JAERI-Tech
95-032

FEASIBILITY STUDY OF FIRST WALL ELECTRICAL CONNECTOR

May 1995

Kazunori KITAMURA, Hideyuki TAKATSU
Kouichi KOIZUMI and Toshihide TSUNEMATSU

日本原子力研究所
Japan Atomic Energy Research Institute

本レポートは，日本原子力研究所が不定期に公刊している研究報告書です。
入手の問合わせは，日本原子力研究所技術情報部情報資料課（〒319－11 茨城県那珂郡東海村）あて，お申し越しください。なお，このほかに財団法人原子力弘済会資料センター（〒319－11 茨城県那珂郡東海村日本原子力研究所内）で複写による実費頒布をおこなっております。

This report is issued irregularly.
Inquiries about availability of the reports should be addressed to Information Division, Department of Technical Information, Japan Atomic Energy Research Institute, Tokai-mura, Naka-gun, Ibaraki-ken 319-11, Japan.

編集兼発行　日本原子力研究所
印　　刷　日立高速印刷株式会社

JAERI-Tech 95-032

Feasibility Study of First Wall Electrical Connector

Kazunori KITAMURA, Hideyuki TAKATSU
Kouichi KOIZUMI and Toshihide TSUNEMATSU

Department of ITER Project
Naka Fusion Research Establishment
Japan Atomic Energy Research Institute
Naka-machi, Naka-gun, Ibaraki-ken

(Received April 25, 1995)

A feasibility study of first wall electrical connector concept has been performed to mitigate plasma disruption effect of electromagnetic force on the blanket structure. A multi-layered thin copper plate was applied to the connector structure, which was installed between adjacent first walls with keys and bolts. An optimization on the connector mechanical stiffness was performed to withstand the large electromagnetic forces at the plasma disruption and to absorb the module displacement between adjacent blanket structures due to thermal expansion of the modular blanket. As the results, a possible structural solution of the first wall electrical connector concept has been developed, which seems feasible in the views of mechanical integrity and fabricability, however, further detailed study on the connector feasibility is required.

Keywords: Multi-layered Thin Plates, DSCu-Copper Alloy, First Wall Electrical Connector, Modular Blanket Structure, Plasma Disruption.

第一壁電気接続構造の実用性研究

日本原子力研究所那珂研究所ITER開発室
喜多村和憲・高津　和幸・小泉　興一・常松　俊秀

(1995年4月25日受理)

核融合炉ブランケットに作用するプラズマ崩壊時の電磁力低減対策として，第一壁を電気接続する構造概念の実用性について検討した。適用した構造概念は，電気接続部を銅合金からなる薄板多層板で構成し隣接する第一壁間にボルトとキーで固定するとともに，ボルトおよびキー部を除熱の観点からロー接合する構造である。検討は電気接続部のプラズマ熱負荷，ジュール発熱に関する熱的検討，強大な電磁力に耐える機械的剛性およびブランケット匡体の熱膨張吸収のための柔軟性等を検討し，上記問題点を満足する電気接続部構造の最適設計領域を求めた。又，設計可能領域を満たす薄板多層板の第一壁電気接続構造の形状寸法を提案した。その結果，熱的，機械強度的および製作的に満足する構造であるも，設計可能領域が狭く，ブランケット匡体の製作精度の信頼性を考慮すると，今後さらに詳細な最適化検討が必要である。

那珂研究所：〒311-01　茨城県那珂郡那珂町向山801-1

Contents

1. Introduction 1
2. Critical Issues on First Wall Electrical Connector 1
3. Assessments of Critical Issues 2
3.1 Temperature Rises of the Connector 2
3.2 Mechanical Strength of the Connector 3
3.3 Optimization of Mechanical Stiffness of Connector 4
3.4 Stress Evaluation of the Connector 4
3.5 Consideration on One-turn Electrical Resistance 5
4. Proposal of F/W Electrical Connector Configuration 5
5. Concluding Remarks 6
References 7

目　　次

1. 序　　言 1
2. 第一壁電気接続の問題点 1
3. 第一壁電気接続構造の健全性評価 2
3. 1 電気接続構造の温度上昇 2
3. 2 電気接続構造の機械的強度評価 3
3. 3 電気接続構造の剛性の最適化 4
3. 4 電気接続構造の応力評価 4
3. 5 炉内構造物の一周電気抵抗 5
4. 第一壁電気接続構造の提案 5
5. 結　　言 6
参考文献 7

1. Introduction

A modular-type blanket structure has been proposed for use as a reference design for its relatively easy maintenance and structural reliability in the ITER-EDA(Engineering Design Activity of the International Thermonuclear Experimental Reactor) [1] . The blanket structure is composed of a box-type shield block welded to a back plate, whose configuration is formed from cylindrical and thick shell in the toroidal direction. A first wall and limiter plates are installed in the front side to protect the blanket from plasma high heat flux of 0.5 MW/m^2 at normal operation and large heat deposition at plasma disruption. The modular blanket is arranged separately from the adjacent module with the gap of 20 mm in both the toroidal and poloidal directions, for absorption of the thermal expansion of the first wall and for easy maintenance. The modular blanket structure is shown in Figs.1 and 2.

The large electromagnetic forces are induced on the first wall, limiter plate and shield box structures, by the interaction effect between toroidal and poloidal magnetic fields and eddy current at plasma disruption. Especially, a support rib of the connection part between the box structure and back plate seems to be one of critical regions on the mechanical integrity for its stiffness discontinuity.

An electrical connection between the adjacent first walls has been proposed, as the back-up concept to reduce the electromagnetic forces induced on the blanket structure, especially on the side walls of the blanket box structures.

Then, feasibility study of the first wall electrical connector has been conducted including thermally and mechanically simple analyses and conceptual development of the connector configuration.

2. Critical issues on first wall electrical connector

In the shield blanket structure separated from the adjacent ones, saddle-type electromagnetic force acting on the box structure is estimated to be ~10 MN/m, and may become a significant problem against keeping its mechanical integrity. On the other hand, the electromagnetic force in the blanket connected electrically at the first wall and the back plates is expected to tremendously decrease.

On consideration of the electrical connector structure between the blanket modules, however, following issues must be solved.

(1) Temperature rises of the connector by joule heating at plasma disruption, and by plasma heat loads including surface heat flux and nuclear heating.

(2) Thermal bending stress on the connector due to toroidal thermal expansion of front part of box structure.

(3) Membrane and bending stresses of the connector due to electromagnetic forces at plasma disruption.

1. Introduction

A modular-type blanket structure has been proposed for use as a reference design for its relatively easy maintenance and structural reliability in the ITER-EDA(Engineering Design Activity of the International Thermonuclear Experimental Reactor) [1] . The blanket structure is composed of a box-type shield block welded to a back plate, whose configuration is formed from cylindrical and thick shell in the toroidal direction. A first wall and limiter plates are installed in the front side to protect the blanket from plasma high heat flux of 0.5 MW/m^2 at normal operation and large heat deposition at plasma disruption. The modular blanket is arranged separately from the adjacent module with the gap of 20 mm in both the toroidal and poloidal directions, for absorption of the thermal expansion of the first wall and for easy maintenance. The modular blanket structure is shown in Figs.1 and 2.

The large electromagnetic forces are induced on the first wall, limiter plate and shield box structures, by the interaction effect between toroidal and poloidal magnetic fields and eddy current at plasma disruption. Especially, a support rib of the connection part between the box structure and back plate seems to be one of critical regions on the mechanical integrity for its stiffness discontinuity.

An electrical connection between the adjacent first walls has been proposed, as the back-up concept to reduce the electromagnetic forces induced on the blanket structure, especially on the side walls of the blanket box structures.

Then, feasibility study of the first wall electrical connector has been conducted including thermally and mechanically simple analyses and conceptual development of the connector configuration.

2. Critical issues on first wall electrical connector

In the shield blanket structure separated from the adjacent ones, saddle-type electromagnetic force acting on the box structure is estimated to be ~10 MN/m, and may become a significant problem against keeping its mechanical integrity. On the other hand, the electromagnetic force in the blanket connected electrically at the first wall and the back plates is expected to tremendously decrease.

On consideration of the electrical connector structure between the blanket modules, however, following issues must be solved.

(1) Temperature rises of the connector by joule heating at plasma disruption, and by plasma heat loads including surface heat flux and nuclear heating.

