Canadian Fusion Fuels
Technology Project

ITER COOLING SYSTEM - ANALYSIS OF HEAT TRANSFER MEDIA, OPERATION AND SAFETY OF COOLING LOOP AND BLANKET DURING CONDITIONING AND BAKING - REVISION 1.0

CFFTP-G-9093
ITER-IL-NE-6-0-3
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ITER Cooling System
Analysis of Heat Transfer Media, Operation and Safety of Cooling Loop and Blanket During Conditioning and Baking.
Revision 1.0

O.K. Kveton CFFTP / ITER

5, November 1990

Contents

1 Introduction - Definition of the Problem

The present specification of the cooling system does not permit its operation with water above 150 C. However, there are operating regimes under which the first wall need to be heated to higher temperatures for the following reasons:

- **Conditioning at 250 C**
- **Bake out at 350 C**

Since most of the conditioning will occur during short shutdowns during which the superconductive coils keep the magnetic field in place, Helium discharge cleaning which is usually being used in such instances for previous machines, will not work. Also the Bakeout procedure, expected to be needed subsequent to contamination of the first wall with air or water, can be undertaken only through heating the wall to the desired temperature. Consequently it is assumed that for both above operations the entire first wall must be heated to the desired temperature. This temperature can not be supplied from the plasma side since the impurities present in the first wall will prevent the plasma from forming. Consequently the heat will have to be supplied from the blanket side of the first wall where the cooling system offers a readily available heat transport system. Unfortunately in order to use the cooling water for the above temperatures the cooling system would have to operate during the Conditioning and Bakeout at 37 and 164 Bar respectively. This is, at this stage of the design, undesirable from the safety analysis point of view [1] and consequently alternative heating methods are to be found.

It is projected that Conditioning (at 250 C) will be required once in one to three weeks at which time the operation can wait for a day for the process to be completed. Bakeout (at 350 C) will occur as often as once in four months and there appear to be no time limit for such operation. The normal operating condition of the Carbon-Fibre-Composite tiles is characterized by operating temperature 1000 C for conductive cooled parts and up to 1800 C for radiation cooled parts.
Several ITER personnel studied the Conditioning and Bakeout problem from different points of view. Estimation of energy consumption were done by Shatalov, Kuroda and Antipenkov. Depending on the degree of conservatism included in their calculations, the heat load is believed to be at the level of 10

to 20 MW. This review concentrates on reviewing the various heat transfer media, their properties and their impact on the operating procedures for the available blanket designs and on the design changes future iterations need to consider if the dual heat transport media concept is applied.

2 Alternative Solutions and Limitations

2.1 Alternative First Wall Compounds

In future first wall designs during the EDA phase the following alternative materials are being considered:

- **Beryllium layer**
- **Tungsten layer**

The above materials may have different and possibly lesser Conditioning and Bakeout requirements.

2.2 Alternative Heating Methods

Since there is no alternative treatment of the first wall other than by heating it to the desired temperature, the following media or methods are addressed:

1. **Electric heat**
2. **Water**
3. **Saturated Steam**
4. **Superheated Steam**
5. **Inert gas**
6. **Organic coolants**

Any design changes external to the blanket cartridge are assumed to be acceptable at this time since these are within the domain of routine engineering and conventional technology.

Table 1 - Heat Transfer Media Properties				
Medium	Condition	Spec. Heat [kJ/kg,°C]	Operating Press. [Bar]	m^3 expanded from $1m^3$
Water	250 C	4.19	37	457
Water	150 C	4.19	5	243
Sat. Steam	250 C	1702.20	37	36
Sat. Steam	150 C	2111.24	5	4
Steam	1 Bar	2.06	1.5	0.5
Helium	1 Bar	5.19	1.5	0.5
Air	1 Bar	1.01	1.5	0.5

2.2.1 Electric Heating

Electric heating is considered to be too complex and probably less reliable. However, such complexity has not yet been fully evaluated against the complexities associated with using inert gas or steam. Examining some designs such as Figure 2. Detail B for the international blanket or Figures 6 and 7 for the US blanket, there is limited space for attaching electric heaters at the back of the first wall between the breeding blanket modules and the back armour of the first wall. The use of electric heating would still necessitate draining of the cooling loop contents since the water remaining in the tubes would be heated almost to the first wall temperature. However, such blow-out could be done segment by segment with inert gas without major risks. The cooling system would not need to be perfectly empty and the procedure would take much less time to accomplish than the procedure for inert gas or superheated steam heating. The potentially most significant draw-back of this method is seen to be in the addition of electric heaters near to the back of the first wall armour which will restrict heat flux from the front face of the blanket to the first wall coolant if this is a critical design consideration. Mainly the conductively cooled tiles if the heat path between the first and second row of piping is important. The reliability of the thousands of heating loops in the radiation harsh environment with the problems with cable penetrations may provide a severe challenge for the design and make the entire structure less reliable. This method is mentioned here for completeness with a little hope that the next EDA phase will find it attractive.

2.2.2 Water as heat transfer medium

Water heating can not be considered as long as the ITER specification does not allow it to be used above 150 C.

2.2.3 Saturated steam as heat transfer medium

From Table 1 can be seen that saturated steam has the best heat transfer properties of the fluids considered. Unfortunately it can not be used with the present system since the condensate can not be reliably removed from the U-tube shaped internal cooling loop where the condensate would form and flow to the lowest point. The system as it is designed now would, when attempted to be operated with saturated steam, experience water hammers or at least "cavitation", both undesirable and uncontrollable situations which would result more likely in coolant or blanket failure than if steady state high pressure water were used. With the delicate structure as it is known today **any chance for water hammer most be avoided at any cost.** The operating pressure for saturated steam at the desired temperatures would be similar to that necessitated by the water operating requirements. However, there would be a drastic difference in the consequence of failure as illustrated in the following example:
If an accident occurred at the conditioning stage, significant amount of steam would be released if hot water method were used and the released amount would be significantly larger than if saturated steam were used. It is calculated that in the event of an accidental release, the 250 C water contains sufficient heat to evaporate 31 % of its weight when expanded to atmospheric conditions. With 845 kg of water per cubic meter, 262 kg of steam could evaporate at atmospheric pressure. This represents an additional volume of 458 m^3. If this amount is restricted by the building walls, the building pressure will increase accordingly. If saturated steam were used, each m^3 of steam at 250°C would contain approximately only 38 m^3 of steam. It can be seen that saturated steam would be substantially safer than water. Theoretically there are solutions to the saturated steam method which are discussed as follows for the EC solid breeder blanket or other similar alternatives:
Examining Figure 1 Detail C it is noticed that the ends of the multiple tubes cooling the first wall are bent upwards to join with the common horizontal

header. It would be relatively easy to slightly change the geometry for all first wall tubes to be sloped to the horizontal header. Further, at the lowest point of the horizontal header a "dynamic steam trap" could be installed with a relatively small diameter discharge line to lead to a condensate collection system operating at slightly above 1 Bar. The saturated steam method would consist of heating the cooling water to approximately 150 C and subsequently using the combination of depressurizing at the collection header side, followed by inert gas or possibly steam chase emptying the internal cooling loop. Steam would be than added at both ends of the cooling loop and condensate as it forms would be discharged at the steam trap. The steam pressure would be gradually increased to the saturation pressure at which the desired temperatures occur. The problem with this method is that the dynamic steam trap, although a very simple and in operation reliable device, is nevertheless a moving part known to require extensive attention during initial and subsequent operations. Each trap collects dirt and in the initial commissioning phase will stop working at some time. These traps are equipped with strainers which need to be "blown down" periodically. Such operation is unthinkable at the designated position of the trap. A refinement of the design would be to simply remove this trap and leave only a carefully sized and pressure drop tested open drain line which, during the heating period, will eject two phase flow of condensate and steam. The flow through it would be controlled through a valve located outside the blanket module. Such loop for saturated steam is indicated in Figure 11. The above method could be considered in the event of a single blanket module. Unfortunately the ITER driver blanket may have as many as 100 modules where the coolant would have to be replaced and monitored individually. In that context the saturated steam method is not feasible.

2.2.4 Superheated Steam or Inert Gas

The advantage of using superheated steam or inert gas is identical in that it can be used at close to atmospheric conditions at which point a failure of the system would not result in building overpressure. This would be the ultimately safest method of operation although the transfer from cooling water to superheated steam would be noticeably more intricate than using inert gas. However, the use of inert gas requires a gas circulator as opposed to superheated steam which could be moved through the loop by way of a condenser with a significant energy loss penalty. A proposed arrangement for the superheated steam system is shown in Figure 12. The superheated steam method would have to implement the following operating sequence:

1. *Heating the cooling water to saturated steam temperature at pressure expected at the blow-out step (slightly above atmospheric but not above 150 C).* This will avoid water hammer during the water expulsion procedure when saturated steam is used to blow out the cooling water.

