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WORKING MATERIAL

CO-ORDINATED RESEARCH PROGRAMME ON BENCHMARK STUDY FOR THE SEISMIC ANALYSIS AND TESTING OF WWER-TYPE NUCLEAR POWER PLANTS

VOLUME 1

DATA RELATED TO SITES AND PLANTS
PAKS NPP
KOZLODUY NPP

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Vienna, Austria, 1995

PREFACE

The Co-ordinated Research Programme on the Benchmark Study for Seismic Analysis and Testing of WWER-Type NPP's was initiated subsequent to the request from representatives of Member States at the Technical Committee Meeting on Seismic Safety Issues Relating to Existing NPP's held in Tokyo, August 1991. The conclusions of this meeting called for the harmonization of methods and criteria used in Member States in issues related to seismic safety.

With this objective in mind a Consultants' Meeting was convened in April 1992 to produce a working document for a CRP. The meeting was attended by twenty specialists coming from Eastern Europe, Western Europe, U.S.A. as well as Japan.

On the basis of the recommendations of this group it was decided that a benchmark study is the most effective way of achieving the principal objective. Two types of WWER reactors (WWER-1000 and WWER-440/213) were selected as prototypes for the benchmark exercise. These prototypes will be dynamically tested on a full scale using explosions and/or vibration generators. The two prototypes are Kozloduy Units 5/6 for the WWER-1000 and Paks for the WWER-440/213 NPP's.

Twenty one internationally recognized institutions (public or private companies) from fourteen countries take part in the state-of-the-art seismic analysis of the two prototypes. Three other institutions are attending the meetings as observers and contributing results of their research on a voluntary basis.

The first RCM was held at the Paks NPP in September 1993 during which time a plant walkdown was also performed to familiarize the programme participants with the WWER-440/213 type NPPs.

The second RCM was held in Kozloduy, 13-17 June 1994. The results of the studies were presented by the participating institutions and a plant walkdown of Kozloduy Unit 5 took place. A detailed workplan was prepared for the coming year during the RCM.

One of the major activities which took place after the Kozloduy RCM was the full scale dynamic testing of Paks NPP using several blasts.

The results of the tests will be prepared by February 1995. Five institutions will be engaged in a blind prediction of the test results using various methods of structural modeling and analysis.

The present set of Working Material comprises seven volumes and covers mainly the work reported since June 1994. The arrangement of the volumes is as follows:

Volume 1 - Data related to sites and plants: Kozloduy NPP, Paks NPP
Volume 2 - Generic material: codes, standards, criteria;
Volume 3A, 3B, 3C - Kozloduy NPP Units 5/6: analysis/testing;
Volume 4A, 4B - Paks NPP: analysis/testing.

No change was made to the original texts in the preparation of this set of Working Material.

Aybars Gürpinar, Project Officer
IAEA, Division of Nuclear Safety

LIST OF PARTICIPATING INSTITUTIONS

(Responsible Persons)

Belgium	-	Westinghouse Energy Systems Europe S.A.	(Monette)
Bulgaria	-	Building Research Institute	(Sachansky)
	-	Central Laboratory for Seismic Mechanics and Earthquake Engineering	(Kostov)
	-	Energoproekt	(Simeonov)
	-	EQE-Bulgaria	(Jordanov)
	-	Kozloduy NPP	(Boyadjiev)
Czech Republic	-	David Consulting	(David)
	-	Stevenson & Associates, Plzen	(Masopust)
Germany	-	Siemens	(Krutzik)
	-	Wölfel	(Henkel)
Hungary	-	Paks NPP	(Katona)
Italy	-	Ismes S.p.A.	(Muzzi)
Macedonia	-	Institute of Earthquake Engineering and Engineering Seismology	(Jurukovski)
Romania	-	Stevenson & Associates Seismic Engineering	(Coman)
Russia	-	Atomenergoprojekt	(Ambriashvili)
	-	CKTI Vibroseism	(Kostarev)
	-	The All-Russia Nuclear Power Engineering Research and Development Institute (VNIIAM)	(Kaznovski)
Slovakia	-	Institute of Construction and Architecture, Slovak Academy of Sciences	(Juhasova)
Spain	-	Empresarios Agrupados	(Ordoñez)
Switzerland	-	Stüssi & Partner	(Stüssi)
USA	-	EQE International	(Asfura)

TABLE OF CONTENTS

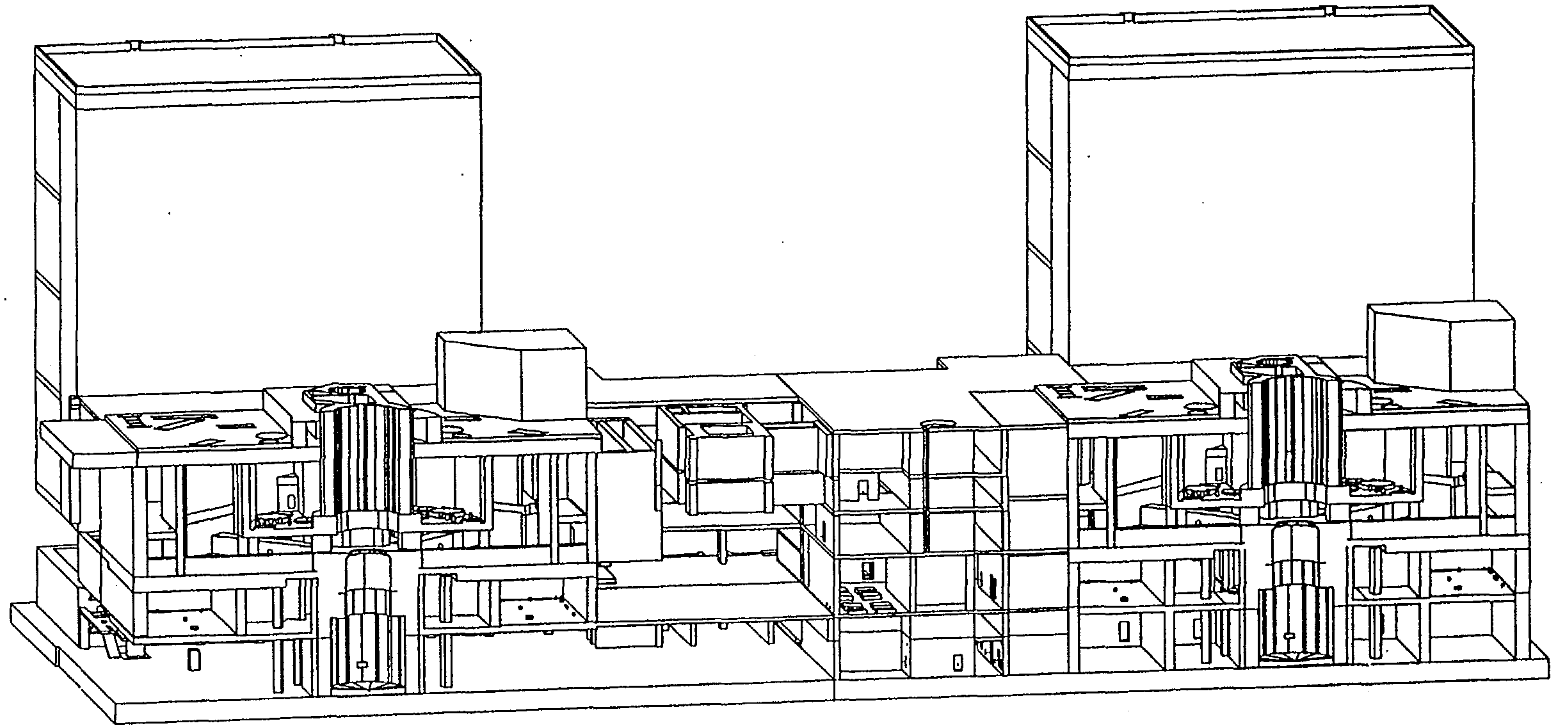
Title: Isometric Drawings, Paks NPP

Contributor: T. Katona

Date: September 1994

PAKSI ATOMERŐMŰ 3-4 BLOKKI FŐÉPÜLET

Tájékoztató album



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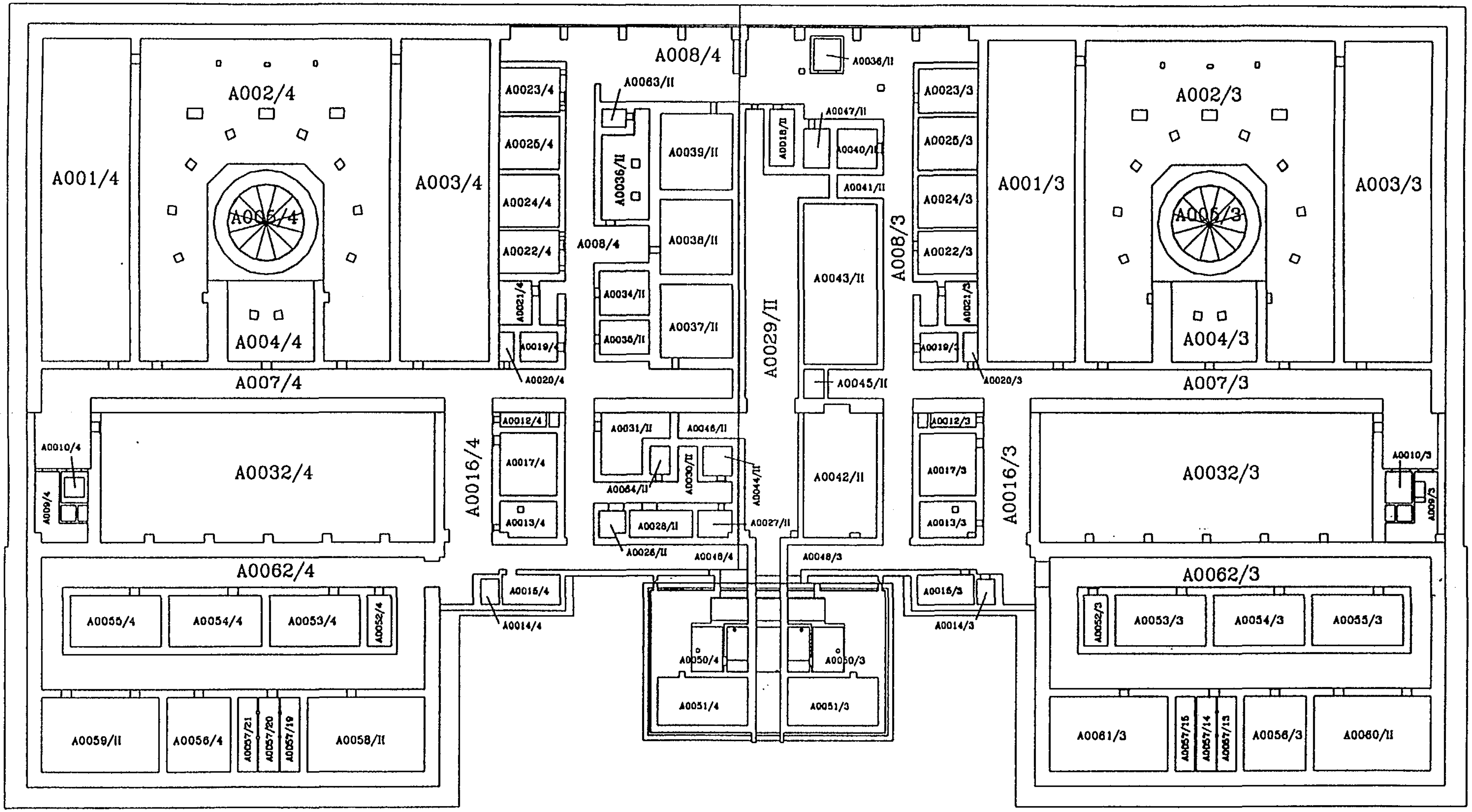

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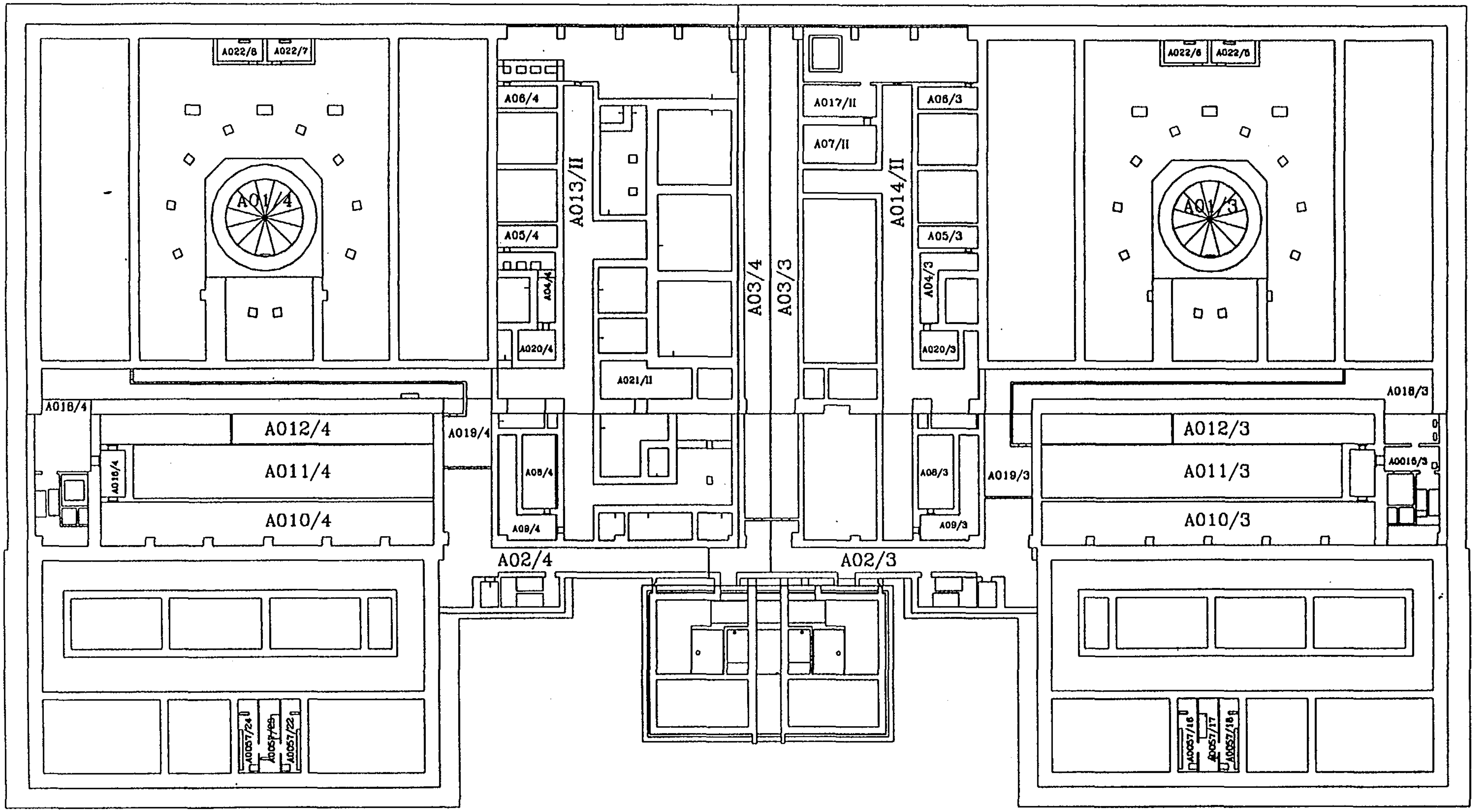

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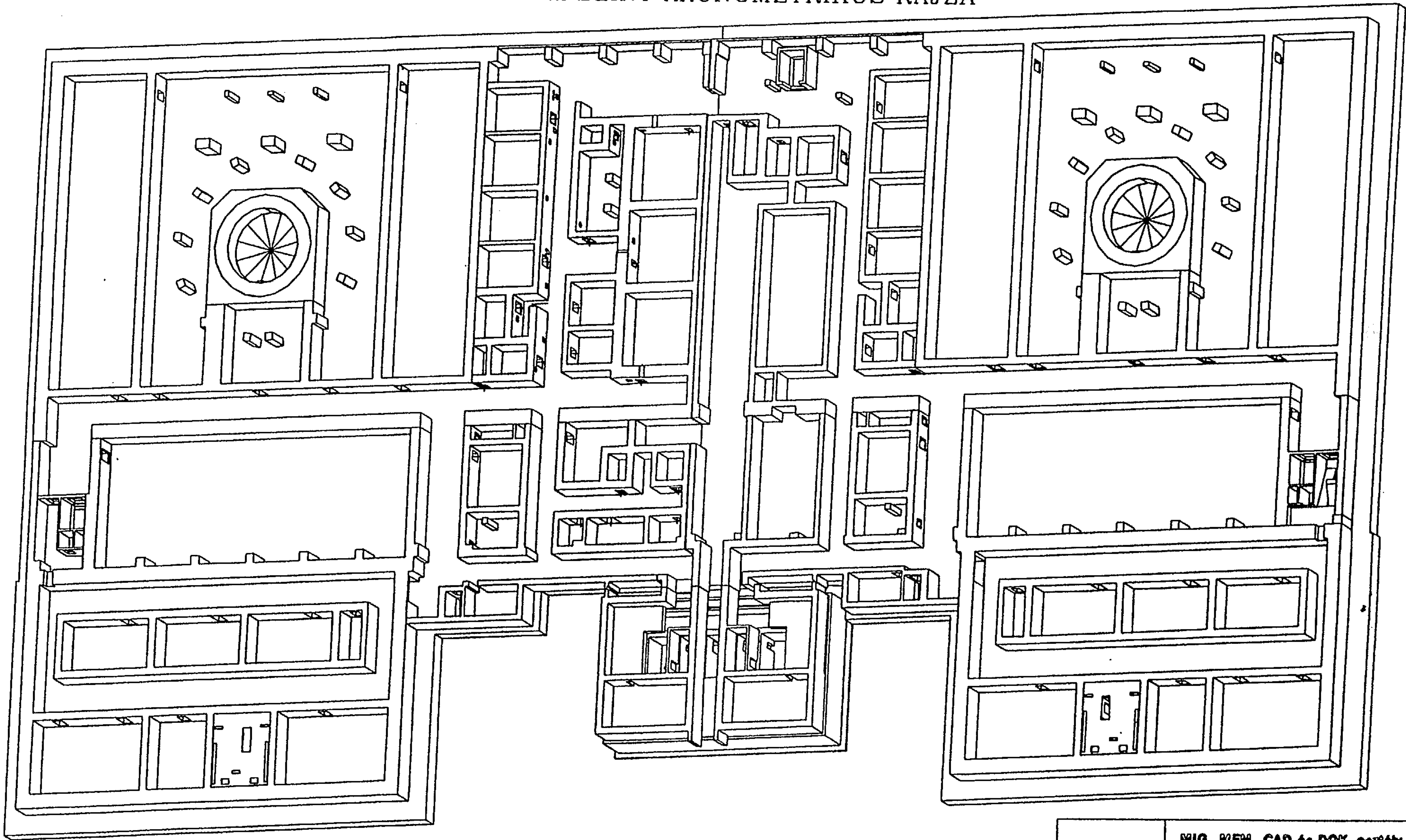

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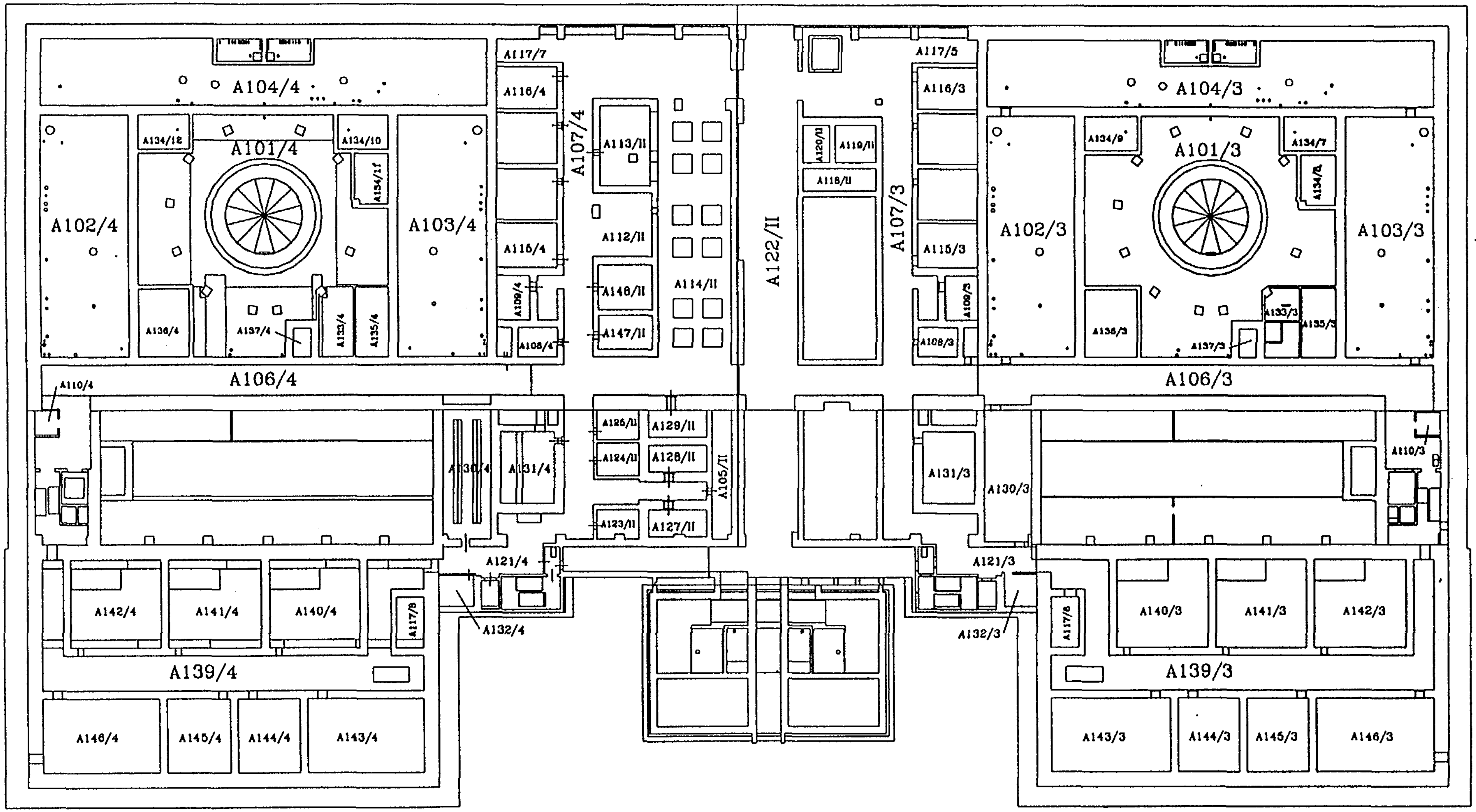

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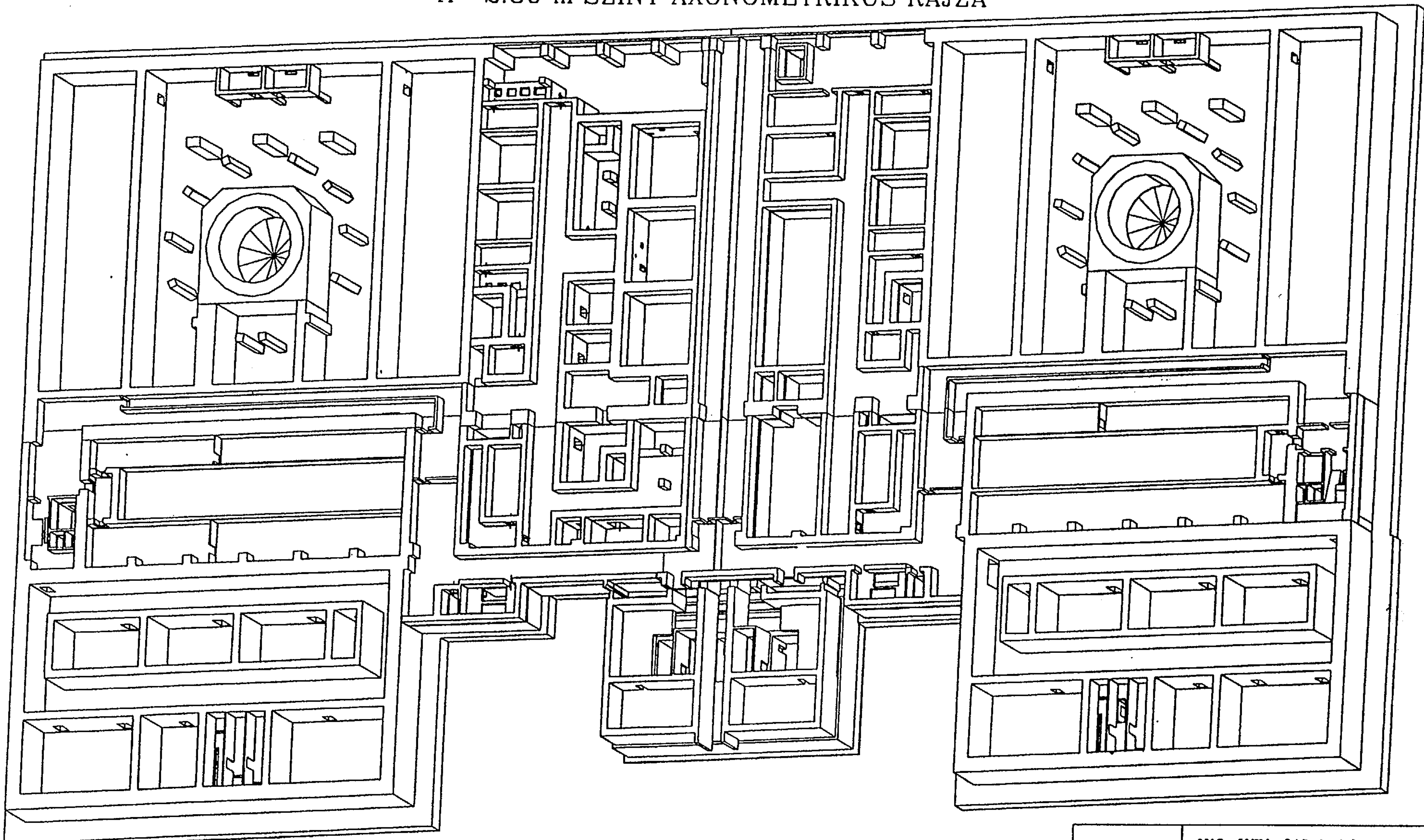

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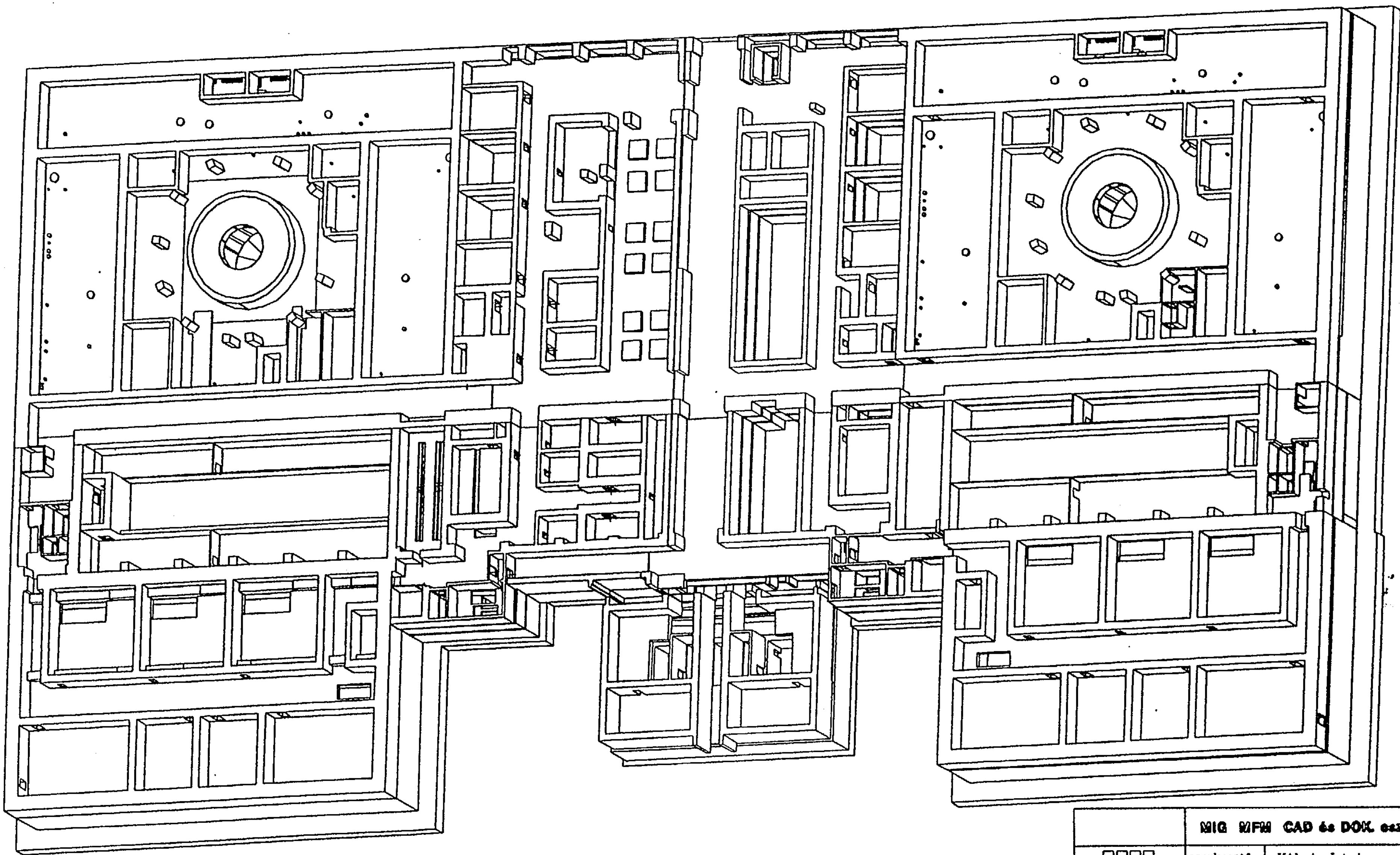

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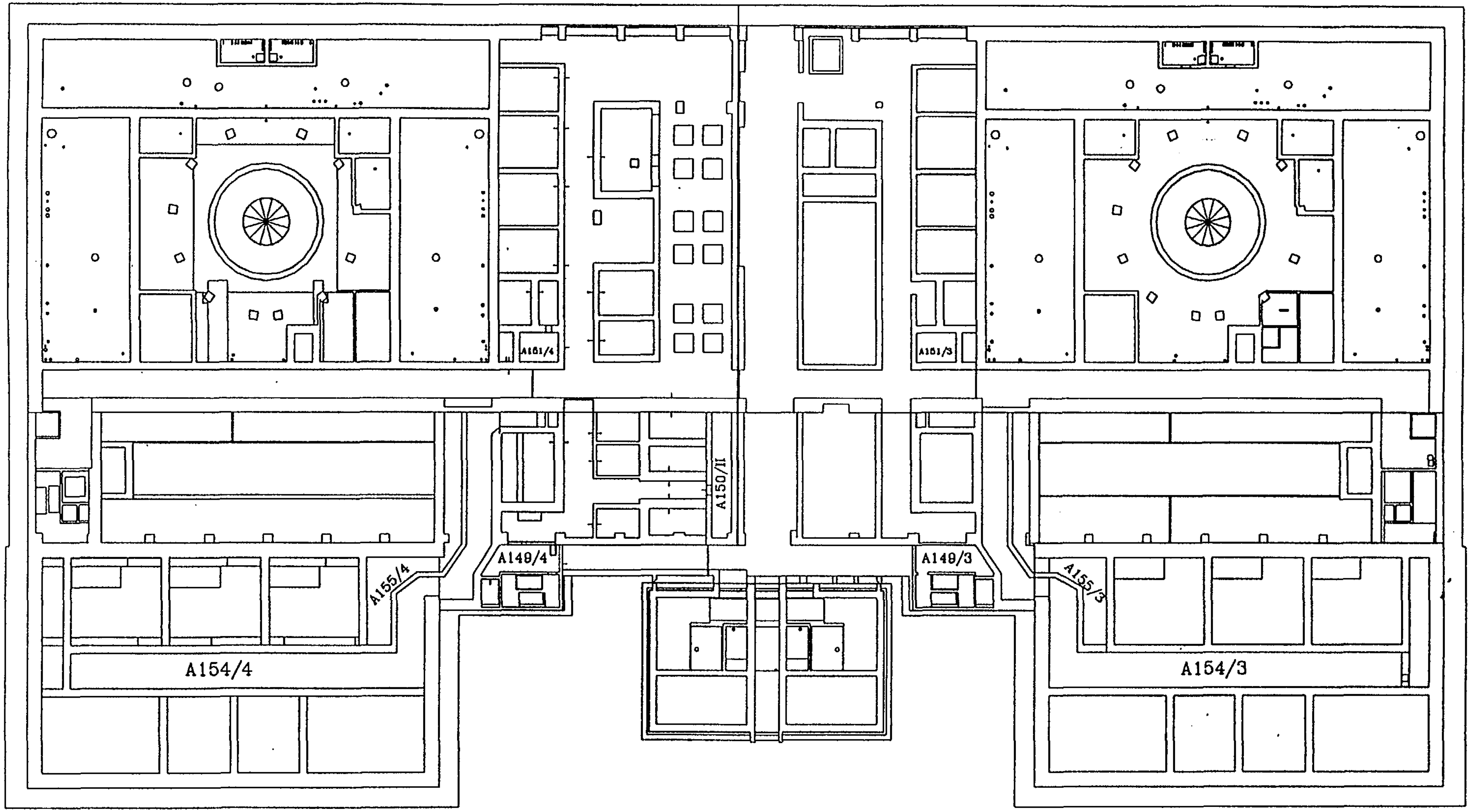

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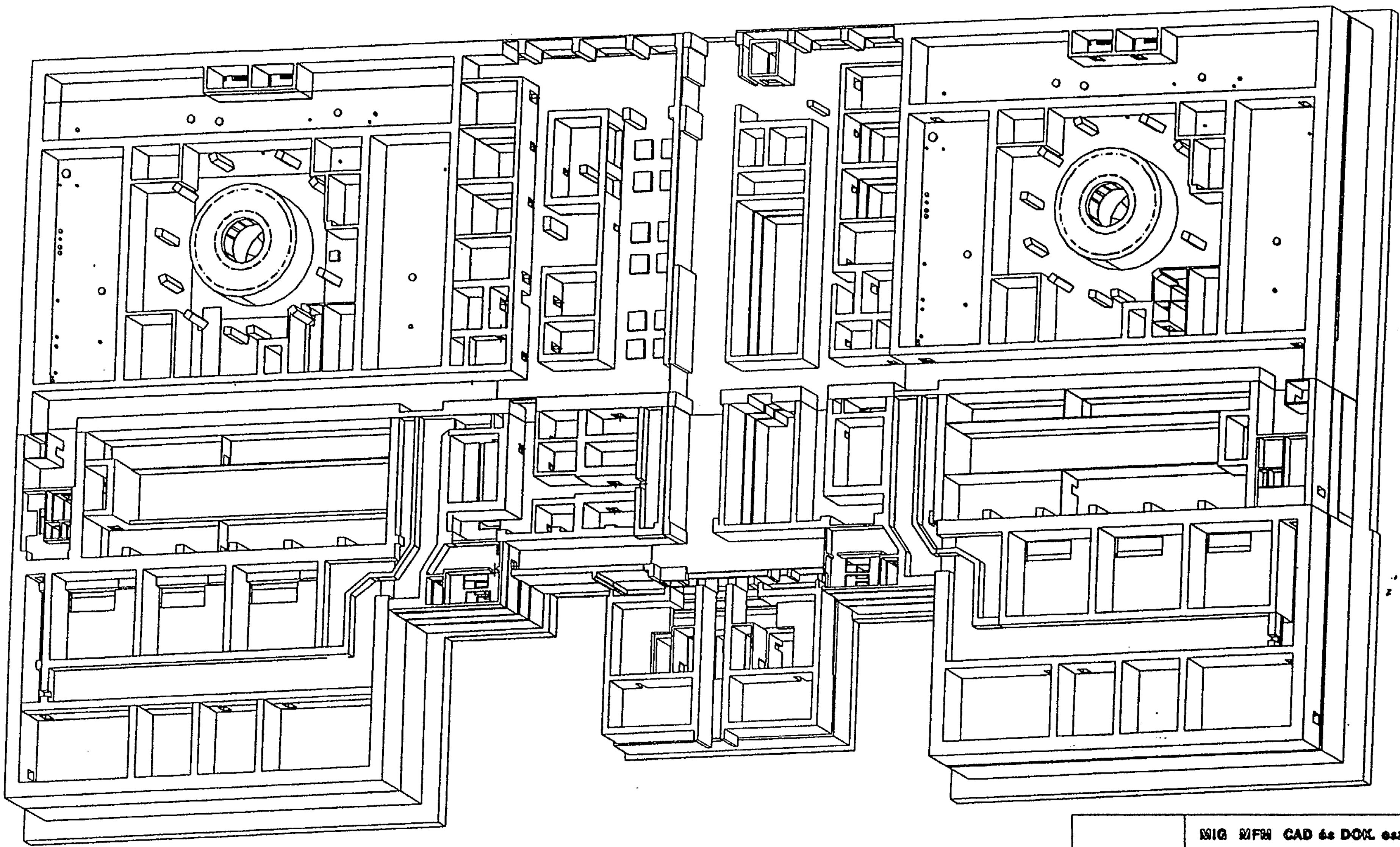

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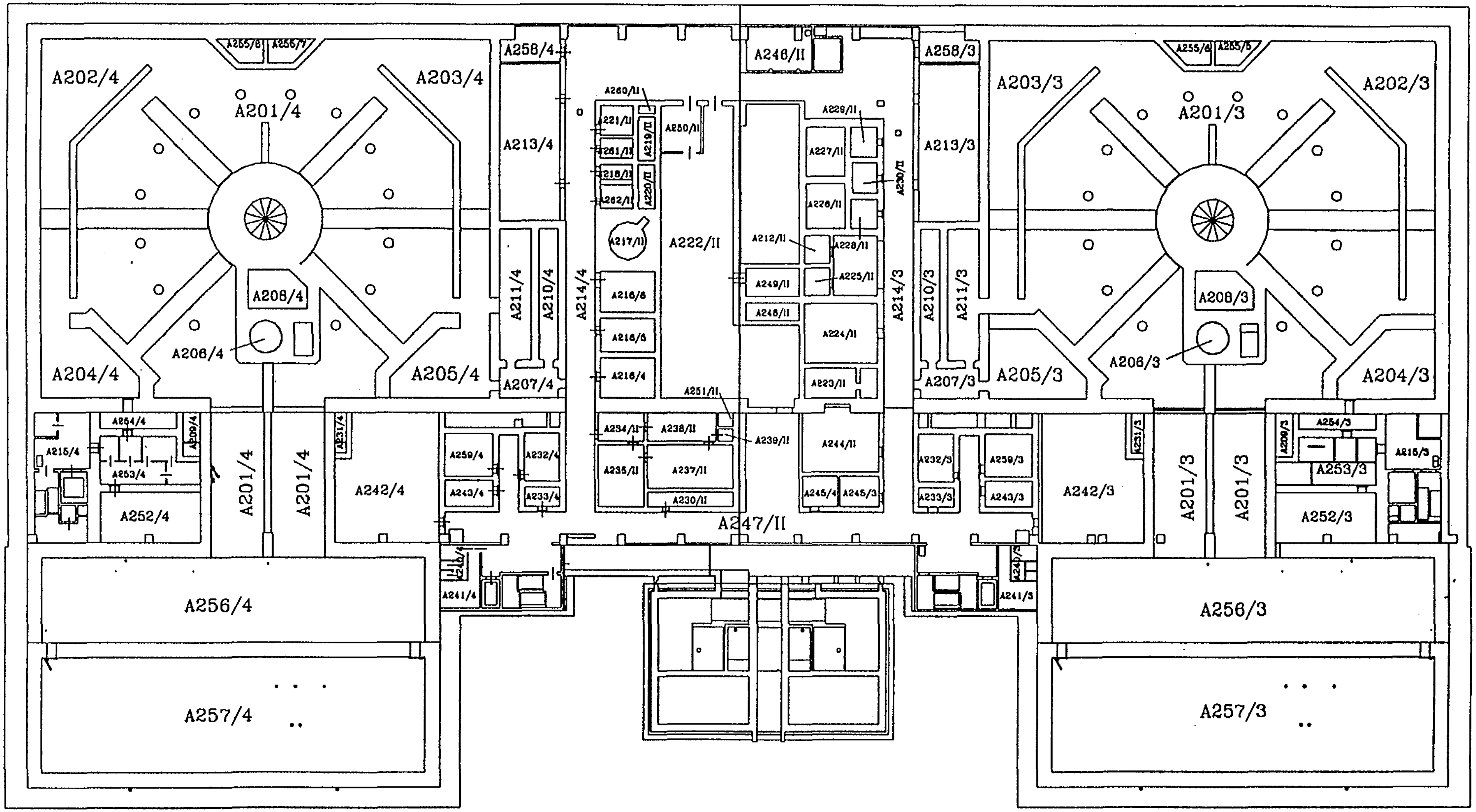

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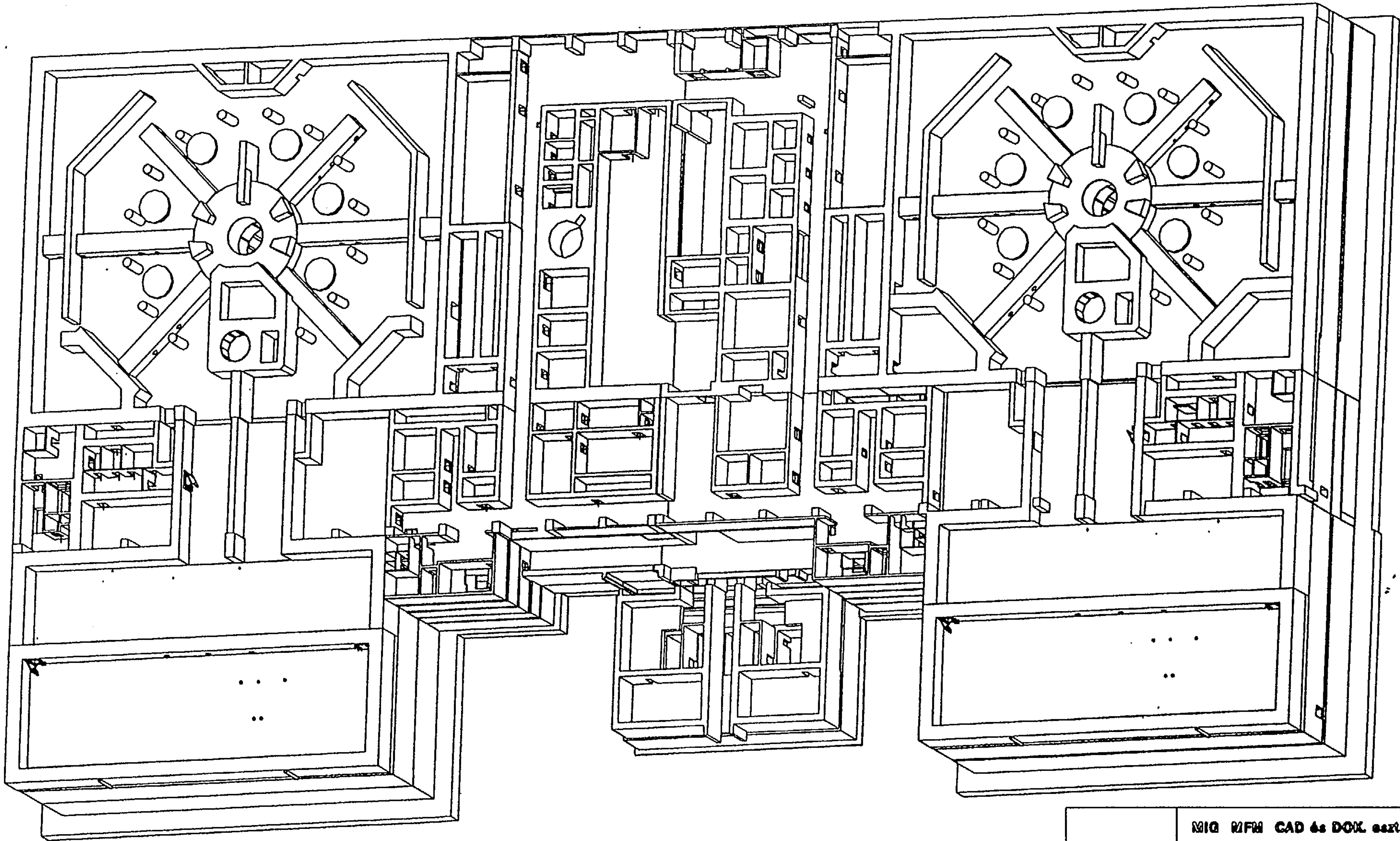

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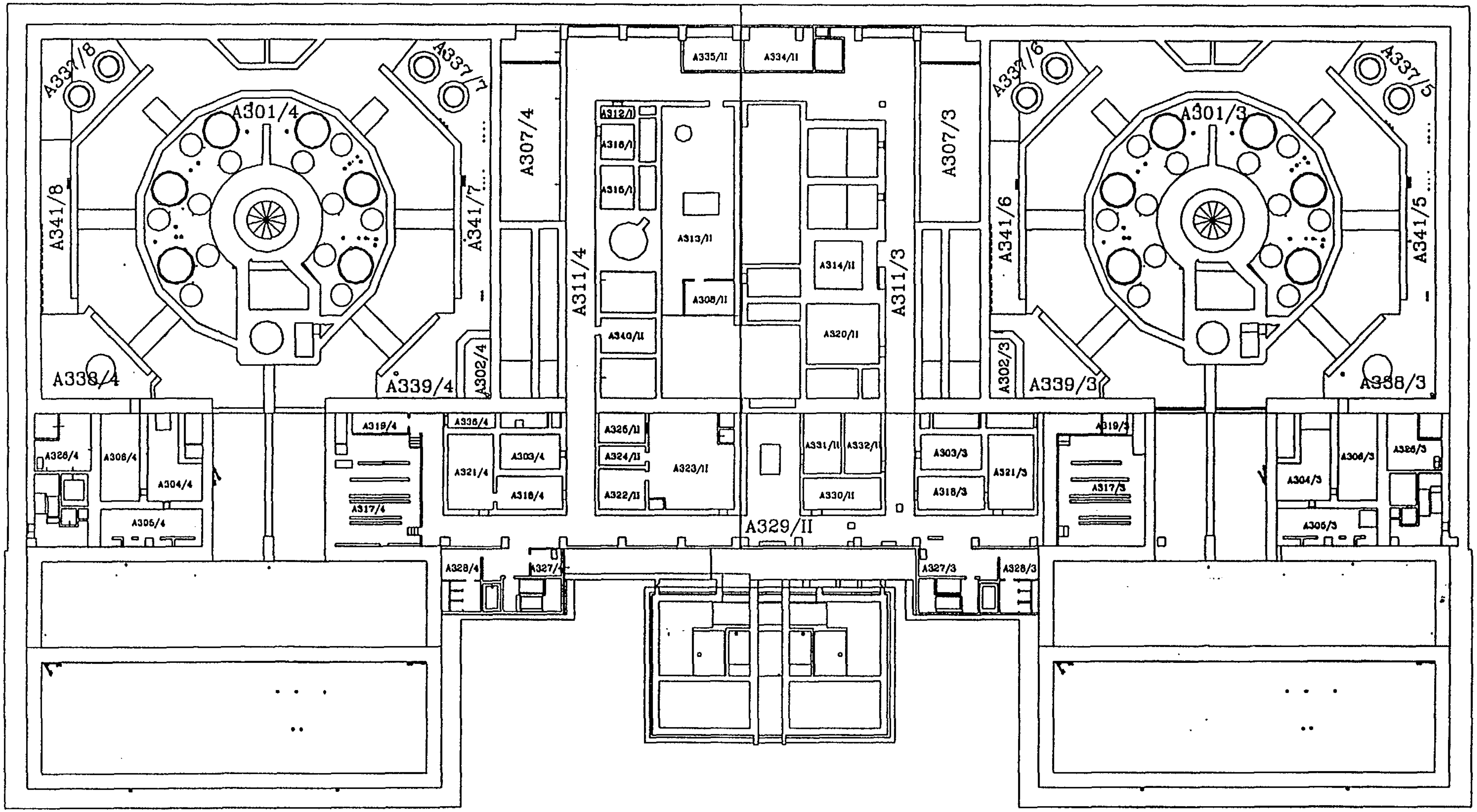

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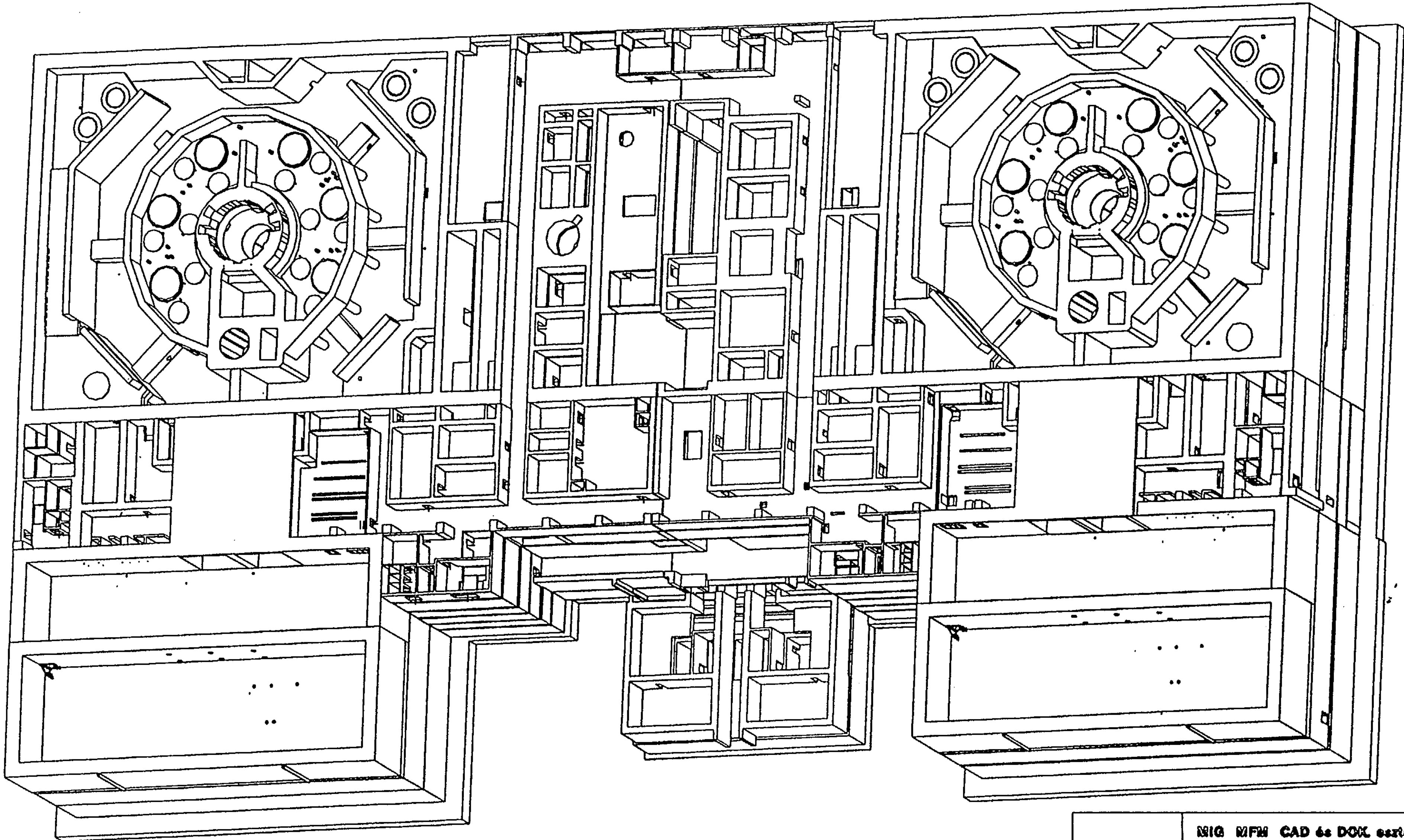

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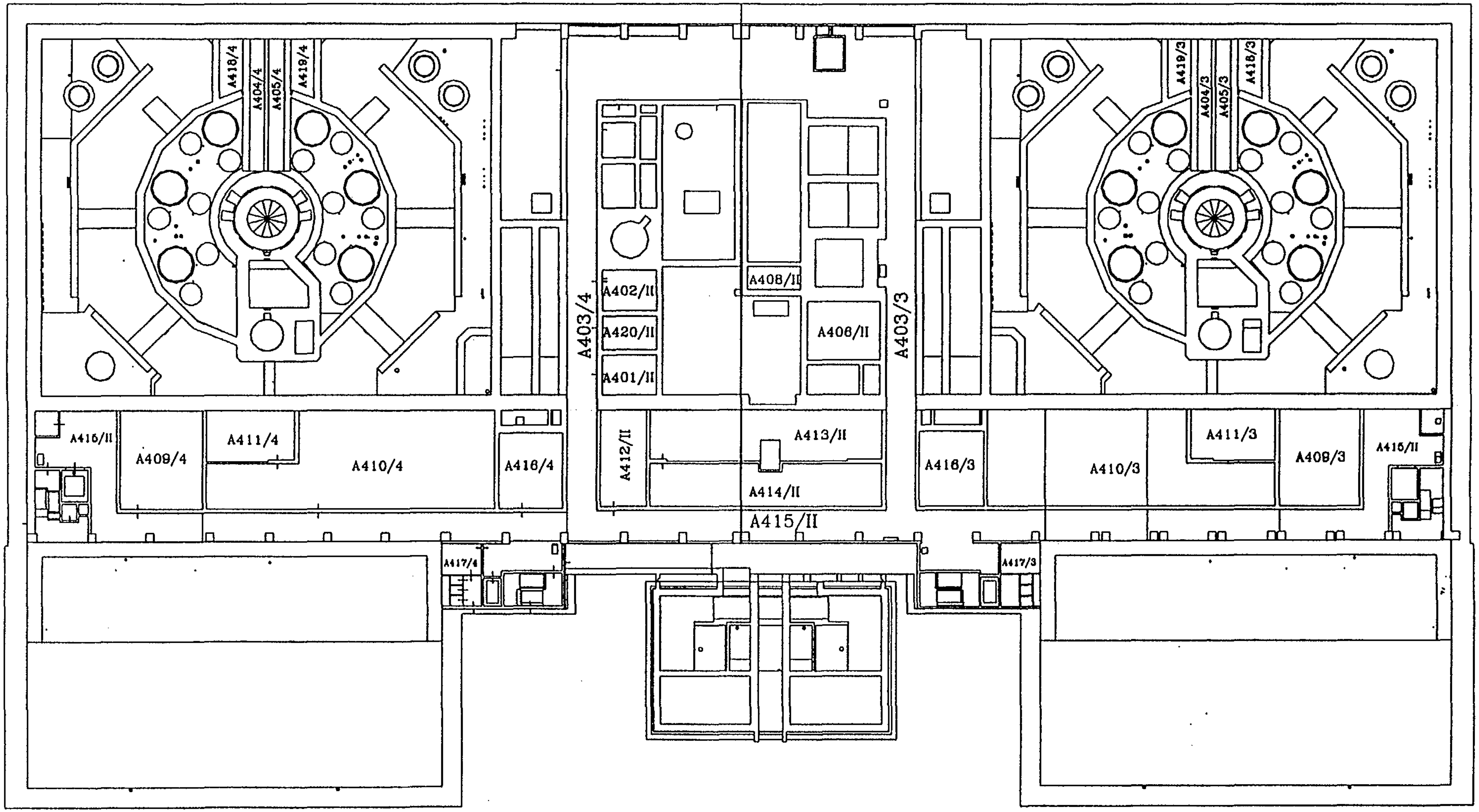

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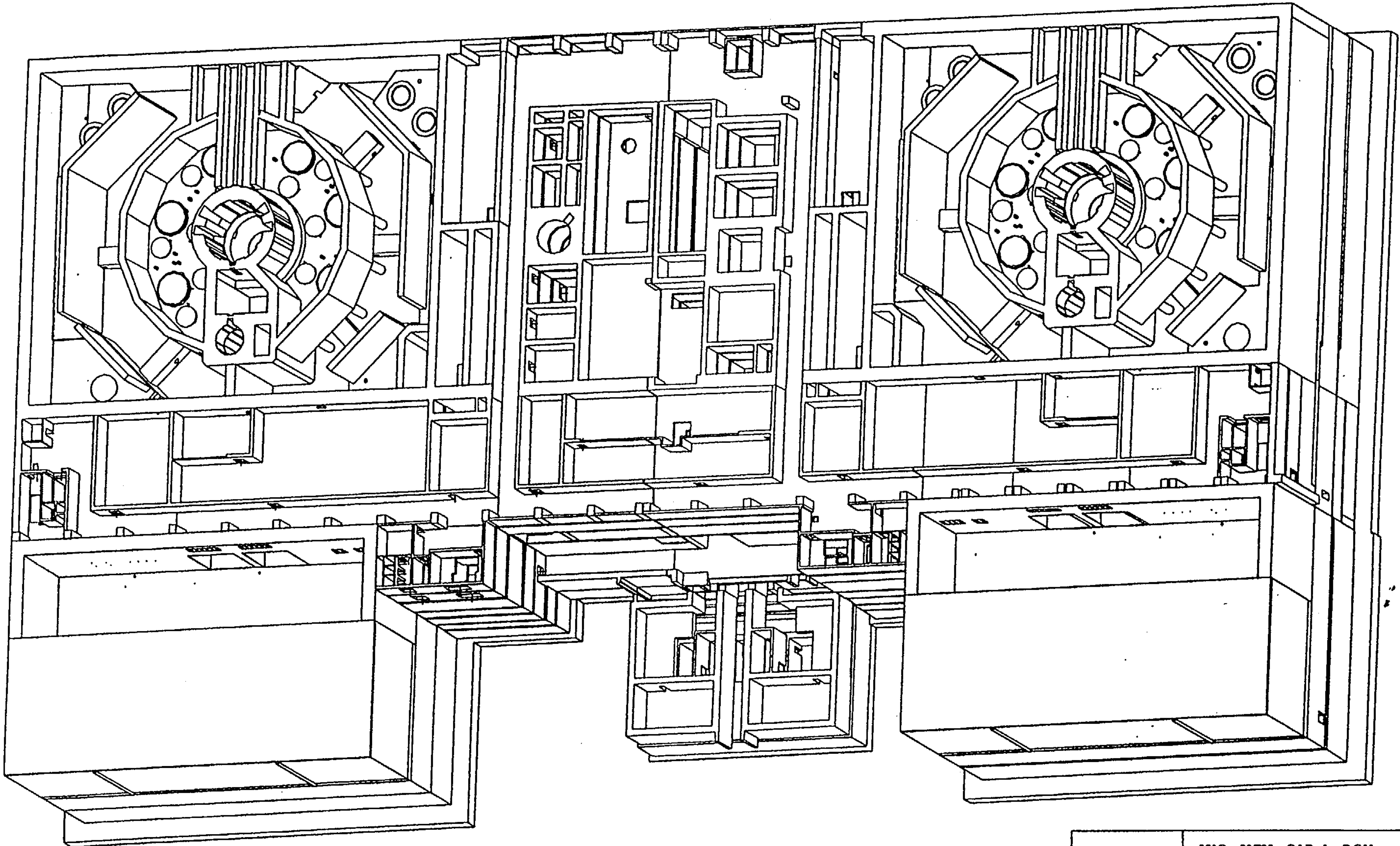

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ellenőr	
dátum	1994. 09.07.

