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Technical and Administrative Preparations Required for Shipment of Research Reactor Spent Fuel to Its Country of Origin

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Greek Experience with Shipment of Research Reactor Spent Fuel

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GREEK EXPERIENCE WITH SHIPMENT OF RESEARCH REACTOR SPENT FUEL

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1. General Description of the Facility

The GRR-1 is a pool-type, light water moderated and cooled, heterogeneous reactor designed by AMF Atomics, which supplied the engineering plans and mechanical, electrical and electronic components and assisted during the final checkout of the control system.

The construction of the containment building and reactor pool and the installation of the reactor, as well as its start-up and calibrations was made by the personnel of the Nuclear Research Center “Demokritos”.

Various modifications and improvements were made to the initial design, as for example the use of prestressed concrete for the construction of the reactor pool to make it watertight.

The reactor being operated by the Nuclear Research Center "Demokritos', went critical on July 27, 1961 at low power, cooled by natural convection.

During the test and calibration period, the reliability of the reactor components was checked thoroughly and reactor operators were trained; critical experiments for various core configurations, control rod calibrations, neutron flux distribution, temperature and void coefficient and several other reactor physics measurements were also performed. This period lasted for about 2 years during which, the reactor cooling system for forced convection for high power operation was completed.

Since April 6, 1964, the reactor started its operation at maximum power of 1 MW for radiation experiments, beam experiments and radioisotope production.

After about 6 years of operation, it was decided to increase the operating power of the reactor from 1 to 5 MW. Works started early in 1970 and included some major changes and modifications like complete replacement of the old cooling system with a new one consisting of primary and secondary circuit equipped with heat exchangers and cooling towers, replacement of the tile liner of the pool with a stainless steel one, installation of new power supply systems, change of the fuel elements from Low Enriched U-235 (20%) to High Enriched U-235 (90%) etc. The reactor reached operation at 5 MW in June 1971 ***[1]*** .

The reactor has been used so far for reactor physics experiments, nuclear physics, neutron diffraction and spectroscopy work, cross section measurements, solid state physics and radiation damage studies, activation analysis, hot atom and nuclear chemistry and biological studies. It also serves for radioisotope production, for medical, agricultural and industrial applications and as a large gamma source for sterilization purposes during the shutdown period. Finally, it provides basic experience and training to students of the Greek Universities in the Reactor Physics / Nuclear Engineering domain.

The Greek Research Reactor-1 (GRR-1) is located at the National Center for Scientific Research "Demokritos" (as the Nuclear Research Center was renamed in 1987), about 12km by road from Athens at the foot of mount Hymettus in the district of Aghia Paraskevi . It is constructed in the outer center of the seventy five acres property, offered by the Greek Government to the Greek Atomic Energy Commission.

2. Reactor Pool

The reactor pool (Fig. 1, 2) is a prestresse concrete structure with a stainless steel liner. The inner dimensions of the pool are 10.30 m length 3.32 m width and 9.00 m height. The pool is divided into two sections, by means of an aluminium gate: the operating section and the storage one. The usual position of the gate during reactor operation and shutdown is at its storage place inside the pool. The gate is inserted in its position in the dividing wall only when it is necessary to drain the operating section of the pool for inspection or maintenance, or in case of emergency .The pool wall consists of 30 cm thick inside layer of prestressed ordinary concrete, followed at the lower part of the pool by a 4 cm thick layer of lead and 110 cm thick outside layer of magnetite concrete, the thickness of which decreases in steps as the height increases to provide the necessary biological shielding. The use of prestressed concrete has been proved to be an excellent means of providing complete water tightness of the pool and anti seismic design.

The stainless steel liner consists of s.s sheets welded together on s.s supports, which are fixed on the prestressed concrete walls of the pool. The thickness of the s.s sheets varies. The sheets which cover the bottom of the pool and the lower part of the walls, up to a height of 3 meters, have a thickness of 5 mm.

The next ones, up to a height of 6 meters, are 4 mm thick, while the sheets which cover the upper part of the walls are 3 mm thick.

The welding of the s.s sheets has been x-ray tested.

Support of the reactor core, ion chambers, control rod drive mechanisms and other control system hardware, is provided by the core support bridge. The reactor core and the ion chambers are suspended in the pool by the core support tower, which is attached to the bridge. The control rod drive mechanisms are directly mounted on the bridge structure. The bridge itself is mounted on rails which permit it to move along the length of the pool.

3. Fuel Assemblies

The reactor core consists of MTR fuel assemblies of high enriched uranium (Fig. 3, 4).

The uranium is contained in an uranium aluminium alloy and is entirely cladded in aluminium.

The standard fuel assemblies consist of either 18 or 19 curved plates, or 18 plane plates. The control fuel assemblies consist of either 9 curved plates or 10 plane plates. The main characteristics and dimensions of the fuel assemblies are given in Table 1.

The Institute of Nuclear Technology-Radiation Protection, one of the Institutes of NCSR “Demokritos”, which operates the Research Reactor, joined the RERTR program early in ’80’s.

According to the study performed at ANL ***[2]***,***[3]***, the characteristics of the new LEU fuel were determined. The LEU fuel assemblies which consist of 18/10 plane plates, of U_3Si_2 -Al type have been manufactured by CERCA. The main characteristics and dimensions of the LEU assemblies compared to the ones of the HEU assemblies are given in Table II.

4. Fuel Management

According to the practice followed so far, as spent fuel assemblies are considered the ones which have riched a burn up status of 30%-33%.

The spent fuel assemblies are determined according to the practice described in ***[2]*** . These assemblies are removed from the reactor core and stored in the appropriate in-pool storage for at least a six months period. After that, they are transferred to a separate storage tank, filled with demineralized water (Fig 5), by means of a special shielded cask (Fig 6). After a "cooling" time of at least 2 years the spent fuel assemblies can be shipped for permanent disposal or reprocessing abroad, since relevant facilities do not exist in the country.

5. Selection and Preparation of Spent Fuel Assemblies for shipping

From the records which are maintained at the Reactor Laboratory, decision is made about the fuel assemblies which are suitable for shipment. The criteria used for this decision are:

- the burn up status of the fuel assembly
- the history of the fuel assembly
- the cooling time

Since the cost of shipment and reprocessing or permanent disposal depends on the total weight of the assemblies, it is recommended to minimize it by cropping parts of them not containing fissile material. A simple device has been designed and constructed for that purpose at the Reactor Laboratory (Fig 7). The device is equipped with one or two cutting disks which can trim one or simultaneously both ends of the assembly. It is recommended for the standard MTR assemblies to get cropped only by the lower end, saving the existing at the upper end handle and therefore facilitating manipulations during the shipment procedure. It must be noticed that the weight of the upper end is small compared to the weight of the lower end.

6. Spent fuel status at GRR-1

After 23 years of operation of GRR-1 at power 5 MW (1971-1994) , a great number of spent fuel assemblies had been stored at the facility. This continuous accumulation resulted serious problems to the Reactor Operator:

- deficiency of spent fuel storage facility which could jeopardize the continuation of the reactor operation
- long residence of some assemblies in aqueous environment could result to corrosion problems, inspite the high quality of the demineralized water of the pool
- continuous pressure from the Regulator (GAEC) for a solution.

Similar problems of course, had been created to all Reactor Operators with fuel of U.S. origin, since any return of irradiated fuel to the USA had been banned for many years.

Common efforts of the RERTR group, working hard for the promotion of new (LEU) fuel, EDLOW Co. and a team of Reactor Operators from Europe, together with the DOE Staff resulted to the preparation of the " Environmental Assessment of Urgent-Relief Acceptance of Foreign Research Reactor Spent Nuclear Fuel (U.S. DOE , April 1994).

Already, in January 1994 a US DOE mission had visited the GRR-1 to verify if the Greek Reactor was fulfilling the requirements for Urgent Relief of spent fuel. It was decided for acceptance of 66 MTR assemblies.

