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EUROPEAN ATOMIC ENERGY COMMUNITY - EURATOM

DESCRIPTION OF THE BETULLA INSTALLATION

by

P. GOLLINELLI, H. HOLTBECKER and M. MONTAGNANI

1970



ORGEL Program

**Joint Nuclear Research Center
Ispra Establishment — Italy**

**Engineering Department
Technology**

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Luxembourg, March 1970 - 44 Pages - 12 Figures - FB 60

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TABLE OF CONTENTS

	<u>Page</u>
1. INTRODUCTION	1
2. HIGH-TEMPERATURE CIRCUIT	1
2.1 Construction Data	1
2.2 Primary Circuit Heating System	2
2.2.1 Preheating of Pipes	2
2.2.2 Heating of Tanks S1, S2 and S3	3
3. VESSEL AND RELATED WATER CIRCUIT	3
3.1 Vessel	4
3.2 Water Circuit	4
4. HIGH-FLOW-RATE NITROGEN CIRCUIT	5
5. LOW-FLOW-RATE NITROGEN CIRCUIT	5
6. COMPRESSED-AIR AND VALVE-OPERATED MOISTURE-REMOVAL SYSTEM	5
7. BUILDING STRUCTURE AND CONTROL BUNKER	5
8. DESCRIPTION OF THE PRESENT TEST SECTION	6
8.1 Vessel	7
8.2 The ORGEL Channels	7
8.3 Feed Zone Elements	7
8.4 Control and Safety Rods	8
9. MEASURING INSTRUMENTATION	8
9.1 Installation	8
9.2 Earthing of Instruments	8
9.3 Continuous Recordings of Signals at Various Frequencies 0 - 4000 c/s	8
9.4 Probes and Measurement Lines	9
9.4.1 Absolute and Differential Pressure Measurements	9
9.4.2 Acceleration Measurements	10
9.4.3 Strain Measurements	11
9.4.4 Temperature Measurements	12
10. PREPARATION OF THE PRESENT TEST SECTION AND EXECUTION OF A TYPICAL EXPERIMENT WITH ORGANIC FLUID	12
ANNEX 1: DESCRIPTION OF THE MAIN COMPONENTS OF THE RIG	15-26
REFERENCES	27
LIST OF FIGURES	27

DESCRIPTION OF THE BETULLA INSTALLATION^{*)}

1. INTRODUCTION

In the safety study of the ORGEL test reactor, one of the fundamental problems was to ascertain whether, in the event of one channel bursting, this would cause a chain failure of the neighbouring channels (Ref. 1). As the answer could not be obtained wholly by calculation, a test rig was built in which this type of incident could be simulated (Fig. 11).

The rig is designed for use not only for the specific ESSOR problem, but generally for research on safety problems connected with the failure of a pipe in the primary circuit of a thermal device, and permits observation of the processes and consequences of such a failure.

As there is a risk of danger to personnel with these tests, the rig, which stands in an isolated area, is covered with a special light structure. While experiments are in progress the personnel involved are sheltered in a bunker designed to withstand external pressure, in which the controls and measurements are carried out.

The rig components are as follows:

- high-temperature circuit
- vessel and related water circuit
- high-flow-rate nitrogen circuit
- low-flow-rate nitrogen circuit
- compressed-air circuit with moisture-removal by valve control
- building structure and control bunker
- test section

In addition to the plant characteristics, the report contains a description of the operations entailed in a typical experiment with the rig, and of the special measuring instrumentation.

2. HIGH-TEMPERATURE CIRCUIT

2.1 Construction Data

The circuit (see flowsheet in Fig. 1) comprises two tanks S2 and S3, a pump and the test section, and has the following characteristics:

*) Manuscript received on 6 November 1969.

total capacity:	5 m ³
maximum pressure:	50 at
(maximum pressure of pump:	35 atm)
delivery of organic-liquid pump installed at present:	50 m ³ /hr
maximum temperature:	450°C

Next to the present pump the attachments are installed for a higher-delivery KSB pump of 100 m³/hr with a delivery diameter of 100 mm and a suction diameter of 150 mm, to be connected, with appropriate reductions, to the main circuit whose tubes have a diameter of 3".

The liquid leaving the pump enters the bottom of tank S2 and leaves it at the point diametrically opposite. There is, however, a baffle to facilitate the mixing and even distribution of the temperature in the tank. The S2 tank outlet is connected to the test section, from which the liquid goes to tank S3 and from there returns to the pump. The pump, tanks and test section each have a bypass. There are both manual and automatic valves. The manual valves are of the gate type with packing seals, the automatic ones being operated by compressed air through diaphragms or pistons according to the response speed required, and have cooling fins on the stem. The maximum pressure differential is 50 atm. The circuit is also connected to a storage tank S1. This can hold the whole of the circuit liquid and is also designed to serve as a preheater for substances that are solid at ambient temperature. A detailed description of the tubing and tanks and a list of the valves are given in Annex 1.

2.2 Primary Circuit Heating System

2.2.1 Preheating of Pipes

Preheating of the pipes is essential where the fluid circulated is solid at ambient temperature. To prepare the rig for work with this type of fluid, all the pipes and valves in the main circuit can be heated by means of Pyrotex heating cable wound round the outside of the tube-section or valve to be heated. Each heating element is 17 m long, with an output of 1320 W, and is wound in such a way that the maximum temperature on the pipes will not exceed 200°C. The 220 V

power supply to the heating cables is controlled from inside the bunker by means of switches, which energize relays located in three leaktight boxes. Each individual relay, and consequently each individual heating element, is protected by a fuse, so that every section can be operated separately.

2.2.2 Heating of Tanks S1, S2 and S3

Tanks S1, S2 and S3 are equipped with electric heating devices for raising the fluid to the desired temperature and keeping it there. In tank S1 the heating is provided by a battery of Hynes electric immersion heaters fitted at the bottom of the tank.

The external diameter of each heating element is 3"; the total power of the heating battery is 70 kW over four elements and is arranged so that the specific power at the element surface shall not exceed 1.5 W/cm^2 . The heating system used in tanks S2 and S3 is basically of the same type, differing in the number, arrangement and total power of the elements. To avoid overheating the elements, the layout in these tanks is such that, according to the level of the liquid, all or only the lower half of the battery can be switched on, so that the hot elements will always be immersed in the liquid.

Each of the two tanks S2 and S3, therefore, is equipped with two sets of elements installed one above the other. In tank S2 the total power is 80 kW (40 kW per set); tank S3 has a total power of 55 kW (27.5 kW per set). The specific surface output of all four sets of elements is less than 1.65 W/cm^2 . All the elements in tanks S1, S2 and S3 are operated by remote control from the bunker and the temperature can be regulated automatically.

3. VESSEL AND RELATED WATER CIRCUIT

The vessel and the water circuit, which simulates the moderator circuit and can be connected up to the channels, consist of two main parts, as follows (see Fig. 2).

3.1 Vessel

The vessel simulates the ESSOR reactor vessel and has the characteristics described in Annex 1 (Figs. 3 and 4). Components simulating the channels and other core components can be passed through the two dished heads. One or more of these components can be connected to the high-temperature and/or the water circuit.

The vessel is of extra-rugged construction, since the bursting of a channel is likely to subject it to considerable dynamic stresses. For greater strength it was hooped with three rings and supported by four strong brackets, which transfer the load to the prestressed concrete base.

3.2 Water Circuit

The water circuit comprises a pump P2 and a boiler. The total capacity of the circuit including the vessel is 12 m^3 , the maximum operating static pressure is 12 kg/cm^2 at a maximum temperature of 185°C and the pump's maximum delivery is $72 \text{ m}^3/\text{hr}$. The water is pumped by P2 out of the vessel and into the boiler, whence it can be sent to the vessel and to any water-cooled channels (the feeding zone channels in the case of ESSOR). The boiler is fitted with two 60 kW immersion heater elements, i.e., a total of 120 kW. These elements, which are operated and regulated from inside the bunker, are cut out by a ball-cock system if for any reason the pump fails to maintain a sufficient level in the boiler to keep the elements submerged; this prevents overheating and destruction of the elements. The circuit is closed and the water temperature can be raised to the level required for experiments.

All the pipes, valves and the pump in the water-circuit can be preheated (see description in Section 2.2.1), the pipe heating in the primary and water circuits being identical. Preheating is necessary because in the channel-failure experiments the fluid from the high-temperature circuit enters the vessel.

4. HIGH-FLOW-RATE NITROGEN CIRCUIT

The high-flow-rate nitrogen circuit (see Fig. 2) consists basically of a tank of 1.5 m^3 capacity, loaded by a cylinder set to a maximum pressure of 85 kg/cm^2 . Connected to this tank a reducing valve (diameter 125 mm, maximum delivery $20,000 \text{ Nm}^3/\text{hr}$) offsets the pressure drop caused by escape of the liquid following the bursting of the channel connected to the high-temperature circuit. When the reducing valve has been set to the desired pressure, the nitrogen circuit can also be employed, by remote control from the bunker, for fast pressurizing of the tank S2 and even of the whole circuit if it is connected to it.

5. LOW-FLOW-RATE NITROGEN CIRCUIT

The low-flow-rate nitrogen circuit (see Fig. 2) consists of a set of eight cylinders which feed four reducers through a 1" tube. Specifically these are one reducer which pressurizes the vessel up to 12 kg/cm^2 , one which pressurizes the tank S1 up to 4 kg/cm^2 , and two reducers, remote-controlled from the bunker, with a nitrogen flow of $1000 \text{ m}^3/\text{hr}$ for pressurizing tanks S2 and S3 respectively. With this system the pressure and, therefore the level can be kept constantly balanced, under all operating conditions, in each separate tank, despite small variations in the flow-rate.

6. COMPRESSED-AIR AND VALVE-OPERATED MOISTURE-REMOVAL SYSTEM

This unit includes a compressor, a tank and an air drier and purifier. The diaphragm compressor (delivery $43 \text{ m}^3/\text{hr}$) pressurizes a 600 litre tank to 7 kg/cm^2 . The air is sent from the tank via the drier to the reducers, which keep the pressure constant at the desired value. The drier is of the carbon-ring type, and these periodically need regenerating. This can be done as the plant is fitted with a regenerator. Other equipment includes an air cooler at the compressor outlet, a condensate separator and a check valve.

7. BUILDING STRUCTURE AND CONTROL BUNKER

The building structure comprises a shed of light corrugated sheet metal, the concrete foundations, a cylindrical prestressed-concrete

pit to house the vessel, a reinforced-concrete bunker, and an outside waste pit of concrete (see Figs. 5 and 6).

The light building can be dismantled easily for removal of the larger components (vessel, tanks, etc.). The various foundation sections are independent of each other, so as to obviate stresses due to soil subsidence.

Particular attention was given to the construction of the cylindrical housing for the vessel. This consists of a main hoop, at ground level, the four brackets of which take up the dynamic vessel thrusts due to failure of the test-section. This hoop, which rests on a prestressed cylindrical structure, is designed to withstand a horizontal static thrust of 180 and a weight of 60 metric tons.

The bunker, an integral oblong reinforced-concrete structure, can withstand an external static pressure of 2 kg/cm^2 . The bunker has two main openings for the leaktight steel doors, of heavy sheet iron, two leaktight penetrations for the instrumentation, three toughened-glass peepholes for observing the installation, five round ports at the back, and one opening for the air conditioner, which is locked during the experiment.

