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LHC Note 135

Shielding of LEP Experimental Areas during LHC Operation

Graham R. Stevenson, Hans Taureg

CERN

Abstract

The shielding of LEP experimental areas during LHC operation is studied. Proposals are made for a shielding allowing access to these areas. The necessary modifications of existing installations are outlined, as well as the installation procedure for the shielding. A very rough cost estimate is given.

1. Introduction

The installation of LHC in the present LEP tunnel brings with it more severe shielding requirements than even LEP200 if access to the underground areas should be allowed during operations of the proton beams. Areas where permanent access is permitted have to be shielded from the proton beams by about 4.5 m of concrete. Where space is at a premium one has to use an equivalent combination of iron and concrete for shielding. In this note we examine the possibilities to shield the LEP experiments in points 4,6, and 8 in their garage positions from the LHC beam. Furthermore the shielding of the US/UW areas in the even points and access to the UX24 shaft are studied.

It is assumed that the reader is familiar with the layout and construction of the LEP experimental areas and the naming conventions used in LEP.

2. Shielding Criteria

The conclusions drawn in this note are based on the draft recommendations of ICRP, 1990[1] , the evaluations used inthe note *Radiological Considerations for the Environment around the LHC*[2] , and further calculations by one of us. The basic assumption is that in an experimental area a complete loss of one full proton beam ($5.0 * 10^{14}$ protons) should be attenuated by the shielding to a dose of 50.0 mSv at the outside surface of the shielding under the most pessimistic conditions. This corresponds to a dose of $1.0 * 10^{-16}$ Sv/proton and translates to a concrete shielding of 4.3 ± 0.3 m thickness transverse to the beam direction and starting at 2 m distance from the beam line for the main ring of the accelerator, see figure 1. The additional shielding required on top of the present shielding plug in shaft PX24 can be determined from figure 2. The total thickness required is 3.5 ± 0.3 m of concrete. Figure 3 shows the required iron thickness of an iron/concrete shield. The shield starts with an iron layer at 1 m from the beam axis and has a concrete layer around the iron to a maximum radius of 5 m around the beam. 60 cm of iron is sufficient to achieve the required attenuation.

3. Point 2

The access conditions and shielding in point 2 depend very much on the situation of the L3 experiment at that time. Will L3 remain a LEP experiment, will it be converted to a LHC experiment, or will there be some other installation? An answer to this question determines if and in which form the LHC beam can be shielded inside the UX25 cavern close to the beam line. Such a possible shielding in UX25 in turn influences the shielding requirements in the shaft PX24 and towards US25.

We assume here that L3 will remain a LEP experiment and that a minimum of changes are done to the installations at point 2. We regard this as the least favourable scenario from the point of view of shielding the proton beams. Furthermore, we assume no shielding of the proton beams inside UX25.

3.1 PX24

The present shielding plug has to be increased in thickness. According to figure 2 one needs 3.5 m of concrete in total or an additional 1 m of concrete on top of the present shielding plug. The larger distance to the beam compared to the main ring case allows a total thickness below 5 m for the shielding at the location of the shielding plug. The civil engineering design of the plug is being checked to see if the plug can support the additional 1 m thick layer of concrete. All the equipment installed on top of the plug has to be relocated.

There are, however, numerous holes for ventilation ducts, water pipes, cables, stairways and a lift in the shielding plug, see figures 4, 5, and 6. This equipment passes through chicanes. The shielding towards the beam consists of 1.2 m of concrete in the weakest areas. One has to study in more detail if these areas can be shielded sufficiently in order to permit access to the electronics barracks in PX24.

The access to the blockhouse at the bottom of PX24 will be prohibited during LHC operations. There is no possibility to sufficiently shield the lift and the blockhouse itself.

3.2 US25

There are about 4 m of rock and concrete between UX25 and US25 in the most advantageous regions from the point of view of shielding. The chicanes between UX25 and US25 reduce this shielding thickness substantially in some areas. Between PX24 and UL24 the separation is only about 1 m of concrete, see figure 7. If the L3 magnet stays in place there is no space in the UX for additional shielding over the length of the solenoid. There is no room for shielding in the US either.

However, given the larger distance of the US to the beam it seems possible to permit access to the US/UW area at point 2 during LHC operations if the following conditions can be met

- The shielding in the regions of the chicanes is reinforced sufficiently.
- UL24 is blocked and shielded.

More work has to be invested in order to give a definitive answer on the question of access to US25.

4. Points 4 and 8

The experiments DELPHI and ALEPH have a sufficient similarity in their general construction that one can treat both experiments at the same time. The shielding arrangements will turn out to be very similar.

We propose to install a shielding similar to the existing LEP shielding which can replace a LEP experiment during LEP operations. For the LHC case the mobile shielding should be in the retracted position. 5 m free space are left between the beam line and the electronics barrack D, see figure 8, when the experiments are in their garage position. This space will be used for shielding under the assumption that personnel will stay close to the outer surface of the shielding. To enter electronics barrack D one has to pass close to the shielding.

4.1 Shielding between the faces of the mobile shielding

This region poses the least problems. The 5 m of available space between the beam line and the electronics barrack D are filled with a combination of iron and concrete shielding. We propose to surround the beam line with a shield of square cross section centered on the beam axis. The shielding starts at 1 m from the beam line with 60 cm of iron. The remaining 3.4 m to the outer edge are filled with concrete. The general layout of the shielding is shown in figure 9. We have to study in more detail how to bridge the gap of about 2 m between the lower edge of the shielding and the cavern floor. Most likely the space will be filled, at least partially, with concrete.

The central part of the shielding described above constitutes about 850 tons of iron and 4300 tons of concrete.

One has to remember that the cavern floor and the beam line are not parallel to each other. The shielding in the middle of the cavern should be constructed parallel to the cavern floor. Consequently one needs special care to close the wedge shaped gap to the front face of the mobile shielding.

4.2 Mobile shielding

The present roof of the mobile shielding has to be removed in order to let the LHC beam line pass. The lower edge of the shielding is situated at the LHC beam position! The 1 m of concrete should be replaced by 35 cm of iron, see figure 9. This leaves enough room for the installation of the LHC vacuum pipe and increases only slightly the total weight of the mobile shielding. In this way the mechanics and support arms of the mobile shielding can be employed during LEP running and do not need further modifications. The 35 cm iron are enough shielding for LEP beams at the highest LEP beam energies.

4.3 Junction of the shielding with the cavern wall

The cavern walls around the mobile shielding are covered with a wide variety of installations and equipment which make it very difficult to have a homogeneous shielding. Therefore modifications of present installations are necessary or the efficiency of any shielding will be severely compromised. Figures 10 to 14 try to give an impression of the amount of equipment installed along the cavern walls.

At present there are 2.2 m of concrete as shielding transverse to the beam in the horizontal direction when the mobile shielding is in the retracted position. The concrete has to be backed up by 60 cm of iron and 1m of concrete for a viable LHC shielding. Consequently all equipment on the cavern wall between the beam line and about 6 m from the beam line and from the cavern floor up to the cable trays under the crane rails has to be displaced. It is here where we expect the most reluctance to free the required space for the LHC shielding and the most technical difficulties for modifications of existing installations.

On the PM side of the beam line there is the chicane which gives access to the LEP low β quadrupoles. One has to study how to shield this area, especially with respect to access in the US/UW. It seems not feasible to fill the passageway of the chicane with shielding material. Nor is it easy to install a sufficient amount of shielding along the UX cavern wall between the entrance of the chicane and the door to the US. There is too much equipment on the cavern walls which cannot be displaced.

On the top of the mobile shielding the fixed installations along the wall and below the crane rails need not be changed. The space is filled with concrete as close as possible to the cable trays and pipes and up to the front face of the mobile shielding which stays in its retracted position. The concrete beams constituting the roof of the fixed part of the mobile shielding are replaced by iron. The passage way over the top of the mobile shielding has to be abandoned, see figure 9. The shielding has then about 1.5 m of iron and at least 1.6 m of concrete apart from the space close to the cavern wall. It has to be checked if the fixed part of the mobile shielding can support the extra weight of iron and concrete. The shielding material around the mobile shielding amounts to 620 t of iron and 250 t of concrete for both sides of the cavern.

4.4 Access to the UX

With the shielding described above, access can be granted to the experiment in the garage position. However no access is possible to the top of the shielding or any region above such as the crane gang ways, cranes etc. because of the weaknesses of the shielding along the cavern wall.

Because the chicanes to the LEP low β quadrupoles represent a hole in the shielding we propose that there will be no access to the region of the UX between the beam line and the US. The UP tunnel cannot be used to reach the PM since there is insufficient rock thickness between the floor of the machine tunnel and the UP. The UP should be equipped with a radiation door at the TX end. In emergencies passing this door dumps the beam and one can reach the PM shaft. In the opposite direction the doors between the US and UX have to be blocked and interlocked correspondingly.