Paksi Atomerőmű Rt.

Title: Reference Book: Paks Nuclear Power Plant, Blocks 3 and 4

Contributor: T. Katona

Date: 1983

PAKS NUCLEAR POWER PLANT

BLOCKS 3 and 4

REFERENCE BOOK FOR THE LONGITUDINAL
AND TRANSVERSAL BUILDING OF THE ELECTRICAL
EQUIPMENTS

This reference book had been made by the ERŐTERV for every day use to make easier the orientation in the longitudinal and transversal building of the electrical equipments.

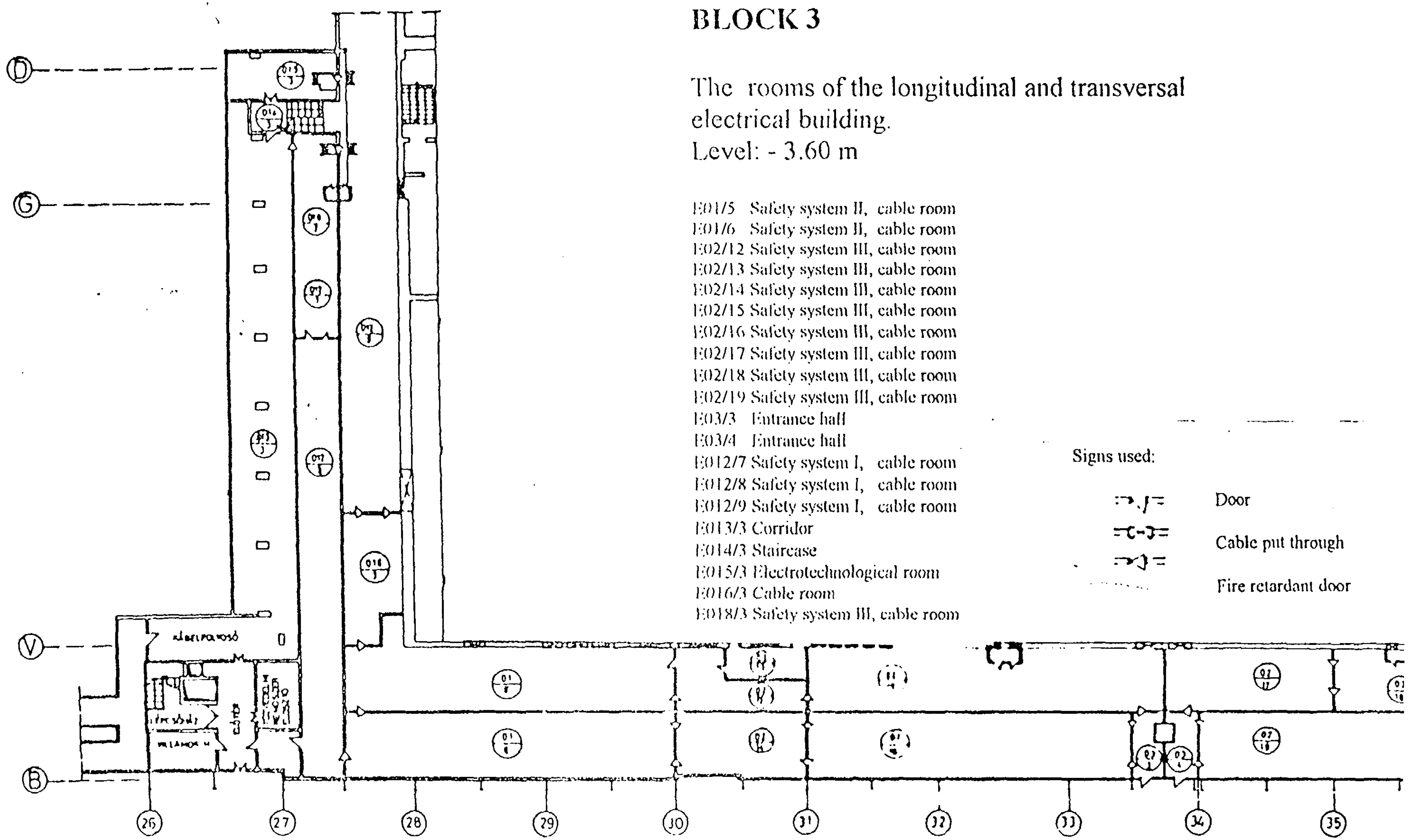
The book involves the ground-plans and list of rooms of the longitudinal and transversal electrical building of blocks 3 and 4.

Compiled by: Paks office of ERŐTERV, Architecture division.
Paks Nuclear Power Plant, Project Management

1983 Budapest

BLOCK 3

The rooms of the longitudinal and transversal electrical building.
Level: - 3.60 m



E01/5 Safety system II, cable room
E01/6 Safety system II, cable room
E02/12 Safety system III, cable room
E02/13 Safety system III, cable room
E02/14 Safety system III, cable room
E02/15 Safety system III, cable room
E02/16 Safety system III, cable room
E02/17 Safety system III, cable room
E02/18 Safety system III, cable room
E02/19 Safety system III, cable room
E03/3 Entrance hall
E03/4 Entrance hall
E012/7 Safety system I, cable room
E012/8 Safety system I, cable room
E012/9 Safety system I, cable room
E013/3 Corridor
E014/3 Staircase
E015/3 Electrotechnological room
E016/3 Cable room
E018/3 Safety system III, cable room

Signs used:

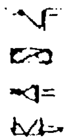
Door
Cable put through
Fire retardant door

BLOCK 4

The rooms of the longitudinal and transversal electrical building.
Level: - 3.60 m

E01/7 Safety system II. cable room
E01/8 Safety system II. cable room
E02/18 Safety system III. cable room
E02/20 Safety system III. cable room
E02/21 Safety system III. cable room
E02/22 Safety system III. cable room
E012/10 Safety system I. cable room
E012/11 Safety system I. cable room
E012/12 Safety system I. cable room
E013/4 Corridor
E014/4 Staircase
E015/4 Electrical room
E016/4 Cable room

Signs used:

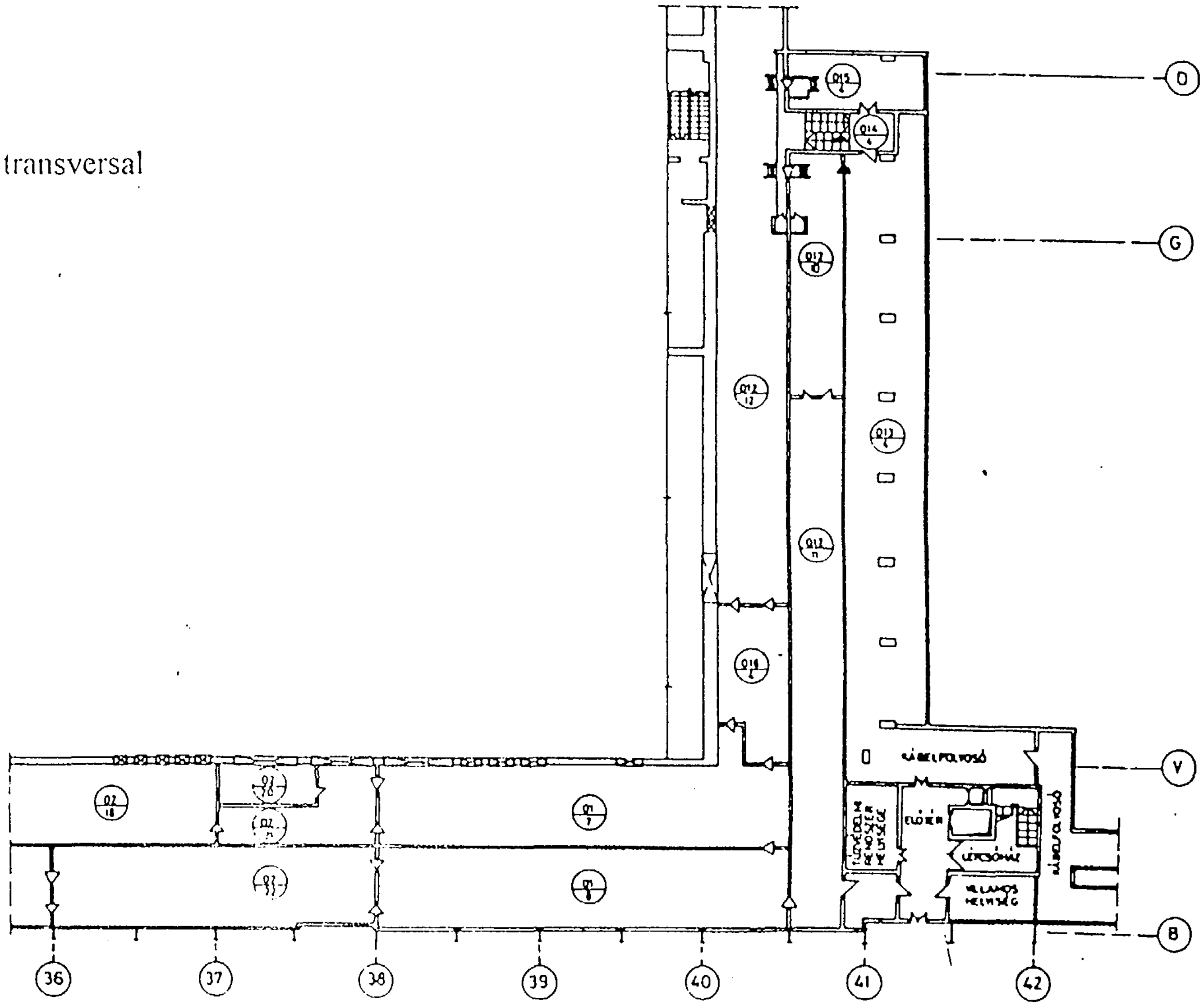


Door

Cable throughput

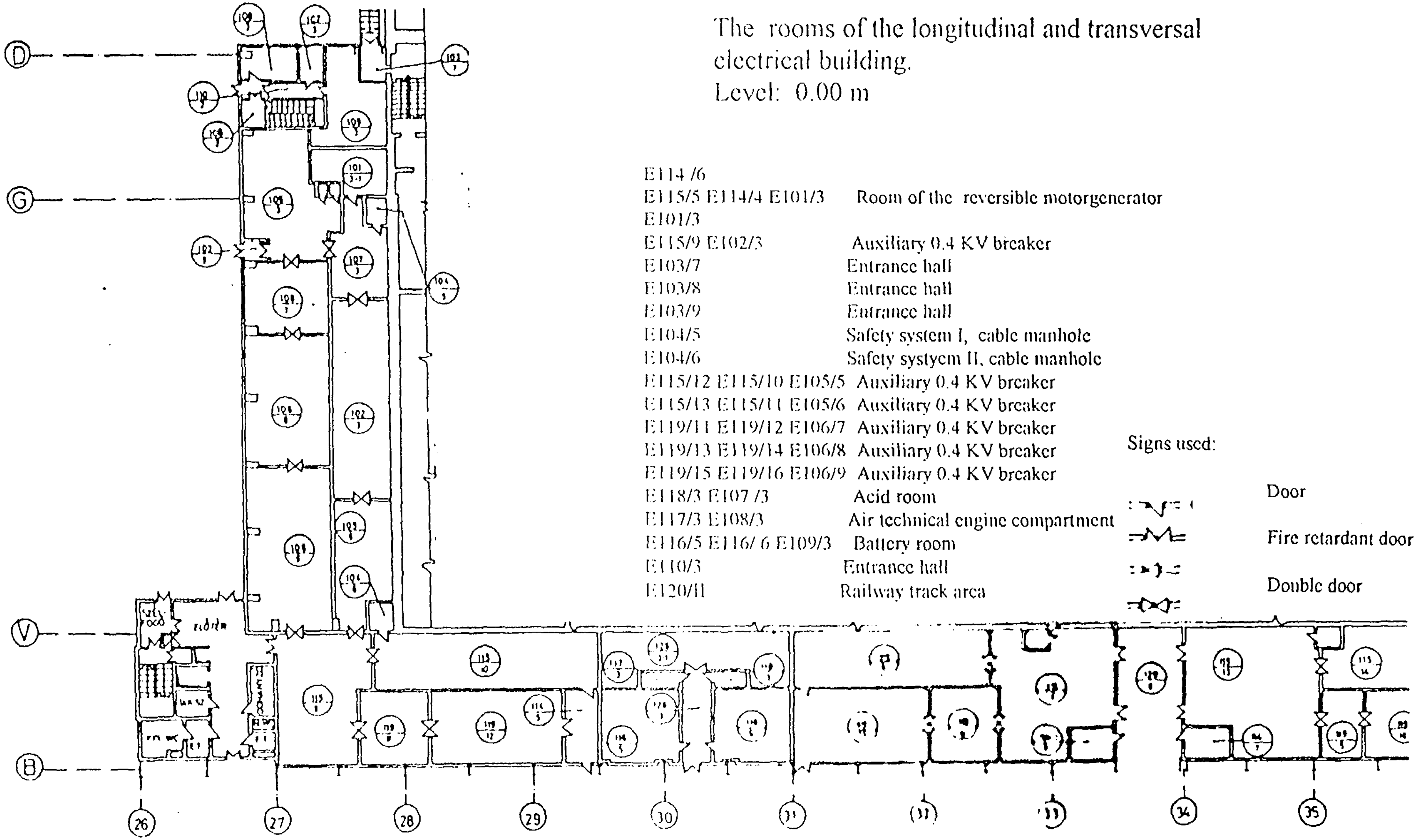
Fire retardant door

Double door



BLOCK 3

The rooms of the longitudinal and transversal electrical building.
Level: 0.00 m



E114 /6	
E115/5 E114/4 E101/3	Room of the reversible motorgenerator
E101/3	
E115/9 E102/3	Auxiliary 0.4 KV breaker
E103/7	Entrance hall
E103/8	Entrance hall
E103/9	Entrance hall
E104/5	Safety system I, cable manhole
E104/6	Safety systyem II, cable manhole
E115/12 E115/10 E105/5	Auxiliary 0.4 KV breaker
E115/13 E115/11 E105/6	Auxiliary 0.4 KV breaker
E119/11 E119/12 E106/7	Auxiliary 0.4 KV breaker
E119/13 E119/14 E106/8	Auxiliary 0.4 KV breaker
E119/15 E119/16 E106/9	Auxiliary 0.4 KV breaker
E118/3 E107 /3	Acid room
E117/3 E108/3	Air technical engine compartment
E116/5 E116/ 6 E109/3	Battery room
E110/3	Entrance hall
E120/II	Railway track area

Signs used:

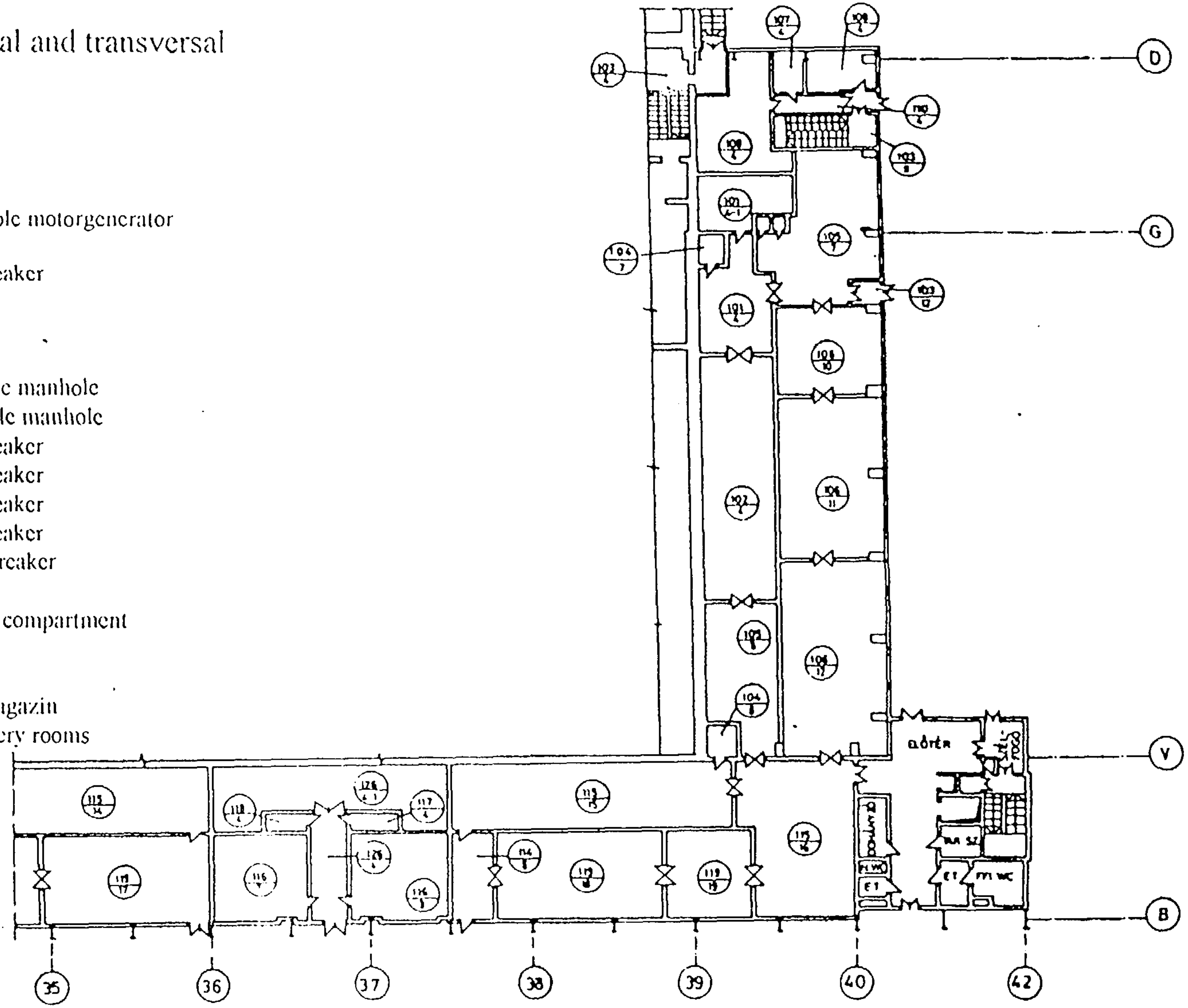
Door

Fire retardant door

Double door

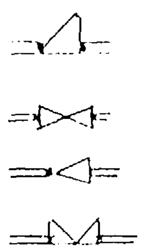
BLOCK 4

The rooms of the longitudinal and transversal electrical building.
Level: 0.00 m



E114/8 E101/4	Room of the reversible motorgenerator
E101/4	
E102/4	Auxiliary 0.4 KV breaker
E103/10	Entrance hall
E103/11	Entrance hall
E103/12	Entrance hall
E104/7	Safety system I, cable manhole
E104/8	Safety systyem I, cable manhole
E115/14 E105/7	Auxiliary 0.4 KV breaker
E115/15 E105/8	Auxiliary 0.4 KV breaker
E115/16 E106/10	Auxiliary 0.4 KV breaker
E119/17 E106/11	Auxiliary 0.4 KV breaker
E119/19 E119/18 E106/12	Auxiliary 0.4 KV breaker
E118/4	Acid room
E117/4 E108/4	Air technical engine compartment
E116/8 E116/7 E109/3	Battery room
E110/4	Entrance hall
E126/4	Electrical service magazin
E126/4	Entrance hall of battery rooms

Signs used:



Door

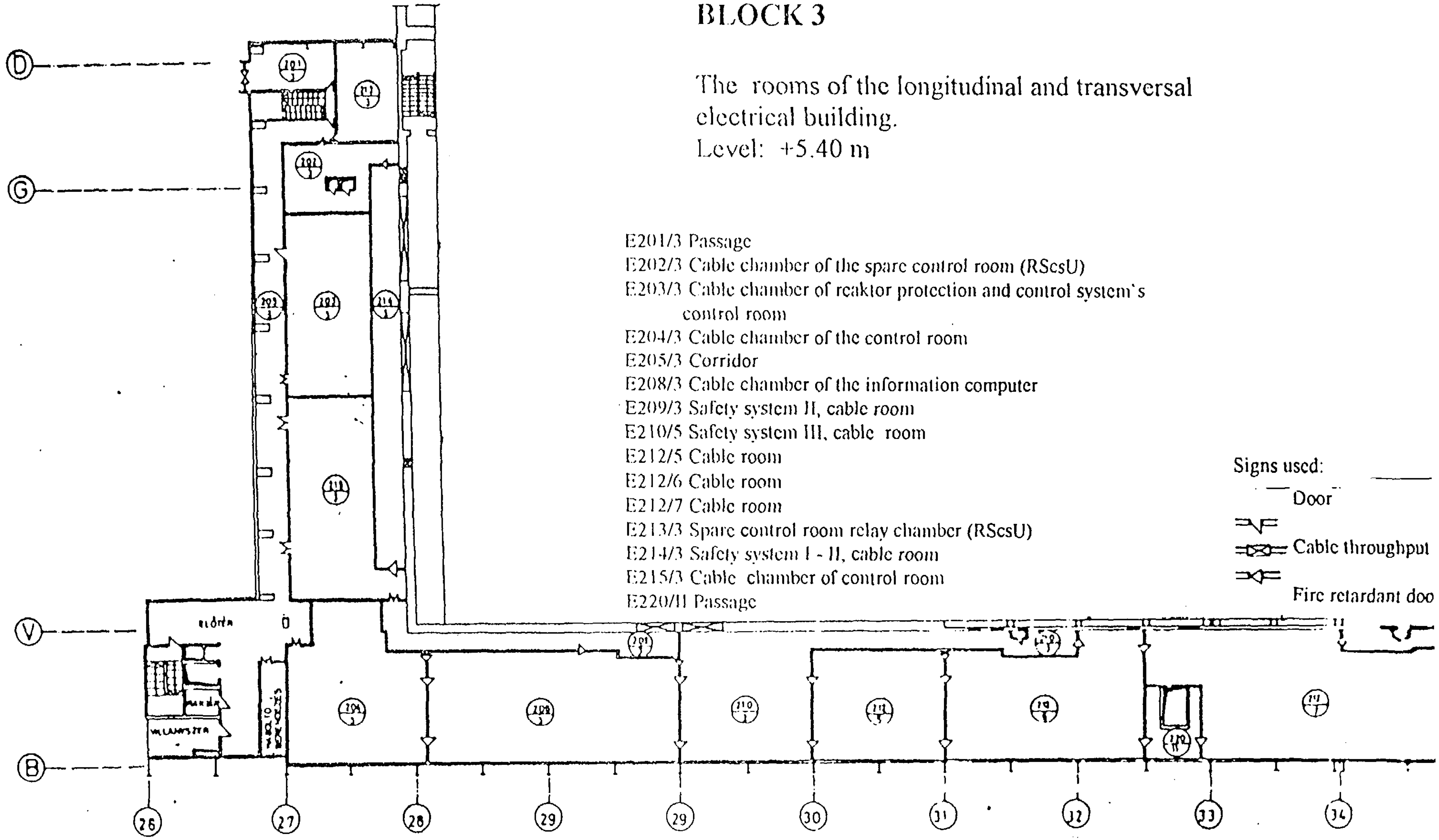
Double swing door

Fire retardant door

Double door

BLOCK 3

The rooms of the longitudinal and transversal electrical building.
Level: +5.40 m

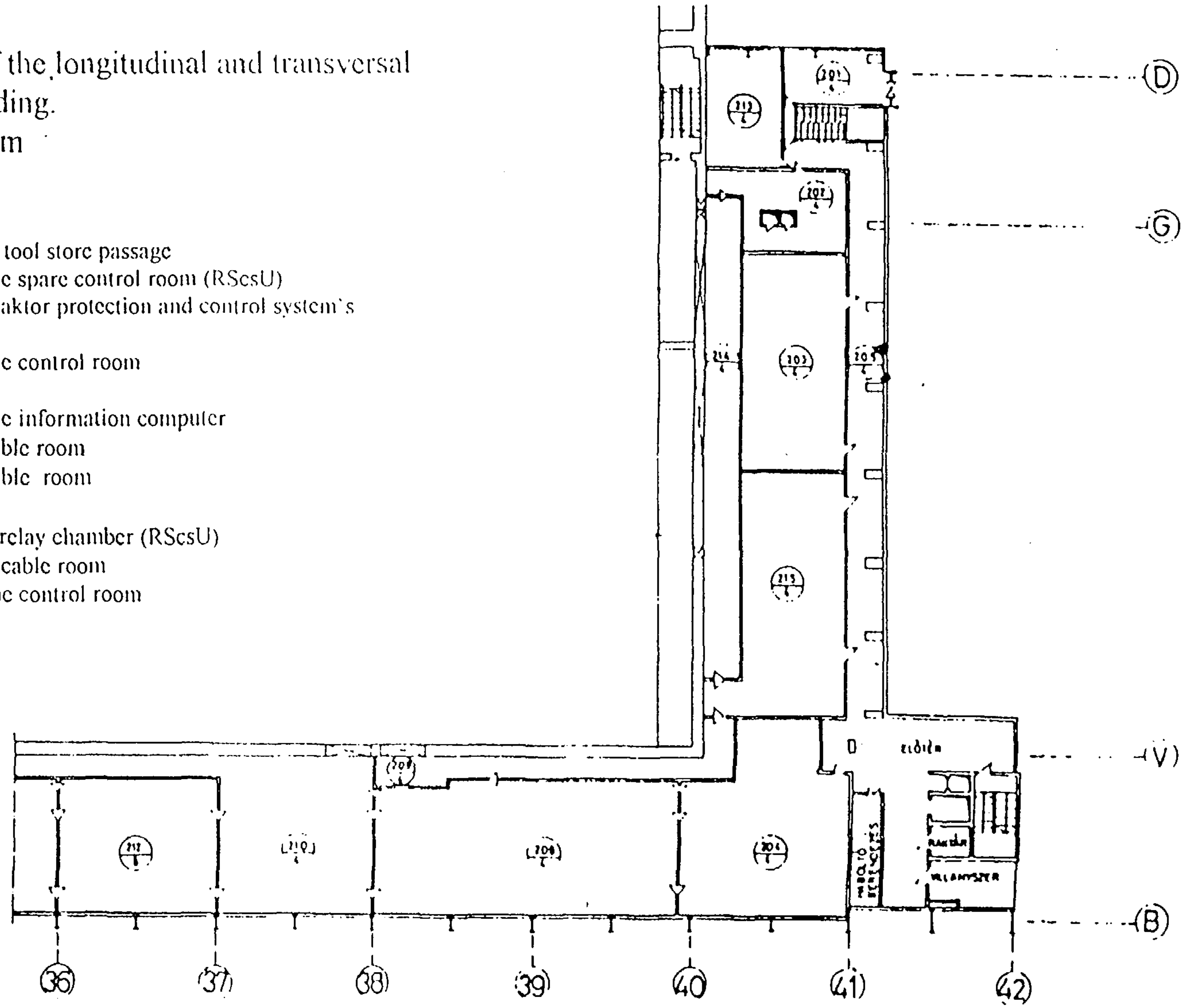


E201/3 Passage
E202/3 Cable chamber of the spare control room (RScsU)
E203/3 Cable chamber of reaktor protection and control system's control room
E204/3 Cable chamber of the control room
E205/3 Corridor
E208/3 Cable chamber of the information computer
E209/3 Safety system II, cable room
E210/5 Safety system III, cable room
E212/5 Cable room
E212/6 Cable room
E212/7 Cable room
E213/3 Spare control room relay chamber (RScsU)
E214/3 Safety system I - II, cable room
E215/3 Cable chamber of control room
E220/II Passage

BLOCK 4

The rooms of the longitudinal and transversal electrical building.
Level: +5.40 m

E201/4 Electrical workshop tool store passage
E202/3 Cable chamber of the spare control room (RScsU)
E203/4 Cable chamber of reaktor protection and control system's distributors
E204/4 Cable chamber of the control room
E205/4 Corridor
E208/4 Cable chamber of the information computer
E209/4 Safety system III. cable room
E210/4 Safety system III. cable room
E212/8 Cable room
E213/4 Spare control room relay chamber (RScsU)
E214/4 Safety system I - II. cable room
E215/4 Cable chamber of the control room



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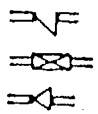


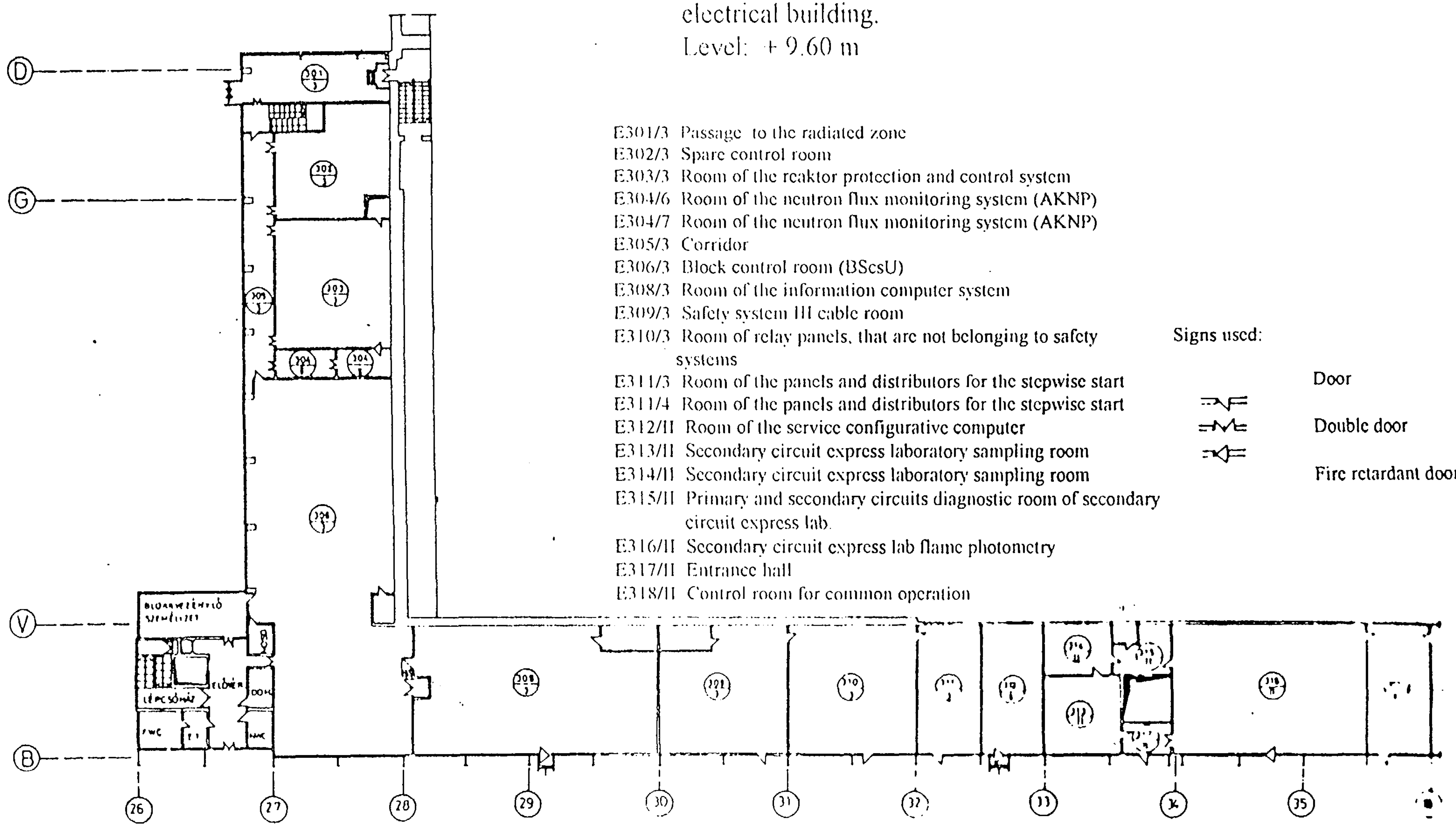
Door

Cable throughput

Fire retardant door

BLOCK 3

The rooms of the longitudinal and transversal electrical building.
Level: + 9.60 m



E301/3 Passage to the radiated zone
E302/3 Spare control room
E303/3 Room of the reaktor protection and control system
E304/6 Room of the neutron flux monitoring system (AKNP)
E304/7 Room of the neutron flux monitoring system (AKNP)
E305/3 Corridor
E306/3 Block control room (BScsU)
E308/3 Room of the information computer system
E309/3 Safety system III cable room
E310/3 Room of relay panels, that are not belonging to safety systems
E311/3 Room of the panels and distributors for the stepwise start
E311/4 Room of the panels and distributors for the stepwise start
E312/II Room of the service configurative computer
E313/II Secondary circuit express laboratory sampling room
E314/II Secondary circuit express laboratory sampling room
E315/II Primary and secondary circuits diagnostic room of secondary circuit express lab.
E316/II Secondary circuit express lab flame photometry
E317/II Entrance hall
E318/II Control room for common operation

Signs used:

Door

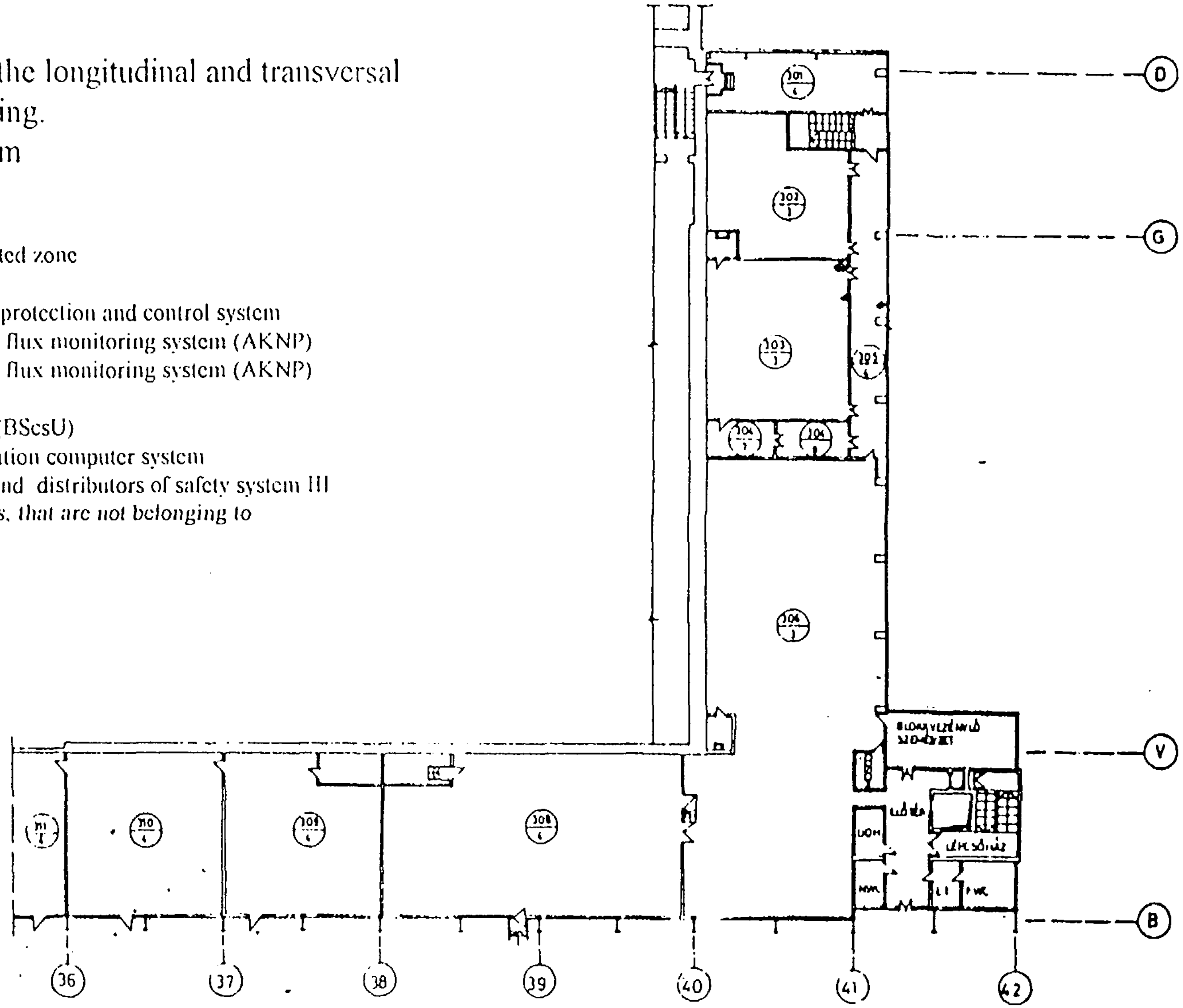
Double door

Fire retardant door

BLOCK 4

The rooms of the longitudinal and transversal electrical building.
Level: + 9.60 m

E301/4 Passage to the radiated zone
E302/4 Spare control room
E303/4 Room of the reaktor protection and control system
E304/7 Room of the neutron flux monitoring system (AKNP)
E304/8 Room of the neutron flux monitoring system (AKNP)
E305/4 Corridor
E306/4 Block control room (BScsU)
E308/4 Room of the information computer system
E309/4 Room for the relay and distributors of safety system III
E310/4 Room of relay panels, that are not belonging to safety systems



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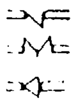
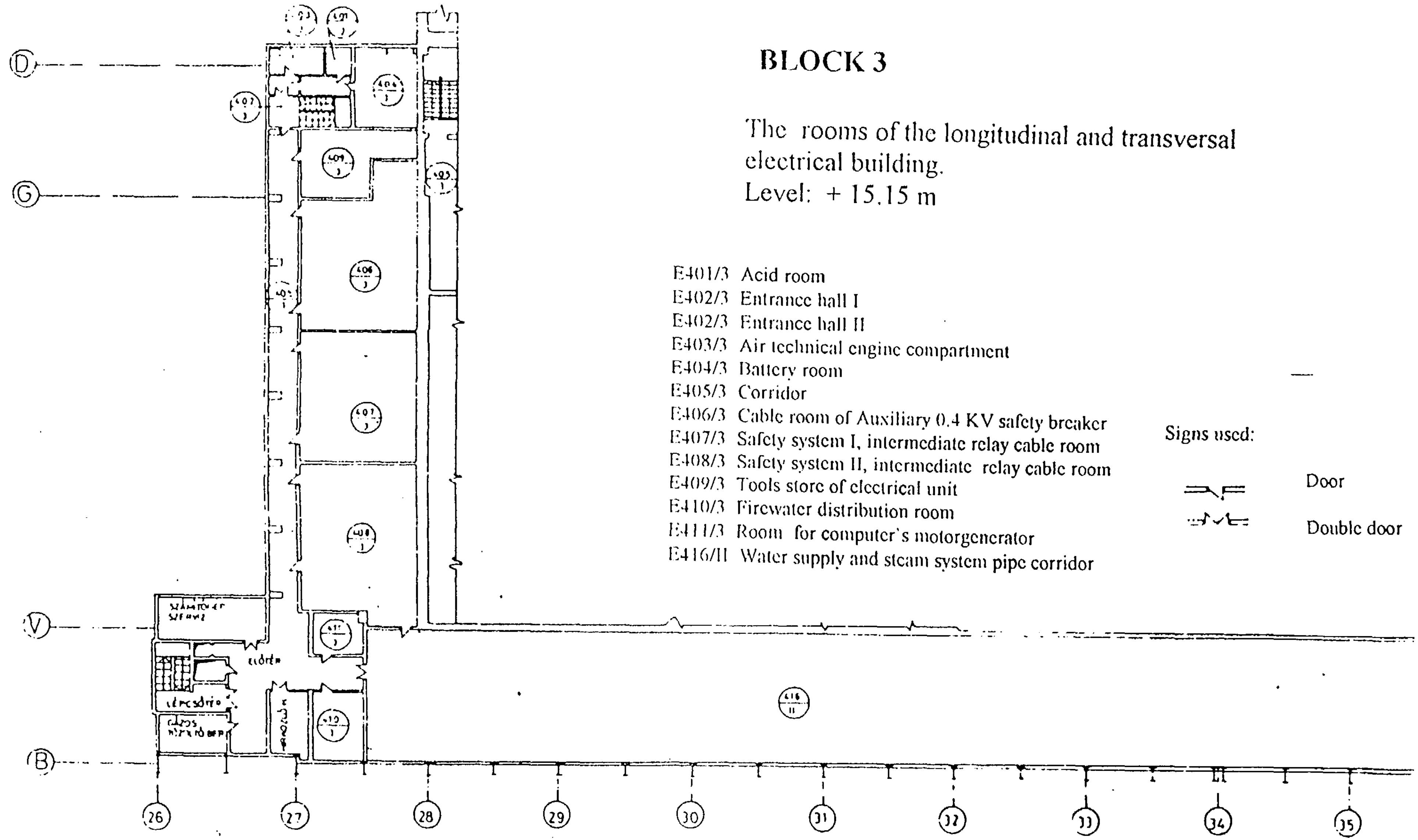


Door

Double door

Fire retardant door



BLOCK 3

The rooms of the longitudinal and transversal electrical building.
Level: + 15.15 m

E401/3 Acid room
E402/3 Entrance hall I
E402/3 Entrance hall II
E403/3 Air technical engine compartment
E404/3 Battery room
E405/3 Corridor
E406/3 Cable room of Auxiliary 0.4 KV safety breaker
E407/3 Safety system I, intermediate relay cable room
E408/3 Safety system II, intermediate relay cable room
E409/3 Tools store of electrical unit
E410/3 Firewater distribution room
E411/3 Room for computer's motorgenerator
E416/II Water supply and steam system pipe corridor

Signs used:

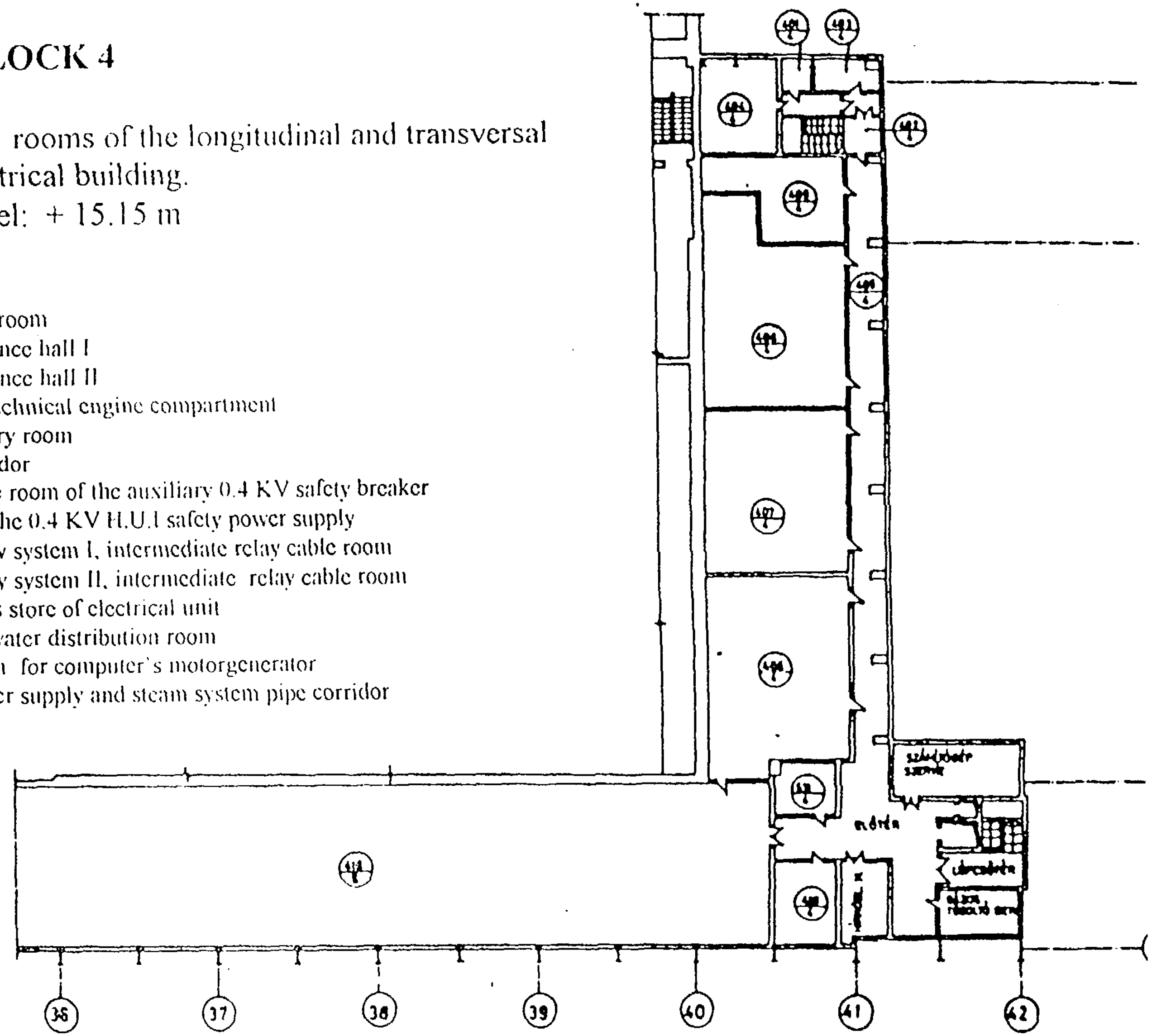
Door

Double door

BLOCK 4

The rooms of the longitudinal and transversal electrical building.
Level: + 15.15 m

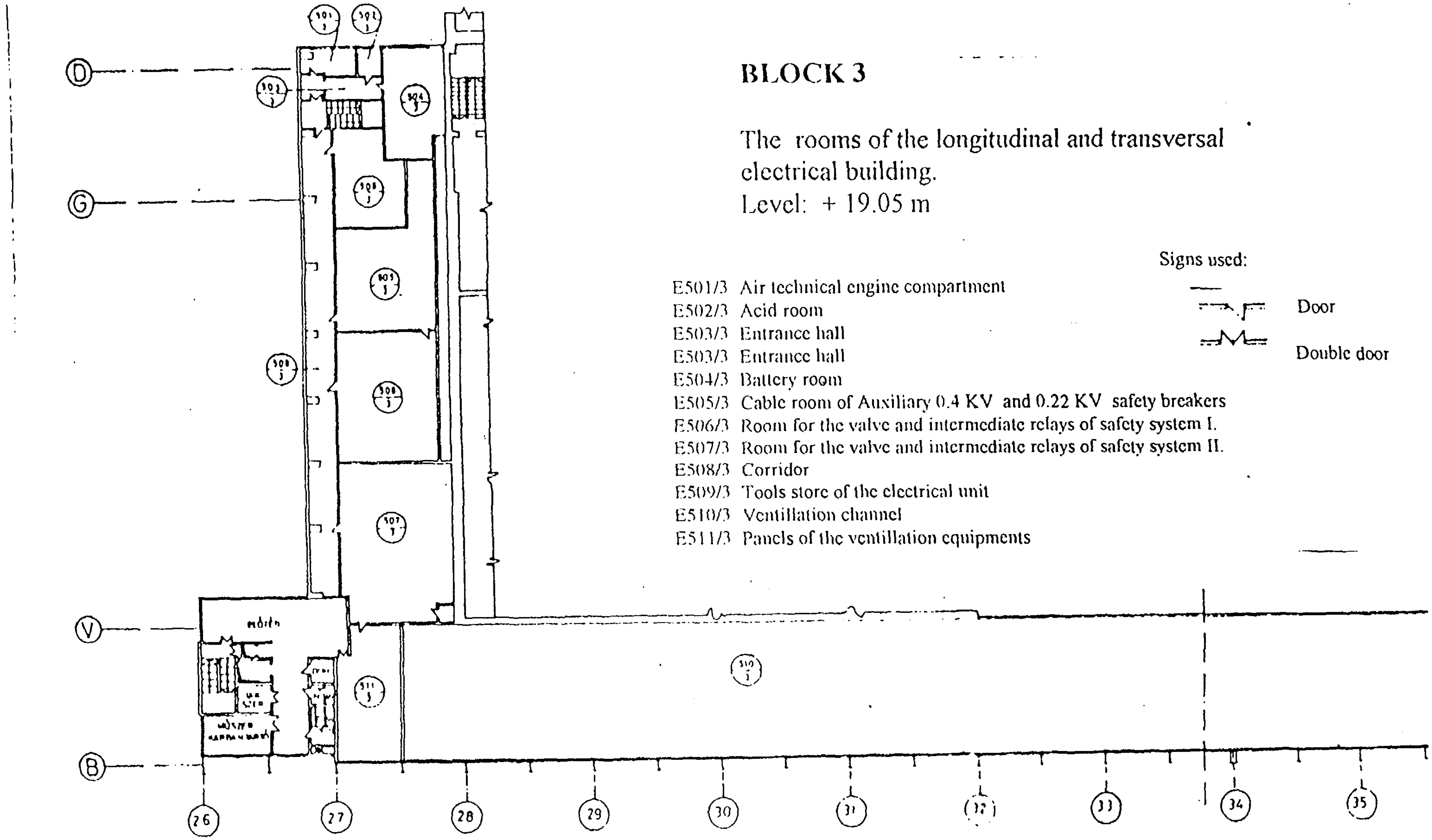
E401/4 Acid room
E402/4 Entrance hall I
E402/4 Entrance hall II
E403/4 Air technical engine compartment
E404/4 Battery room
E405/4 Corridor
E406/3 Cable room of the auxiliary 0.4 KV safety breaker and the 0.4 KV H.U.I safety power supply
E407/4 Safety system I, intermediate relay cable room
E408/4 Safety system II, intermediate relay cable room
E409/4 Tools store of electrical unit
E410/4 Firewater distribution room
E411/4 Room for computer's motorgenerator
E416/II Water supply and steam system pipe corridor



Signs used:

Door

Double door



BLOCK 3

The rooms of the longitudinal and transversal electrical building.
Level: + 19.05 m

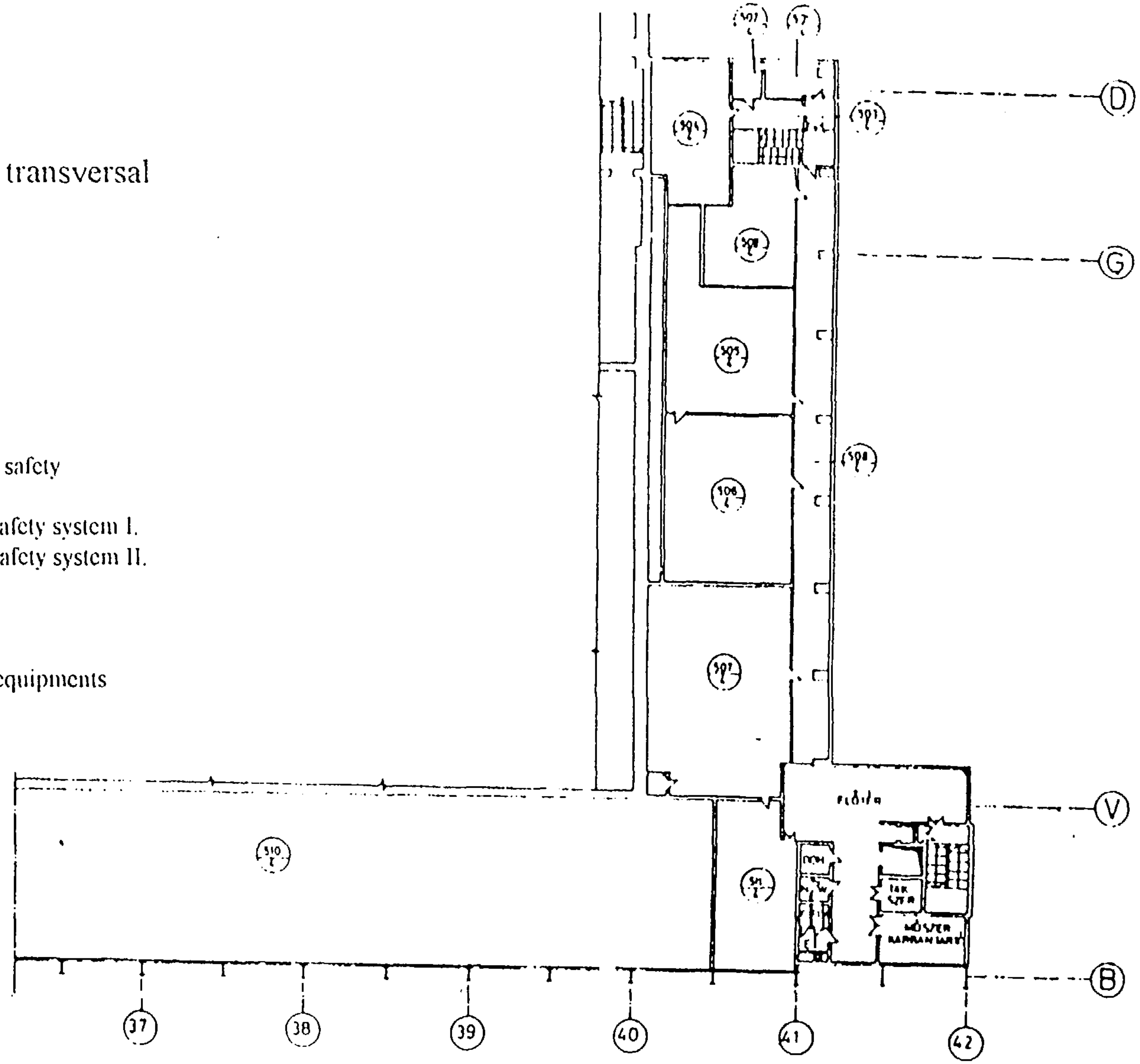
Signs used:

- Door
- Double door

E501/3 Air technical engine compartment
E502/3 Acid room
E503/3 Entrance hall
E503/3 Entrance hall
E504/3 Battery room
E505/3 Cable room of Auxiliary 0.4 KV and 0.22 KV safety breakers
E506/3 Room for the valve and intermediate relays of safety system I.
E507/3 Room for the valve and intermediate relays of safety system II.
E508/3 Corridor
E509/3 Tools store of the electrical unit
E510/3 Ventillation channel
E511/3 Panels of the ventillation equipments

BLOCK 4

The rooms of the longitudinal and transversal electrical building.
Level: + 19.05 m

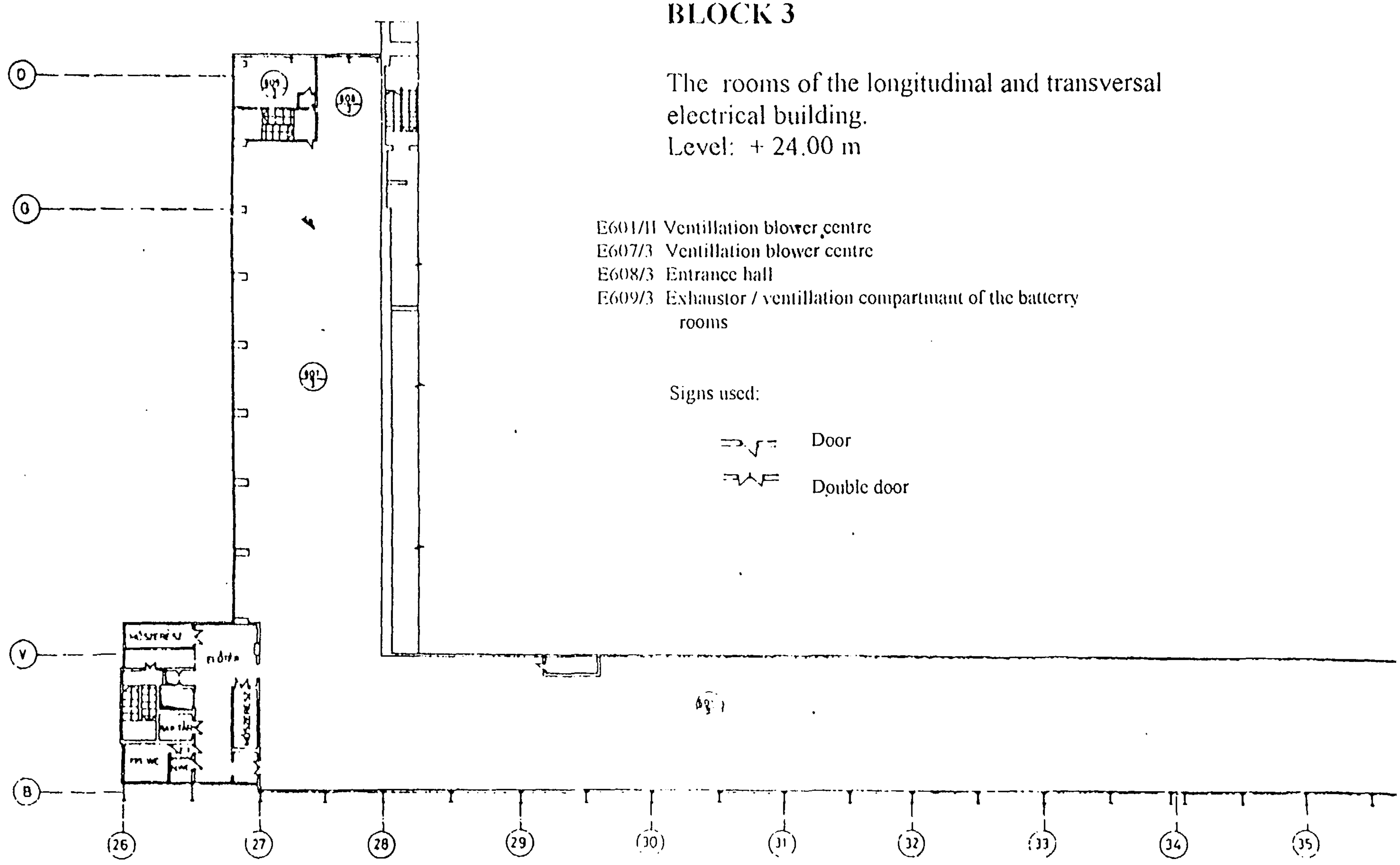


E501/4 Air technical engine compartment
E502/4 Acid room
E503/4 Entrance hall I
E504/4 Battery room
E505/4 Cable room of Auxiliary 0.4 KV and 0.22 KV safety breakers
E506/4 Room for the valve and intermediate relays of safety system I.
E507/4 Room for the valve and intermediate relays of safety system II.
E508/4 Corridor
E509/4 Tools store of electrical unit
E510/4 Ventillation channel
E511/4 Room for power supply box of the ventillation equipments panels

Signs used:

Door

Double door



BLOCK 3

The rooms of the longitudinal and transversal electrical building.
Level: + 24.00 m

E601/II Ventillation blower centre
E607/3 Ventillation blower centre
E608/3 Entrance hall
E609/3 Exhaustor / ventillation compartmant of the batterry rooms

Signs used:

Door

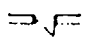
Double door

BLOCK 4

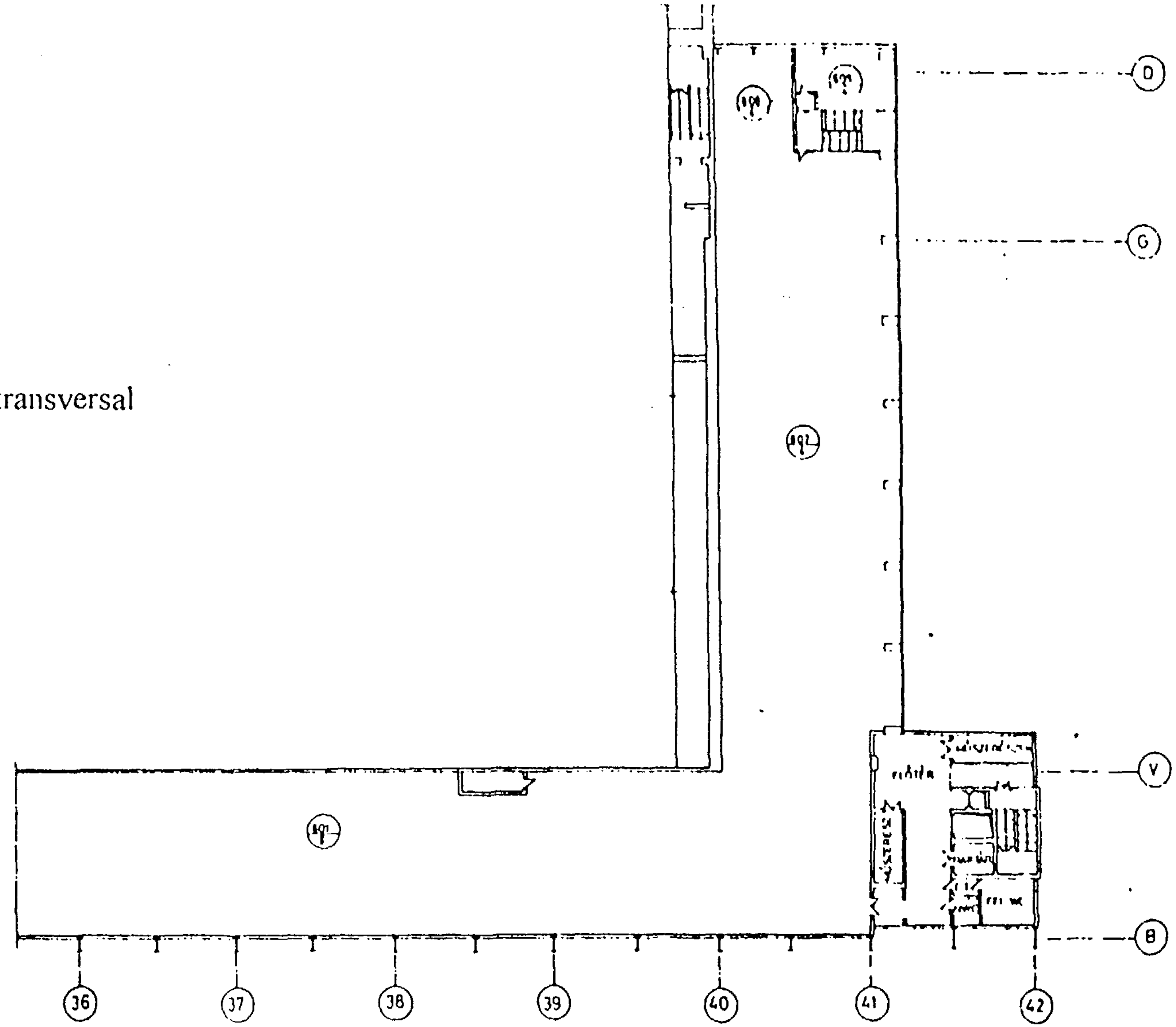
The rooms of the longitudinal and transversal electrical building.
Level: + 24.00 m

E601/II Ventillation blower centre
E607/4 Ventillation blower centre
E608/4 Entrance hall
E609/4 Exhaustor / ventillation compartmant of the battery rooms

Signs used:

 Door

 Double door



Title: Review of Studies Pertaining to the Seismic Input at Paks NPP

Contributor: F. Muzzi

Date: January 1994

BENCHMARK STUDY FOR SEISMIC SAFETY ANALYSIS ON NUCLEAR POWER PLANTS IN EASTERN EUROPE

REVIEW OF STUDIES PERTAINING TO THE SEISMIC INPUT AT PAKS NPP

REVISION 0
JANUARY 1994

Prepared for:
The International Atomic Energy Agency

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TECHNICAL REPORT ON INDEPENDENT EVALUATION OF THE MATERIAL PRODUCED FOR THE SEISMIC INPUT OF PAKS NPP

p.c.: IAEA - Vienna

Proj. ASP-7317.30; Doc. n. RAT-DGF-054/94

document of pages 23

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AKNOWLEDGMENTS
This work was funded by ENEL-DSR-VDN (Rome) and was done in the frame of the International Atomic Energy Agency (Vienna) Benchmark Study for the Seismic Analysis and Testing of WWER-Type Nuclear Power Plant.

Revisions

Rev. 00: First release

Distribution list

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I N D E X

SUMMARY

This report refers on the examination performed on the available material relevant to the seismic input estimate for the Nuclear Power Plant of Paks, Hungary (hereafter Paks NPP), within the frame of the IAEA benchmak study for the seismic analysis and testing of existing NPP, and in the aims of the nuclear activities of ENEL DSR/VDN.

The aim of the report is to provide an expert judgement about the quantity and quality of the data and studies performed so far.

The first chapter describes the sources of the data set examined.

The second chapter is about the criteria followed in the judgment.

The third chapter contains the detailed opinion on the content of the data set.

Conclusion and suggestion are reported in chapter four.

1. FOREWORD

The independent evaluation of the seismic input data was performed as a phase of the activities foreseen in the frame of the IAEA benchmark study for the seismic analysis of existing Nuclear Power Plants and it was funded by ENEL S.p.A. DSR/VDN Rome.

The seismic reassessment started from the consideration that the nuclear power plant of Paks was designed by the former Soviet Union engineers taking into account that nuclear power plants cannot be built in localities where the estimated maximum earthquake intensity is equal or greater than category IX on the MSK - 64 intensity scale.

Until 1978 the Design earthquake level was derived starting from the seismic intensity forecasting indicated on a map based on soils of a so called "category 2": for soils of category 1 (rock) the seismic intensity of the MSK scale was reduced 1 grade and for soils of category 3 (soft soils) the intensity forecasting was increased one grade. In any case for Nuclear Power Stations the grade was increased one grade (Maximum calculated earthquake) [Ref. 1].

Since 1978, after the 1977 earthquake of Vrancea-Roumania, the seismic backfitting was requested for all the already existing plants or new plants under design and the seismic design was requested for completely new plants.

It should be kept in mind, however, that the civil structures design of a nuclear power plant must take into consideration the potential seismic activity when installation is foreseen in a zone starting with intensity IV on the MSK-64 scale, whereas for conventional structures the seismic design is requested by the Soviet building codes starting from category VI [Ref. 2]. In any case the structures accomodating safety systems should be designed to withstand the maximum earthquake likely to occur once in 10 000 years; the seismicity of the construction site at Paks NPP was taken at the design stage as V degree on MSK-64 scale (up to 0,03 g) [Ref. 3].

At present, after some evaluation studies performed by Hungarian, Russian and English Commission, the peak ground acceleration for the design earthquakes is 0,35 g (3.5 m/sec^2) [Ref. 3]: thus a seismic reassessment is needed.

However, before deciding to perform a reassessment of seismic input estimate, it's necessary to give an independent judgment regarding the quality and quantity of the material produced about this topic.

For this revision activity, it is important to note that only English reports have been examined, supported by the material in Hungarian or Russian when the amount of graphic content was enough to allow an expert to recognize the data presented. Finally, in order to use an unique criterion to judge the data set collected and the studies performed, it has been decided to follow the suggestions of the IAEA technical guide 50 - SG - S1 (rev. 1), as a check list for the evaluation of the completeness of the material available for the seismic input estimate.

2. THE AVAILABLE DATA SET

The material produced for the seismic input estimate for Paks NPP can be subdivided, as a first step, according to the language in which it has been prepared. A large amount of data is available only in Hungarian or Russian. For part of this documentation, a translation in English is available.

For this revision activity, only English written reports have been examined, but also material in Hungarian or Russian has been taken into acccount when the amount of graphic content was enough to allow an expert to recognize the data presented. Besides this, it has been considered also lists of translated titles of report documenting the existence of certain data and/or studies.

The two main sources listing previous studies are:

1) A list entitled "Scientific and technical reports on problem related to seismic safety of Paks NPP until 1991", compiled by Prof. Lázló Tóth, of the Hungarian Academy of Sciences, Seismological Observatory.

2) A summary report entitled "Geological evaluation of Paks NPP site" edited by the Scientific Coordinating Committee of the National Atomic Energy Office of Hungary.

The first reports clearly deals with studies performed before 1991, while the second contains a list of further researches carried out after 1991. The two list are given here as annexes 1 and 2 respectively.

3. THE CRITERIA USED

The aim of this work was to give an independent judgement regarding the quality and quantity of the material produced for the seismic input estimate of Paks NPP. It is not aim of this work to provide a further re-assessment of the values given by previous studies.

In order to use a unique criterion to judge the completeness of the examined data set, it has been decided to follow the suggestion of the IAEA technical guide 50-SG-S1 (rev. 1, hereafter S1.1). This guide was prepared as part of the Agency program for establishing Codes and Safety Guides relating to nuclear power plants. It provides guidelines and recommends procedures to adopt in the consideration of earthquakes and associated topics for nuclear power plant siting. It is worth noting that this guide states at paragraph 105 that ".. this document is applicable to new nuclear power plant sites. It does not address the complex issue of the seismic re-evaluation of existing nuclear power plant site..... although it contains general information useful for those purposes". Thus it has been decided that even if the same IAEA guide highlights its non-mandatory purpose for existing NPP, it seems to be appropriate to follow this guide as a checklist for the evaluation of the completeness of the material produced for the seismic input estimate for Paks NPP. In the following chapter, the same index of the guide S1.1 will be followed, and for each items IAEA expectation will compare with the available material.

4. DETAILED EXAMINATION

4.1 General requirements

Par. 101-204 of S1.1 guide are regarding the introduction and the scope of the work, and thus are not considered for this examination.

Par. 205 of S1.1 guide states that "regardless of any lower apparent exposure to seismic hazard, it is recommended that every nuclear power plant adopt a minimum value of 0.1g peak ground acceleration corresponding to the safety level SL-2 earthquake, as defined in Section 5".
This recommendation is not necessary, since several studies have proposed for Paks NPP peak ground acceleration up to 0.35 g (Refs 15, 19, 23, 24 of Annex 1, part 1).

Par. 206 of S1.1 guide states that "A quality assurance programme shall be established and implemented to cover all the data collection, data processing, field and laboratory investigations, desk studies and evaluations which are within the scope of this Guide.".
It does not seem that a QA program has been followed during previous estimates of seismic input for Paks NPP, or at least no references are given to it in the examined documentation. Even if the general judgement on the reliability of the material considered will not be affected by the lack of a QA programme, it is advised that in the case further studies will be necessary, a proper quality assurance procedure should be implemented.

4.2 Required information and investigations (Data-Base)

Par. 301-303 of S1.1 guide state that ".. it is necessary to acquire an integrated database which coherently incorporates the information needed to evaluate and resolve all hazards associated with earthquakes .... In order that rational decisions can be made, it is important to ensure that each element of any practical database has been investigated as fully as possible before integration of the various elements is attempted. The total database should include all the relevant information, i.e. not only geological and seismological data but also any other information which reveals the pattern of current geodynamics. The elements of the database should be studied most intensively close to the site .."

The material provided it is not organized as a real data-base. Nevertheless, the studies carried out fulfil IAEA recommendation relevant to the extent of the reaserches to be performed. Thus it is advised to organise the material examined as a data base, only if further studies will be planned.

4.2.1 Regional scale

Par. 304 of S1.1 guide states that "The regional study shall investigate a geographical area sufficiently large to contain all the evidence which potentially affects the seismic hazard at the site. The size of this area will vary .... Its radial extent is typically 150 km or more."

Geological and seismological studies for Paks NPP fulfil this request, as described in the following for each item.

Par. 305 of S1.1 guide it is not applicable to Paks NPP, since it is dealing with the potential for tsunamis.

Par. 306-307 of S1.1 guide state that "In most cases, an appropriate database can be obtained from either published or unpublished sources. However, where existing data are deficient for the purpose of delineating seismogenic structures, it may be necessary to verify and complete the database by acquiring new geological, geophysical and seismological data at the appropriate scale....The data are typically presented on maps at a scale 1:500.000, or smaller".

For the Paks NPP a great deal of *ad hoc* studies has been carried out. The reports 2, 3, 4, 11, 14, 15, 16, 18, 19, 20, and 21 listed in Annex 2 are examples of studies performed to integrate or re-evaluate the available sources. More examples can be found in Annex 1.

4.2.2 Near regional scale

Par. 308-310 of S1.1 guide state that "Near regional studies should investigate a geographical area typically up to 25 km in radius...The data are obtained from existing published and unpuhlished sources, augmented by specific remote sensing, geological, geophysical, geodetic and seismological studies designed to acquire new information on critical parameters...The data are typically presented on maps at a scale of 1:50 000 or smaller. The aim is to show the seismotectonic details of the near region."
Geological and seismological studies for Paks NPP fulfil this request, as described in the following for each item.

4.2.3 Site vicinity scale and Site area scale

Par. 311-310 of S1.1 guide state that "Site vicinity studies should investigate a geographical area typically up to 5 km in radius...In most cases, additional techniques such as boreholes, trenching and geological mapping are likely to be required in order to obtain a database that is more detailed ...The data are typically presented on maps at a scale of 1:5000 or smaller....Site area studies shall investigate the area covered by the plant, which is typically 1 km^2 or more...The dabase is developed from detailed geological, geophysical and geotechnical studies augmented by in situ and laboratory testing. The data are typically presented on maps of 1:5000 or smaller".
Also in this case geological and seismological studies for Paks NPP fulfil this request, as described in the following for each item.

4.3 Seismological Data-Base

Par. 317-318 of S1.1 guide are regarding the introduction and the scope of this chapter and thus are not considered in our examination.

4.3.1 Historical earthquake data

Par. 319-320 of S1.1 guide state that "All available historical earthquake data (i.e. events for which no instrumental recording exist) shall be collected, extending as far back in time as possible...The information to be obtained for each earthquake includes:

1. Date and time of earthquake;
2. Isoseismal contours;
3. Location of the macroseismic epicentre;
4. Maximum intensity and intensity at the macroseismic epicentre, when they differ, with a description of local conditions;
5. Estimated magnitude;
6. Estimated focal depth;
7. Estimates of uncertainty for each of the above parameters;
8. Intensity at the site, accompanied by any available details on soil effects.

An assessment of the quality and quantity of data from which the above parameters have been estimated.
The magnitude and depth estimated for such earthquakes should be based on relevant empirical relationships between instrumental and macroseismic information which may be developed from the data described in par. 321. When the catalogue of relevant historical earthquakes has been compiled, estimates should be made of its completeness."
For the Paks NPP an historical earthquake catalogue is available starting from 456 AD, in format of computer file.
As concerning IAEA recommendations :

1. Date and time of earthquake are provided.
2. Isoseismal contours are not included in this catalogue. Intensity maps (about one hundred) with isoseismal are available, but it does not seem that all the data have been digitized and stored in an uniform computer format.

3. Location of the macroseismic epicentre is provided.

4. Maximum intensity is provided, but it is not clear if an intensity at the macroseismic epicentre has been estimated.

5. Estimated magnitude is provided. See point below for comments.

6. Estimated focal depth is provided. Most of the events are shallow (D<15 Km). Because magnitude and depth are estimated from the same formula a trade off between the two cannot be ruled out.

7. Estimates of quality is given for epicentral determination and maximum intensity.

8. Intensity at the site is not given, whilst there is an estimate of the radius of the isoseismal having intensity IV.

As far as the completeness is concerned, an estimate was done, and reported below:

Starting year	Magnitude threshold
1700	5.6
1800	5.0
1850	4.4
1880	4.0

The quality appears to be good, and completeness can probably extended backward for higher intensities.

4.3.2 Instrumental earthquake data

Par. 321 of S1.1 guide states that "All avaible instrumental earthquake data shall be collected. The information to be obtained for each earthquake includes:

1. Time of origin;

2. Locations of epicentre and hypocentre;

3. All magnitude determinations, including those on different scales, and any information on seismic moment;

4. Dimensions and geometry of the aftershock zone;

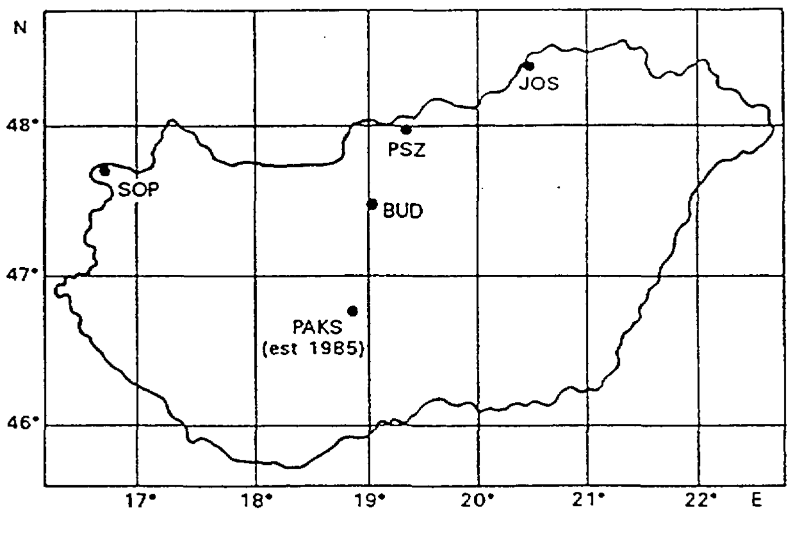
5. Other information that may be helpful in understanding the seismotectonic regime, such as focal mechanism and other source parameters;

6. Estimates of uncertainly for each of the above parameters;

7. Macroseismic details as discussed in para. 320.

When the catalogue of relevant instrumental earthquakes has been compiled, estimates should be made of its completeness."

The seismic catalogue has lower quality for the Paks region with respect to the historical one. The reason is the fact that the Hungarian seismic network is manly located in the Northern part of the country, far from Paks (see figure below).



(After Toth, 1981)

A completeness/detection threshold is given for instance in ref. 23 of annex 1. The proposed value of magnitude 4 seems to high to allow the use of microseismicity for detailed microzoning mapping. See also the following point for comments about the Paks station.

4.3.3 Site specific instrumental data

Par 322-324 of the S1.1 guide state that "To supplement the available data on earthquakes with more detailed information on seismic sources, it may be useful to operate a network of sensitive seismographs having microearthquake recording capability. Earthquakes recorded within and near such a network should be carefully analysed in connection with seismotectonic studies of the near region. The minimum monitoring period required to obtain meaningful data for seismotectonic interpretations is several years. Wherever possible, regional strong motion recordings shall be collected and used for deriving appropriate seismic wave attenuation functions and in developing the design response spectra for the proposed nuclear power plant, as discussed in Section 5. The value of the investigation may be enhanced by having strong motion accelerographs installed within the site area for as long as possible."
In Paks a single 3-component station is operating since 1985. The locations precision that can be obtained with a single station is of course worse than that provided by a network. Anyhow, those data should be fully exploited to obtain at least preliminary indication of microeartquake activity in the vicinity of Paks NPP, and thus providing indications very important in view of installing in the future a microearthquake network as suggested by IAEA. It does not seem that microearthquake indication have been included in the seismotectonic model. No strong motion recordings are available for the site and no regional attenuation relationship is available.

4.4 Geological data-base

4.4.1 Regional investigations

Par. 325-326 of the S1.1 guide state that "The main purpose of the regional studies is to provide knowledge of the geological and tectonic framework of the region and its general geodynamic; setting and to identify those geological features that may influence or relate to the seismic hazard at the site. The data will usually be obtained from published and other existing geological and

geophysical sources and should be presented on a map with cross-sections and a commentary. However, it may be necessary to conduct additional geological and geophysical studies on some structures identified in the regional investigations in order to obtain the desired detail."
For the Paks NPP, the regional data are mainly coming from published sources, and in general their quality is lower with respect to near site data. Many feature described in literature are hypothetical or at a very large scale, and this accounts for the different interpretation given when different expert have proposed their seismotectonic model. More attention should be payed to large scale gravimetry, geodesy, heat flow and aereomagnetic investigation, as well as satellite imagery. Unfortunately, few large scale seismic profile are available for the region.

4.4.2 Near region investigations

Par 327-328 of the S1.1 guide state that "... Investigations to amplify the published and existing information should typically include:

1. Geological mapping to define the stratigraphy, structural geology and tectonic history of the near region. Subsurface information derived from geophysical investigations using seismic, gravimetric and magnetic techniques is needed in the preparation of the geological map. Use should be made of remote sensing data, such as those derived from satellite imagery, side scan radar, aerial photographs, aeromagnetics and gravimetries. In areas of unusual geological complexity, it may be necessary to perform specific field investigations, such as boring, trenching and seismic (reflection and refraction) surveys.

2. Neotectonic studies to determine the latest movements of faults. To reach this goal, geomorphology, boring, trenching, pedology, studies of the Quaternary deposits and age dating may be necessary, as well as palaeoseismicity, geophysics, geochemistry, geodesy and in situ stress measurements".

For the Paks NPP area a large amount of ad-hoc studies are available, such as borehole data, seismic reflection surveys and other geological and geophysical investigation. Unfortunately, the probably most important data, that is seismic surveys, do not allow at present to observe the first 100 meters of the subsoil. Due to this, it is not possible to establish if the proposed faults are continuing toward the surface and thus, ultimately, if they are capable faults. Re-interpretation or (if necessary) re-execution of the seismic profiles is strongly recommended.

4.4.3 Site vicinity investigations

Par. 329-330 of the S1.1 guide state that "Investigations of the site vicinity shall be conducted to define in greater detail the neotectonic history of faults and to identify sources of potential instability. The investigations should provide the following:

1) A geological map with cross-sections and a commentary.

2) A neotectonic history showing the age and amount of fault displacement based on trenching and age dating, as appropriate.

3) A characterization of the seismic stability of slopes, soils and strata with emphasis on geomorphic, physiographic and hydrogeological data (e.g drainage, vegetation, soil, acclivity, water table) and of locations exhibiting potential geological hazards such as differential erosion, karsic phenomena, fractures, fault creep and unstable materials (e.g. expansive soils).

4) The identification and characterization of locations exhibiting potential geological hazards induced by human activities. Special attention should be given to the potential for induced seismicity, particularly that resulting from large dams or reservoirs or from extensive fluid injection into or extraction from the ground."

For the Paks site the examination of the availble material lead to the following comments:

1-2) A large amount of data is available. Trenching was performed giving ambiguous findings. No unique interpretation was given of some disturbances find in near surface soils. In case of further investigation for the site, more trenches should be excavated, paying attention also to strata plunge and dip in order to consider the possibility of performing forward modeling of surface deformation using the various near site fault models proposed.

3) This section is commented with greater detail in a separate report on geotechnical activities at Paks NPP prepared by ISMES.

4) No large reservoirs exist upstream of Paks NPP site. The nearest mine is 60 km away and the strongest induced earthquake occurred was of magnitude 3.5. There are some water wells around Paks NPP site, but no earthquakes or instability phenomena were reported.

4.4.4 Site area investigations

Par. 331-332 of the S1.1 guide state that "Investigations at the site area should extend and add further detail to the databases developed in the studies described above. In addition to geological mapping, the emphasis is on defining the physical properties of the foundation materials and determining their stability and response under dynamic earthquake loading. The following investigations shall be performed, using geological, geophysical, seismological and geotechnical techniques...."
This section is commented with greater detail in a separate report on geotechnical activities at Paks NPP prepared by ISMES.

4.5 Construction of regional seismotectonic model

Section 4 of the S1.1 guide refer to the seismotectonic model, the definition of seismogenetic zones, the assignment of maximun potential magnitudes and how to deal with zones of diffuse seismicity. It is beyond the scope of this work to evaluate any single model and/or study performed up to now. It has already pointed out that regional data are partly not very well defined, and thus it is not surprising to find such different opinions in the different studies. Moreover, the seismotectonic zoning practice contains an internal degree of uncertainty linked to experts personal judgement. One of the study for Paks NPP seismic input estimate (Ref 23 in annex 1) quotes the TERESA project, that is a clear example of this kind of problem for the European area. Another example of diverging experts judgement is given by the LLNL-EPRI-SOG study for the preliminary assessment of seismic hazard for NPP in the Eastern United States.

4.6 Determination of design basis ground motion

Section 5 of the S1.1 guide "..presents guidelines and procedures regarding the levels and characteristics of the design basis ground motions..". As for the point above, the examination of the results of the several studies performed for Paks NPP is beyond the scope of this work. We can provide some general remarks.

1) Historical data could have been used more extensively. If on one hand we have a non-univocous seismotectonic model, on the other hand the historical data seem to be complete and reliable. Thus probabilistic estimate of site return period for the different intensities should have more emphasis, even including observation of historical earthquake available in the immediate surrounding of the site.

2) The attenuation relationship for acceleration are generally derived from published studies based on collection of several earthquakes in different world region. More care should be devoted in preparing an attenuation relationship taking into account only data coming from stable continental region and recorded in site condition similar to those of Paks NPP.

3) In one case (Arup report, ref 23) the attenuation relationship for intensity was given as a function of the magnitude. Because a large part of

the magnitudes in the Hungarian catalogue are determined from intensities, this may cause a logical loop. More attention should be paid to the use of original intensity data, avoiding the use of isoseismals.

4) A value of 0.35 g of PGA for SS1 seems too high for this region. It seems even too high if compared with a maximum intensity of VIII MSK. This subjective judgement is based on past experience in several sitings performed by ISMES in Italy and abroad. As an example, we should mention that the Irpinia earthquake that caused more than 3000 casualties in 1980 had a maximum intensity of X MCS, but the maximum recorded acceleration measured by the ENEA-ENEL accelerographic network was less than 0.35 g.

5) Caution should be used when adopting probabilistic model without upper boundaries: for an arbitrarily low probability of occurrence one can obtain an arbitrarly high PGA. But keeping in mind the physical process generating earthquake, we should observe that an acceleration of 0.35 g likely requires a fault lenght of the order of 30÷40 Km able to produce at least 1 to 1.5 meter of slip. In a region of shallow seismicity, this may easily cause 1 meter of surface deformation, that would very probably give evidence more clear than the doubtful and debated one available for Paks site.

4.7 Potential for surface faulting at the site

Section 6 of guide S1.1 "..gives guidelines and procedures for assessing the potential for surface faulting (i.e. capability) which may jeopardize the safety of the nuclear power plant..".
For Paks NPP site, the comments expressed at point 3.4.2 and 3.4.3 remain valid, and will be highlighted again in the conclusions.

4.8 Seismically generated water waves

Section 7 of guide S1.1 "gives guidelines and procedures for addressing seismically generated water waves (tsunamis, seiches) and dam failures..".
For Paks NPP none of the above problems has to be taken into account.

4.9 Potential for permanent ground displacements

Section 7 of guide S1.1 "gives guidelines and procedures for assessing the potential for permanent ground displacement from liquefaction, slope instability, subsidence and collapse. Safety Guide 50-SG-S8 provides comprehensive guidance on all aspects of the problem, including bearing capacity and settlement."
This section is commented with greater detail in a separate report on geotechnical activities at Paks NPP prepared by ISMES.

5. CONCLUSIONS AND SUGGESTIONS

The available material used by different studies for assessing Paks NPP seismic input was examined.

A judgement was given following the requirements of IAEA guide 50-SG-S1 (rev. 1). This guide states at paragraph 105 that ".. this document is applicable to new nuclear power plant sites. It does not address the complex issue of the seismic re-evaluation of existing nuclear power plant site..... although it contains general information useful for those purposes". Anyway, even if the same IAEA guide highlights its non-mandatory purpose for existing NPP, it seems to be appropriate to have followed this guide as a checklist for the evaluation of the completeness of the material produced for the sesimic input estimate for Paks NPP.

The main suggestion derived from the examination of the previous studies are listed in the following:

* It does not seem that a QA program has been followed during previous estimates of seismic input for Paks NPP, or at least no references are given to it in the examined documentation. It is recommended that in the case further studies will be necessary, a proper quality assurance procedure should be implemented.

* It is advised to organise the material examined (geological and seismological data) as a data base if further studies will be planned.

* In Paks a single 3-component station is operating since 1985. Those data should be fully exploited to obtain at least preliminary indication of microeartquake activity in the vicinity of Paks NPP, and thus providing indications very important in view of installing in the future a microearthquake network as suggested by IAEA. Microearthquake indication should be included in the seismotectonic model.

* Intensity maps should be digitized and stored in an uniform computer format.

* Different experts have proposed their different interpretation of the seismotectonic model. A further effort should be done to reach an unique seismotectonic zoning, possibly combining different experts subjective judgement. More attention should be payed to large scale gravimetry, geodesy, heat flow and aereomagnetic investigation, as well as satellite imagery.

* Seismic surveys, do not allow at present to observe the first 100 meters of the subsoil. Due to this, it is not possible to establish if the proposed faults are continuing toward the surface and thus, ultimately, if they are capable faults. Re-interpretation or (if necessary) re-execution of the seismic profiles is strongly recommended.

* In case of further investigation at the site, more trenches should be excavated, paying attention also to strata plunge and dip in order to consider the possibility of performing forward modeling of surface deformation using the various near site fault models proposed.

* Historical data could have been used more extensively. Probabilistic estimate of site return period for the different intensities should have more emphasis, even including observation of historical earthquake available in the immediate surrounding of the site.

* A value of 0.35 g of PGA for SS1 seems too high for this region. It seems even too high if compared with a maximum intensity of VIII MSK. This subjective judgement is based on past experience in several sitings performed by ISMES in Italy and abroad, and explained in more detail at point 3.6.

6. REFERENCE

Ref. 1 VSN-15-78 Minehnergo USSR, "Provisional design standards for Nuclear Power Plants in seismic region", Moscow 1979.

Ref. 2 V. Dubrovsky, "Construction of Nuclear Power Plants", Mir Publisher, Moscow, 1981.

Ref. 3 T. Katona, "Seismic Safety of Paks Nuclear Power Plant", IAEA Regional Training Course, Paks, Hungary, 10 - 21 May 1993

ANNEX 1

LIST OF REPORTS AVAILABLE AT DEC., 1991

1. **Earthquake Research and Reports**

1. Catalogue of historical earthquakes near to Paks at epicentral distances less than 150 km. Reestimation of basic earthquake parameters. (1984; Report N. 1 to EROTERV).

2. Microseismic earthquake catalogue in the region of Paks (150 km) from the beginning of Hungarian seismograph station network (1911) until now (1984; Report N. 2 to EROTERV).

3. Detailed study of geologic structures in the outskirts of Paks (20 km); Field study and site selection for a seismological station. (1984; Report N. 3 to EROTERV).

4. Seismic noise measurement in the outskirts of Paks (20 km) for suitable site selection for a seismograph station. (1985; Report N. 5 to EROTERV).

5. Investigation of seismic noise field in the surroundings of PAKS NPP site (1985; Budapest).

6. Technical description of bore-hole seismometers for noise reduction (1985; Report N. 6 to EROTERV).

7. Bullettin of seismic events recorded at PAKS seismic station in 1985.

8. Technical description of a 3-channel seismic recorder (1986; Report N. 10 to EROTERV)

9. Investigations of automatic seismic signal detectors (1986; Report N. 11 to EROTERV).

10. Installation of an additional highly sensitive seismic station near to Paks (1986; Report N. 17 to EROTERV).

11. Earthquake engineering studies for four potential source regions: Pincehely, Dunaharaszti, Peremarton and Keeskemét (1986; Report N. 18 to EROTERV).

12. Influence of PAKS NPP, 3760 MW on the Environment (Seismological Part) (1986; Report N. 18 to EROTERV)

13. Bulletin of seismic events recorded at PAKS seismic station in 1987. (1987; Report N. 20 to EROTERV).

14. Site selection for a new Nuclear Power Plant: historical earthquake catalogue and seismic qualification of the potential sites (1987; Budapest).

15. Final Report on Investigations of earthquake hazard in Paks region (1987; A. F. Gracsov et al.)

16. Bulletin of seismic events recorded ad UZD seismic station in 1988.

17. Bulletin of seismic events recorded at PAKS seismic station in 1988.

18. Technical Concept for seismic monitoring network of additional 2 x 1000 MW Blocks at PAKS NPP (1989)

19. Seismic Qualification of PAKS. The most detailed investigations of probabilistic evaluations, earthquake source regions, potential ground motions characteristics, response spectra of local geologic structures (1990).

20. Seismic noise measurements at PAKS (1990; Supported by National Science Foundation, OTKA).

21. Bulletin of seismic events recorded at PAKS seismic station in 1990.

22. The Kecskemét earthquake of 8th July, 1911. Analysis of earthquake effects on local building structures. (1990).

23. ARUP Report

24. Summary Report of the SCC

25. Comparison of earthquake zones (different theoretical models) and their influence on the seismic risk in the Paks region. Budapest, 1992 (Zsiros T.). Magyar Tudományos Akademia.

26. Site specific response spectra (in ungherese, figure in inglese). Confronto tra ...... e altri modelli (analisi parametrica, Budapest, 1993, Dr. Bondár I. (Gorisk).

2. Geophysical, Geological and Tectonic Investigations

1. Report on acoustic logging in PAKS-2 bore-hole (1979; L. Rákóczy and K. Posgay).

2. Expert's report on the region South from Paks city for geological mapping at 1:5000 scale 91985; G. Chilkán et al.).

3. Magnetotelluric and telluric investigations in the vicinity of Paks. (1985; Report N. 8 to EROTERV).

4. Key to geologic maps of Paks city. (1985; J. Erdélyi, G. Chickán, A. Kókaj).

5. Relative horizontal gradient and truncated vertical gradient maps (scale 1:50000) derived from the Buoguer anomalies (of Hungary) in the 30 kms vicinity of Dunaharaszti, Komárom and Paks (K. Kiss).

6. Reinterpretation of seismic profile MK-7/81, Part 26400 - 48200.

7. Engineering geological study at Kecskemét. Peremarton and Pincehely (1986; G. Chikán and G. Kovács).

8. Geological structures in the surroundings of Paks.

9. Report on geological survey in the outskirts of Paks (1986; G. Chikán et al.)

10. Report on geological survey in Paks - 2/A bore-hole.

11. Report on geological survey in Paks - 3 and Paks - 4/B bore-holes (1987; G. Chikán et al.).

12. Report on Paks 4/A bore-hole (1987; G. Chikán et al.).

13. Report on recomputation of seismic profiles Du-1-8624 and Du-2-8624 (1987).

14. Report: Geophysical correlations based on bore-hole data from Paks (1987).

15. Report on seismic, stratigraphic and tectonic interpretation of seismic profiles recorded in Paks area in 1986 making use of deep drilling results sinked in the meantime. (1987; L. Lakatos).

16. Summary of geophysical logging (well logging and acoustic logging) in drill holes sinked at Paks NPP site (based on the contract between FTV and M_ELGI). (1987; R. Bagi and J. Rákóczy).

17. Report on geophysical prospecting for seismic hazard estimation at Paks NPP. (1987; L. Zilahi - S., J Rákóczy).

18. Geological structures in the region of Paks (Report by a Hungarian Expert Group of geophysicists and geologists).

19. Report on reinterpretation of seismic profiles and geological mapping of young dislocations in the territory between the rivers Danube and Tisza.

20. Report to EROTERV on electrical resistivity surveys near Paks (1988).

21. Report on seismic profiles at the vicinity of Paks in 1987 (1988; J. Rákóczy et al.).

22. Report on the results of seismic prospecting at Orgovány - Kiskórös - Fulöpszállás. (1988; L. Szilágyl and G. Vakarcs).

23. Geological nature and position of the tectonic fault in the environment of Paks NPP (January, 1989; A.F. Gracsov et al.).

24. Geological nature and position of the tectonic fault in the environment of Paks NPP (April, 1989; A. F. Gracsov et al.).

25. Comments on "Geological nature and position of the tectonic fault in the environment of Paks NPP (1989; Z. Szabó et al.).

26. Geological investigations at Pusztahencse and Tengelic vineyards (1989; G. Chikán and Kókay).

27. Report on neotectonic Investigations using shallow seismic methods in the vicinity of Paks (Dunaszentbenedek) in 1989. (1990; T. Guthy and E. Hegedüs).

28. Neotectonics of Paks region. (1990; F. Horváth et al.).

29. Geophysical and geological characteristics in the epicentral regions of major (1>=6, MSK-64) Hungarian earthquakes since 1763. (1990; Z. Szabó).

3. Geodetics Reports

1. Long periodical crustal movement investigation in the surroundings of Paks using geodetic data from archives. Collection of second and third order triangulation and high order levelling data (1984; Report N. 7.1, 7.31, 7.32, 7.33 to EROTERV).

2. Long periodical crustal movement investigation in the surroundings of Paks using geodetic data from archives. Long periodical investigation of the collected data. Short periodical investigations. (1985; Report N. 7.1, 7.2, 7.3 to EROTERV).

Second phase: repeated horizontal and levelling measurements, short periodical crustal movement investigation. (1986; Report n. 7.35, 7.36, 7.37 to EROTERV).

3. Additional geodetic measurements. Horizontal and vertical crustal movement measurements in the surroundings of the Paks NPP. (1987; Report N. 16 to EROTERV).

4. Additional geodetic measurements. Horizontal and vertical crustal movement measurements in the surroundings of the Paks NPP. (1987; Report N. 19 to EROTERV).

5. Local geodynamic investigation of the Nuclear Power Plant Paks:

1/a. Design and monumentation of a new extended horizontal network. (1987; Report to PAV).

6. Local geodynamic investigation of the Nuclear Power Plant Paks:

1/b. First measurements of the extended network. (1988; Report to PAV).

7. Local geodynamic investigation of the Nuclear Power plant Paks.

1/f-1Extension to the South of the local geodynamic network of the Paks NPP site (1988; Report to PAV).

8. Local geodynamic investigation of the Nuclear Power Plant Paks:
1/c and 1/f-2.. Repeated measurements of the network including the South directional extension. (1989; Report to PAV).

9. Local geodynamic investigation of the Nuclear Power Plant Paks:
1/d. Crustal movement analysis based on all available data (1989; Report to PAV).

10. GEODAT Version 1.0: Geodynamic Information System; Software Description. (1989; G. Bartha, L. Bányai, J. Czompó, Gy. Katona, G. Papp).

11. GEODAT Version 2.0: Geodynamic Information System: Software Description. (1990; Gy. Katona, G. Papp, T. Szabó).

12. Results of experimental GPS (Global Positioning System) measurements on the local geodynamic network Paks (1990; Supported by National Science Foundation, OTKA).

List of reports submitted to the Scientific Coordinating Committee

1. A. F. Grachev et al. (1987): Report about seismic hazard for Paks NPP.

2. A. F. Grachev et al (1989): Further analyses of geological position and character of the fracture near the Paks NPP.

3. G. Chilkán et al. (1990): Geological structure studies between Tengelic-Szölöhegy and Pusztahencse.

4. T. Guthy, E. Hegedüs (1990): Report on neotectonic studies performed near Paks (Dunaszetbenedek) in 1989 using shallow seismic methods.

5. F. Horvárt et al. (1990): Neotectonics of Paks region.

6. Z. Szabó (1990): Study on geological and geophysical parameters of epicentral regions of earthquakes with I = 6 (MSK-64) observed in Hungary since 1763.

7. Gy Szeidovitz et al. (1990): Seismic risk of Paks.

8. B. Csák (1990): Analysis of impact on buildings of the earthquake in Kecskemét on 8 July 1911.

9. É. Kilényi (1991): On the review of studies concerning the seismic hazard of the Paks NPP.

10. Gy. Scheuer (1991): On the review of geological structural data obtained for the Paks NPP site.

11. Z. Balla (1991): Remarks and proposal concerning the review of structural data for the Paks NPP site.

12. S. marosi, F. Shweitzer (1991): Remark to the geological works performed about the Paks NPP area.

13. Safety Guide of IAEA "50 - SG- Earthquakes and associated topis in relation to nuclear power plant siting.

14. Report on seismic measurements performed in 1987 in Paks region, ELGI. 2 volumes.

15. Report on the computerized reprocessing of seismic profiles in the young laterally deplaced zone observed in the region between Danube and Tisza and the mapping works of the said zone. GKV, 1988.

16. Report on the seismic profiles measured in the Paks are in 1986 .... GKV, 1987.

17. Report about the seismic profiles Du-1 18624 and Du-p2 8624 ..... GKV, 1988.

18. Report about the shallow ..... performed near Paks (Dunaszentbenedek) in 1989. ELGI.

19. Report on the seismic measurements performed on the area Orgovány - Kiskörös - Fülöpszállás. GKV 1988.

20. Report on the seismic logging performed in Paks-2 borehole, M_ELGI, 1979.

21. Summary report about the logging and seismic logging measurements in boreholes at the Paks NPP site performed under a contract between Land Measuring and Soil Investigating Co. and M_ELGI, 1987.

ANNEX 2

LIST OF REPORTS AVAILABLE AFTER 1991

1. Geological structural studies for improving the picture of Paks tectonics and detailed geological description of Paks and its environment. Hungarian State Institute of Geology, team leader: Dr. G. Chikán.

2. Seismic measurement for better location of the fault line supposed between Kecskemét and Paks (Kapos zone).

3. Seismological studies: Institut of Geodesy and Geophysics, Hungarian Academy of Sciences.

   3.1 Reevaluation of parameters of earthquakes in Hungary during XIX and XX centuries, team leader: Gy. Szeidovitz.

   3.2 Comparison of earthquake source zones with respect to seismic hazard at Paks,. team leader: T. Zsiros.

   3.3 Study of the impact of geological formations on the earthquake effects in the Paks NPP area, team leader: I. Bondár.

4. Seismotectonic synthesis.
   R. Eötvös University, Dept. of Geophysics, team leader: Dr. F. Horváth.

Title: Geological Evaluation of the Paks NPP Site

Contributor: T. Katona

Date: May 1993

GEOLOGICAL EVALUATION OF THE PAKS NPP SITE

The geological evaluation of the site of nuclear power plant constitutes the basis for the assessment of seismic hazard important in terms of the safety of the NPP. Its re-evaluation is imperative because of the new safety requirements on one hand, and the new scientific knowledge on the other.

Preliminaries

The revision of the issue of seismic hazard started in 1986 when it turned out that the seismic characteristics of the site may widely differ from those taken into consideration at the time of design. Since then there have been extensive examinations made for establishing the seismic hazard of the site. The estimation of the site seismicity has never been fully concerted. The examination of the seismic hazard of the site can be described with the following milestones:

- Based on historical earthquakes and isoseistic maps, at the time of site selection the area was declared as safe.

- In 1978 the Geophysical Research Institute of the Academy of Sciences of the U.S.S.R. estimated the intensity of the design base earthquake to 8th grade. Opposed to this, the Hungarian official position of that time considered the 5th grade as relevant and it was taken as design basis.

- In 1986 the same Soviet scientists set the characteristic intensity at 7 grades supposing the site to be a homogeneous block although they had found indications of fault lines in the seismic profiles. In the period of 1987 - 1989 the Geophysical Research Institute of the Soviet Academy of Sciences made every effort, using all the methods and techniques available, to prove that the site does not show any fault lines.

Before the beginning of recent research works the following picture was established about the tectonics of Paks region:

- There are two transcurrent fault zones perpendicular to each other. One of them is a WSW-ENE fault line, the so-called Middle-Hungarian Line or in other words Zagreb - Kapos - Szolnok - Máramaros lineament and the other is a transversal fracture deemed to be the continuation of a trench called Móri árok drawing parallely to Mezőföld Valleys and shifting to left by 1 to 2 km the above mentioned Middle-Hungarian Line. According to assumptions, the line of intersection of the two lines is located south of Paks, just on the area of the nuclear power plant. In 1989 Hungarian scientists estimated the intensity of the design base earthquake to 8 grade, and the corresponding peak horizontal acceleration was estimated first at 0.19 g, later 0.28 g.

- At the beginning of 1992 the English company Ove Arup determined the maximal intensity at 8 grades and the corresponding peak horizontal acceleration at 0.34 g using and re-evaluating the data available.

There are made about 80 studies, research reports and papers concerning the seismic risk of the site. In 1991 the president of the National Atomic Energy Commission established a Scientific Co-ordinating Committee for clearing up the essential controversy of views, for controlling the scientific researches about the seismic charasteristics of the site and shaping out a competent official view. The committee submitted its final report on 28 February, 1993.

Geological evaluation of the site

We shall relate the main points of the report of the Scientific Co-ordinating Committee, sometimes word for word.

The 1:50000 scaled geological map and the 1:10000 scaled exposure of the region was done on the basis of geological research of site region within a radius of 30 km. The geological structure of the area consists of three main formations: the Pleistocene - Holocene superficial deposits, the neogene basin deposits and the palaeozooic-mesozoic basin bottom.

There are no direct data about the basin bottom in the Paks region. According to the borings made in the region, the basin bottom is mesozoic to the south and west of Paks, and there are crystal formations to the north and east of Paks.

The lower layer of the basin deposit on the basin bottom is volcanogene deposit of more than 500 m thickness, originating from the Kárpát - Ottnang age. The younger Miocene complex is composed of rhyolite tufa, tuff, sandstone conglomerate, clay marl, limestone, Sarmatian conglomerate, sandstone, aleurite, Low Pannonian limy marl. The thickness of the Miocene deposit is more than 1100 m on the Paks area. It can be proved from the deep borings in Paks region that there are several levels of tectonical motion crossing the Low Pannonian layers. The thickness of the pliocene (upper Pannonian) deposit is about 600 m at Paks and it is the last part of the basin deposits with its clay-bearing rock-powder layers getting more and more sandy as going upwards.

Pleistocene-Holocene deposits cover almost the whole surface of the Paks region with wide variety of formations. The red clay and the loess are the most frequent formations to the west of the Danube, their thickness amounting sometimes over 60 m. The sandy rock powder of eolitic origin and the drift sand are the most frequent formations to the south and west of Paks, they are hardly separable from similar Holocene equvivalents. There are Pleistocene fluvial gravel and sand on the surface of the western edge of the Danube basin on which there are younger Pleistocene - Holocene fluvial sand, clayey sand and clay.

According to the field work, geoelectric and georadar examinations there has not been any ground motion in the surroundings of Paks in about the last 450.000 years (in the Quaternary, or at least in its upper stage and in the Holocene) which would have formed apparent tectonical structures - such as plicated or ruptured forms, faults, transcurrent faults or reverse faults - in the thoroughly examined layers near the surface. The shallow seismic profiles recorded near the plant showed rupturing of the Pleistocene Danube deposit by tectonic zones.

The seismotectonic synthesis relies on the results of about 1000 km long seismic material taken for oil industry, the seismic profiles around Paks and on 30 wildcat wells, enabling us to outline the deep structure and the Neogene-Quaternary structure development of the Paks region. Despite the lack of the cross sections the structural connections in the eastern direction can be traced with sufficient certainty but the presence of the faults in the direction of the Mór trench could not be examined with the new seismic data.

The area examined - namely a part of the Middle Hungarian Mobile Zone - has undergone an intensive and varied tectonic development during the last 22 million years, the main phases of which are as follows:

- transtensional basin development in the low Miocene age,
- Intrabaden compression,
- late Baden - Sarmatian sinking and basin development,
- intra - lower-Pannonian compression,
- lower and upper Pannonian alluvium,
- Quaternary compression and tectonic reactivation.

From the point view of seismic hazard the most important is the result of the Quaternary phase, a 1 to 2 km long and wide "disturbance zone", which starts at Paks and passing through Páhi and Orgovány follows the direction toward Kecskemet. It is presumable that the disturbance zone is an "en echelon" settled superficial manifestation of a right- sided transcurrent fault rooted in the crust.

The stratigraphic timing and alluvial deposit model of the area evidences the significant mobility of the region, characterised by subsequent reverse faults (basin inversions) occurring in several phases. One of the identified areas of Quaternary reverse fault is just to the south of the plant site and it is in genetic relation with the right- sided transcurrent fault.

It can be stated that the Kecskemet - Nagykörös fault line as a neotectonic rupture system continues until Paks. However, the Kapos line runs until Paks only as a pre-Neogene structural zone and continues to the East in the above mentioned system, but its younger restructuring did not happen until Paks.

According to the structural geological examinations and shallow-seismical considerations one can conclude that the Quaternary tectonics acted in the Pleistocene. There is no reliable geological evidence for the continuation of this activity during the Holocene.

Comparison of the epicentres of the known domestic neotectonic zones and the historical earthquakes leads to the conclusion that the majority of earthquakes in the Pannonian basin have tectonic origin. It follows from the foregoing considerations and the Paks - Kecskemét structural correlation, that during the determination of different levels of the seismic hazard an earthquake of Kecskemét - type and intensity has to be taken into consideration as possibly occurring also in the Paks region.