2. *Blow water from blanket with saturated steam, discharge steam through the return header.*

3. *When water is removed from the blanket coolant loop, start increasing the steam temperature to dry lines and to heat the first wall through the internal blanket cooling loop to the desired temperature.*

4. *When lines are dry, as monitored by discharge temperature and dry steam conditions, change from blowing into the recirculation mode (use circulator or condenser)* The steam pressure can be reduced to the lowest possible pressure necessary to flow the steam through the system, the steam temperature is increased to rise the temperature of the structure in accordance with the permitted rate of temperature rise given by the detailed design.

The inert gas heating method is considered the safest method because it is the only one virtually guaranteeing water hammer free operation. The decision between superheated steam and inert gas will be affected also by the following considerations:

- **At the end of the conditioning process steam would be condensed into a relatively low volume of mildly tritiated water which actually originated from the cooling water and need not be disposed.** If required, it can be processed in the waste water processing system.

- **Helium or other inert gas will not be volume reduced.** Since it will contain some tritium, it would have to be stored in special containers for that purpose, than used in the process or processed through an appropriate gas purification system. For Helium the blanket purge processing system could be used but other gas would have to be processed by the available inert gas purification system.

- **Gas recirculation flow rate for steam would have to be twice the Helium recirculation rate for the identical heat input.**
- **Steam could be recirculated without a pump if the energy waste penalty of using a condenser is acceptable.**
- **Transfer from water to steam is, in the context of evaluated blankets and the number of units (approximately 100) a very risky operation**

In conjunction with the use of superheated steam or inert gas the potential problem with stress corrosion cracking usually associated with drying tubes has been mentioned. Since this operation is rather infrequent and since the same cooling water would be used, the cumulative effect of growing depositions may not be a problem in this highly quality controlled environment.

2.3 Organic Coolants

In respect to the advanced stage of ITER design the use of organic coolants was not seriously considered. However, this idea could be revisited in subsequent iterations of the ITER design. Organic coolants offer a unique set of characteristics for fusion applications. Their advantage include high temperature (670 K or 400 C) but low pressure (2 MPa) operation, limited reactivity with liquid metal breeders, reduced corrosion and activation, good heat transfer capabilities, no magnetohydrodynamic effects and an operating temperature range that extends to room temperature. The major disadvantages are decomposition and flammability. However, organic coolants have been extensively studied in Canada [3], including nineteen years with an operating 60-MW organic fluid cooled reactor. This experience, summarized in [4], provides an extensive data base for design under fusion conditions. Some typical comparison data published in reference [4] are reproduced in Table 2. The coolant adopted for the Canadian program was partially hydrogenated terphenyl mixture, OS-84 (original designation HB-40) by the Monsanto company. This coolant demonstrated radiation resistance in the CANDU like application.
The proposed consideration of Organic Coolant for fusion applications was also carried out earlier by Argone National Laboratory [5]. At present it is

understood that the ARIES-III study is also reviewing organic coolants and there will be a paper presented at ISFNT-2 in Karlsruhe in 1991.

3 Cooling System Design

For the purpose of this study a number of breeding blanket proposals and national interpretations for the Solid Breeder Helium Purged Water Cooled blanket design was reviewed from the internal cooling loop suitability point of view. Also the USSR proposal for the Li/Pb Eutectic blanket was reviewed. The External Cooling system for these designs is described by van der Krogt in [2] and the schematic is shown in Figure 10. The most critical part of the heating/cooling system is the part which is integrated with the blanket module or what is here called the "internal cooling loop". In general all the blanket alternatives considered share the basic limitation given by the top replacement concept, namely the U-tube multiple of loop and/or element configuration with the supply and return headers at the top. The critical disadvantage of this concept is that the U-tube like arrangement does not permit draining. Consequently, liquid coolant has to be blown out of the tubes before the replacement, in this case gaseous heat transfer medium, can take over the heating function. The internal cooling loops and the results of review of individual national blanket concepts are described in the following paragraphs.

3.1 Solid Breeder Blanket - EC Design

Arrangement of the Cooling System is represented in the following drawings:

- **Inboard First Wall - Blanket Segment Manifolding At the Ends is shown in Figure 1;**
- **First Wall Design Concepts Integrated with Blanket Segments (international design) in Figure 2;**

The critical portion of the European internal cooling loop design is best seen in Figure 1. There are two systems, the first wall system and the internal blanket cooling system which consist of a number of independent and individually configured U-tubes. For such arrangement the blow-out can not work and it is certain that some tubes will remain with a considerable

amount of residual water in them.
The outermost first wall system has a better but still insufficiently suitable configuration for replacing the liquid with gas. These cooling tubes are fortunately configured as multiple tubes all joined at the bottom to a common header. This arrangement provides a hope that if the tubes are emptied in the direction to this header, the emptying process could be successful. These key design features may have a decisive impact on the selection of the heating media, development of the change procedure and on the time required for making the media change. However, if space and other consideration permit, a relatively easy solution to this problem could be found in the form of an additional pipe connected to the bottom collection header and connecting it to an independent drain collection system. The "blow" procedure would than pressurize both the supply and return distribution system with the heating gas and the water would be drained through the proposed new drain pipe. During discussions with the European blanket designers was revealed that the design is still considering different arrangement of the cooling channels and that the versions shown on the identified sketches may soon not be representative of the European design. For this reason one of the recommendation of this study would be that in the future the blanket designs consider replacement of coolant media in both directions on a regular basis.

3.2 Solid Breeder Blanket - Japanese Design

The cooling arrangement of the Japanese solid breeder blanket design is indicated in figures:

- **Manifold and Coolant Flow Concept (outboard side module); in Figure 3;**
- **Manifold and Coolant Flow Concept (outboard central module); in Figure 4;**

The characterization of the internal cooling loop is described for the outboard blanket side module (Figure 3) and to the upper portion of the central module (Figure 4). First wall cooling is supplied by and distributed from a vertical channel. The actual first wall is cooled by a number of poloidally configured rectangular channels supplied from the vertical channel and collected in a second vertical channel. The overall arrangement represents a multiple U-tube configuration where each higher U-tube functionally bypasses the neighbouring lower U-tube. Such system would be impossible to empty of liquid by blowing the content with gas. The procedure may empty part of the system but it is not possible to guarantee that the cooling system could be functionally emptied. However, if space and other consideration permit, a relatively easy solution to this problem could be found in the form of an additional pipe connected to the bottom of one of the vertical supply or return channels. Such drain pipe would be connected to an independent drain collection system. The "blow" procedure would than pressurize both the supply and return distribution system with the heating gas and water would be drained through the special drain pipe. This arrangement would be similar to the one proposed for the European blanket design. Since the lower central module is fed and drained from the bottom, (Figure 4.) there is no internal blanket design problem associated with replacement of the cooling media. There are other cooling channels in the Japanese blanket. These are rectangular boxes forming several independent U-tube configurations. These would be impossible to empty unless the arrangement described for the first wall cooling system is adopted. The Japanese design, in this respect, has an advantage that it has less individual U-tubes to drain than for example the internal portion of the european blanket. Equally it is felt that the internal channels, if they can be isolated from the first wall channels, do not need to participate in the conditioning step and can remain filled. However, future design iteration must consider and examine the rate of heat propagation through the blanket material to see how much of the water remaining in these channels will evaporate and how the cold inner channels will affect the conditioning and/or the bake-out procedure.

3.3 Solid Breeder Blanket - US Design

The cooling arrangement of the US solid breeder blanket design is indicated in figures:

- **Outboard Side Module in Figure 5;**
- **Outboard Side Module - Cross Section in Figure 6;**
- **Midplane Cross Section of Inboard in Figure 7;**

The US solid breeder design features different configuration for the inboard and outboard internal cooling loops respectively. The outboard loop design is similar to the Japanese configuration and consequently the method and recommendations described for the Japanese design would apply. The inboard blanket, however, features vertical rectangular cooling channels which have an arrangement in concept similar to the European design. For this application the description of the European design is analogous to the US inboard breeder blanket.

3.4 Lithium Lead Breeder - USSR Design

The cooling arrangement of the USSR lithium lead blanket design is indicated in figures:

- **Equatorial Cross Section in Figure 8;**
- **Equatorial Cross Section - Details in Figure 9;**

The lithium lead breeder blanket is, from the heat transfer media replacement point of view, well suited for the task. The entire blanket consist of concentric modules consisting internal and external cooling water space surrounding the eutectic breeder channel. The purge gas inlet and outlet is entering and leaving the module in a pipe which is inside the cooling water pipe. All cooling/heating fluid pipes are at the bottom collected in a common header which is connected with the main ring header at the top. This arrangement applies uniformly throughout the blanket and the liquid coolant can be replaced in the direction of the normal flow. In the final analysis the return pipe may be shown to be too large for blowing out the liquid without reasonable residue in the piping.