4.5 Access to US/UW

The shielding around the beam line in the UX is automatically sufficient for the US/UW area. However, the chicane allowing access to the RB region represents a hole in the shielding. The consequences have to be studied in more detail. Furthermore one has to check what shielding will be required in the UL tunnels in addition to the existing shielding door of the UJ caverns.

4.6 Installation of shielding

The shielding close to the cavern wall should be installed once and for all and be left there. The region is very difficult to reach with any lifting device.

The shielding between the front faces of the mobile shielding has to be assembled or disassembled each time one changes from one machine to the other. The pieces can have a weight of maximal 80 t (including lifting gear). The access from the TX to the beam line is very restricted.

In the case of DELPHI there is no space available for lifting the shielding over the top of barrack D to the beam position. The shielding has to be transported on a special trailer from the TX to the beam line. On the floor there are only about 1.5 m free passage between the cavern wall and barrack D.

In the case of ALEPH the shielding blocks can be picked up by the UX crane when the barrel part of ALEPH is in front of the TX. There is a free passage on the roof of barrack D allowing the transfer of the blocks from the TX to the beam line.

We estimate the time to install the central portion of the shielding between the mobile shielding to be at least 10 working days of 8 hours.

The feet of the mobile shielding should be in the position parallel to the beam line. The LHC shielding will be built around the feet and their actuating braces. The shielding has to have some cut outs for this purpose.

5. Point 6

Point 6 has a somewhat different mobile shielding compared to points 4 and 8. More important, the construction of OPAL is quite different and therefore the space requirements of the experiment in the open configuration are different. The OPAL experiment has electronics barracks which hang and travel below the crane rails, called gondolas. These gondolas occupy space closer to the cavern wall than the front face of the retracted mobile shielding. The pole pieces of the OPAL detector hang from a girder which is supported by the fixed part of the shielding when the experiment is opened in the beam position. For the time being there is only one garage position where this girder can be supported.

5.1 Shielding

The shielding for point 6 has essentially the same construction as in points 4 and 6. The shielding has to take into account the different support structure of the mobile shielding.

The shielding along the cavern walls, around the mobile shielding, has to take into account the space occupied by the gondolas and the support of the central detector girder. Parts of the shielding along the cavern wall will have to be installed or removed for each LEP/LHC or LHC/LEP change over in UX65 in contrast to points 4 and 8.

5.2 Space available for OPAL

Already with the shielding of the LEP beam in point 6 there are some problems for the OPAL experiment in the open configuration. Some stairways to the electronics barracks have to be dismounted and the LEP shielding is positioned asymmetrically. In the case of the LHC shielding another 2.5 m of floor space are required. The pole pieces can no longer occupy their present garage position but have to stay with the central detector. The resulting configuration does not allow much access to the detector parts for work on them.

5.3 Installation

During the installation period of the shielding the OPAL detector is moved close to the PZ shaft. One has then a 6 m wide passage from the TX to the UX which allows the use of the transfer platform.

6. Costs

Based on CHF 1.20/kg for cast iron and CHF 300.00/m^3 for concrete one arrives at a cost of MCHF 1.54 for the central part of the shielding in one LEP area. For the shielding along the cavern walls we arrive at a cost of about MCHF 0.78 for one cavern.

The costs for one cavern amount then to MCHF 2.32 in material alone.

In addition one has to count the installation costs for the shielding along the cavern walls around the mobile shielding and the costs for modifying the equipment on the cavern walls which is in the way of the shielding.

7. Conclusions

The possibilities for shielding LEP experimental areas have been studied. In point 2 access to the electronics barracks inside PX24 may be possible with some difficulties. The access to the US/UW areas at point 2 seems to be possible given a modest shielding installation. In points 4,6, and 8 a viable shielding can be constructed which permits access to the UX and US/UW areas. Details of the shielding along the UX cavern wall need more study. In the case of OPAL the remaining space in the UX is insufficient for maintenance or modification work on all parts of the detector. The material costs for shielding in one cavern are about 2.3 MCHF.

8. Acknowledgements

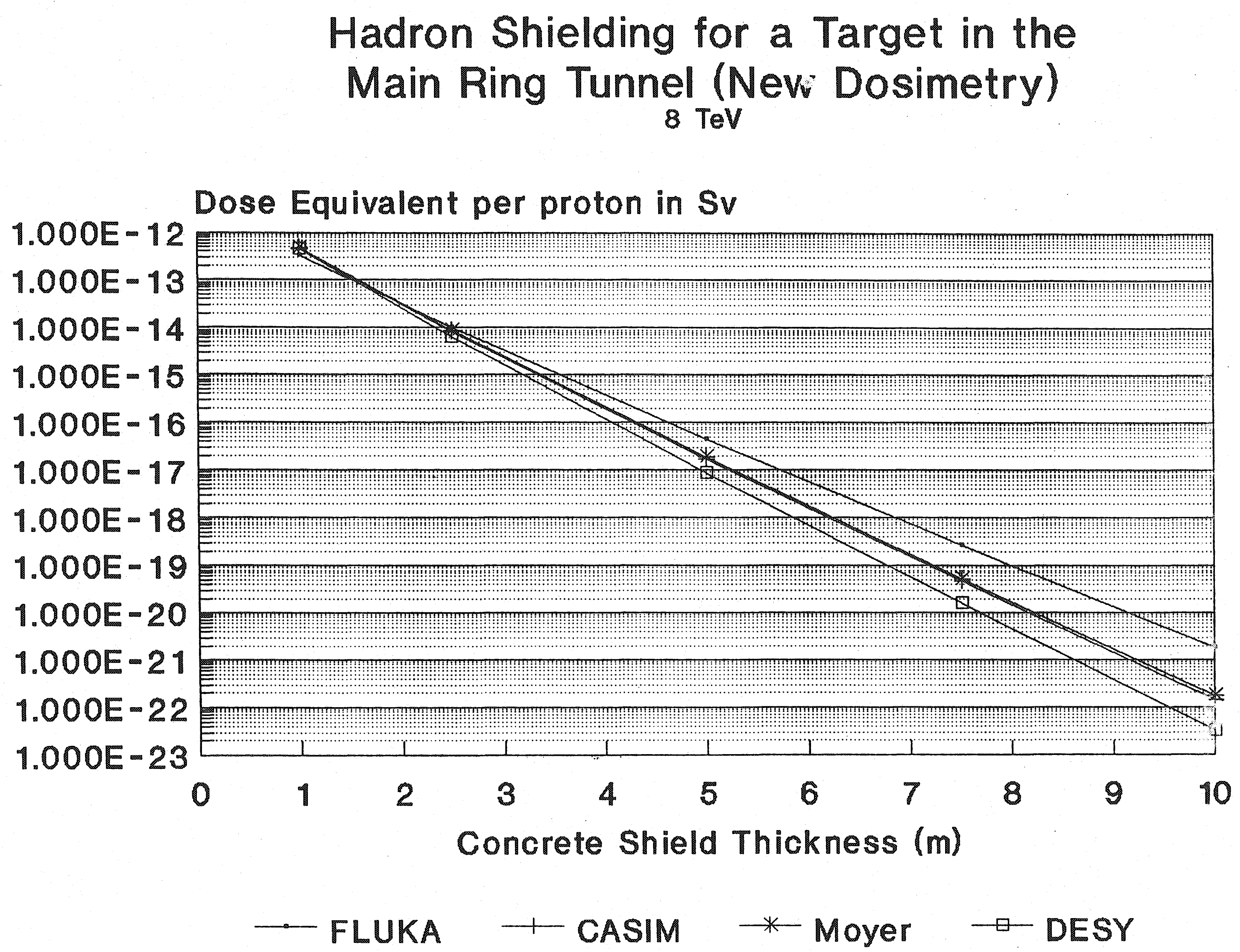
We would like to thank K.Potter, L.Leistam, and B.Bianchi for their advice and comments.

Appendix A. List of figures

References

[1] R. H. Clarke.
A summary of the draft recommendations of ICRP, 1990.
J. Radiol. Prot., 10(2):143-145, 1990.

[2] G. R. Stevenson and R. H. Thomas, Ed.
Radiological Considerations for the Environment around LHC.
CERN LHC Note 115, 1989.



