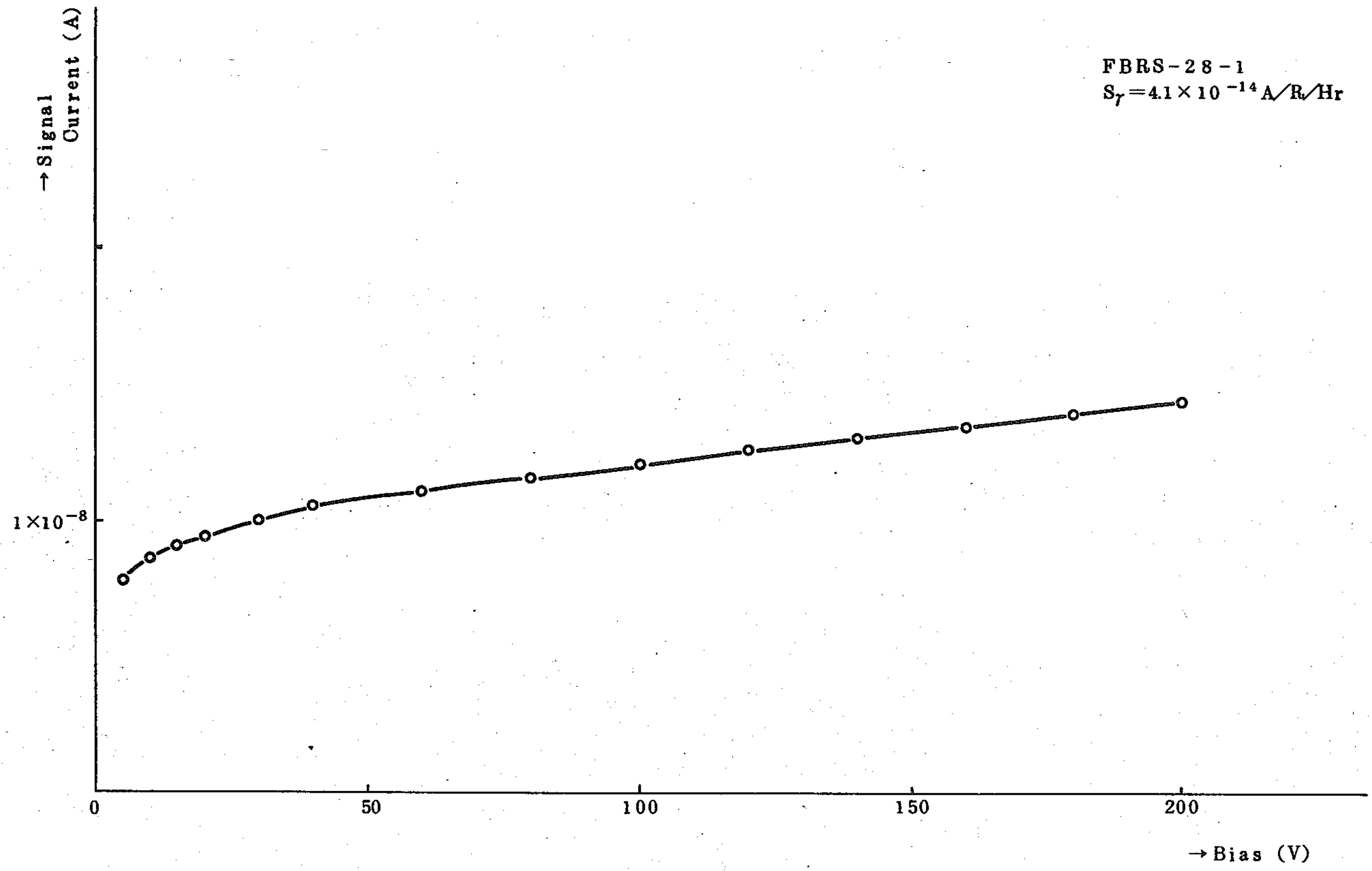

Fig. 3 Gamma Plateau Characteristics