4 Additional Safety Considerations for the EDA Phase

It is being observed that there are significant differences between the divertor and the first wall in terms of consequence of tube failure. In the event of the Divertor and such designs such as the US design (Figure 6 and 7) any cooling tube or channel failure will directly result in spill of the heat transfer media into the vacuum vessel. Other designs, such as the EC and the international design (Figure 2 Detail B), failure of the coolant tube in the first wall cooling may not necessarily result in direct release of the coolant into the torus. These tubes are embedded in the first wall armour and the brazing between the tubes and armour is believed to form an additional barrier for such leak. It is not certain, however, that such arrangement can be represented as a double containment system. Arrangement in Figure 2

Detail B indicates the presence of a leak detection system which would be effective only if the brazing is between the flat portions of the two armour plates. This leads to a possibility of revisiting of the idea of conditioning the more safe first wall with water to avoid the very inconvenient transfer from water to steam or inert gas. The lower divertor, which has a much better configuration for draining, would be conditioned with inert gas, superheated steam, or if the external piping configuration permits even with saturated steam. This optimism must be reduced by the consideration that ruptured water line would pressurize the space between the two sections of the armour plate (at the location of the tube failure) to the pressure of the fluid in the cooling loop which is feasible. If the tube fails at a location which is not embedded between the armour, such as at the bottom or top box adjacent to the vacuum vessel (such as in Figure 1 view D and detail B, this box can be protected by a using a relief device with an appropriate drain line to prevent the escaping fluid from over-pressurizing the box and failing into the vacuum vessel.

5 Conclusions and Recommendations

5.1 Conclusions from the Meeting of 25, September 1990.

A meeting was held between G.E. Shatalov, T. Kuroda, G. Vieider, A. Antipenkov and O. Kveton. The results of individual studies and contributions were discussed and a consensus reached for the present phase of ITER. The resulting recommendations are in Table 3. These recommendations were accepted during the systems integration meeting of the same date [6].

5.2 Conclusions and Recommendations of this Study

Due to additional work subsequently to the meetings of 25, September some recommendations were further advanced but these are not intended to be in conflict with the consensus documented in Table 3:

- **The use of saturated steam is not feasible for blanket design reasons. Superheated steam, although theoretically feasible, is impractical for the number of units to be changed from water to steam (approximately 100);**

- **Inert gas is the only heating method suitable at this stage of ITER without major changes in the blanket and divertor redesign.** However, the equipment needed for the external loop is extensive as shown in Figure 12.

- **If inert gas heating is retained for the next phase of ITER, the reference blanket design must consider dual heat transfer media, namely design to facilitate changes from one to another in both directions**

- **Alternative heating fluids such as organic coolant should be investigated to eliminate the exchange the heat transfer media, particularly if the conditioning becomes a more frequent procedure.**

References

[1] ITER Team. *ITER Safety Assessment.*

[2] C.A.J. van der Krogt, *Cooling System of First Wall, Divertor, Blanket-Shield and Vacuum Vessel* 11, September 1990.

[3] J.L. Smee, V.R. Puttagunta, R.F.S. Robertson and S.R. Hatcher, *Organic Coolant Summary Report* Atomic Energy of Canada Limited Report, AECL-4922 (1976).

[4] P.J. Gierszewski, R.E. Hollies, *Organic Coolants and Their Applications to Fusion Reactors*, CFFTP-G-86004, AECL- 8405, August 1986.

[5] J.B. Romero, *Evaluation of Organic Moderator/Coolants for Fusion Breeder Blankets*, Fusion Power Program Argone National Laboratory, March 1980.

[6] *Minutes of Integration Meeting, 25 September. 1990* ITER-IL-DE-9-0-27, 25, September 1990.

Table 2.

COMPARISON OF CANDIDATE FUSION COOLANTS

Parameter	Organic Coolant[a]	Helium	Water	Draw Salt	Lithium	17Li-83Pb	Flibe
Typical Properties:							
Density (kg/m^3)	850	3.5	800	1760	490	9330	2000
Viscosity ($x\ 10^{-4}\ kg \cdot m^{-1} \cdot s^{-1}$)	6	0.3	0.8	11	3	20	1000
Thermal conductivity ($W \cdot m^{-1} \cdot K^{-1}$)	0.11	0.18	0.6	0.57	46	22	0.8
Specific Heat, c_p ($J \cdot kg^{-1} \cdot K^{-1}$)	2500	5200	6000	1550	4200	180	2300
Min. Temperature (K)	340[b]	20	~300	410	450	508	636
Max. Temperature (K)	670[b]	> 1000	610	~750	1620	> 1000	> 1000
Typical Operating Parameters:							
Temperature (K)	650	700	570	650	700	700	870
Temperature Rise, ΔT(K)	100	200	40	80	250	150	100
Flow Speed (m/s)	10-20	20-100	3-10	1-5	0.1-1	0.1-1	< 2
Pressure (MPa)	3	5	15.2	0.4	3	2.4	0.3
Pressure Drop, ΔP(MPa)	2	0.1	0.2	0.3	3	2.2	0.06
Pump Power Ratio[c] (% of thermal)	1	3	0.1	0.1	0.06	0.09	0.01
Typical Cost: ($/kg)	5[d]	<< 1	<< 1	1.5	40 natural	6.2 30% ^{6}Li	40

a 40% high boiler OS-84, reactor-grade terphenyls

b Minimum practical temperature limited by increasing viscosity, Maximum temperature limited by thermal decomposition.

c Ratio defined as (Pressure drop)/(Specific heat x Temp. rise)

d 1985 price for small amounts (WR-1)

Table 3. Recommendations Presented During Systems Integration Meeting on September 25, 1990.

STEAM CONDITIONING OF FIRST WALL - CONCLUSIONS

1. **Superheated steam or gas heating can be used for both baking and conditioning.**

2. **Two Steam Heating Alternatives are available**

   - Superheated steam with recirculator - preferred option;
   - Superheated steam with condenser and heat recovery;

3. **Blanket design must consider the use of dual heat transfer media, mainly changes between them in both directions.**

   This equipment may be the limiting factor in the conditioning time through temperature gradient constraints.

4. **Transfer from water to gas or steam is the most intricate and risky part of the entire heating process.**

   - Change to a different medium will be about equally time consuming, but with steam it will be more difficult;
   - There is a potential for cavitation, surges caused by two-phase flow and with steam - waterhammer;
   - Equipment required for steam is more complex and larger;
   - Inert gas will have to be stored, (water can be used in the cooling system);

5. **Steam conditioning appears unfavourable at this first consideration. It is recommended to use inert gas and to revisit water heating at 250 C in the next phase in conjunction with the blanket design.**