On the basis of the seismotectonic evaluation and the seismological data the seismic hazard of the plant site was determined with the help of both probabilistic and deterministic methods. Two earthquake levels were determined according to the IAEA 50-SG-S1 (Rev.1), one of them is the SL-1 or design basis earthquake, the other is the SL-2 or safe shutdown earthquake. The probability of SL-1 earthquake is 1/100 year while that of SL-2 is 1/10000 year. The SL-1 and SL-2 grade values at 50 percent and 84 percent confidence levels are on the MSK-64 scale as follows:

Level	50%	84%
SL-1	6.2 g	6.5 g
SL-2	8.5 g	8.9 g

Taking into consideration the impact of local geological circumstances on the acceleration the corresponding peak horizontal acceleration values are as follows:

Level	50%	84%
SL-1	0.06 g	0.08 g
SL-2	0.3 g	0.35 g

For earthquakes to be expected at Paks the the relative shift of stone blocks capable to accumulate the stresses can be estimated between 30 and 50 cm. This estimated shift decreases under the influence of the deposit covering the substratum, and pressumably it would not exceed several centimeters on the surface.

It can be seen that the geological characteristics of the plant effect the safety of the NPP.

17 May 1993, Paks

Title: Seismic Safety Programme at NPP Paks

Contributor: T. Katona

Date: April 1992

SEISMIC SAFETY PROGRAMME AT NPP PAKS

PROPOSITIONS FOR COORDINATED INTERNATIONAL ACTIVITY IN SEISMIC SAFETY OF THE VVER-440 V-213

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APRIL 1992

1. INTRODUCTION

There are four VVER-440 units in operation at Paks NPP site. The units are of V-213 type, i.e. they represent the new design, approaching in many respects the current, demanding western standards. The reliability of the units shown over the 26 reactor-year of operation has been fairly satisfactory. The cummulative load factor is 84.3% (at the end of 1991).

The V-213 version of VVER-440 units has a number of advantegeous features. E.g. the power density of the core is low, and there is a huge water inventory in the primary and secondary circuits for fighting down any possible LOCA cases. The hermetic reactor box, analogous to the containment is also dimensioned to bear a LOCA event.

The V-213 design has also some deficiencies, e.g. practically no impacts of outside events as earthquake, airplane crash, etc. had been taken into consideration.

At the time of site selection the current site was decided suitable, taking into consideration the historical seismic activity data, the seismic hazard was characterized by an intensity of V (MSK-64) at an annual frequency of 10^{-3} and with this values no special seismic design was needed.

Due to the eventual extension of the plant in 1986 a new site seismic hazard evaluation, essentially more detailed than the previous one, was started. These studies are still on, but hopefully the assessment of the seismic hazard will have been completed by the end of 1992. The expected result is well characterized by the recent examination by Ove Arup. According to this, the probabilistic seismic hazard assessment calculations show that the safe shutdown earthquake with annual probability 1 in 10000 has an MSK intensity VIII with a peak horizontal acceleration of about 3.3 ms^{-2}.

Due to the above mentioned, already in 1987 a seismic safety program was established and launched that was redefined year by year in course of the implementation, owing to the from year to year varying, but continouosly „increasing" seismic hazard assessment. Up to 1992 significant preparation work has been done despite of the uncertainity of the site's assessment. Presently there is the seismic safety program based on the above, rather pessimistic assessment, the purpose of which is to determine the actual seismic strength of the plant and work out the neccessary reconstructions.

In this paper we present the Paks NPP's seismic safety program, highlighting the specifics of the VVER-440 type V-213 in operation, and the results of the work up to now.

2. ESTABLISHING THE SEISMIC SAFETY PROGRAM

When establishing the seismic safety program first of all

- the safety phylosophy approved in the design,
- the original assessment of the seismic hazard for the site,
- the safety regulations, design procedures and input data taken into account,
- as built characteristics

should be compared to the up-to-date knowledge and the current safety requirements for the seismic hazard of the site.

The principles and the actual programme of the implementation of the seismic safety at higher level can be formed from this comparision being a qualitative analysis of the issue.

The procedure being followed below is shown in figure 1.

2.1. THE ORIGINAL SEISMIC DESIGN

In the design of the Paks NPP maximum earthquake expected at the site in 1000 years had to be taken into account according to the Soviet regulations and safety ideas of that time.

For the site earthquake of intensity grade V according to MSK-64 was assumed with an annual frequency of 10^{-3}.

Accordingly, the Soviet designer had no special dimensioning for earthquake, in compliance with the norms (e.g. SzNIP-II-A 12-69) in effect.

2.2. CURRENT REQUIREMENTS

2.2.1. Safety regulations

Today the seismic safety of NPP's are defined by rules significantly unified. As presently there is no Hungarian standard or regulation in this field the IAEA recommendations, standards of some countries (USA, GFR), and the regulations in the supplier's country are taken into account in the Hungarian practice.

In accordance with this, in point of the safety for the NPP the maximum design eartuquake (safe shutdown earthquake - SSE or level S2) is regarded to be deciding, when the nuclear safety of the plant is still warranted. At the site this is the maximal earthquake assumable with a frequency of 10^{-4}/year, which is justified by the historical records and the geologic and seismologic conditions of the site.

In order to provide seismic saftey for the power plant a protective system is needed which shuts the reactor down in case of earthquake. Suitable technical solutions have to ensure the operability and integrity of the technological systems, including the associated electric and C&I systems, involved in boration, cooling down the reactor and permanent heat removal from the reactor, as well as the tightness of the containments with radioactive media.

2.2.2 Current assessment of the seismic hazard of the site

According to our present knowledge the most probable value of the maximal design earthquake (with frequency of 10^{-4}/year) is eight degree at the MSK-64 scale, which a maximal acceleration value of 3.3 ms^{-2} (0.34 g) can be ordered to. The acceleration value characteristic for the earthquake with an annual frequency of 10^{-2} can be taken as 0.06 g.

2.3 PRINCIPLES OF SEISMIC SAFETY

As for the realization of the new seismic safety of higher level on one hand the following unfavourable facts should be regarded:

- the power plant was not designed for dynamic effects caused by an earthquake;
- the suppliers did not qualified the equipment and components (except for several ones) for earthquake and this kind of qualification actually can not be obtained from the (ex-Soviet) suppliers any more;
- the dynamic characteristics of the maximal design earthquake (SSE) for the site are high (maximum horizontal acceleration is 0.34 g, significant amplification in the response spectrum between 2 and 10 Hz);
- the maximum acceleration value characteristic for an earthquake with probability of 10^{-2} event/year is 0.06 g which itself can be regarded relatively low, but considering the fact that the power plant was not qualified for earthquake at all, unfortunately this value is very high, too.

On the other hand, the preliminary studies since 1987 shows that the main building and the main safety related components and pipings have significant strength reserves.

Due to the above mentioned the following principles can be formulated:

- The only realistic goal can be to make the power plant safe for a maximal design earthquake;
- The power plant can not be operated during an earthquake smaller than the SSE, and the restart can not be guaranteed, because it would need to redesign the whole plant, to qualify and then to reconstruct all the components.

(Simplified: the nuclear safety is expected to be guaranteed for the SSE but the restart and the operation safety can not be guaranteed in any kind of earthquake.)

- Even the safety requirements for the SSE can be met only such a way that the number of systems and components needed for the realization of the seismic safety are minimized. If the „normal" technology were used for cooling down, boration and permanent cooling then the seismic safety would be impossible to be realized – within reasonable limits – due to the large number of components and pipings to be reinforced.

This requests a specific seismic protection technology to be developed, i.e. the application of a special, cooling down, boration and permanent cooling technology the realization of which needs the least equipment operable during and after earthquake. This technology should be based on existing plant capabilities including the possible use of some systems beyond their originally intended function, to return the plant to controlled state and mitigate the consequence of the earthquake. (This special method and technology for the realization of seismic safety is called seismic safety conception below.)

In the evaluation of the seismic resistance the standards and regulations can be observed only by given justified compromises, thus, the qualification of the buildings, technological components, pipings, etc. should be performed according to a criteria document well established and developed for a special VVER-440 model V-213.

As the NPP in case is a plant in operation which is not designed for earthquake, it is necessary to use parallelly several methods for its qualification, decreasing by this the conservatism of analyses. Therefore, parallelly with the computational analyse, it is reasonable to perform e.g. dinamical experiments.

The coincidence of several events (earthquake, LOCA) should be re-considered.

The basic principles of safety realisation in case of VVER-440 are summarised in Figure 2.

2.4. STRUCTURE OF THE SEISMIC SAFETY PROGRAM

The seismic safety program was launched in 1986 when the seismic features of the site turned out to be significantly different to those taken into account in the design but the progress was slow because the seismic hazard assessment changed from year to year, as the increase of the parameters charaterizing the maximal designe arthquake affected not only the the input of the analyses but also the content of the program.

In defining the activity the known foreign practice was followed as there is no any experience with seismic safety for the nuclear facilities and even for the industrial facilities in Hungary. However, the program has become „tailored" due to the specifics of the Paks NPP and the scientific debate about the seismic hazard.

The program includes three main activities:

examining the seismic hazard;

establishing a seismic safety conception and defining the dynamic features of the systems and buildings given by this conception, as well as the actual seismic resistance; and

developing and realizing the technical solutions needed for the implementation of seismic safety of higher level.

The overall structure of the program is shown in Figure 3.

3. IMPLEMENTATION OF THE SEISMIC SAFETY PROGRAM

3.1. ASSESSING THE SEISMIC HAZARD OF THE SITE

In the site of the power plant geologic examinations have been conducted since the sixties. In 1986 a new site evaluation more detailed than the previous ones was started because of the eventual power plant extension. The first results recieved in 1987 gave an earthquake intensity of degree VII with an expected frequency of 10^{-4} event/year, and a maximal horizontal acceleration of 0.15 g. The examination for the seismic hazard ofthe site have not completed yet due to the scientific debate developed during the evaluation. About 70 papers, research reports have been prepared to support the seismic hazard assessment for the site. The existing papers and reports have been reviewed by the authors and by independent experts. An example is the Ove Arup study quoted above. On the base of the critical analysis additional geologic and seismic examinitions were performed in 1992. The purpose was to precise the geologic structure and tectonics of the site, on the base of which the allowed models of the source of the seismic hazard have to be defined and the hazard has to be determined again. Hopefully the seismic hazard assessment will be completed by the end of 1992 and a qualification based on a scientific consensus will be available. The expected result is well characterized by the recent examination by Ove Arup quoted above.

3.2 DEVELOPING THE NEW CONCEPTION OF SEISMIC SAFETY FOR THE PLANT

With the specifics of the as built state and the new requirements, as well as considering the principles in para 1.3 a special procedure has to be established to shut down, borate and cool down the reactor and for the heat removal, as well as to preserve the tightness of containments with media of high activity, and to eliminate the additional damages caused by the earthquake. The new seismic safety conception for the plant defines this procedures.

The development progress of the conception is shown in Figure 4. According to this the following had or have to be carried out:

3.2.1. Design evaluation

The systems for reactor shut down, cooling down and heat removal were not designed for the dynamic effects caused by an earthquake.

The components of the mechanic systems (equipment, pipelines) were dimensioned for static and heat expansion loads on the base of the Soviet standards and technical norms of that time.

On the base of the preliminary dynamic calculations for the primary circuits piping and for ECC piping it can be stated that in general there are significant reserves in the systems in normal operation, which enables to take the additional dynamic loads into account.

3.2.2. Developing the technology to realize of the seismic safety, defining the set of the earthquake resistant systems

3.2.2.1. Seismic safety system to shut the reactor down

According to the safety requirements a system should be installed on each unit and this system initiates emergency signal if the acceleration measeured at the characteristic points of the main building (on its base plate) exceeds a certain value.This acceleration threshold value is far less than the free field acceleration value caused by the SSE.

The seismic protection system should fit to the existing unit protection in point of channel number, logics, redundancy and reliability.

This system supplied by the Swiss firm SIG SA was installed in the units in 1991. In 1992 an alarm system built in each control room allows the operator to shut down the reactor manually. The experiencies gained with the system will be evaluated in November 1992 and then the decision will be made on the way of integration into the protection system and on the introduction of the automatic operation mode. Of course, this is reasonable only in the case if the unit protection system itself is seismic resistant. This issue will be addressed later, too.

3.2.2.2. Boration, cooling down the reactor and permanent heat removal in case of earthquake

The first essential step to realize the seismic safety is to develop the technology for the boration, cooling down and heat removal of the reactor. This technology will be realized as follows:

<u>Normal state:</u>

The unit operates with the rated parameters, according to the operation instructions in effect. The primary, secondary and electric parameters complies with the nominal parameters. The Diesel generators, as well as the active and passive ECC systems are ready for operation.

<u>Earthquake:</u>

When the set acceleration limit is exceed an „Earthquake" signal is recieved by the reactor protection system.

An emergency signal level 1 generated on the principle „2 from 3" stops the reactor. A command is sent to stop the turbogenerator unit, too. The same time the Diesel generators and stepwise automatic loading program after earthquake start.

When the emergency actions are completed the unit reaches a stable hot condition.

Boration:

The boration and and the compensation for volume decrease of the coolant due to the cooling down are carried out by the operator using the high pressure ECC pumps.

Cooling down:

First stage: cooling down to $T_{pr.\ circ.}$ 130 °C

- controlled steam release through the safety valves of steam generators;
- the level in the steam generators is ensured by the emergency feed water pumps
- the primary side pressure is decreased by steam release through the safety relief valve of the pressurizer into the bubble condenser.

Second stage: Further cooling down below 130 °C, to 60 to70 °C.

- the primary side pressure is decreased to 0.4 MPa;
- putting the low pressure ECC system into operation together with the primary side cooling down system to be installed (cooling the primary coolant through ECC heat exchangers)

Heat removal:

continuous circulation of the primary coolant by the low pressure ECC pumps through the ECC heat exchangers in orderto cool the active zone.

The limits of above technology determines the set of systems and components assured for the maximal design earthquake. At the so outlined system limits a safe isolation should be realized with existing or new quick action valves that close on the earthquake signal.

The outlined seismic safety conception developed in detail was completed in January 1992.

3.2.2.3. Electric and C&I conditions

A safety electric power supply system needed for realization of the seismic safety technology has to be worked out. The power has to be distributed for the consumers identified in the above mentioned conception, the earthquake-proof electric power supply systems have to be determined, and the requirements for the operability of these systems have to be established (operation during the earthquake, function maintenance during the earthquake).

In realization of the seismic safety it is important to provide the necessary C&I conditions for the emergency signal generation, etc. The procedure here is the same as in case of the electric conditions, i.e. the C&I components needed for the implementation of the seismic safety technology have to be identified and the requirements for the operability of these systems have to be established (operation during the earthquake, function maintenance during the earthquake).

This job is planned to be carried out during 1992. It is important to note that in this case it is not a simple compilation of list of equipment and components. In the review of safety related electric and C&I equipment, components, systems the opportunity for reconstructions or quality improving exchanges have to be taken into account, where the demand of seismic resistance can ab ovo be provided.

3.2.2.4. Containments with radioactive media

The list of such containments (systems, tanks, pools) has to be compiled the damage of which would increase the risk of environmental emission in an earthquake, or would hinder the safe operation of the plant after the earthquake. The integrity of the containments with radioactive media has to be maintained and, accordingly, they have to be subject to the same procedure as the mechanic systems (review, reconstruction). The isolation between the containments of significant volume with radioactive media and the seismically non-safe environment has to be provided using suitable existing or newly installed quick action valves.

The list of containments to be protected and that of the isolation valves will be completed during 1992.

3.2.2.5. Additional problems

The analysis of effects not belonging to the range of nuclear safety but substantially affecting the after-earthquake situation (fires, floods) is an organic part of the seismic safety conception. It includes also the suitable amendment of accident management procedures, and the overview of the infrastructural consequences of the accident mitigation after the earthquake.

3.3. ASSESSING THE SEISMIC RESISTANCE OF THE BUILDINGS

The procedure followed is shown in Figure 5.

3.3.1. Selection of the safety related buildings

Actually all the buildings of the power plant has to be reviewed in order to realize the seismic safety, i.e. the main reactor building (which actually takes the role of the containment), the gallery around the main building, the Diesel room, the pump station and the auxiliary building.

3.3.2. Design data

The design was according to SzNIP which was in effect between 1965 and 1982 in the Soviet Union. Regarding that the most important building, the main building, was designed for inner pressure of 2.5 bar there are significant strength reserves for taking the additional dynamic loads into account.

3.3.3. Defining the requirements

The criteria document made specially for VVER-440 type V-213 mentioned in paragraph 1.3 has to contain the classification of the power plant buildings and also the strength requirements for the seismic safety of the buildings.

3.3.4. Qualifying the seismic resistance of the buildings

In case of NPP in operation the conservatism of the analysis has to be decreased as far as possible because there might not be a way to increase the safety arising from that. Thus, the best estimation method is preferable to be applied in each phases of the analysis.

Below the major stages of the seismic resistance review for the buildings of Paks NPP is outlined.

Main building:

Three independent model of finite elements has been made:

two-dimensional model with beams and discs, two different models were made according to the two main axes of the building (see Figure 6.);

lumped-mass, beam model (see Figure 7.);

three-dimensional shell model;

2D model:

Calculations were made for earthquakes characterized with 0.15 g ZPA. On the base of the results the main building could be qualified as appropriate in point of strength for the given dynamic excitation. The model was also completed with a soil model and also pre-calculations were carried out for 0.28 g, in which case the load limits were reached for the steel structure of the main building.

3D lumped-mass, beam model:

Dynamical features and response were determined for earthquake characterized by maximum horizontal accelereation of 0.28 g.

3D shell model:

This model includes the gallery building around the main building and the turbine hall. The calculation will be completed by April1992.

Other buildings:

3D model with shell elements of the auxiliary building (see Figure 8.) and the pump station, as well as the model of the Diesel room has recently been completed.

Presently test calculations are on for 0.3 g ZPA value using US NRC standard response spectrum.

The final dynamic analysis will be made on the base of the response spectrum specific for the site that is to be completed by the end of 1992.

In order to decrease the conservatisms building dynamical experiments were carried out. In the course of the experiments the buildings was excited by blowing explosives of 100 to 500 kg in 20 m depth in a distance of 2 to 5 km and the acceleration in the buildings was measured. On the base of the acceleration signals experimental modal analysis was carried out. The experiments and the comparasion of the calculations to the measurement results are in Appendix 1.

The examinations are expected to be extended for the issue of soil liquifaction in the future.

3.4. EVALUATING THE SEISMIC RESISTANCE OF THE TECHNOLOGY

The procedure followed is shown in Figure 9.

3.4.1. Detailed list of equipment and pipes, list of electric and C&I devices, cables, cabinets, etc.

The seismic safety of the power plant can be achieved by ensuring the operability of

a seismic protection system generating emergency signal level 1 operation,

technological systems needed for the cooling down, boration and heat removal,

quick action valves isolating the seismically safe systems,

and the electric and C&I systems needed for the operation of the above systems,

and further by

making the containments with high activity media earthquake resistant, and using valves to isolate these containments, and operating these valve in seismically safe way.

The first stage of the review is to compile a detailed list of equipment (pipeline, component, device, cable, etc. – in one word: equipment) that contains the followings:

- unit No;
- system identification;
  - identification number,
  - location (level, room),
  - seismic safety class,
  - the demanded requirements (stability, integrity, operation, operation maintenance),
  - criterion of suitability (reference to standard)

for the equipment.

The list should contain the boundary valves between the seismic resistant and non-seismic-resistant parts. These valves can be:

valves being always closed in normal operation,

check valves,

valves being always open in normal operation; in this casethe seismically safe operation has to be ensured,

valves to be installed.

This list of equipment exists for mechanic systems, for electric and C&I systems it will have been completed by June 1992. The list will be prepared in a form of computer data base. The data base will contain arrangement information related to the accomplishment, beside the technical information.

3.4.2. Review of the documentation, survey of the as-built state

The next logical stage of the seismic resistance review is to collect the design documentation for each items of the list of equipment compiled as given in the previous paragraph.

The documentation has to be reviewed following the aspects below:

wether the documents contain dimensioning for earthquake;

what standards were used for the strength design and what loads were regarded;

What the as built state is like, escpecially as for the anchorage of equipment.

The documentation was checked by site survey in 1991 and thefollowings were checked:

layouts,

anchorage

fix points (in case of pipelines),

location of potential additional supports,

location of boundary valves or other additional equipment,

issues to be dealt by management actions (e.g. obligation to refix after maintenance)

The documentation volume will be compiled for every equipment to be reviewed after the site surveys and the data procession, and this volume is needed for the further examinations with calculation, experimental or other methods, to plan the reconstruction.

This particular stage for the mechanic systems will be completed in 1992.

Similar procedure for the electric and C&I systems will be performed in 1992-93.

3.4.3 Qualification

Qualification of the seismic resistance for a power plant in operation, according to new criteria, and the eventual increase of the seismic resistance is very sophisticated work with very high cost, especially if the particular plant was not designed for earthquake. During the qualification and planning the reinforcement the conservatisms covering the technical uncertainities and inaccuracy should minimize as the conservatism results in additional costs, outage, work in contaminated environment.

Among the methods of the qualification those are to be applied which can be supposed to lead - with the same safety - to minimal reconstruction changes. In order to minimize the interventions particular procedures, redundant check methods, innovative approach are to be applied. In this point of view the joint application of experimental and calculation qualification;

using particulary based „best estimate" data instead of the parameters given in the standards (e.g. damping value) as these latter includes significant conservatism

should be highlighted.

A criteria system which takes the specifics of the power plant into account is absolutely neccessary to be established for the qualification.

Here below two aspects of the qualification are detailed.

3.4.3.1 Experiments

The experimental method is to be used first of all for equipment (devices, components) with relatively low mass where checking the maintenance of operability is an important requirement. This kind of equipment usually is qualified and certified by the manufacturer. In Paks NPP, just like in the other VVER-440 NPP's, the seismic resistance of the equipment is not qualified and certified – except for some very rare cases. In some cases (e.g. the battery plant) the equipment itself is qualified but the way of installation is not appropriate.

The post-qualification by means of vibration table can be used for electric and C&I cabinets, devices, equipment and components and for some mechanic components (e.g. valves). For example the vibration table test of the reactor protection system (sensors, cabinets together with relays and circuits in it) can not be avoided.

The experimental examinations of dynamic features of a particular critical system – which actually are components connected by pipes into a complex system – can become neccessary, especially with the purpose to define individual empiric values instead of the damping stipulated in a conservative way in the standards.

In Paks NPP in-situ experimental dynamic examinations has been performed for the primary circuits, the upper reactor block, and for some typical piping systems such as the pipelines of the ECC. In paralel with these experiments dynamical calculations of finite elements were carried out and the resulst were compared to the results of the experimental modal analysis.

In the units of Paks NPP the pipelines were designed very „soft", thus, the low frequency resonances are characteristic for thepipelines. Due to this flexibility the stresses caused by heat expansion or unit transients are generally moderated. However, the disadvantage of this design conception is that the pipe responses fall in the characteristic frequency range of an earthquake. In this case the realization of seismic resistance will involve an essential redesign of the pipe supports.

In 1991 vibration table tests were conducted to qualify 5 C&I cabinet of different types, the control desk and relays and devices belonging to the reactor protection. In parallel with the tests of the cabinets and the desk dynamic calculations of finite elements were carried out and the results of the tests and the calculations were compared (see Figure 10). Above test had first of all methodological character. The list of seismic safety related electric and C&I equipment and components will be completed in 1992 and this document will determine the neccessity and scope of the further tests.

3.4.3.2. Possible application of the SQUG method

The use of the qualitative method developed by the American Seismic Qualification Utility Group (SQUG) would be very usefeul.

The main problem of the practical use of the SQUG qualification method is that the equipment of the VVER-440 V-213 NPP is substantially different to those in the SQUG data base. In our case a lot of Soviet equipment has to be requalified and there are not even similar ones in the data base based mostly on items of Western make. Despite the expected difficulties a large number of equipment that has not been certified and that can not be post-qualified on test table or at the site can be examined for the seismic resistance only by the SQUG method.

A data bank based on the mutual adventages would be very useful for VVER-440 V-213 equipment tested and checked by calculations.

4. REALIZATION OF THE SEISMIC SAFETY OF HIGHER LEVEL (TECHNICAL SOLUTIONS, EXECUTION DRAWINGS, REALIZATION)

At Paks NPP a large scale program is under way to increase the seismic safety.

The implementation of the program is within reasonable technical limits as there has not been yet the final expert opinion for the seismic hazard of the site. The activities until 1992 give a good methodological preparation and offers many results that can directly be used.

Figure 11 summarizes the activities in an overview logical schedule.

The reconstruction actions for the realization of seismic resistance of higher level can be defined during 1993 and 1994 and this actions can be executed during the period between 1993 and 1996 in several small reconstruction steps.

However, until the completion of the qualifications there is chance to progress in improving the seismic resistance if

in course of reconstructions or component replacement in the units - as needed - the seismic resistant requirements are considered;

the connection of the parallel safety improving actions to the seismic safety program and its eventual positive effects are exploited;

the condition of the fixation for the components, electric and C&I cabinets etc. checked during the maintenance periods is reviewed;

5. IDEAS AND PROPOSITIONS FOR COORDINATED INTERNATIONAL ACTIVITY

Site examination:

in the assessment of the seismic hazards of the sites political issues are often involved so an objective international assessment organized and published by IAEA is very important for the NPPs, so that the financial resources for the safety improvement can be concentrated on elimination of real safety deficiences;

PSA:

According to the latest researches the probabilistic features of the events determining the safety in case of NPP unit of VVER-440 V213 type are as follows:

	frequency of the occurance [1/y]	frequency of core melt due to this [1/y]
large pipe break	10^{-5}	$2 * 10^{-8}$
small pipe break	10^{-3}	$2 * 10^{-6}$
max. design earthquake	10^{-4}	?

For the above figures it is worth noting that the given probability for pipe break relates only to one unit, while the earthquake with the given probability affects the site, i.e. affects all the four units at the same time.

Proposition:

A VVER-440 PSA has to be established with the coordinated efforts of the involved countries to determine the occurance probability of accidents following an earthquake.

On the base of this a Seismic Safety Philosophy has to be developed specially for the VVER's in operation.

Qualifying the seismic resistance:

As the NPP in case is a plant in operation which is not designed for seismicity, it is necessary to use several methods in parallel for its qualification, decreasing by this the conservatism of analyses.

Qualification of the buildings:

Proposition:

Selection of best estimate methods – on experimental base.

Mechanic, electric and C&I components:

Components not qualified by the manufacturer for earthquake:

in-situ tests are impossible in many cases

Tests on the spare componenets is not very simple and especially is not cheap

Proposition:

selection of checked best estimate methods;

coordinated activity like SQUG, common data base on the base of equal costs and mutual advantages;

The selection of the best methods and means is served by the coordinated research program "Benchmark Study for Seismic Analysesand Testing of VVER-tupe NPP's" suggested by IAEA. In our opinion the experimental experiences and results obtained at Paks NPP can be used for this, especially in the field of the dynamic examination of the main building.

Criteria for the qualification:

Deficient information about the standards, design principles and methods used in the design. In many cases the seismic qualification gives the only information about the strength character of the system.

Problems:

incompability between the norms and methods of the original design and those of the seismic qualification;

the material properties used in the design calculations are often unknown;

Proposition:

A unified criteria document has to be established that takes the norms and methods used in the design and the up-to-date norms and methods into consideration as far as possible.

The propositions above are summarized in Figure 12.

STRUCTURE OF THE SEISMIC SAFETY PROGRAM

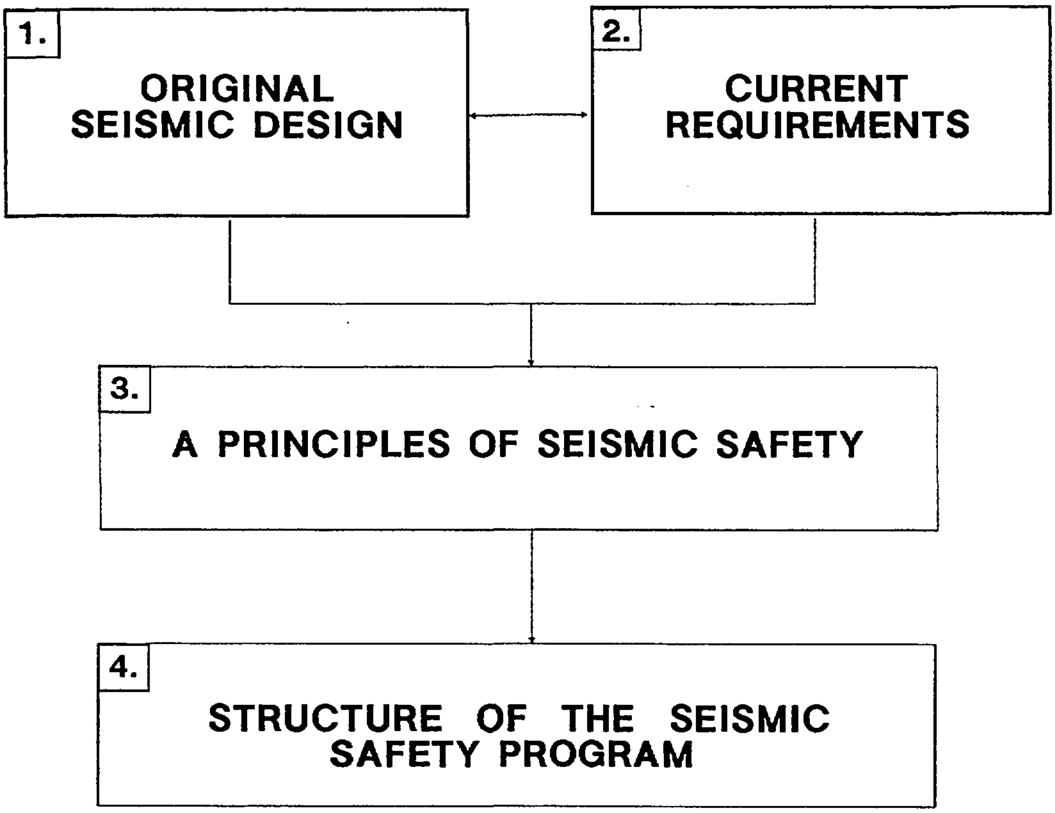


Fig. 1.

BASIC (REALISTIC) PRINCIPLES OF SEISMIC SAFETY OF VVER-440 v-213

GOAL:

- NO REQUALIFICATION FOR OBE
- QUALIFICATION ONLY FOR SSE

HOW TO REACH SAFETY FOR SSE?

— NOT FOLLOW STANDARD WAY IN CLASSIFICATION OF SYSTEMS

— SPECIAL TECHNOLOGY FOR INTRODUCING BORON, COOLING DOWN, AND HEAT REMOVAL REDUCING THE NECESSARY NUMBER OF SYSTEMS AND EQUIPMENTS

— USE FOR SOME SYSTEMS BEYOND THEIR ORIGINALLY INTENDED FUNCTION

— ELABORATE CRITERIA FOR MINIMUM ACCEPTANCE

— USE PARALLELLY SEVERAL METHODS, BEST ESTIMATE PROCEDURES TO AVOID CONSERVATISM

— RE-CONSIDER THE SAFETY PHILOSOPHY

Fig. 2.

SEISMIC SAFETY PROGRAM

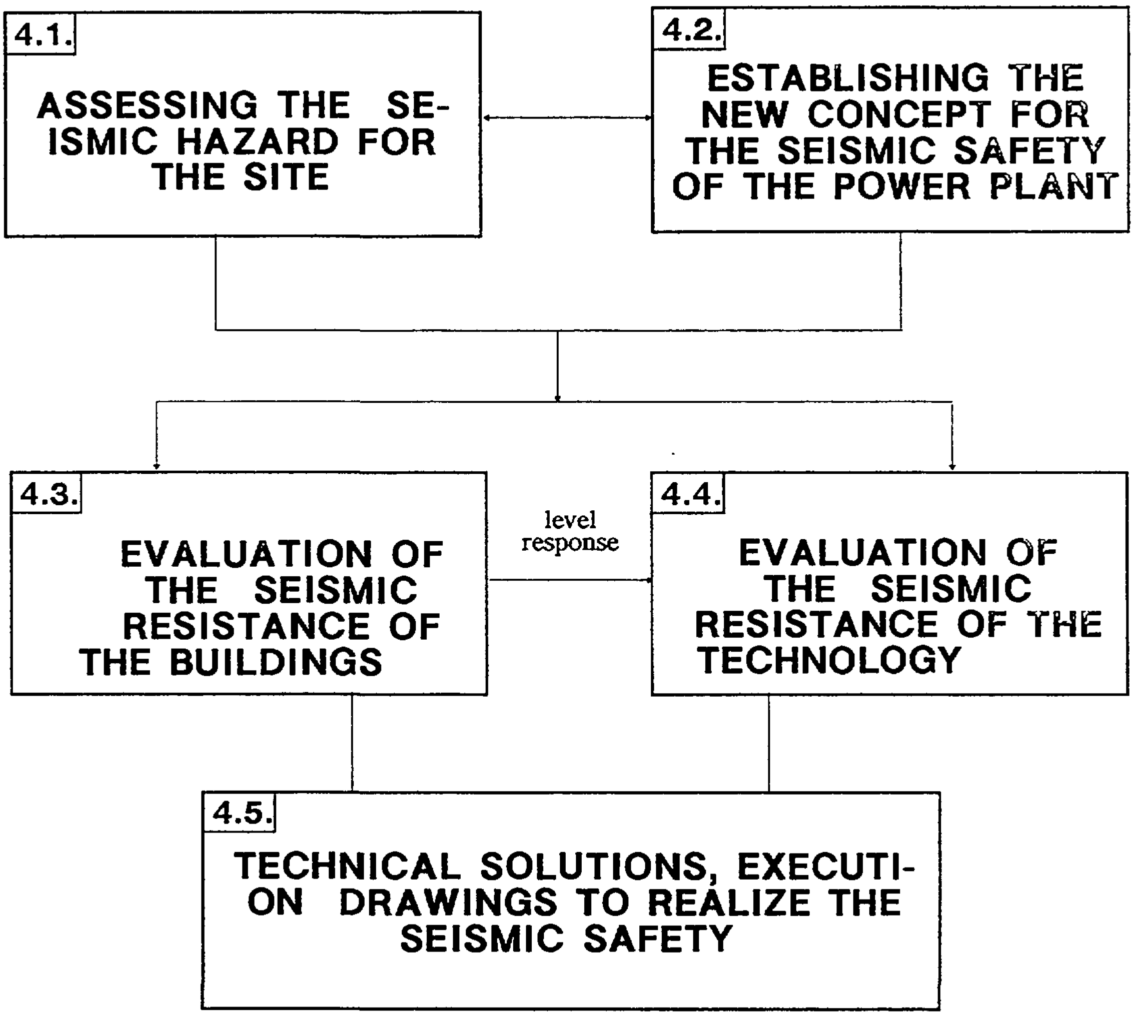


Fig. 3.

SEISMIC SAFETY PROGRAM

4.2. DEVELOPMENT OF THE NEW CONCEPT OF SEISMIC SAFETY FOR THE POWER PLANT (TECHNOLOGY)

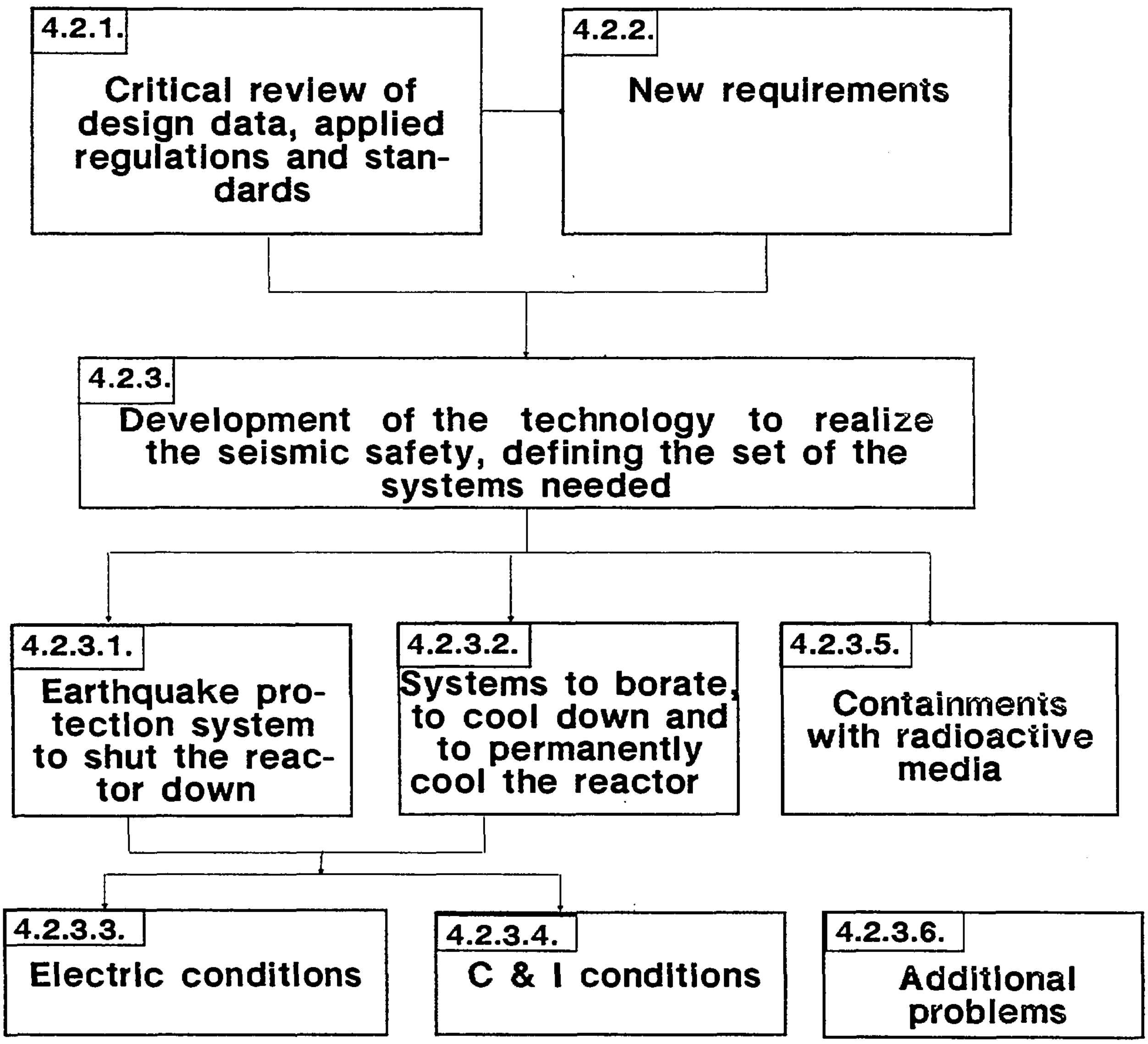


Fig. 4.

SEISMIC SAFETY PROGRAM

4.3. SEISMIC RESISTANCE ASSESSMENTS FOR THE BUILDINGS

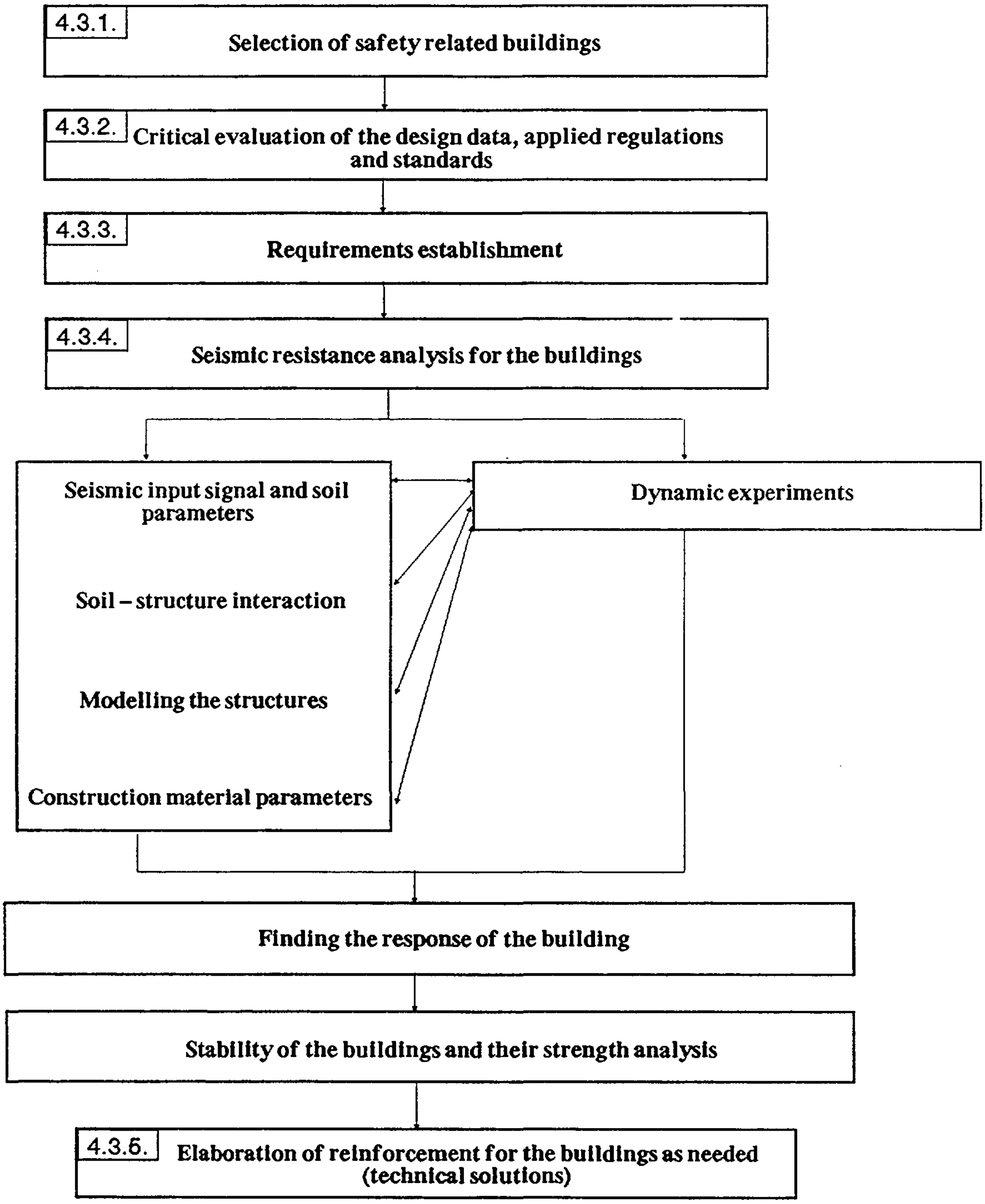


Fig. 5.

NAGYKERET-KERESZTMETSZET

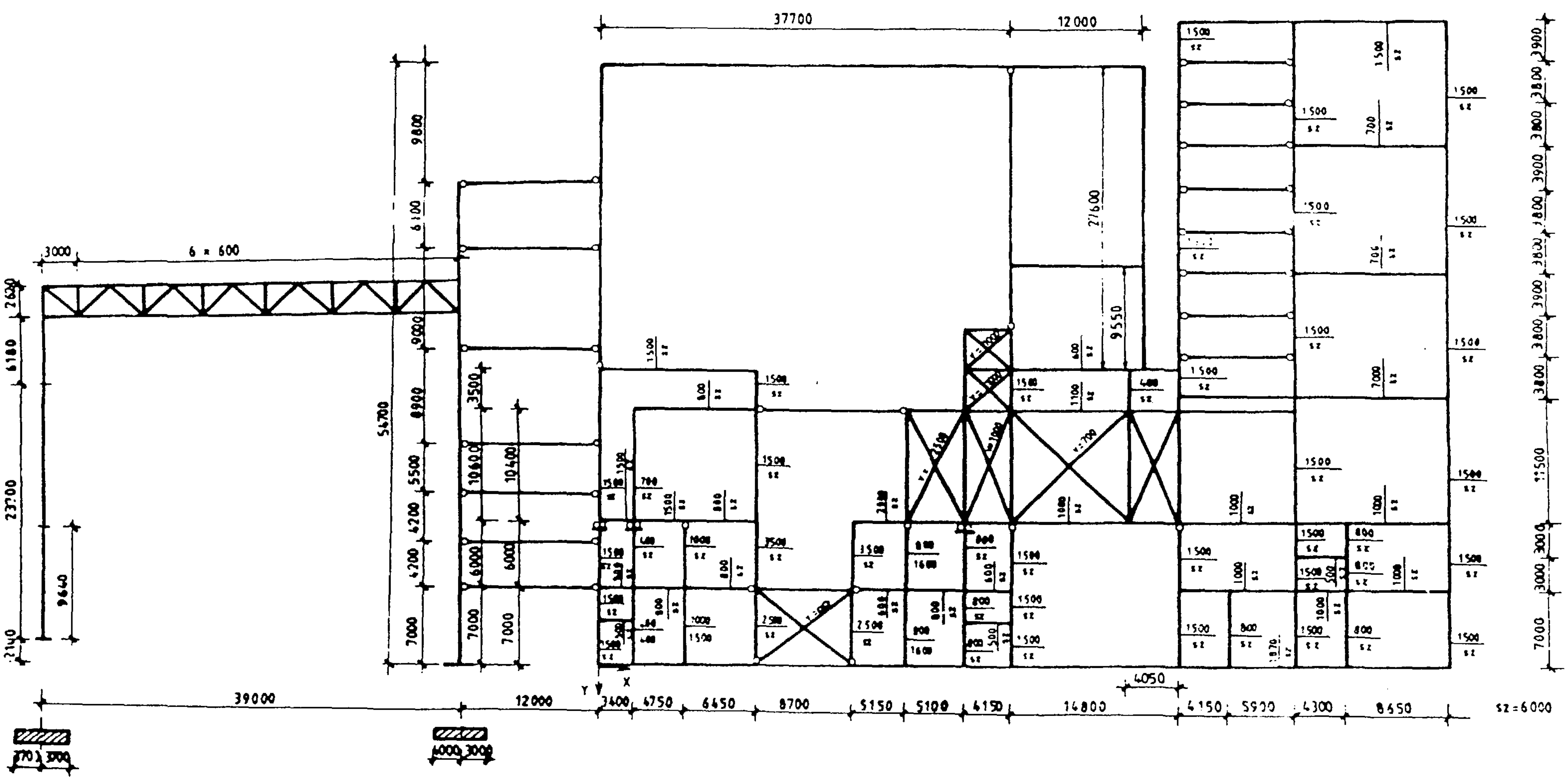
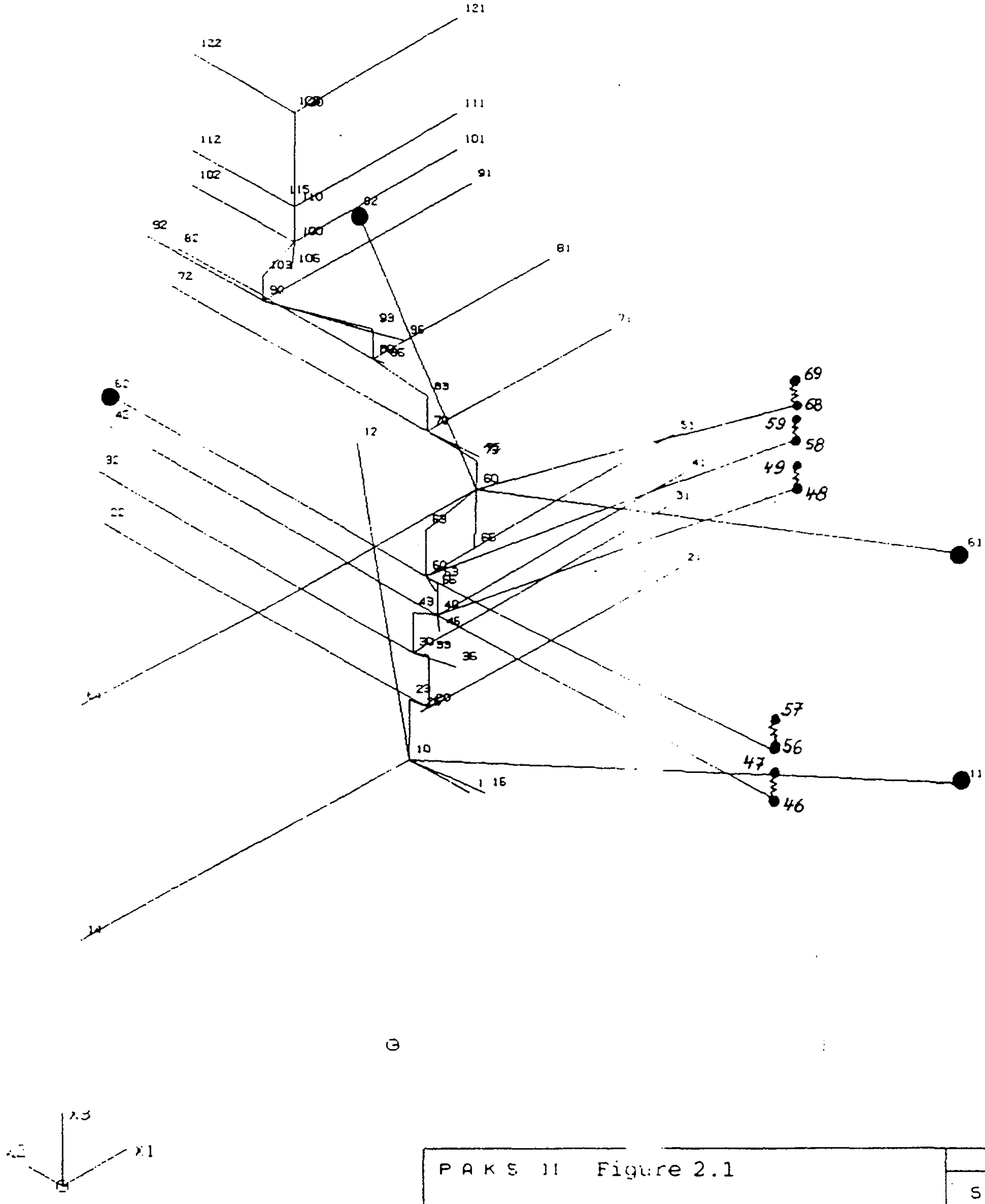


Fig. 6.



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P A K S II Figure 2.1	6-SEP-91
	SIEMENS
PAKS II MAIL BUILDING BEAM MODEL V424/91/0043 POINTS NUMBERING	STRUDYN

Fig. 7.

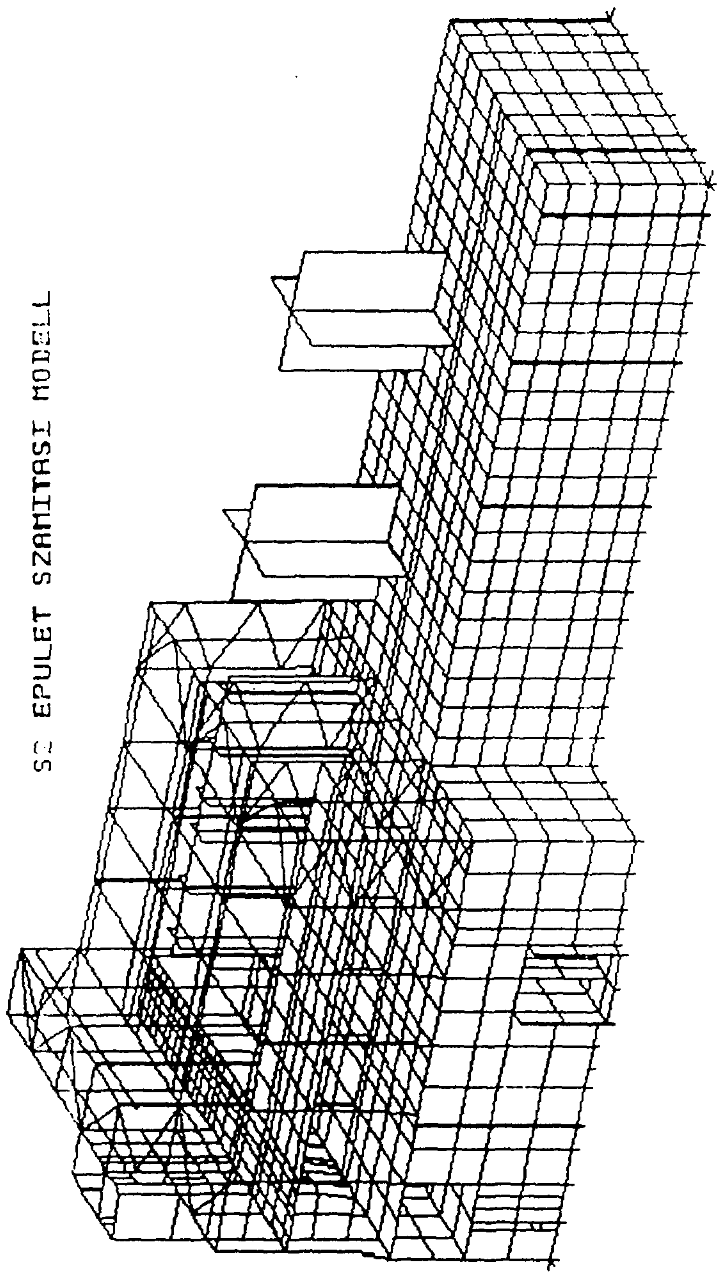

Fig. 8.

SEISMIC SAFETY PROGRAM

4.4. SEISMIC RESISTANCE ASSESSMENT FOR THE TECHNOLOGY

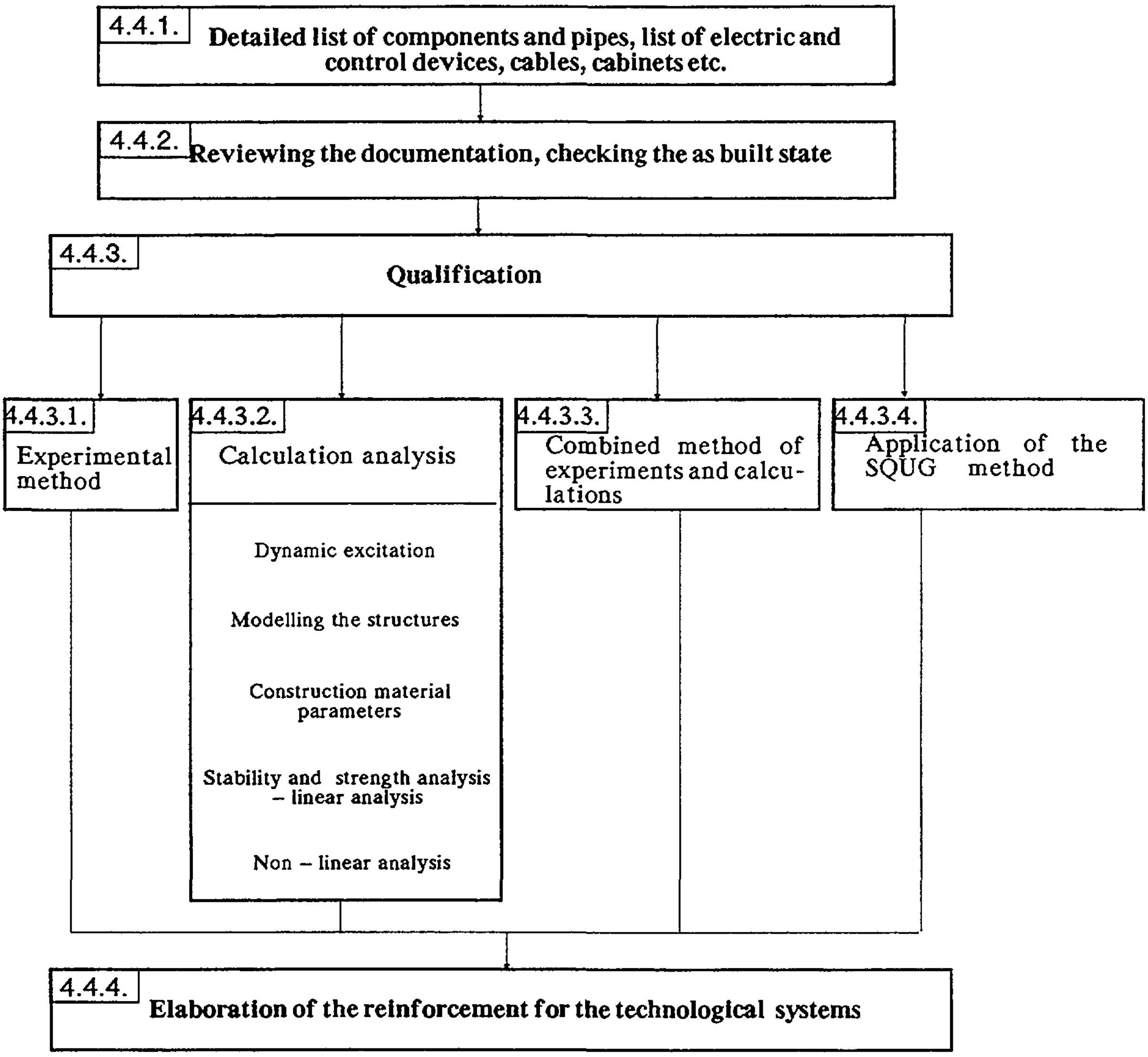

Fig. 9.