The pit is used for discharging water and high-temperature liquid after the experiment and can be reached, via a chute, by mechanical appliances for cleaning operations.

8. DESCRIPTION OF THE PRESENT TEST SECTION

The present test section is a 1:1 scale simulation of the ESSOR test reactor core. Hence the two heads of the vessel have the same pitch as that reactor (Fig. 3). The core consists of 12 internal ORGEL (i.e., organic-cooled) channels, 16 feeder elements water-cooled, and 16 safety and control rods, which form the outermost ring.

One quarter of the core is simulated with real elements, i.e., with the actual geometry and actual materials of the elements used in the reactor. The other three quarters are represented by aluminium tubes with the same external diameter as the actual elements.

8.1 Vessel

The test vessel, unlike the actual ESSOR vessel, has dished heads to give it greater strength, because it has to stand up to greater stress conditions. A false bottom, however, is fitted to guide the elements at the same level as that formed by the flat bottom in the actual vessel. The top cover of the vessel, which can be used to house a gas plenum, is connected via a 300 mm (12") diameter pipe, which divides into two of 300 mm diameter each, to the safety discs, which may operate during the test.

From the discs the pipes lead to the outside pit. There is also a drain in the bottom head, which carries the liquid (light water in the experiments) away to the pit.

8.2 The ORGEL Channels

The ORGEL channel (Fig. 7) consists of a SAP 10% Al_2O_3 pressure tube rolled onto two stainless steel ends which are connected to the high-temperature circuit. A calandria tube, which may be of aluminium or Zircaloy-2, depending on the test, separates the pressure tube from the water used to simulate the moderator. The gas-filled space between the two tubes provides the heat insulation.

The pressure tube and, sometimes, the calandria tube are weakened by milling so that failure will occur along the desired generatrix and at the desired pressure. A system of expansion joints is fitted to permit differential expansion between the pressure tube and the calandria tube. The experiment can be conducted with or without the fuel element (Fig. 8) inside the pressure tube.

8.3 Feed Zone Elements

These (Fig. 9) are simulated simply by a double tube in which tap-water circulates and are connected to the water circuit so as to reproduce the actual temperature distribution on the outer tube after the impact of the hot liquid escaping from the channel connected to the high-temperature circuit.

8.4 Control and Safety Rods

Of these (Fig. 10), only the guide tube is present in the simulated core; it may be of aluminium or Zircaloy, depending on the test. As in the actual case, the inside contains gas at the desired pressure.

9. MEASURING INSTRUMENTATION

9.1 Installation

During the experiments, up to a maximum of eighty measurement points were plotted dynamically at the same time. The signals are transmitted by shielded cables from the sensors in the test section to the bunker. The cables run through an underground duct in tubes of about 3" diameter. The tubes can be closed to prevent the infiltration of gas or vapours into the bunker in the event of an accident occurring during the tests. Inside the bunker (see Fig. 12) the measuring instruments can be kept at a constant temperature so that maximum accuracy is ensured.

9.2 Earthing of Instruments

The rig has two earths, the mains earth at elevation -1 m and the measurements earth at about -6 m. The object in separating the two earths is to reduce the background noise as far as possible, as in this way very high sensitivity and accuracy is obtained. This system proved invaluable for readings using the magnetic recorder.

9.3 Continuous Recordings of Signals at Various Frequencies 0 - 4000 c/s

A large proportion of the recordings needed do not require a higher band-pass. In order to obtain a direct visual recording we used six galvanometric UV strip-chart recorders. Each of these can be equipped with fifty galvanometers, but as the chart is about 30 cm wide, it is advisable to use not more than about 15 tracks per instrument, so that the results can be read easily. As the instruments are connected to a single timer, the coincidence of all the measurement points can always be determined exactly. The maximum chart speed is 2 m/sec.

The galvanometers have various sensitivities, according to their natural resonance frequencies. The maximum natural frequency is 8000 c/s.

0 - 20,000 c/s

A CEC 3300 magnetic recorder is used and the signal is recorded in frequency modulation. In all, seven signals can be recorded on a 1/2-inch wide tape.

Here again the signal can be plotted. For this purpose the recording is made at the maximum tape speed (60"/sec) and the signal is played back at 7.5"/sec and simultaneously recorded on the chart recorder described above.

0 - 500,000 c/s

A CEC 3600 magnetic tape recorder is employed. At present the instrument is fitted for three channels (out of a total of seven) for direct and frequency modulation recording.

Reproduction can also be effected here with the system described above, i.e., recording of signal on CEC 3600 at maximum speed; replay at 3³/₄" /sec and simultaneous recording on CEC 3300 at 60"/sec; replay on CEC at 1⁷/₈" /sec and recording on chart recorder.

By this method the time scale is lengthened by a factor of 1024. The total error introduced is $\pm 10\%$.

400 c/s - 1.5 Mc/s

For μ sec rise times and for signals repeated in time, a Mincom CM 100 magnetic recorder is used. It should be borne in mind that frequencies lower than 400 c/s cannot be recorded. Readings are obtained with an oscilloscope coupled to a Polaroid camera.

9.4 Probes and Measurement Lines

9.4.1 Absolute and Differential Pressure Measurements

The following transducers were used and are available:

<u>Type</u>	<u>Model</u>	
CEC absolute pressure	4-317	resistor bridge
SEL differential pressure		inductive
Endevco absolute pressure	2501	capacitive
ACB " "	G 7000	capacitive
Southern " "	62025	capacitive

All these probes have response times corresponding to a 0 - 5000 c/s band-pass. They are no longer adequate when pressures with rise times comparable to those of shock waves have to be measured. For that purpose we used Kistler and Vibrometer piezoelectric transducers. We also used transducers designed by ourselves to meet the various operating requirements, e.g., immersion in water or contact with high-temperature liquid. The principal types of transducer developed were:

piezoelectric transducer without protective diaphragm, to function in water at temperatures up to 120°C and rise times of $< 3 \mu\text{sec}$;

bar transducer for measuring high pressures with rise times of $< 1 \mu\text{sec}$;

inductive transducer with temperature compensation up to 500°C.

All the transducers for high frequencies were calibrated in a shock tube in which various pressure rise times can be produced by a special device. For a more detailed description see Ref. 2. The following amplifiers were used for the various types of sensor:

Vibrometer, General Electric, Hottinger (KWS/II-5, KWS/II-50) and Brandau.

9.4.2 Acceleration Measurements

Acceleration measurements were effected on the outside of the hot tanks with CEC 4-202-0001 and Endevco 2227 accelerometers.

For vibration measurements in organic liquid at 420°C inductive transducers were built in order to obtain data on the behaviour of the element inside the test channel.

4.3 Strain Measurements

- a) Strain measurements on structures in water at temperatures up to 100°C.

The high cost of Microdot weldable strain-gauges is offset by their convenience and ruggedness. Hitherto it has been impossible to waterproof standard strain-gauges so as to obtain a constant earthing insulation of 100 MΩ. The Microdot strain-gauges (SG 122 and SG 132) are supplied with the connecting cables already sheathed in stainless steel tubes that will withstand an external pressure of 175 atm.

The strain-gauge is spot-welded to the structure. Each measuring point is composed of the active strain-gauge welded to the test structure and a passive resistance located in the bunker. Because of the long connecting cables - in some cases over 20 m - it was necessary to amplify the compensating power of the measuring bridges by adding precision resistances and capacitors, which together with the passive resistance are housed in a "compensation device" of our own design. Calibration is effected with a calibration bridge consisting of 600 Ω resistances with a K factor of 2. As the amplifier bridge is also based on a K factor of 2, the recorder reading is accurate. The strain-gauges used have a K factor of 1.8 ±5.0%. To obtain the actual deformation, the recorded values must be multiplied by 1.11. This factor increases to 1.13 if the drop in sensitivity due to the length of the cable is taken into account.

To the occasional error value of ±5% given for the K factor should be added the amplifier errors, evaluated at ±1%, and the galvanometric recorder errors of ±10%.

Taking all the occasional errors together, therefore, the results may be distorted by ±16%. It must be understood that to keep the error within these limits there must be no variation in either the temperature on the strain-gauge during measurement or the earthing insulation, which must in all cases remain higher than 100 MΩ.

About 40 simultaneous strain measurements can be performed at present.

- b) Strain measurements at temperatures up to 400°C in insulating liquid or gas.

Budd strain-gauges (e.g., type C 1Z-620) are employed here. The same firm also supplies the special high-temperature cement.

9.4.4 Temperature Measurements

Dynamic temperature measurements were carried out on water-submerged structures attacked by a jet of hot liquid. The following Sodern thermocouples were used:

2 ABAC	0.25 mm diameter	
2 ABAC	0.5 mm	"
2 ABAC	1 mm	"

The diameters quoted are those of the outer sheath containing the two insulated wires (0.2 mm dia.) that form the thermocouple. For mounting purposes, each thermocouple wire is welded to the wall of the structure. This entails preventing the infiltration of water into the Al_2O_3 powder which insulates the wires and the sheath. Treatment was carried out with Aerosil and ensures complete watertightness up to temperatures of 300°C. The Sodern cable is passed to the vessel wall, where it is joined to a Lemo connector. The line continues with a compensating cable as far as the reference joint in melting ice. A copper cable leading away from this point can be connected either directly or via a d.c. amplifier to the galvanometric recorder. The response times of the thermocouple and measurement line are $< 1/100$ sec. Measurement is accurate to within $\pm 2\%$ at 400°C.

10. PREPARATION OF THE PRESENT TEST SECTION AND EXECUTION OF A TYPICAL EXPERIMENT WITH ORGANIC FLUID

The object of the experiment described here was to study the effect the bursting of the ORGEL channel would have on an adjacent ORGEL channel, on the neighbouring feeder channels and control rods, and on the vessel.

The first step in setting up the experiment is the construction of the ORGEL channels. The pressure tubes, of SAP 10% Al_2O_3 , and the calandria tubes (aluminium for the burst channel, Zircaloy for the adjacent channel) are subjected to measuring and non-destructive tests.

Next, the pressure tube is rolled onto the two steel ends. Then the pressure tube and the calandria tube are weakened for the burst channel by grinding along a generatrix. The adjacent ORGEL channel is mounted in the vessel and fitted out with strain-gauges and thermocouples fitted on the calandria tube. The weakened channel is then installed, with its weakened area facing in the required direction.

The next step is to install and calibrate a pressure transducer, connected to the insulating gas-filled space between the pressure and calandria tubes, which signals the bursting of the pressure tube and the pressurization of the calandria tube. Other pressure transducers are mounted on various parts of the vessel. One by one the other channels (feeder and control-rods) are inserted and fitted with strain-gauges and thermocouples. Altogether about eighty measuring points are employed in this test.

After the high-temperature circuit pipe and tanks have been preheated, the organic liquid is released from the storage tank into the circuit, bypassing the test section in the vessel. The pump P1 is started up and power fed to the S2 and S3 tank heaters. At the same time the vessel is filled with water, circulated by pump P2 through the boiler.

When the temperature reaches $80^{\circ}C$ in the water (i.e., above the organic melting point) and about $360^{\circ}C$ in the organic liquid (i.e., below the boiling point at ambient pressure), the organic liquid flow to the test section is opened by cutting out the bypass.