A contract was signed between US DOE and NCSR " Demokritos" for receipt and disposal at Savannah River Site of the above mentioned fuel, in August 1994. In an Appendix to the contract a complete set of drawings, as well as, all data concerning composition, dimensions, irradiation History e.t.c for each fuel assembly were included.

In December of the same year , a contract between NCSR "D" and EDLOW was signed for the transportation of that fuel from the GRR-1 site to the SRS. It was mentioned that EDLOW as our representative would use two NAC-LWT casks.

During the Spring of 1995 NAC engineers visited the GRR-1 site and discussed with the reactor technical staff in details the whole procedure of loading the NAC-LWT casks. Special problems, as the limited capacity of the reactor crane (10 tons) , the relatively small dimensions of the track entrance of the reactor hall, the big size and weight of the cask e.t.c had to be solved. The only approach to the problem was to load the big casks outdoors using a transfer cask (7 tons) which could transfer each time 7 MTR assemblies positioned in a special canister. NAC had to manufacture the canisters ,as well as, the shielded cone which would support the transfer cask while it was loaded from the pool.

7. Preshipment Activities-Documentation

The Reactor Operator submitted to the Regulator (GAEC) all the necessary documents in order to get issued the Export License for Nuclear Material. Such documents were: a complete set of drawings of the cask, shielding and criticality calculations, practices and procedures of loading, characteristics of the cask, valid license of the cask from US NRC and US DOT e.t.c. (provided by NAC). Also GAEC asked from the Reactor Manager to give all data concerning the under shipment assemblies, i.e. their identification, their nominal and actual isotopic masses and their activities. Also GAEC in order to issue permission for the ship to enter the Greek territory in case she was carrying nuclear cargo (from an other reactor) , requested valid licenses for that containers, as well as, description, quantities and activities of the nuclear cargo. Finally , arrangements were made in advance with the police, the port authorities and the customs in order to facilitate the whole operation.

8. Loading of the Casks-Shipment

Early in September 1995 the two NAC-LWT casks, the “Dry Transfer System” and many auxiliary parts were delivered at GRR-1 site. Soon after that NAC engineers joined the operations group of GRR-1 for the loading of the casks.

The loading procedure was accomplished according to the following steps:

a. Transfer of the cropped f.as. from the spent fuel storage to the main Reactor Pool.

b. Assemble the NAC-LWT cask (Fig 8) with the adaptor assy (Fig 9) using a mobile 40 tons crane.

c. Installation of the support core for the loading of the dry transfer System (DTS) (Fig 10) on the pool wall, (away from the core).

d. Loading of the canisters (Fig 11) with 7 spent f.as. each.

e. Loading of the DTS with one full canister.

f. Move the DTS, positioned it on top of NAC-LWT cask and transfer the loaded canister in it (Fig 12).

g. Repeat the steps d to f and load the NAC-LWT cask with 6 canisters.

h. Remove the cask adaptor assy and secure the cask with the lid.

i. Check the cask for watertightness and for any external contamination.

j. Assemble the cask with the two impact limiters.

k. secure the cask into the ISO containers.

The ISO containers with the two casks were transported by tracks to the harbor and loaded on the special ship.

9. Conclusions

The whole operation was well organized and was performed quite successfully, inspite some problems which appeared due to the complicated manipulations and to the lack of any previous experience, since these casks were used for a first time for transportation of MTR assemblies. All problems were sollved in the best way and no incident (any injury or personnel exposure) occurred. The Reactor Personnel prooved their good training and ability and many of them worked hard overtime to finish the job on time. Finaly I would like to stress here, the flexibility and ability of the NAC engineers, as well as, the high quality services provided by the EDLOW staff before and during the operation.

REFERENCES

[1] Safety Analysis Report of GRR-1
Edited by C. Papastergiou, NCSR "Demokritos", 1985.

[2] Neutronic calculations for the Conversion of the GRR-1 from HEU to LEU Fuel
C. Papastergiou and J. Deen , ANL, September 1981

[3] Improvements in operational infrastructure of the GRR-1 and Performance Changes due to Be Reflector Addition and new LEU fuel usage.
C.Papastergiou, Ch. Zikidis, I.Armiriotis, I.Anoussis and E.Stakakis,
Presented at the Interregional Seminar on Research Reactor Centres-Future Prospects, IAEA, Budapest November 1993.

Table I. Fuel Elements Characteristics

Fuel Element Dimensions (mm)	19 curved plates		18 curved plates		18 plane plates	
	STANDARD	CONTROL	STANDARD	CONTROL	STANDARD	CONTROL
Length	873.0 ± 0.5	873.0 ± 0.5	873.1 ± 0.5	952.5 ± 0.5	873 ± 1	952 ± 0.5
Width	76.1 - 0.5	76.1 - 0.5	75.9 ± 0.2	75.9 ± 0.2	76.1 - 0.4	76.1 - 0.4
Height	80.0 - 0.5	80.0 - 0.5	80.0 ± 0.1	79.6 ± 0.1	80.0 - 0.4	80.0 - 0.4
Plate Dimensions (mm)						
Length	625.0 ± 0.2	625.0 ± 0.2	625.4 ± 0.1	625.4 ± 0.1	625.5 ± 0.4	625.5 ± 0.4
Width	71.15 ± 0.15*	71.15 ± 0.15*	71.02 ± 0.08*	71.02 ± 0.08*	71.0 ± 0.05	71.0 ± 0.05
	70.75 ± 0.15**	70.75 ± 0.15**	70.53 ± 0.08**	70.53 ± 0.08**		
Thickness	1.27 ± 0.04	1.27 ± 0.04	1.27 ± 0.05	1.27 ± 0.05	1.52 ± 0.08	1.52 ± 0.08
Meat Dimensions (mm)						
Length	600 ± 10	600 ± 10	597 ± 13	599 ± 13	596.5 ± 13	596.5 ± 13
Width	61.15 ± 2.5	61.15 ± 2.5	60.3 ± 0.1	60.3 ± 0.1	62.3 ± 3.1	62.3 ± 3.1
Thickness	0.51	0.51	0.51	0.51	0.5	0.5
Cladding Thickness (mm)	0.38 ± 0.125	0.38 ± 0.125	0.38 ± 0.1	0.38 ± 0.1	0.51	0.51
Water Channel Thickness (mm)	2.95 ± 0.25	2.95 ± 0.25	3.12 ± 0.2	3.12 ± 0.2	2.90 ± 0.25	2.90 ± 0.25
Plates/Elements	19	9	18	9	18	10
U-235/Plate (approx. av.), (gr)	9.5	9.5	10.4***	10.4***	10.05	10.05
U-235/Element (approx. av.), (gr)	180.79	85.56	176.79	83.15	180.83	100.32
U-238/Plate (approx. av.), (gr)	1.05	1.05	0.77***	0.77***	0.75	0.75
U-238/Element (approx. av.), (gr)	20	9.4	13	6.15	13.54	7.51
Enrichment in U-235 (%)	89.85	89.85	93.12	93.12	93	93
U - metal/Plate (approx. av.), (gr)	10.55	10.55	11.17***	11.17***	1.08	10.8
U - metal/Element (approx. av.), (gr)	200.0	94.4	189.79	89.3	194.37	107.83