(2) Thermal bending stress on the connector due to toroidal thermal expansion of front part of box structure.

(3) Membrane and bending stresses of the connector due to electromagnetic forces at plasma disruption.

(4) One-turn electrical resistance of torus blanket structures with electrical connectors.

(5) Simple and reliable connector structure compatible with full remote maitenance.

Assessments concerning the above issues were performed to investigate the connector feasibility and to optimize the connector configuration.

3. Assessments of critical issues

The critical issues mentioned above were assessed on temperature rise and mechanical strength of the electrical connector by simple analyses.

3.1 Temperature rises of the connector

(1) Temp. rise due to joule heating

Temperature rise of the connector due to joule heating at plasma disruption is given by the following equation.

$$\Delta T = (\tau \rho / 2 C_p \gamma)(I_o/t)^2 \qquad (3.1)$$

where, τ :plasma decay time (=10-400 msec)

ρ :electrical resistivity (=1.68x10^{-8} Ωm for copper alloy)

C_p:specific heat (=386 J/kg℃)

γ :specific weight (=8960 kg/m^3)

I_o:eddy current on connector (=1.5-0.6 MA/m) [2]

t:total thickness of connector (m)

Temperature rise by joule heating, ΔT, is shown in Fig.3 as a function of total thickness of the copper connector.

(2) Temp.rise due to plasma heat loads

Temperature rise of the connector due to plasma heat loads is obtained as follows.

$$\Delta T = q_o D^2/(4 \lambda t) + \pi^2 D^2 q_n/(32 \lambda) \qquad (3.2)$$

where, q_o:plasma surface heat flux (=0.5 MW/m^2)

q_n:nuclear heating (=23 MW/m^3 for copper alloy)

D:gap distance between adjacent blankets (= 20 mm)

λ :thermal conductivity (=390 W/m℃)

t:total thickness of connector (m)

Temperature of the connector is estimated in Fig.4, in addition of connector temp. rise ΔT to maximum first wall temperature of 290 ℃.

The temperature rises of the connector are reduced with the increase of the total thickness of the connector. From the results shown in Figs.3 and 4, reasonable thickness of the connector is considered to be beyond 3-4 mm for temperature rise of the connector.

(4) One-turn electrical resistance of torus blanket structures with electrical connectors.

(5) Simple and reliable connector structure compatible with full remote maitenance.

Assessments concerning the above issues were performed to investigate the connector feasibility and to optimize the connector configuration.

3. Assessments of critical issues

The critical issues mentioned above were assessed on temperature rise and mechanical strength of the electrical connector by simple analyses.

3.1 Temperature rises of the connector

(1) Temp. rise due to joule heating

Temperature rise of the connector due to joule heating at plasma disruption is given by the following equation.

$$\Delta T = (\tau \rho / 2 C_p \gamma)(I_o/t)^2 \qquad (3.1)$$

where, τ :plasma decay time (=10-400 msec)

ρ :electrical resistivity (=1.68x10^{-8} Ωm for copper alloy)

C_p:specific heat (=386 J/kg℃)

γ :specific weight (=8960 kg/m^3)

I_o:eddy current on connector (=1.5-0.6 MA/m) [2]

t:total thickness of connector (m)

Temperature rise by joule heating, ΔT, is shown in Fig.3 as a function of total thickness of the copper connector.

(2) Temp.rise due to plasma heat loads

Temperature rise of the connector due to plasma heat loads is obtained as follows.

$$\Delta T = q_o D^2/(4 \lambda t) + \pi^2 D^2 q_n/(32 \lambda) \qquad (3.2)$$

where, q_o:plasma surface heat flux (=0.5 MW/m^2)

q_n:nuclear heating (=23 MW/m^3 for copper alloy)

D:gap distance between adjacent blankets (= 20 mm)

λ :thermal conductivity (=390 W/m℃)

t:total thickness of connector (m)

Temperature of the connector is estimated in Fig.4, in addition of connector temp. rise ΔT to maximum first wall temperature of 290 ℃.

The temperature rises of the connector are reduced with the increase of the total thickness of the connector. From the results shown in Figs.3 and 4, reasonable thickness of the connector is considered to be beyond 3-4 mm for temperature rise of the connector.

3.2 Mechanical strength of the connector

(1) Thermal bending stress due to toroidal thermal expansion of blanket module

The blanket structure has temperature gradient between plasma side surface and rear side, whose temperatures are estimated to be 290 ℃ at the plasma side surface of first wall and to be 150 ℃ at the rear side near cooling header, respectively. Because of this, the gap distance between adjacent blankets at the plasma side is narrowed down by toroidal thermal expansion of the blanket, and the connector installed between the blanket modules is consequently compressed in the toroidal direction.

Bending stress acting on the connector is expressed as follows.

$$\sigma_{bth} = 4Et\Delta L / [n(\pi^2-8)(D-t)^2] \qquad (3.3)$$

where, E:Young's modulus (=114 GPa for copper alloy)

t:total thickness of connector

ΔL:compressive displacement of the gap (=~1.53 mm for inboard blanket, ~2.35 mm for outboard one)

n:number of multi-layered thin plates

D:gap distance between adjacent blankets (= 20 mm)

The bending stress of the connector due to the compressive displacement of the gap is shown in Fig.4 as a function of total thickness of the connector and the number of the multi-layered plates. The stress decreases with the increase of the number of multi-layered plates and with the reduction of total thickness of the connector.

(2) Membrane stresses due to electromagnetic forces

An electrical connection between the adjacent first walls seems to lead to significant reduction of shearing electromagnetic forces on the side walls of the modular blanket box structure. The mechanical assessments of the connector due to the electromagnetic forces at the plasma disruption were performed with following condition for eddy current on the connector, which is estimated to be slightly larger for a conservative evaluation.

Eddy current : I_o~1.5 MA/m

Toroidal field : B_t~ 10 Tesla

Poloidal field : B_p~ 1 Tesla

A membrane shear stress on the connector by the interaction of the eddy current and toroidal magnetic field, and membrane stress due to the poloidal field are given by followings.

$$2\tau = I_o B_t (D-t)/t \qquad (3.4)$$

$$\sigma_o = I_o B_p (D-t)/2t \qquad (3.5)$$

where, t: total thickness of connector (m)

D: gap distance between adjacent blankets (= 20 mm)

The membrane stresses on the connector due to electromagnetic forces are depicted in Fig.5 as a function of the connector total thickness.

(3) Bending stress due to electromagnetic force

The electromagnetic force caused by the interaction of toroidal eddy current and poloidal field induces the bending stress on the connector.

It is given by the following equation.

$$\sigma_b = (1-\pi/4)(3n/2)I_e B_p\,[(D-t)/t]^2 \qquad (3.6)$$

The bending stress obtained from above-mentioned equation is shown in Fig.6 as functions of connector total thickness and number of multi-layers. Total primary stress of summation of membrane and bending stresses due to electromagnetic force is also indicated in Fig.7.

3.3 Optimization of mechanical stiffness of connector

The primary stresses decrease with the increase of connector thickness from Fig.7, but thermal bending stress decreases with the reduction of connector thickness and the increase of number of multi-layers from Fig.4. Then, total stress on the connector was obtained in Fig.8 by summation of the primary and thermal bending stresses to investigate the optimum connector thickness and to assess the mechanical integrity of the connector.

The total stress becomes minimum value of 640 MPa with t=3 mm and n=10, of 490 MPa with t=4 mm and n=20 and of 350 MPa with t=6 mm and n=50.

3.4 Stress evaluation of the connector

Stress evaluation was conducted based on the standard of ASME Sec. III [3]

Considering the stress due to electromagnetic forces, $(2\tau+\sigma_e)$ to be primary membrane stress, Pm, $(2\tau+\sigma_e+\sigma_b)$ to be primary stress, (Pm+Pb), and total stress, $(2\tau+\sigma_e+\sigma_b+\sigma_{bth})$, to be primary and secondary stress, (PL+Pb+Q), these stresses have to be below the following stress limits.

$$2\tau+\sigma_e < Sm \qquad (3.7)$$

$$2\tau+\sigma_e+\sigma_b < 1.5Sm \qquad (3.8)$$

$$2\tau+\sigma_e+\sigma_b+\sigma_{bth} < 3Sm \qquad (3.9)$$

where, Sm means design stress limit of the material, which is obtained from the comparison of ultimate and 0.2% proof strengths.

