JAERI-Tech
94-026

PEAKING FACTORS OF NUCLEAR HEATING DUE TO VOID DUCTS IN THE 80% SS-20% H_2O SHIELDING BLANKET OF FUSION EXPERIMENTAL REACTORS

November 1994

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編集兼発行　日本原子力研究所
印　　　刷　㈱高野高速印刷

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(Received October 11, 1994)

Peaking factors of nuclear heating in the stainless steel behind the 80% SS−20% H_2O shielding blanket are obtained for straight void ducts in the blanket of fusion experimental reactors. The three ducts of 50 cm length and 5, 10 and 15 cm diameter are considered to make the obtained data base useful for other researches and engineers engaged in a fusion reactor design. The peaking factors of nuclear heating behind those ducts range from 2.3 to 17.5, respectively.

Keywords : Neutron Streaming, Neutron Transport Calculations, ITER, Shielding Blanket, Nuclear Heating, Neutronics.

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JAERI-Tech 94-026

核融合実験炉の遮蔽ブランケットにおけるボイドダクト近傍の核発熱率分布

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高津　英幸

（1994年10月11日受理）

核融合実験炉では，ブランケットの固定等の目的で，ブランケット本体にプラズマ側から直視できる直線状のダクトが設けられることがある。本報告では，ＩＴＥＲで検討されているステンレス鋼80％，水20％で構成される厚さ50cmの遮蔽ブランケットを対象に，直径５～15cmの直線状ボイドダクトの後部における構造体の核発熱率分布を，２次元の輸送計算にて評価した。解析の結果，一般部と比較して，直径５，10，15cmのボイドダクトによる核発熱率のピーキングは，各々2.3，7.9，及び17.5であることが分かった。

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1. INTRODUCTION

The neutron streaming in and/or behind straight-through void ducts in blankets and shields has been discussed in many studies, e.g. [1-7]. That data base can be used to estimate the decrease of shielding effectiveness in and/or around those penetrations. However, no discussion was done on the streaming effect in ducts of less than 10-15 cm diameter (D) at relatively small distance (L) from the first wall, say 20-50 cm. The D/L parameter of such ducts is comparable with unity that prohibits to use the Simmon-Clifford formula. The streaming effect at such a duct is determined by the three neutronics processes as follows :

- neutrons passing through the duct with (line 1 in Fig. 1) reflection from the duct wall;
- neutrons passing through the duct without (line 2 in Fig. 1) any interaction with the duct wall;
- neutrons diffusing to the duct after passing through a relatively short distance in the composition around the duct (lines 3 in Fig. 1) either with one or more interactions in that composition.

Therefore, it is relatively difficult to use the existing design data base to obtain peaking factors of nuclear heating in ducts having D/L comparable with unity. Further, the streaming effect of nuclear heating in steel components of blankets is determined mainly by gamma-rays. Thus, it is even more difficult to estimate that effect for ducts having the D/L comparable with unity due to the need to consider the streaming of gamma-rays.

Therefore, we decided to conduct neutron transport calculations for a number of ducts to obtain a design-independent information on peaking factors of nuclear heating so that obtained information could be used for other designs of a fusion reactor.