* Before curving

** After curving

*** Outer plates contain approx. 5 gr U-235 + 0.37 gr U-238 = 5.37 gr U-metal

Table II. GGR-1 Standard Fuel Elements Characteristics

	HEU	LEU 1	LEU 2	LEU 3
Enrichment, %	93	19.75	19.75	19.75
Fuel meat composition	UAl	UAlx-Al	U308-Al	U3Si2-Al
Density in meat, g/cc	0.58	2.2	3.0	3.36
U235 Dens. In meat, g/cc	0.54	0.43	0.59	0.66
U235/plate (ang), g	10.05	12.34	16.83	12.34
U235/Element, g	180.83	222.2	303	222.12
U238/Element, g	13.54	902.8	1231	902.54
U Metal/Element, g	194.37	1125.0	1534	1124.66
U Metal/pl. (avg), g	10.798	62.5	85.2	62.48
No. of plates/Elem.	18	18	18	18
Plate length, cm	62.55	62.55	62.55	62.55
Plate width, cm	7.1	7.1	7.1	7.1
Plate thickness, cm	0.152	0.152	0.152	0.152
Meat length (avg), cm	59.65	60.00	60.00	59.65
Meat width (avg), cm	6.23	6.23	6.23	6.23
Meat thickness, cm	0.050	0.076	0.076	0.050
Clad thickness, cm	0.051	0.038	0.038	0.051
Water channel thick., cm	0.290	0.290	0.290	0.290