Figure 9 shows mechanical strengths and design stress limit of the copper alloy(DSCu) as a function of service temperatures [4] . Sm value at the connector service temperature of ~300 ℃ becomes 120 MPa. Therefore, total thickness of the connector must be beyond 2.5 mm to satisfy the equation (3.7), and must be beyond 2.1 mm at n=1, 3.6 mm at n=10, and 6 mm at n=50 to satisfy the equation (3.8). Then, optimim connector configuration leads to have the total thickness of 6 mm and number of multi-layers of 50. However, primary and secondary stresses of 350 MPa with t=6 mm and n=50 are barely within the allowable stress limit of 360 MPa. Therefore, mechanical strength of the electrical connector is considered to be marginal against allowable limit of the material.

3.5 Consideration on one-turn electrical resistance

A one-turn electrical resistance of torus structures including vacuum vessel and blanket structure with F/W electrical connectors is estimated to be ~4.9 $\mu\Omega$ for 40 mm thick double walls SS316LN vacuum vessel and ~6.1 $\mu\Omega$ for 30 mm thick walls Inconel vessel [1] . On the other hand, the one-turn resistance of the torus structures without F/W electrical connectors is estimated to be ~8 and ~10 $\mu\Omega$ for above-mentioned SS316LN and Inconel vessels, respectively [6] .

The one-turn resistance of the torus structures required for plasma start up is said to be beyond 5~10 $\mu\Omega$. The one-turn resistance with F/W electrical connectors seems to be marginal in the view of the plasma start up, so that the lower limit of one-turn resistance of the torus structures needs to be studied in detail, according to the plasma start-up scenarios.

4. Proposal of F/W electrical connector configuration

A mechanical configuration of F/W electrical connector was considered on the basis of above-mentioned assessments on the critical issues of the connector. As the results, following concepts are drawn.

(1) The electrical connector has a multi-layered thin plates structure with a total thickness of ~6 mm and number of multi-layers of ~50, whose values are reasonable from the thermal and mechanical points of view.

(2) The thermal shielding structure with ~2 mm copper plate is installed in front of the electrical connector, which is insulated electrically at the center location, for protection of the multi-layered connector from the plasma heat loads.

(3) Key and bolt joints are employed between the connector plates and F/W side edges to withstand large electromagnetic forces on the connector, and they are brazed with relatively low-temperature melting braze material to enhance thermal conductance between keys and key grooves and between bolts and nuts.

(4) The connector configuration possible to access from the front side is

be beyond 2.1 mm at n=1, 3.6 mm at n=10, and 6 mm at n=50 to satisfy the equation (3.8). Then, optimim connector configuration leads to have the total thickness of 6 mm and number of multi-layers of 50. However, primary and secondary stresses of 350 MPa with t=6 mm and n=50 are barely within the allowable stress limit of 360 MPa. Therefore, mechanical strength of the electrical connector is considered to be marginal against allowable limit of the material.

3.5 Consideration on one-turn electrical resistance

A one-turn electrical resistance of torus structures including vacuum vessel and blanket structure with F/W electrical connectors is estimated to be ~4.9 μΩ for 40 mm thick double walls SS316LN vacuum vessel and ~6.1 μΩ for 30 mm thick walls Inconel vessel [1] . On the other hand, the one-turn resistance of the torus structures without F/W electrical connectors is estimated to be ~8 and ~10 μΩ for above-mentioned SS316LN and Inconel vessels, respectively [6] .

The one-turn resistance of the torus structures required for plasma start up is said to be beyond 5~10 μΩ. The one-turn resistance with F/W electrical connectors seems to be marginal in the view of the plasma start up, so that the lower limit of one-turn resistance of the torus structures needs to be studied in detail, according to the plasma start-up scenarios.

4. Proposal of F/W electrical connector configuration

A mechanical configuration of F/W electrical connector was considered on the basis of above-mentioned assessments on the critical issues of the connector. As the results, following concepts are drawn.

(1) The electrical connector has a multi-layered thin plates structure with a total thickness of ~6 mm and number of multi-layers of ~50, whose values are reasonable from the thermal and mechanical points of view.

(2) The thermal shielding structure with ~2 mm copper plate is installed in front of the electrical connector, which is insulated electrically at the center location, for protection of the multi-layered connector from the plasma heat loads.

(3) Key and bolt joints are employed between the connector plates and F/W side edges to withstand large electromagnetic forces on the connector, and they are brazed with relatively low-temperature melting braze material to enhance thermal conductance between keys and key grooves and between bolts and nuts.

(4) The connector configuration possible to access from the front side is

adopted for easy maintenance.

(5) DSCu with high mechanical strength and high thermal conductivity at ~300 ℃ is employed as a connector material.
(0.2% proof stress of 280 MPa and ultimate strength of 360 MPa at 300 ℃)

Electrical connector features proposed here are shown in Fig.10. A configuration, shown in Fig.10, is installed between the gap at the F/W side wall front surface. The fixture of the connector to the F/W front surface is conducted with bolts and keys, which are brazed with relatively low-temperature melting braze material to enhance thermal conductance between keys and key grooves and between bolts and nuts.

It is well-known such a multi-layered connector formed with 400-layered 0.03 mm thick copper sheets has been commercially applied to ~KA-class circuit breaker [5] .

5. Concluding remarks

A feasibility study of first wall electrical connector has been performed to mitigate plasma disruption effect of electromagnetic force on the blanket structure. A multi-layered thin copper plate was applied to the connector structure, which is installed between adjacent first walls with keys and bolts. From the study, following conclusions were drawn.

(1) A multi-layered thin plates structure, made of DSCu, has an effective feature as a first wall electrical connector configuration, which requires a flexible absorption of the blanket thermal expansion and mechanical integrity against the large electromagnetic forces.

(2) An optimum configuration of the connector leads to the total thickness of 6 mm and number of multi-layers of 50 from the thermal and mechanical points of view. However, more detailed optimization study on the connector configuration seems to be required in the future.

(3) A thermal shielding structure with ~2 mm copper plate is installed in front of the electrical connector, which is insulated electrically at the center location for protection of the multi-layered connector from the plasma heat loads.

(4) The connector configuration possible to access from the front side is adopted for relatively easy maintenance, where key and bolt joints are employed between the connector plates and F/W side edges to withstand large electromagnetic forces.

(5) The connector maintenance depends on the fabricability and assembling toler-

adopted for easy maintenance.

(5) DSCu with high mechanical strength and high thermal conductivity at ~300 ℃ is employed as a connector material.
(0.2% proof stress of 280 MPa and ultimate strength of 360 MPa at 300 ℃)

Electrical connector features proposed here are shown in Fig.10.
A configuration, shown in Fig.10, is installed between the gap at the F/W side wall front surface. The fixture of the connector to the F/W front surface is conducted with bolts and keys, which are brazed with relatively low-temperature melting braze material to enhance thermal conductance between keys and key grooves and between bolts and nuts.

It is well-known such a multi-layered connector formed with 400-layered 0.03 mm thick copper sheets has been commercially applied to ~KA-class circuit breaker [5] .

5. Concluding remarks

A feasibility study of first wall electrical connector has been performed to mitigate plasma disruption effect of electromagnetic force on the blanket structure. A multi-layered thin copper plate was applied to the connector structure, which is installed between adjacent first walls with keys and bolts.
From the study, following conclusions were drawn.

(1) A multi-layered thin plates structure, made of DSCu, has an effective feature as a first wall electrical connector configuration, which requires a flexible absorption of the blanket thermal expansion and mechanical integrity against the large electromagnetic forces.

(2) An optimum configuration of the connector leads to the total thickness of 6 mm and number of multi-layers of 50 from the thermal and mechanical points of view. However, more detailed optimization study on the connector configuration seems to be required in the future.

(3) A thermal shielding structure with ~2 mm copper plate is installed in front of the electrical connector, which is insulated electrically at the center location for protection of the multi-layered connector from the plasma heat loads.

(4) The connector configuration possible to access from the front side is adopted for relatively easy maintenance, where key and bolt joints are employed between the connector plates and F/W side edges to withstand large electromagnetic forces.