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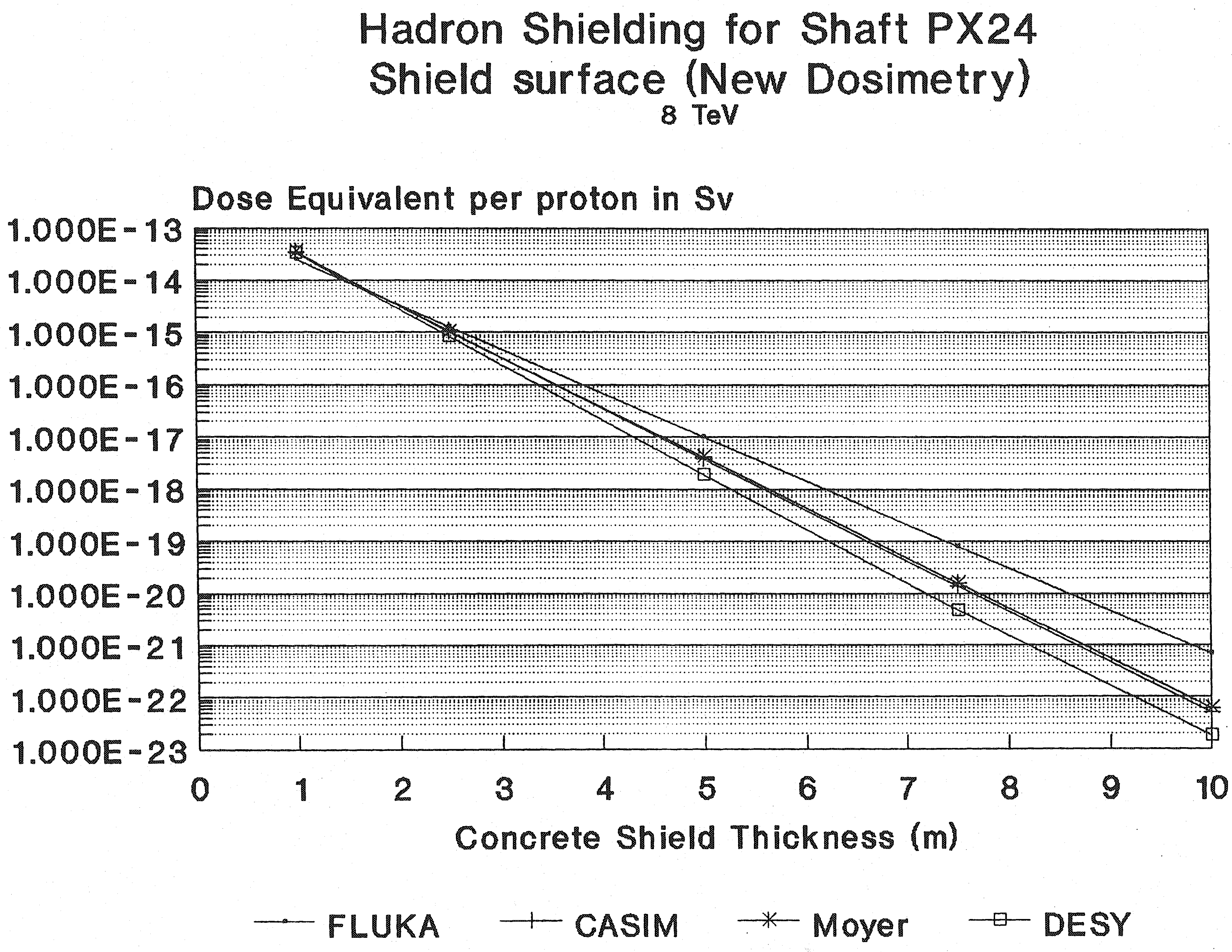

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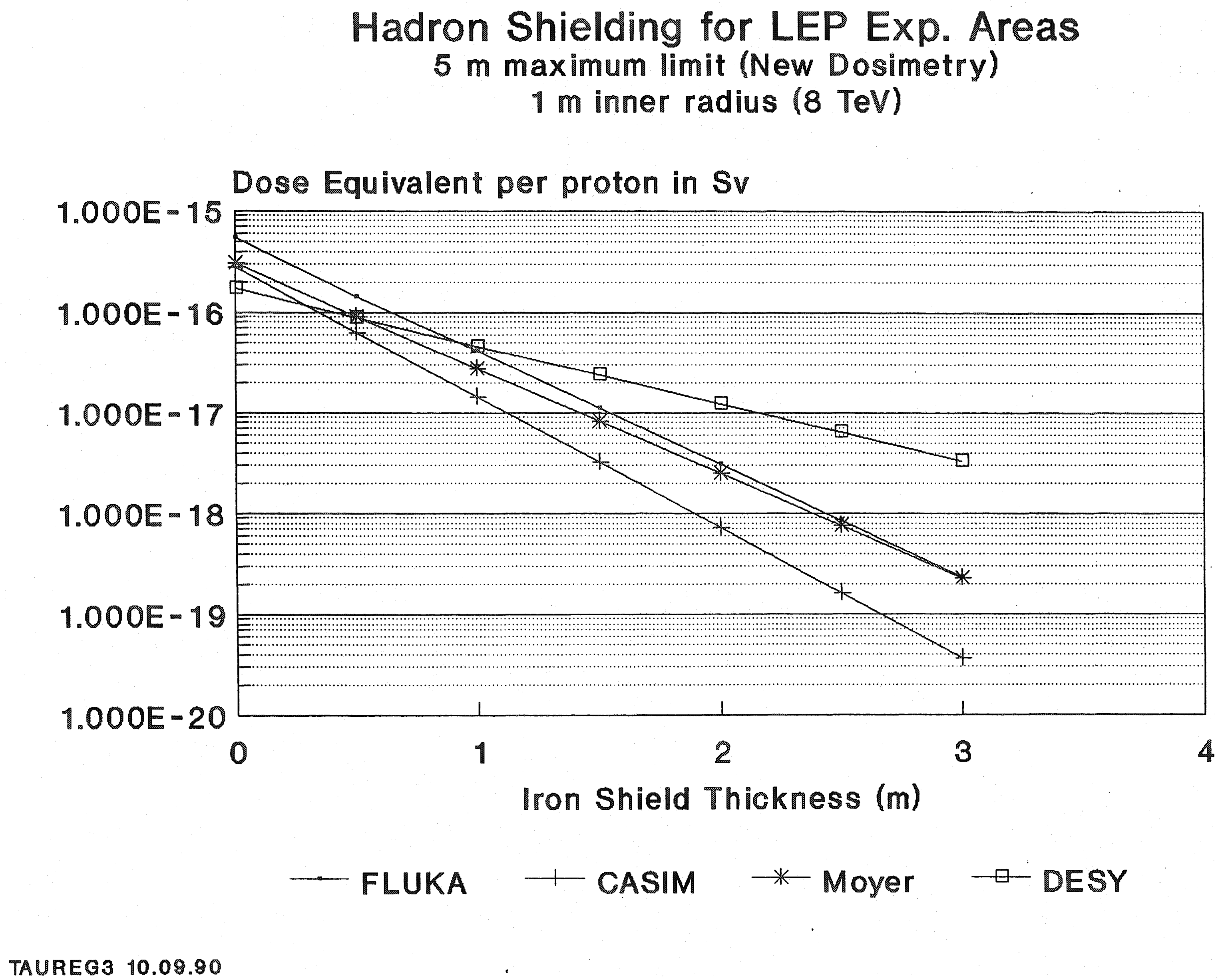