The water temperature is then brought down to the test value (about $50^{\circ}C$) by draining the hot water off and replacing it with cold. At the same time the organic liquid continues heating up to the test temperature (about $400^{\circ}C$). At this point the personnel leave the rig and retreat to the bunker, shutting it carefully.

The subsequent operations are all actuated from the bunker. The only personnel remaining outside, at a safe distance, are those on firefighting and first-aid duties.

The measuring instrumentation is checked, and then pump P1 is cut out and the high-flow-rate gas circuit switched in; this raises the pressure in the tank S2 - and hence the whole circuit - to the level at which the pressure tube in the weakened channel fails.

When failure occurs, the flow of organic liquid into the vessel and the nitrogen flow are continued for a period of normally less than 30 seconds. Then the quick-acting intercept valves VA1 and VA2 close, cutting off the organic ingress, and the operative part of the experiment can be regarded as terminated. The vessel is then emptied and cleaned out and the results analyzed.

DESCRIPTION OF THE MAIN COMPONENTS
OF THE RIG

1. VESSEL

The vessel, designed for a pressure of 12 kg/cm^2 at a temperature of 190°C , has the following specifications:

- internal diameter: 2380 mm
- height of cylindrical part: ~ 2300 mm
- plate thickness: min 16, max 18 mm Aq 42
- heads, max design thickness: 26 mm Aq 42
- material, carbon steel Aq 42

Construction: welds checked and radiographed. Interior zinc-galvanized. The vessel has two dished heads with appropriate connections (as shown in our drawing No. 133.0.6) and more specifically:

- 12 fuel elements (labelled 1), of which three in particular can be connected up to the organic circuit
- 16 feed zone elements (labelled 2)
- 16 control and safety elements (labelled 3 and 4)

Elements 2, 3 and 4 are centred on a bottom grid. Both heads also contain the following penetrations:

- five holes each, $\frac{3}{4}$ " max., for passing thermocouples and strain-gauges
- two threaded holes each

The upper head also contains:

- a connection for 300 mm dia discharge pipe (rupture discs)
- nitrogen circuit connection
- safety valve connection
- nozzle height, first part: about 900 mm
(for three nozzles) from bottom dia 6" (Schedule 80)
- nozzle height, second part: about 100 mm
(for nine nozzles) dia 6" (Schedule 80)

- nozzle height, third part: about 900 mm
(for four nozzles from bottom) dia 5" (Schedule 80)
- nozzle height, fourth part: same elevation of nozzles 2 dia 5"
(Schedule 80)
- nozzle height, fifth part: about 900 mm
(for four nozzles) dia 3" (Schedule 80)
- nozzle height, sixth part: same elevation 2 and 4 dia 3"
(Schedule 80)
- blind flanges for nozzles in upper part
- blind counterflanges for top nozzles in false-tube zone
- false bottom suitably supported, max. thickness 15 mm
- 32 centring supports for tubes
- nozzle height, position 1, from false bottom downwards
1780 mm (for three nozzles) dia 6" (Schedule 80)
- bottom nozzle height, position 2 (for nine nozzles)
100 mm, fitted with blind counterflanges
- boiler tolerances for nozzles 2, 4 and 6

All the above tubes are bolted to facilitate dismantling. On the bottom head there is a 100 mm dia flange for the water discharge. In the cylindrical part there are two 200 mm dia inspection ports and one manhole, dia 450 mm, located alongside the test section.

2. ORGANIC CIRCUIT - TANKS

2.1 Tank S2

Tank S2 (net capacity 3 m^3) is designed for a pressure of 50 kg/cm^2 and a temperature of 450°C and meets the following specifications:

- outer diameter: $\sim 950 \text{ mm}$
- height of cylindrical part $\sim 4900 \text{ mm}$
- minimum thickness: 25 mm
- heads dished
- materials of CrMo steel, with similar characteristics to type UNI 15-CD-3.

Construction: welded, checked, radiographed and then annealed.

Tank S2 has flanged openings suitably distanced from the outer wall:

- two 3" dia connections to organic circuit
- two connections to nitrogen circuit and vents
- two connections to safety valve and rupture disc
- two 8" hand ports for heater control.

The tank is fitted internally with 3" dia vertical tube heaters, with a total capacity of 80 kW. The pipe connections are arranged so as to permit gravity dumping of the rig and to ensure, with the pump in operation, uniform distribution of the temperature in the liquid.

2.2 Tank S3

Tank S3 (net capacity 2m^3) is designed for a pressure of 50 kg/cm^2 and a temperature of 450°C and meets the following specifications:

- outer diameter $\sim 950\text{ mm}$
- height of cylindrical part: $\sim 3560\text{ mm}$
- minimum thickness: 25 mm
- heads dished
- material, Cr Mo steel, with similar characteristics to type UNI 15-CD-3.

Construction: welded, checked, radiographed and then annealed.

Tank S3 has flanged openings suitably distanced from the outer wall:

- two 3" dia connections to organic circuit
- two connections to safety valve and rupture disc
- two connections to nitrogen circuit and vents
- one 8" dia hand port.

The tank is fitted internally with 3" dia vertical tube heaters. The specific power on these tubes is equal to or less than 1.65 W/cm^2 . The total output of the heaters is 55 kW. The pipe connections are arranged so as to permit gravity dumping of the rig and to ensure, with the pump in operation, uniform distribution of the temperature in the liquid.

2.3 Storage Tank

The storage tank (net capacity 5 m³) is designed for a pressure of 4 kg/cm² at a temperature of 200°C and meets the following specifications:

- diameter: 1400 mm
- height, cylindrical part: 2900 mm
- minimum thickness: 10 mm
- head dished
- material: carbon steel Aq 42

Construction: welded, checked, radiographed and annealed in accordance with ASME UW 52 standards.

The tank has flanged openings suitably distanced from the outer wall:

- one 18" dia. opening for charging
- one connection to organic circuit
- two connections to nitrogen circuit and vents
- one connection to safety valve
- one discharge to tank, with manually-operated valve VM 14.

The tank is fitted with horizontal sheathed heating elements for the organic liquid, and with heater-support flanges (in lower third of tank). The heaters have a specific power equal to or less than 1.65 W/cm³ and a total output of 30-40 kW.

3. PIPES

3.1 Organic Circuit Pipes

Pipes 3" in dia in Aq 35 or ASTM A-106 Grade B, dimensions according to ASA B-16-10, extra-strong thickness, flange ASA 600-B 15-5 ring-joint; the charge and discharge tubes and the vents are of standard thickness (Schedule 40).

For 2¹/₂" or larger pipes, carbon steel flanges, dimensions according to ASA B-16-5, series 600 LB with collar, RJ.

For 2" or smaller pipes, 600 RF flanges with Flexitallic or soft iron seals. Tie bolts and nuts in high-strength carbon steel.

2 Vessel Pipes

Pipes 12" in dia in Aq 35 or ASTM A-106 Grade B, dimensions according to ASA B-16-10, standard thickness (Schedule 40).

Pipes 8, 6 and 4" in dia Aq 35 or ASTM A-106 Grade B, dimensions according to ASA B-16-10, standard thickness (Schedule 40).

Flanges in carbon steel according to ASA B-16-5, series 150 LB with collar, RF 1/16".

3 Water Circuit Pipes

3" dia zinc-galvanized pipes in Aq 35 or ASTM A-106 Grade B, dimensions according to ASA B-16-10, normal thickness (Schedule 40).

Flanges in carbon steel according to ASA B-16, series 150 LB to be lap-welded, RF 1/16".

VALVES

1 Organic Circuit Valves

- two 3" dia automatic valves (VA1, VA2) in molybdenum-alloy carbon steel, body series ASA 600, extra-rapid automatic action (less than 1 sec) with electromagnetic control;
- four 3" dia automatic valves (VA3, VA4, VA5, VA6) in molybdenum-alloy carbon steel; body ASA 600 series, pneumatic action with electromagnetic control;
- eleven 3" dia manual valves (VM 1, 2, 3, 4, 5, 6, 7, 8, 14, 15, 16) in molybdenum-alloy chrome steel, body series ASA 600;
- five 2" dia manual valves (VM 13) in carbon steel body series ASA 150.

2 Water Circuit Valves

- four 3" dia automatic valves (VA 8, 9, 10, 11) in carbon steel, pneumatic action with electromagnetic control, ASA 150;
- four 3" dia manual valves (VM 9, 10, 11, 12) in carbon steel, ASA 150;
- three 2" manual valves (VM 17 + 2 for pump cooling circuit) in carbon steel, ASA 150;
- one safety valve (VS7) in carbon steel, pressure setting 12 kg/cm², temperature 200°C.

4.3 Off-Gas Circuit Valves

- one 6" dia automatic valve (VA 17), ASA 150, pneumatic action with electromagnetic control (vessel vent);
- two 1" dia automatic valves (VA 16, VA 18) in carbon steel, ASA 600 LB (S2 and S3 vents);
- one 3" dia valve VA 19, ASA 150; pneumatic action (S1 vent);
- one 4" dia automatic valve (VA 12) in carbon steel, ASA 150 LB;
- one 6" dia automatic valve (VA 100), carbon steel body, series ASA 600 RJ (high nitrogen flow);
- two 1/2" dia automatic valves (VA 101, VA 102) carbon steel body, series ASA 600 (low nitrogen flow).

4.4 Safety Valves

- one 8" dia safety valve (VS1) in carbon steel, pressure setting 12 kg/cm², temperature 200°C;
- two 3" dia safety valves (VS2, VS3) in molybdenum-alloy carbon steel, pressure setting 50 kg/cm², temperature 450°C;
- one 3" dia safety valve (VS6) in molybdenum-alloy carbon steel, pressure setting 30 kg/cm², temperature 450°C;
- one 3" dia safety valve (VS4), pressure setting 4 kg/cm², temperature 200°C.

4.5 Rupture Discs

- two 3" dia rupture discs for S2 and S3, with housings, rupture pressure 75 kg/cm², temperature 450°C;
- two 12" dia rupture discs for vessel, rupture pressure 18 kg/cm², temperature 250°C, with housings.

5. ORGANIC LIQUID PUMP

One Worthington organic pump, with following characteristics:

- delivery 50 m³/hr
- head 50 m
- max. suction pressure 30 kg/cm²
- organic temperature 450°C
- mechanical seal
- 2900 rpm

The pump is equipped with an 18 HP motor and a leaktight remote control switch.

6. ORGANIC LIQUID FILTER

Two metal mesh filters in series, one between tank S1 and the organic circuit and the other in the pump bypass.

7. ELECTRIC HEATING CIRCUIT

7.1 Heater R2

One heater R2 for tank S2, consisting of tubular elements immersed in the liquid in S2; maximum total power 80 kW; specific power on heater pipes 1.65 W/cm^2 .

7.2 Heater R3

One heater R3 for tank S3, consisting of tubular elements immersed in the liquid in S3; maximum total power 55 kW, specific power on heater pipes 1.65 W/cm^2 .

NB. The maximum height of the sheathed heaters in tanks S2 and S3 is 70% of the length of the cylindrical part of the tank; they are divided into two sets. The preheating of tanks S2 and S3 can be effected by switching on these heaters.