(5) The connector maintenance depends on the fabricability and assembling toler-

ance of the blanket modules, especially on the accuracy of the gap length between the adjacent first walls, so that it is required to assess in detail taking into account the manufacturing and assembling of the blanket structures.

References

[1] ITER Design Assessment Meeting, Oct.17-28, 1994, San Diego.
[2] I.Senda, Private Communication.
[3] ASME Boiler and Pressure Vessel Code, Sec.III.
[4] E.Zolti, Material Data for Predesign Analysis of In-vessel Components, Edition 2, pp44.
[5] M.Shibui, Private Communication.
[6] S.Nishio, Private Communication.

ance of the blanket modules, especially on the accuracy of the gap length between the adjacent first walls, so that it is required to assess in detail taking into account the manufacturing and assembling of the blanket structures.

References

[1] ITER Design Assessment Meeting, Oct.17-28, 1994, San Diego.
[2] I.Senda, Private Communication.
[3] ASME Boiler and Pressure Vessel Code, Sec.III.
[4] E.Zolti, Material Data for Predesign Analysis of In-vessel Components, Edition 2,pp44.
[5] M.Shibui, Private Communication.
[6] S.Nishio, Private Communication.

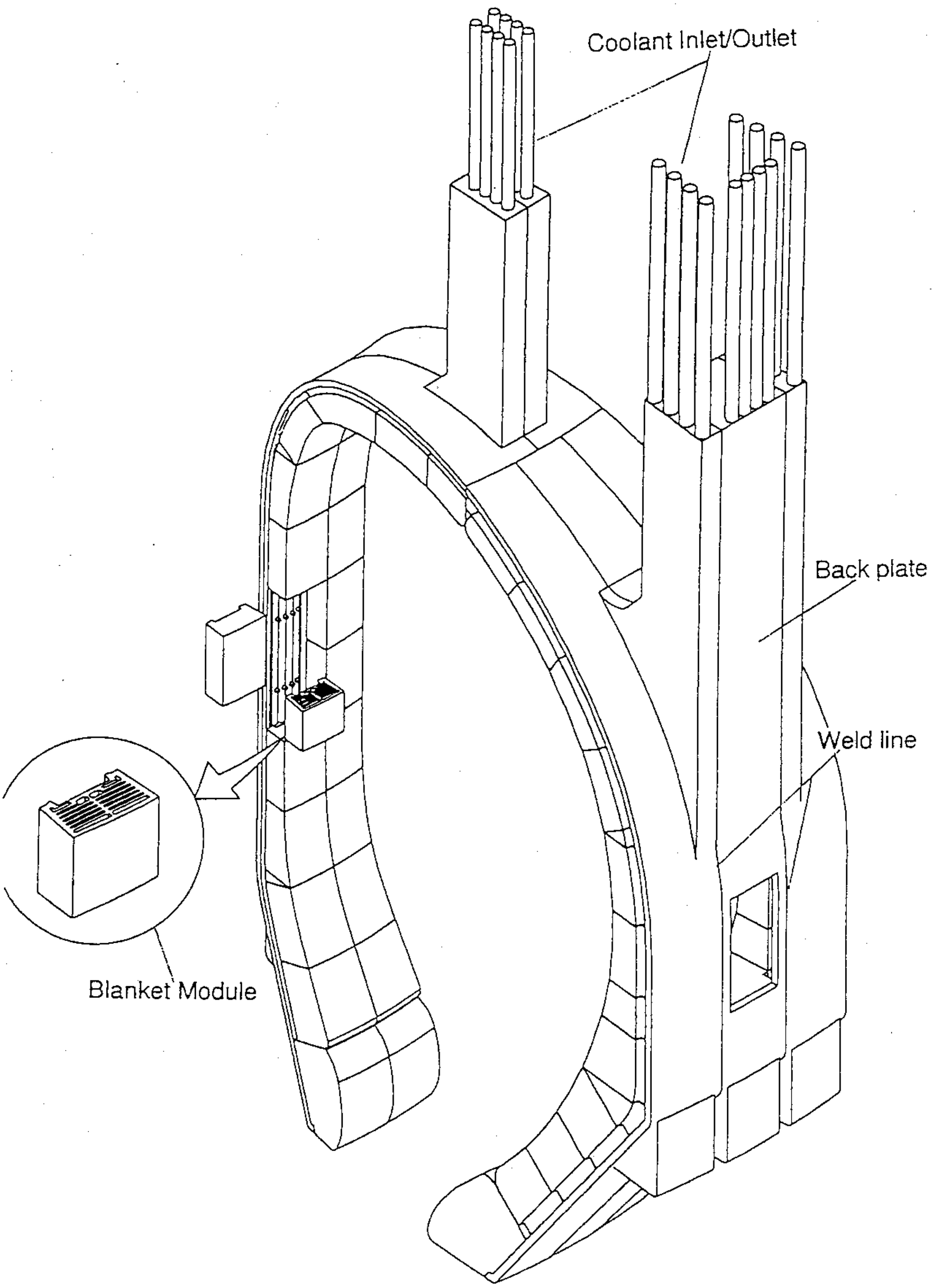


Fig.1 Mechanical Configuration of Modular Blanket Structures

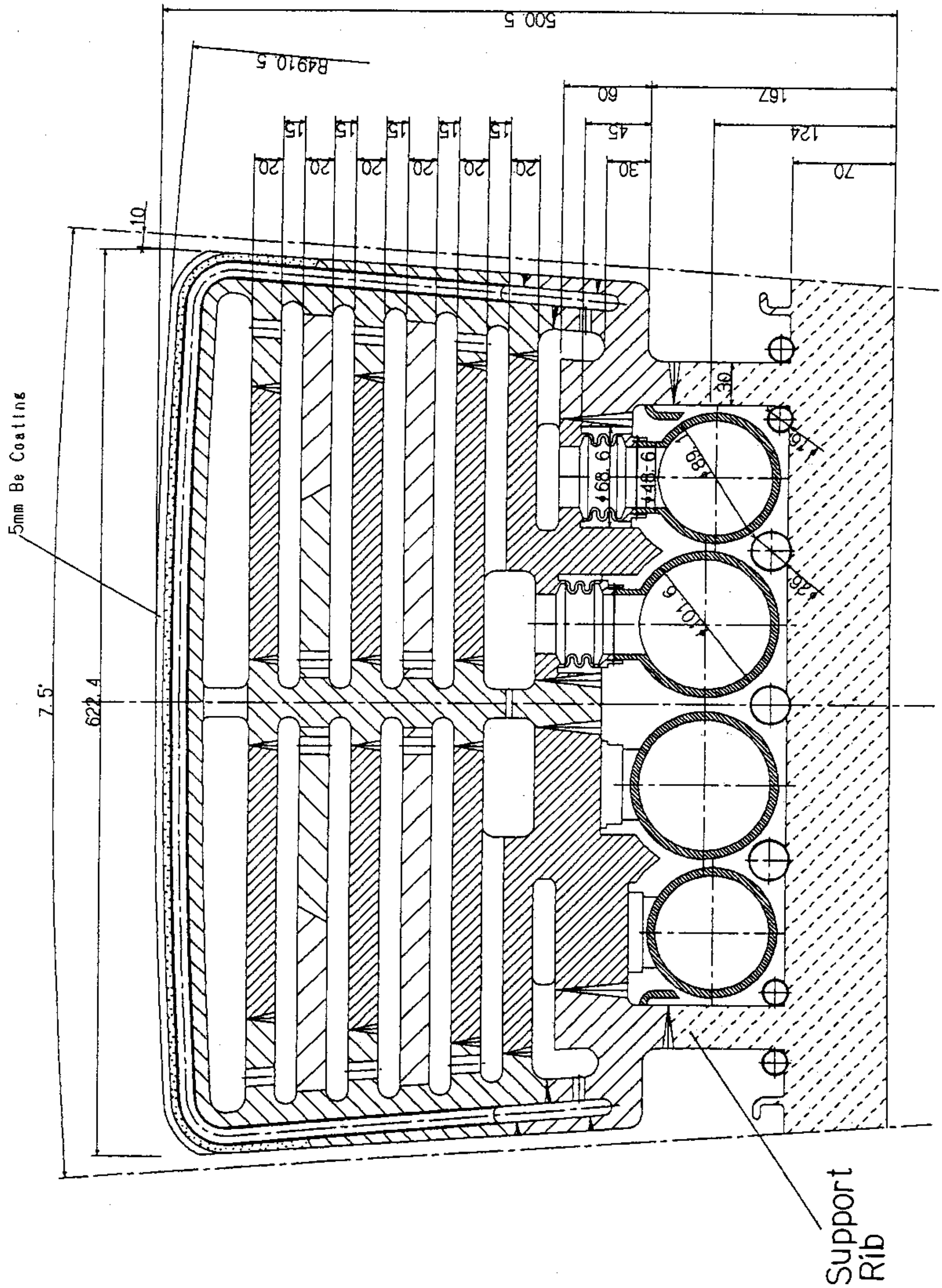


Fig.2 Module Type Shield Blanket Inboard Segment

14R50100HA250-06

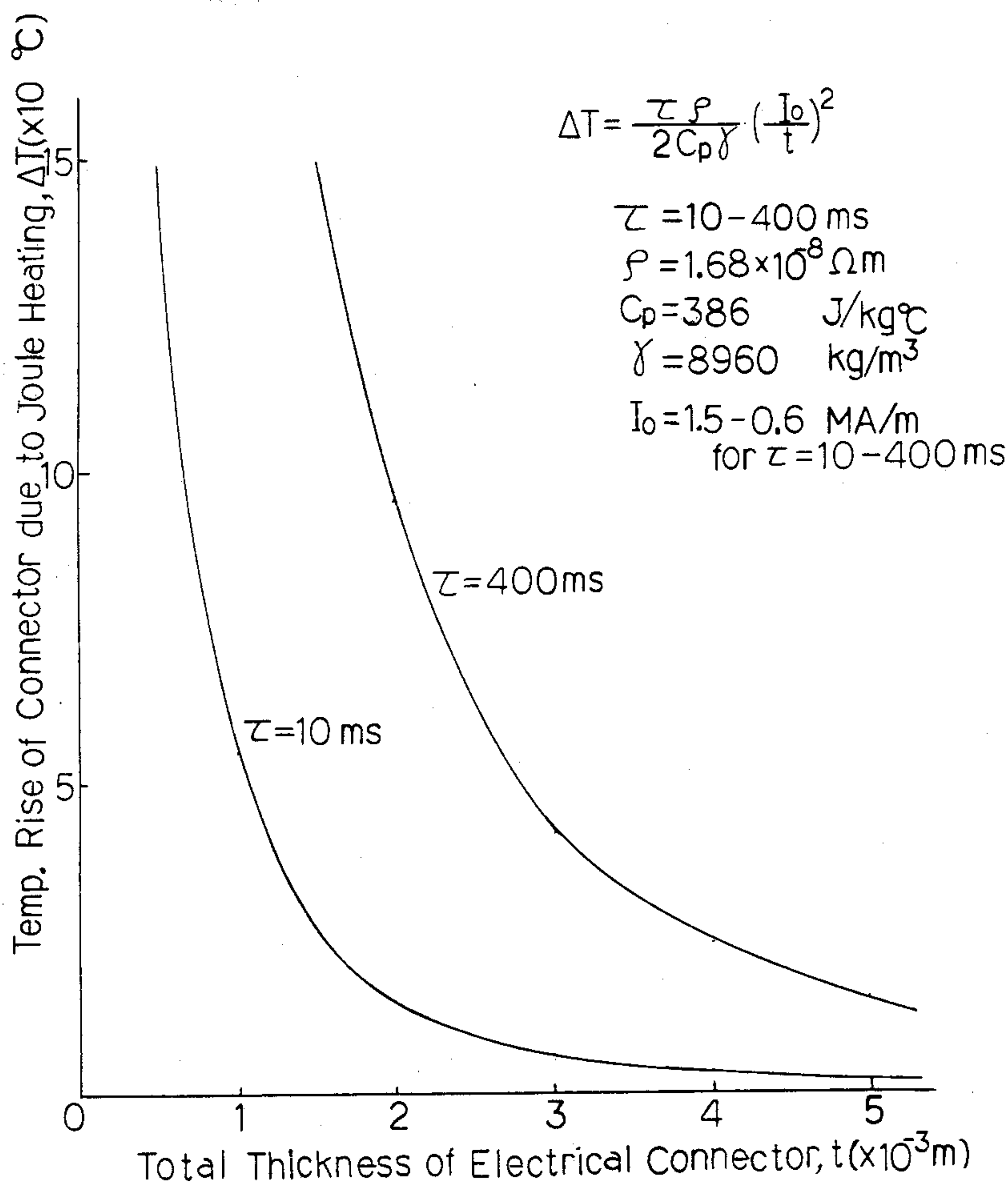


Fig.3 Temp. Rise of Connector due to Joule Heating

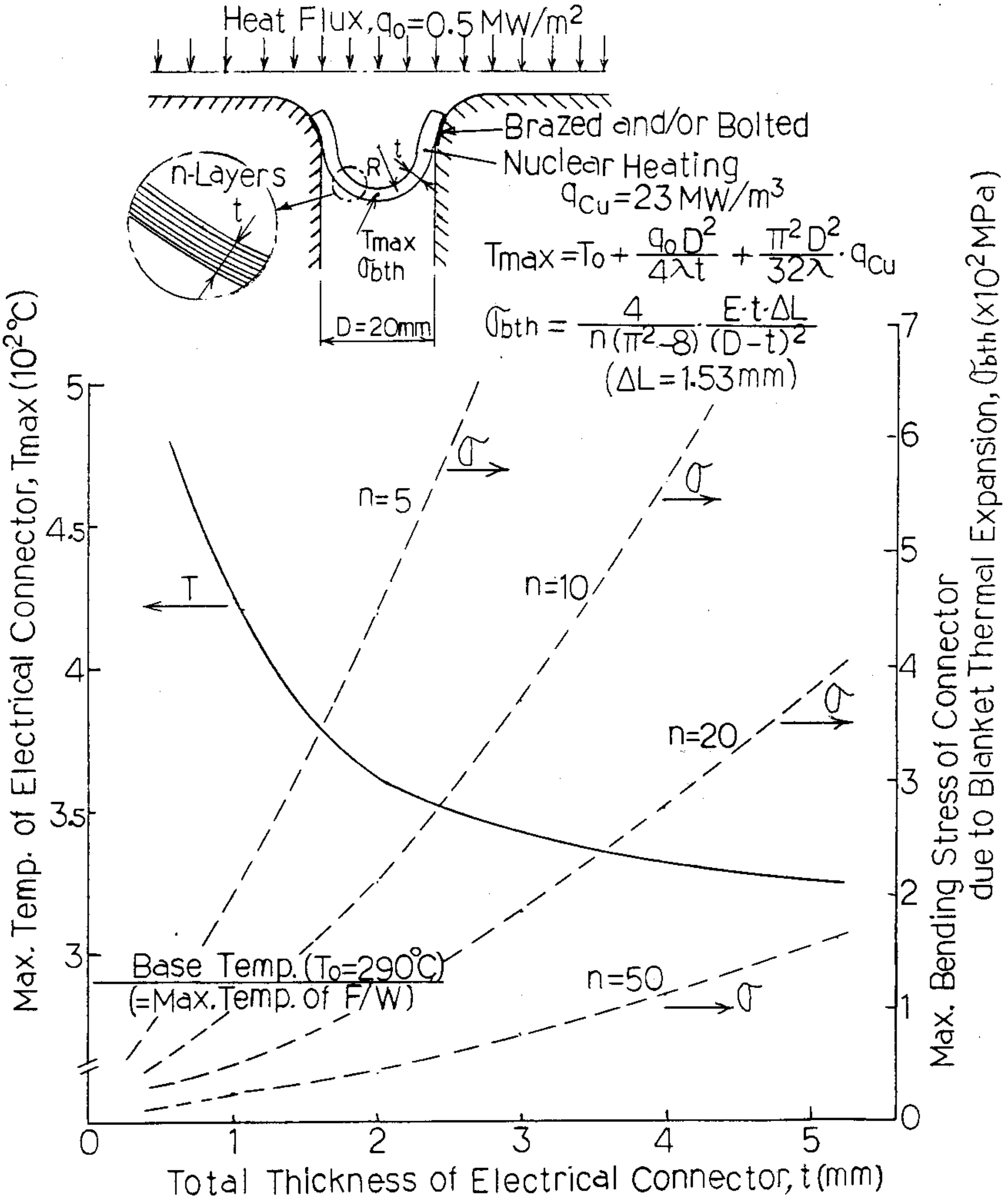
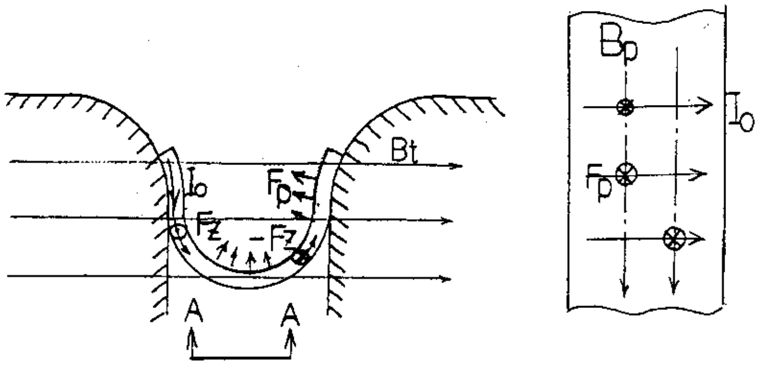