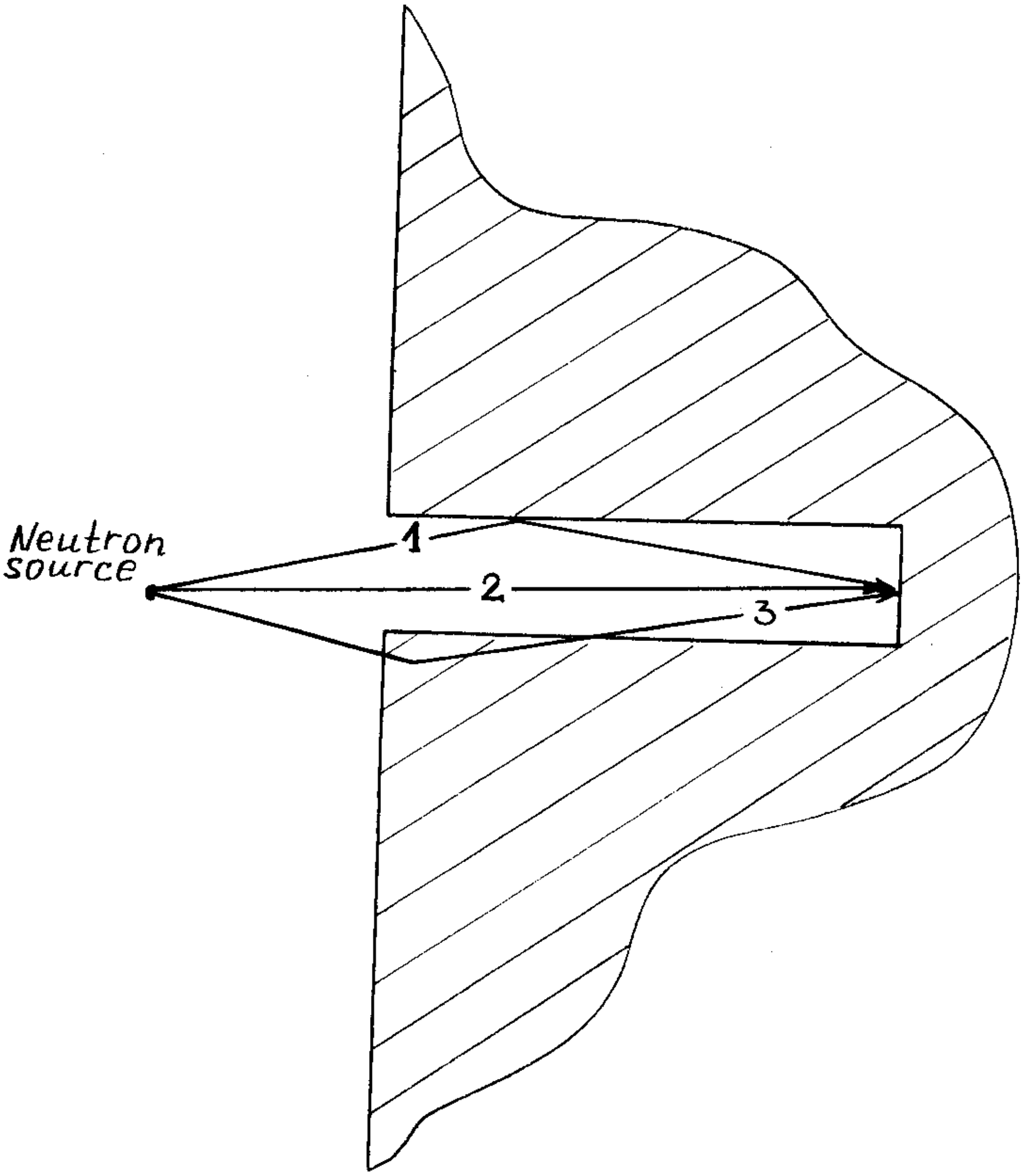

Fig. 1 Radiation streaming through the cylinder duct.

2. CALCULATIONAL METHOD

The DOT3.5 code [8] with the FUSION-40 library of multigroup constants [9] are used in this study. The simplified geometrical model of inboard and outboard shielding compositions of a fusion reactor is shown in Fig. 2.

A uniform volume source of 14-MeV monoenergetic neutrons was assumed to exist at the plasma zone. The 80% SS -20% H_2O homogeneous mixture is chosen for both the inboard and outboard shielding blanket so that the results obtained could provide useful design-independent information on peaking factors of nuclear heating in steel components of a fusion reactor.

The neutron transport calculations in two-dimensional cylinder geometry were performed using the discrete ordinate method with an 166 (biased up) angular quadrature set and a P_5 Legendre expansion for the scattering cross sections.