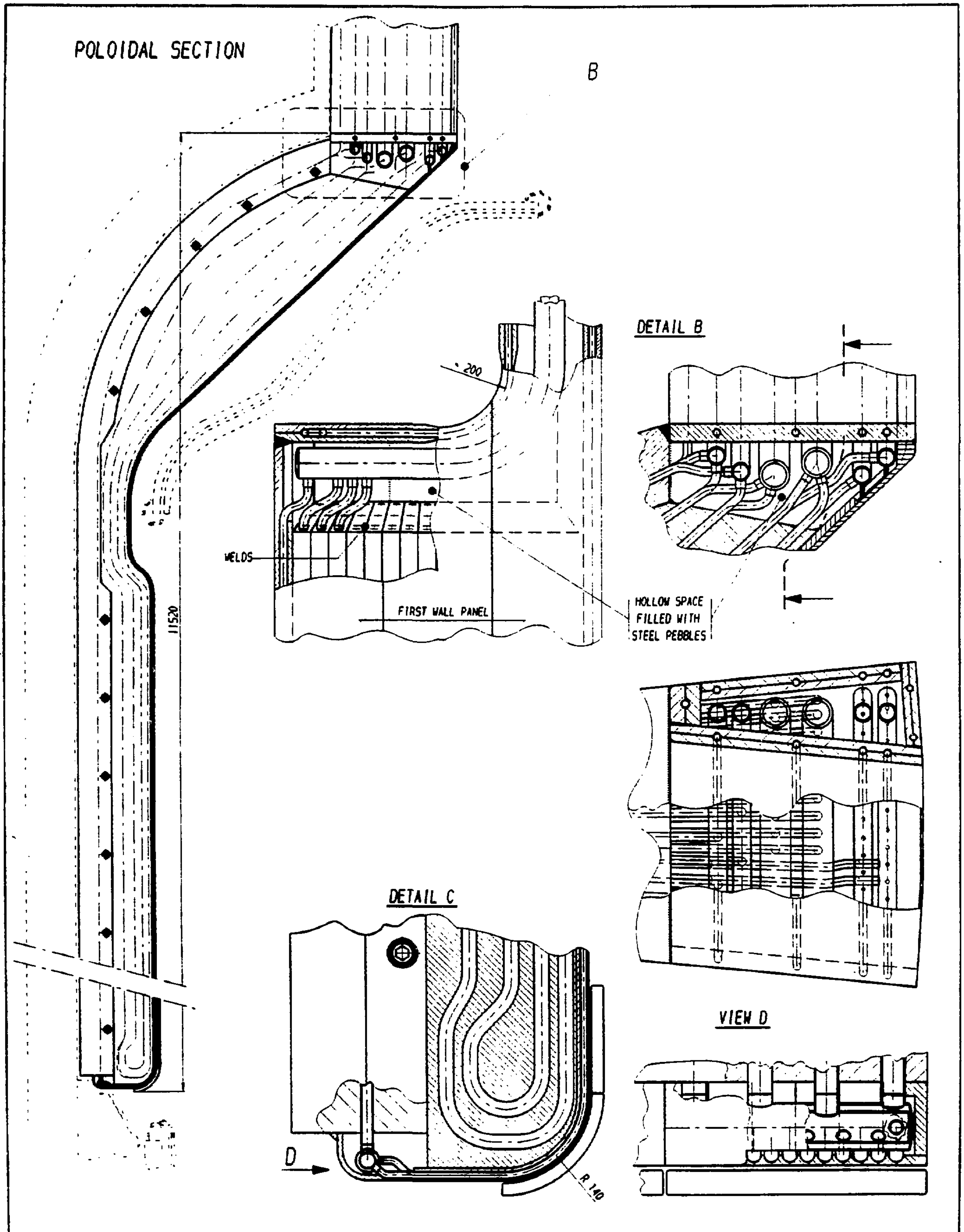


Fig. 1. INBOARD FIRST WALL - BLANKET SEGMNT MANIFOLDING AT THE ENDS

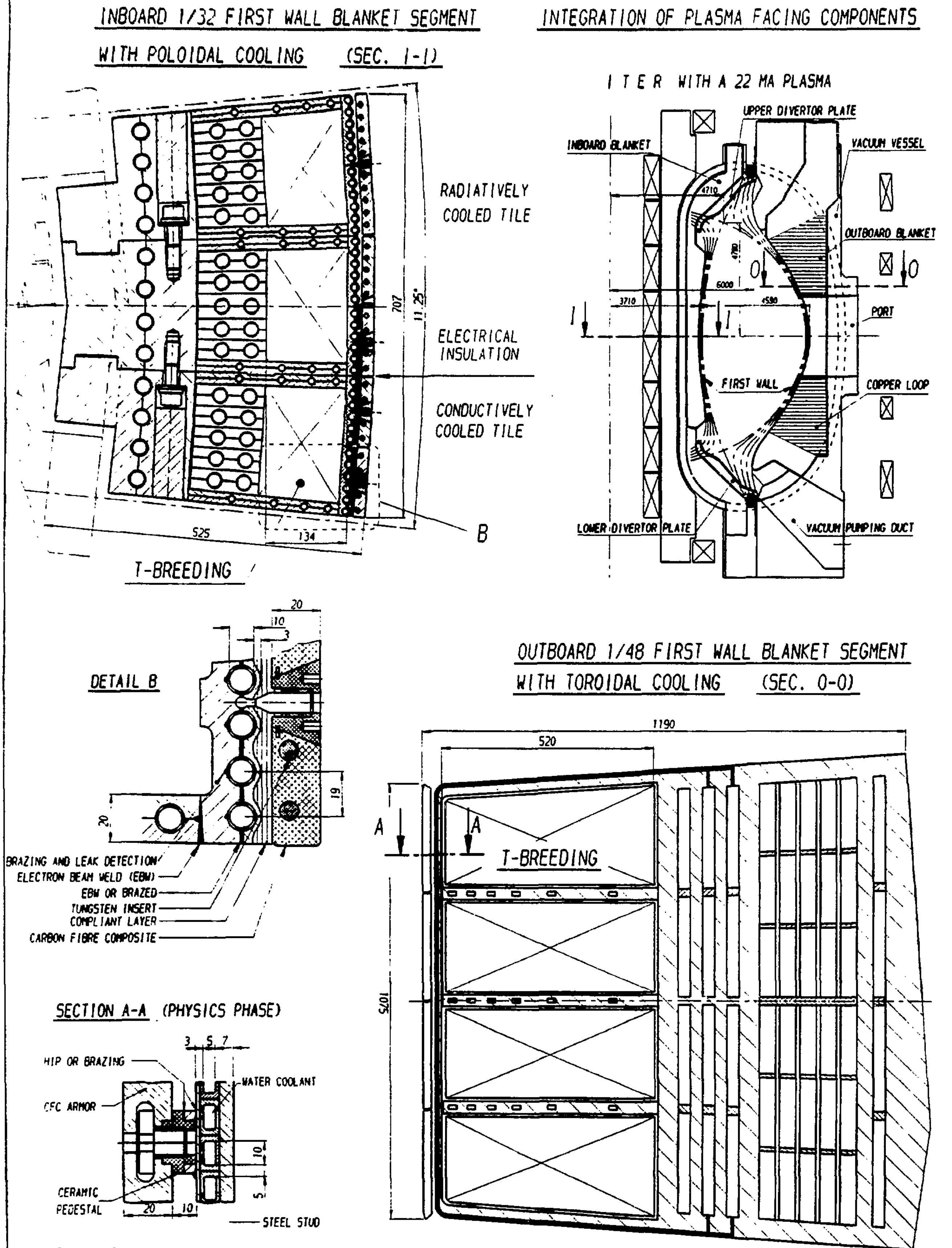
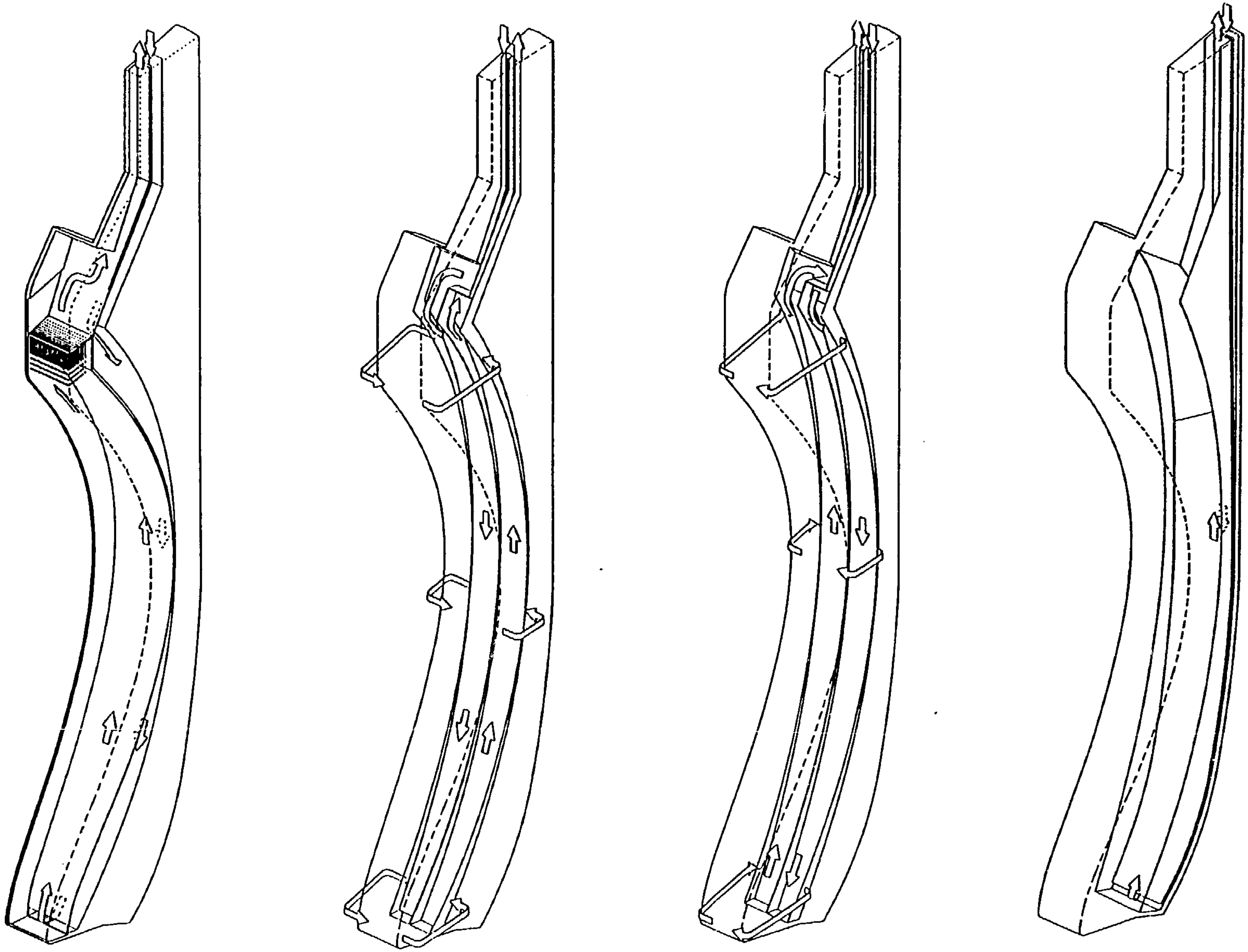


Fig. 2.