Fig.4 Temperature and Bending Stress of F/W Electrical Connector (Inboard)



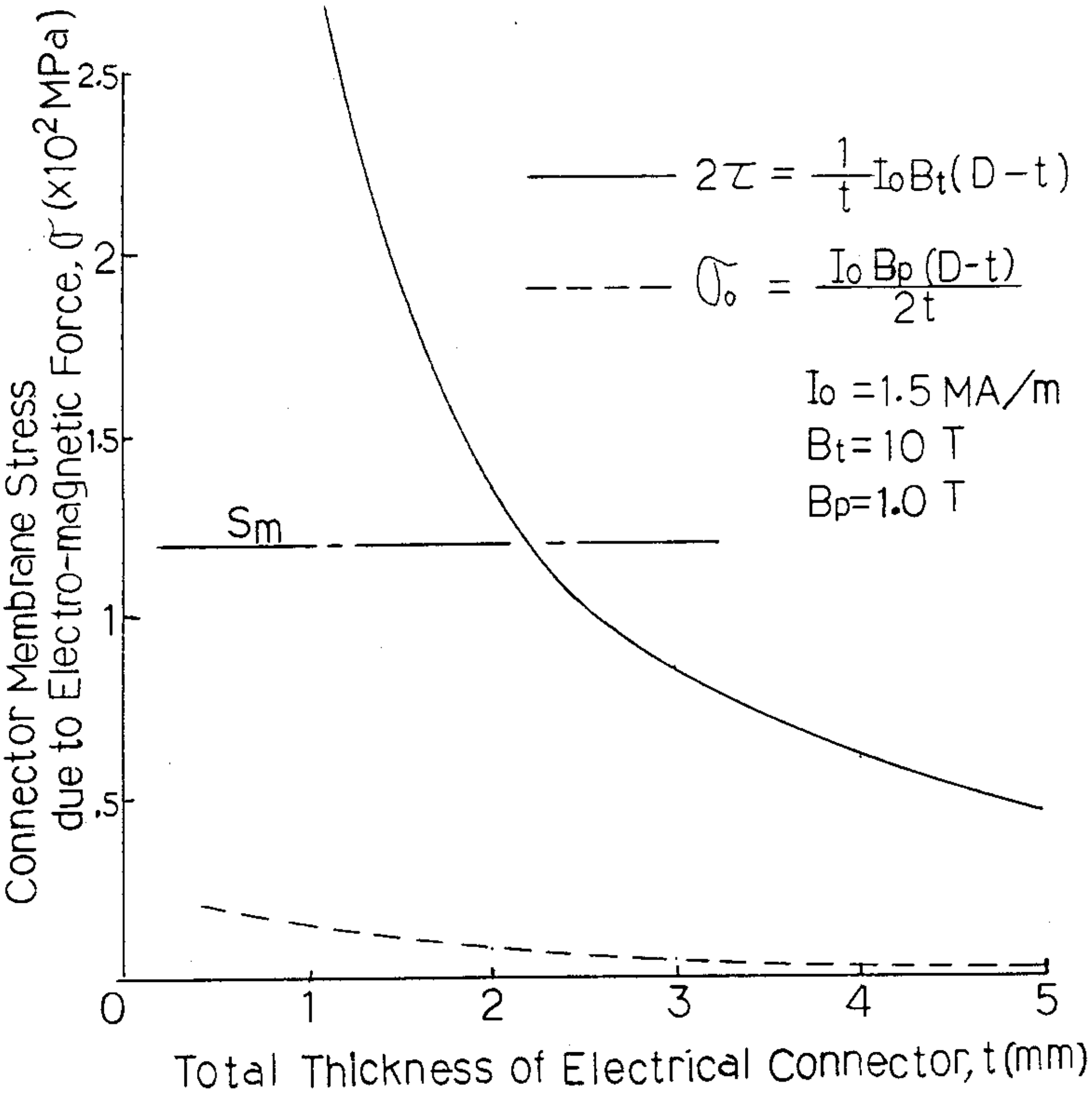


Fig.5 Connector Membrane Stress due to Electro − magnetic Force

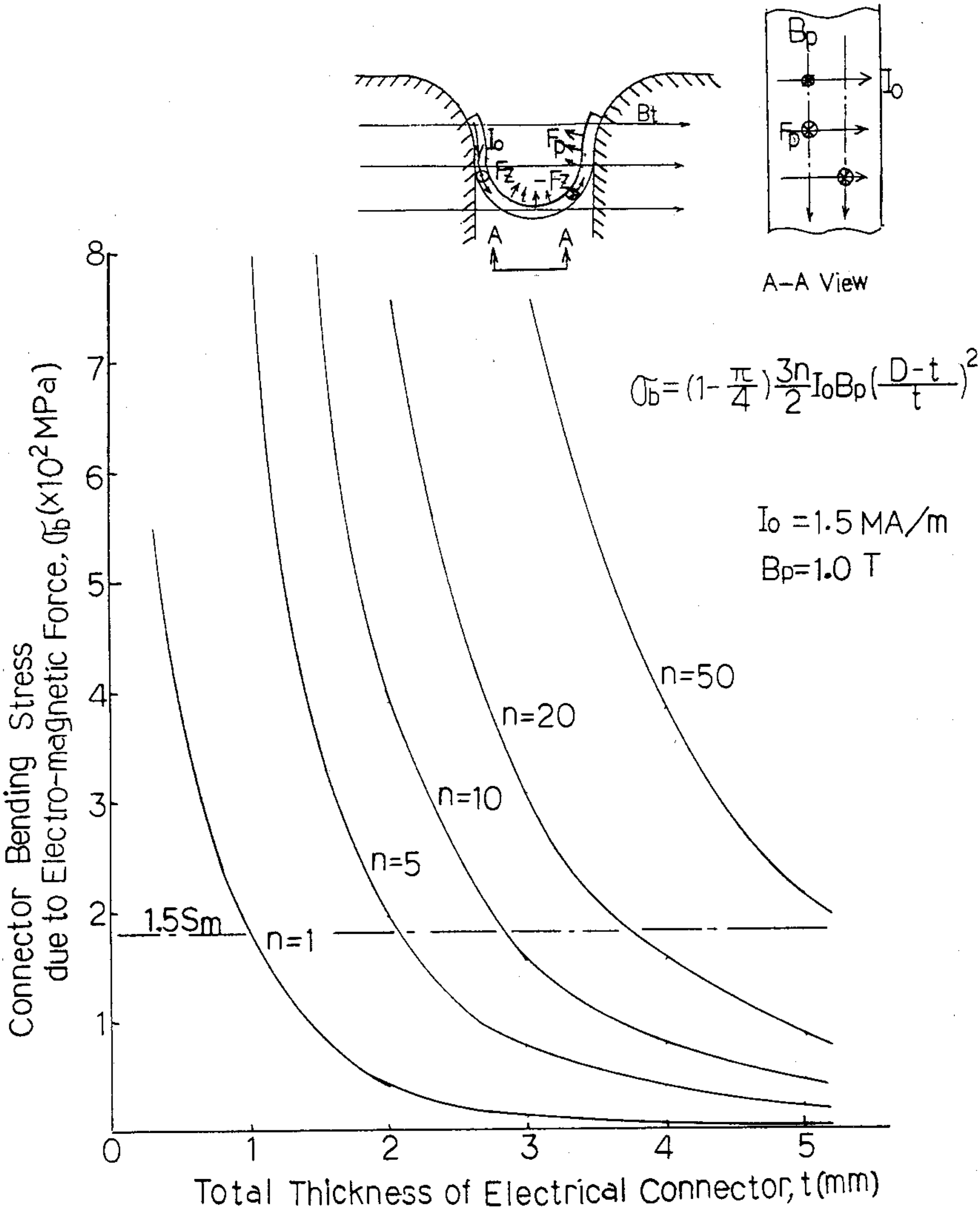