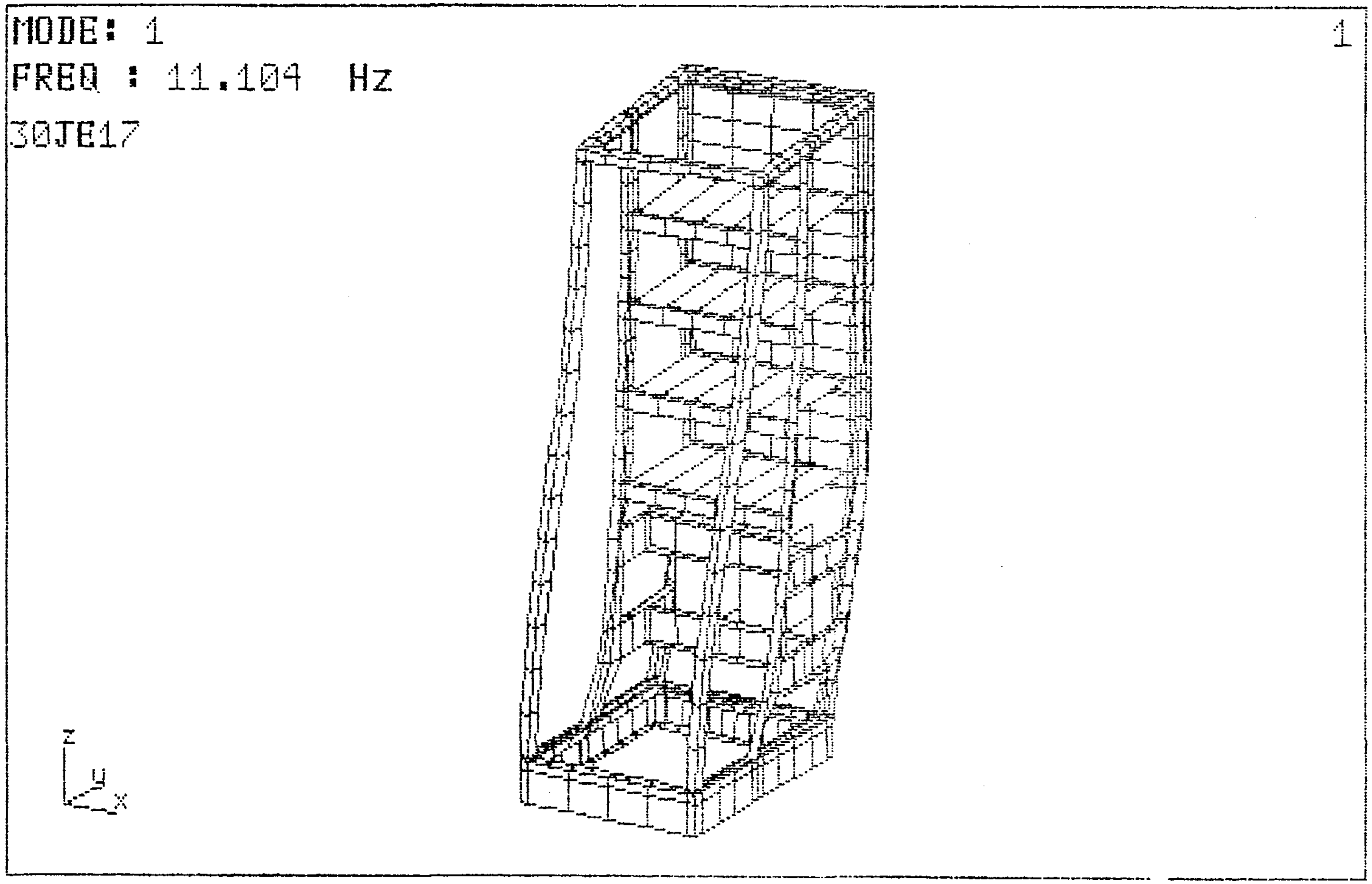

Fig. 10.

WORK	1992-93	1994-95	1996
ASSESMENT OF THE SEISMIC HAZARD FOR THE SITE (Official opinion of the Scientific Coordination Commitee)			
ESTABLISHMENT OF THE NEW CONCEPT OF SEISMIC SAFETY FOR THE POWER PLANT			
SEISMIC RESISTANCE ASSESSMENT FOR THE BUILDINGS – MODELLING, PRELIMINARY DINAMIC CALCULATIONS – FINAL EVALUATION – DESIGN OF (EVENTUEL) REINFORCEMENTS			
SEISMIC RESISTANCE ASSESSMENT FOR THE TECHNOLOGY *MECHANIC* – EVALUATION OF THE ACTUAL SEISMIC RESISTANCE – DEVELOPING THE TECHNICAL SOLUTIONS – DESIGNING THE REINFORCEMENTS *ELECTRIC* – CONCEPT AND LIST OF COMPONENTS – FINDING OUT THE ACTUAL SEISMIC RESISTANCE – DESIGNING THE MODIFICATIONS *CONTROL AND INSTRUMENTATION* INSTALLATION OF THE EARTHQUAKE PROTECTION SYSTEM – TEST RUN IN MANUAL MODE – INTEGRATION INTO THE REACTOR PROTECTION SYSTEM, AUTOMATIC MODE C&I ITEMS – CONCEPT AND LIST OF COMPONENTS – QUALIFICATION OF THE SYSTEMS AND COMPONENT – DESIGNING THE MODIFICATIONS			
REALIZATION			

Fig. 11.

PROPOSALS FOR COORDINATED ACTIVITY AND IAEA SUPPORT

— IAEA SUPPORT IN SEISMIC HAZARD RE-EVALUATION OF OPERATING VVER-440 SITES TO AVOID „POLITICAL" DISTURBANCES

— PSA FOR EARTHQUAKE - A COORDINATED RESEARCH PROGRAM - NEW SEISMIC SAFETY PHYLOSOPHY

— EVALUATION OF AS-BUILT SEISMIC SAFETY

- BEST ESTIMATE METHODS SUPPORTED BY EXPERIMENTS
- SPECIFIC ACCEPTANCE CRITERIA FOR VVER-440 v-213
- SQUG-LIKE DATA- AND KNOWLEDGE-BASE

COORDINATED RESEARCH PROGRAMMES

Fig. 12.

Title: Experimental and Analytical Investigation of Paks NPP Building Structures

Contributors: T. Katona, N. Krutzik

Date: 1993

Experimental and Analytical Investigation of Paks NPP Building Structures

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ABSTRACT: The dynamic characteristics of VVER-440 NPP building structures were experimentally investigated using explosive techniques. The same characteristics were calculated analytically. The comparison of experimental and analytical results shows the adequacy of the modeling of the structures and soil-structure interaction.

1 INTRODUCTION

There are four VVER-440 units in operation at the PAKS NPP site. The units are of the V-213 type, i.e. they represent the new design, approaching in many respects the current, demanding western standards. The reliability of the units shown over 26 years of reactor operation has been fairly satisfactory. The cumulative load factor is 84.3 % (as of end of 1991).

The V-213 version of the VVER-440 units has a number of advantageous properties. E.g. the power density of the core is low, and there is a huge water inventory in the primary and secondary circuits for mitigating any possible LOCAs. The hermetic reactor box, analogous to the containment, is also dimensioned to bear a LOCA event.

The V-213 design also has some deficiencies, e.g. practically no impacts of outside events such as earthquake, airplane crash, etc., had been taken into consideration.

At the time of site selection the current site was decided to be suitable, taking into consideration the historical seismic activity data: the seismic hazard was characterized by an intensity level of V (MSK-64) at an annual frequency of 10^{-3} and with these values no special seismic dimensioning was needed.

The recent probabilistic seismic hazard assessment calculations show that the safe shutdown earthquake with an annual probability of 1 in 10000 has an MSK intensity VIII with a peak horizontal acceleration of about 3.3 ms^{-2}.

As a consequence, a comprehensive seismic safety program has been started to determine the actual seismic strength of the plant and work out the necessary reconstructions. As the NPP in question is a plant in operation which is not designed for seismicity, we decided to use in parallel several methods for its qualification, decreasing by this the conservatism of analyses. Therefore, in parallel with the computational analyses of the reactor building, we also performed dynamic experiments. The present paper reports on these dynamic measurements, gives their results and presents a comparison of measuerd data with the computed ones.

2 DESCRIPTION OF MEASUREMENTS

2.1 Object of studies

The object of the studies was the reactor building and we intended to determine its primary dynamic characteristics, eigenfunctions and forms as well as damping to the extent allowed by the restrictions imposed by the measuring conditions. As the reactor building is located on a relatively loose ground, the soil-structure interaction cannot be neglected. Therefore, prior to giving a short description of the reactor building we quote the characteristics of the site itself.

2.1.1 Characteristics of site

The Paks NPP site is located in the central region of the Pannonian Basin. The ground level at the site is about 97 m above sea level. The region in the vicinity of Paks generally consists of wind-blown Loess deposits dating from the Pleistocene Age. The Danube has cut a wide flood plain through the Loess deposits into the Pannonian deposits. The flood plain consists of recent Holocene deposits. The deep boreholes beneath the Paks site show that the Pannonian deposits extend down to 600 meters. Below this is limestone dating from the Badenlain Age and then older rocks. The shallow borings show about 26-30 meters of alluvial silts, sands and gravels. Their density varies from loose to medium in the upper 12 meters, becoming dense below 16 meters. Below 26 meters there are very dense Pannonian silts and sands.

The relatively dense layer, with high propagation velocity of transversal waves, is covered by a loose layer with lower velocity of transversal waves. This gives the possibility for surface waves (Love) to be formed.

2.1.2 Description of reactor building

The Paks NPP consists of so-called twin units. The primary building of two units is located on a common monolith basement block of 2 m thickness. The main buildings are connected by two, in a symmetrical layout. The bottom of the base block is set at the elevation of -8.5 m. The twin units consist of a foundation of 145 m length, 52 m width and 18.9 m height, with a dilatation separation at the middle. On this foundation there are two condensing towers having a base surface of 42 x 24 m^2, and emerging up to 50 m elevation. The studied reactor building is a structure designed to bear a 2.5 bar pressure generated by a LOCA. Above the 18.9 m elevation there is a hall serving for reactor maintenance and reloading. The reactor building not only houses the process equipment of the first category but is also the third safety barrier in the way of radioactive materials. The floor and wall thicknesses vary from 0.6 to 1.5 m, complying with structural and radiation shielding demands. Besides the generally used standard concrete with a density of 2100 kg/m^3, here and there also heavy concrete of 3600 kg/m^3 is used for biological protection.

The overall volume of a building belonging to a unit amounts to 47,000 m^3.

On the eastern side there is a NW oriented gallery building of 12 m width and the turbine hall of 39 m span attached to the reactor building. Both are constructed of steel. On the southern side there is also a gallery building attached to the reactor building supported partly by reinforced concrete pillars and by the reactor building wall and oriented WE.

2.2 The methods of studies

The studies consisted of getting the buildings to move using distant explosion, with subsequent measuring of the acceleration response of the structure. By analysis of acceleration signals the characteristic eigenfrequencies and forms of the reactor building have been identified.

2.2.1 The excitation

The dynamic study of the buildings was performed with the help of a series of explosions generated far from the buildings, at a distance of 2.5-4.5 km. The maximum quantity of explosives blown at the same time amounted to 500 kg. The loads were located in 20 m deep boreholes, 50 kg in each. The form of the building is an elongated rectangle with the main axis oriented NW, therefore we made explosions in the directions of both axes, i.e. both east and south of the building.

The distances of explosion points and the masses of explosive were determined during a set of preliminary experiments. At the same time we had to take into account the allowed vibration speed limits for the buildings on site and in its neighborhood and the level of the reactor building response necessary for a reliable measurement. The results of these preliminary experiments showed more reasonable blowing up higher explosive quantities (500 kg) at higher distances (2-5km), because in this case the exciting signal contains the lower frequencies in the range of eigenfrequencies of the building.

After the preliminary measurements we carried out two series of experiments.

In the first series the points of explosion were located south of the plant at distances of 2.5 and 4.5 km. At 2.5 km the quantities of explosive amounted to 50, 100 and 200 kg, while at 4.5 km the quantities were 200 and 500 kg.

In the second series of experiments at the eastern point at 2 km distance one load of 100 kg and two loads of 300 kg, while at southern point at 2.6 km 2 loads of 450 kg were detonated.

2.2.2 Array of detectors

In the forementioned two series of experiments the location patterns of the acceleration sensors were slightly different.

In the first series the sensors were located at a number of points of the floors at the elevations of -6.50, 0.00, 18.90, 38 and 49.80 meters so that the form of motion of the floors could be identified. In addition, we had free field measuring points at 5 and 100 meters from the building, in the direction of the explosions.

The detector layout for the 2nd series of measurements is shown in Fig. 1.

At every measuring point triaxial sensors were used. In the free field boreholes the sensors were located at 0, -5, -10, -15 and -20 m depth in a dense sludge ensuring coupling to the ground. (Sorry to say, a significant number of these sensors were damaged during the experiments, and so the data are incomplete.)

During the test explosion and the first series it turned out that the sensors inside the building measured strong local vibrations; therefore for the subsequent explosions we put sensors only on the places representing the building motions. The detector positions F, G and H were located at the elevations -6.5 m, 18.9 m and 38 m, respectively; position P was on the top of the condensing tower at 48.9 m. The positions I, J, K and L monitored 4 points of a frame element of the steel structure of the turbine hall at the elevations -6.50, 18.90, 18.90 and 0.00 m, respectively.

The detector positions M, N and O were at elevations -3.60, 9.60 m and 19 m of the gallery building beside the reactor building.

2.2.3 Data acquisition

The signals of the accelerations sensors were recorded at every sensing point in the frequency range of 0.2-33 Hz by a local digital data acquisition system. The data were sent to a central data acquisition system (IBM286PC) through optical cables.

The explosions time signal triggered the data acquisition process so that the correct phase of signals coming from different measuring places was ensured.

2.3 The measuring process

The explosions of higher quantity explosives were always preceded by trial explosions of minor quantities (100 kg). These were intended to convince us that the explosions would not do any harm, and to demonstrate the same to the authorities. On the other hand, we had to determine the expected vibration amplitudes for setting the measuring equipment ranges.

3 RESULTS OF MEASUREMENTS

Fig. 2 shows the x component of the acceleration time signal measured in the free field at measuring position 3A with an explosion in the eastern direction. The outer excitation acceleration time signal has characteristic sections.

The first section can be identified as the arrival of the longitudinal wave having a relatively high frequency content (8-13Hz). Its propagation velocity determined by time of arrival is 1900 m/s. The velocity of the surface wave package arriving a little later is in the range 270-380 m/s depending on the frequency showing the characteristic dispersion of surface waves.

The response measured in the building follows the peculiarities of the excitation as it can be seen in Fig. 3 showing the response time signal measured on the top of the condensing tower at position 5P.

3.2 Short time interval spectra

The time evolution of the frequency content of the excitation was also analyzed using the frequency spectra formed from short sections of the measured acceleration signal. The short range spectra were made on records of a length of 1.28 s using Hannings window. The window was moved along the time axis with a spacing of 0.25 s. Fig. 4 shows the section beginning at 4 s of the processed time signal measured at the free-field position 2A. One can clearly see the arrival of different phases of the exciting waves.

3.3 Evaluation of results

3.3.1 Free field

Fig. 5 shows the PSD of the acceleration signal measured at the free field position 2A after an southern explosion. As it can be seen, the excitation signal is characterized by several well separated lines between 1.8 and 4.3 Hz such as e.g. that of 2.0, 2.3-2.4, 2.5-2.6, 2.83, 3.0, 4.1 - 4.3 Hz.

The longitudinal and transversal waves did not excite the lowest eigenfrequencies of the building but after their decrease the excitation effect of the subsequent surface waves could be measured. The frequencies measured in the free field are very close to the lowest eigenfrequencies of the building, but they are not identical.

The acceleration response spectra at point 3A due to explosion in south direction are presented in Fig. 6. They were obtained considering the measured time histories up 6 seconds eliminating partially the high frequency content of the excitation.

3.3.2 Structure

The acceleration response of the structure was measured at the positions indicated in Fig. 1. The predominant frequencies of the reactor building obtained from the tests are 1.9 - 2.1, 2.25, 2.45 Hz and they match very well with the analytical results (2.12, 2.38 Hz). For the reactor hall the experimental and analytical frequencies compare also satisfactory (1.6-1.9 and 1.84 Hz respectively). Near frequencies were obtained for the turbine hall and for the galleries. The response spectra obtained from the measured time histories and calculated using a complete 3D finite element model including the soil-structure interaction are plotted for some points (Fig. 7). The finite element model was excited using the measured free field acceleration time histories. The comparison of the structural responses obtained using both methodologies is satisfactory.

3.4 Determination of damping

Using the trailing edge of the acceleration function measured on the reactor building the global damping value characterizing the current state can be determined provided that the building after excitation is supposed to be a freely vibrating system. This damping can be evaluated by fitting the expression

$$a(t)=c_4\exp(-c_1 t)\ \sin\ (c_2 t+c_3)+c_5$$

to the trailing edge of the low frequency vibrations. The damping can be defined as the ratio

$$\beta = c_1/c_2$$

This approximation is quite acceptable because in the decaying section the time signal is shaped out practically in all cases by a single predominant frequency.

The following values have been derived:

	For excitations from East		South		
	X	Y	X	Y	Z
Reactor building					
Pos.4G	6.9%	-		9.1%	10.1%
Pos.4H	7.5%	6.8%		8.7%	5.5%
Pos.5P	10.0%	7.7%	11.8%	10.4%	6.4%
Turbine hall					
Pos.4K	6.4%	-	9.8%	9.4%	8.1%
Gallery building					
Pos.50	6.1%	9.4%	8.4%	9.2%	14.8%

According to expectations, the values show some uncertainties. Both the values and the high dispersion are due to the very weak excitation.

Damping is strongly dependent from soil strain and consequently in case of earthquake higher damping ratios are expected. In the case of explosion excitation the amplitudes can be detected only by instruments, so the damping values determined this way can be much less than those for an earthquake. The determined values can be taken as lower limits especially because the structure vibrating at its trailing edge is still subject to excitation, so that the decay is more prolonged than that for a freely oscillating system. Thus, for the calculations these values are low limits only.

4 CONCLUSIONS

A good approximation between the natural frequencies (determined experimentally and analytically) were verified.

Damping ratios are a function of the deformation and for this reason the experimental values must be corrected in case of real earthquake. The comparison between the response spectra obtained using both approaches is reasonable. The experimental investigation here developed validates the analytical/numerical dynamic calculation of the PAKS NPP.

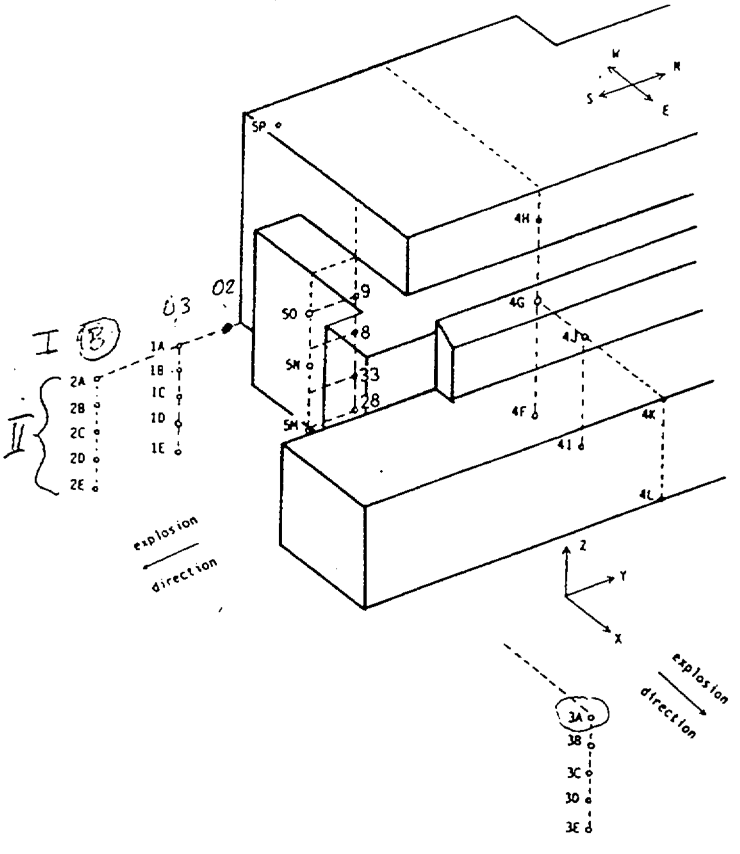

Figure 1. PAKS NPP site. Explosion and measuring point positions.

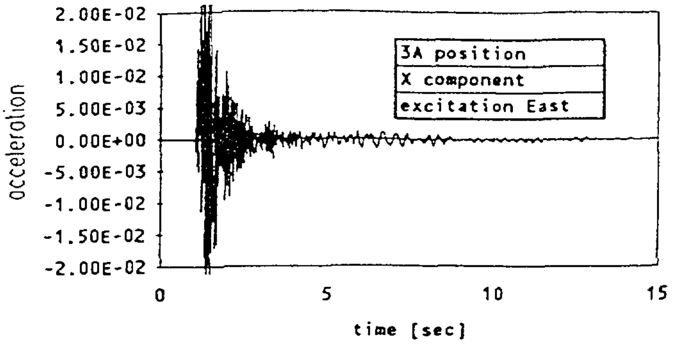

Figure 2. Free-field acceleration signal measured at point 3A.

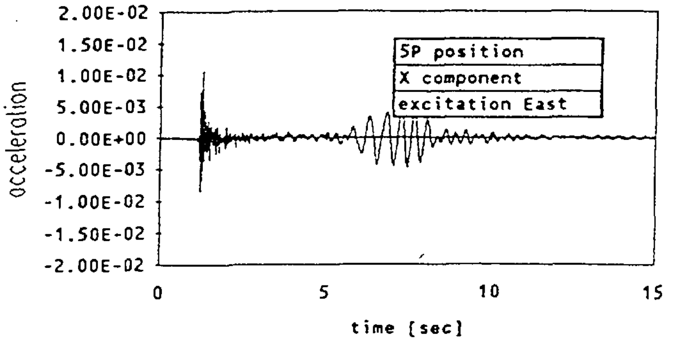

Figure 3. Acceleration response signal measured at point 5P.

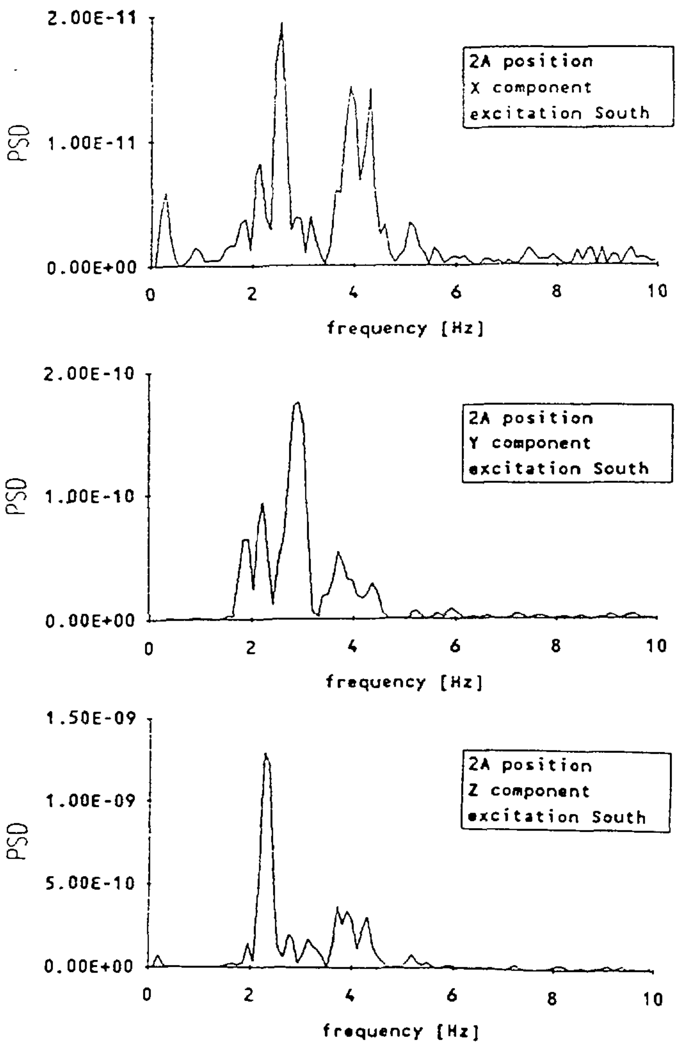

Figure 5. PSD of the free-field acceleration measured at point 2A, excitation "south"

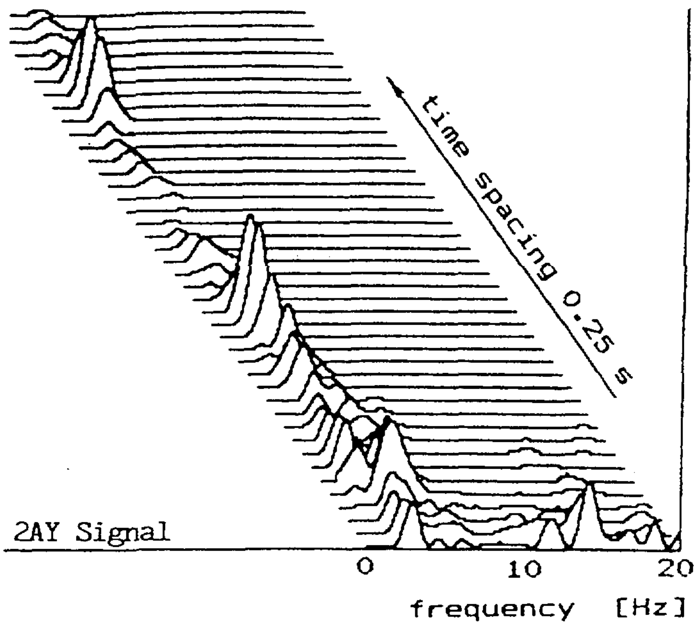

Figure 4. Short time PSD of the 2A signal

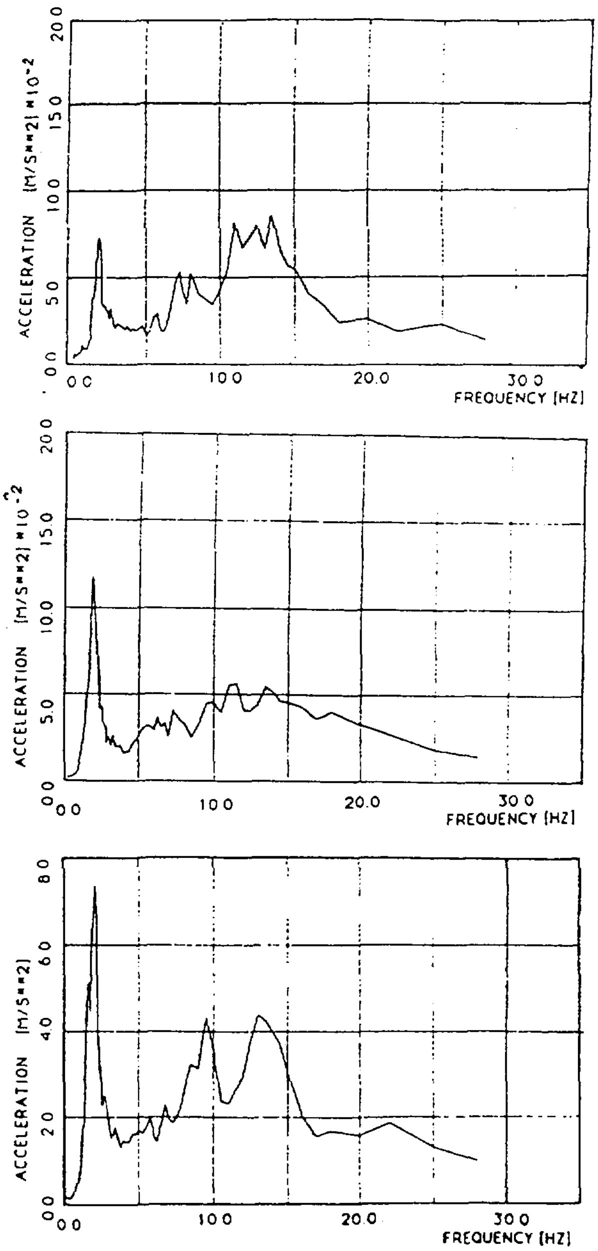

Figure 6. Response spectra of the free-field acceleration signal at point 2A/I excitation "south" (500 kg)

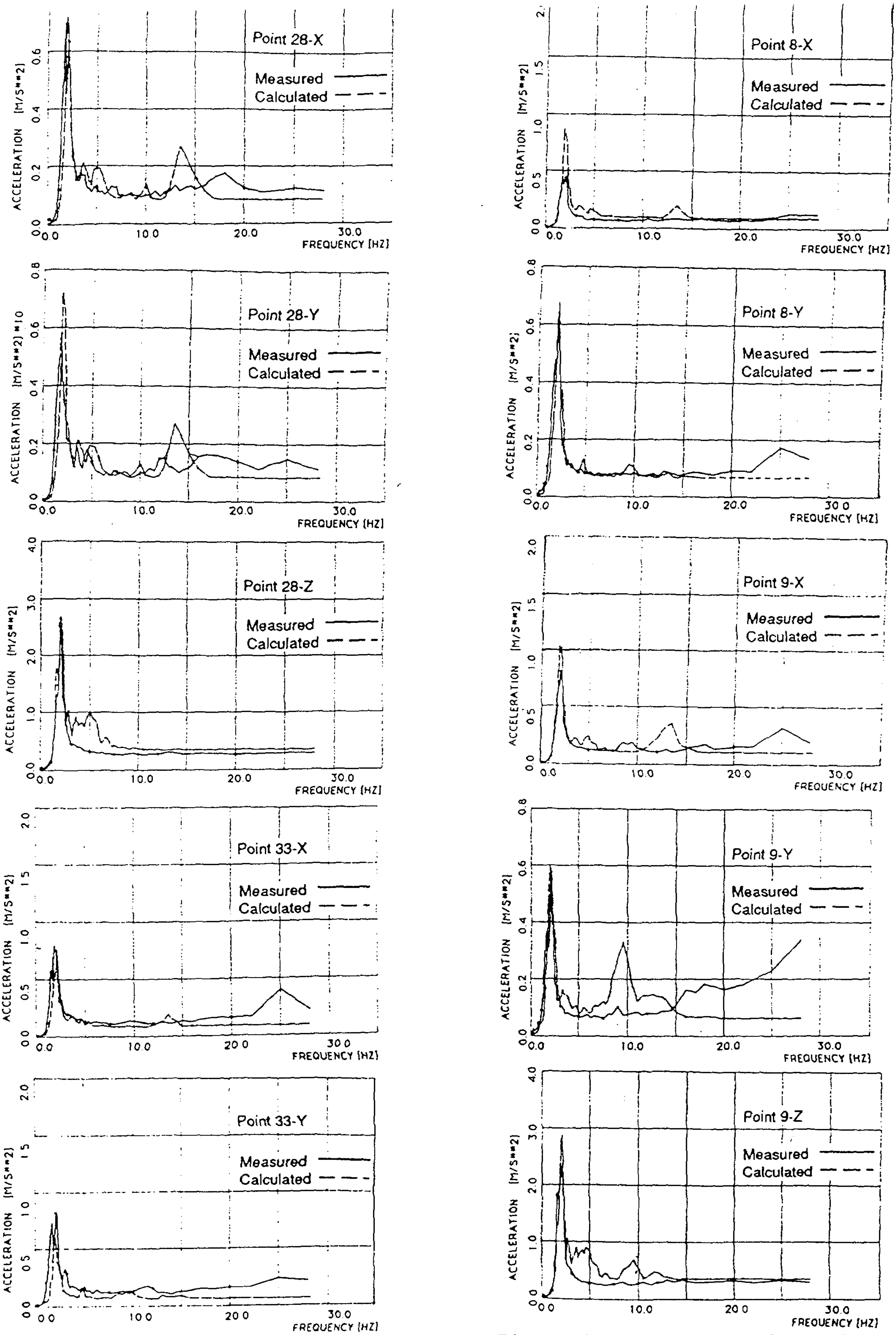

Figure 7 Comparison of FRS (D=2 %)

Title: Seismic Safety of Paks Nuclear Power Plant

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Date: May 1993

Paks Nuclear Power Plant Ltd

SEISMIC SAFETY OF PAKS NUCLEAR POWER PLANT

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MAY, 1993

1. Introduction

At the present time there is an extensive program underway for the evaluation of the seismic safety of Paks Nuclear Power Plant, and for development of the necessary safety increasing measures. This program until now included five main activities:

- investigation of methods, regulations and technics utilized for reassessment of seismic safety of operating nuclear power plants and promoting upgrading of safety;

- investigation of earthquake hazard;

- development of concept for creation of the seismic safety location of earthquake warning system; and

- determination of dynamic features of systems and facilities determined by the concept, and - casually

- preliminary evaluation of the seismic safety.

In the present summary an overview of the results of the above activities is given. Having on mind the preliminary character of the performed investigations, and the activities to be performed in 1993, in the present material we limit on summary of investigation of dynamic features of building structures, the building dynamical experiments and experimental investigation of the equipment. The evaluation of the technological systems, among them that of the reactor and the primary circuit is anticipated to be finished in 1993.

2. The basis of the realization of seismic safety

The competent earthquake, characteristic for the site, the safety requirements and the methods, criteria of evaluation of suitability make the basis of earthquakeproof design, and that is at the same time the basis of the reassessment of the seismic safety of the operating power plant as well.

Having on mind that at the present time there are no Hungarian standards or regulations for this area, in the domestic practice the recommendations of the International Atomic Energy Agency (IAEA) (50-C-S [9], 50-SG-S1 [10], 50-SG-D15 [11]) and regulations of certain countries (USA, Japan, Germany) are considered as competent ones. Furthermore, it is taken into consideration that during the revision of the Hungarian Nuclear Power Plant Safety Regulations, the regulation of questions of the seismic safety was done with utilization of Finnish requirement YVL 2.6. [12]

3. Design seismic safety of Paks Nuclear Power Plant

In documents of the nuclear power plant there is - usually - only a stereotype sentence saying that "the design was made according to valid Soviet norms and procedures", indicating the requirements, which were followed during the design. For that reason the evaluation of the design is problematic, having on mind that the designer has followed beyond published requirements and standards a number of internal regulations as well.

According to item 3.1.11. of the valid at the time of the design Soviet regulation PBJA-04-74 "Safety Rules of Nuclear Power Plants" [20] the systems necessary for assurance of nuclear safety were to be designed for loads caused earthquakes, according to the valid regulations. During the design the SNiP (for e.g. SNiP II-21-75 [21], SNiP II-15-74 [22]) was in force for design of building structures; for technological equipment the norms published in literature e.g. in [23], and for experimental investigation and qualification of equipment and installation the GOST 16962-71 [24]. In 1978 a document titled VSN-15-78 "Preliminary norms for design of nuclear power plants for seismic sites" was published. After that the design was made taking into consideration the seismic risk of the site, but in case of certain started projects it was neglected. During eighties a Soviet regulation complying with the Western practice was established in question of seismic safety, proved by literature [27-33]. Anyhow the development of the regulation influenced the V-213 model of VVER-440s, so the Paks Nuclear Power Plant as well.

The definition of the design base earthquake in not given in the presently available official documents (Technical Design, PSAR), probably the maximum earthquake anticipated in 10.000 years period should be considered as competent one.

According to Technical Design Vol.IX. [7] "The seismicity of the construction site of Paks Nuclear Power Plant is 5 degrees according to MSK-64 scale. The consideration of seismic influences is performed in accordance with the valid norms and rules."

In the PSARs, there is information given concerning the applied norms and rules, so for example according to PSAR of unit 1. [8], in the design, on the basis of the above mentioned base value "the requirements of regulation SNiP-II-A12-69 were taken into account", which - citing the PSAR - prescribes, that "sizing of the civil engineering structures for seismic impacts should be performed in the case if the seismicity of the given site is not less than 7 ball. So - in accordance with the approved technical design - neither the construction design contained measures for increase of seismic safety of the nuclear power plant equipment and structures."

From the above written derives that according to the general civil engineering strength norms applied during the design the dynamical impacts of earthquakes of less than 7 degree intensity could have been neglected when taking into account the constant and additional loads (within the applied safety factors). Concerning the sizing of the technological equipment there are no references to standards neither in the Technical Design Vol.IX., neither in PSAR.

So, according to the design

- the safety of the power plant is guaranteed in case of earthquakes of degree 5 intensity;

- the safety of the civil engineering structures of the power plant (above all the main building) is anticipated in case of earthquakes with intensity not more than 6 degrees.

In case of objective evaluation of the seismic safety it is more practical to take into account not the intensity but the value of the maximum horizontal acceleration. According to the latest investigations on the site of Paks Nuclear Power Plant an earthquake of 6.2 intensity degree according to MSK-64 scale - due to local effects - corresponds a maximum horizontal acceleration of 0.06 g [34]. However, it would be misleading to rely on actual data related to the site, but the valid in the Soviet Union at time of Technical Design norms are to be taken into account, on which the cited SNiP was based. According to GOST 6249-52 [35] a 0.0122-0.0155 g maximum horizontal acceleration interval belongs to 5 degree intensity. To 7 degree, mentioned in PSAR as limit value, a 0.051 maximum horizontal acceleration value can be corresponded, which is the upper limit of the acceleration interval of the 6 degree intensity.

The formal statements cited from the documents of the power plant do not characterize the real seismic safety neither the V-213 model, nor the Paks Nuclear Power Plant. The real seismic safety, which can be considered as significant due to built-in strength margins, can be determined only by detailed reassessment.

4. Basic principles of realization of seismic safety upgrading

The seismic safety upgrading has to be based on the following facts of negative influence:

- actually the power plant has not been sized for dynamical impacts, caused by earthquakes, the equipment, components were not seismicly qualified by the suppliers, today it is practically impossible to obtain such qualifications from the (former Soviet) suppliers;

- according to the present judgment the maximum horizontal acceleration of the characteristic for the site SL-2 earthquake is about ten times higher than the supposed at the time of the design;

- the maximum horizontal acceleration value of the SL-1 earthquake is once again much higher than the value given in the design.

On the other hand the preliminary investigations performed since 1987 indicate that the main building and the important from point of view of safety main equipment and pipelines have considerable strength margins. This fact is supported indirectly by safety analysis of VVER units performed upon request of the USA government [36].

Due to above described facts the following basic principles might be established:

- The power plant should be made safe for the maximum design base earthquake, the SL-2 level.

- The safety requirements for the case of SL-2 earthquakes can be only met if the number of systems, equipment necessary for assurance of seismic safety will be minimized.

- With reasonable from technical economical point of view efforts the continuous operation of power plant cannot be assured in case of earthquake of much higher intensity, then earthquake of 5 degree intensity indicated in the Technical design, neither can be guaranteed the restart of the power plant after an earthquake, less than the maximum designed one.

During creation of seismic safety the following items are to be taken into consideration:

- the earthquake cannot result a pipeline break in the primary circuit, the primary circuit should be enforced accordingly;

- no offsite electrical source is available.

During reassessment of the seismic capacity and planning the safety upgrading measures such methods are to be used which take into consideration the characteristic features and limit of modifications of an operating nuclear power plant.

Due to lack of domestic regulations the suitability of the basic principles is proved by their comparison with the international practice.

5. Concept the seismic safety

In the case if we would use the "normal" technology for cooling-down, borating and long term cooling, then due to high number of the equipment and pipelines to be reinforced the seismic safety would be - within reasonable limits - unachievable. According to that a special procedure is to be developed for shut down of the reactor, borating and cooling down as well, as for long term cooling and the preservation of leaktightness of volumes containing high activity media as well as for liquidation of consequential damages caused by the earthquake.

The concept of the seismic safety of the power plant determines this procedure, which is summarized in the followings:

5.1 Seismic protection system for shut-down of the reactor

Such a system should be installed to each unit, which provokes a protection functions in the case if on competent points of the main building (on the base plate) the measured acceleration signal in beyond a determined value. The seismic protection system should from point of view of number of channels, logics, redundancy and reliability comply with the existing unit protection system. This protection should be, on the basis of experience gained in manual operational mode, of automatic operation.

5.2 Borating, cooling down and long term cooling of the reactor

It is supposed that prior the earthquake the units are operated at nominal power according to the valid operational procedures. The diesel generators, and the active and passive systems of emergency core cooling system (ECCS) are in stand-by condition.

At exceeding the adjusted acceleration limit value an "Earthquake signal will be sent to emergency protection of the reactor. The SCRAM signal generated by the earthquake protection system will shut down the reactor. An impulse signal will be given to shut down the turbogenerator unit as well. Simultaneously the diesel generators will be started and the post earthquake step-by-step start-up program initiated.

After the run of the protection programs the unit will be in hot stabile condition.

The compensation of the volume caused by borating and cooling down will be done by the operator by high pressure ECCS pumps (TH10, 20, 30D001).

The cooling down of the reactor might be divided into the following phases:

First phase - Cooling down to approx. 130C of primary temperature:

- regulated steam blow-down via safety valves of steam generators;

- the water level in steam generators is assured by emergency feed water pumps (UTSZ, KUTSZ);

- the decrease of the primary circuit pressure is done by steam blow-down from the pressurizer to bubbling tanks via the blow-down line (YP12).

Second phase - Cooling down to primary circuit temperature of 60-70C.

- decrease of primary circuit pressure to value of 0.4 MPa;

- starting of the low pressure ECCS system, along with the new primary circuit cooling system to be established (cooling of the primary coolant through ECCS heat exchangers)

Keeping cool:

- continuous circulation of the primary coolant by low pressure ECCS pumps through the ECCS heat exchangers, in order to assure the cooling of the active core.

The limits of the above described technology determine the circle of the systems, equipment assured for maximum design earthquake. Safe disconnection should be established at the so determined system border by the existing or newly installed quick valves that close upon earthquake signal.

The adequate electric power supply of consumers defined in the seismic safety concept should be assured. According to that the system of the safety electric power supply system should be made earthquakeresistent.

The measurement and I&C conditions necessary for shut-down of the reactor, its monitoring and cooling technologies are to assured. The so determined measurement and I&C systems are to be made earthquakeproof.

The leaktightness of those volumes (systems, tanks, pits) should be preserved, the damage of which during an earthquake would increase the risk of releases to the environment or hamper the safe post-earthquake management of the power plant. The safe disconnection of the significant volumes containing radioactive media from the non-earthquakeproof environment should be solved by newly installed or the adequate existing quick valves.

An organic part of the seismic safety concept is the analyze of the effects caused by an earthquake, not belonging to the area of nuclear safety, but significantly influencing the post-earthquake situation (fires, floods). Here belongs also the sufficient completition of the Emergency Preparedness Plan, and review of the infrastructure requirements of the post-earthquake emergency management. This part of the concept has not yet been prepared.

5.3 Classification of structures and systems

From the point of view of the safety target defined in the previous chapter should the buildings and technological systems be classified. In this subject we do not follow strictly the IAEA's classification system, but keep more to the Finnish regulation, which is more suitable from practical point of view.

To the I. category are enrolled those systems the error of itself could provoke accident by itself, and those systems which during or after the earthquakes should remain in operation or in stand-by mode according to the seismic concept.

To the II. category belong those systems the structural integrity and leaktightness of which is necessary for preservation of the nuclear safety and do not belong to the I. category. Such is for example the liquid, solid and gaseous waste system, etc.

To the III. category are enrolled all the remaining systems and equipment.

The buildings belonging to the I. category are those facilities which incorporate the systems and equipment of first category from point of view of safety, and act simultaneously as hermetic border to the environment. Such are for example the reactor building and a part of the auxiliary building.

To the II. category belong those buildings which contain important from safety point of view, first category equipment, but do not have any other functions. Such are the diesel machine hall, the water pump station, the pipeline corridor of the contaminated liquids, the galleries with the control rooms and the communication lines.

To the third category belong all the remaining buildings, including the turbine hall.

Those buildings or equipment the damage of which might cause the damage of a higher category system, are enrolled to the given higher category.

6. Method of the reassessment

During the afterwards evaluation and establishment of the seismic safety of the Paks Nuclear Power Plant the practice used during design of new power plants cannot be strictly followed. The method and criteria of the seismic safety reassessment should be determined taking into account the characteristic features of the operating nuclear power plant.

6.1. Analysis

There were extensive investigations performed in field of the reassessment of seismic safety of operating nuclear power plants during the past two decades, primarily in the USA upon initiative of the NRC. On the basis of the established methods the reassessment of the seismic capacity of the operating nuclear power plants can be performed by three approaches: according to deterministic design procedure and standards, by seismic margin assessment (SMA), or by seismic PSA.

An object-lesson of the seismic PSA was the investigation performed on Zion unit 1. [31]. The PSA gives an answer to the question what is the probability of the core-melting following of an earthquake and which are - from the point of view of core-melting - most sensitive parts of the power plant, but the PSA does not replace the design information, which is totally lacking in case of the Paks Nuclear Power Plant, and at the same time is absolutely necessary for the planning of the safety upgrading measures.

Due to the above written during the seismic safety reassessment of the Paks Nuclear Power Plant the deterministic design procedure and the SMA method is going to be followed.

The SMA investigation method seeks for answer if the given nuclear power plant is capable to stand with sufficient safety an extreme earthquake - which is beyond the SL-2 level considered during the design phase - a so called control or new SL-2 level earthquake.

The seismic margins (SM) determined for structures, systems are to be interpreted according to the High Confidence of Low Probability of Failure (HCLPF) concept. The HCLPF seismic margin is a conservatively determined margin, in case of which is known with 96% precision that the probability of the failure does not exceed 5%.

The HCLPF seismic margins will be determined by Conservative Deterministic Failure Margin (CDFM) method. The CDFM method is practically the utilization of the design procedures and standards, but is in some cases - taking into account the specific features of an operating nuclear power plant - in certain way more liberal [38,39].

Some principal elements of the CDFM method are summarized below:

- The input free surface response spectrum should be given for 84% probability, that is for 16% risk level.

- The control earthquake level (SL-2) should be combined with L1, normal mode loads and all the loads should be taken into consideration with single safety factor. (Only the containment is a certain exclusion).

- The damping values are practical to be recorded according to NUREG/CR-0098 [40]. The calculation of the soil-stucture interaction should be performed with average parameters. In case of the floor response determination the response spectrum should be created by the frequency shifting method.

- The determination of the HCLPF capacity of the equipment, components should be done according to the failure mode of the which is determined experimentally, by expert's examination and judgment.

- In case of determination of seismic capacity the ductility can be taken into account. The determination of the capacity generally can be done by limit loadability, since the occurrence of loads exceeding the loads and load combinations used during the reassessment has extremely low probability. In case of concrete, reinforced concrete structures the ACI 318-83 [44] or ACI 349-85 [45] standards are applicable. In case of steel structures the AISC -Plastic Design [46] can be applied, especially in case of platform structures and fixing elements of equipment. Investigation of pressure vessels, pump cases, tanks, pipelines should be performed according to ASME BPVC Section III, Division 1. [15], Service Level D for all non-functional failure mode. In case of linear analysis the seismic response can be decreased by kD ductility factor in case of every non rupture failure mode. Knowing the allowed ductility for each equipment class the kD factor can be calculated according to [47].

6.2 Experimental method

The determination of the suitability of the equipment, especially ascertainment of their operability can be done by experimental way for example according to regulations [11], [16] and [17]. Rules for determination of HCLPF capacity are in papers [38-39].

In case of qualification of seismic capacity of the Paks Nuclear Power Plant the experimental method can be used in a limited way in those cases where there is a possibility for a shaking-table test of the spare equipment, or in cases in which the domestic low capacity experimental equipment are suitable.

The full-scale building dynamical experiments make up a separate category of the experiments, aiming the modeling of the building structures and checking of the calculated dynamical features.

6.3 Utilization of experiences of earthquakes

The Seismic Qualification Utility Group (SQUG) in the USA has developed a procedure, the Generic Implementation Procedure (GIP), by which the experiences gained during real earthquakes can be utilized at qualification of equipment of operating nuclear power plants [48]. Taking into account that there are certain limits of afterwards qualification of the equipment of operating nuclear power plants it essentially necessary to use the GIP method, and/or database. This utilization requires solution of specific problems, as the experience of behavior of the equipment of Western origin during earthquakes should be transferred to Soviet made nuclear power plant equipment.

The reassessment method and system of criteria discussed in here in general are described in detail in document [49].

7. Evaluation of seismic capacity of nuclear power plant buildings

In the performed until now, preparationally phase of the seismic safety program the investigation of the buildings was in the concentrated at. The selection of the important from the point of view of safety buildings in case of the Paks Nuclear Power Plant was rather unambiguous, can practically be considered independent from realization of the seismic safety concept, as - though according to different criteria - all the operational building are subjects of investigation. According to item 5.3. to the I. category belong the reactor main building, to the II. category the auxiliary buildings, the diesel machine halls, the water pump station, bridges and tunnels connecting the main building and the auxiliary buildings and the ventilation stocks, the longitudinal and crossing galleries etc. To the III. category belong all the other buildings, including the turbine hall, though this later is specifically built together with the longitudinal galleries and the main building and accordingly represents a common with the main building analytical unit.

The analysis of the seismic capacity of the Paks Nuclear Power Plant practically has started in 1987 by investigation of the main building. At that time the Mechanical Department of the Civil Engineering Faculty of the Budapest Technical University prepared a two dimension finitive element model for the main building, and the calculation performed with this model indicated that the main building is totally capable to withstand an earthquake, that can be characterized by 0.15 g maximum horizontal acceleration. The two dimension model has undergone further development during the recent years and was completed with an also two dimension soil model for investigation of the soil-stucture interactions. With that updated model preliminary estimation was made for 0.28 g maximum horizontal ground acceleration, that turned out to be critical from the point of view of the steel structures of the reactor hall. The two dimension model has been compared with the two dimension models of the V-2 units of the Bohunice Nuclear Power Plant. The two models show some different dynamical features, first of all concerning behavior of the localization towers. Already the early explosion stucture dynamical experiments have pointed out that the three dimension models are more suitable for the description of the behavior of the main building of V-213 VVER-440, so all the further calculations were performed in case of all the buildings by three dimension finitive element models. In the followings, when giving the results the early two dimension calculations will not be included, though they are considered as useful preliminary studies.

The seismic capacity investigations of the buildings were performed according to the deterministic design procedure. The analysis of the buildings in the future will be performed both by CDFM method and by design procedure.

Lacking site specific data that could be considered ultimate 0.3 g free surface maximum horizontal acceleration was used as seismic input and corresponding to it standard response spectrum according to US NRC Regulatory Guide 1.60 [50].

7.1 Analysis of the main building

The calculation was performed by SIEMENS by so called time-domain procedure, in accordance with regulations KTA 2201.3.

The input of the calculation was a syntethized acceleration time-function corresponding to response spectrum according to US NRC Regulatory Guide 1.60. The excitement acted simultaneously in N-S, E-W and vertical directions in non-correlated with each other way, the vertical value was two third of the horizontal value.

The three dimension finitive element model of the structure is made of shell and rod elements. Due to structural connections the calculation includes the longitudinal and cross galleries and the turbine hall.In the 3D model the soil-stucture interaction is represented by springs and concentrated absorbing elements, which effect the points of junction of the base plate. The equivalent frequency independent spring constants and absorbtions were determined by calculation of impedance function related to rigid basis.

During calculation the handling of nonlinearity caused by deformation dependence of the share modulus of the soil was made by iterative technics.

In the case of deep founded reactor main building the calculation was performed by excitement related to the embedding depth, which was determined by de convolution of the free surface excitement.

On the basis of the performed calculations it can be stated, that low natural frequency is characteristic for the main building, the horizontal movements of the reinforced concrete part of the reactor building can be characterized by 2.12 Hz and 2.38 Hz modulus, while the vertical movements by 4.16 Hz modulus. The characteristic lower natural frequency of the steel structures of the halls is 1.8 Hz. 95% of the modal mass of the main building is for natural frequency below 19 Hz.

On the basis of the acceleration response of the building floor response spectrums were determined by peak shifting (according to the share modulus of the soil) and by widening and lining technics according to US NRC Regulatory Guide 1.222. The strength analysis of the main building on the basis of dynamical calculation performed with the above finitive element model will be done during 1993. Further details about the calculations can be found in literature [52-53].

7.2 Analysis of the second category buildings

For the investigation of the second category buildings time-history and response spectrum method was used, the description of which can be found for example in standard ASCE 4-86 [41]. As an input for strength control calculations by response spectrum method the standard response spectrum of the US NRC Regulatory Guide 1.60 [50] was taken with 7% damping, recalculated for 0.3 g free surface maximum horizontal acceleration value. The excitement acted simultaneously in N-S, E-W and vertical directions, the vertical value was two third of the horizontal value.

The generation of the floor response spectrums was made on the basis of acceleration created by direct integral method. Using the procedure and program, according to [54], meeting the requirements of standard ASCE 4-86 10 horizontal and 10 vertical time-signals were synthetized. From those three x, y, z sets were selected as inputs of the calculation. The investigation of allowed by a number of standards (see e.g. YVL 2.6.[12]) two effect combinations: the horizontal and vertical acceleration component pair operate to one and then to other structurally characteristic direction. Our calculation was performed by the strictly more conservative three direction simultaneous excitement.

The input modifying effect of the building embedding was neglected, that also increases the conservatism of the calculation. The ground-stucture interaction was taken into account with equivalent springs, that was modeled in the calculations by spring elements. One end of the spring is entrapped in a fixed way and the other end is connected to the base plate of the building at the junction points. The springs prevent the shifting and the convolution. The determination of the spring constants was made by infinitive semisphere model used for interactions. From the determined vertical and horizontal embedding factors were characteristic for the given stucture spring rigidities selected. The radiation damping caused by soil-stucture interaction was neglected, what can be considered as a very serious conservatism.