Hadron Shielding for LEP Exp. Areas
5 m maximum limit (New Dosimetry)
1 m inner radius (8 TeV)
Dose Equivalent per proton in Sv
1.000E-15
1.000E-16
1.000E-17
1.000E-18
1.000E-19
1.000E-20
0
1
2
3
4
Iron Shield Thickness (m)
FLUKA
CASIM
Moyer
DESY
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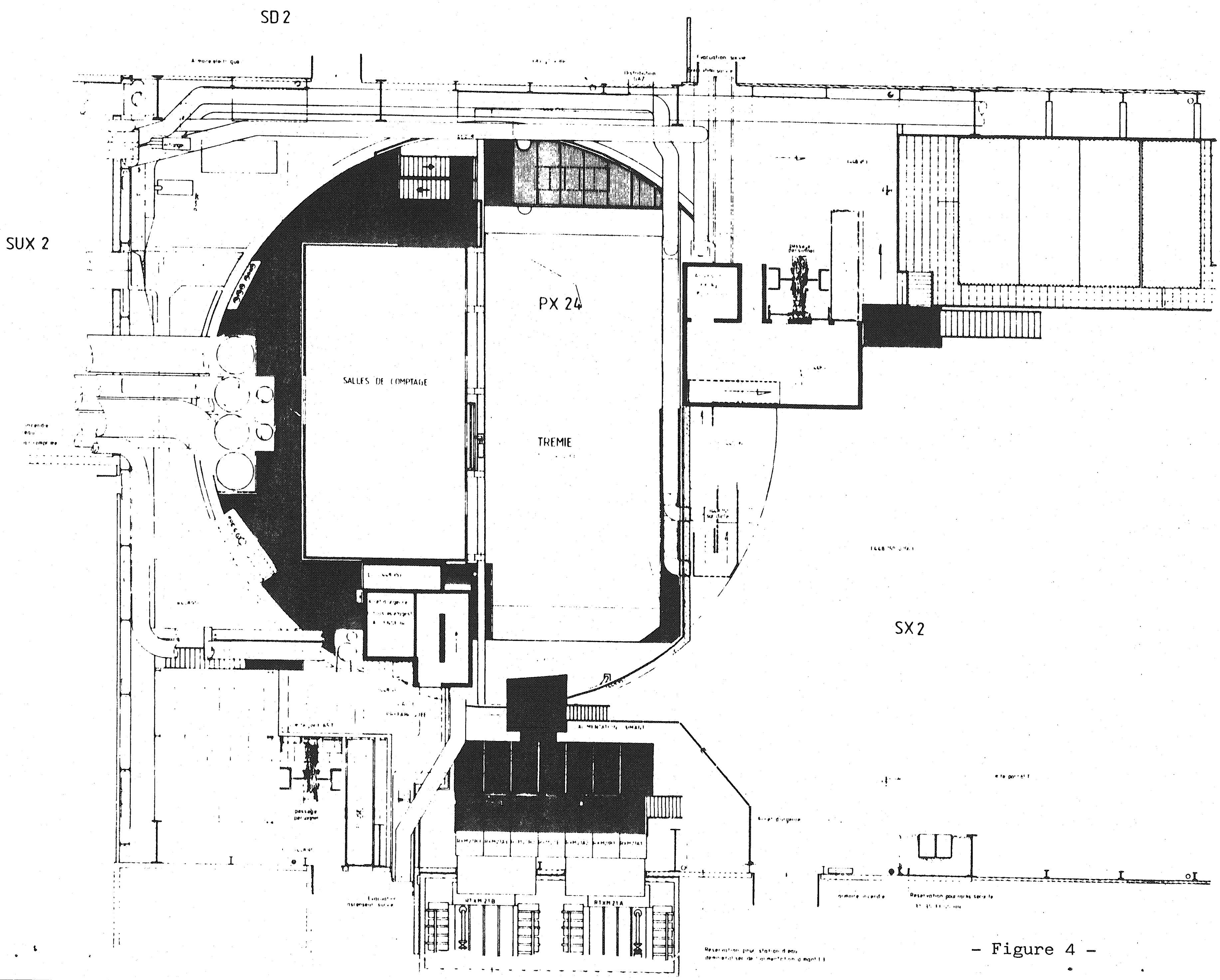
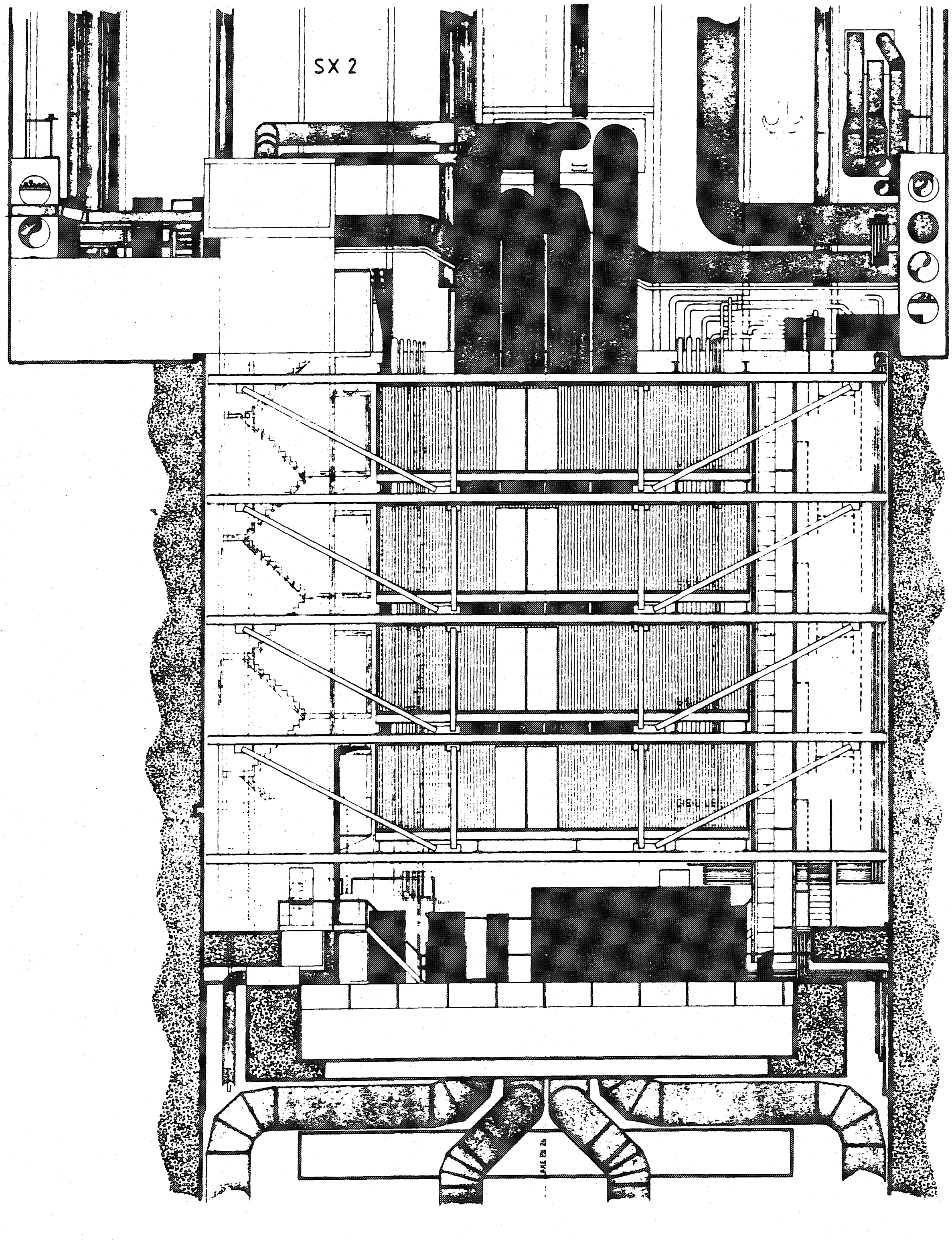
- Figure 3 -



- Figure 4 -



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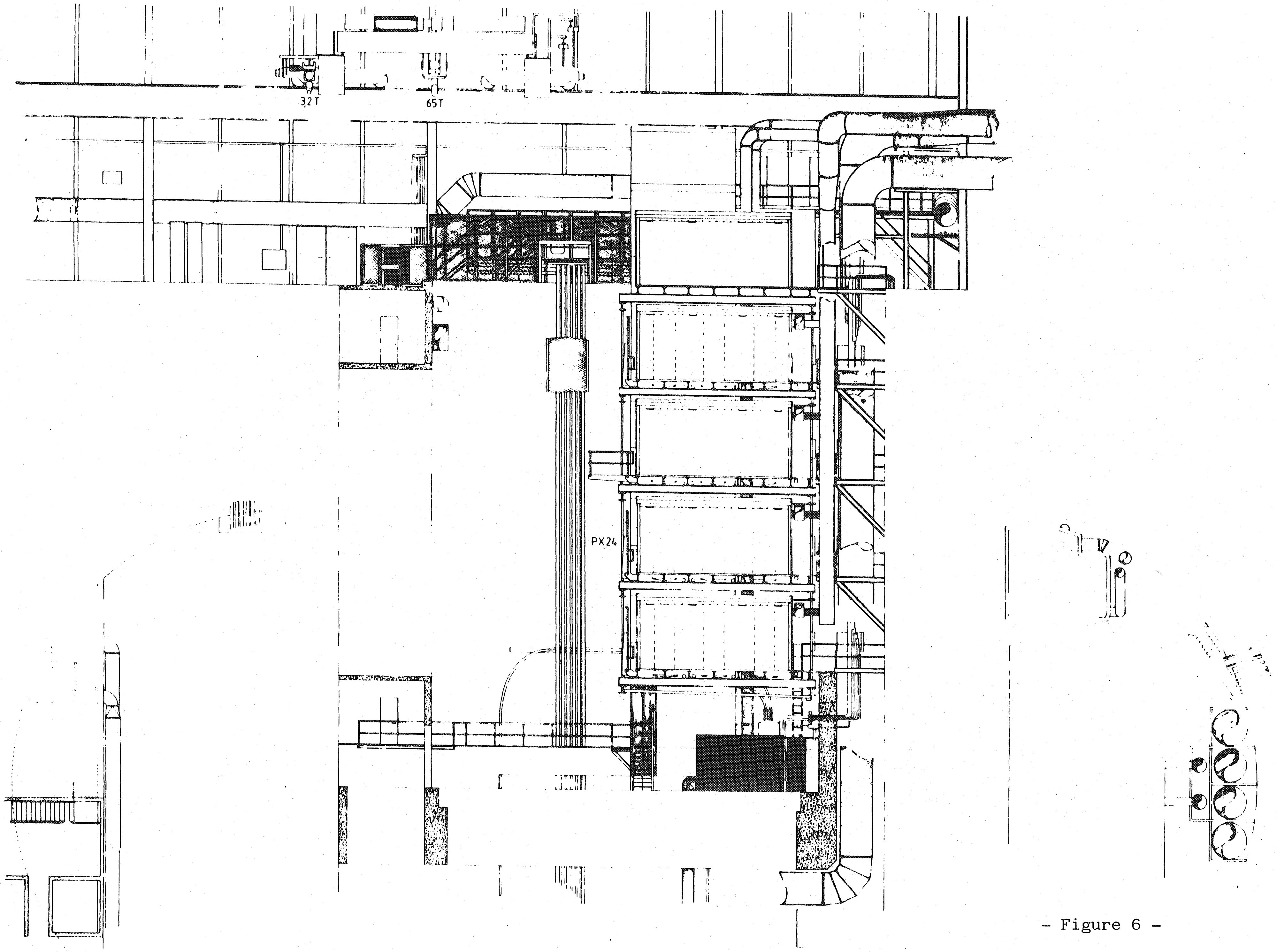