Fig.6 Connector Bending Stress due to Electro－magnetic Force

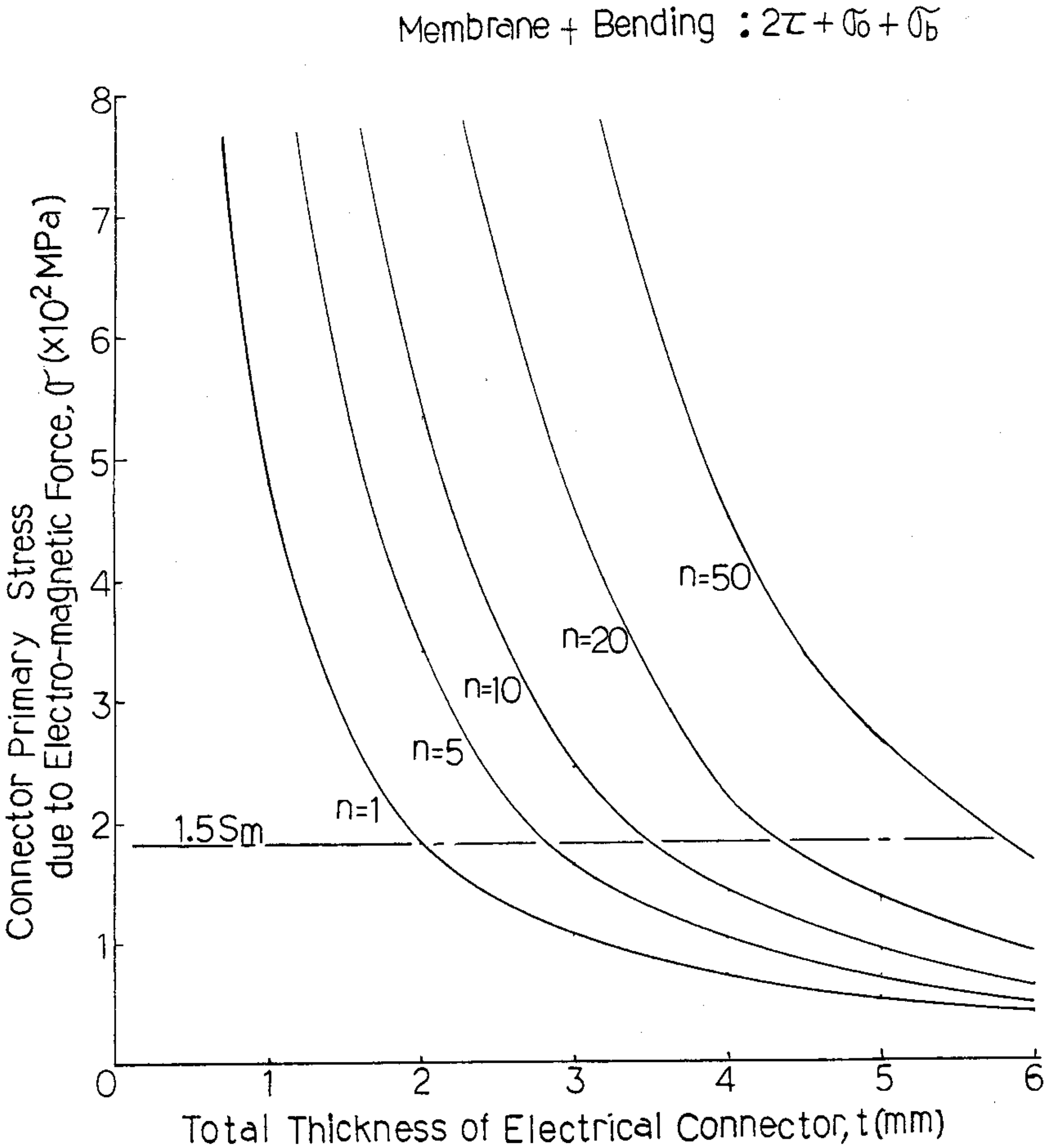


Fig.7 Connector Primary Stress due to Electro－magnetic Force

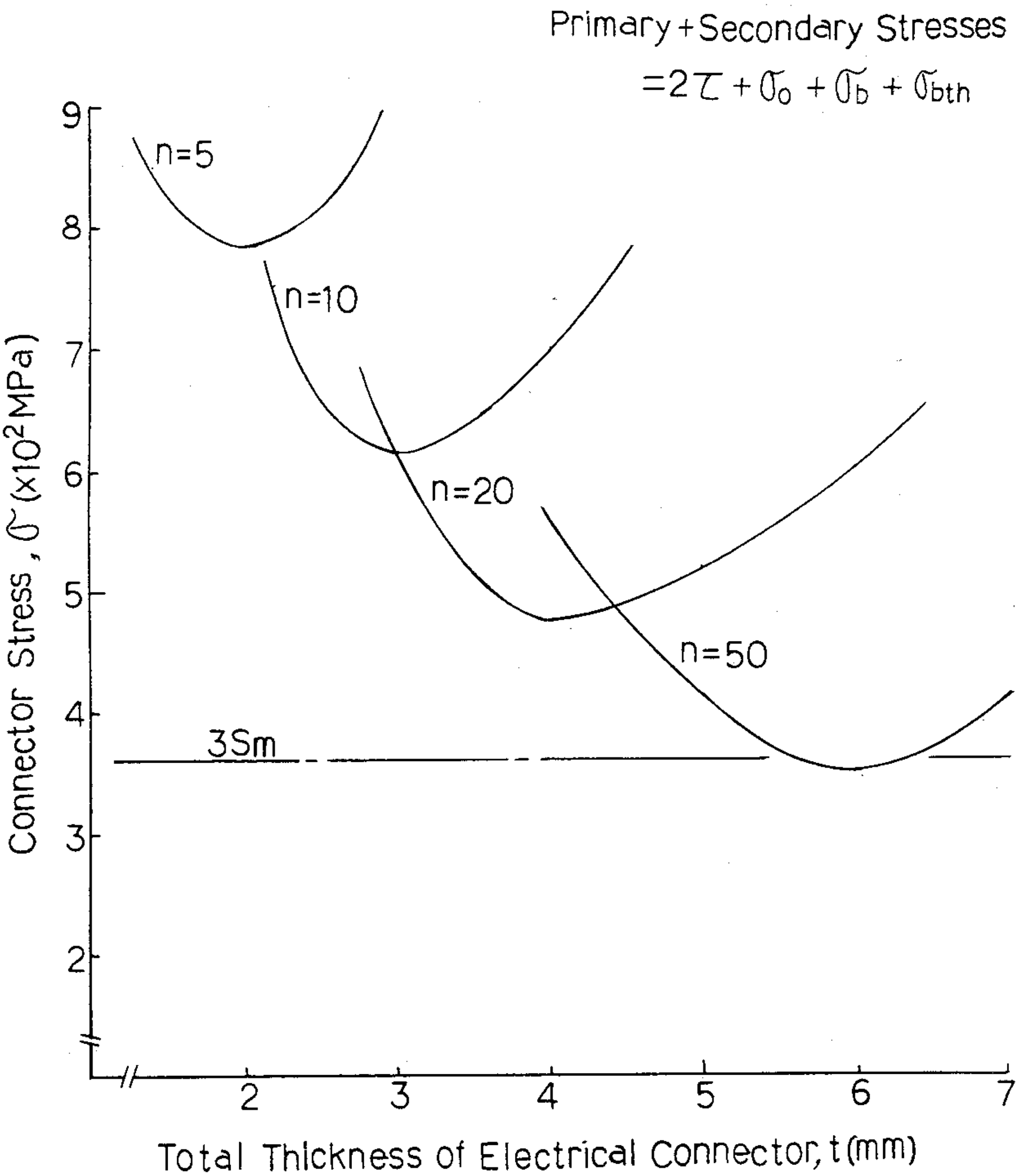


Fig.8 Total Connector Stress as a function of Connector Thickness