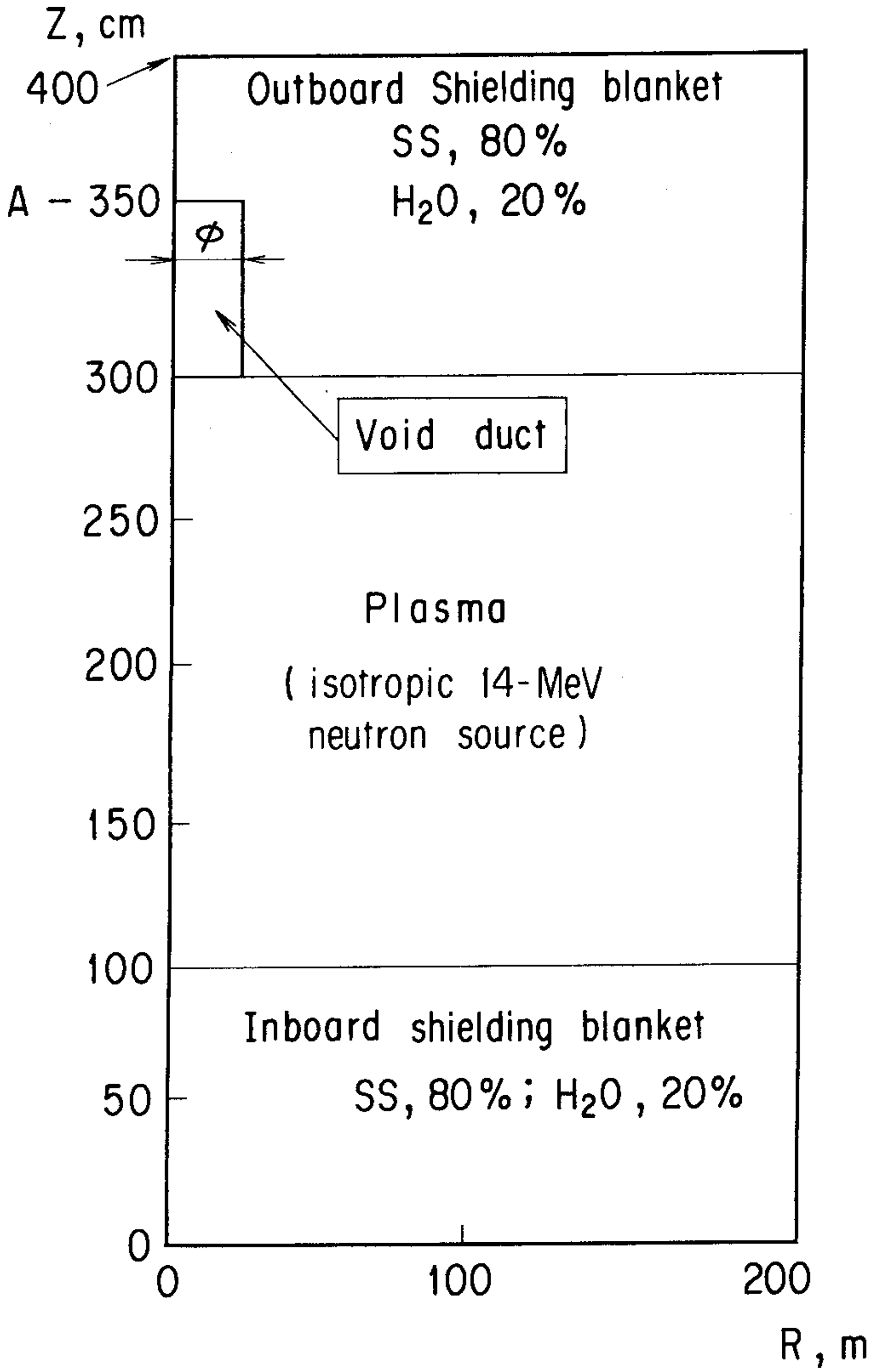

Fig. 2 R-Z cylinder calculational model.

3. PEAKING FACTORS

The peaking factor in this study is defined as the ratio of the nuclear heating in steel inside the duct at a distance L from the duct entrance to that at the same position of the bulk shielding blanket without a duct. Thus, the peaking factors are dependent on the material composition of the shielding blanket. In the case of 80% SS - 20% H_2O shielding blanket the peaking factors are expected to reach largest numbers due to the largest shielding effectiveness of that bulk shielding comparing with those having other SS/H_2O fractions [6].

Nuclear heating distribution at the end of a 5 cm, 10 cm and 15 cm diameter duct (cut A-A in Fig. 2) is shown in Figs. 3-5, respectively. Those results are summarized in Fig. 6 as peaking factors of nuclear heating in stainless steel due to both only neutrons (solid curves) and neutron&gamma-rays (dashed curves).