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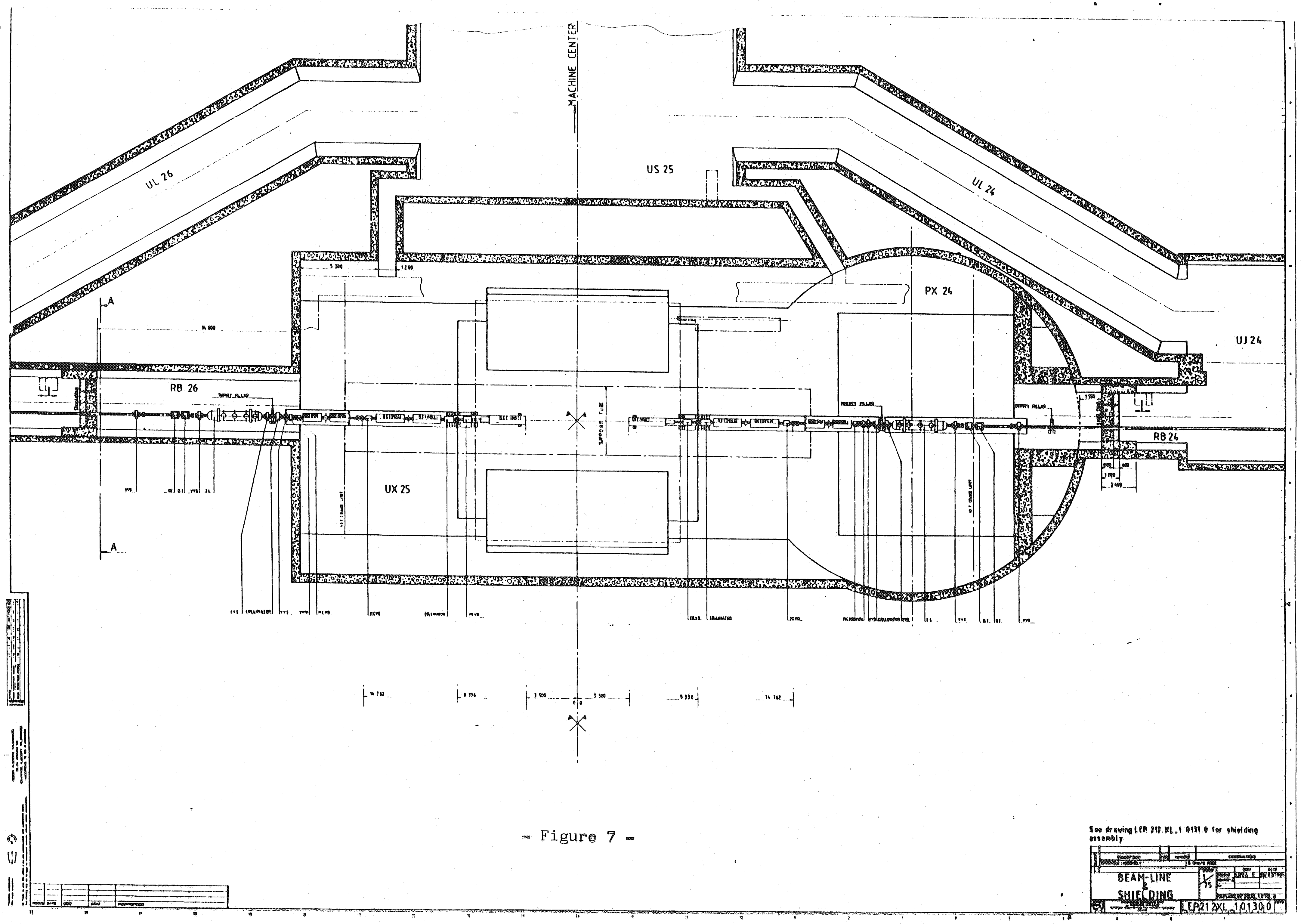
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BEAM-LINE & SHIELDING
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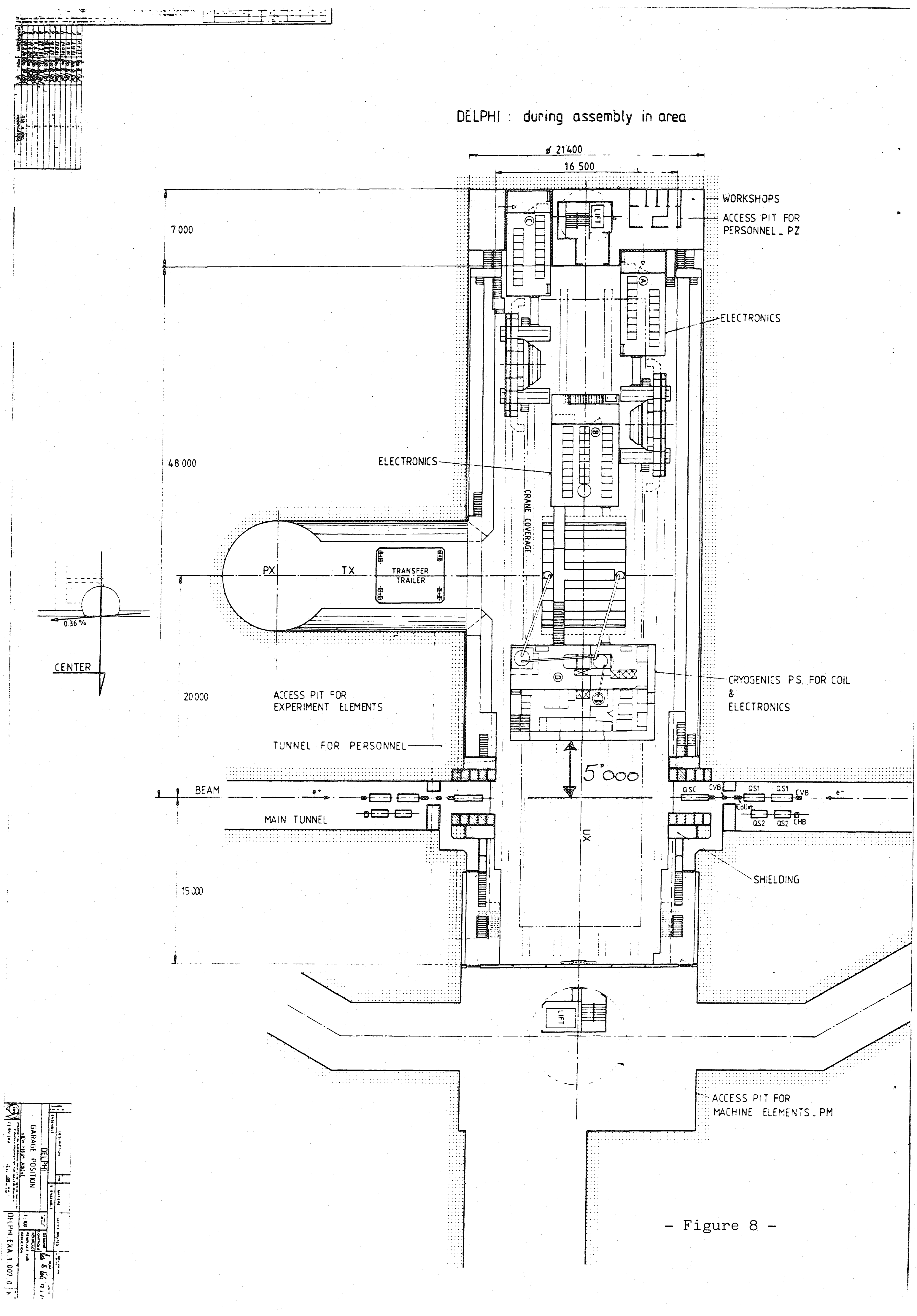
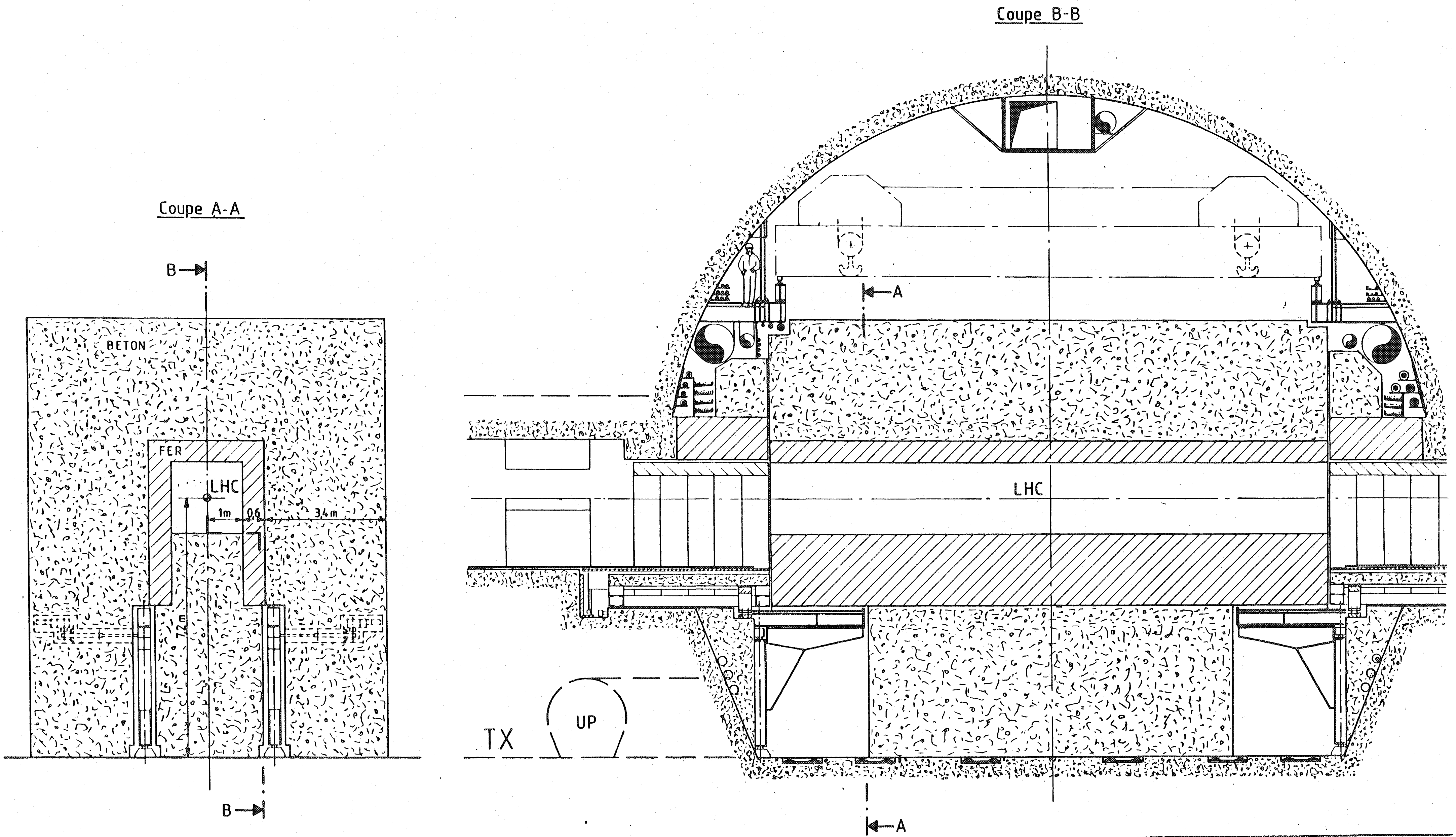
\- Figure 7 -