7.3 Electric Heater for Storage Tank

One Santowax electric sheathed heater for the storage tank, total power 30-40 kW, specific power 1.65 W/cm^2 .

7.4 Electric Heating Elements for Pipes

The pipes, pumps, valves and flanges are equipped with Pyrotanax stainless steel heating cables with cold outlets and terminals for the connections. In addition to the Pyrotanax cables there are the leak-tight distribution boxes, fuses, remote control switches, conduits, fittings and wiring connecting the electric pipe-heating elements to the switchboard. Water circuit pipes and vents are also heated (constant at about 150°C).

Separate heating elements are used for the different pumps, valves and flanges and convenient pipe lengths. They enable the empty pipes to be preheated from 10 to 150°C in about two hours, with a maximum cable temperature of about 400°C .

8. NITROGEN CIRCUIT

The nitrogen circuit is used to:

- pressurize tanks S2 and S3 up to 50 atm, the vessel to 12 atm, the test channel to 12 atm and tank S1 to 4 atm.

It consists of:

- a nitrogen-cylinder discharge circuit with 4 + 4 connections fitted with pressure gauges of 0-300 kg/cm² range and equipped with 8 HP intercept valves; manifold of HP copper tubing; coils connecting cylinders to circuits;
- a tank (S10, total capacity 1.5 m³, maximum pressure 85 atm);
- a PN 125 (Fiorentini) pressure reducer (for high-flow-rate) upstream pressure variation by counterbalanced valve, downstream pressure regulated by manual pilot valve.
maximum delivery: 20,000 m³/hr
working pressure: upstream 85-5 atm
downstream 5-50 atm
- two P 20 (Fiorentini) pressure reducers (low-flow-rate), pressure variation upstream by counterbalanced valve; downstream pressure remote-controlled by manual pilot valve.
maximum delivery: 1000 m³/hr
working pressure: upstream 200 atm
downstream 50 atm
- one ASGD (SIO) pressure regulator;
working conditions: upstream 200 atm
downstream 12 atm
- one ASGD (SIO) pressure regulator
working conditions: upstream 200 atm
downstream 4 atm
- one connection per cylinder set for charging tank S10

The reducers and the tank are fitted with safety valves and gauges for upstream and downstream pressure control.

9. WATER CIRCUIT

9.1 Electric Boiler

This is in galvanized steel and cast-iron, with immersed electrodes, the characteristics being as follows:

- maximum pressure: 12 atm
- maximum temperature: 185°C, to be reached in 10 hours with a volume of 10 m³ water
- power adjustable up to 120 kW

The boiler is fitted with automatic actuating, control and regulating equipment.

9.2 Pump

This is used for water circulation, with seals compatible with organic contamination, the characteristics being as follows:

- flow: 20 l/sec
- head: 40 m
- canned motor: 20 HP, with remote control switch
- 2900 rpm
- maximum temperature: 185°C

10. AIR COMPRESSING AND DRYING PLANT

10.1 Compressor and Drier for Instrument Air

This consists of:

- a Corblin A4C50 carbon-ring air compressor, to provide air completely free of lubricating oil, effective delivery 43 m³/hr, working pressure 6 atm, complete with motor
- a compressed-air tank, capacity 600 litres, max. pressure 7 kg/cm²
- one after-cooler
- one separator
- one non-return valve
- one drier for above-listed compressed air, efficiency, referred to 6 atm pressure, corresponding to dew point = -10°C
- two pressure-reducing filters
- 21 three-way electromagnetic valves to actuate pneumatic valves
- pipes, fittings and intercept valves

11. THERMAL INSULATION

All the pipes, valves, pumps, vessel, tanks and heaters are lagged with mineral wool covered with 1 mm sheet aluminium. There is also a heat exchange space inside the insulation, obtained by means of a metallic mesh, for all the pipes, valves and pumps in the organic circuit. The valves and flanges are insulated with special sections, for easier dismantling. The insulation thicknesses are designed to allow a temperature rise, with the pumps in operation, of from 150 to 450°C in about 8 hours.

12. ELECTRIC HOIST FOR RAISING TEST CHANNELS

One Stahl C 50/E electric hoist of leaktight construction, with electric crab, running along lower flange of a girder, load 5000 kg. The hoist is fitted with leaktight electric control equipment.

13. INSTRUMENTATION

13.1 Temperature Recording and Regulation

The temperature is recorded at the following points of the rig:

- at one point on tanks S2 and S3, and the vessel;
- at two points at the test channel organic inlet and outlet;
- at one point on tank S1.

The following recording equipment is used:

one temperature indicating and recording unit:

- measuring circuit: potentiometric
- balancing system: by reversible motor operated by electronic simplifier
- recorder for plotting six numbered and differently coloured curves on a ribbon chart of useful width 250 mm
- speed of chart travel: 2"/hr
- balancing time: 3 sec from start to full scale
- stroke interval: 4 sec/point
- linear scale, with 250 mm length graduated from 0 to 600°C for iron-constantan thermocouples
- automatic compensation by reference-joint temperature
- continuous calibration with Zener diode power supply

- error $\pm 0.3\%$ of full scale
- power supply 220 V, 50 c/s, with built-in transformer

3.2 Temperature Monitoring

The temperature is monitored in tanks S2 and S3, the vessel and S1, and again with surface thermocouples in the various pipe sections. The monitoring equipment in the circuits is as follows:

- electronic temperature indicators and monitors, iron-constantan thermocouple calibration as indication on profile scale, set-point can be shifted over entire scale, on-off control with photoresistance regulating device to actuate the power relay, bimetallic spiral compensating device for ambient temperature variations, power supply to instrument 220 V, 50 c/s;
- two units as above, but with scale 0-300, iron-constantan;
- two units as above, but with scale 0-600, iron-constantan.

The temperature readings taken by surface thermocouple on each pipe section and other temperature readings on the circuits are transmitted to the console and indicated on the following instrument:

one temperature indicating and recording unit:

- equipped for 100 measuring points
- measuring circuit: potentiometric
- balancing system: reversible motor operated by electric simplifier
- iron-constantan thermocouples
- automatic compensation by reference-joint temperature
- continuous calibration with Zener diode power supply
- error $\pm 0.3\%$ of full scale
- power supply: 220 V, 50 c/s, with built-in transformer

3.3 Static and Dynamic Pressure Measurements

Three tubular spring pressure-gauges, cast iron case and ring, leaktight construction, movement transmission to pointer and attaching pin of stainless steel, NPT $1/2$ " threaded radial attaching pin, scale 0-100 kg/cm², accuracy $\pm 0.5\%$ of full scale, 300 mm dial;

One pressure-gauge as above, but with 115 mm dial.

Two dynamic pressure-gauging systems for tanks S2 and S3, with rapid-action detector elements, type CEC 4-317, linear response up to 600 c/s.

13.4 Static and Dynamic Level Measurements

One magnetic-signal local level indicator for vessel, carbon steel construction, 2" dia flanged connections, ASA 150 lb, distance between connecting flange centres 2500 mm;

Two units for continuous static and dynamic level-gauging, capacity type, for tanks S2, S3, consisting of: two Endress & Hauser Gilometer SM 3/A capacitor probes inserted vertically in the tanks and equipped with amplifier and detector;

Accuracy for emptying speed of 50 cm/sec approximately 2%.

13.5 Control Console (Fig. 12)

One console containing measuring and regulating instruments, closed on all sides except the back and bottom, used to house the following instruments (built-in type):

- one electronic temperature recorder, standard case
- one 100-position temperature indicator-recorder panel, standard case
- four electronic regulators (on-off)
- ten electric switches for operating heaters
- twenty-one manual controls for pneumatic valves
- two push-buttons switching general motor power on and off
- eighty preheating switches

14. AIR CONDITIONING IN ASSEMBLY AREA OF BETULLA RIG

Three Delchi SU 803A conditioners with Freon coolers and fans provide air cooling in hot weather.

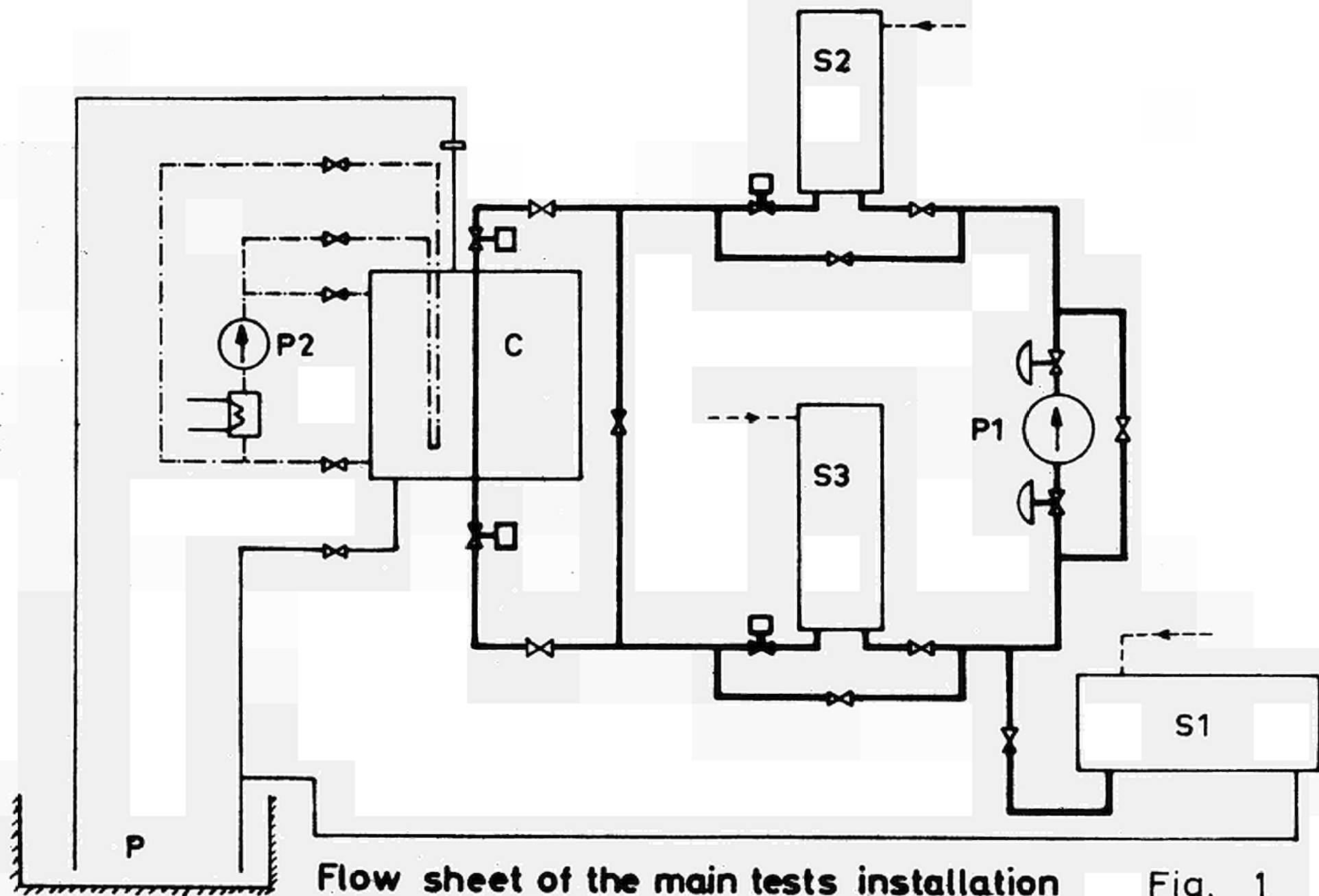
The fans pass the air to three 21 kW heating elements in winter.