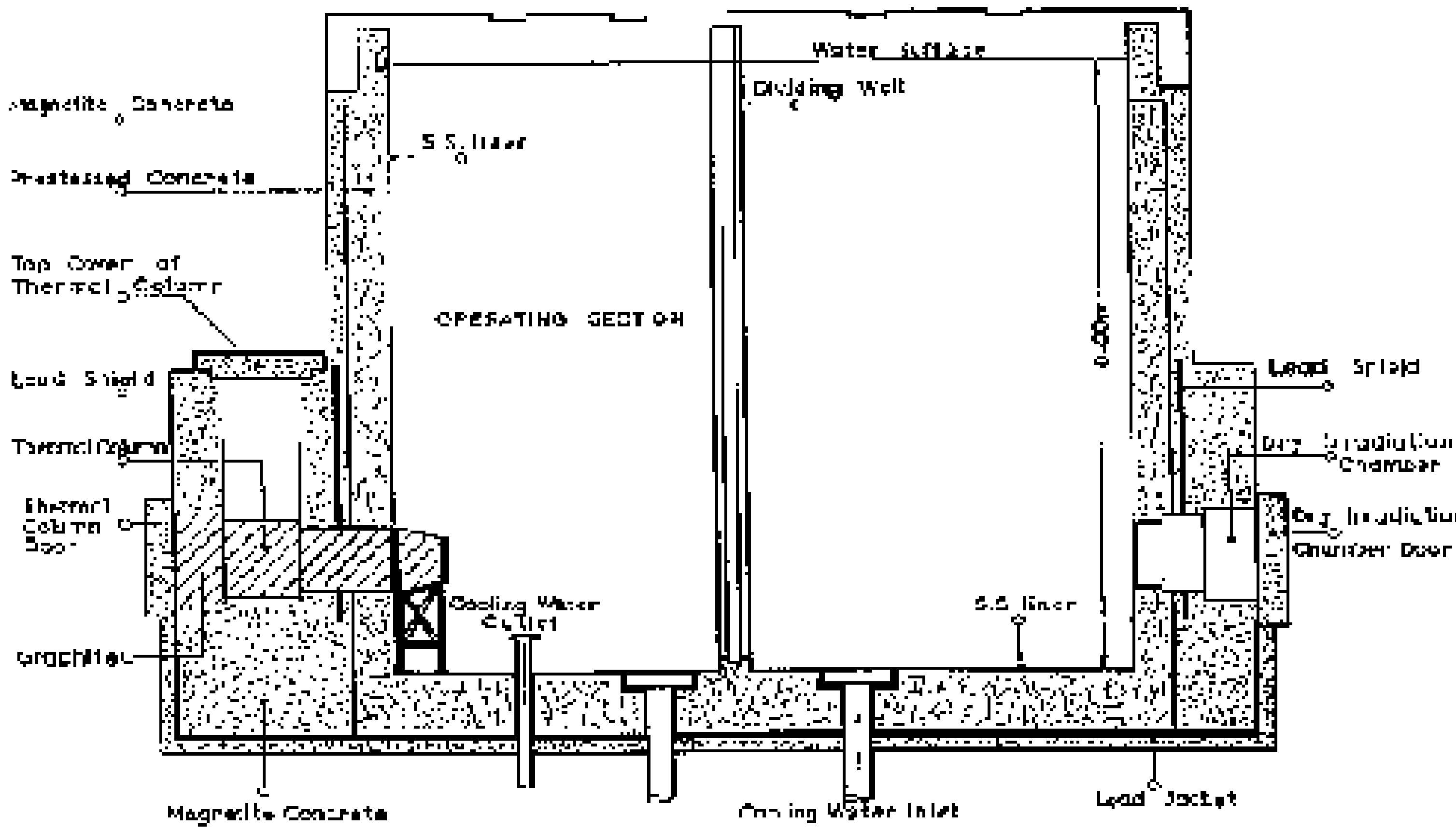

Fig. 1 GRR-1 Pool, vertical Section. Scale 1:100

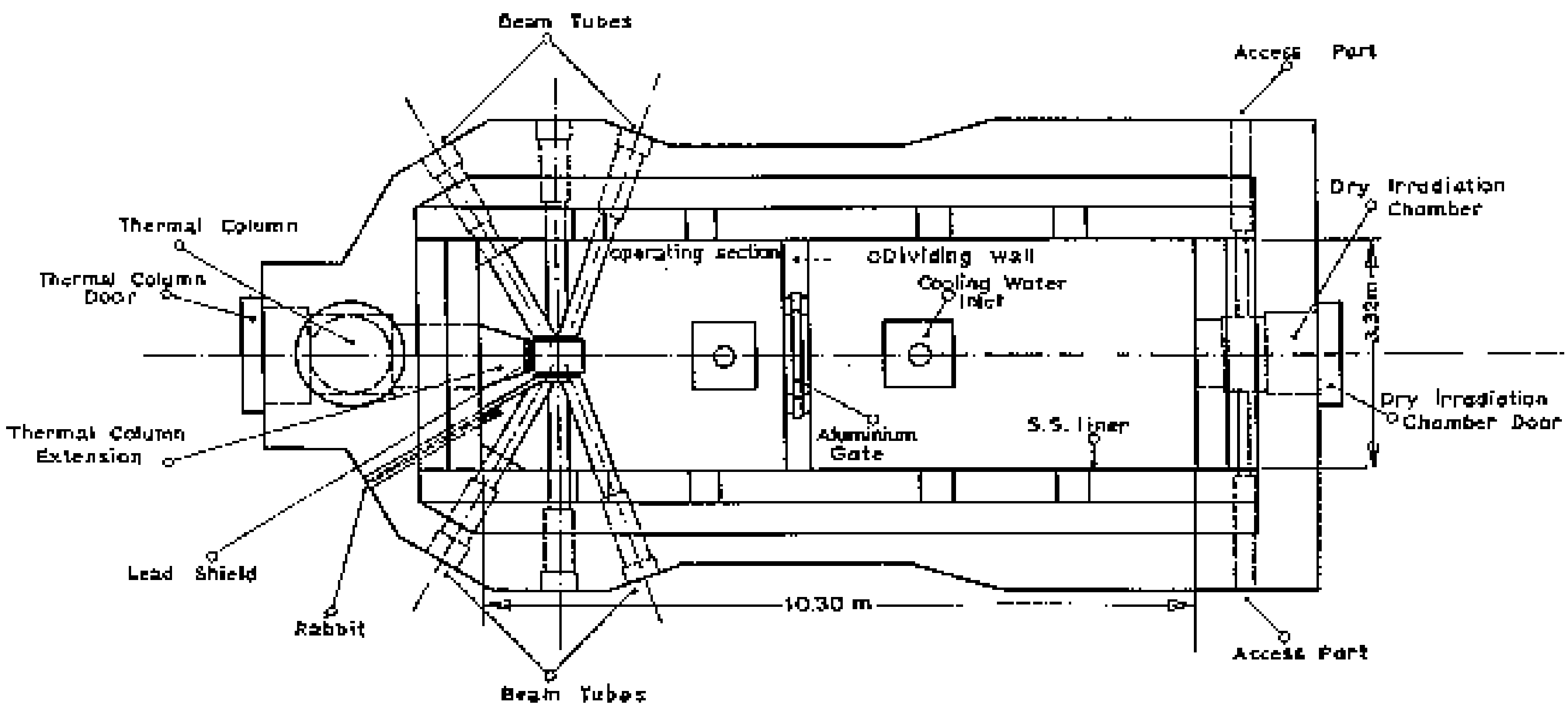

Fig. 2 GRR-1 Pool, horizontal section. Scale 1:100

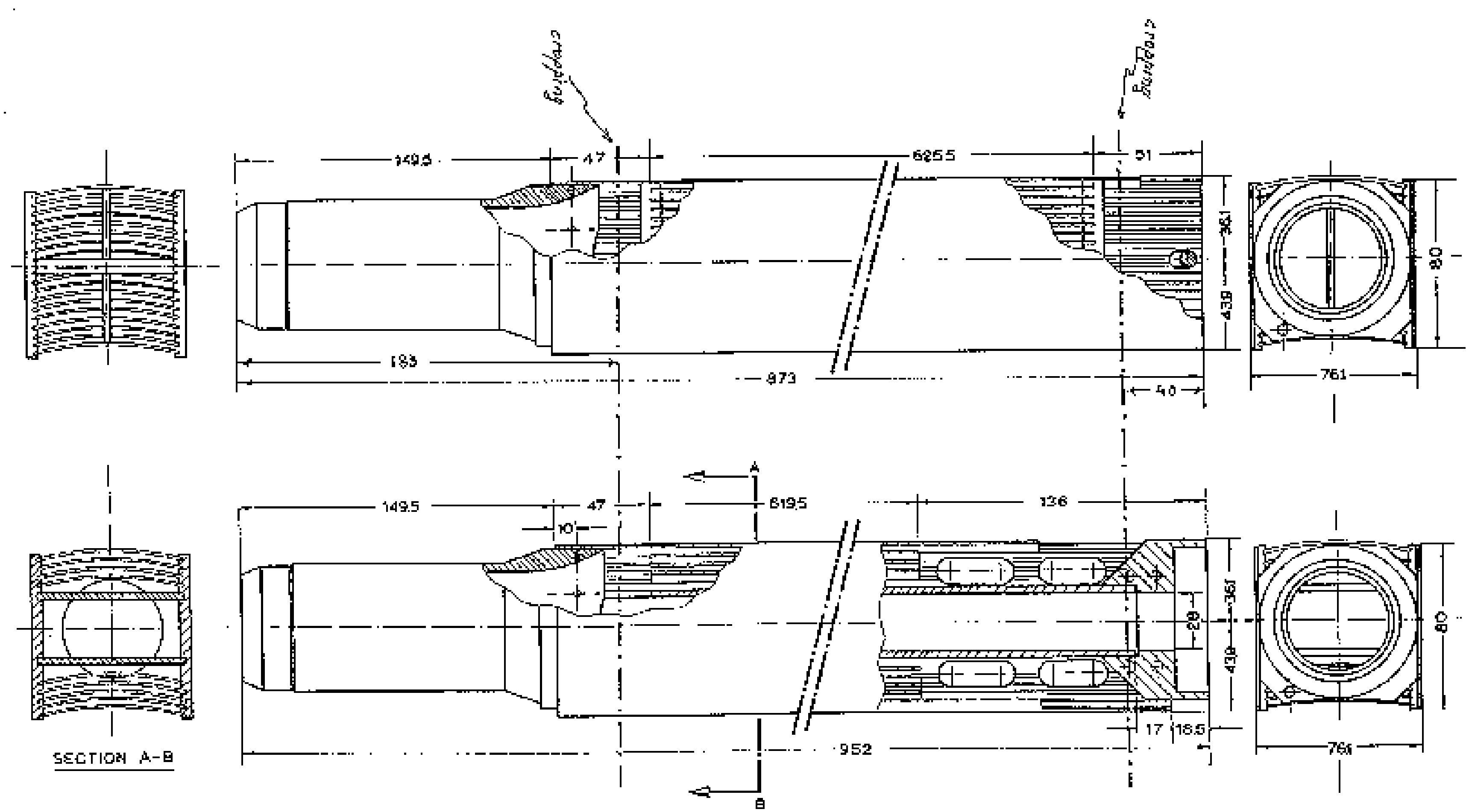