Peaking factors of nuclear heating due to only neutrons are by 2-10 times larger than those due to neutrons&gamma-rays. It is due to larger streaming effect for neutrons than that for gamma-rays. However, most important for a fusion reactor design are peaking factors due to neutrons&gamma-rays. Indeed, as shown in Figs. 3-5, the nuclear heating in steel due to gamma-rays is by about 50-100 times larger than that due to neutrons only.

Peaking factors increase with the distance from the duct entrance. This effect is shown in Fig. 7 for all considered diameters of ducts.

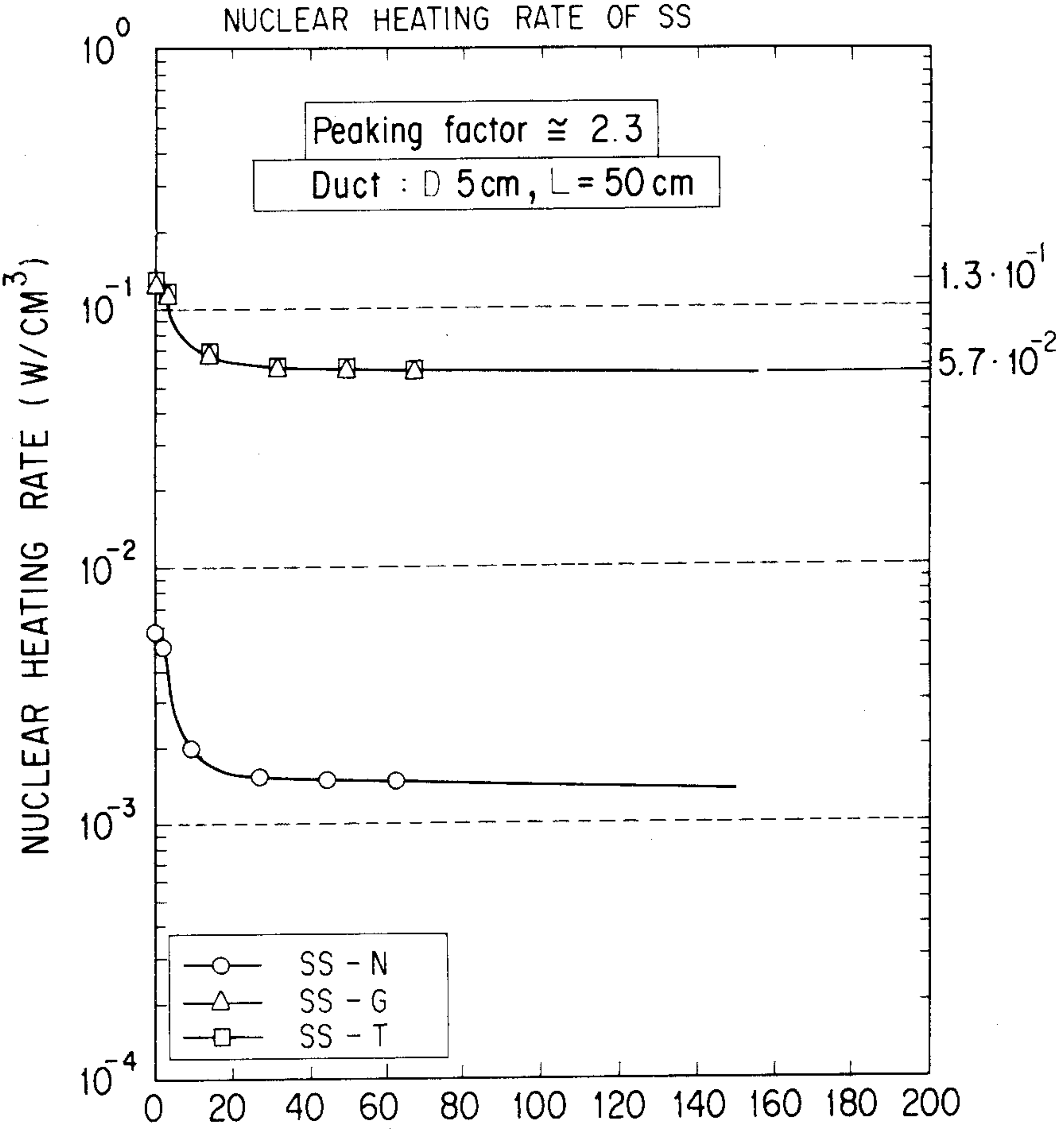

Fig. 3 One-dimensional distribution of nuclear heating in stainless steel (Cut A-A in Fig. 2).