FIRST WALL DESIGN CONCEPTS INTEGRATED WITH BLANKET SEGMENTS

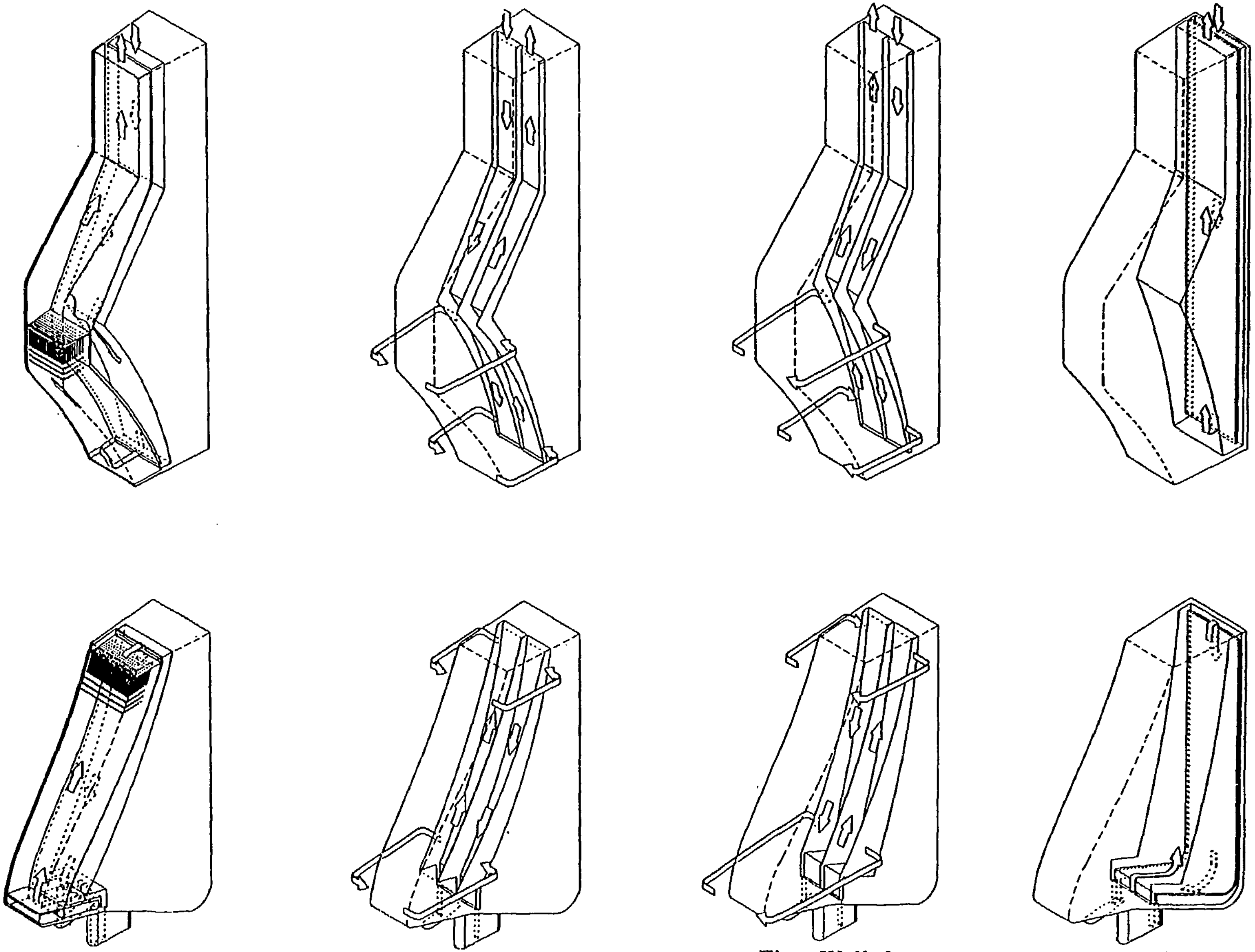
Fig. 3.



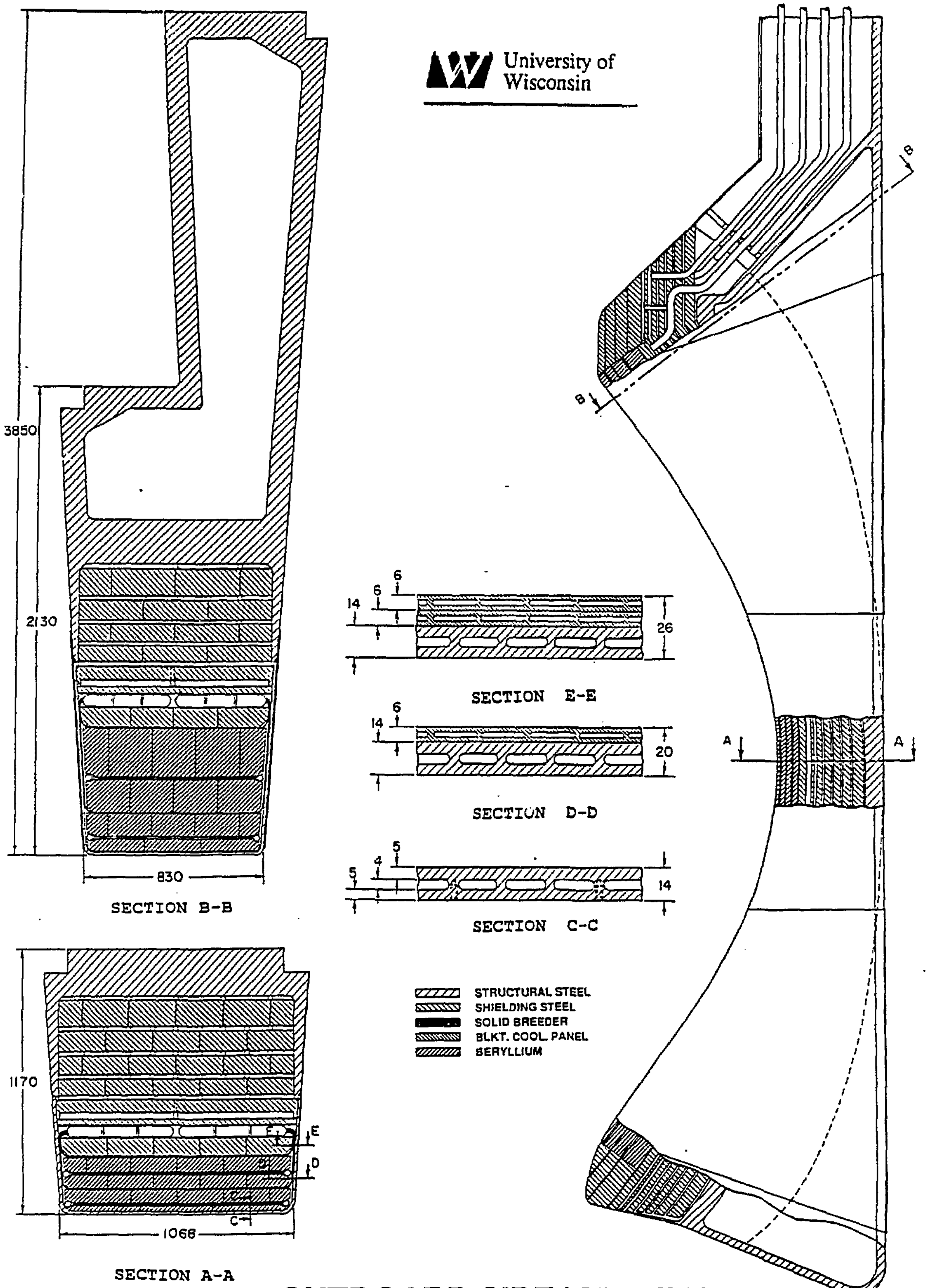
Breeding Zone | First Wall 1 | First Wall 2 | Shield Zone

Manifold and Coolant Flow Concept
(outboard side module)

Fig. 4.