The base plates, ceiling plates and walls of the buildings were made from thick and thin shell elements (SHELL4T elements), the steel beams and wind braces from beam elements (BEAM3D elements), the connection of the soil and building is represented by the already mentioned spring elements. In the dynamical model the masses corresponding to the loads are modeled by MASS elements. For the concrete and structural materials material parameters of the standards corresponding to their qualities were used. The damping was considered according to SL-2 level of the KTA, so for example for the damping of the reinforced concrete structures it is 7%. During the analysis beside the seismic effect the constant loads are to be taken into account, that made of the dead weight of the structure, the static loads, as the weights of the equipment, and in certain cases other prescribed loads. According to the relating Hungarian (non nuclear) requirements in case of extraordinary loads the meteorological loads should not be taken in consideration (MI-04.133-81). The in-stucture cranes were taken into consideration on their parking places, out of operation. In the case of the water pump station the water loads were taken into consideration at an average level. On the servicing levels the working loads were considered according to the Hungarian Standards (MSZ) as 2 kPa. According to the mechanical model four calculation models were created: G mark, dead weight type, K mark, additional dead weight type, T mark, static from technological loads, and E mark, dynamic model. The geometry of the four models is identical, the junction point and element distribution, the geometrical sizes of the elements, the boundary conditions are the same, but the loads are different, and in the case of the dynamic model there are mass elements replacing the loading and in certain cases the substructure.

With the exclusion of the diesel machine halls for the investigation of the buildings was performed by COSMOS/M finitive element program-package, version running of 1.62 IBM PC AT386. During the preliminary strength analysis the ductility of the structures was not taken into account, exclusion were the diesel machine halls, in case of which in one of the calculation versions the calculation was performed with input decreased by ductility as well.

During the calculations the followings were defined:

- natural frequencies of the buildings and the corresponding characteristic form,

- displacements and stresses in cases of given input response spectrums,

- the building's response for synthetized accelerograms, floor response spectrums on the basis of acceleration response, which were generated by 2, 5, 7 and 10% damping according to the regulations of the US NRC 1.122 Regulatory Guide.

By evaluation of the stresses calculated by response spectrum method the determination of the suitability of the stability and strength of the buildings was performed according to the corresponding 1520 series Hungarian Standard and Technical Principles.

The results related to each building are summarized below (see more [55-56]).

7.2.1 Auxiliary buildings

Auxiliary buildings of not identical structure were erected during the two construction phases of the Paks Nuclear Power Plant. The reinforced concrete structure of the auxiliary building of the first phase is divided by dilatation, while in the case of the second phase the reinforced concrete infrastucture makes one structure. In case auxiliary building of the first construction phase the southern, the hall and the northern low building parts were modeled separately due to dilatation (models S1A and S1B), while in the case of the second phase one finitive element model was prepared for the whole building.

The dynamical behavior of the structures can be characterized by very low natural frequencies. In case of both buildings the lowest natural frequency of the steel structure is 1.3 Hz, and 2 Hz, but the reinforced concrete infrastructure itself too is capable for low frequency movements, even the hundredth eigenfrequency is below 20 Hz.

According to the preliminary strength evaluation on the hall part of the auxiliary building of the first construction phase among the reinforced concrete ceilings those on the level + 10.10 m and + 17.90 m level will be demolished for sure. From the reinforced concrete walls the outer ones on 0.0 m level are not suitable for shearing. Neither are suitable the outer walls between levels - 1.80 m and +10.10 m, the staircase outer walls, the walls on level + 12.00 m and some walls on level +24.00 m. At the same building from the reinforced concrete ceilings of the northern building part the middle one are not suitable for shearing on level +10.10 m. From the reinforced concrete walls the loads of the outer ones seem to be extreme, the calculations should be checked, but anyhow it can be stated with great certainty that the walls will be demolished. The strength evaluation of the steel structures is going on.

In the auxiliary building of the second construction phase only the pre-fabricated TT panel ceilings on +18.60 m level will crash. From the reinforced concrete wall those at x=0.0 m and x=-3.50 m will be demolished.

7.2.2 Ventilation twin-stocks

For the ventilation stocks, like for all the other buildings low frequency natural oscillations are characteristic, the first 100 natural frequency is in the interval of 3-52 Hz.

The elements of the 100 m high twin stock are not adequate with the exclusion of some elements. In the stock body itself and in

the connecting walls the competent stresses will be some fifty times higher the limit loadibility, the higher level is investigated the
higher is the over-load value. On the basis of the unambiguously can be stated that the stock will collapse.

7.2.3 Connecting tunnel

Certain wall and ceiling connections of the tube tunnel connecting the main building and the auxiliary building, the ends of the tunnel, the pit, and the section under the rails are not suitable from strength point of view, but this fact will probably not prevent the usability of the tunnel. Further analysis are needed.

7.2.4 Connecting bridges

The dynamical calculations were completed, but additional information concerning the differential movements of the main building, stocks and auxiliary building is needed for evaluation of the seismic capacity, as with great probability the bridges might fall down due to move off of the elonging supports.

7.2.5 Water pump station

The model and the dynamical calculations are completed. The strength evaluation is going on. According to the preliminary results local damages might be at one wall connection and in case of two plates.

7.2.6 Diesel machine halls

The calculation of the building was performed on the basis of practically applicable for spatial rod-structure calculation theory of finitive rods with the software of the Mechanical Department of the Civil Engineering Faculty of Budapest Technical University.

The diesel machine hall of the first construction phase is nearly symmetrical and of repeating load bearing structure and for that reason only one tract was taken into consideration in the calculation. Within that separate models were made for independent from static point of view structural parts (models mark A and B). In those spatial rod structure models the monolithic reinforced concrete walls - ceilings - as elastic discs, plates were transformed into equivalent rods and so were integrated into the spatial rod structure.

The load bearing structures of the diesel machine hall of the second construction phase were made of pre-fabricated reinforced concrete elements. The modeling of the building was done in a way similar to the method used in case of 1-2 diesel buildings, but transformed in one model.

Below some natural frequencies are given, characteristic for the dynamical behavior of the different buildings (values are given in Hz):

No.	I. const. phase Model A	I. const phase Model B	II. const phase
1	0.69	3.86	4.46
2	3.94	4.96	8.43
3	4.31	6.97	8.61
10	13.52	29.86	22.62

The checking of the loadibility of the reinforced concrete cross-sections of the diesel machine hall of the first construction phase was performed on the basis of MSZ 15022/1-86. The calculations indicated that columns do not have the required by the corresponding standards adequate safety against stresses caused by the given earthquake, but there is a chance to reinforce the structure with relatively simple tools. Calculations were performed for the diesel machine hall of the first construction phase on the basis of input response spectrums decreased by ductility. Those calculations resulted much more favorable availability, what indicates that within the given building category it is by all means practical to make use of ductility.

The diesel machine hall of the second construction phase was made of pre-fabricated reinforced concrete elements, and for that reason the strength qualification was performed according to the published by TTI Design Reference-book. On the basis of calculations it was proved that the load-bearing parts of the structure are adequate according to the corresponding standards against stresses caused by a given earthquake.

7.3 Dynamic experiments

Each step of the mechanical modeling and mathematical method includes certain conservatism. However in case of an operating nuclear power plant efforts should be made in order to decrease the conservatism of the seismic capacity calculations, as the possibility of afterward safety upgrading measures is technically limited. Due to above written in the case of qualification of seismic capacity of the first category buildings it is practical in order to decrease the conservatism follow a combined experimental-numerical method. The essence of the experimental investigation is that from the responses of the building to some artificial excitement (e.g. explosion, VIBROSEIS) experimental modal analysis can be performed. The results of the experimental modal analysis can be compared with the results of the numerical modal analysis and by that way the accuracy of the modeling can be checked.

For determination of the dynamical features of the buildings of Paks Nuclear Power Plant three explosion experimental series were performed. During each experiment the explosive material was Paxit. The charges were loaded in 20 m deep bores, maximum 50 kg in each. The bores were located in a regular network each in approx. 10 m distance from each other. The first, so called test-explosions were made for determination of distance-charge relationship and checking of the detectibality. The responses of the test-explosions were well measurable at the base plate of the building, the explosions did not represent any hazard to the operating units, and did not cause any damage to the surrounding buildings. But it was determined that the explosion distance should be increased up to 2-4 km and simultaneously the charge could be increased up to 500 kg, so the excitement was shifted towards lower frequencies. The first series of explosion gave possibility for determination of the dynamical features of the main building, auxiliary building of units 1.-2. and the diesel machine halls. Two explosions were performed with 200 kg charge at a distance of 2300 m South - South-East from the building, and one 200 kg charge and two 500 kg charges were exploded at a distance of 4500 m in South-East direction. On the basis of the measured acceleration response-signals the experimental modal analysis of the main building could have been performed and the characteristic natural frequencies of the other investigated buildings could have been performed. The aim of the second series of experimental explosions was the examination of the dynamical features, the absorption and soil-stucture interactions of the main building, the longitudinal and cross galleries, the turbine hall and the water pump station.

In this series of experiments - having on mind that the main building is of protracted rectangle shape, the longitudinal axis of which is of N-S direction - explosions were made separately in direction of both axis of the building, that eastward and southward from the building in order to indicate the direction sensitivity of the dynamical response. At the eastward explosion point at 2 km one 100 kg and two 300 kg charges were exploded, while at the southward point at 2.6 km two 450 kg charges were exploded.

The detectors were located in south and east directions from the main building on the free space at a distance of 5 and 100 m in borings at depth 0, -5, -10, -15, -20 m. Acceleration sensors were located in the primary circuit main building at levels -6.50, 18.90 and 38 m, and on the top of localization tower at level 48.90 m. Four detectors were placed on four points of one frame of the turbine hall steel structure, sequentially on -6.50, 18.90, 18.90 and 0.00 m levels. Three detectors were placed on the -3.60, 9.60 and 19 m levels of the gallery building nearby the main building. All the detectors were equipped with three acceleration sensors oriented to directions x, y, and z.

The time signal of the acceleration of the external excitement effecting the building has typical phases. The first phase can be identified by arrival of a relatively high frequency longitudinal wave, the velocity of propagation of that, calculated from the arrival time, is 1900 m/s. The velocity of propagation of the later arriving surface wave package is in the range of 270 - 380 m/s, depending on the frequency, according to the typical dispersion of the surface waves.

Below some natural frequencies of the main building are compared, that were determined by experiments and calculations and that obviously demonstrates the way of utilization of the measurements results as well.

Reactor building:

Modus	Measured eigenfrequency [Hz]	Calculated eigenfrequency [Hz]
1 *	1.6 - 1.9	1.84
2	1.9 - 2.1	2.12
3	2.3	2.38
4	2.5	2.82

* reactor hall

Turbine hall:

Modus	Measured eigenfrequency [Hz]	Calculated eigenfrequency [Hz]
1	1.9 - 2.2	1.84
2	3.0	2.82
3	3.6	3.34
4	4.3	4.38

From the decay of the acceleration signal measured on the main building the global damping characteristic for the given conditions can be determined if we consider the building after excitement to be a freely vibrating system. This damping can be determined on the basis of sinus function with exponentially decreasing amplitude that is applied to the decay phase of the low frequency swinging. Such an approach is acceptable as is decay phase practically in each case a dominant frequency forms the time signal.

In that way we got the following values for excitement for the East and South directions (all the values are given in %):

Measurement point	E x-dir.	E y-dir.	S x-dir.	S y-dir.	S z-dir.
Main build. 4G	6.9	-	-	9.1	10.1
Main build. 4H	7.5	6.8	-	8.7	5.5
Main build. 5P	10.0	7.7	11.8	10.4	6.4
Turbine hall 4K	6.6	-	9.8	9.4	8.1
Gallery build. 5O	6.1	9.4	8.4	9.2	14.8

In opposition to the above written the calculations for x, y and z directions were made with 8, 8 and 10% damping values.

As it was anticipated the damping values are significantly scattering. Both the values and the scattering are characteristic for the given very weak excitement. In case of calculations for the buildings for example according to KTA 2201.3 15 and 30% damping can be used for horizontal and vertical directions. Naturally those values are valid for earthquakes for great amplitudes. The excitements made by explosions cause amplitudes which can be measured only by instruments, and for that reason the damping determined in that way might give much lower values then those in case of an earthquake. On the basis of measurement the damping is regularly underestimated, as there are excitement coming to the system being in decay phase as well, and so the decay is longer than in case of a left alone system and in consequence the measured damping will be lower. So the damping determined in such way might be a lower limit for the damping values used during the calculations.

The detailed evaluation of the measurements will be finished in 1993.

8. Experimental investigation of the equipment

Samples of important from point of view relays, frames (panels) and instruments were investigated on vibro-plates during 1990-92. The results of those are summarized below.

8.1 Relays

Most of the relays operated in the power plant are Soviet made. Totally 49 relays of 17 different types were investigated. Among them there were auxiliary relays, delay cut-in, delay cut-off and instabil relays. The relays similar in electrical parameters, but equipped with different contact numbers were not considered as different types. At the Paks Nuclear Power Plant in instrumentation and control areas there no other types of relays.

*The investigations were performed according to standard IEE-E-*501/78. (response spectrum 1 Hz 0.25%, 4 Hz 250%, from 33 Hz 100%; contact change shorter than 2 ms is allowed). The vibro-plate allows two direction excitement of same amplitude and phase. The utilized maximum acceleration was 1 g ZPA (zero-period acceleration). All the relays met the investigation requirements, but two relays were to be repaired.

8.2 Frames

Vibro-plate investigation of five different instrument frame or cabinets and one instrument panel was performed. Those are the followings: regulation and safety protection relay holder, regulation and safety protection low frequency transformer, neutron control system, unit control room panel, unit control room relay room, gate valve distributor. The selected samples generally cover the box types used in the power plant. One of the purposes of the investigation was to correct on the basis of the investigation results the calculations with finitive elements, and to able to take into consideration the reinforcement of the frames by calculations in the future.

The investigations were performed according to standard IEEE 344/75 on one direction vibro-plate. The natural frequencies, modus were determined as well as the modal damping by sinus investigation test, and the resistance of the frames. On some levels the value of the acceleration corresponded to 0.3 g maximum free surface acceleration value amplified by the building.

In case of some frames cracks of welding beams were observed at maximum sized earthquake level excitement. The enforcement of the internal support in case of several frames were not adequate, the supports strongly swung. Those errors are simple to liquidate.

8.3 Instruments

Those instruments were selected which are essentially necessary for safe operation, shut-down and long term cooling of the reactor. Those are the followings:

- Low frequency transformer
- Neutron control system transformer
- Regulation units
- Temperature transmitters
- Pressure transmitters
- Compensation recorders
- Circular scale indicator
- Light indicator
- Signal reverser
- Limit value switches
- Contact manometers

The list can be considered as a full one from the point of view that within one selected instrument type the different electrical parameters can be neglected from the point of view of evaluation of seismic capacity, it is enough to investigate only one representative.

The investigations are going on according to standard IEEE-344/75. By now investigation of eight instruments has been completed using as input spectrum the covering curves of the response spectrums occurring on the ceiling levels of the place of locations of the instruments, corresponding to 0.3 g GPA.

9. Earthquake monitoring system

An earthquake monitoring system has been installed on the units of Paks Nuclear Power Plant. The system has two functions: generates protection signals and records the seismic events.

Sensors of different types belong to the protection and registration system. The detector itself is a geophone of 10 Hz natural frequency which generates by help of correction and differentiator circuit acceleration signals from velocity signals. The sensors belonging to the protection system operate in range of 0.4 - 30 Hz range, while those belonging to the registration system operate in range of 0.4 - 50 Hz, with even sensitivity in the full range.

The registration of the seismic events is performed by three acceleration meters of high sensitivity which are independent from the protection system and which are located on characteristic from dynamical point of view places of the building. The base sensitivity of the acceleration detectors is 0.006 g, which means that they sense a number on non or hardly sensible by people seismic events, or building vibrations of non-seismic origin.

REFERENCES

[1] Code on the Safety of Nuclear Power Plant, Design, IAEA Safety Series No. 50-C-D (Rev.1.)

[2] Application of the Single Failure Criterion, IAEA Safety Series No. 50-P-1

[3] Safety Functions and Component Classification for BWR, PWR and PTKI, AEA Safety Series No. 50-SG-D 1

[4] J. Györgyi, A. Lovas, Theoretical Basis for Completing a Mechanical Model for Structures of the PAKS Containment Investigations for Extreme Conditions, Politechnika Kft, 1991 (in Hungarian)

[5] J. Györgyi, A. Lovas, Mechanical Model for Structures of the PAKS Containment Investigations for Extreme Conditions, Politechnika Kft, 1992 (in Hungarian)

[6] Birbraer A. N., Shulman S. G., Protsnost i nadeshnost konstrukcij AES pri osobih dinamicheskih vozdejstviah, Moszkva, Energoatomizdat, 1989

[7] Technical Design, Volume IX (in Hungarian)

[8] The Safety Analysis Reports of the Paks NPP Prior to Start-up (in Hungarian)

[9] 50-C-S (Rev. 1) Code on the safety of nuclear power plants: Siting, IAEA Safety Series, 1992.

[10] 50-SG-S1 (Rev. 1) Earthquakes and associated topics in relation to nuclear power plant siting, IAEA Safety Series, 1991.

[11] 50-SG-D15 Seismic design and qualification for nuclear power plants, IAEA Safety Series, 1992.

[12] YVL 2.6. Provision against earthquakes affecting nuclear facilities, Sateilyturva- keskus, Helsinki, 1988.

[13] 50-SG-S9 Site survey for nuclear power plants, IAEA Safety Series, 1984.

[14] Japan Electric Association, Technical Guidelines for Aseismic Design of Nuclear Power Plants, Tokyo, 1987.

[15] ASME "Dynamic analysis methods", Boiler and Pressure Vessel Code, Section III, Division 1. American Society of Mechanical Engineers, New York, 198

[16] KTA 2201. Kerntechnische Ausschuss, Auslegung von Kernkraftwerken gegen seismische Auswirkungen

[17] Institute of Electrical and Electronics Engineers, IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generation Stations, Standard 344-1987, IEEE, New York, August 1987.

[18] YVL 3.5. Nuclear power plant pressure vessels. Stress analysis, draft May 5, 1978, Sateilyturvakeskus, Helsinki

[19] SP AES-79, Sanitarnie pravila proektirovania i ekszpluatacii atomnih elektrostancii, Moszkva, Energoizdat 1981.

[20] PBJA 04-74, Safety Rules for Nuclear Power Plants (in Russian)

[21] SzNiP II-21-75 Betonnie i shelezobetonnie konstrukcii, Normi proektirovania, M. Strojizdat, 1976,

[22] SzNiP II-15-74 Osnovania zdanii i soorushenii, Gosstroi SSSR, M. Srojizdat 1975.

[23] Normi rascheta na prochnost elementov reaktorov, parogeneratorov, sosudov i trubo- provodov atomnih elektrostancii, opitnih i issledovatelskih jadernih reaktorov i ustanovok, Moszkva, Metallurgia, 1974.

[24] GOST 16962-71, Izdania elektronnoi tehniki i elektroniki. Mehanicheskie i kinema- ticheskie vozdejstvia. Trebovania i metodi ispitania, 1971.

[25] VSN-15-78 "Nuclear Power Plant Design for Seismic Regions, Preliminary Norms", Moscow, MINENERGO, 1979 (in Russian)

[26] SzNIP II-7-81 Stroitelstvo v seismicheskih rajonah, Moszkva, Strojizdat, 1981.

[27] Tatarnikov V.P. et al.: O normah proektirovania seismostoikih atomnih stancii, Energeticheskoe stroitelstvo, 1983. No 7. c. 67-69,

[28] RTM 108.020.37-81 Raschet na protshnost pri seismicheskom vozdeistvii, MINENERGO, Moszkva, 1981.

[29] Normi rascheta na prochnost oborudovaniai i toboprovodov atomnih elektrostancii s vodo-vodianimi reaktorami na seismicheskoe vozdejtsvie. Approved by Gosgortech- nadzor SSSR, Moszkva, 1980.

[30] PiN AE-5-006-87, Normi proektirovania seismostoikih atomnih stancij, Moszkva 1987.

[31] PiN AE-7-002-86, Normi rascheta na prochnost oborudovanija i truboprovodov atom- nih energeticheskih ustanovok, Moszkva, 1986.

[32] SzNiP 2.01.07-85 Nagruzki i vozdeistvia, Gosstroi SSSR, CITP Gostria SSSR, Moszkva, 1987.

[33] Kirillov A. P., Ambriasvili Ju. K.: Seismostoikost atomnih elektrostancij, Moszkva, Energoatomizdat, 1985.

[34] Geological Evaluation of the Site of the Paks NPP, Final Report of the Scientific Coordinator Committee, February 1993. (in Hungarian)

[35] GOSZT 6249-52 (in Russian)

[36] Department of Energy`s Team`s Analyses of Soviet Designed VVERs, Background Appendix J, Seismicity, US Department of Energy, Assistant Secretary for Nuclear Energy, Washington DC, September 1989

[37] Kennedy, R.P. et al., Probabilistic Seismic Safety Study of an Existing Nuclear Power Plant. Nuclear Engineering and Design, Vol. 59, No. 2, pp. 315-338, 1980.

[38] A Methodology for Assessment of Nuclear Power Plant Seismic Margin. Report NP-6041. EPRI, Palo Alto, 1988.

[39] A Methodology for Assessment of Nuclear Power Plant Seismic Margin (Revision 1). Report NP-6041-M, Rev. 1., Palo Alto, 1991.

[40] Newmark, N.M.and Hall, W.J., Development of Criteria for Seismic Reviews of Selected Nuclear Power Plants. Report NUREG/CR-0098, NRC, Washington, 1978.

[41] Seismic Analysis of Safety Related Nuclear Structures and Commentary on Standard for Seismic Analysis of Safety Related Nuclear Structures, ASCE Standard, ASCE 4-86, New York, 1986.

[42] Dynamic Investigation of the ECC Piping in Paks NPP, A-GÉP Kft, 198 (in Hungarian)

[43] Katona T. et al., Experimental and Analytical Investigation of Paks NPP Building Structures, Earthquake Engineering, Tenth World Conference, 1992. Balkema Rotterdam, ISBN 90 5410 060 5

[44] ANSI/ACI 318-83, Building Code Requirements for Reinforced Concrete, American Concrete Institute, Detroit, 1983.

[45] ANSI/ACI 349-85, Code Requirements for Nuclear Safety Related Concrete Structures. American Concrete Institute, Detroit, 1985.

[46] ANSI/AISC N690-1991, Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities. American Institute of Steel Construction, Chicago, 1991.

[47] Newmark, N.M., A Response Spectrum Approach for Inelastic Seismic Design of Nuclear Facilities, Trans. 3rd Int. Conf. SMiRT, London, Aug. 1975, Vol. K, Paper K5.1., Publ.by CECA, Luxembourg, 1975.

[48] Generic Implementation Procedure for Seismic Verification of Nuclear Power Plant Equipment. Rev. 2., SQUG, 1990.

[49] Masopust R., Guidelines for Seismic Qualification of Technological Equipment of NPP Paks, 1992., made for PA Rt. by a Stvenson and Associates as subcontractor of SKODA Praha

[50] US NRC Regulatory Guide 1.60, Design Response Spectra for Seismic Design of Nuclear Power Plants

[51] US NRC Regulatory Guide 1.222, Development of Floor Response Spectra for Seismic Design of Floor-Supported Equipment or Components

[52] SIEMENS Working Report, KWU R324/92/E002

[53] Katona T. et al, Dynamic Analysis of VVER-440 Nuclear Power Plant for Seismic Loading Conditions at Paks, to be published, SMiRT 12, Stuttgart, 1993.

[54] Katona T., Rátkai S., Converter Procedure and Program for Earthquake Signals, and Correlation of Power and Response Spectra, PAV, 1991. (in Hungarian)

[55] Lenkei P. et al, Earthquake Resistance of Existing Secondary Structures in a Nuclear Power Plant, Int. Conf.on Failures of Concrete Structures, Strbske Pleso, 1993, to be published

[56] Lenkei P. et al, Final Report of the Investigations of the Structure Response of some Buildings of NPP Paks, 1992

Title: **Systems Required During and After an Earthquake - Summary Report**

Contributor: **Ph. Monette**

Date: **September 1994**

SMT/94/062R

VVER-1000 NUCLEAR POWER PLANTS

SYSTEMS REQUIRED DURING AND

AFTER AN EARTHQUAKE

SUMMARY REPORT

15 September 1994

WESTINGHOUSE ENERGY SYSTEMS EUROPE
Boulevard Paepsem, 20 - 1070 Brussels (Belgium)

Table of Contents

List of Abbreviations

ECCS	Emergency Core Cooling System
PDTQ	High Pressure Positive Displacement Safety Injection
HHTQ	High Head Safety Injection
LOCA	Loss of Coolant Accident
LHTQ	Low Pressure Safety Injection
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
SG	Steam Generator
PRT	Pressurizer Relief Tank
RHR	Residual Heat Removal System
YR	Emergency Steam-Gas Mixture Removal System
TY	Organized Leakage System
RY	SG Blowdown System
RL	Main Feedwater System
RA	Main Steam Line System
TX	Emergency Feedwater System
TK	Charging and Letdown System
TQ	Containment Spray System
VF	Essential Service Water
TF	Intermediate Cooling System
TV	High Pressure Sampling System
UA	High Pressure Instrument Air System
YT	Hydro-accumulator System

1.0 INTRODUCTION

The scope of this document is to list the mechanical, instrumentation and electrical components required during and after an earthquake, in order to achieve and maintain safe shutdown conditions of a VVER-1000 type of nuclear power plant.

This list of components is based on the study made in WESE report PS-G-94-1321

The main objective pursued in establishing the systems and equipment list is to provide guidance for the design and implementation of the backfits which are necessary to increase seismic resistance of the components required after earthquake.

The present list is established on generic bases, i.e. applicable to any specific VVER-1000. For most of the systems (at least for the main systems), the list is supported by a color-code mark-up of system drawings (Appendix A). For other systems however, such support mark-up is not provided, and a detailed review of plant specific information should be performed for each plant separately.

2.0 FLUID SYSTEMS REQUIRED AFTER AN EARTHQUAKE

This section specifies the fluid systems which shall keep their integrity and/or remain operable during and after an earthquake, to ensure that the safe shutdown functions can be performed.

The systems can be categorized as "main systems" and "auxiliary systems".

The main systems perform directly a safe shutdown function, whereas the auxiliary systems provide a support function to one or several main systems and/or to other auxiliary systems, e.g., cooling water systems, diesel generators, etc...

Flow Diagrams, marked up to show the piping, components and boundaries of the systems, subject to seismic evaluation, are collected in Appendix A.

2.1 Main Systems

2.1.1 Reactor Coolant System (RCS) and RCS Emergency Venting System (YR) (Figure 1)

The integrity of the Reactor Coolant Systems (RCS) must be maintained including the connections up to the first isolation device, in order to prevent the development of a non-isolable LOCA.

The following components are concerned :

- Reactor vessel
- Pressurizer
- Reactor coolant pumps
- Steam generators (primary side)
- Reactor coolant loop piping and isolation valves
- All auxiliary piping and valves connected to the RCS up to and including the isolation device
- All RCS drain lines and vent lines up to and including the isolation device
- All RCS instrumentation impulse lines up to and including the isolation devices.

In addition, to ensure reactor trip function, rod cluster control assemblies and control rod drive mechanism operation is required.

Reactor core and internals geometry shall be maintained during and after an earthquake.

The integrity of the reactor coolant pump/shaft/motor assembly must be maintained as well as the integrity of the reactor coolant pumps autonomous seal cooling system.

The YR system must keep integrity and functionnality. This system connects the pressurizer, reactor vessel head and primary collectors in the steam generators to the pressurizer relief tank (PRT) and to the Organized Leakage System (TY) tank.

Integrity of the TY (seismic qualification) is not required.

Integrity of the PRT itself is not strictly required either, but since it acts as a fixed point for the YR system, its anchorage must be qualified for seismic loads.

Vital parts of the RCS and YR to be qualified are shown on figure 1 and 5.

2.1.2 Charging/Letdown (TK) System and Seal injection and return System (Figure 2)

In case of earthquake, the control of inventory of the primary system is performed by other means. Therefore, the operation of these systems is considered as not required after an earthquake. However, integrity of the portions inside containment (See figure 2) should be ensured for RCS boundary integrity.

2.1.3 High Pressure Safety Injection (PDTQ/HHTQ) Systems (Figures 1 and 8)

The Positive Displacement (PDTQ) pumps can inject above the nominal RCS pressure while the high pressure injection pumps (HHTQ) have a lower shut-off head.
The PDTQ and the HHTQ system are three train systems, comprising each a boric acid storage tank and a pump (see figure 8).
These systems are required as well as the instrumentation for monitoring of flow and level in the tanks .

2.1.4 Hydro-accumulators of the Safety Injection (YT) System (Figure 1)

The hydro-accumulators are not required to operate after an earthquake.

Only the integrity of their connections to the LHTQ and RCS must be ensured, which requires accumulator anchorage and connecting piping qualification.

2.1.5 Low Pressure Safety Injection (LHTQ) System (Figure 7)

The LHTQ system including the suction line from the RCS, will be required after the earthquake for residual heat removal .

It is a three train system comprising each a boric acid storage tank, a LHTQ pump and a heat exchanger on the suction side, common to the HHTQ and containment spray systems.

The required instrumentation for monitoring system operation includes the injection flow, the boric acid storage tanks level, the confinement sumps level and the outlet temperature of the heat exchangers.

2.1.6 Spray (TQ) System (Figure 7)

The confinement spray system is required to be operable.
This system comprises 3 pumps which share suction with the LHTQ pumps.
Instrumentation for spray flow monitoring is required.

2.1.7 Steam Generators Secondary Side (Figure 12)

The secondary side of the steam generators, including the connecting lines up to an isolation device, shall remain intact.
It encompasses the integrity of the blowdown lines (RY), of the main feedwater lines (RL) to the check valve (Figure 12), of the steam generators drain lines and of the instrumentation lines.

Seismic qualification of these lines from the SG to the next fixed point beyond the isolation valves is required.

2.1.8 Main Steam (RA) System (TX valves) (Figure 12)

The integrity of this system is required, steam generators included up to the fast closing steam line isolation valves. Operability of the latter valves and of the steam generators safety valves are required during and after the earthquake.
The main steam lines have to be seismically qualified up to fixed point downstream from the valves.

2.1.9 Emergency Feedwater (TX) System (Figure 12)

The three-train emergency feedwater system has to supply water to the four steam generators for decay heat removal and plant cooldown. The pumps take suction from three emergency feedwater water storage tanks, which must remain intact after the earthquake. All connections to the tanks up to an isolation device must also keep their integrity.
Instrumentation for feedwater flow and tanks level monitoring is required.

2.2 Auxiliary Systems

2.2.1 Essential Service Water (VF) (Figure 6)

This system supplies cooling water to required users after earthquake but also to non-required users.

This system provides cooling water to the TQ pumps mechanical seals and bearing coolers, to the ECCS recirculation heat exchanger, as well as to the TF (Intermediate Cooling Water System - see 2.2.2 below) cooler. Therefore the integrity and functionality of these parts must be ensured after the seismic event.

Unless the complete essential service water system is seismically qualified, isolation valves will have to be provided wherever needed to separate the qualified from the non-qualified portions.

2.2.2 Intermediate Cooling Water (TF) System (Figure 3)

This system provides cooling water to required and not required users such as the reactor coolant pumps, the primary sample coolers, pressurizer relief tank cooler, RCP seal cooling, etc...

Only the operability of the intermediate cooling water system portion needed to feed the RCP seal external coolers and the HP sampling coolers (loops) should be available. The remaining non-required part shall be isolable from the required one or be also seismically qualified.

2.2.3 High Pressure Sampling (TV30/40/50) System (Figure 1 and 3)

Sampling capability from the reactor coolant loops must be provided. Integrity of the high pressure sampling system must therefore be ensured.

2.2.4 High Pressure Instrument Air (UA) System

The integrity of the instrument air system is very difficult to guarantee.

The air operated valves should take a safe position in case of loss of their air supply. For example, confinement isolation valves close on loss of air.

For those few valves which would have to be operated after an earthquake, a seismically qualified local air accumulator should be provided.

On that basis, the instrument air system is not included in the list of systems required after earthquake.

2.2.5 Safety Diesel Generators System

There are two series of diesel generators: two "non-safety" diesel generators designed to supply power to non-safety systems (like normal charging, auxiliary feedwater, ...) and three safety diesel generators designed to supply power to the safety systems.

The safety diesel generators must provide the emergency power to the required users in case of loss of off-site power simultaneous with the earthquake.

Therefore, integrity and operability of the safety diesel generators and their support systems must be maintained. That includes fuel storage and supply, starting air system, cooling systems and lubrication system.

Non-safety diesel generators are not necessary after an earthquake.

2.2.6 Ventilation Systems

Room cooling by ventilation system is required in the areas where heat sensitive essential equipment is located, i.e., equipment which could fail if a certain temperature is exceeded. Examples of areas where atmosphere cooling might be required are ECCS pumps room, rooms with electrical cabinets, rooms with electronic instrumentation.

Control room inhabitability must also be ensured after the earthquake, which requires operability of its air conditioning system.

The determination of which ventilation and air conditioning systems are mandatory after an earthquake requires an extensive plant specific evaluation.

2.2.7 Containment Isolation

Since a small LOCA is postulated as a result of the earthquake, all containment penetrations isolation valves and, more generally, any equipment (active or passive) that participates to the containment isolation function must fulfill its function and keep integrity (tightness) during and after the earthquake. In particular, any containment penetration isolation valves must be seismically qualified.

3.0 ELECTRICAL SYSTEMS

It is assumed that offsite power is not available during 72 hours. Therefore every motor of a component which belongs to the main systems and to the auxiliary systems identified in sections above must be fed by the emergency electrical power supply. This emergency power supply system from the diesel generators included down to the individual components must remain operable after the seismic event.

For each emergency power supply train, this requirement implies the integrity and operability of :

- Diesel generator and its auxiliaries (see section 2.2.5)
- 6.3kV and 0.4 kV busbars/breakers
- Transformer 6.3kV/0.4 kV
- Thyristor
- Motor/generator set
- 220V DC busbars/breakers
- Batteries
- Motor control centers
- Electrical cabling including cable trays

4.0 INSTRUMENTATION AND CONTROL SYSTEMS

The I&C systems comprise :

- The reactor protection and the safeguards systems actuation
- The instrumentation needed to operate the systems and to provide information to the operators.

Reactor Protection and Safeguards Actuation

As a general rule, the reactor protection and safeguards system actuation must remain operable during and after the seismic event. Therefore all the components in the chain of those actuation systems must be verified, including power supply, process sensors, transmitters, protection and logic cabinets, cabling and cable trays, etc...

In particular, concerning safeguards systems, the following actuations are critical :

- Emergency Safety Features start
- Emergency feedwater start
- Diesel generator start and loading sequence
- Isolation of non-required users in the essential service water and intermediate cooling water systems.

Monitoring Instrumentation

The necessary instrumentation to monitor the good operation of the main and auxiliary systems needs to be functional and its seismic adequacy has to be verified.

The main parameters to monitor are mentioned in the relevant sections on systems.

In addition and as a general rule, control switches and indicating lights for the motors of pumps and motor operated valves must be available.

Control Rooms

The main control room and the reserve control room integrity and operability is required for safe shutdown.

APPENDIX A- FLUID SYSTEMS DIAGRAMS

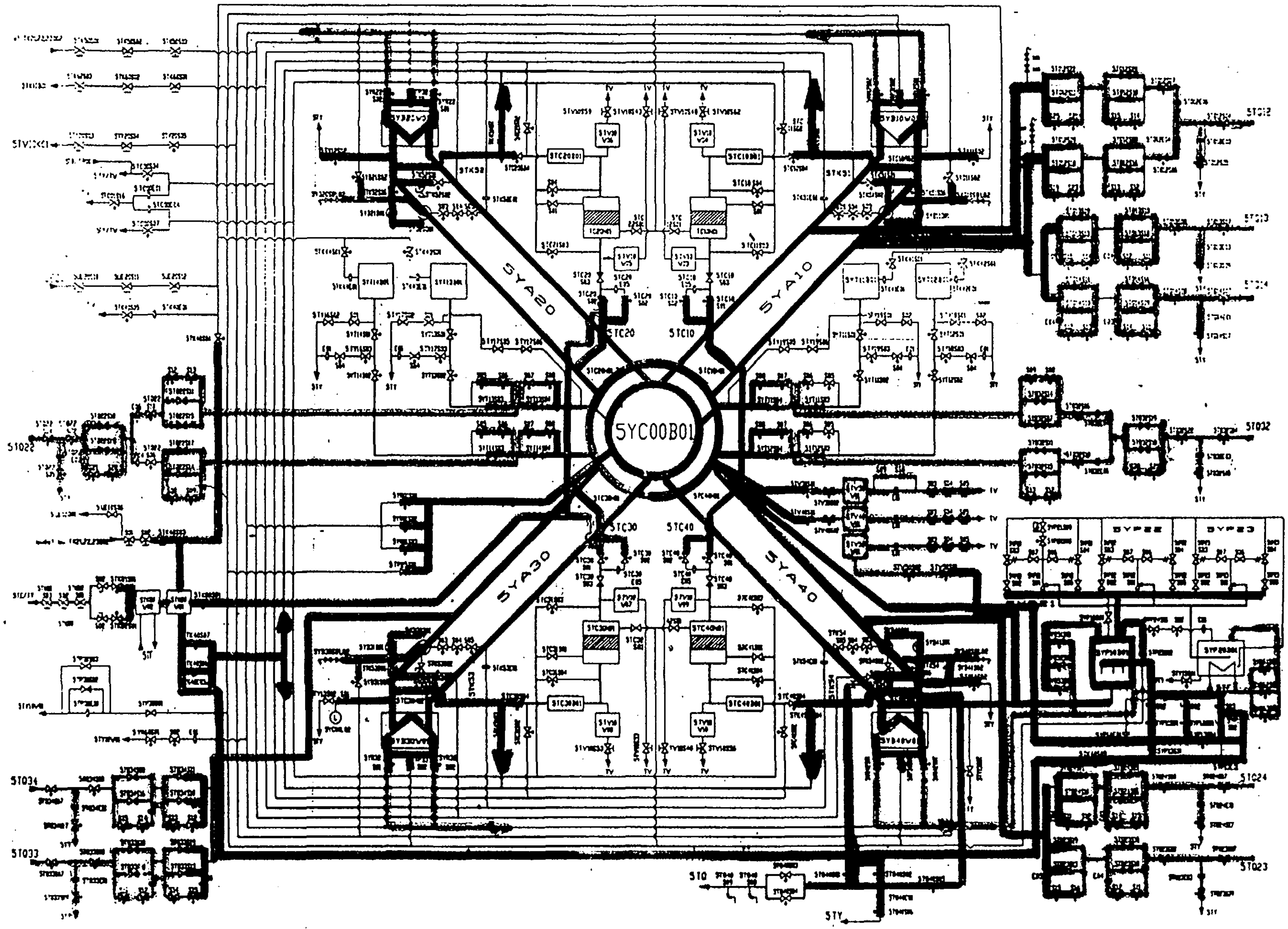
a) Note on colour coding

The components which are marked-up in colour on the diagrams shall be seismically qualified.

Meaning of the different colours is as follows :

- pink = RCS boundary
- blue = secondary side systems
- green = system required to be operable after an earthquake

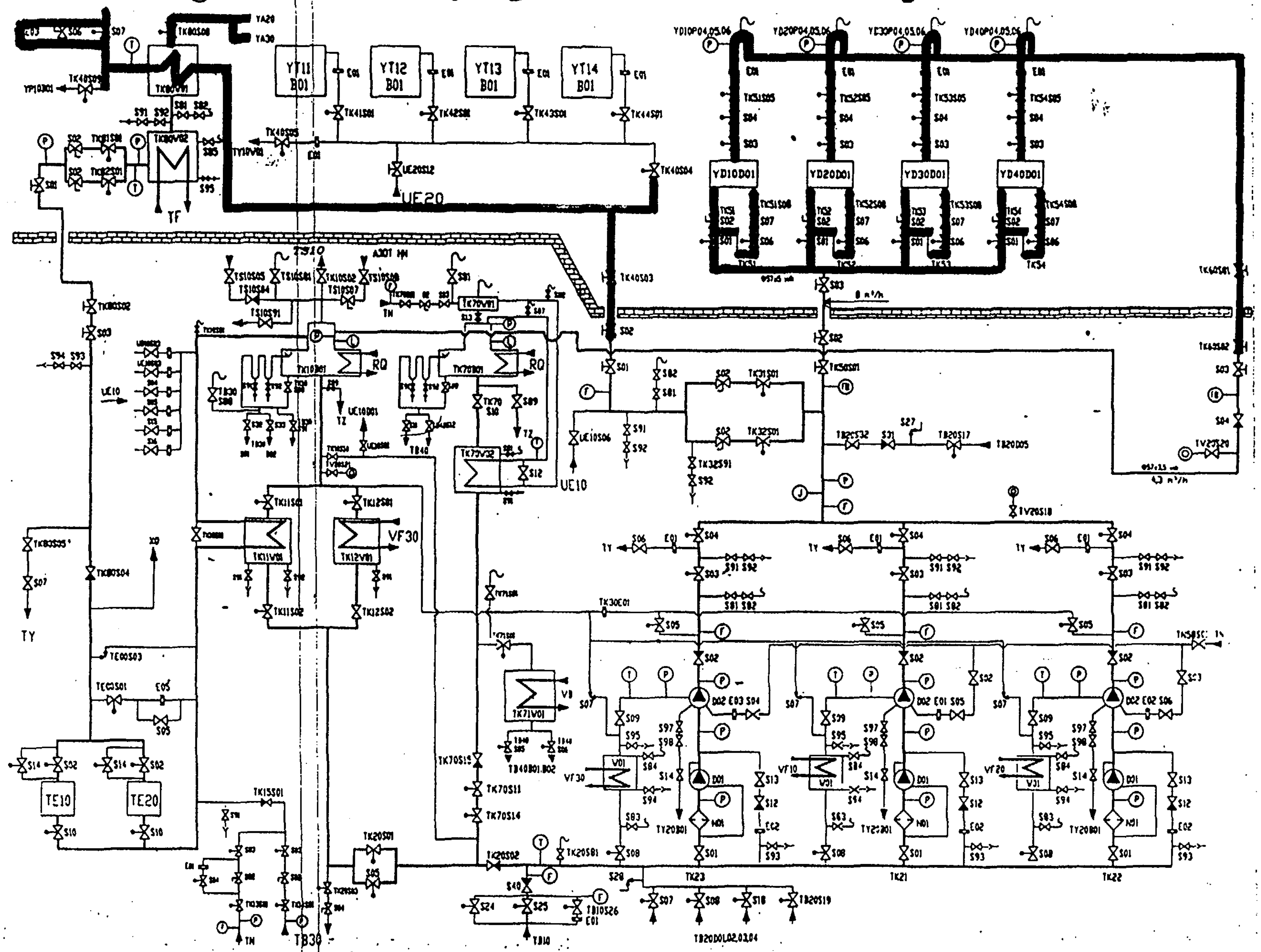
Figure 1: RCS and YR



ВП КОНТУР
35.РЦ.YA.TC.02
АЕЦ"КОЗЛОДУЙ"-ЕП
V-енергоблок
R05 YA

1

Figure 2: charging/letdown & seal injection return



Продувка-подпитка 1-ви контур | ТК
35. РЦ. ТК. ТС. 04.
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3
TK

6

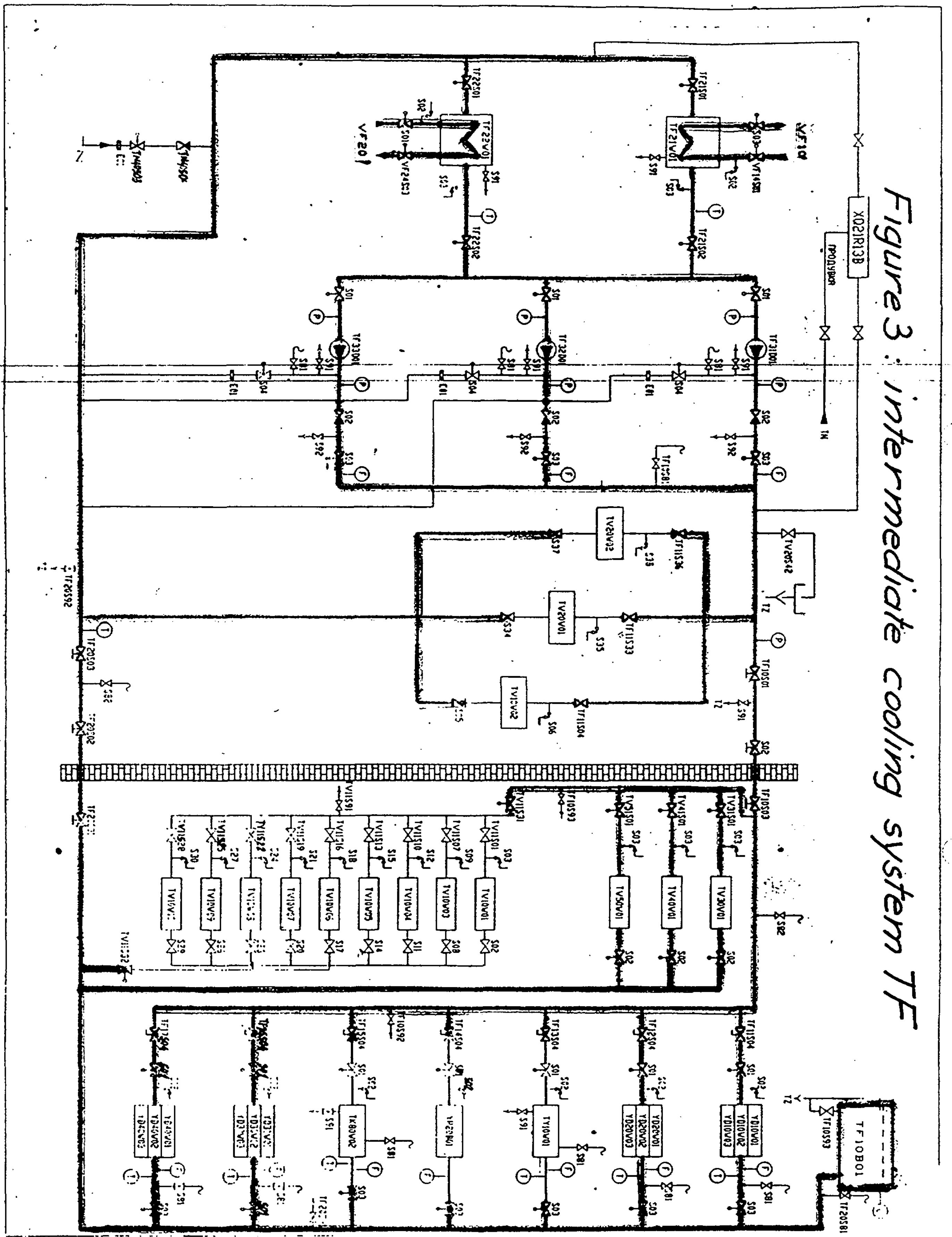
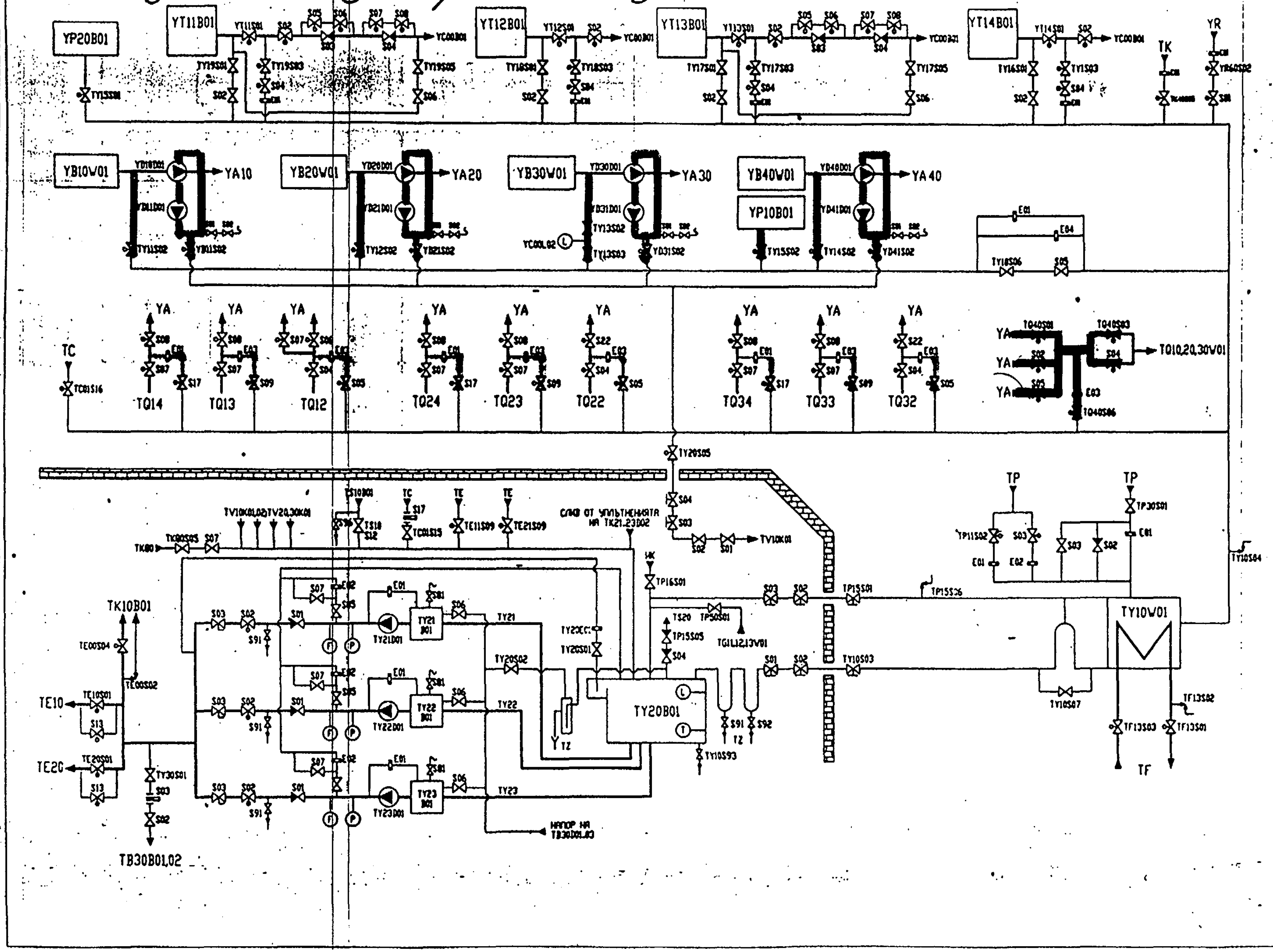


Figure 3: intermediate cooling system TF

Гл. инженер	Хаджиев		93.04	Междинен контур
Р-л напр. Е				
Н-к цех	Цовчев		93.04	35. РЦ. ТF. ТС. 07 — АЕЦ "КОЗЛОДУЙ" Е V-енергоблок

Figure 4 : organized leakage / YA interconn



Система организирани протечки	TY
35. РЦ. TY. TC. 09	АЕЦ "КОЗЛОДУЙ" - ЕП2 V-енергоблок

Figure 5: emergency steam gas mixture removal system / interc. with YA

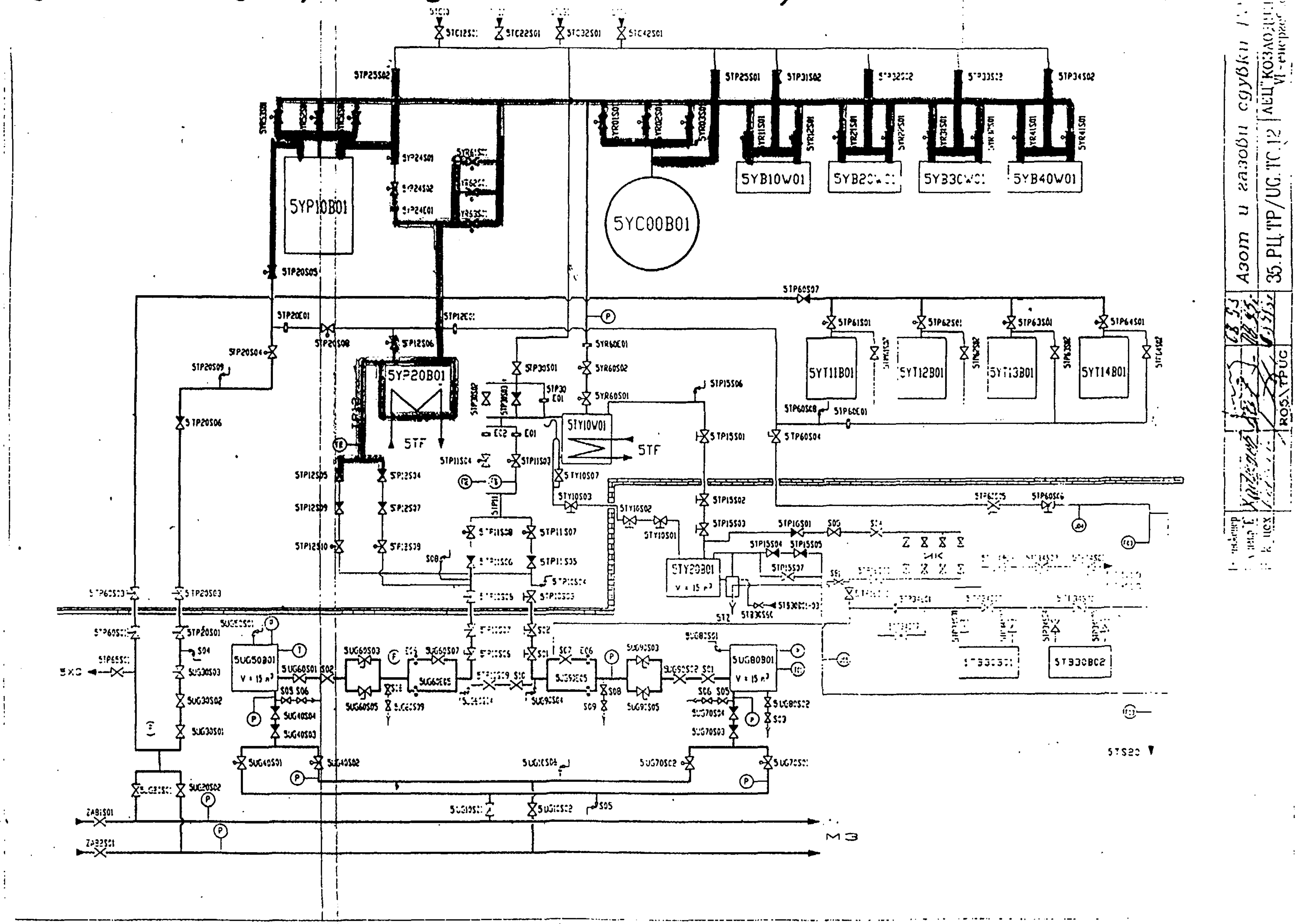
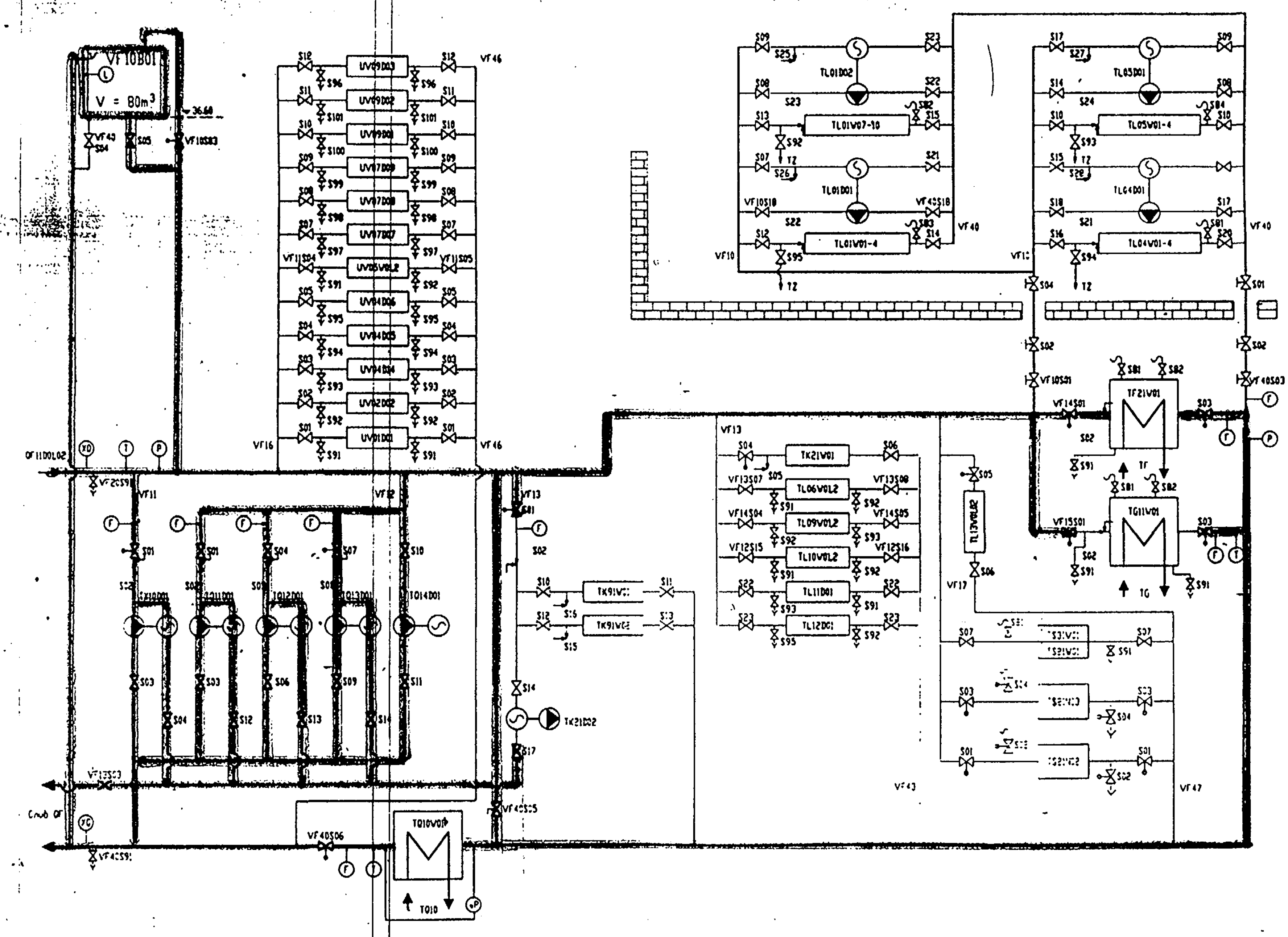