Fig. 3 "Standard" and "control" fuel elements of the GRR-1 with curved plates.

Dimensions in m/m

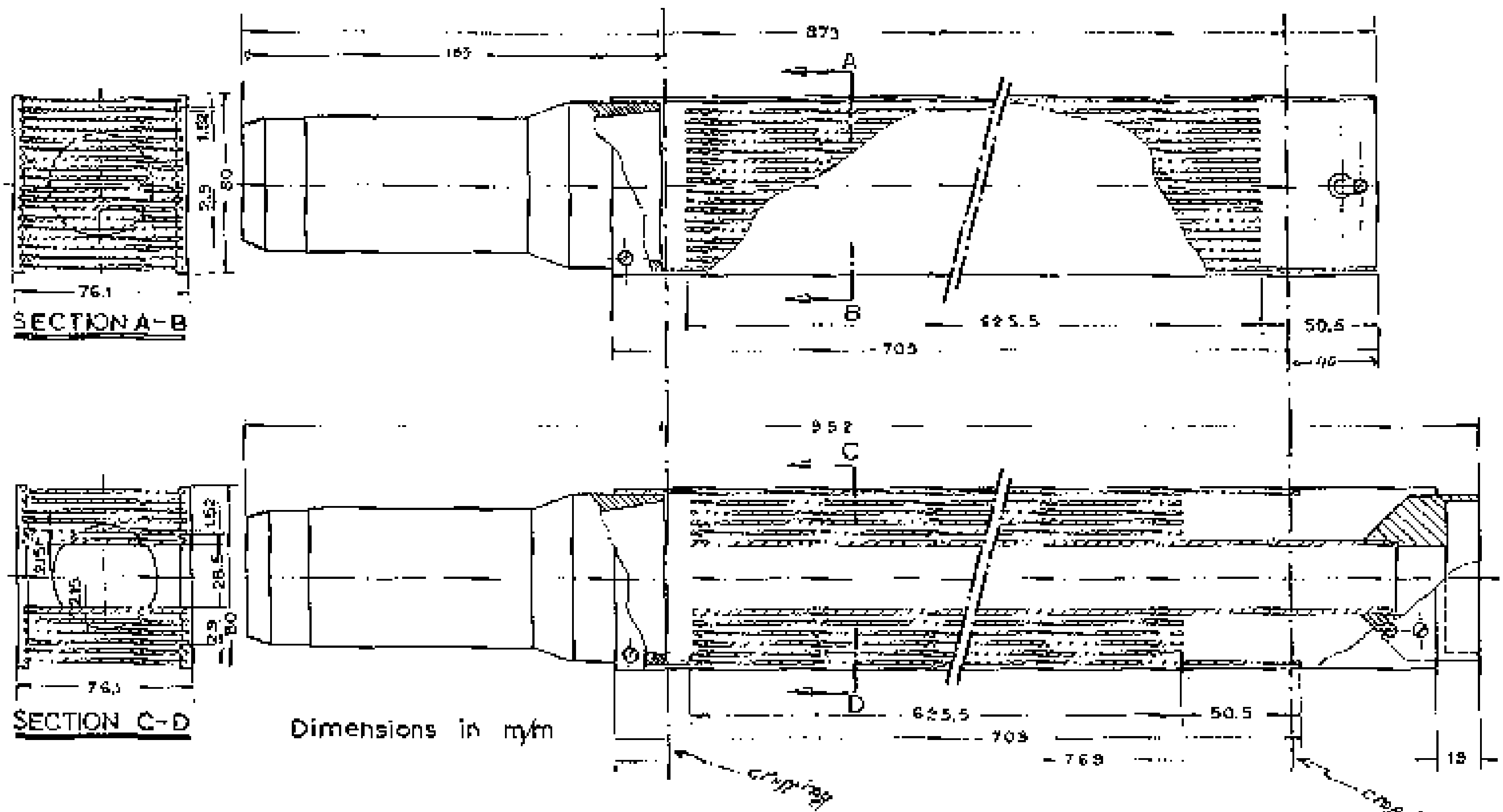

Fig. 4 "Standard„ and "Control„ fuel elements of the GRR-1 with plane plates.