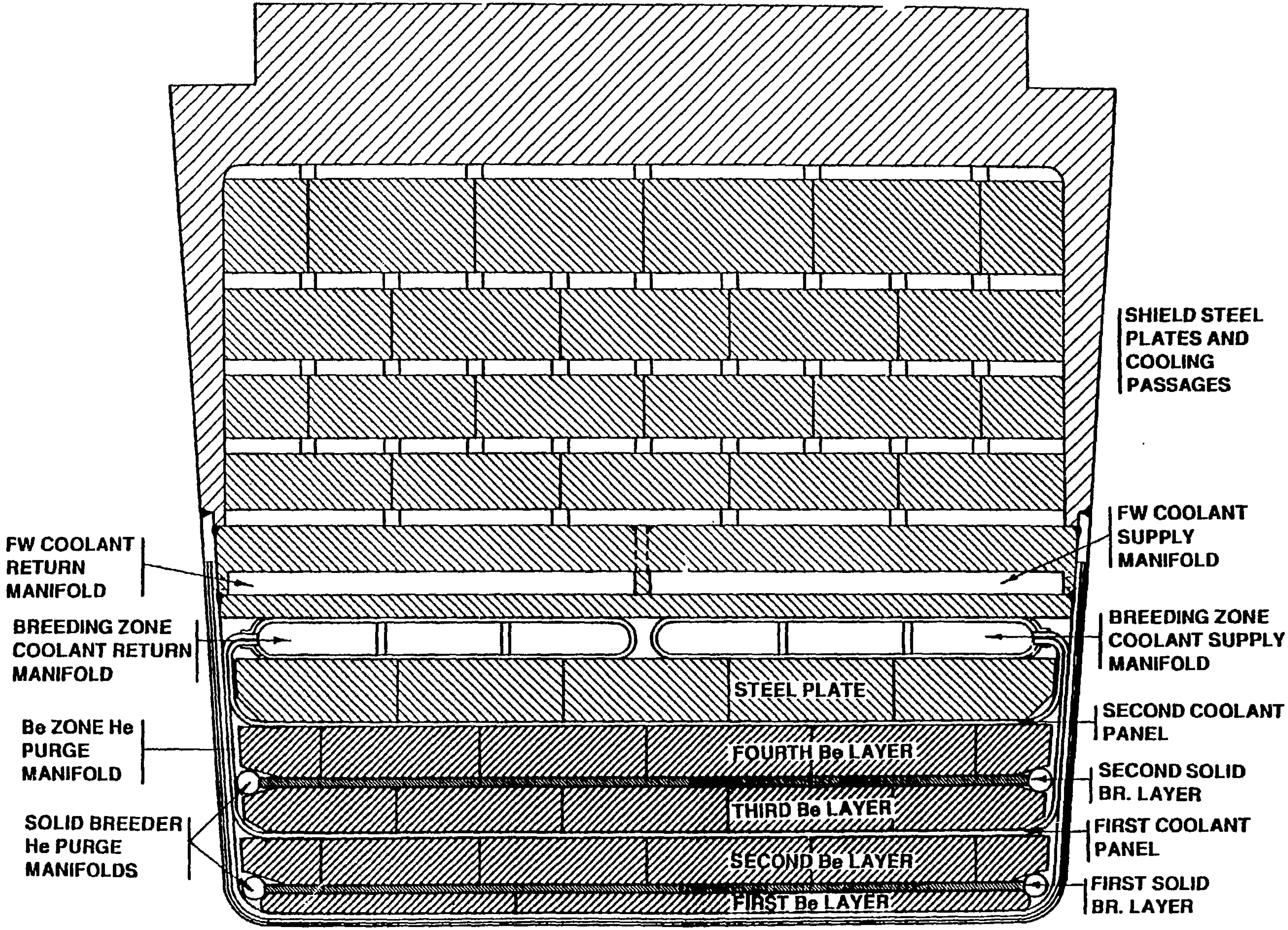


Manifold and Coolant Flow Concept
(outboard central module)



OUTBOARD SIDE MODULE

Fig. 5.



OUTBOARD SIDE MODULE

University of Wisconsin

Fig. 6.

University of Wisconsin

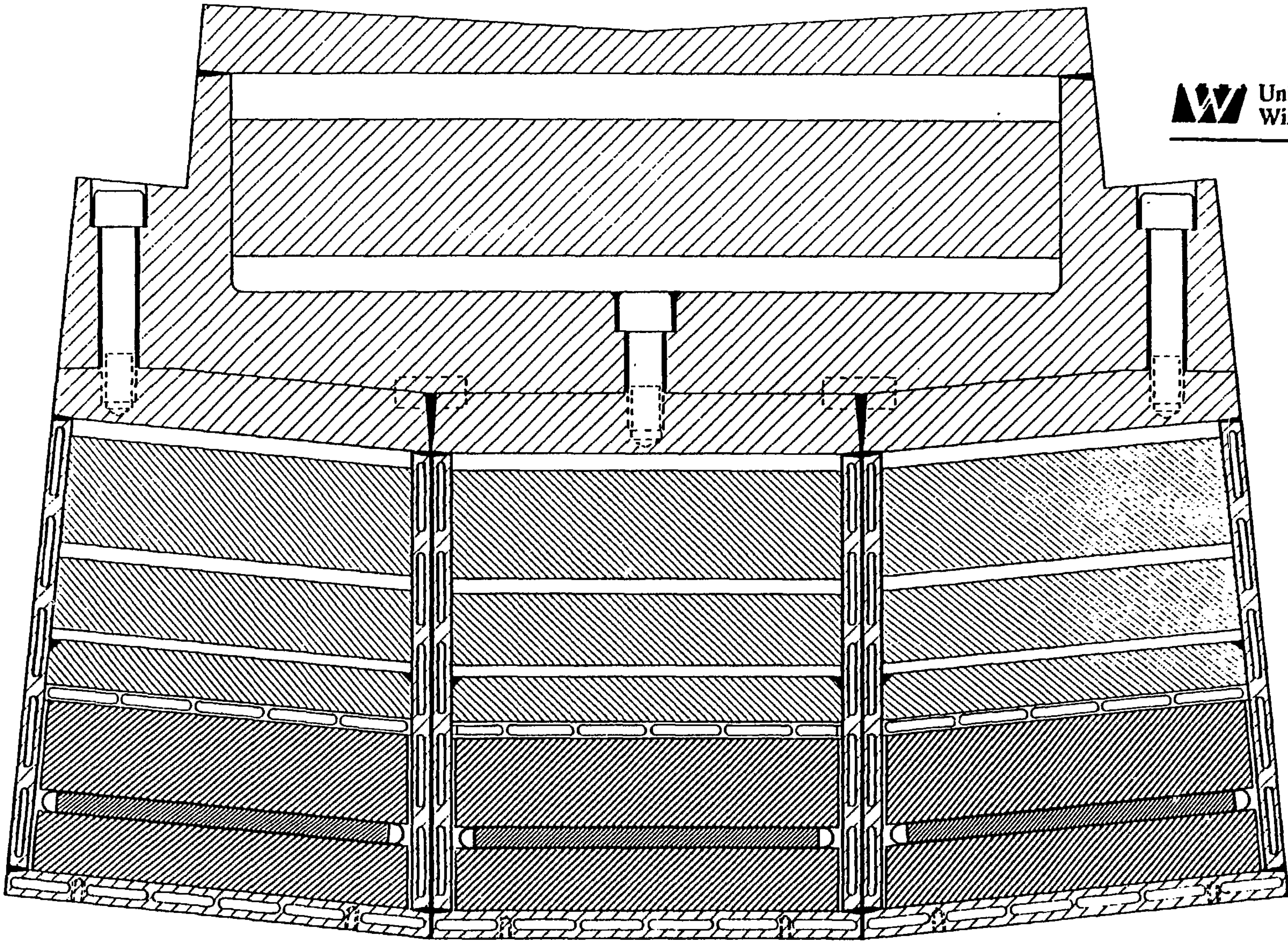
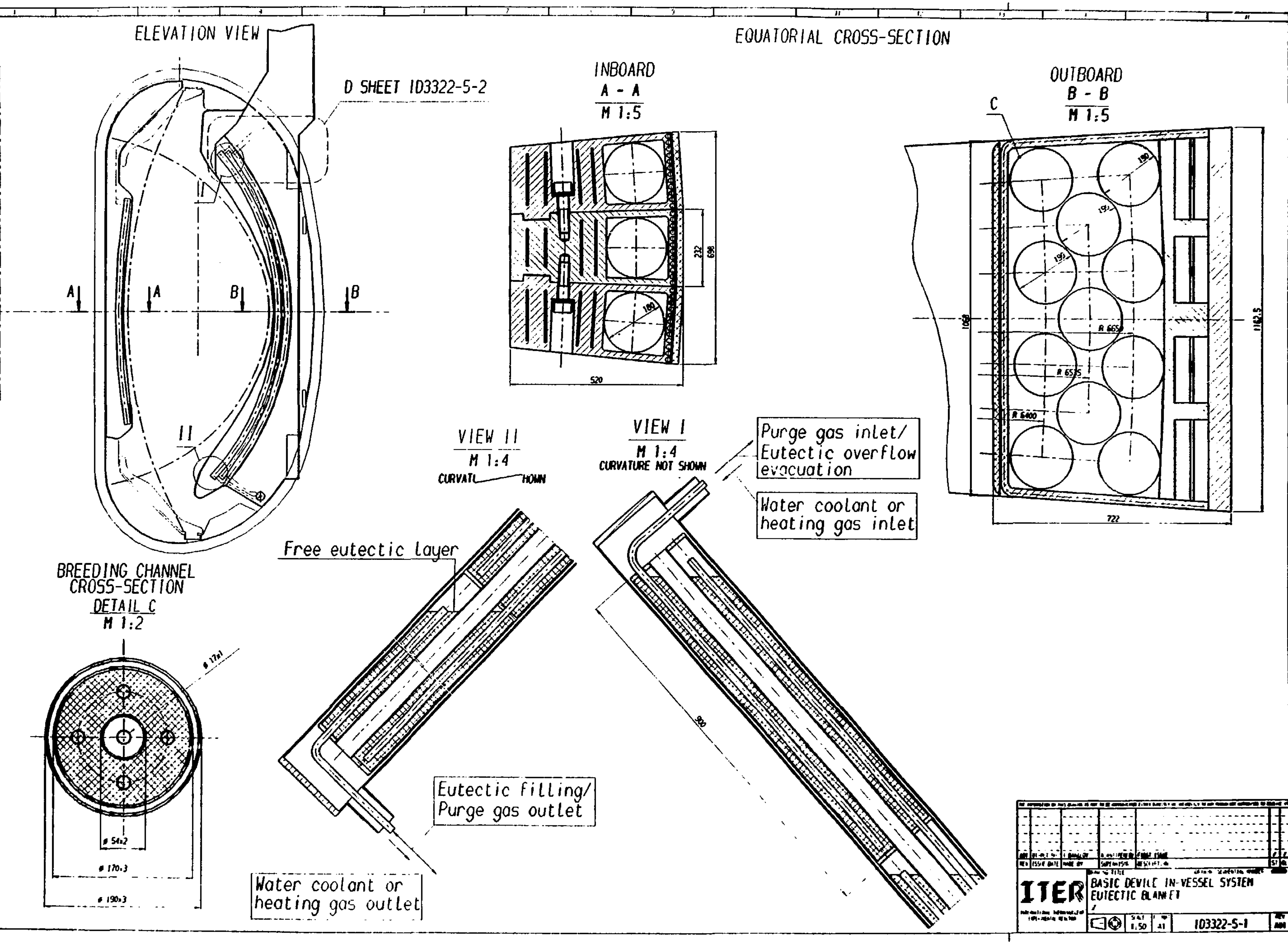


Fig. 7.