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LIST OF FIGURES

- Fig. 1 High-temperature Circuit Flow Sheet
- Fig. 2 General Flow Sheet
- Fig. 3 Vessel
- Fig. 4 Cross-section of the Vessel
- Fig. 5 Building Structure (Ground Plan)
- Fig. 6 Building Structure (Sections)
- Fig. 7 ORGEL Channel
- Fig. 8 Fuel Element
- Fig. 9 Feed Zone Elements
- Fig. 10 Control and Safety Rods
- Fig. 11 View of Part of the Main Test Installation
- Fig. 12 Control Console



Flow sheet of the main tests installation

Fig. 1

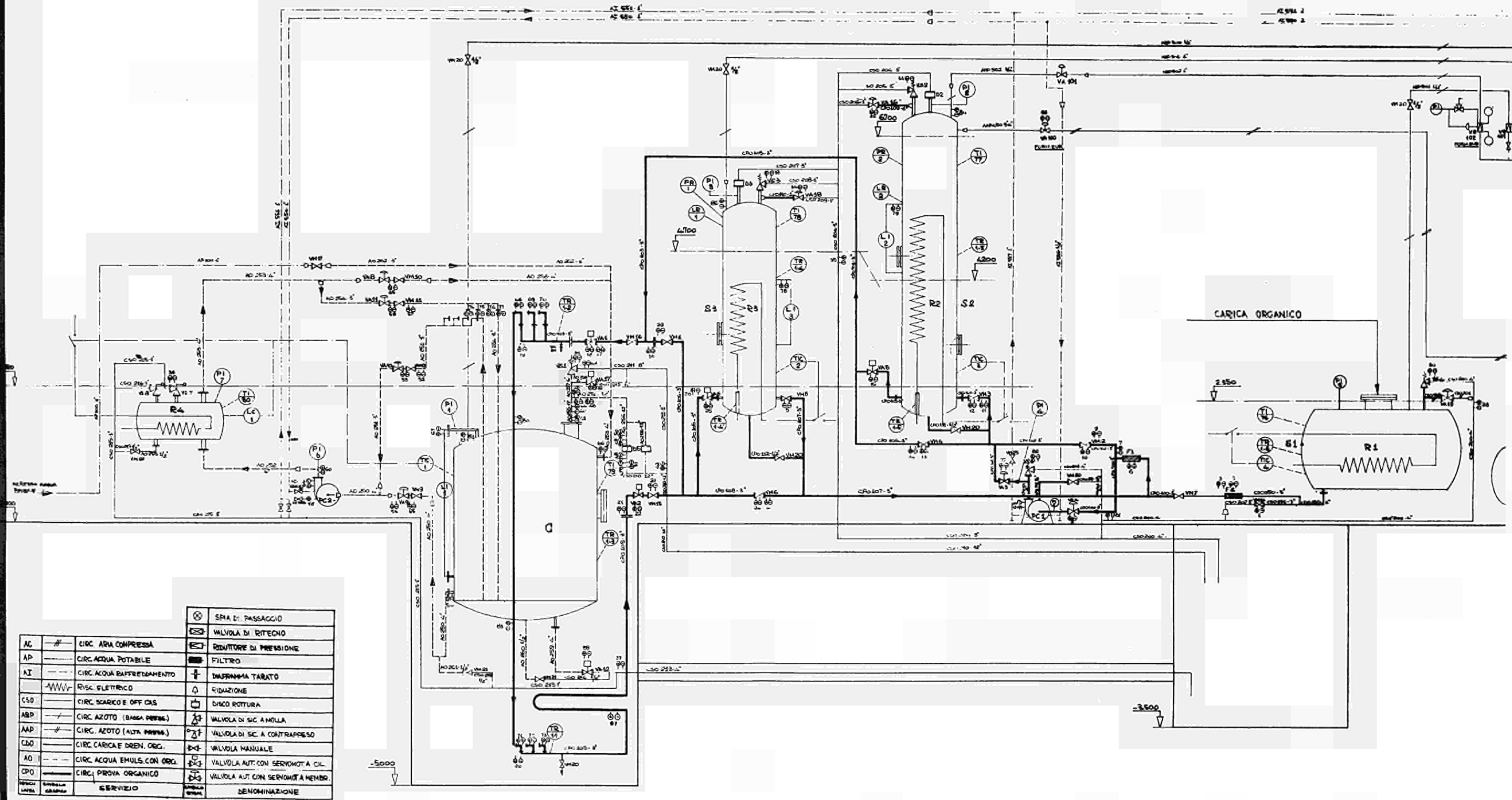
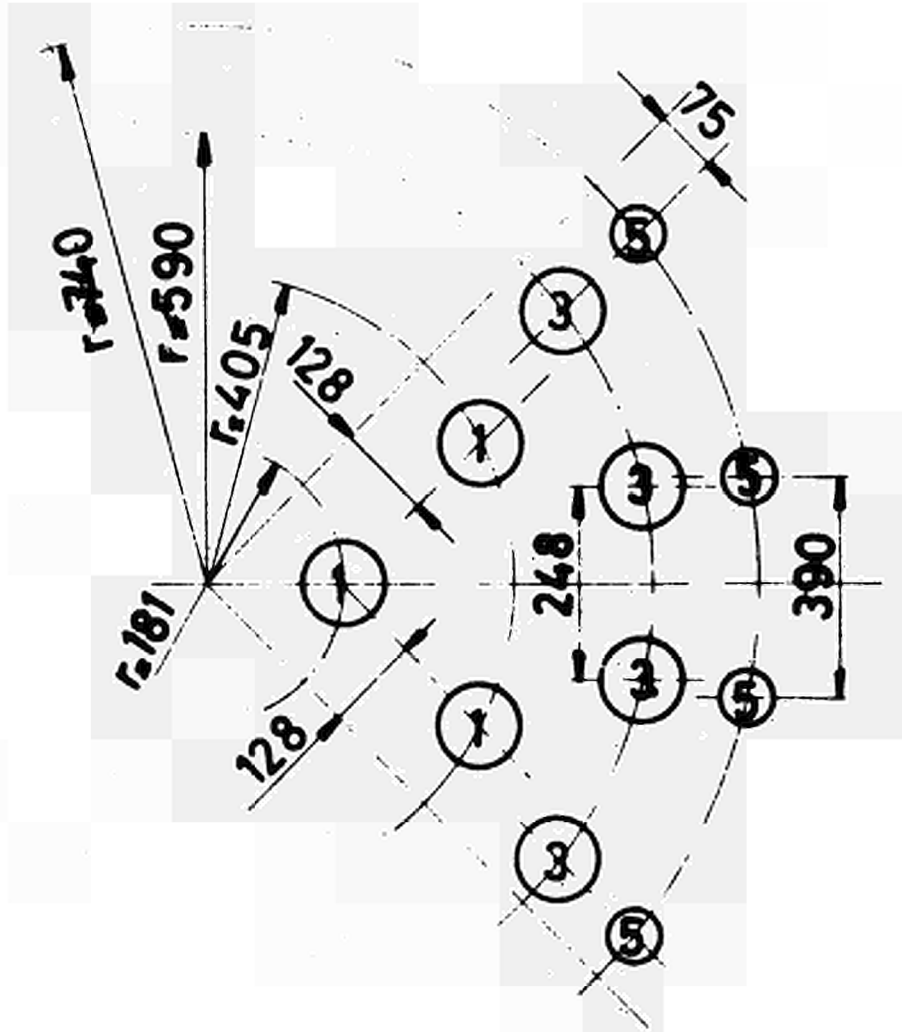
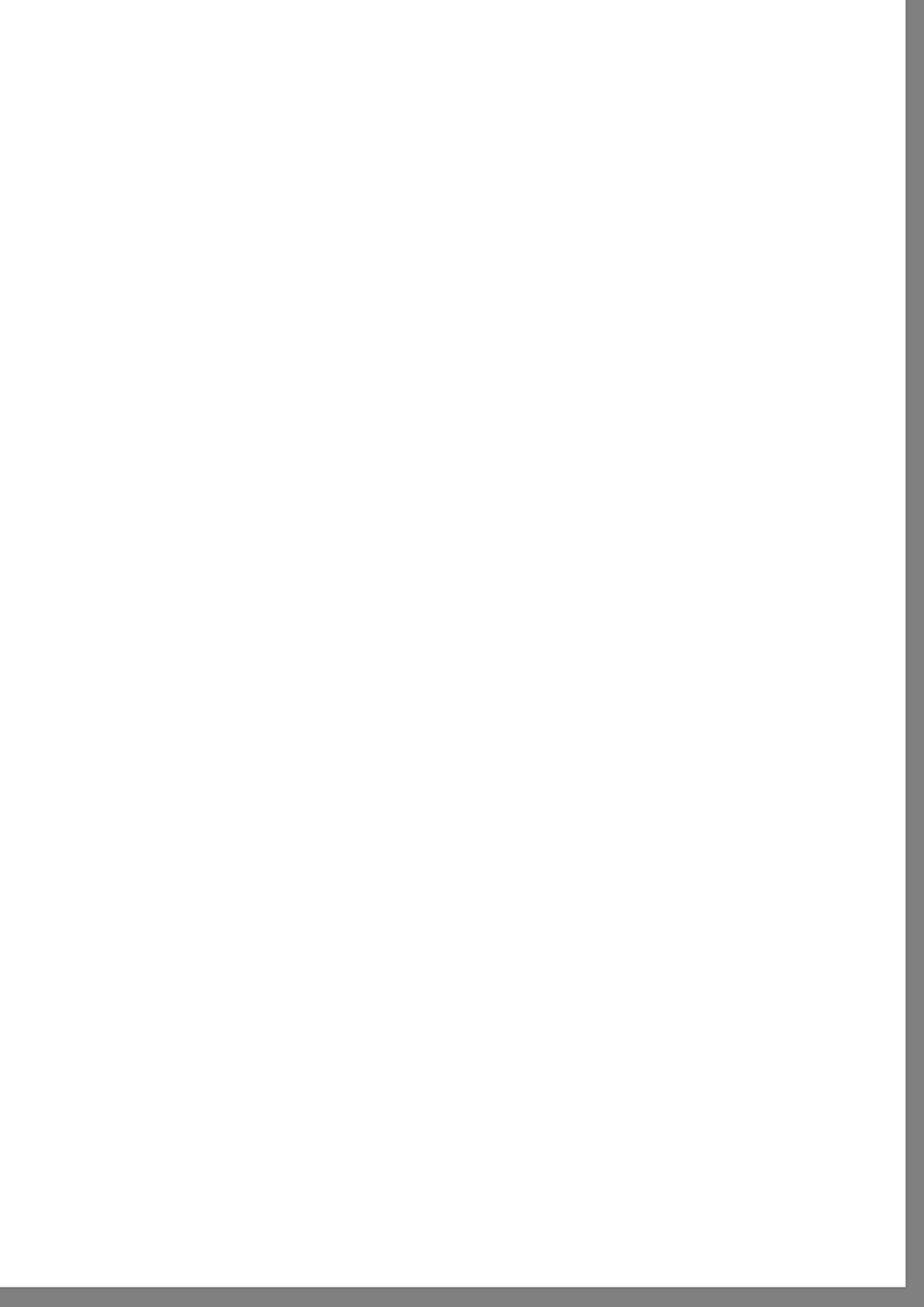
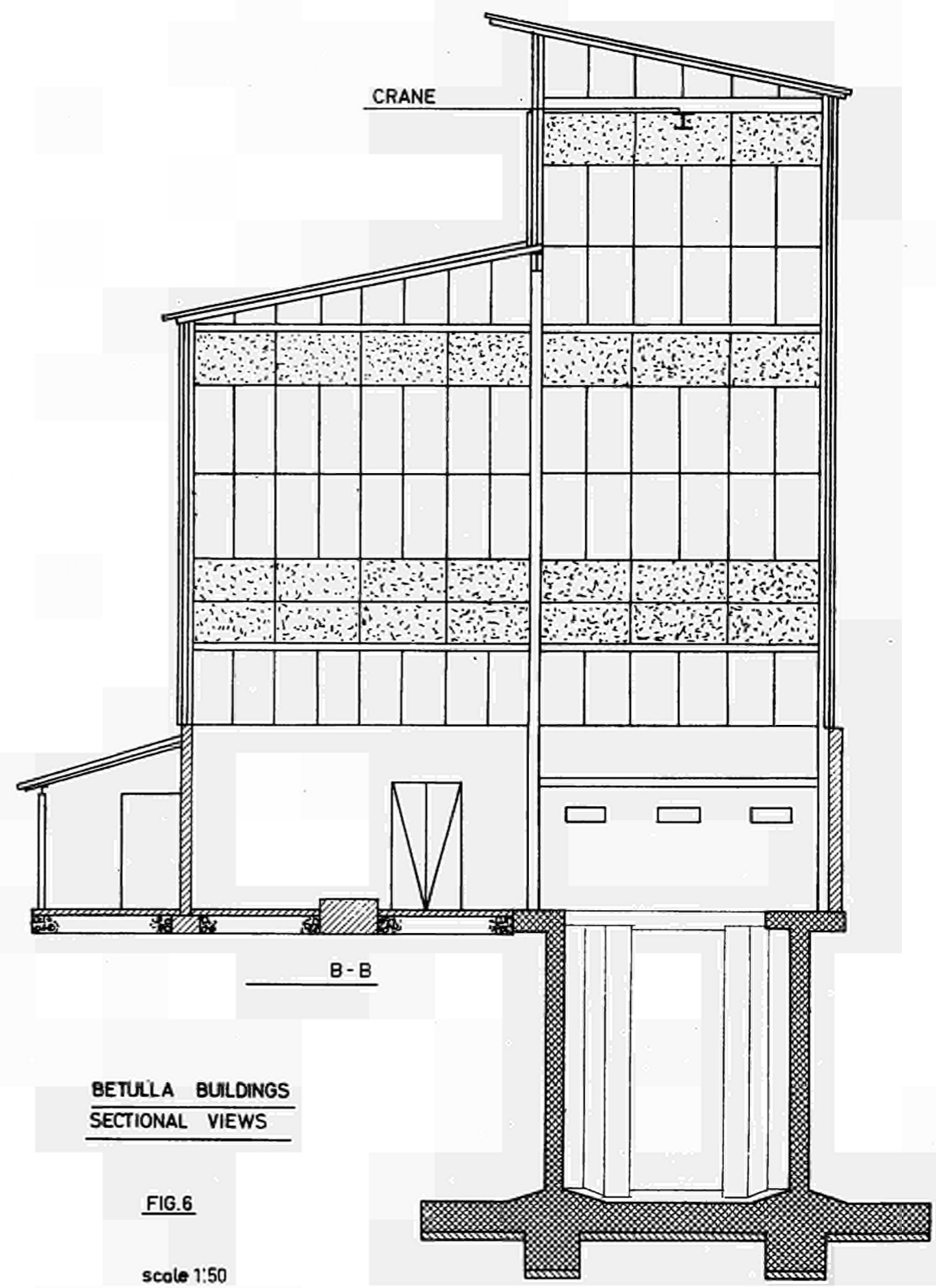
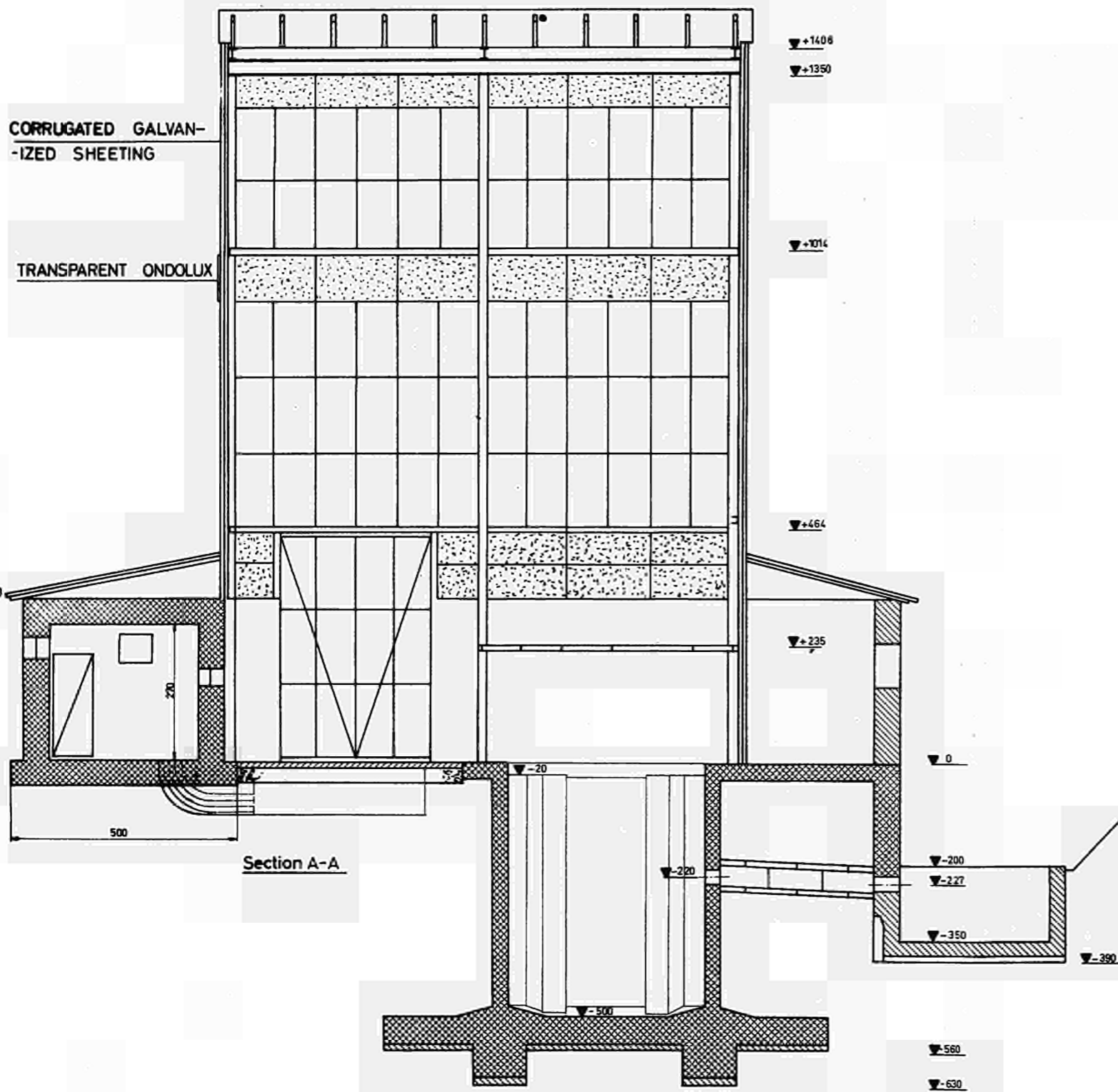