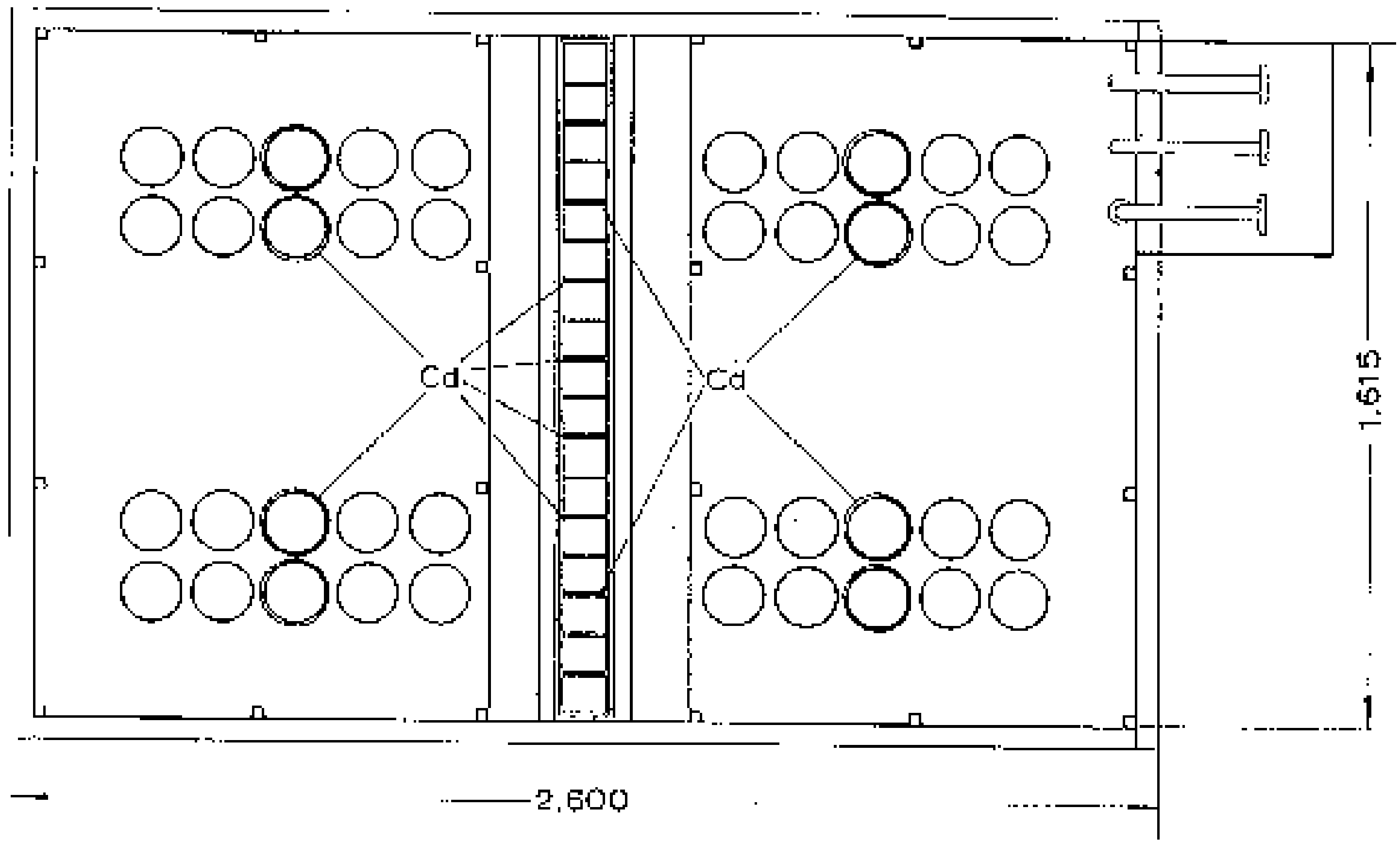

Fig. 5 Storage Tank, horizontal section.

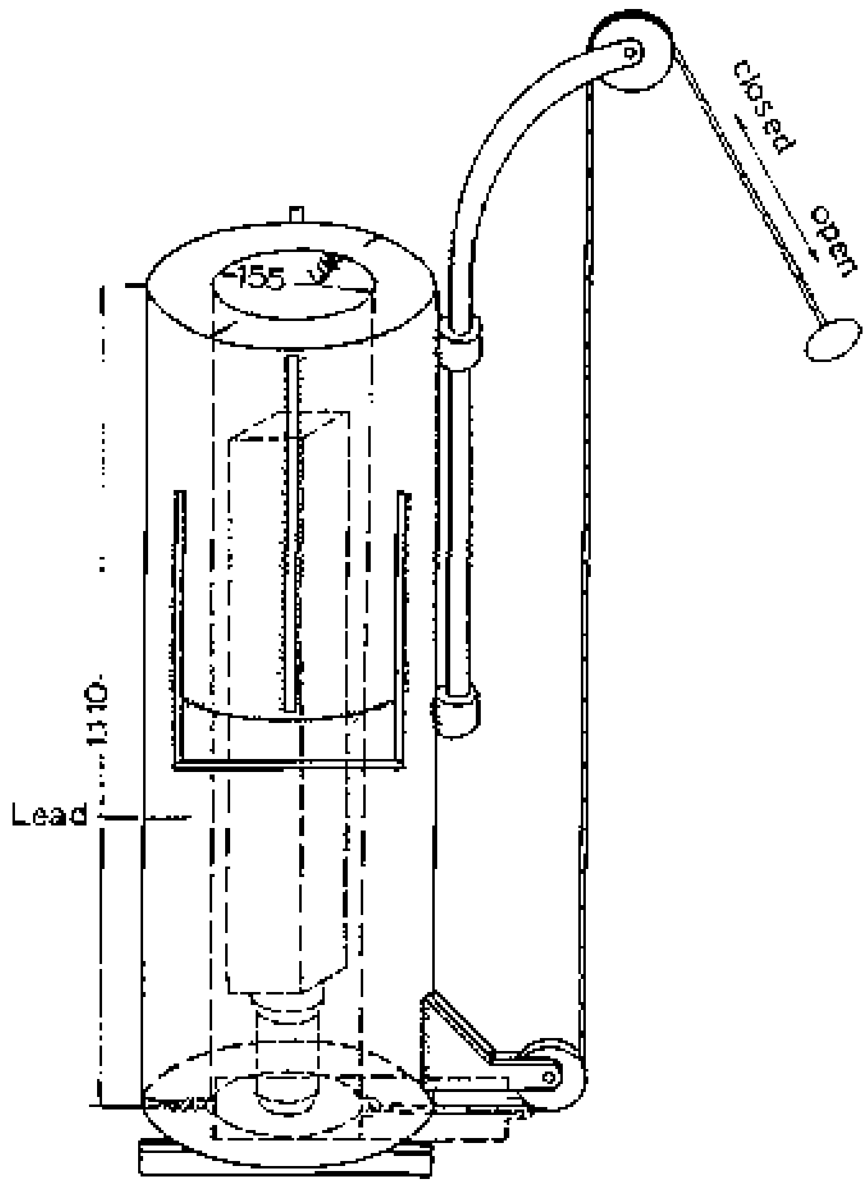

Fig. 6 Spent Fuel transportation container.