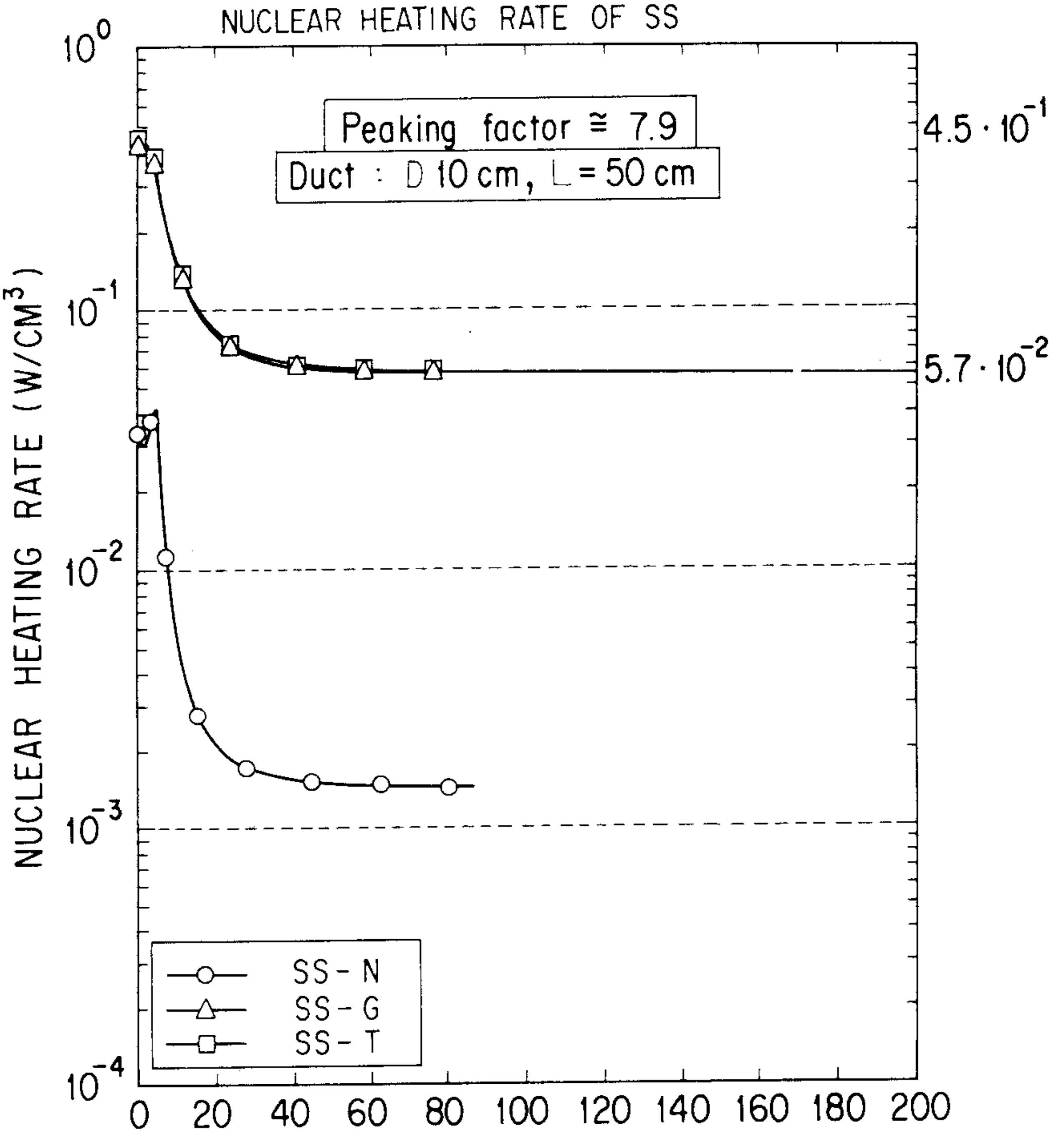

Fig. 4 One-dimensional distribution of nuclear heating in stainless steel (Cut A-A in Fig. 2).