DELPHI : during assembly in area



- Figure 8 -



- Figure 9 -

DELPHI

Blindage LHC

1:50

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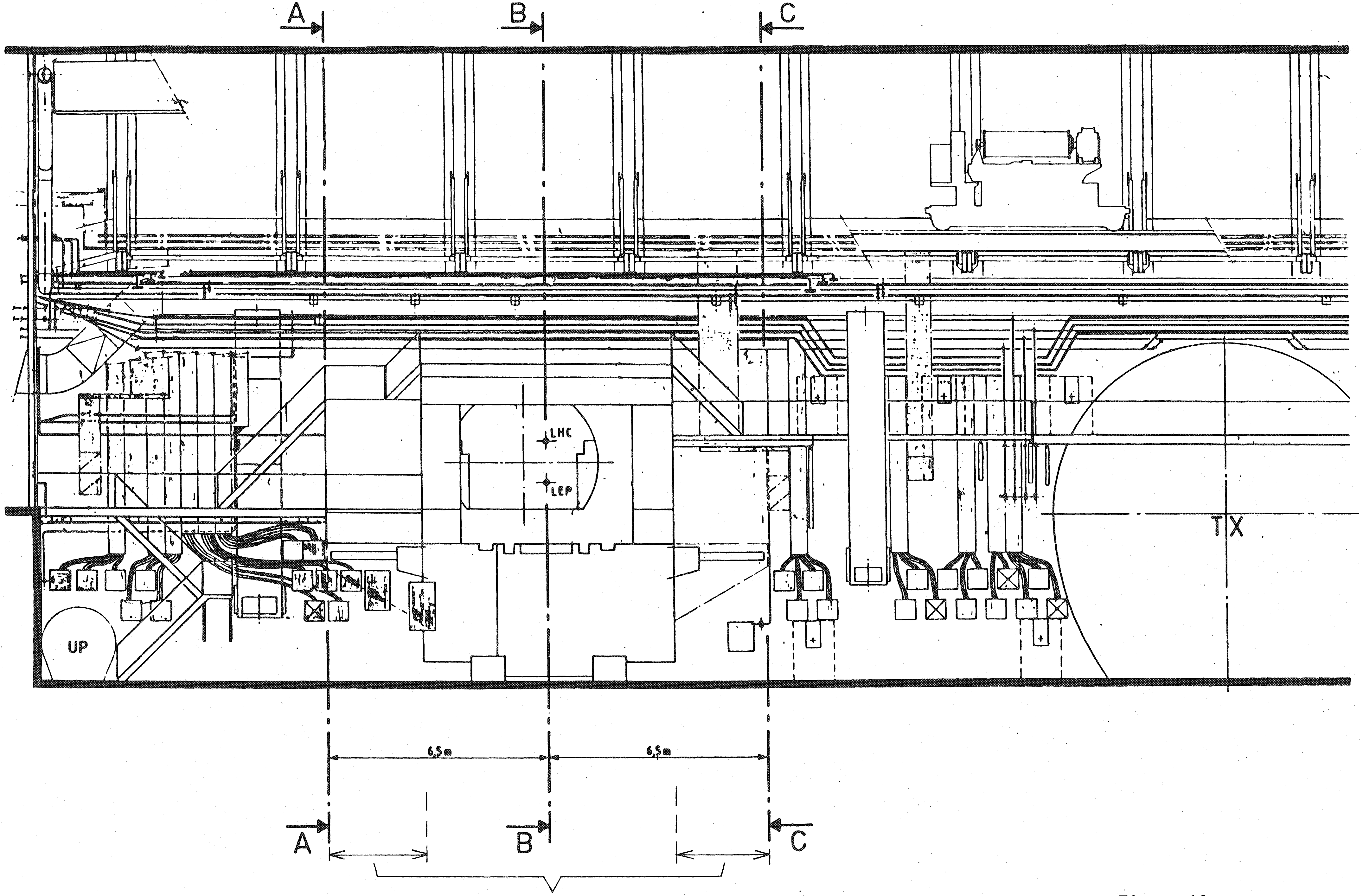
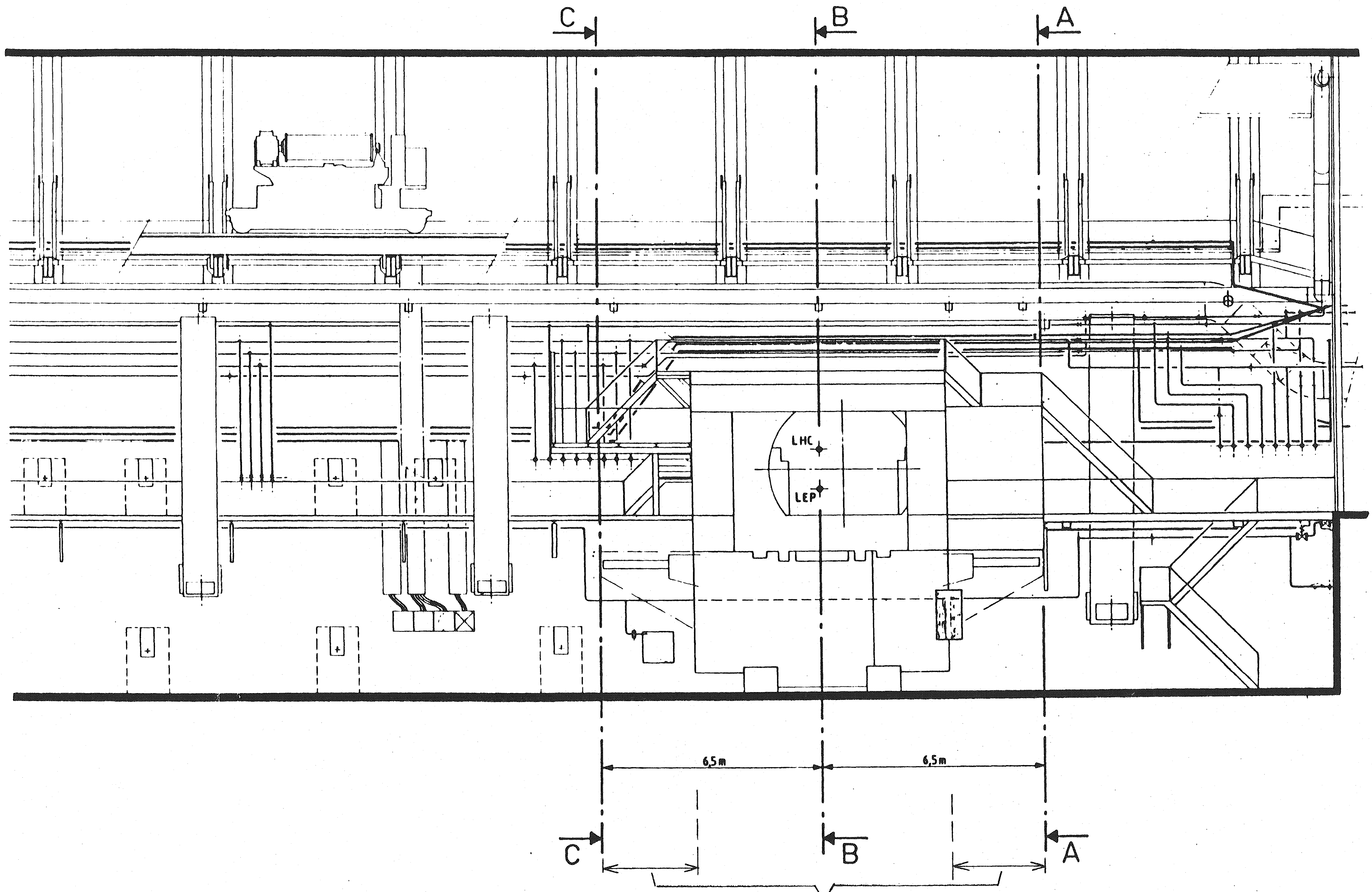