FIG. 4 CROSS SECTION OF THE TEST SECTION
IN THE VESSEL



- POSITION 1 ORGEL type channel
- " " 3 FEEDING zone elements
- " " 5 Control and security rods





ESSOR C-3 FUEL ELEMENT

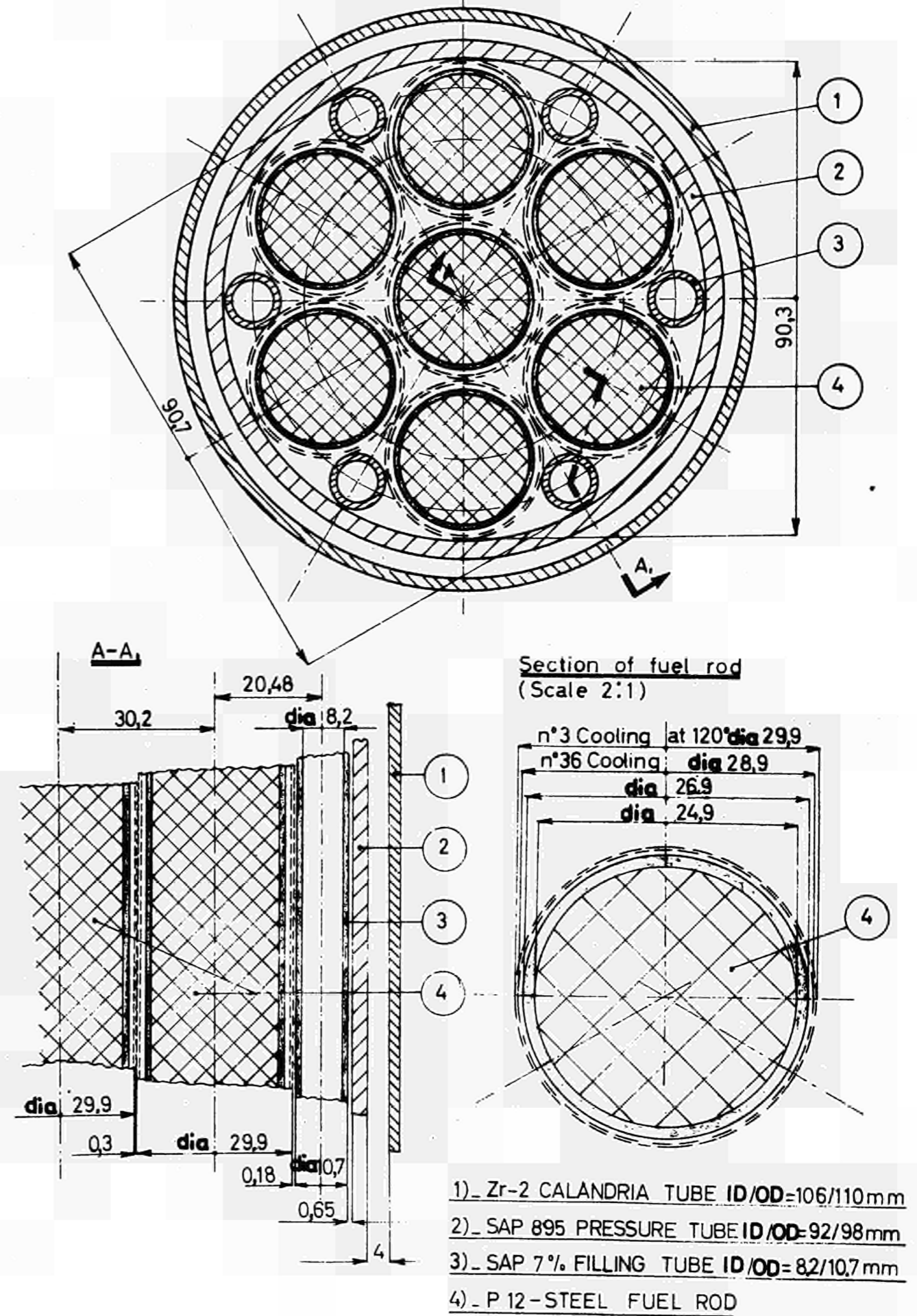
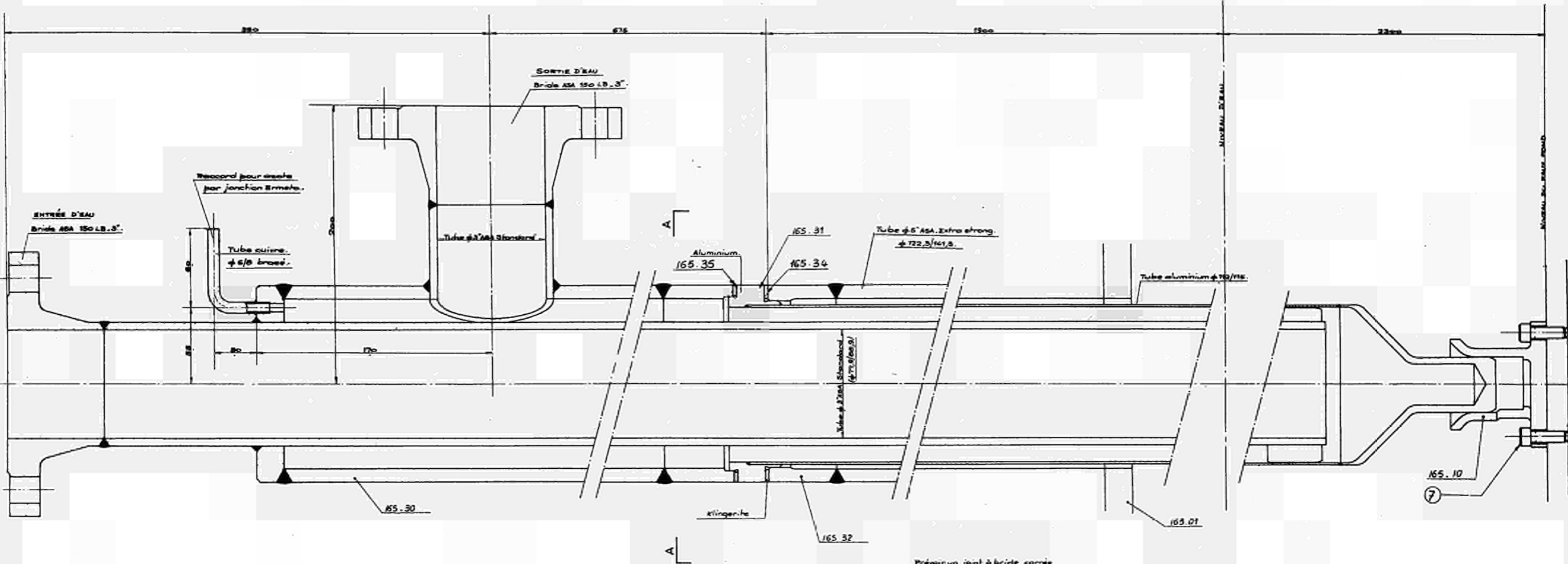
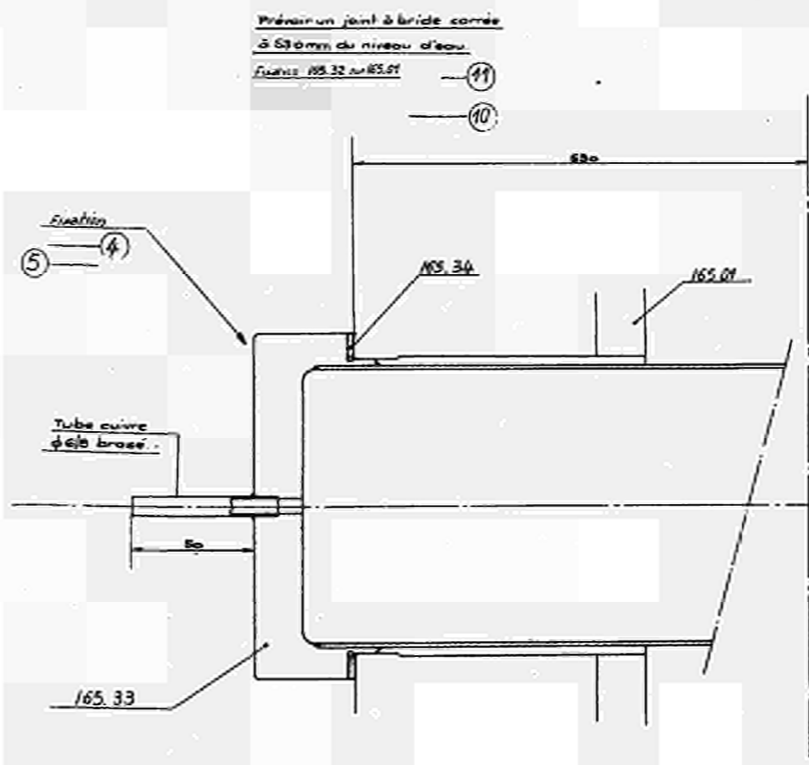
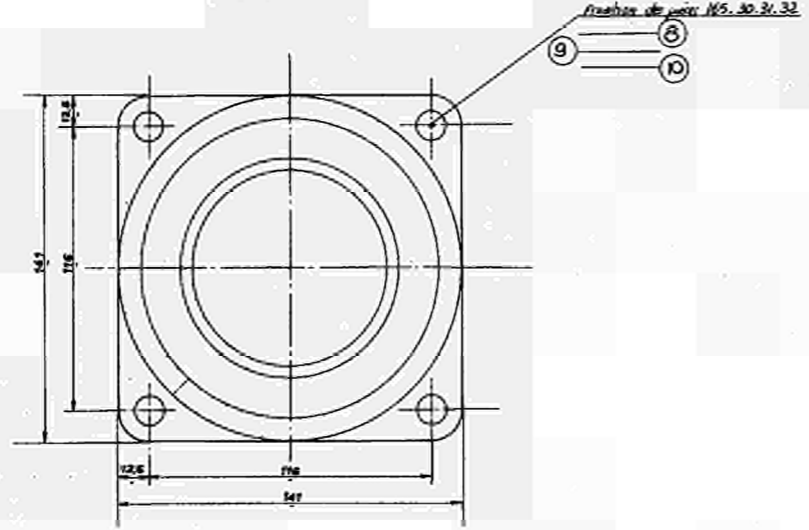


Fig. 8

CANAL TYPE "3."



COUPE A.A



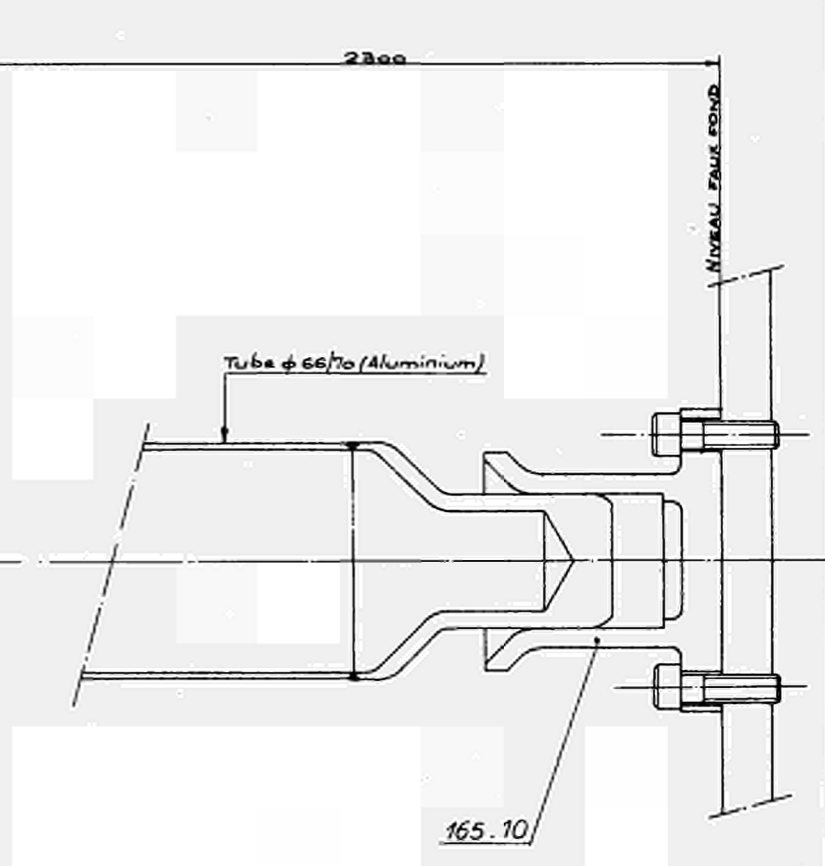
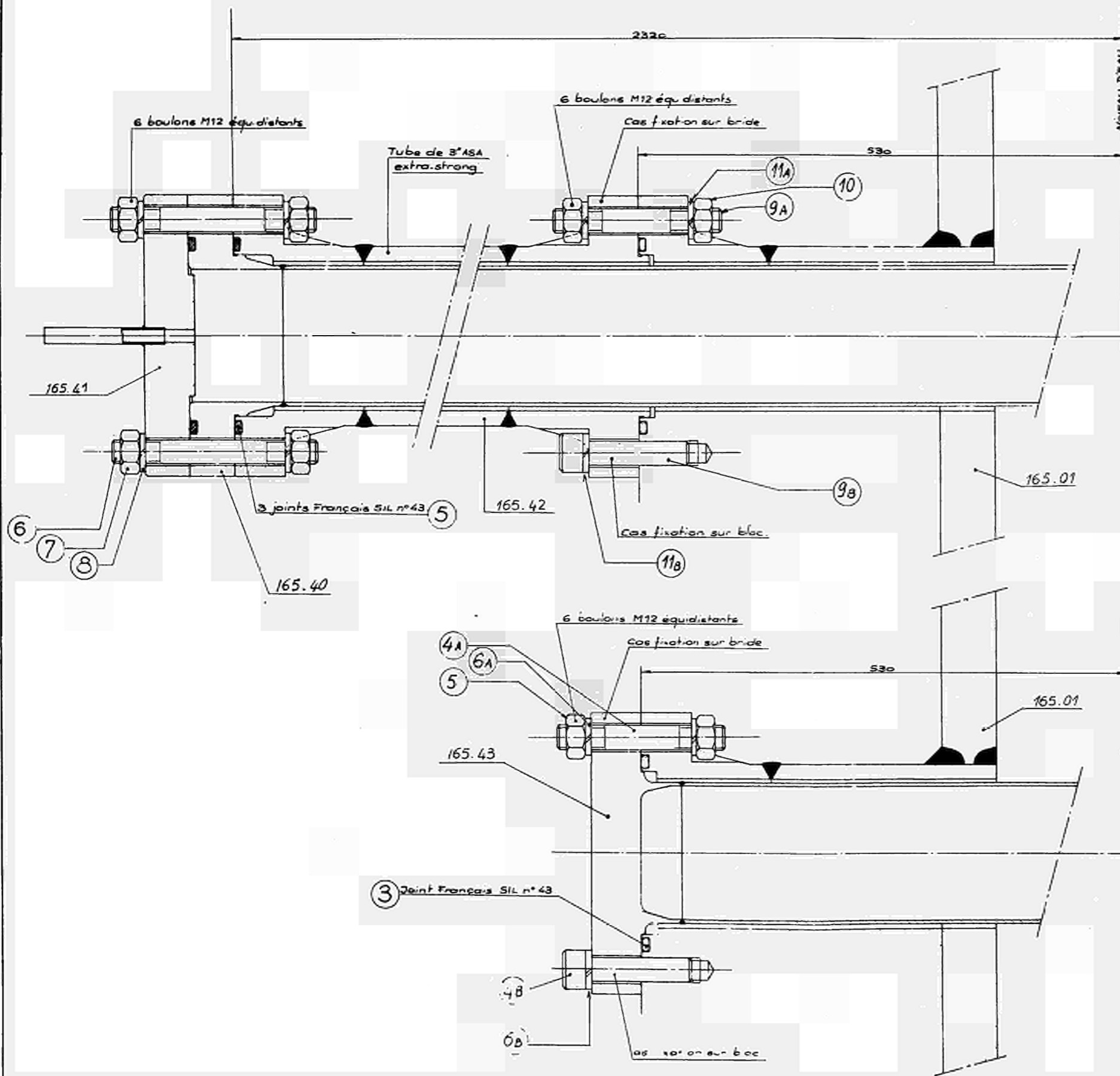
CANAL TYPE "4."