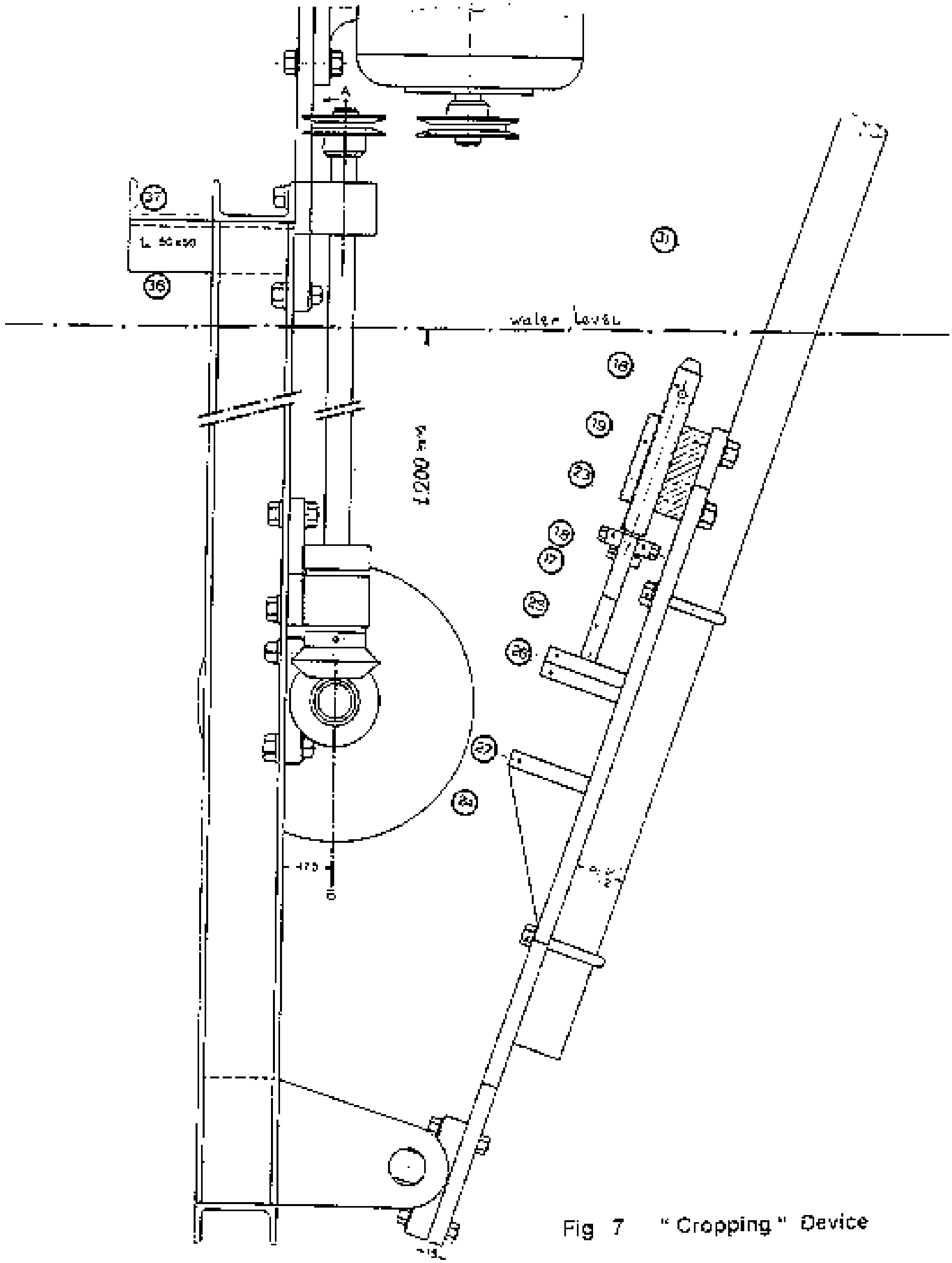

Fig 7 " Cropping " Device

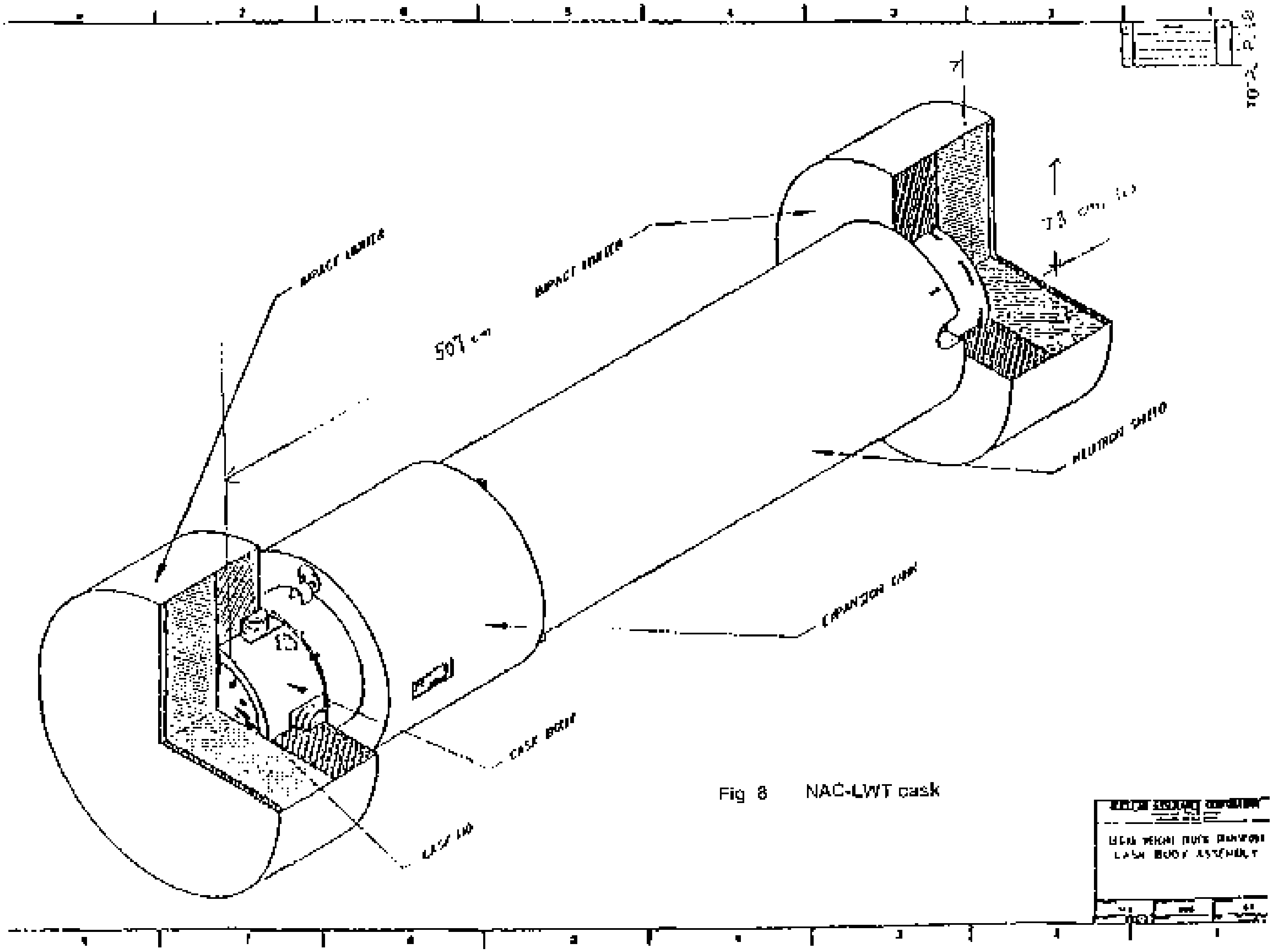

Fig 8 NAC-LWT cask

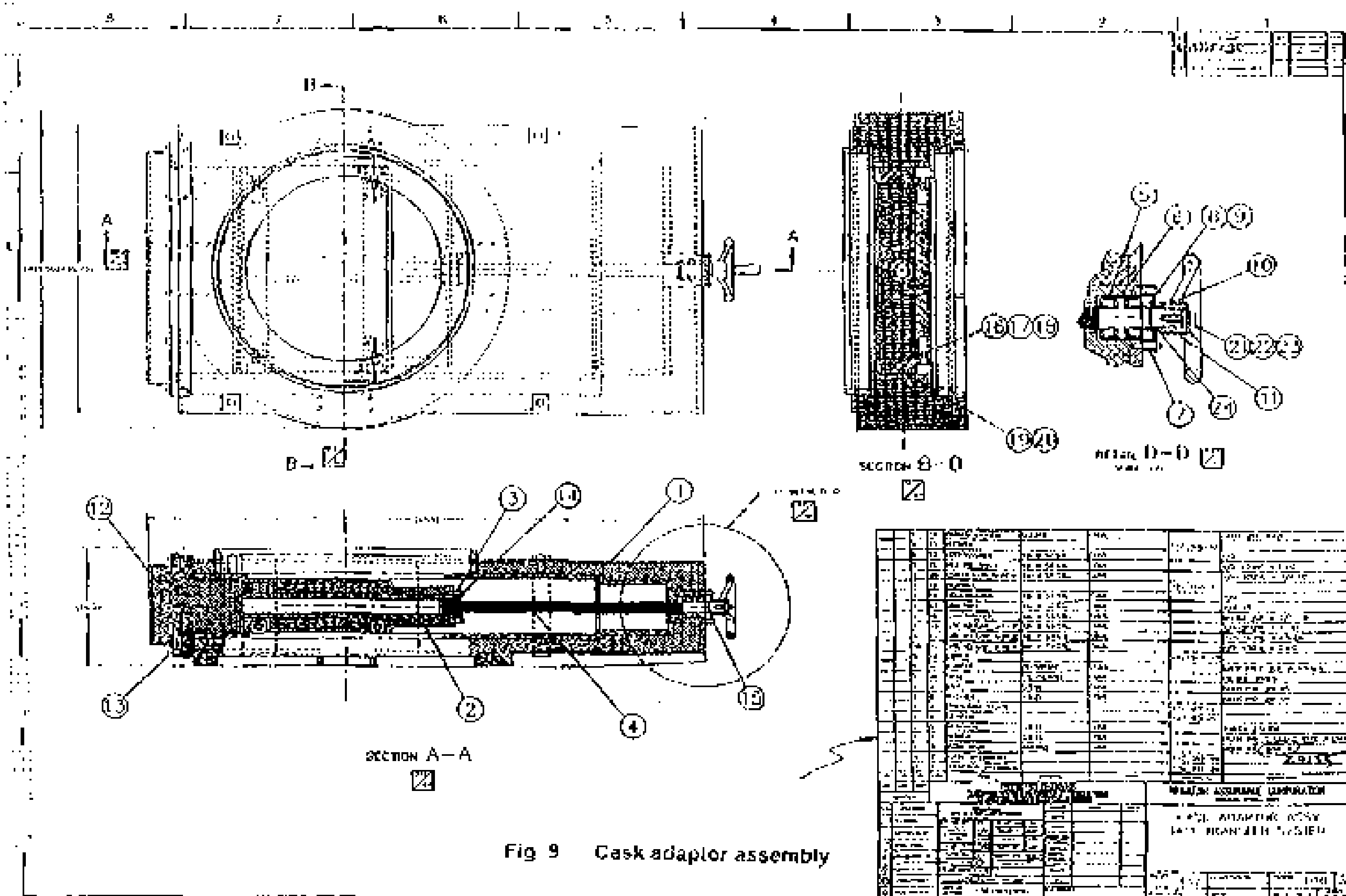

Fig 9 Cask adaptor assembly