MIDPLANE CROSS SECTION OF INBOARD MODULE


ELEVATION VIEW
D SHEET 1D3322-5-2
EQUATORIAL CROSS-SECTION
INBOARD
A - A
M 1:5
OUTBOARD
B - B
M 1:5
C
A
A
B
B
II
I
VIEW II
M 1:4
VIEW I
M 1:4
CURVATURE NOT SHOWN
Purge gas inlet/
Eutectic overflow
evacuation
Water coolant or
heating gas inlet
Free eutectic layer
BREEDING CHANNEL
CROSS-SECTION
DETAIL C
M 1:2
Eutectic filling/
Purge gas outlet
Water coolant or
heating gas outlet
520
698
232
180
722
1068
1162.5
R 6650
R 6525
R 6400
900
ø 54x2
ø 170x3
ø 190x3
ITER
BASIC DEVICE IN-VESSEL SYSTEM
EUTECTIC BLANKET
1:50
A1
1D3322-5-1
Fig. 8.

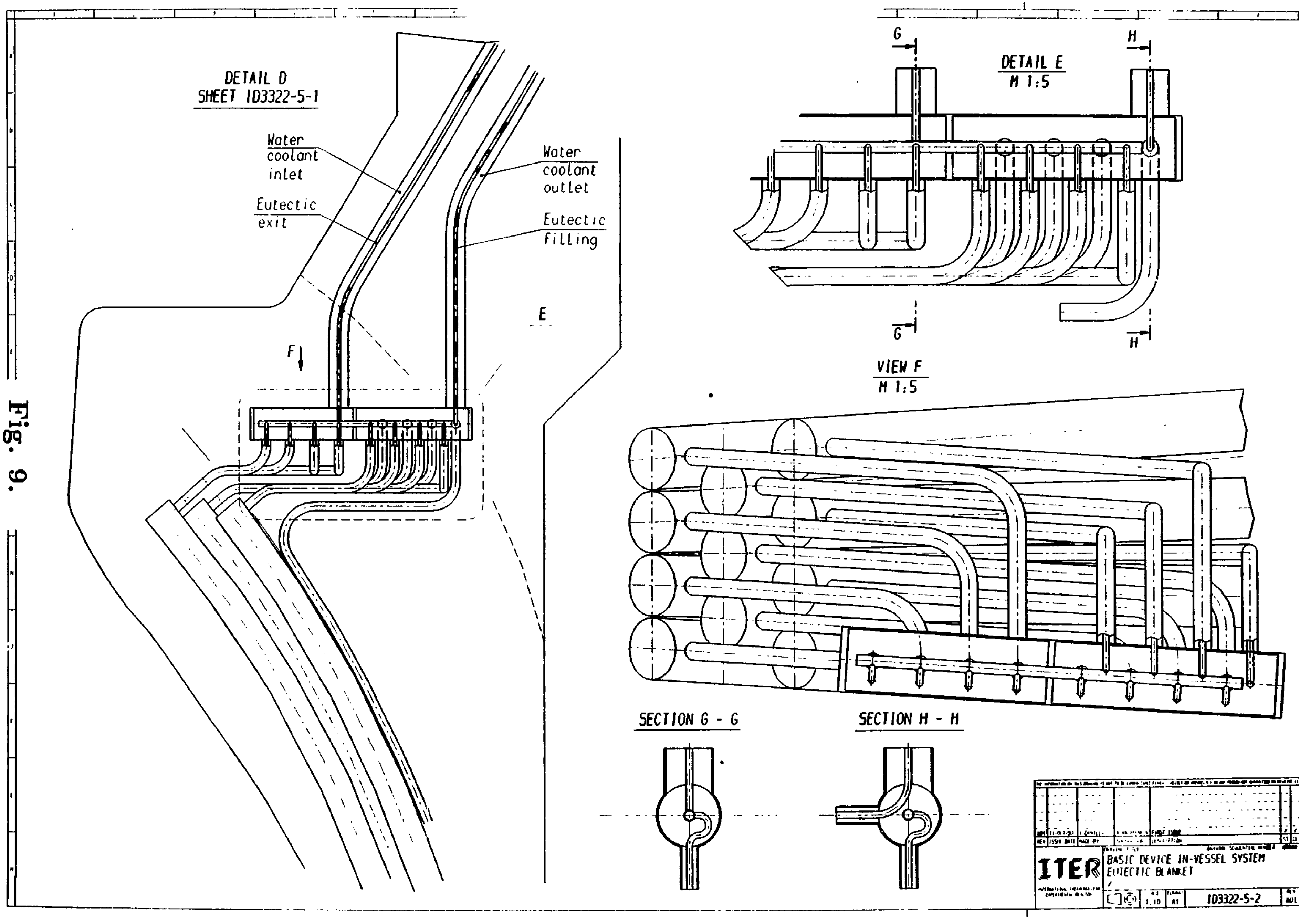

DETAIL D
SHEET 1D3322-5-1
Water coolant inlet
Eutectic exit
Water coolant outlet
Eutectic filling
E
F
DETAIL E
M 1:5
G
H
VIEW F
M 1:5
SECTION G - G
SECTION H - H
ITER
BASIC DEVICE IN-VESSEL SYSTEM
EUTECTIC BLANKET
1:10
A1
1D3322-5-2

Fig. 9.