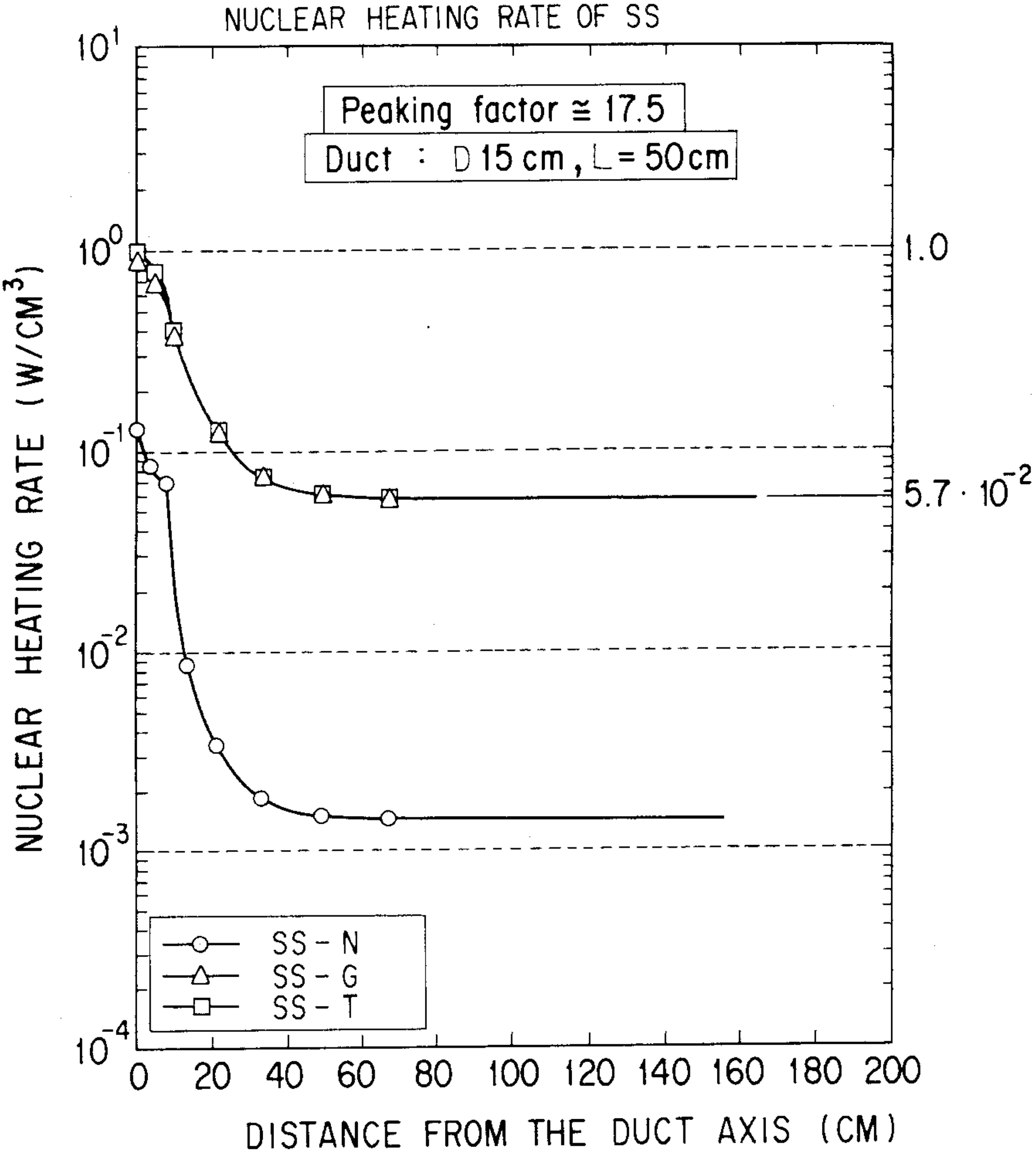

Fig. 5 One-dimensional distribution of nuclear heating in stainless steel (Cut A-A in Fig. 2).