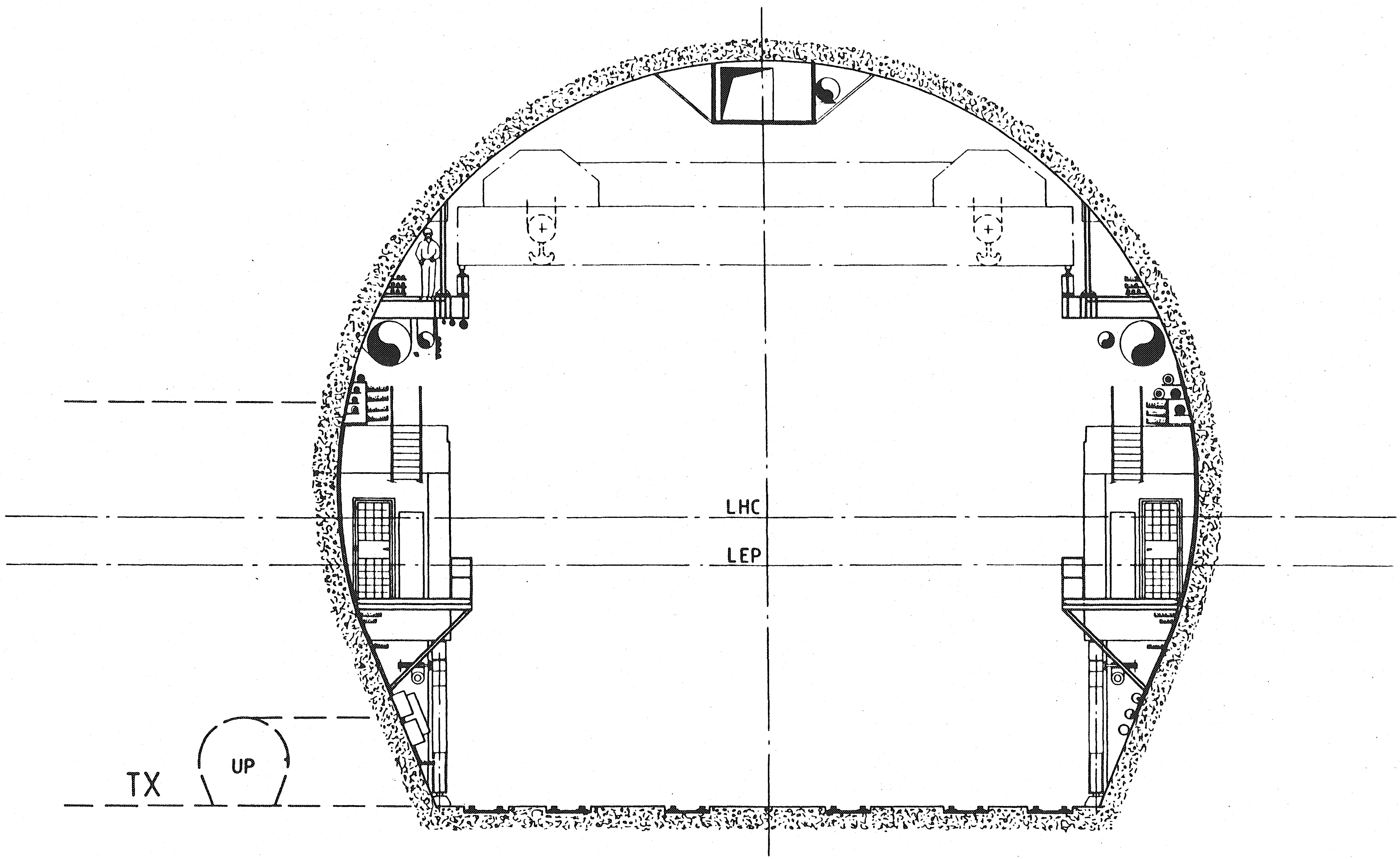
regions to be freed of equipment on the wall

- Figure 10 -



regions to be freed of equipment on the wall

- Figure 11 -



- Figure 12 -

QUANT	DESCRIPTION	POS	MATIERE	OBSERVATIONS
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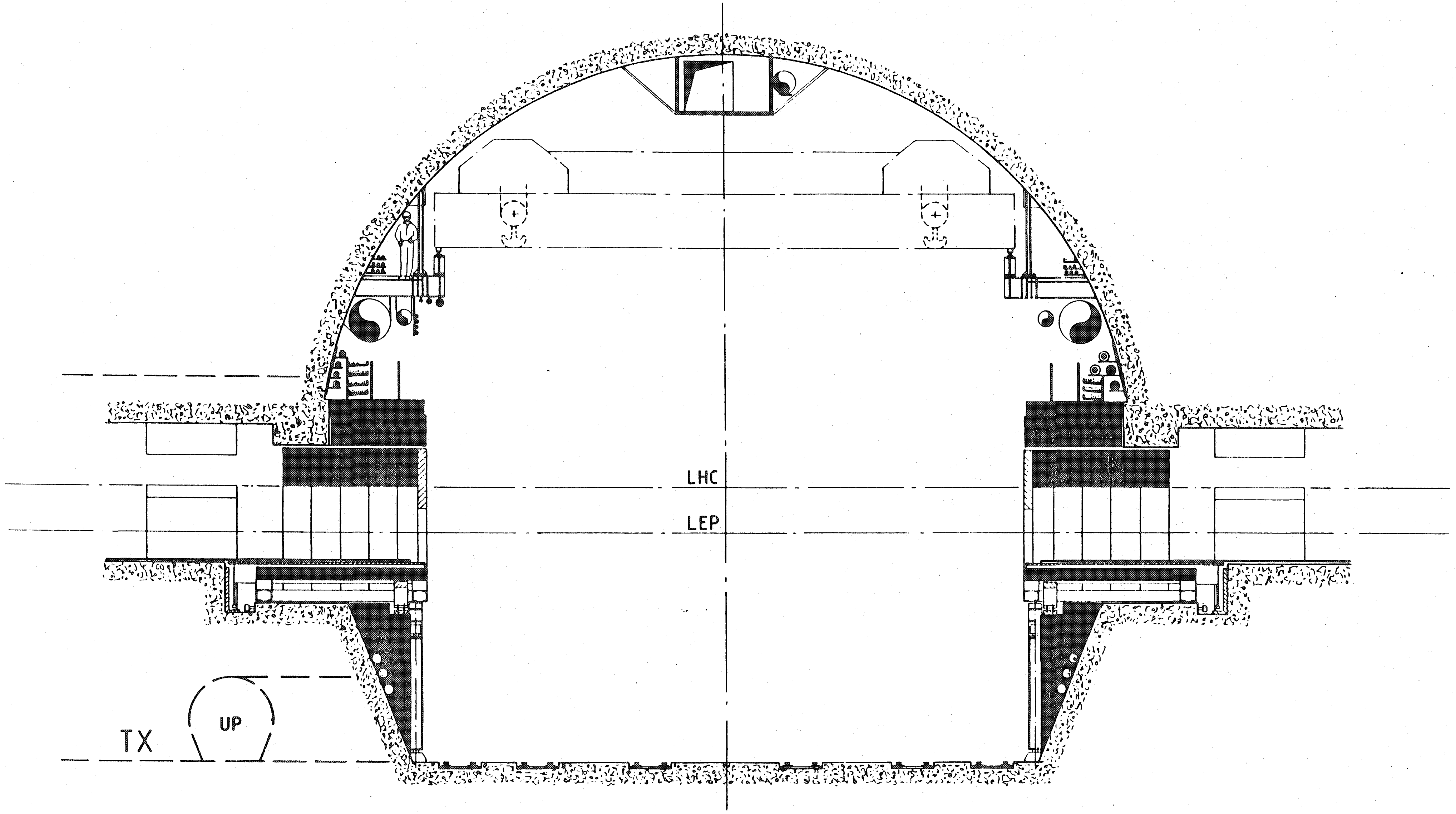