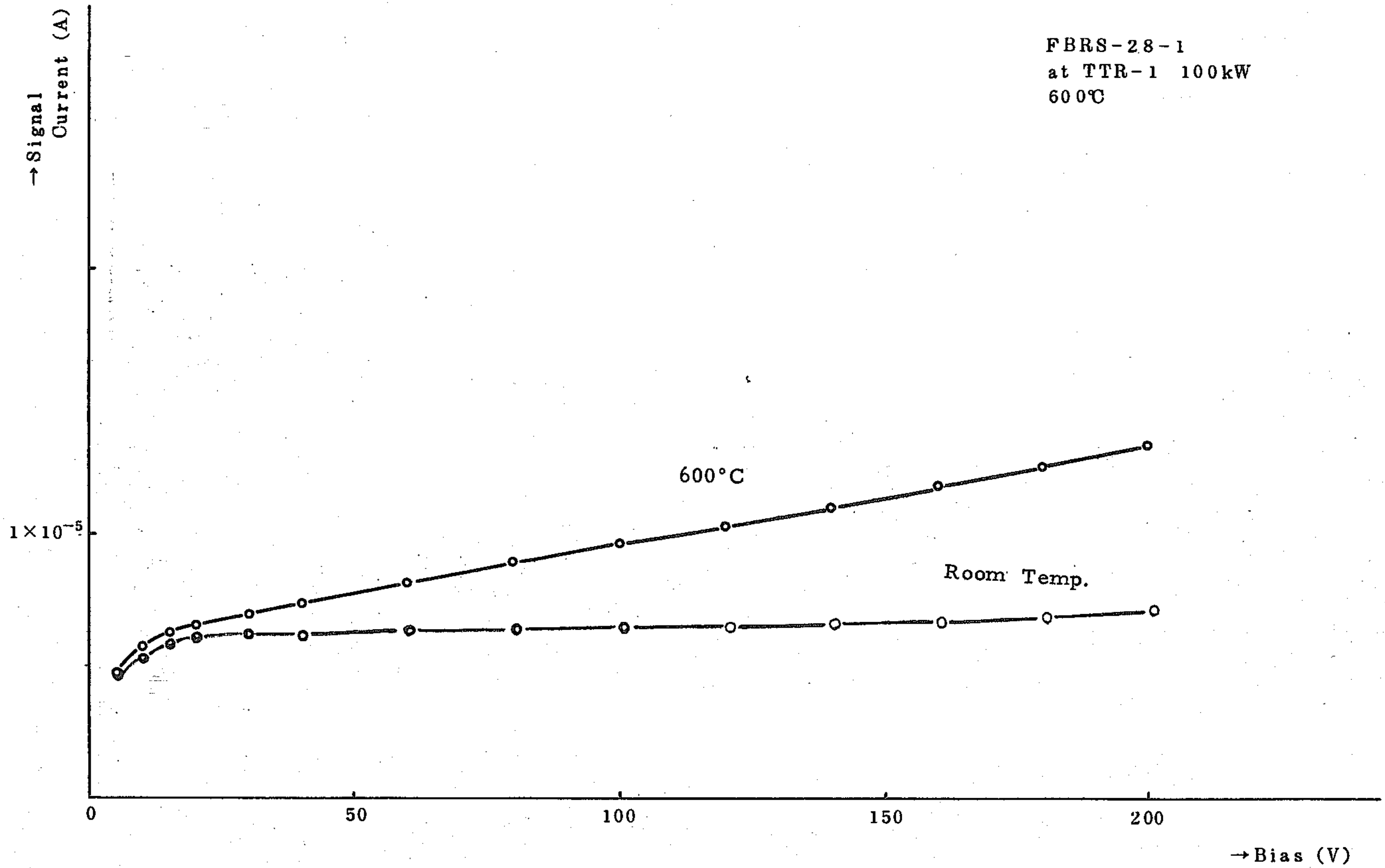

Fig. 4 **Plateau Characteristics (High Temperature)**