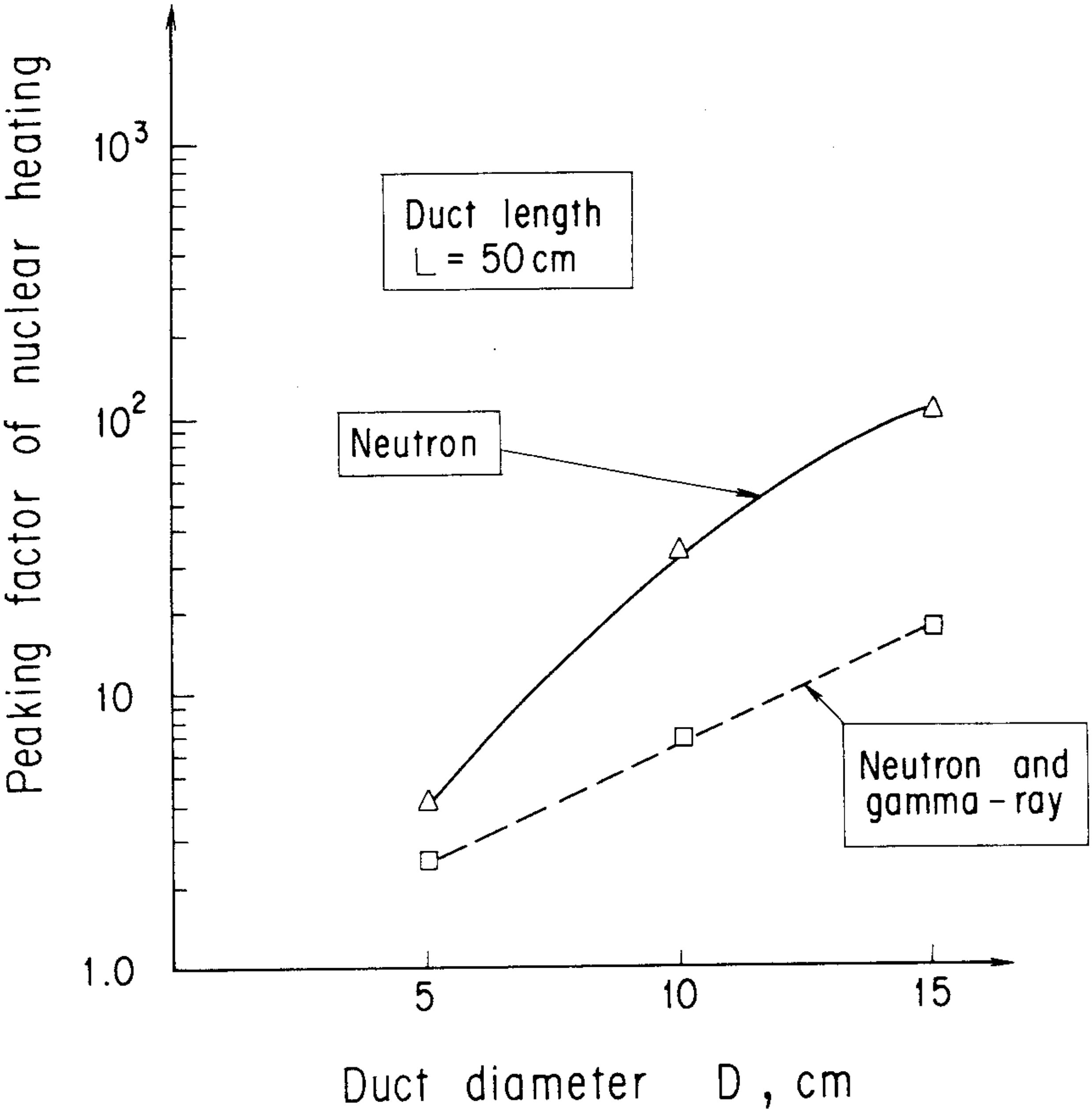

Fig. 6 Peaking factors of nuclear heating in stainless steel versus the duct diameter.