TYPICAL COOLING LOOP CONFIGURATION
FIRST WALL AND DIVERTOR

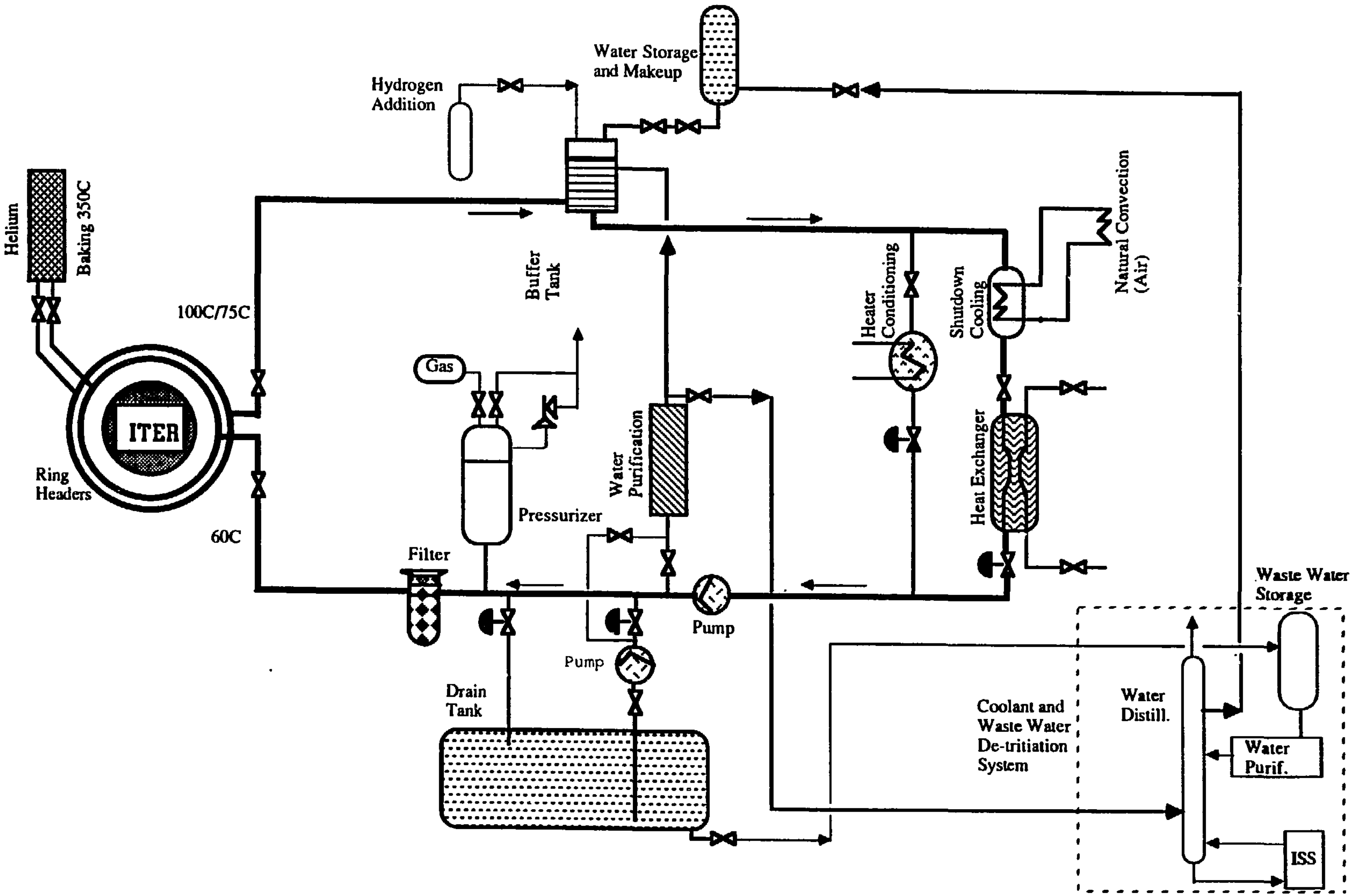
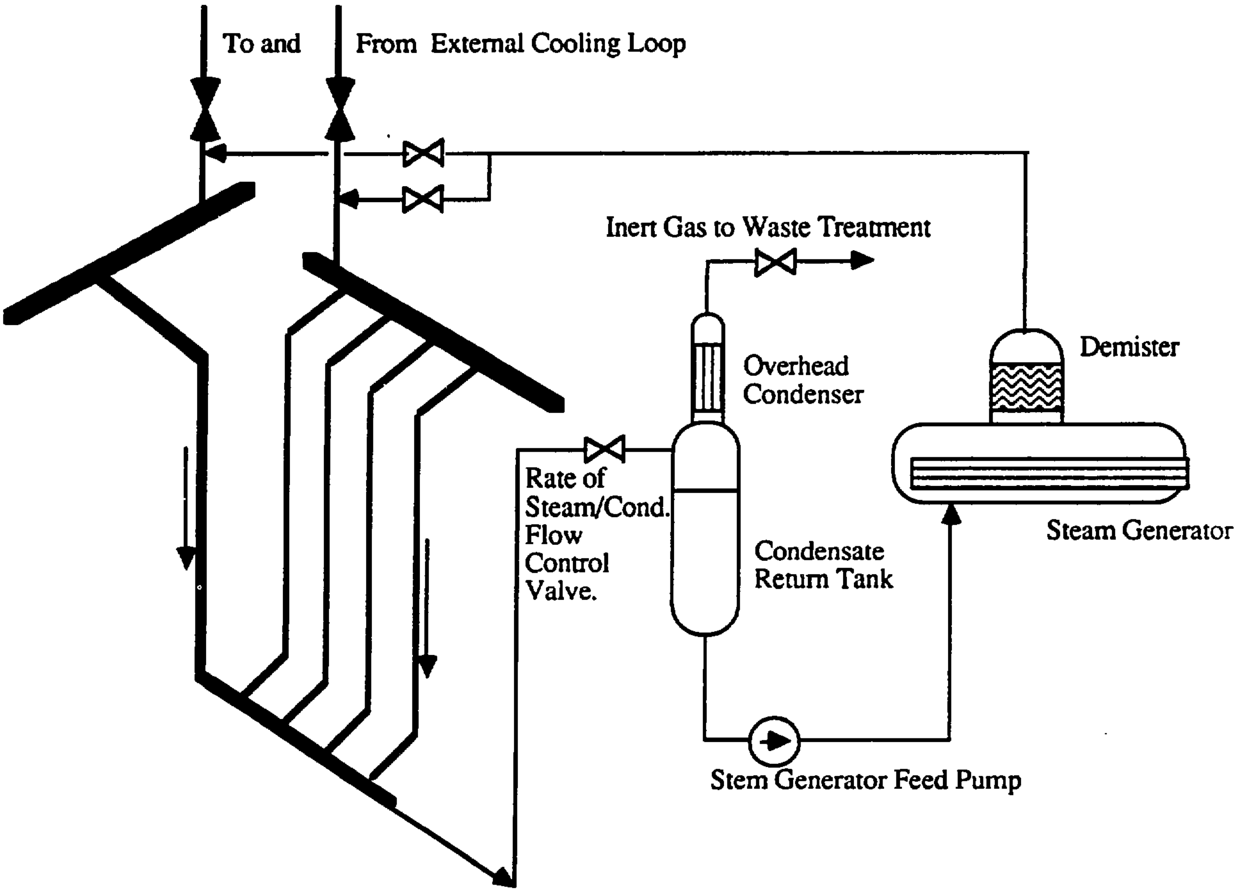


Fig. 10.



COOLING LOOP SATURATED STEAM
CONDITIONING ARRANGEMENT

Fig. 11.

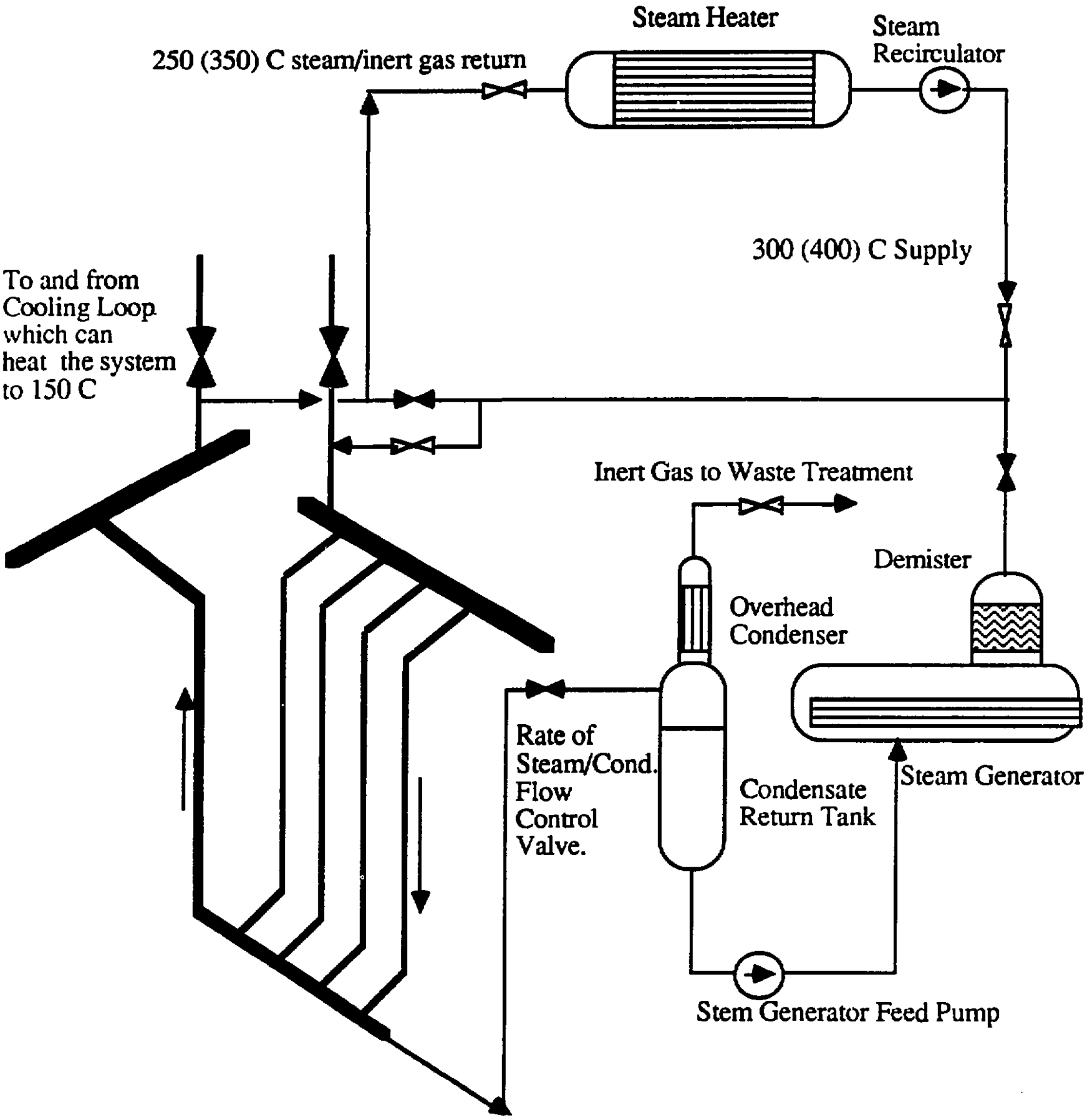


Fig. 12. COOLING LOOP SUPERHEATED STEAM CONDITIONING ARRANGEMENT