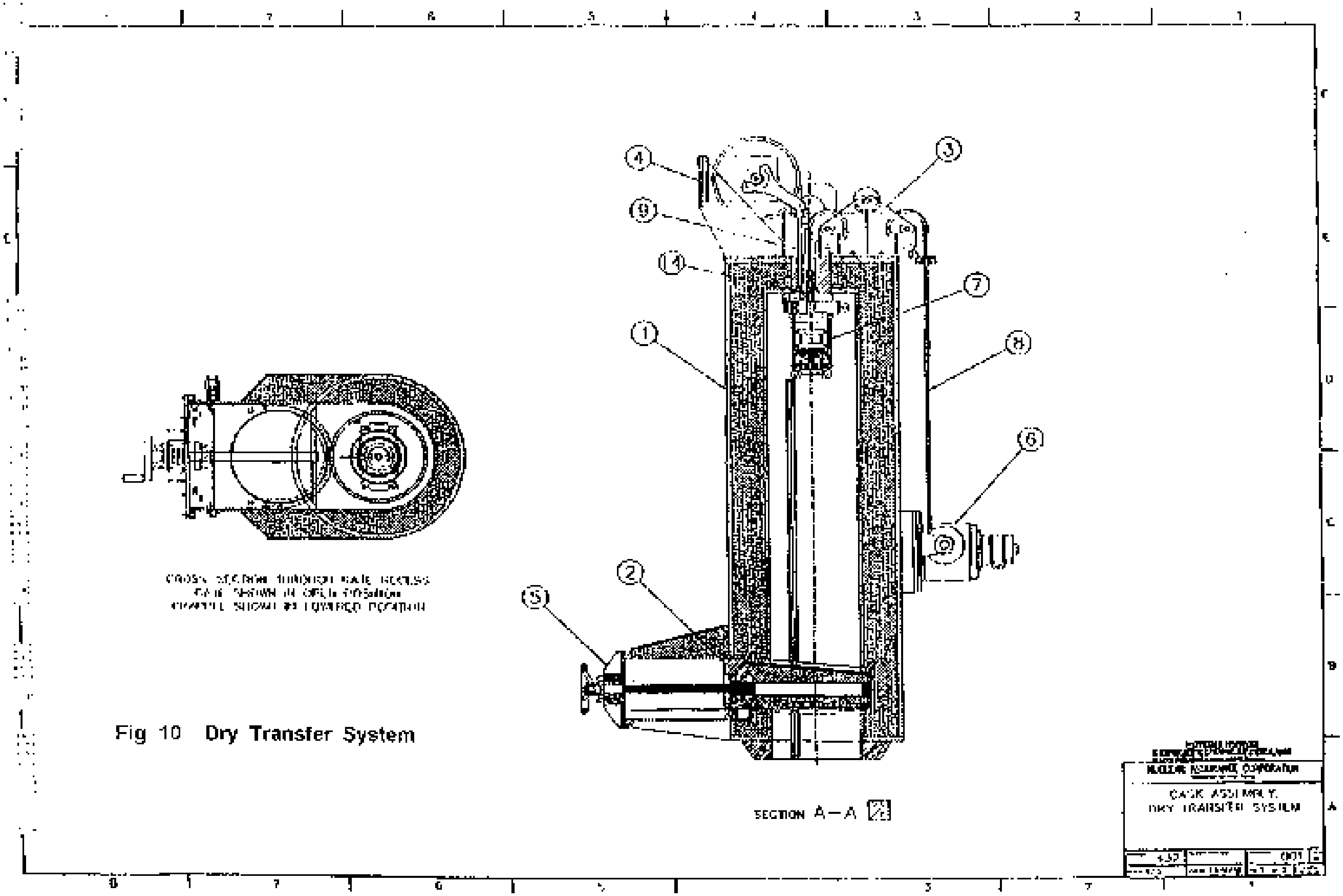

Fig 10 Dry Transfer System

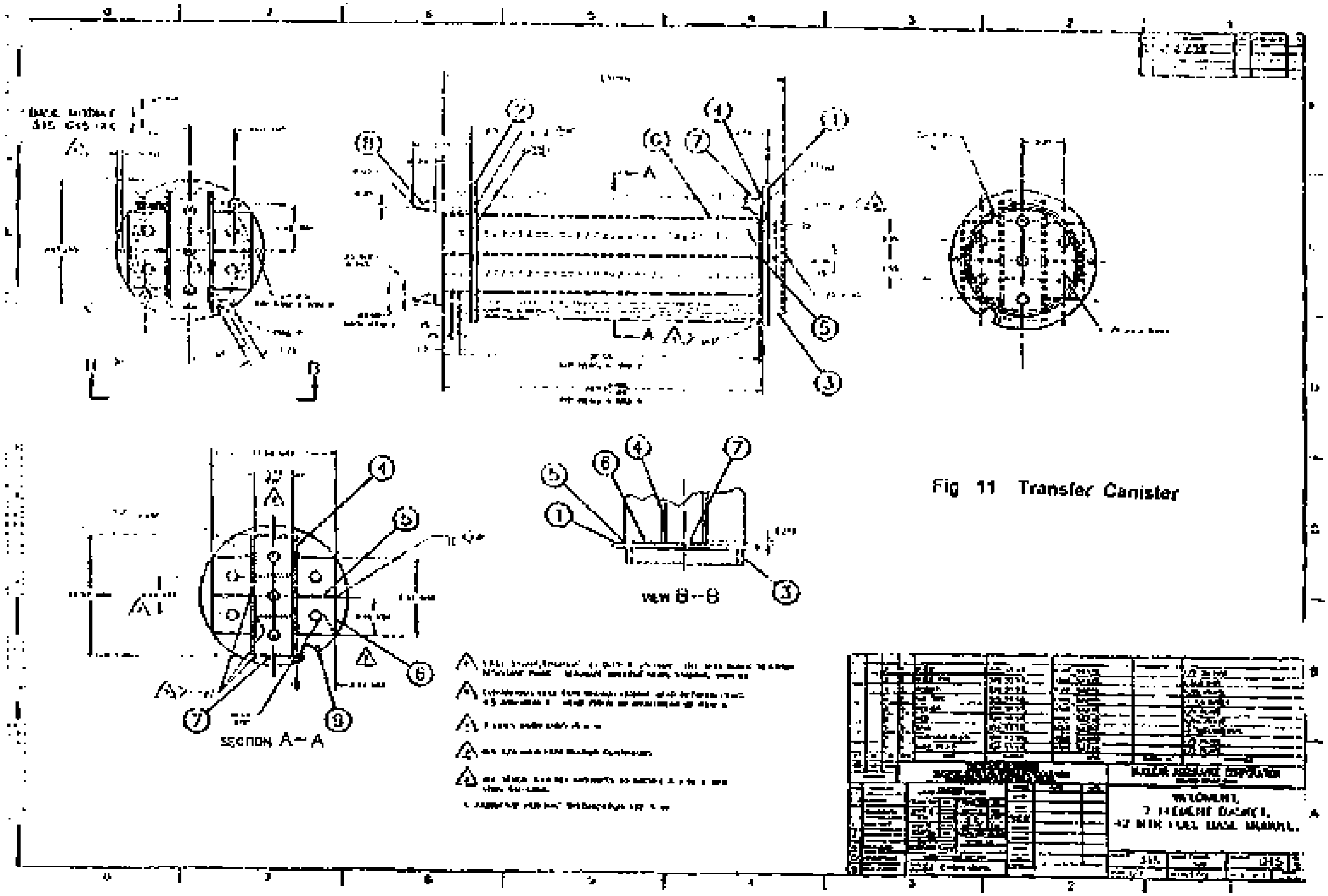

Fig 11 Transfer Canister

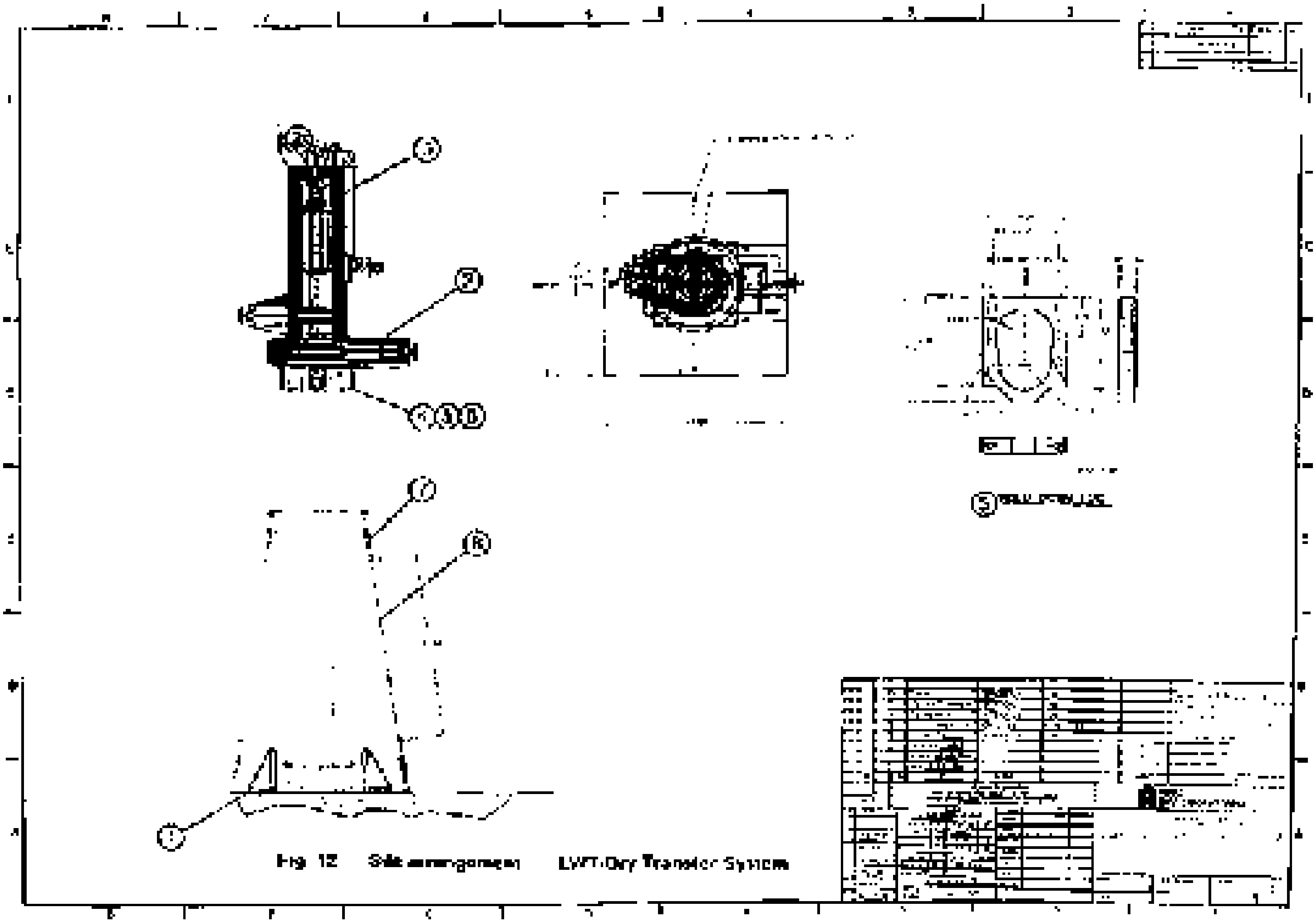

Fig. 12   Site arrangement   LWT-Dry Transfer System