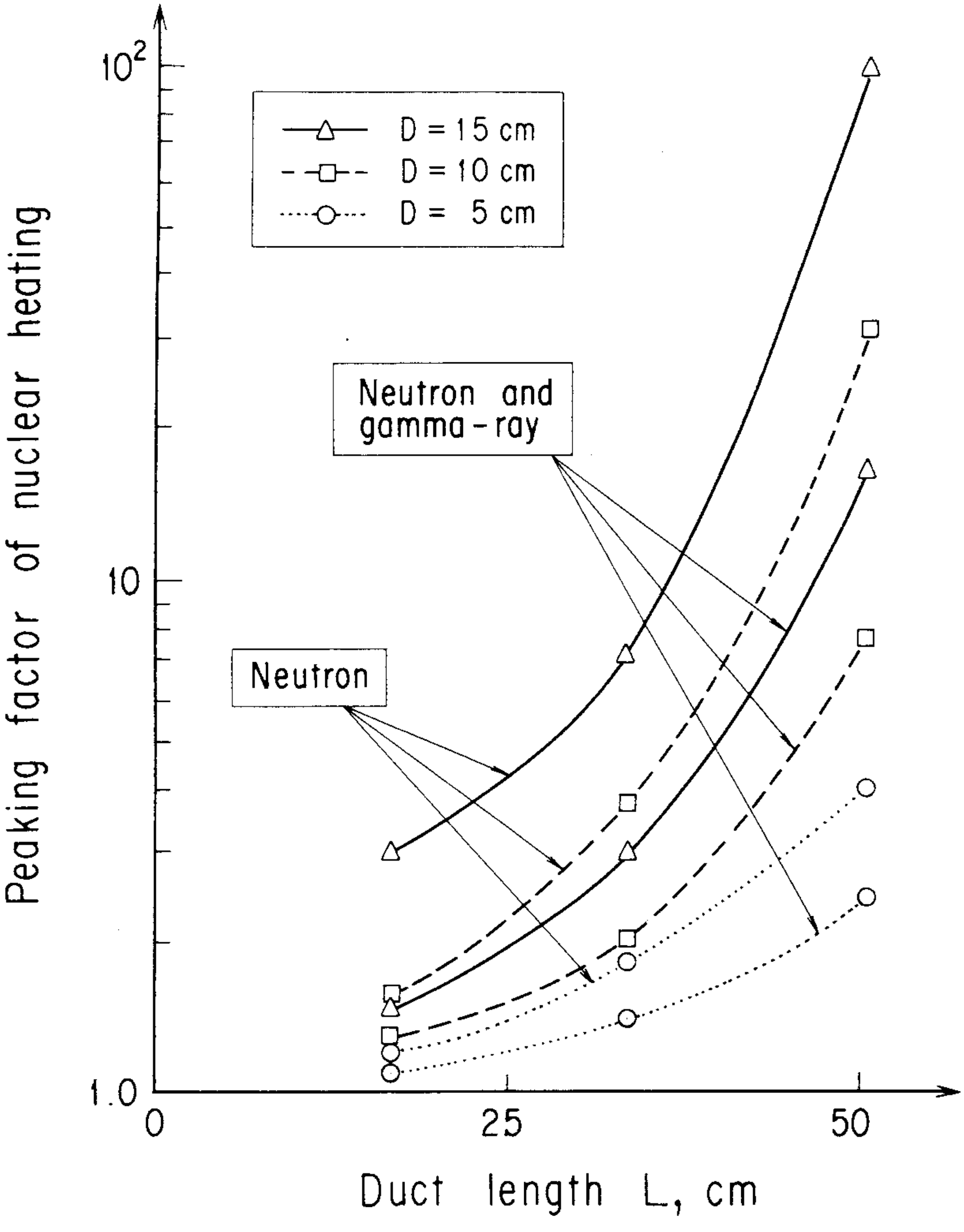

Fig. 7 Peaking factors of nuclear heating in stainless steel versus the duct length.

4. CONCLUSION

The peaking factors of nuclear heating in steel of the 80% SS - 20% H_2O shielding blanket behind void ducts of 50 cm length and 5, 10 and 15 cm diameter are obtained to be 2.3, 7.9 and 17.5, respectively. Those peaking factors for nuclear heating due to neutrons only are larger by about 10 times.

ACNOWLEDGEMENTS

This work was performed as part of the design study of ITER conducted by the Department of ITER Project of JAERI which is under the leadership of Dr. S. Matsuda.

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