Figure 6: essential service water VF10/20/30 (example: VF10)

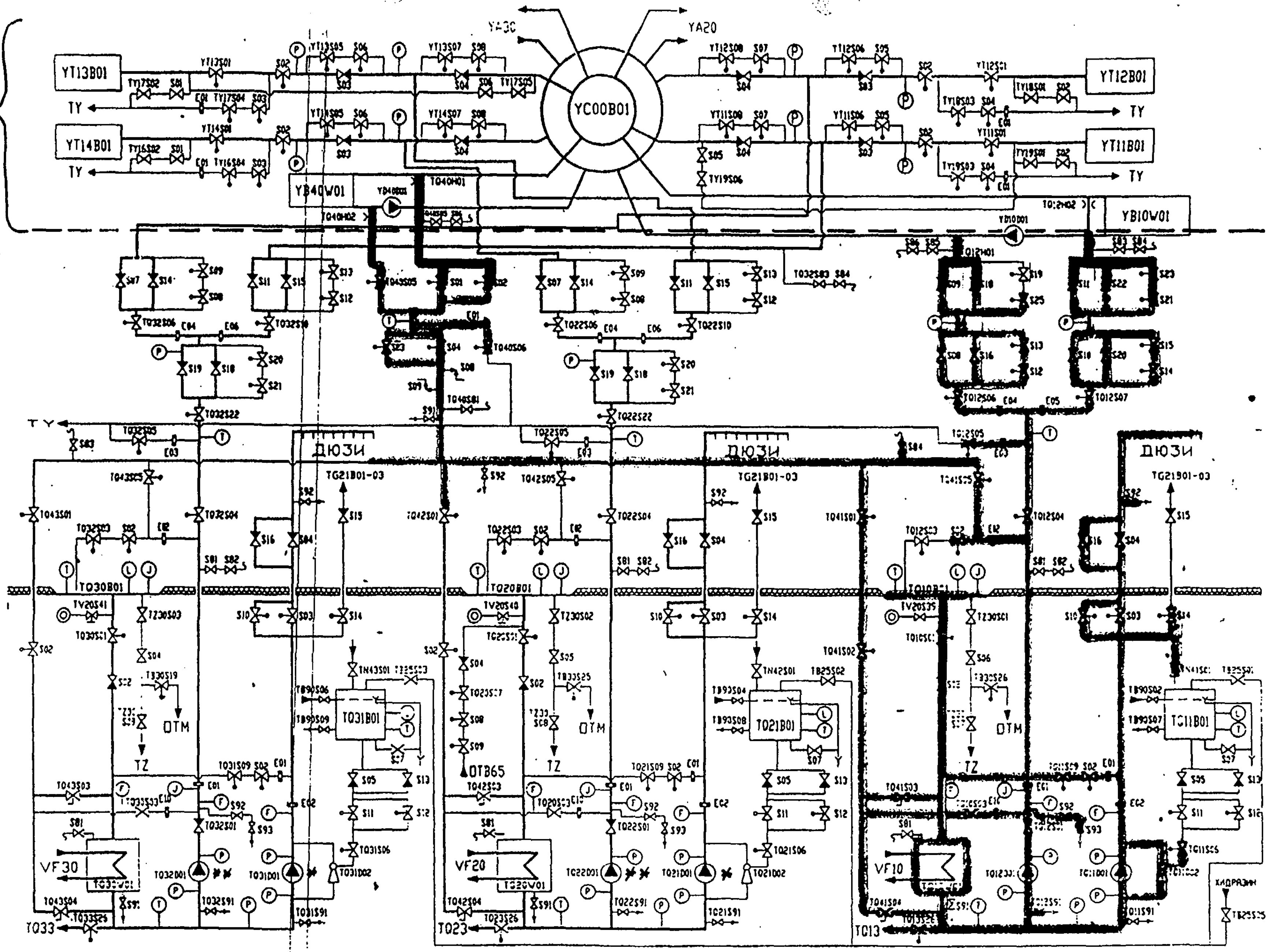


Гл. инженер			I Система техническа вода	VF10
Р-л напр. Е	Харчкин	13.04.		
Н-к цех	Иванов	93.04.	35. РЦ. VF10. TC. 14	АЕЦ "КОЗЛОДУЙ" – ЕП2 V-енергоблок
		R05 VF10		

13

Figure 7: containment spray (TQ 11 *) & low head SI (TQ 12**)

details: Figure 1



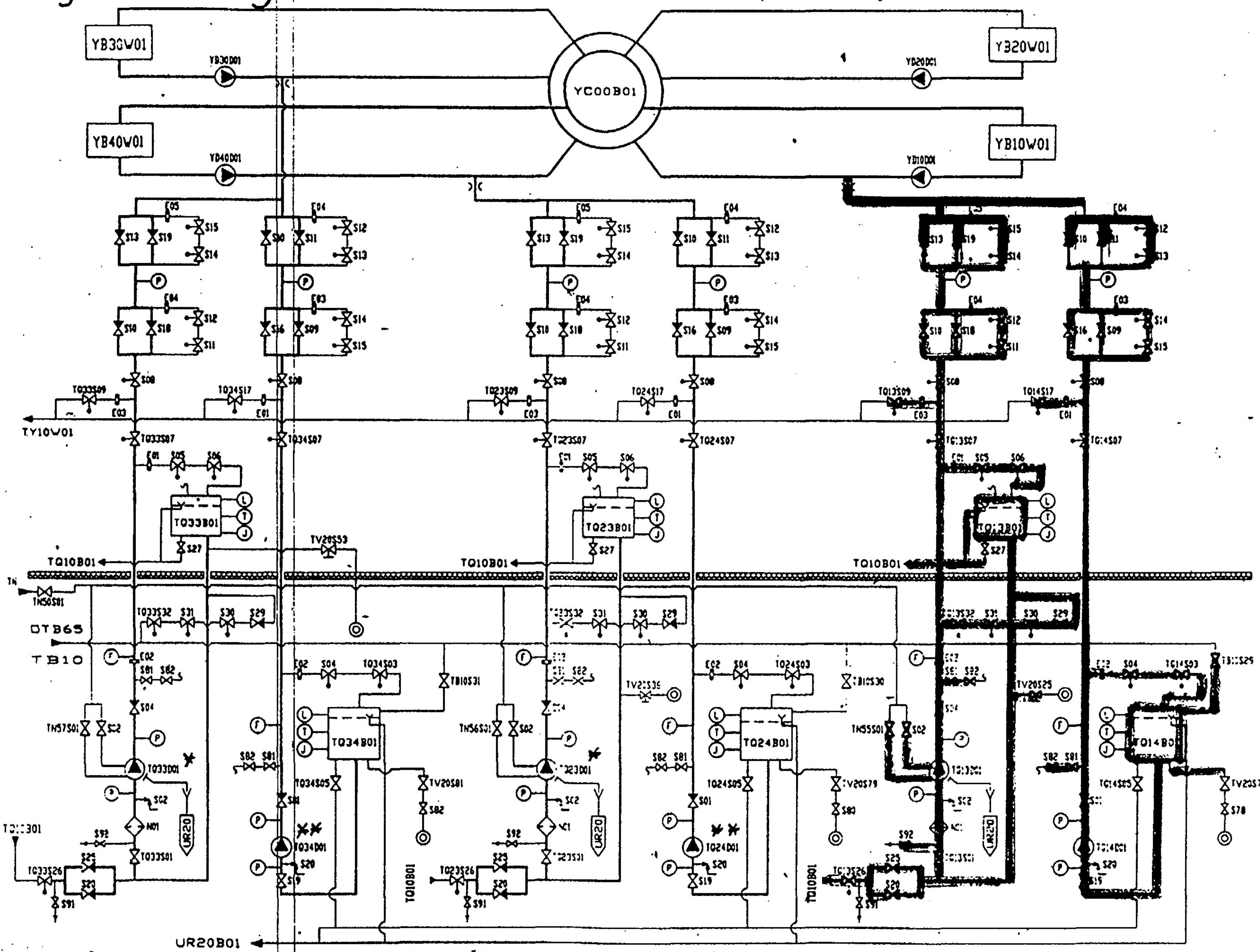
* IDEM TQ11D01
** IDEM TQ12D01

Спликерна система и планово TQ аварийно разхлаждане TQ

35.РЦ.TQ1,2.TC.19

АЕЦ "КОЗЛОДУЙ" - ЕГ V-енергоблок

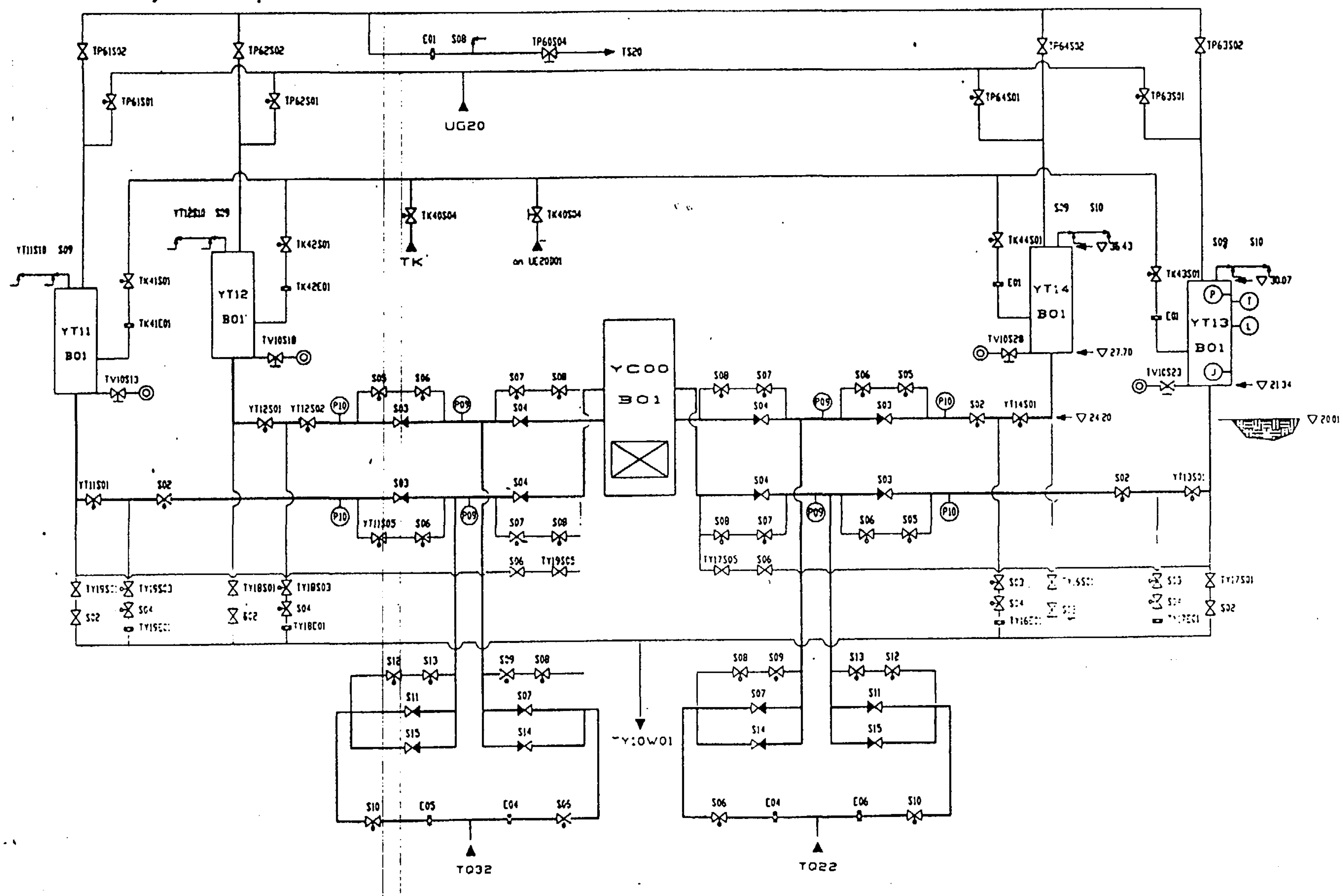
Figure 8: high head SI (TQ 13*/TQ 14**)



* SAME AS TQ 13D01.
** SAME AS TQ 14D01.

Figure 9: hydro. accumulators.

- not required
- only connection with YA & TQ (see Figure 1.)



САО3 – пасивна части | 35.РЦ.YT.TC.21 | АЕЦ "КОЗЛОДУЙ"-Е V-енергоблок | Y

Гл. инженер
Р-л напр. "Е"
Н-к цех

Figure 10: TC high pressure purification
• not required ◯ • see Figure 1.

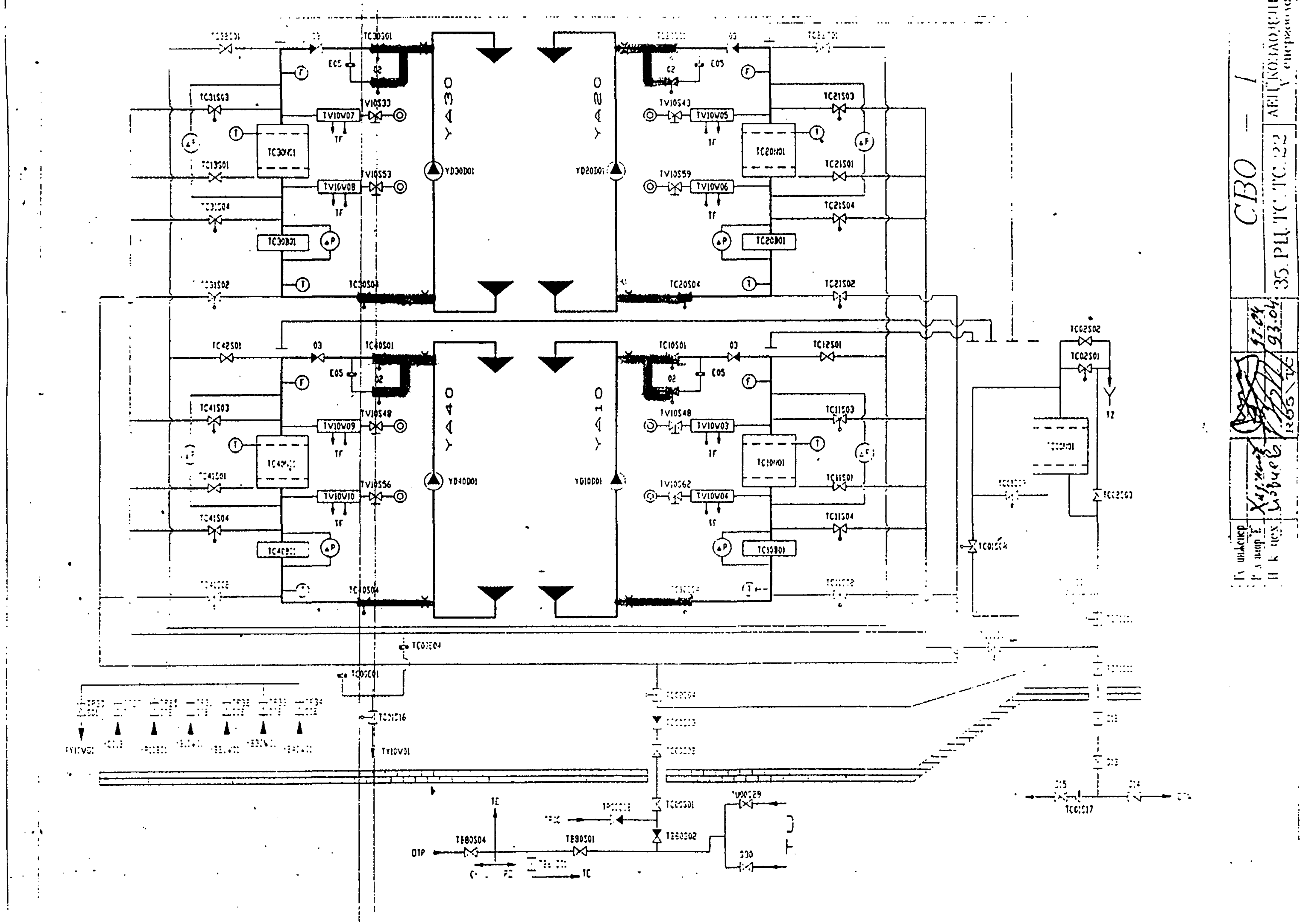


Figure 11: TB reagent tanks - not required

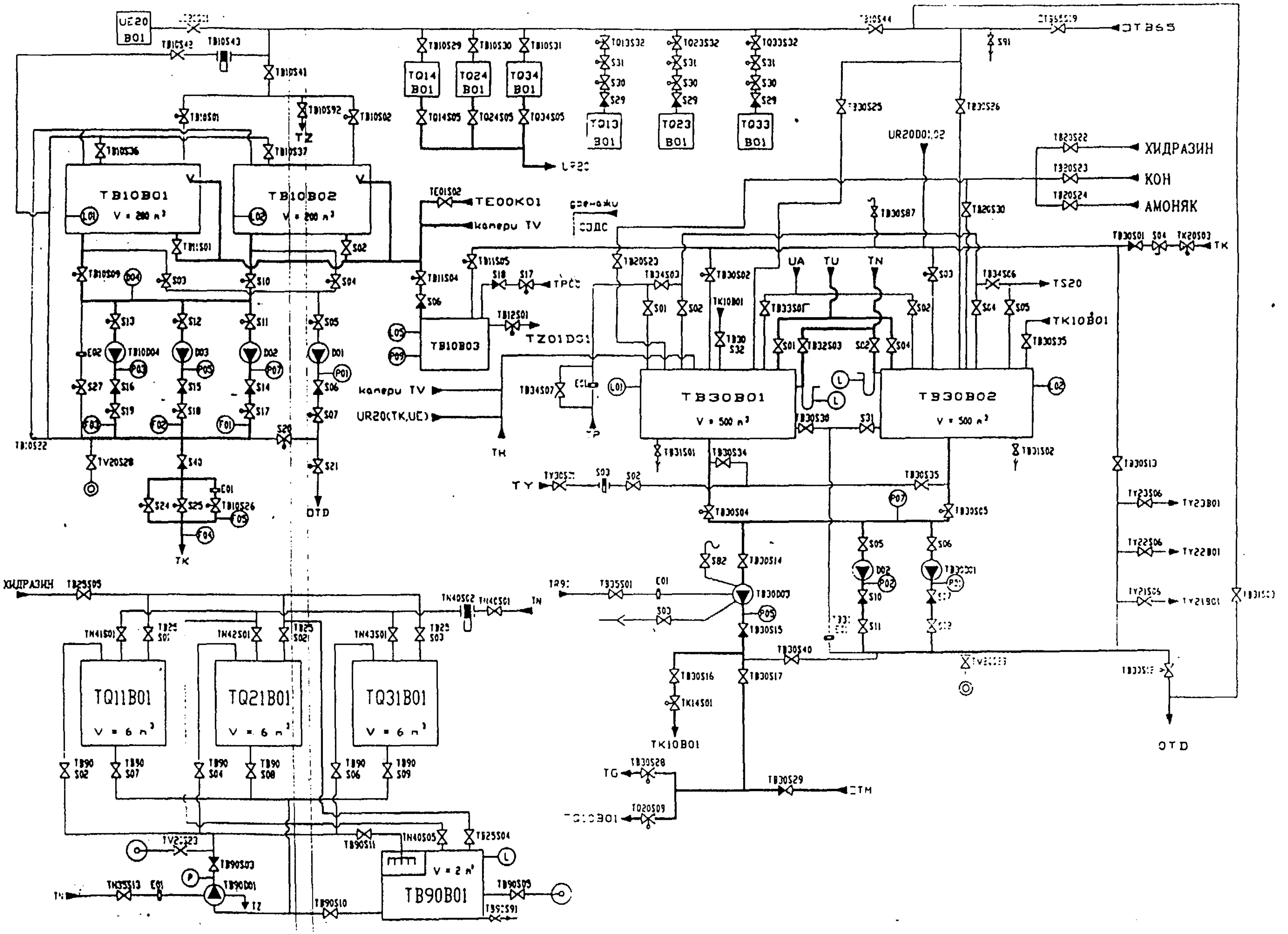
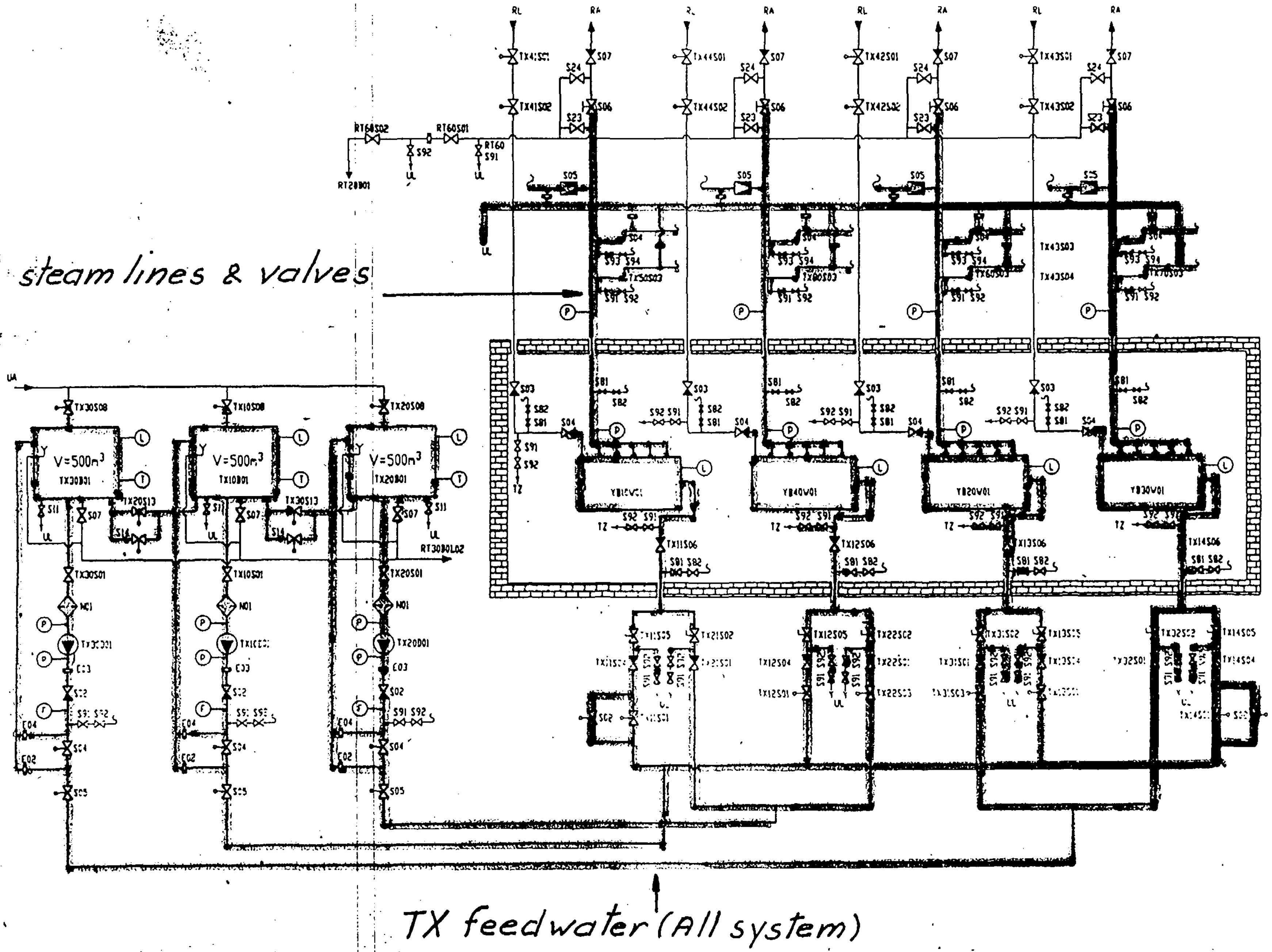


Figure 12: emergency feedwater TX & YB MSIV's & safety



Гл. инженер				Аварийна подпитка на ПГ
Р-л напр. Е				35. РЦ. ТХ. ТС. 37
Н-к цех		ROS\TX	93.04	АЕЦ "Козлодуй" – I V-енергоблок

Title: Design Floor Response Spectra for Kozloduy NPP

Contributor: Y. Ambriashvili

Date: October 1994

DESIGN FLOOR RESPONSE SPECTRUM FOR UNITS 5 & 6

KOZLODUY NPP.

Units 5 and 6 KOZLODUY NPP were designed as a standardized NPP WWER-1000, which was build in USSR last 15 years, on the basis standardized scheme designs, including those building structures and reactor building. Design model was developed on the basis of working drawings , the main dimensions in the Fig.1.

In a view of the fact that this type of NPP was planned to be built in various regions of the USSR and other countries, calculations have been made of the set of accelerograms, which includes artificial and already known recordings of earthquakes as a Nish, Bucharest, Helena, Santa Barbara etc .Envelope response spectrum of the set of accelerograms is shown on Fig.2. and in Table 1.

The accelerograms and response spectrum were adopted on the basis of the analysis of the seismological, geological, geophysical and others conditions in the regions where the NPP is to be probability locate, so as to obtain the wider coverage of the amplitude-frequency characteristics of weak and strong earthquakes, of different epicentral distances for different ground geological conditions.

The maximum acceleration amplitude of the horizontal oscillations for all accelerograms was assumed to be 4.0 m/s2 and those of the vertical oscillations 2.0 m/s2.

It was assumed that for the calculation of the specific structures the maximum amplitudes and accelerograms could be standardized and adopted as follows

Intensity level	9	8	7	6	5
Max. accelerati-on m/sec2	4.0	2.0	1.0	0.5	0.25

With this approach, and subject to allowance for a wide range of dynamic characteristics of earthquakes, it is possible, with some degree of error, to dispense with taking separate account of the influence of the special ground properties of sites and of amplitude and phase shift frequency characteristics in the case of weak and strong earthquake.The vertical component in this case is assumed to be equal to half the horizontal.

Material properties.

The following material properties were employed for the soil and reinforced-concrete structures:

SOlL

- Medium soil, dynamic share module G = 1500 MN/m^2

STRUCTURES

- Module of elasticity E= 3 10/7 kN/m^3
- Poisson's ratio - 0.2
- Specific gravity - 25 kN/m^3
- Damping (percent of critical) D = 5 %

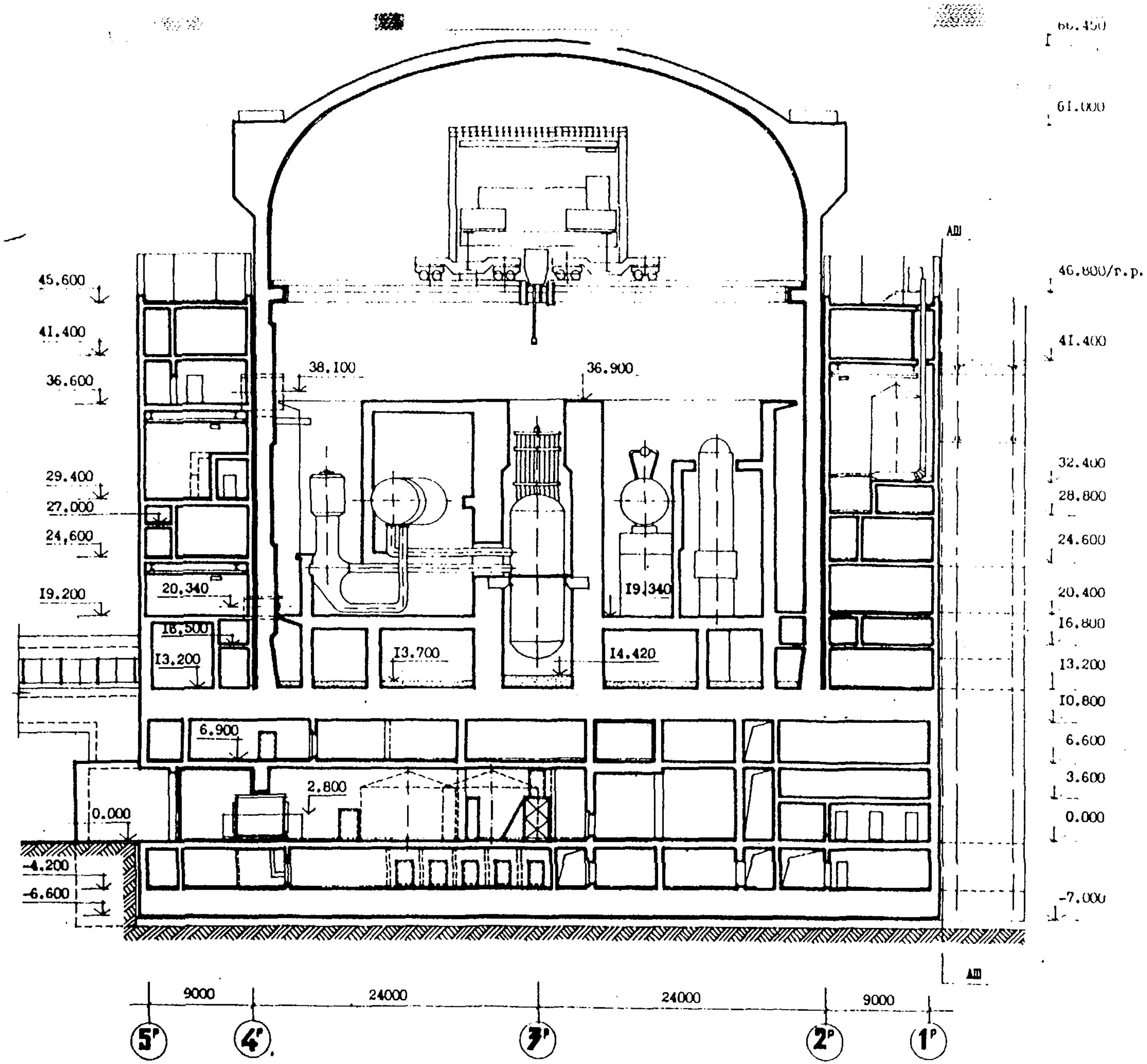


Figure . 1 : Section of Building

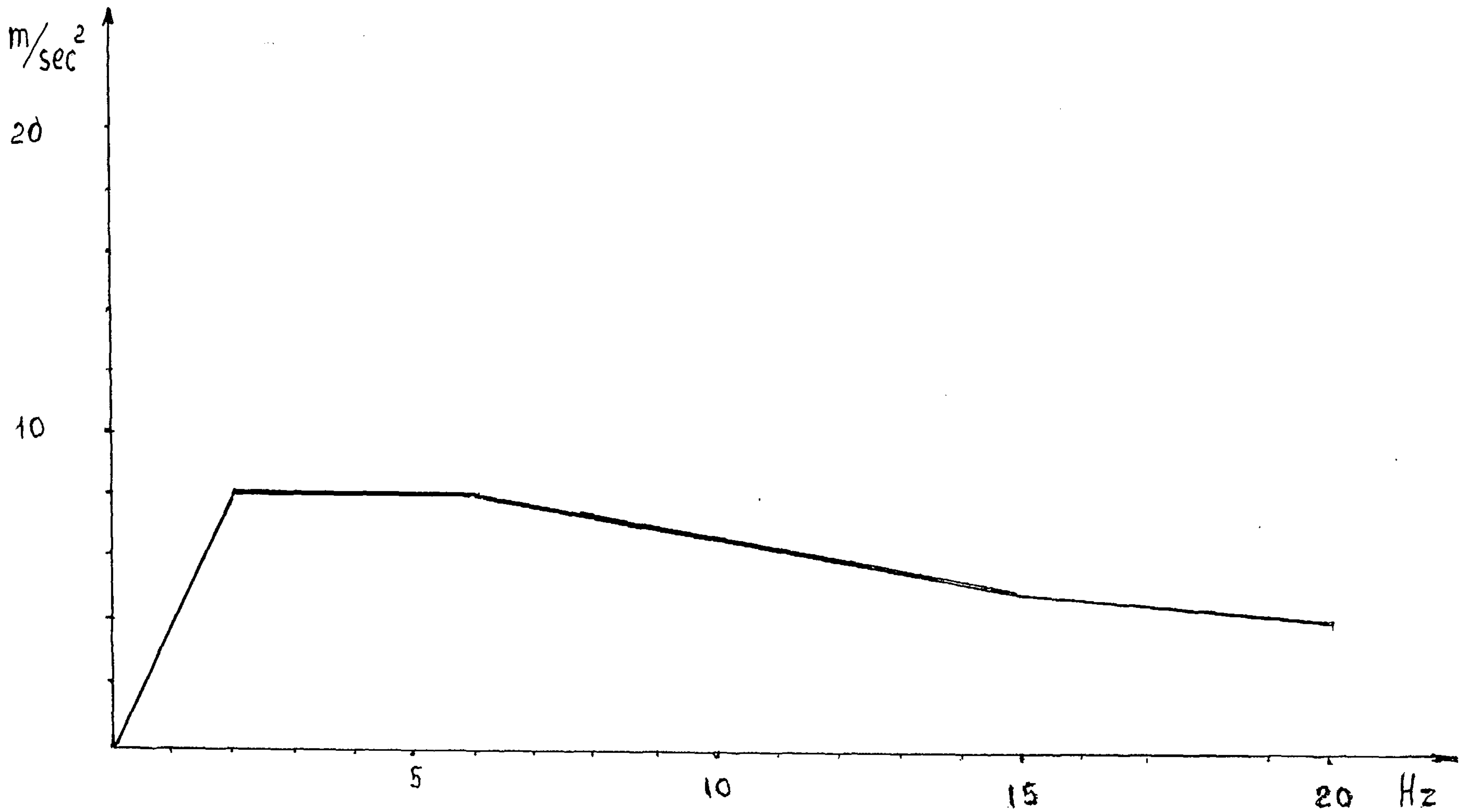


Figure 2. Envelop response spectrum from 10 set accelerograms defined by the Academy of science in 1980.

ATOMENERGOPROJECT

Moscow,Russia

FAXIMILLE TRANSMISSION

TO : Mr. Boyadjiev (Kozloduy NPP)
FAX : 359 973 25 91
COPY : Mr. A.Gurpinar (IAEA)
FAX : 431/234564
FROM : Dr. Y.Ambriashvili

June 1, 1994

Subject: Research co-ordination Meeting on Benchmark Study for Seismic Analysis and Testing of VVER Type NPPs, Kozloduy NPP. June 13-17, 1994.

I'm pleased to confirm my participation in the above mentioned Seminar.

I'll leave from Moscow for Sofia on Sunday, June 12, flight SU 171, depature from Moscow at 9:10 a.m.

I have my fixed ticket back to Moscow from Sofia on Sunday , June 19, flight 172, depature at 12:30 p.m.

Thank you for your assistance.

Best regards,

Yuri Ambriashvili

TRANSMISSION REPORT

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PD : POLLED BY REMOTE SF : STORE & FORWARD RI : RELAY INITIATE RS : RELAY STATION
MB : SEND TO MAILBOX PG : POLLING A REMOTE MP : MULTI-POLLING RM : RECEIVE TO MEMORY

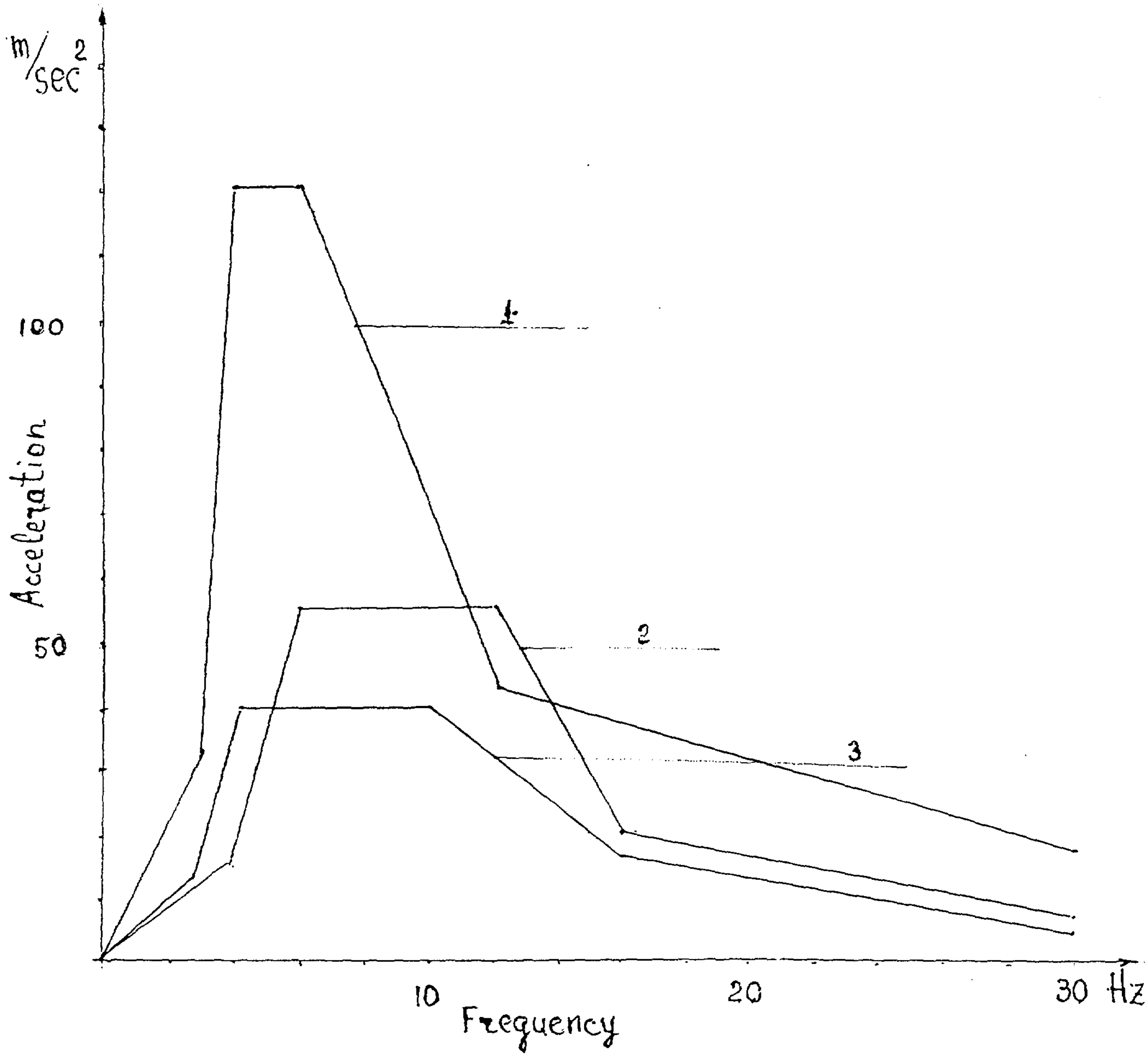


Figure 3 Envelop design floor response spectrum for units 5 and 6 Kozloduy NPP (Horizontal Direction)

Points: -1- Elevation ----45.6 m.
-2- Elevation ----36.6 m.
-3- Elevation ----24.6 m.

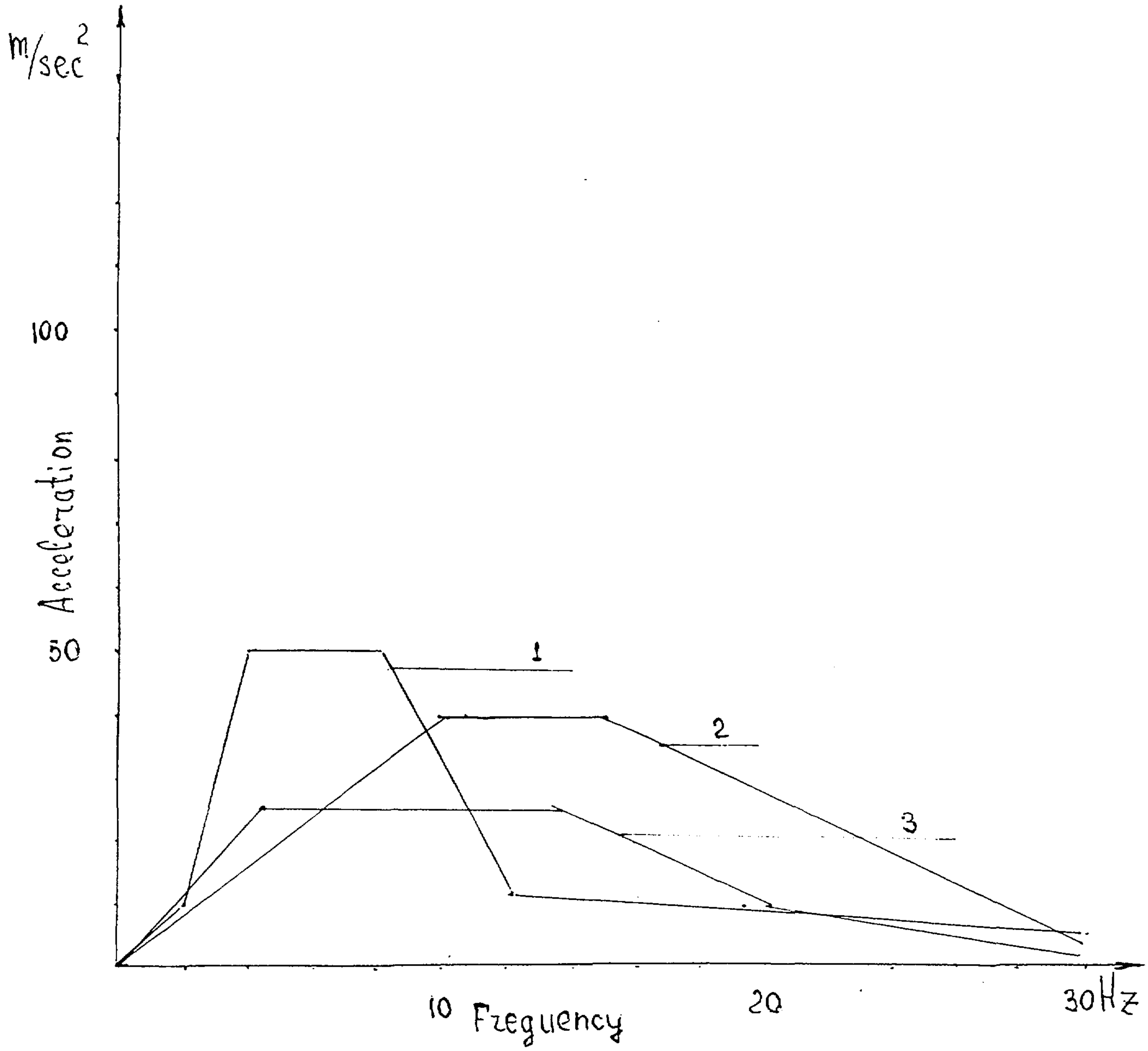


Figure 4 Envelope design floor response spectrum for unit 5 and 6 Kozloduy NPP (Vertical Direction)

Points: -1- Elevation ----45.6 m.
-2- Elevation ----36.6 m.
-3- Elevation ----24.6 m.

Table of acceleration

Table 1

f(Hz)	0	3.0	7.0	30
a m/sec2	0	13	13	4.0

Table of acceleration

(Horizontal Directione)

Table 2

Elevation 45.6m.

f(Hz)	0	3	4	6	12	30
am/sec2 ST NPP*	0	32	120	120	42	18
Kozloduy NPP	0	8	30	30	10.5	4.5

ST NPP-standardized NPP

Elevation 36.6m. Table 3

f(Hz)	0	4	6	12	16	30
a m/sec2						
ST NPP	0	15	55	55	20	7
Kozloduy NPP	0	4	14	14	5	2

Elevation 24.6m Table 4

f(Hz)	0	1.5	2	10	16	30
a m/sec2 ST NPP	0	13	40	40	16	5
Kozloduy NPP	0	3	10	10	4	1

Table of acceleration

(Vertical Diretion)

Elevation 45.6m. Table 5

f(Hz)	0	2	4	8	12	30
a m/sec2 ST NPP	0	10	50	50	10	6.0
Kozloduy NPP	0	2.5	12.5	12.5	2.5	1.5

Elevation 36.6m. Table 6

f(Hz)	0	10	16	30
a m/sec2 ST NPP	0	40	40	4.0
Kozloduy NPP	0	10	10	1.0

Elevation 24.6 Table 7

f(Hz)	0	4	14	20	30
a m/sec2	0	25	25	10	2.0
Kozloduy NPP	0	6.25	6.25	2.5	0.5

Title: **Full-Scale and In-Situ Tests on the Structures and Sites of Kozloduy and Belene NPPs**

Contributor: **S. Simeonov**

Date: **November 1994**

L I S T

OF FULL-SCALE AND IN-SITU TEST HAVE BEEN CARRIED OUT ON THE STRUCTURES AND THE SITES OF NPP KOZLODUI AND NPP BELENE

NPP	OBJECT	SEISMIS SURVEY APPARATUS	EXITATION	RESULTS	YEAR
KOZLODUI	UNIT 1 Reactor Building, Turbine hall and Foundations of Deaerator and Turbine	OYO McSeis 1500 - 24 Channels Survey System, Receivers VEGIK and SM-2	Underground blasts, Inertia forces of bridge crane and crab	Dynamic parameters of structures - natural frequencies damping ratios and amplification functions	1992
	UNIT 2 Reactor Building and Turbine hall	6 Channels Russian System (POB 12M, VEGIK)	Underground blasts, Microtremors	Dynamic parameters of structures - natural frequencies natural modes and damping ratios	1988
	UNIT 3 Reactor Building and Turbine hall	OYO McSeis 1500 - 24 Channels Survey System, Receivers VEGIK and SM-2	Vibromachines, Microtremors	Dynamic parameters of structures - natural frequencies damping ratios and amplification functions	1991
	UNIT 5 Reactor Building and Turbine hall	OYO McSeis 1500 - 24 Channels Survey System, Receivers VEGIK and SM-2	Vibromachines, Microtremors, Underground blasts	Dynamic parameters of structures - natural frequencies damping ratios and amplification functions	1991

CONTINUED

NPP	OBJECT	SEISMIS SURVEY APPARATUS	EXITATION	RESULTS	YEAR
	UNIT 5 Reactor Building and Turbine hall	6 Channels Russian System (POB 12M, VEGIK)	Inertia forces of bridge crane and crab	Dynamic parameters of structures - natural frequencies natural modes and damping ratios	1986
	BOREHOLES near channels for additional techni cal water supplay	OYO McSeis 1500 and and Borehole pick model 3315	Underground blasts, Hammering	Seismic wave velocities - Vp, Vs	1989
	BOREHOLES near Unit 2 and Unit 3	OYO McSeis 1500 and and Borehole pick model 3315	Underground blasts, Hammering	Seismic wave velocities - Vp, Vs	1991
	BOREHOLES near Unit 5	OYO McSeis 1500 and and Borehole pick model 3315	Underground blasts, Hammering	Seismic wave velocities - Vp, Vs	1991
	BOREHOLES near Pumphouse #1	OYO McSeis 1500 and and Borehole pick model 3315	Underground blasts, Hammering	Seismic wave velocities - Vp, Vs	1992
	BOREHOLES near Concrete center	VSS-1	Hammering, Microtremors	Seismic wave velocities - Vp, Vs Level of microtre-mors	1988

CONTINUED

NPP	OBJECT	SEISMIS SURVEY APPARATUS	EXITATION	RESULTS	YEAR
BELENE	SPECIAL MEASUREMENT PROFILE	OYO McSeis 1500, 6 Channels Russian System	Underground blasts, Hammering, Weight dropping	Seismic wave velocities - Vp, Vs Attenuation of seismic waves	1980 1981 1983
	GRAVEL EMBANKMENT	OYO McSeis 1500	Hammering	Seismic wave velocities - Vp, Vs Level of microtre-mors	1983

Title: Initial Data of Seismic Input and Soil Conditions of Kozloduy NPP Site

Contributor: Z. Boyadjiev

Date: June 1994

NPP Kozloduy

Initial Data

of Seismic Input and Soil Conditions

# of Kozloduy NPP Site

Extention to Part II
Soil Conditions
issued October '93

June, 1994

following summrized data rated for the project geotechnical seismic model of the site "free field" (Table 3.3.1 and Figure 3.3.1):

Notes to Table 3.3.1.:

1. The geotechnical seismic model of the "free field" profile is made out on the basis of the data about the lithological profile of Borehole C1/92 with coordinates A=587.28 and B=918.110.

2. The depths are measured from a levelled terrain elevation at Borehole C1/92 (...34.70).

3. The velocities below 245 m have been determined by the author by analitical relationships for Vs = f (H).

4. The bulk density and the lithological description for depth below 254 m are according to data of Borehole MCD1/78, made for depth up to 505 m [2].

The lithological profile at the different parts of the site is different from the synthesis profile of the whole site (Figure 3.3.1) both in type and in the thickness of the types of soils representing it and this is true especially for the foundations

of the main buildings. As an example of that the geological profiles of the study boreholes below the foundation plate of the reactor building of Unit V may be given (Figure 3.3.2). For this reason, when solving the tasks of the "soil - structure unteraction analysis" for the different structural units on the NPP site, it is necessary to make out a geotechnical seismic model of the profiles of the particular soil conditions at the places of these structures. As an example of a geotechnical seismic model under the foundation we may submit - for one to get an idea - the model of the soil profile below the foundation plate of the reactor building of Unit V (Figure 3.3.3).

TABLE 3.3.1. SUMMARIZED DATA FOR THE GEOTECHNICAL SEISMIC MODEL OF THE SITE "FREE FIELD" PROFILE

No	LITHOLOGICAL DESCRIPTION	DEPTH FROM THE SURFACE h, m from..to..	THICK-NESS H, m	VELOCITIESS V: Vs m/s	VELOCITIESS V: Vp m/s	BULK DENSITY ρn g/cm3	PUASC COEF: CIEN μ
	(1) IN SITU DETERMINED						
1.	Fills by loss materials	0.0-3.0	3.0	170	470	1.60	0.4[illegible]
2.	Sandy loess	3.0-7.0	4.0	175	540	1.60	0.4[illegible]
3.	Clayey loess	7.0-13.5	6.5	450	1180	1.80	0.4[illegible]
4.	Gravelly sand, clayey at the basis	13.5-18.5	5.0	500	1600	2.00	0.45
5.	Compact clay, slightly weathered	18.5-21.5	3.0	500	1600	2.00	0.45
6.	Sand-fine, clayey, gravelly at some places	21.5-31.0	9.5	500	1600	2.12	0.45
7.	Sandy clay, compact	31.0-42.0	11.0	430	1700	2.10	0.47
8.	Sand -fine, clayey	42.0-84.6	42.6	520	1700	1.92	0.45
9.	Sand-fine, highly clayey	84.6-104.0	19.4	550	1700	1.98	0.44
10.	Highly sandy clay to highly clayey sand at the basis	104.0-133.0	29.0	450	1600	2.01	0.46
11.	Marly clay , compact	133.0-151.0	18.0	540	1600	1.98	0.44
12.	Marly caly, compact	151.0-175.0	24.0	580	1750	2.00	0.44
13.	Marly caly, compact	175.0-204.0	29.0	530	1470	1.96	0.43
14.	Marly clay, compact	204.0-224.0	20.0	630	1470	1.98	0.37
15.	Clayey marl	224.0-245.0	21.0	680	1700	2.00	0.40

TABLE 3.3.1. SUMMARIZED DATA FOR THE GEOTECHNICAL SEISMIC MODEL OF THE SITE "FREE FIELD" PROFILE (continued)

No	LITHOLOGICAL DESCRIPTION	DEPTH FROM THE SURFACE h, m from..to..	THICK-NESS H, m	VELOCITIESS V Vs m/s	Vp m/s	BULK DENSITY ρn g/cm3	PUASON' COEFFICIENT μ
	(2) RATED (assumed)						
16.	Clayey marl with interlayers of comoact sands (seismic bed rock)	245.0-265.0	20.0	705	1760	1.96	0.40
17.	Clayey marl with interlayers of compact sands sands	< 265.0	-	>705	>1760	2.00	-

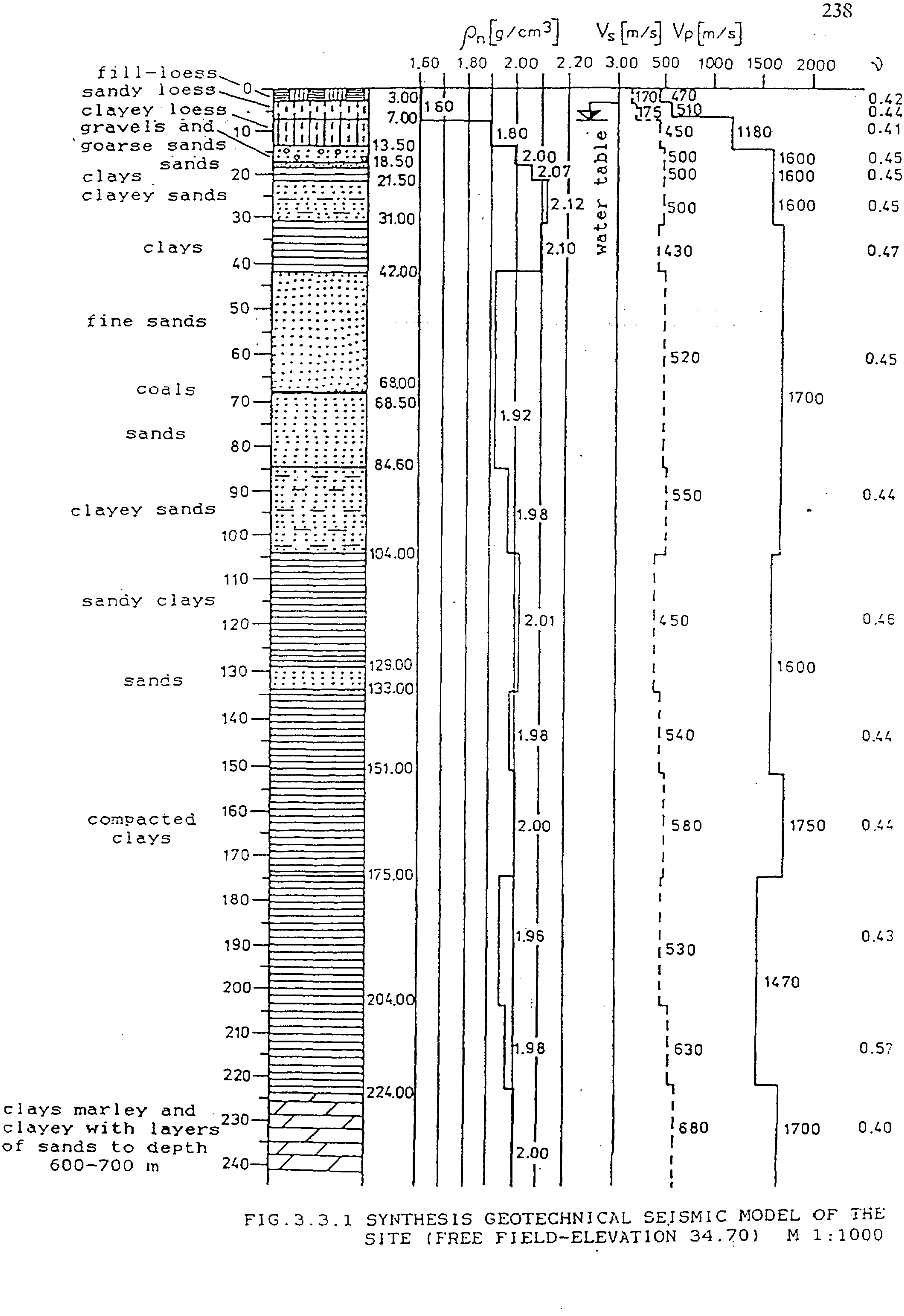


FIG.3.3.1 SYNTHESIS GEOTECHNICAL SEISMIC MODEL OF THE SITE (FREE FIELD-ELEVATION 34.70) M 1:1000

SUMMARY

On the basis of the results of the carried out experimental (laboratory and in situ) investigations of the dynamic characterstics, the following conclusions have been made for the Kozloduy NPP site:

(1) The established through experimental studies relationships for the shear modulus (G) and the damping factor (D) as strain dependent of representative samples of soils of the site profile , can be used for all similar soils in the profile in the different parts of the site, taking into account the possible differences by means of the initial shear modulus (Go) in the normalized relationship G/Go--.. for the respective generalized soil type (Tables 3.2.1 - 3.2.5 and Figures 3.2.1 - 3.2.5).