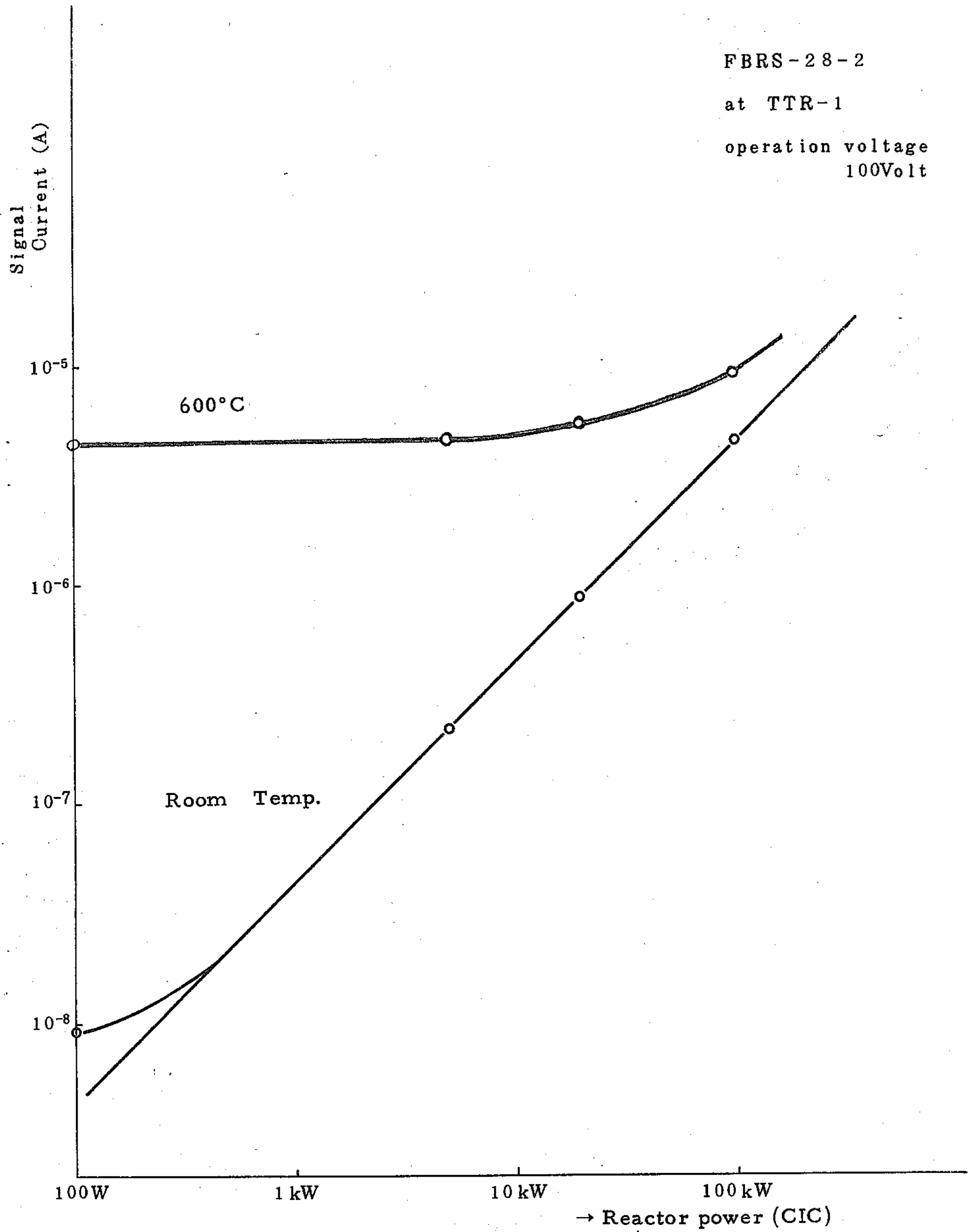

Fig. 5 Linearity Characteristics
(High Temperature)