PARTIE INFÉRIEURE IDENTIQUE AU CANAL TYPE "3."

Finition guideage canal "4" - ⑥

N°	REVISION	REVISION DATE	REVISION	REVISION	REVISION
1	1				
PROJET : Installation d'essais pour scotement de tubes de force PROJET : CANAUX TYPE "3 ET 4"					EURATOM C.C.A. ISRA
D.T.R. - 165. D.L.A.					E
N° de plan : 165.00					165.06

CANAL TYPE "5..



CANAL TYPE "6..

Partie inférieure identique à celle du canal "5..

N°	PROJET	DATE	REVISION	REVISION	REVISION
1:1	PROJET				
Installation d'essais pour éclatement de tubes de force PROJET					EURATOM C.C.R. ISRA
CANAUX TYPE "5.. et "6..					D7B - 165.05
F					E N - 165.00 - 165.06

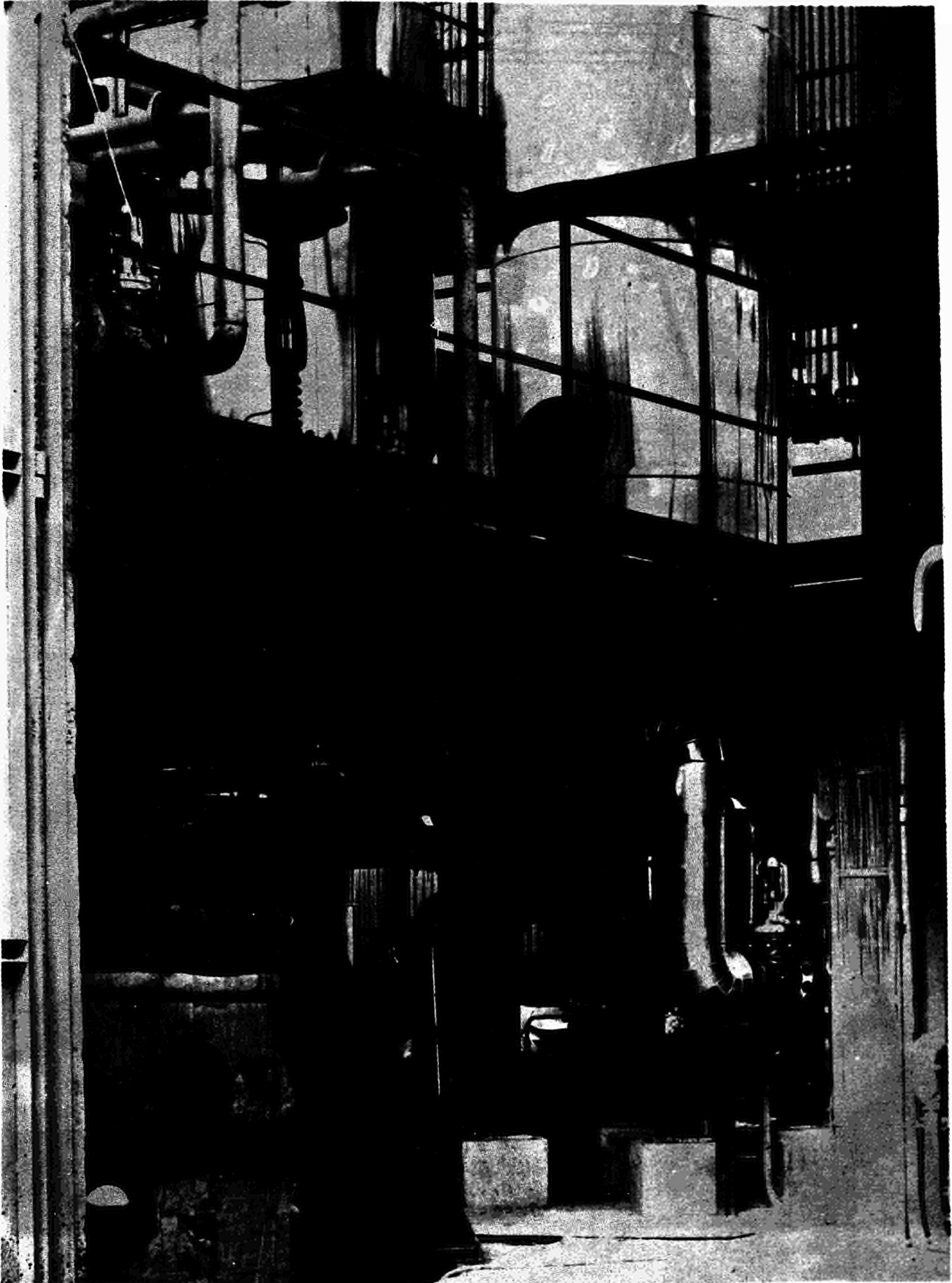


Fig. 11 - VIEW OF PART OF THE MAIN TEST INSTALLATION

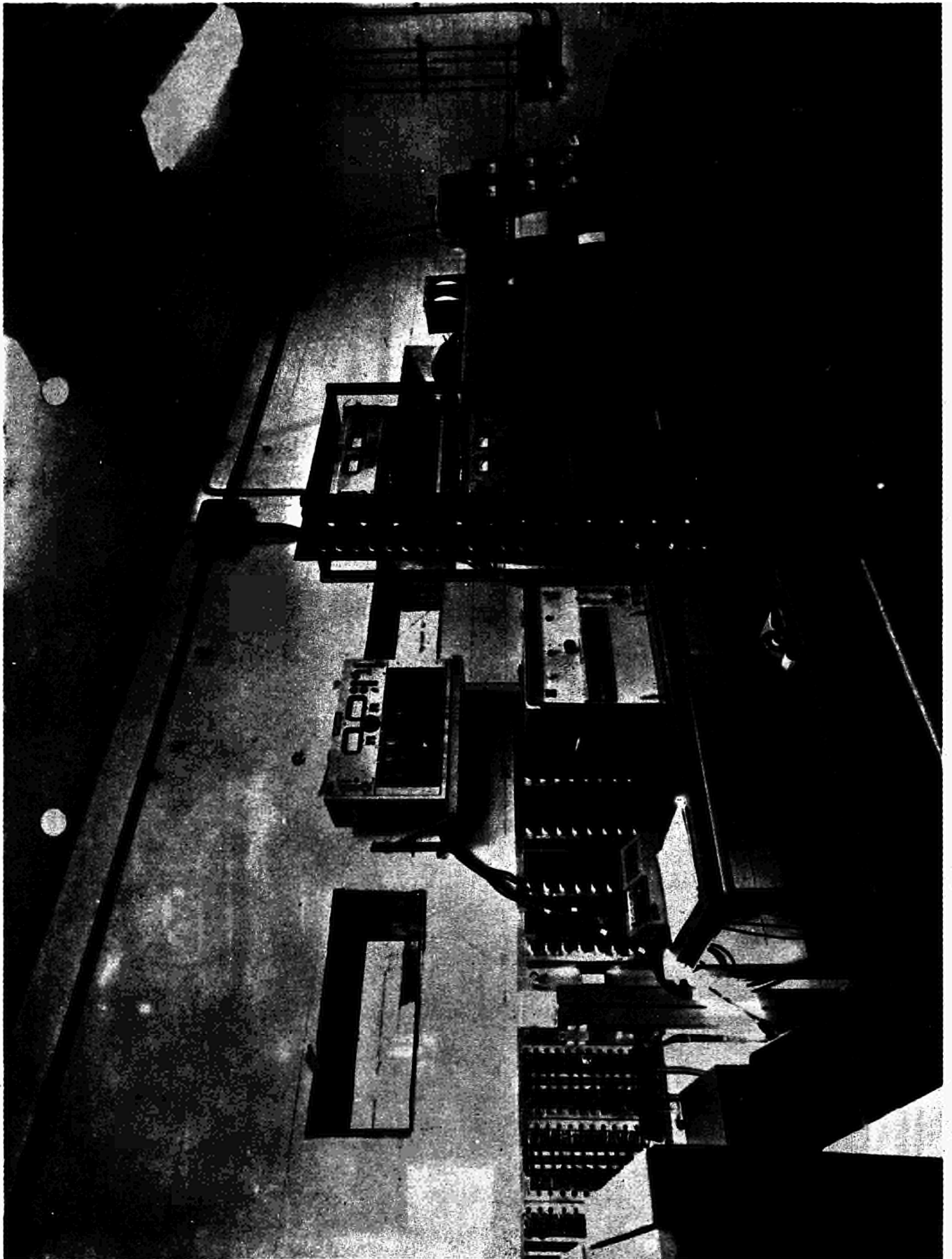


Fig. 12

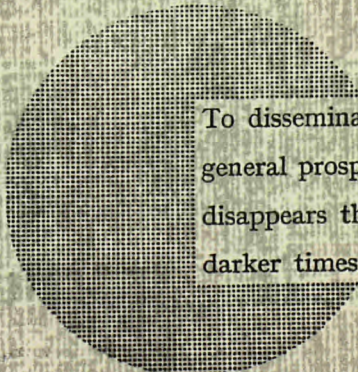
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Alfred Nobel

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