- Figure 13 -

DELPHI

Services Techniques dans UX 85. Section B-B

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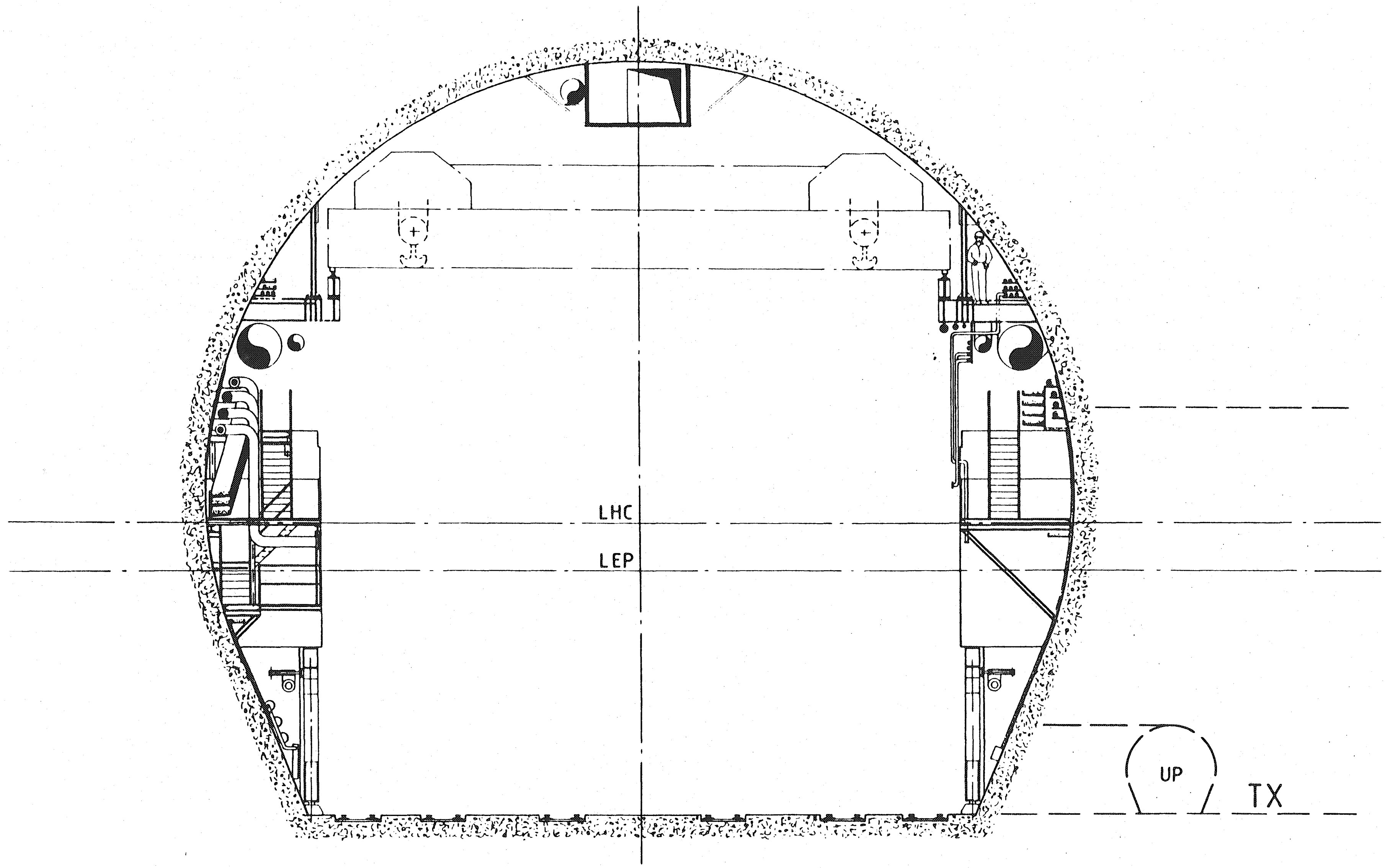

- Figure 14 -

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DELPHI

Services Techniques dans UX 85. Section C-C

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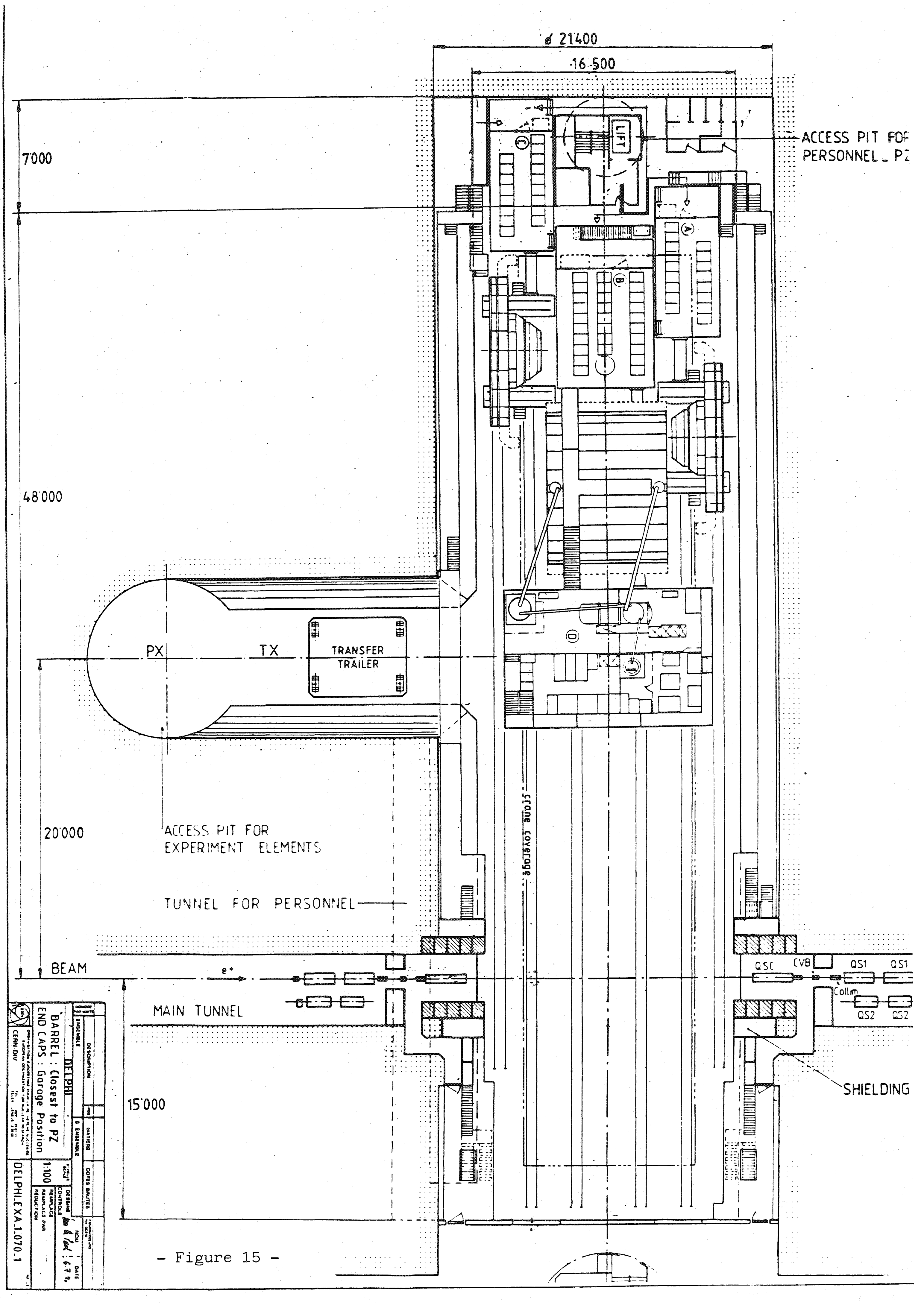
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TUNNEL FOR PERSONNEL
crane coverage
BEAM
e+
QSC
CVB
QS1
QS1
Collim
QS2
QS2
MAIN TUNNEL
SHIELDING
15000
DELPHI
BARREL : Closest to PZ
END CAPS : Garage Position
CERN-DIV
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- Figure 15 -