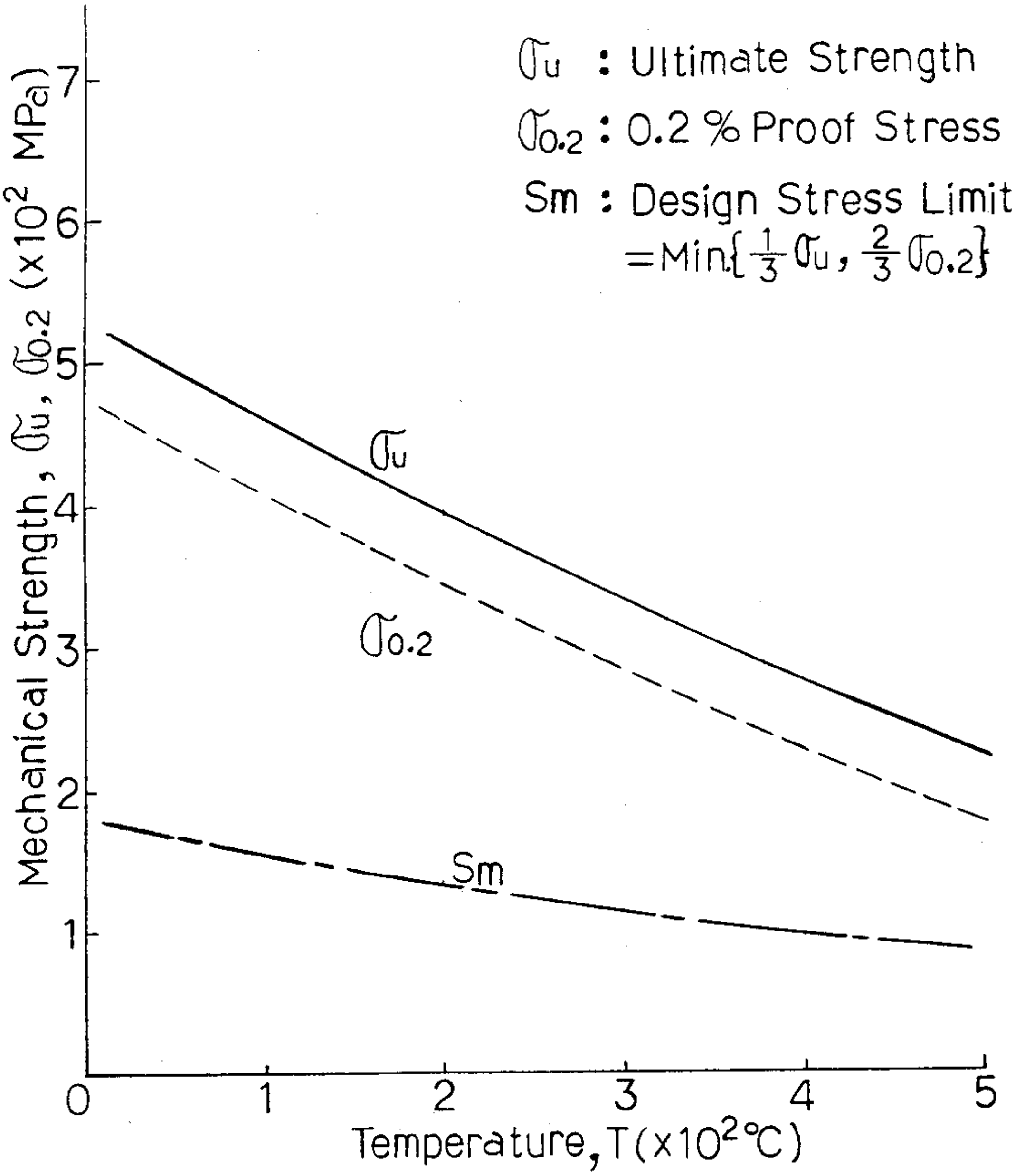


Fig.9 Mechanical Strength of Copper Alloy ($Cu-Al_2O_3$)

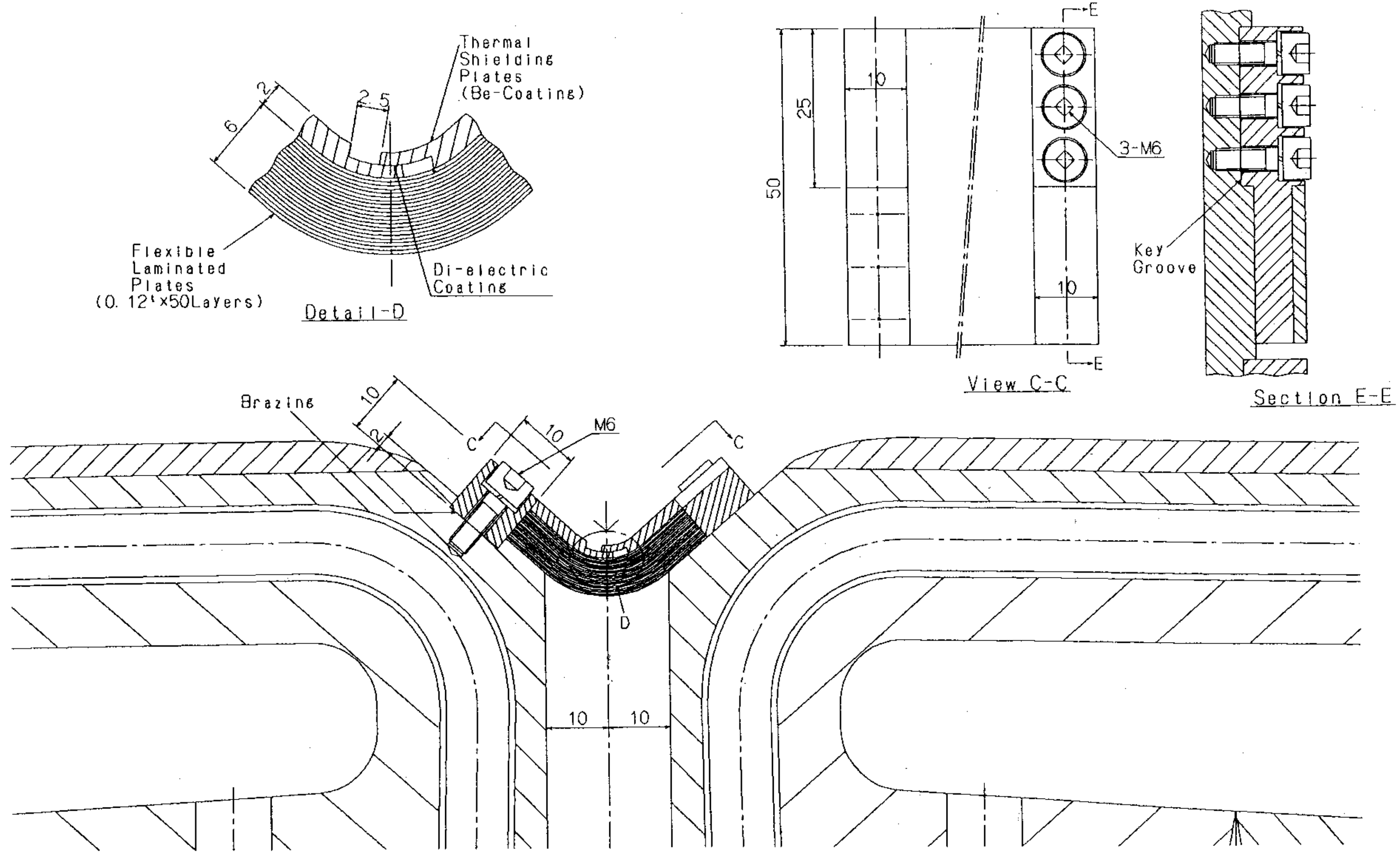


Fig.10 F/W Electrical Connectors Concept for Mitigating Plasma Disruption Effects

14R50100HA468-00