(2) When solving the problems of the site response and the "soil - structure analysis", the geotechnical seismic model of the "free field" profile (Figure 3.3.1) can be assumed for all parts of the NPP site.

(3) The changes of the lithological profile in the different parts of the site, in respect of type and thickness, as well as in view of the different way and depth of the NPP structures foundation, make it necessary to elaborate also a geotechn ical seismic model of the profile below the foundation plates of the reactor buildings of the NPP units in each particular case. These models can be made out on the basis of the summarized data about the shear velocities (Vs) of the soil types (Table 3.3.1), the lithological data of the study boreholes in these places and the data about the natural bulk density (ρ_n) at 30 - 40 m depth determined by the laboratory studies of samples of these soils, assuming with approximation that the geotechnical seismic model below this depth is the same as the one of the "free field" (Table 3.3.1 and Figure 3.3.1).

(4) Studies have been carried out through in situ and laboratory studies of all the fundamental structures on the NPP site and the results of them are sufficient as an additon to the present initial data for solving the problems of the site response and the "soil-structure inter-action (SSI) analyses of each structure.

REFERENCES

1. Vlahov, J. "Kozloduy" NPP. Engineering-geological Investigations of the Site in Connection with Its Seismic Safety, Sofia, 1991, Geological Archives, (In Bulgarian).

2. Gogov, K. "Kozloduy" NPP. Results of the Carried Out Borehole and Laboratory Investigations in Connection with the Microseismic Regioning, Sofia, 1978. Geological Archives, (In Bulgarian).

3. Gogov, K. "Kozloduy 3" NPP. Engineering-geological and Hydrogeological Conditions in the area of the Apparatus Room - Unit V, Sofia, 1980, Geological Archives, (In Bulgarian)

4. Gogov, K. "Kozloduy 3" NPP. Engineering-geological and Hydrogeological Conditions in the area of the Engine Room - Unit V, Sofia, 1980, Geological Arhives, (In Bulgarian)

5. Gogov, K. "Kozloduy 3" NPP. Engineering-geological and Hydrogeological Conditions in the area of the Apparatus Room - Unit VI, Sofia, 1980, Geological Archives, (In Bulgarian)

6. Gogov, K. "Kozloduy 3" NPP. Engineering-geological and Hydrogeological Conditions in the area of the Engine Room - Unit V, Sofia, 1980, Geological Archives, (In Bulgarian)

7. Ivanov, R. Boev, S. "Kozloduy 3" NPP. Resultss of the geophysical Investigations in the area of the Main Buildings (Units V and VI), Sofia, 1980, Geological Archives, (In Bulgarian)

8. Ivanov, R. Nakova, E. "Kozloduy" NPP. Seismic Investigations of the site in connection with its Seismic Safety, Sofia, 1991, Geological Archives.(In Bulgarian).

9. Kolev, Iv. "Kozloduy 3" NPP - Unit V. Physical-technical Characteristics of the Artificial Soils and the Geological Varieties below theFoundations of thepparatus Room, Sofia,1985, Geological Archives. (In Bulgarian).

10. Kovel, Iv. "Kozloduy" NPP. Carrying out of Seismic Studies for Specifyingthe Changes in the Seismic Waves Velocities in the site,Sofia, 1992, Geological Archives. (In Bulgarian).

11. Michev, St."Kozloduy" NPP. Carrying out of Seismic Studies for Specifying the Changes in the Seismic Waves Velocities in the site, Sofia, 1992, Geological Archives of "Geology and Geophysics" .(In Bulgarian).

12. Pavlov, I."Kozloduy" NPP. Carrying out of Seismic Studies for Specifying the Changes in the Seismic Waves Velocities in the site,Sofia, 1992, Geological Archives of "Geology and Geophysics" .(In Bulgarian).

13. Petkov, Ts."Belene" NPP. Dynamic Characteristics and Connected with them Density Indices and Seismic Waves Velocities of the Engineering-Lithological Types of the site Profile. Sofia, 1992, NPP Geological Archives. (In Bulgarian).

14. Stefanov, Iv. "Kozloduy" NPP. Initial Data for the Expert Examination by IAEA Concerning the Seismics of the Site, Sofia, 1990, Geological Archives. (In Bulgarian).

15. Stefanov, Iv. "Kozloduy" NPP. Hydrological Investigations and building piezomers for Radio-isotope Studies. Sofia, 1985, Geological Archives. (In Bulgarian).

16. СНиП II-19-79 Foundations of Dynamic Load Machines, Moscow, 1982 (In Russian).

17. * * * ННИИОСП N.M. Gersevanov Manual in Designing Foundations of Dynamic Load Machines, Moscow, 1982 (In Russian).

18.Ishihara, K. Evaluation of soil properties for use in earthquake response analysis, International Simposium on Numerical Models in Geomechanics, Zurich, 1982.

19. Stoikovic, M. Investigation of the StationaryCharacteristics of Microtremors and Equivalent Geotechnical Models,Disertation, Skopie, 1985.

20. Thiers, G.R., Seed, H.B., Cyclic Stress - Strain Characteristics of clay, J. SMMFD, ASCE, Vol 94, No SM2, 1968.

21. * * * IZIIS - Investigations for increase of the seismic safety of the NPP Kozloduy. Dinamic Laboratory Testing and Investigationsof Soil Samples for Determination of the G-modulus and Damping of the Soil Layers as strain Dependent, Skopie, 1991.

22. GLBAS, Investigations and activities for increasing of the NPP "Kozloduy" site safety - summary Sofia, April, 1994.

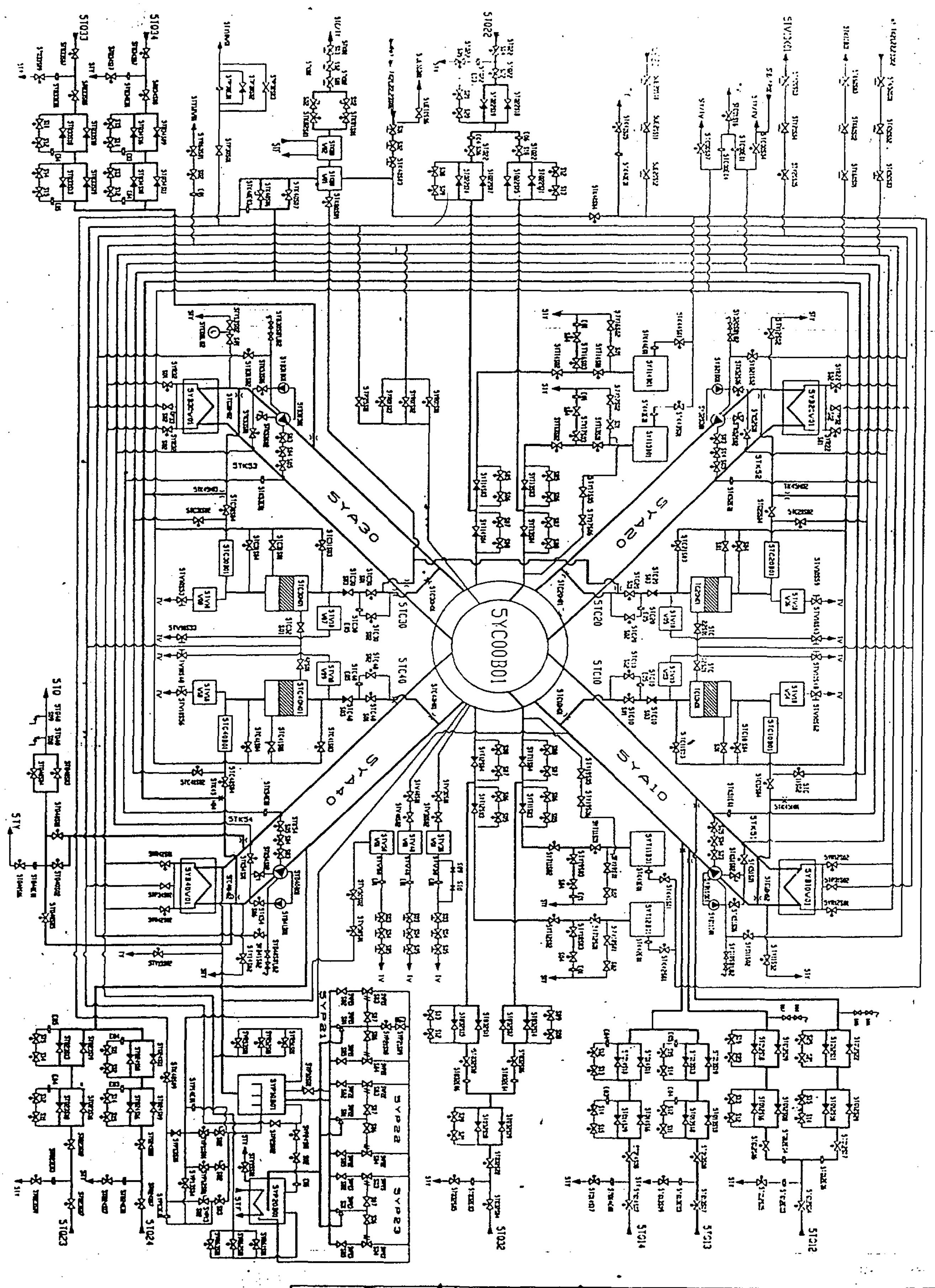
Table 5.25. Normalized Numerical Mean Values of Shear Moduli G/Gmax and Damping Coefficients D Depending on Shear Strain Amplitude γ, Soil Material TYPE 6. Loess cement IZIIS 91-99

Shear Strain γ (%)	Mean Values	
	G/G_{max}	D (%)
0.000316	1.0000	
0.001000	0.9804	0.0458
0.003160	0.9201	0.0603
0.010000	0.8123	0.0872
0.020000	0.7353	0.1078
0.050000	0.6261	0.1499
0.100000	0.5179	0.1875
0.200000	0.3961	0.2236
0.500000	0.2733	0.2466
1.000000	0.1915	0.2558
3.160000	0.1158	0.2583

Title: **Drawings: Kozloduy NPP**

Contributor: **Z. Boyadjiev**

Date: **June 1994**



Гл. инженер	Гиздонов		09.93	I Ви КОНТУР Y
Р-л напр. Е			09.93	
Н-к цех	Йорданов		09.93	35. РЦ. YA. TC. 02 — АЕЦ"КОЗЛОДУЙ"-ЕП V-енергоблок
		R05 \ YA		

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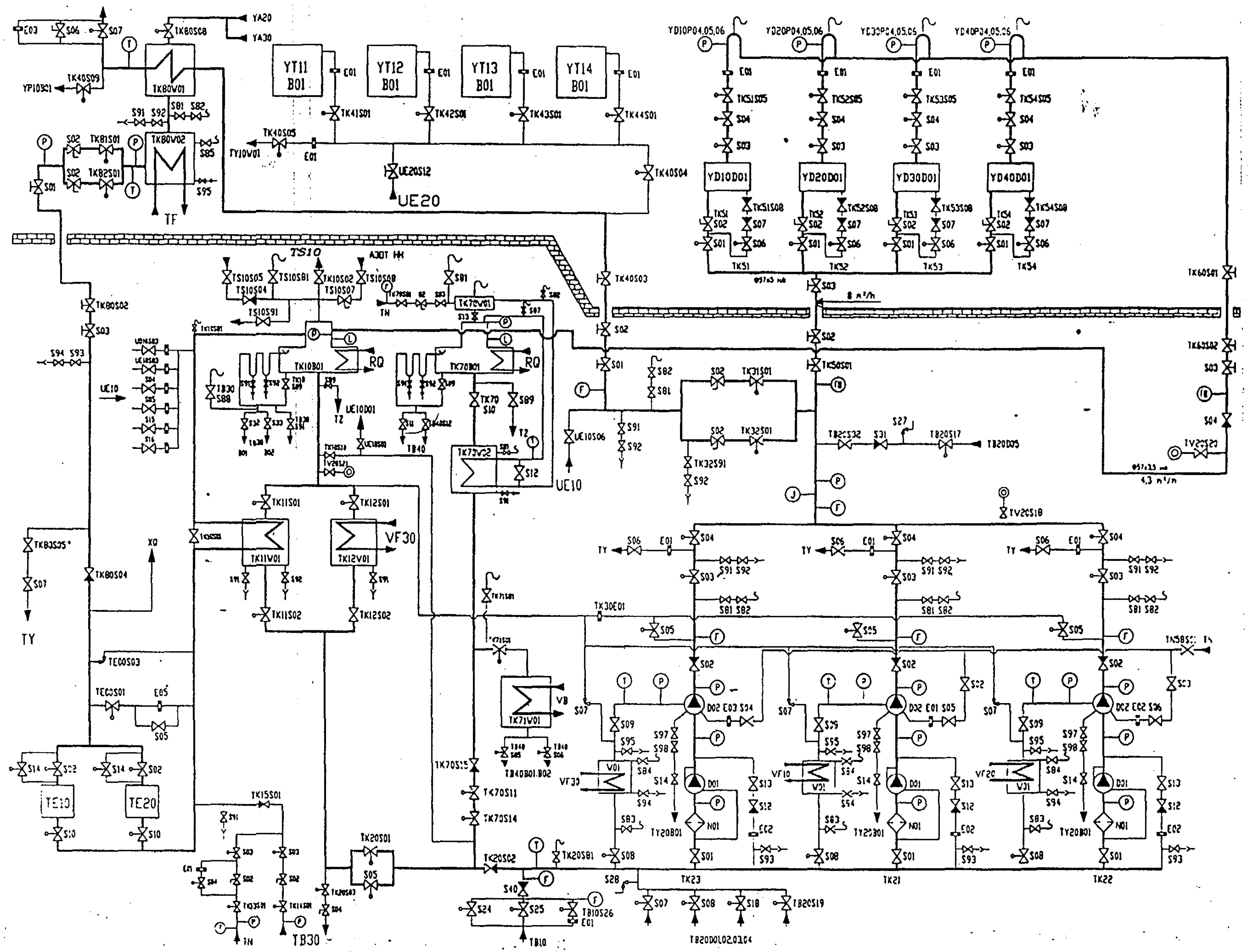
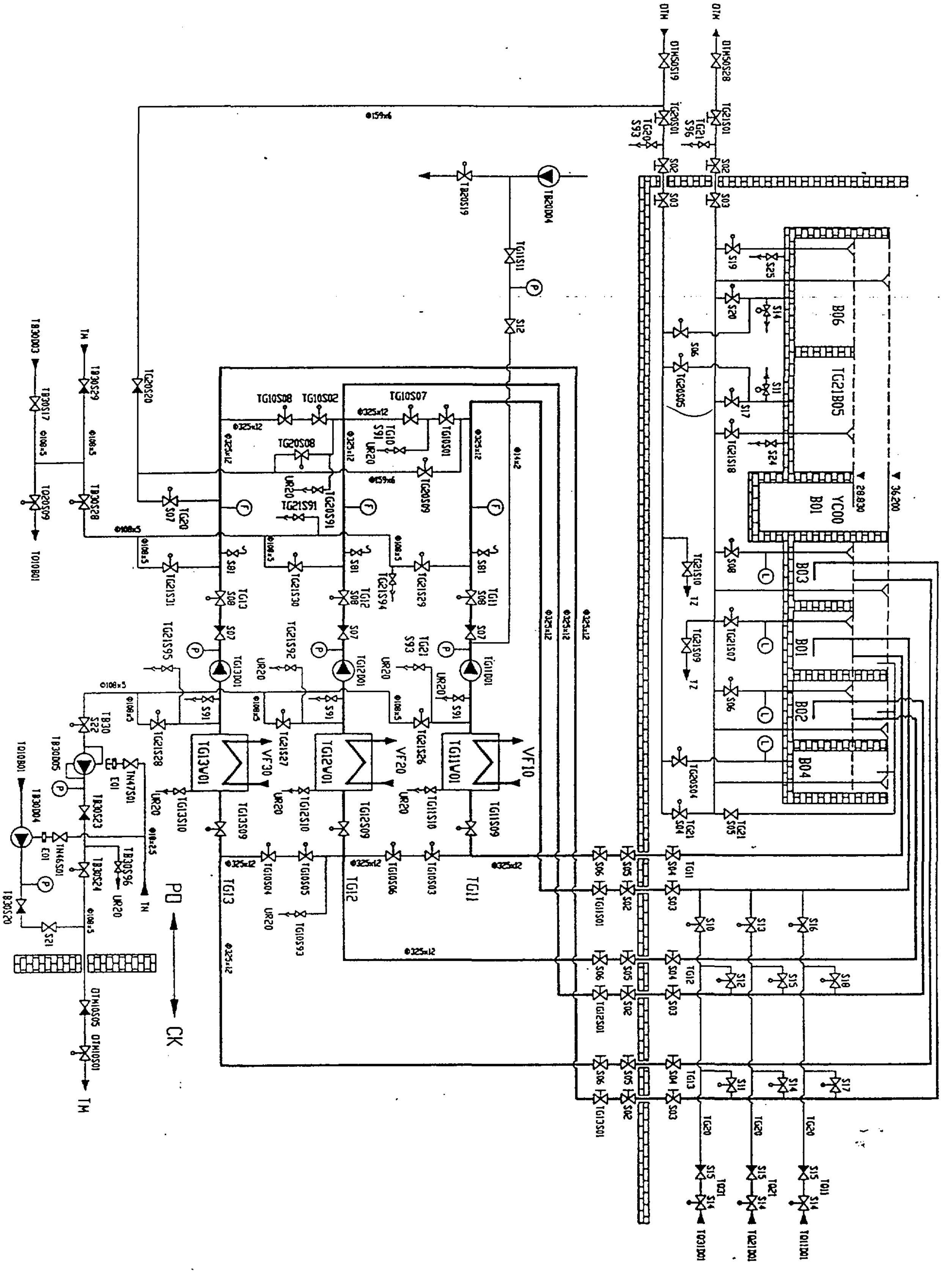


Гл. инженер
Р-л напр. Е
II-к цех
ROS\TK
Продувка–подпитка I-ви контур
ТК
35.РЦ.ТК.ТС.04
АЕЦ "КОЗЛОДУЙ" – ЕП2
V–енергоблок

3
TK



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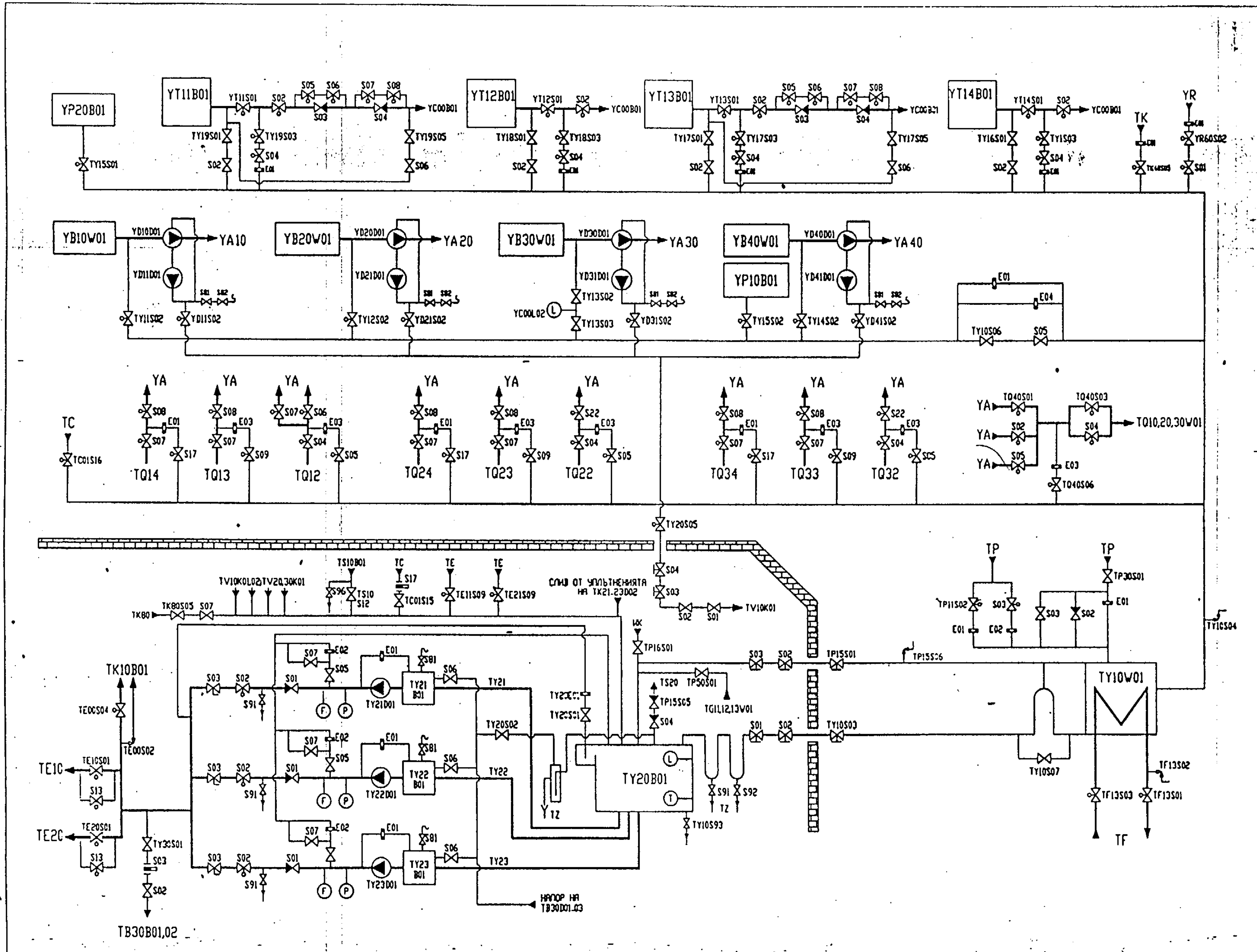
Р-л напр. "Е"	[signature]	Хаджиев	01.94	35. РЦ. TG. TC. 06	АЕЦ "КОЗЛОДУЙ" - ЕП2 V-енергоблок
Н-к цех	Йовчев	[signature]	94.01		
		R05\TG			



35. РЩ. ТУ. ТС.09

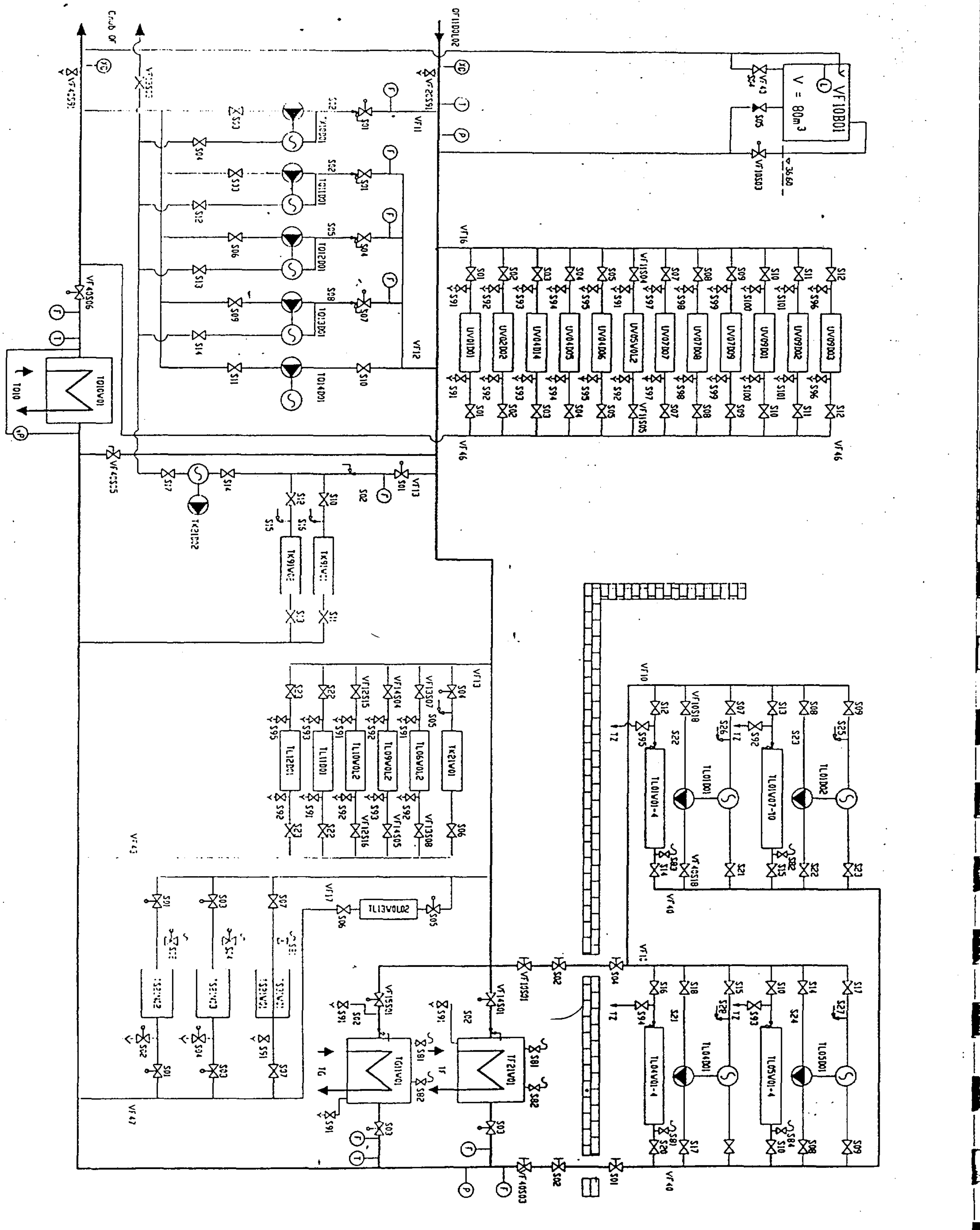
АЕЦ "Козлодуй" - ЕП2 V-енергоблок

Система организирани протечки

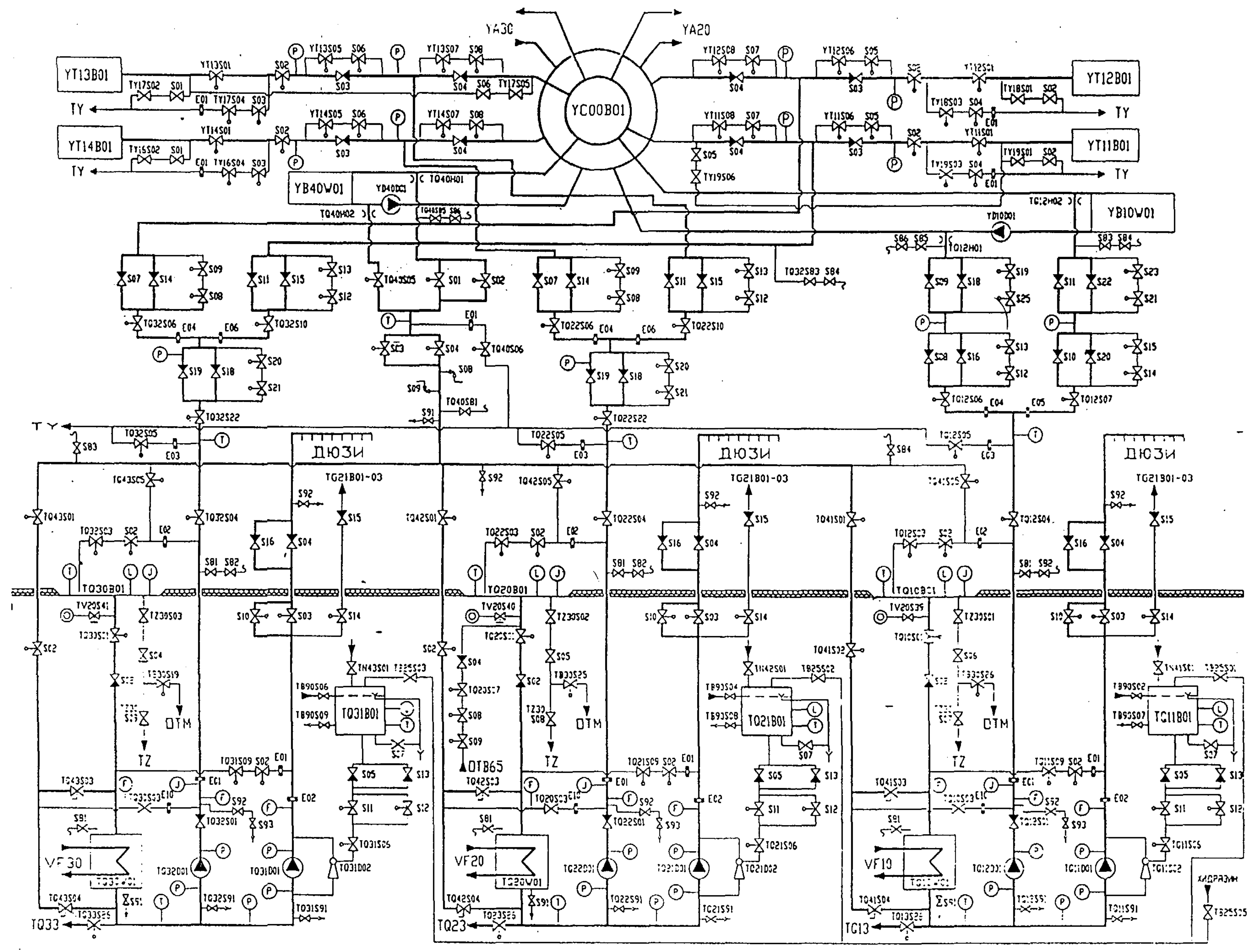
ТУ

Гл. инженер			08.93
Р-л напр. "Е"	Харизанов		08.93
II-к цех	Льдзов		07.93

8

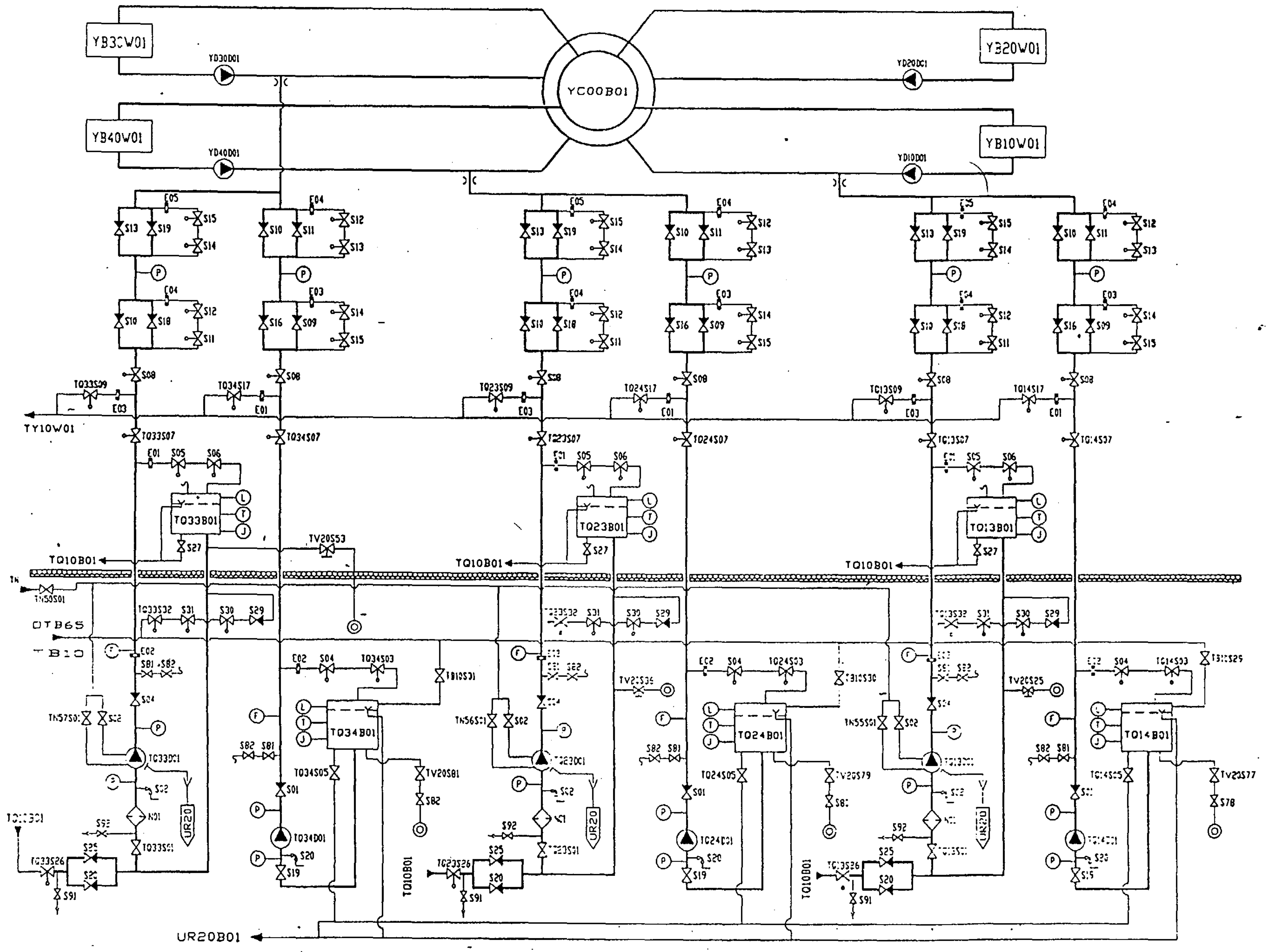


Гл. инженер			I Система техническа вода	VF10
Р-л напр."Е"	Хаджиев	11.07		
Н-к цех	Мовчев	93.04.	35.РЦ.VF10.TC.14	АЕЦ"КОЗЛОДУЙ"-ЕП2 V-енергоблок
		K05\VF10		



Гл. инженер	Халачев	08.93	Сплинкерна система и планово, аварийно разхлаждане TQ1 TQ2
Р-л напр. Е			35.РЦ.TQ1,2.TC.19
Н-к цех			АЕЦ "КОЗЛОДУЙ" - ЕП2 V-енергоблок
	ROS\TQ1		

18



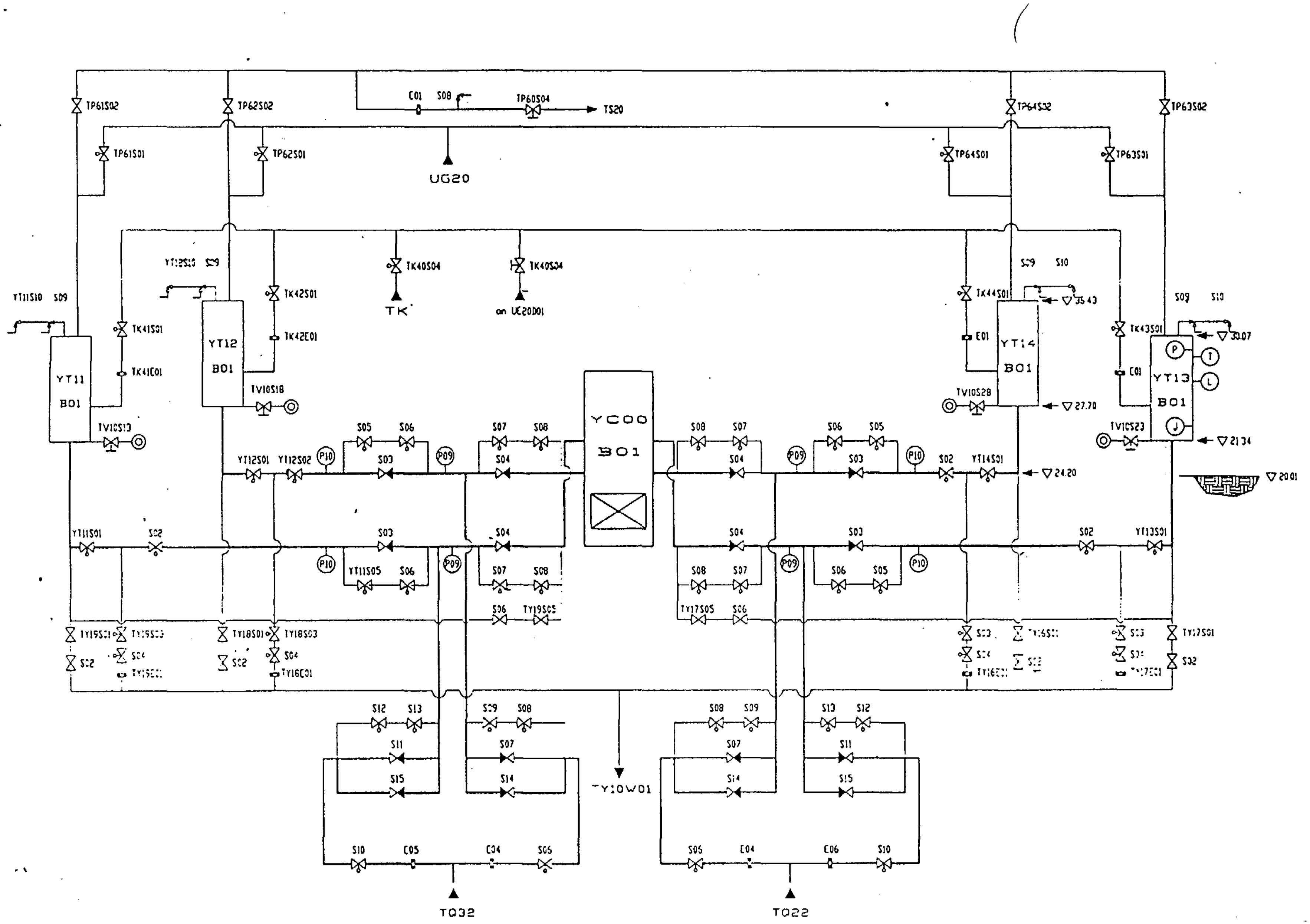
Система за аварийно въвеждане на борна киселина ниско и високо налягане TQ3 TQ4

35.РЦ.TQ3,4.TC.20

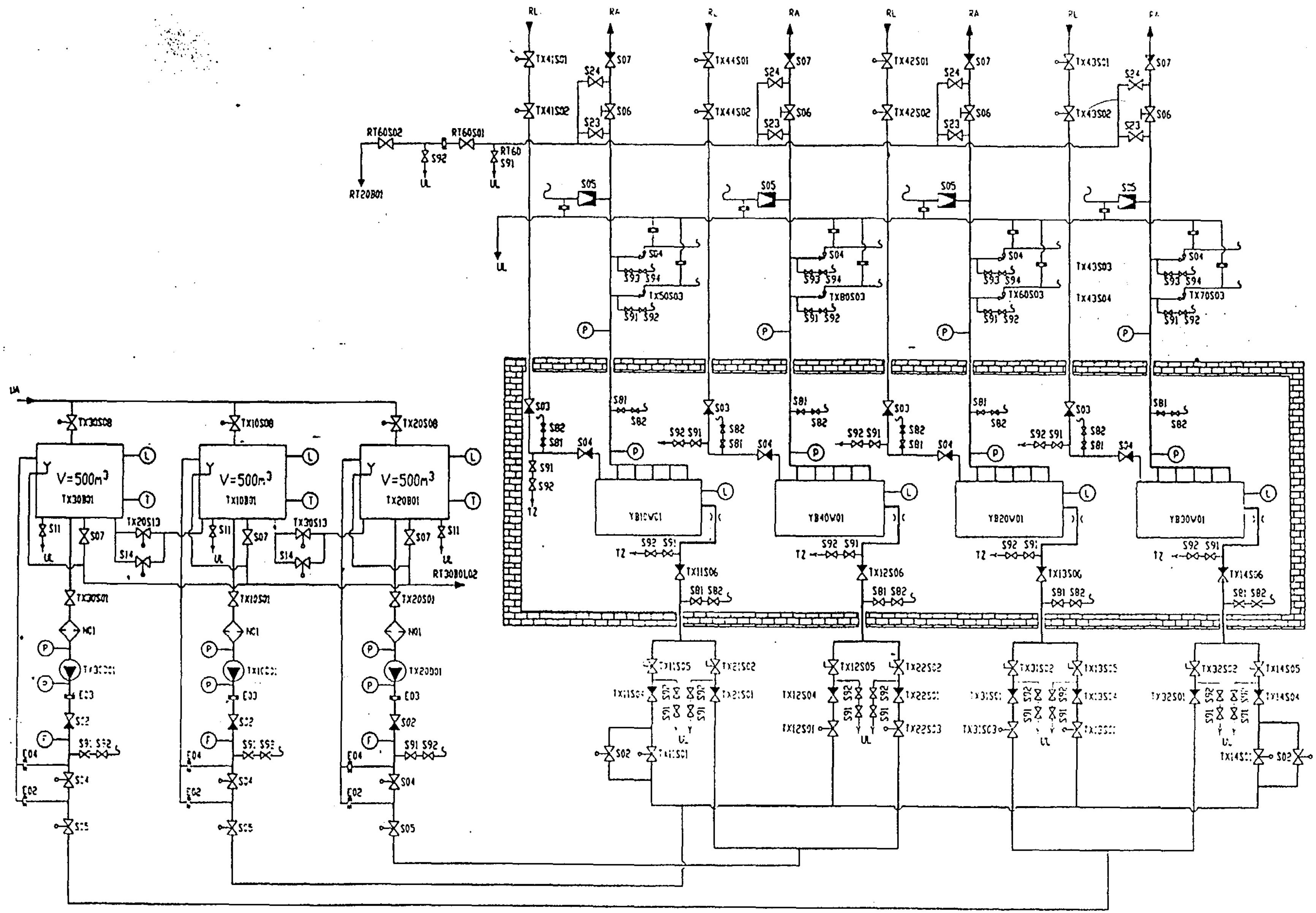
АЕЦ"КОЗЛОДУЙ"-ЕП2 V-енергоблок

Гл. инженер
Р-л напр. Е
Н-к цех

08.93



Гл. инженер		93.01	САО3 – пасивна част	YT
Р-л напр. Е		93.04	35.РЦ.YT.TC.21	АЕЦ"КОЗЛОДУЙ"–ЕП2 V-енергоблок
II-к цех		ROS\YT		



Гл. инженер			*Аварийна подпитка на ПГ* TX
Р-л напр. "Е"	Харитов	02.04	
Н-к цех	Ицычев В.	93.04	35. РЦ. TX. TC. 37
		R05\TX	АЕЦ "КОЗЛОДУЙ" – ЕП2 V-енергоблок

List of safety and safety-related systems of WWER-1000

1. .Systems for normal operation - safety related

- reactor and internal equipment (YC)
- main circulation pipes (YA)
- main circulation pumps (YD10-40)
- steam generators (YB10-40)
- pressurizer system (YP)
- make-up/let-down system (TK)
- bypass purification system (TC)
- ionite filers (TE)
- drainages and organized leakages (TY)
- special air purification system (TS10,20)
- intermediate circuit (TF)
- sampling and reagent system (TB,TV)
- steam lines (RA)
- feed water system (RL)
- let-down of the steam generators (RY)
- spent fuel pool cooling system (TG)
- service water- cooling of equipment (VB)
- ventilation systems (TL)
- system for monitoring and control (ASUTP),

2. Safety systems

2.1. Protection systems

- control rods
- hydroaccumulators (YT)
- high pressure Boron injection (TQ4)
- Boron injection (TQ3)
- low pressure injection and cooling system (TQ2)
- protection of the primary circuit from over pressurization
- protection of the secondary circuit from over pressurization
- emergency gas evacuation system (YR)

2. Localizing systems

- containment
- containment spray system (TQ1)
- isolation valves

3. Support systems

- reliable electrical supply
- service water system (QF, VF)
- venting of the safety equipment rooms
- emergency lighting
- fire extinguishing (UJ)

4. Control systems

- instrumentation related to starting of safety systems
- control of the equipment of safety systems, set points and interlocks
- main control room and emergency control room
- programmes of ASP.

IDENTIFICATION LIST OF THE MAIN SYSTEMS

ES	Main grid distribution system
ARM	Automatic power controller
ASP	Programmes of automatic safety systems starting
BA,BB,BC,BC	Electrical supply sections 6 kV (house loads)
C*	Electrical supply sections 0.4 kV (
BV,BW,BX	Reliable electrical supply sections 6kV
CV,CW,CX	Reliable electrical supply sections 0.4 kV
GV	Diesel generator 1 channel
GW	Diesel generator 2 channel
GX	Diesel generator 3 channel
EF	Invertors
QF	Service water group A - for safety systems
BT	High voltage transformers (main and reserve)
BU	Transformers 6/0.4 kV
EA	Accumulator batteries
EGSR	Electro-hydraulic turbine control system
EQ	System for uninerruptable AC supply
F	Emergency lighting
RA	Fresh steam lines
RB	System for moisture separating and steam reheatig
RC	Turbine bypass system (BRU-K)
RD	High pressure heaters
RE	Secondary coolant purification system with ionite filers
RH	Low pressure heaters
RL	Feed water system
RM	Turbine condensate system
RN	Condensate from heaters
ROM	Power restriction controller
RQ	Steam for service systems
RT	Drain system in turbine building
RY	SG let-down system
RZA	Protections and interlocks of electrical equipment
SA	Turbines
SC	Lubrication of turbine bearings
SC90	Hydraulic system for turbine rotor lifting
SD	Condenser
SS	Cooling of generator
ST	Cooling of hydrogen in the generator
SU	Sealing of generator shaft
SU90	Lubrication system for condensate pumps
SUZ	Reactor protection
TA	Oil system in reactor building
TB	Reagent tanks
TC	Primary coolant filtering system
TE	Primary coolant purification system with ionite filers
TF	Intermediate circuit
TG	Spent fuel pool cooling system
TK	Make-up/discharge and Boron control system
TL	Venting systems

TN	Demineralised water in reactor building
TQ1	Containment spray system
TQ2	Core cooling system
TQ3	High pressure Boron injection (TQ3)
TQ4	High pressure Boron injection
TR	Radioactive drainage cleaning system
TS	Gas purification and Hydrogen ignition system
TU	Decontamination of equipment
TX	Emergency feed water system
TY	Organized leakages system
TZ	Special drainage treatment system
UA	Demineralized water in turbine building
UJ	Fire extinguishing
UV	Air conditioners
VB	Service water group B cooling of equipment
VC	Service water for cooling of turbine condensers
VF	Service water group A in reactor building - for safety systems
XQ	Radiation monitoring system, incl. sampling from main building
YA	Primary cooling system
YB	Steam generator
YC	Reactor
YD	Main coolant pumps
YD50,60	Oil systems for primary coolant system pumps
YP	Pressurizer system
YR	emergency gas evacuation system
YT	Hydroaccumulators
YZ	Instrumentation related to starting of safety systems

Each element of the equipment of NPP has an unique alphanumeric identification code of the type:

5TX20D01

5: Unit number (numeric)
TX: System code (literal)
20: Part of system code (numeric)
D: Type of the element
01: Sequential number of the element of the same type in the system

The type of element is:

B - reservoir
D - pump
W - heat-exchanger
N - filter
S - valve
F - flow measurement
L - level measurement
T - temperature measurement
P- pressure measurement

Equipment for fragility development

Elevation	Room	Equipment	Group
-4.20	034	Concentrated boric acid system pumps	13
	036/1	Spray pump, 1st train Water-jet pump, 1st train Low pressure injection pump, 1st train High pressure injection pump, 1st train	18 18 18 13
	036/2	Spray pump, 2nd train Water-jet pump, 2nd train Low pressure injection pump, 2nd train High pressure injection pump, 2nd train Spray solition mixing pump	18 18 18 13 13
	036/3	Spray pump, 3rd train Water-jet pump, 3rd train Low pressure injection pump, 3rd train High pressure injection pump, 3rd train	18 18 18 13
	038/1	Emergency feed-water pump, 1st train	18
	038/2	Emergency feed-water pump, 2nd train	18
	038/3	Emergency feed-water pump, 3rd train	18
	052 057	Auxiliary Control Room	24
	018/1	Oil tank Oil pump Oil pump Oil cooler Oil cooler	7 13 13 7 7
	018/2	Oil tank Oil pump Oil pump Oil cooler Oil cooler	7 13 13 7 7
	018/3	Oil tank Oil pump Oil pump Oil cooler Oil cooler	7 13 13 7 7

Elevation	Room	Equipment	Group
0.00	123/1	Spray System tank Emergency Concentrated boric acid tank Emergency cooling heat exchanger Spent fuel tank head exchanger Spent fuel tank cooling pump Emergency boric injection pump	10 10 6 6 18 18
	123/2	Spray System tank Emergency Concentrated boric acid tank Emergency cooling heat exchanger Spent fuel tank head exchanger Spent fuel tank cooling pump Emergency boric injection pump	10 10 6 6 18 18
	123/3	Spray System tank Emergency Concentrated boric acid tank Emergency cooling heat exchanger Spent fuel tank head exchanger Spent fuel tank cooling pump Emergency boric injection pump Spent fuel tank clearing pump Emergency boric acid solution clearing tank	10 10 6 6 18 18 13 13
	119/1	Buster pump Make-up pump	13 18
	119/2	Buster pump Make-up pump	13 18
	119/3	Buster pump Make-up pump	13 18
	124/1	Clear boric concentrate tank	10
	124/2	Clear boric concentrate tank	10
	128/1	Unified computing System	25
	128/2	Unified computing System	25

Elevati	Room	Equipment	Group
3.60	205	Emergency chemically treated water	10
6.60	336	Ionisation chambers	26
	340	Panels	25
	341	Main Control Room	24
	ГА201	Emergency Water Tank	10
	329/1	I&C - 1st system	26
	329/2	I&C - 1nd system	26
	329/3	I&C - 3rd system	26
	319	Make-up Sistem head exchangers	7
13.20 и 13.70	Г306/1	Boric acid tank	10
	Г306/2	Boric acid tank	10
	Г306/3	Boric acid tank	10
	408/1	Unified	34
	408/2	Technological connections	34
	408/3	Technological connections	34
	407/1	Batteries	21
	407/2	Batteries	21
	407/3	Batteries	21
	415/1	Automatic neutron flow control	34
	415/2	Automatic neutron flow control	34
	415/3	Automatic neutron flow control	34
	423	Make-up Sistem deaerator	9
	424	Boric Control Deaerator	9
19.20 и 20.4	Г407/1	Steam generator Room	
	Г407/2	Steam generator Room	
	Г401	Spent fuel tank	10
	607/1	House loads Switchgear - 1st system	27
	607/2	House loads Switchgear - 2nd system	27
	607/3	House loads Switchgear - 1rd system	27
	609/1	Reactor Control&Pressurizer Switchgear	34
	609/2	Reactor Control&Pressurizer Switchgear	34
	606	House load switchgear - 4th system	27

Equipment groups for fragility development

Category	Equipment	Group number
Site Specific Components	Reactor core	1
	Reactor pressure vessel	2
	Pressurizer	3
	Steam Generator	4
	Reactor Coolant Pump	5
Mechanical equipment	Large Horizontal Vessels	6
	Small to medium vessels and heat exchangers	7
	Piping	8
	Large vertical storage vessels with formed heads	9
	Large vertical flat bottom Storage tanks	10
	Miscellaneous small valves	11
	Large vertical centrifugal motor-driven pumps	12
	Motor-driven pumps and compressors	13
	Large motor-operated valves	14
	Small motor-operated valves	15
	Large hydraulic and airactuated valves	16
	Large relief and check valves	17
	large horizontal motor-driven pumps	18
I&C and Electrical equipment	Generators	19
	Diesel-generators	20
	Batteries	21
	Switchgears	22
	Dry tansformers	23
	Control panels	24
	Panels	25
	Local instruments	26
	Bus-bars	27
	Emergency light	28
	Communications equipment	29
	Inverters	30
	Cable trays	31
	Ciruit breakers	32
	Relays	33
	I&C	34
	Ceramic insolators	35
Miscellaneous equipment	Fans	36
	Ducts	37
	Hidraulic snubbers and pipe supports	38

Elevantion	Room	Equipment	Group
24.60 и 25.70	Г506/1	Steam generator compartment	5
	Г506/2	Steam generator compartment	5
	Г502/1	Hydro-accumulator	9
	Г502/2	Hydro-accumulator	9
	Г504/1	Reactor Control pump drive	5
	Г504/2	Reactor Control pump drive	5
	Г504/3	Reactor Control pump drive	5
	Г504/4	Reactor Control pump drive	5
	725	Reactor protection panels - 1st set	34
	733	Reactor protection and control panels	34
	734	Reactor protection panels - 2nd set	34
	726/1	Reactor protection Control panels	34
	726/2	Reactor protection Control panels	34
	732	Reactor protection and control system battery	21
	739	d.c. switchgear	27
	738	Battery	21
25.7 и 28.8	Г506/1	Steam generator	4
	Г506/2	Steam generator	4
	Г506/3	Steam generator	4
	Г506/4	Steam generator	4
	826/1	Fire pumps	13
	826/2	Fire pumps	13
	820	Steam dump to the athmosphere Fast acting isolation valves Relief valves	17 17 17
	819/1		15
33.6	910/1	Aux. service water tank	10
	910/2	Aux. service water tank	10
	910/3	Aux. service water tank	10
41.4	1035/1	II category 0.4 kV bus-bar	27
	1035/2	II category 0.4 kV bus-bar	27
	1035/3	II category 0.4 kV bus-bar	27

Гл. инж.:
/инж. Ив. Грозанис/

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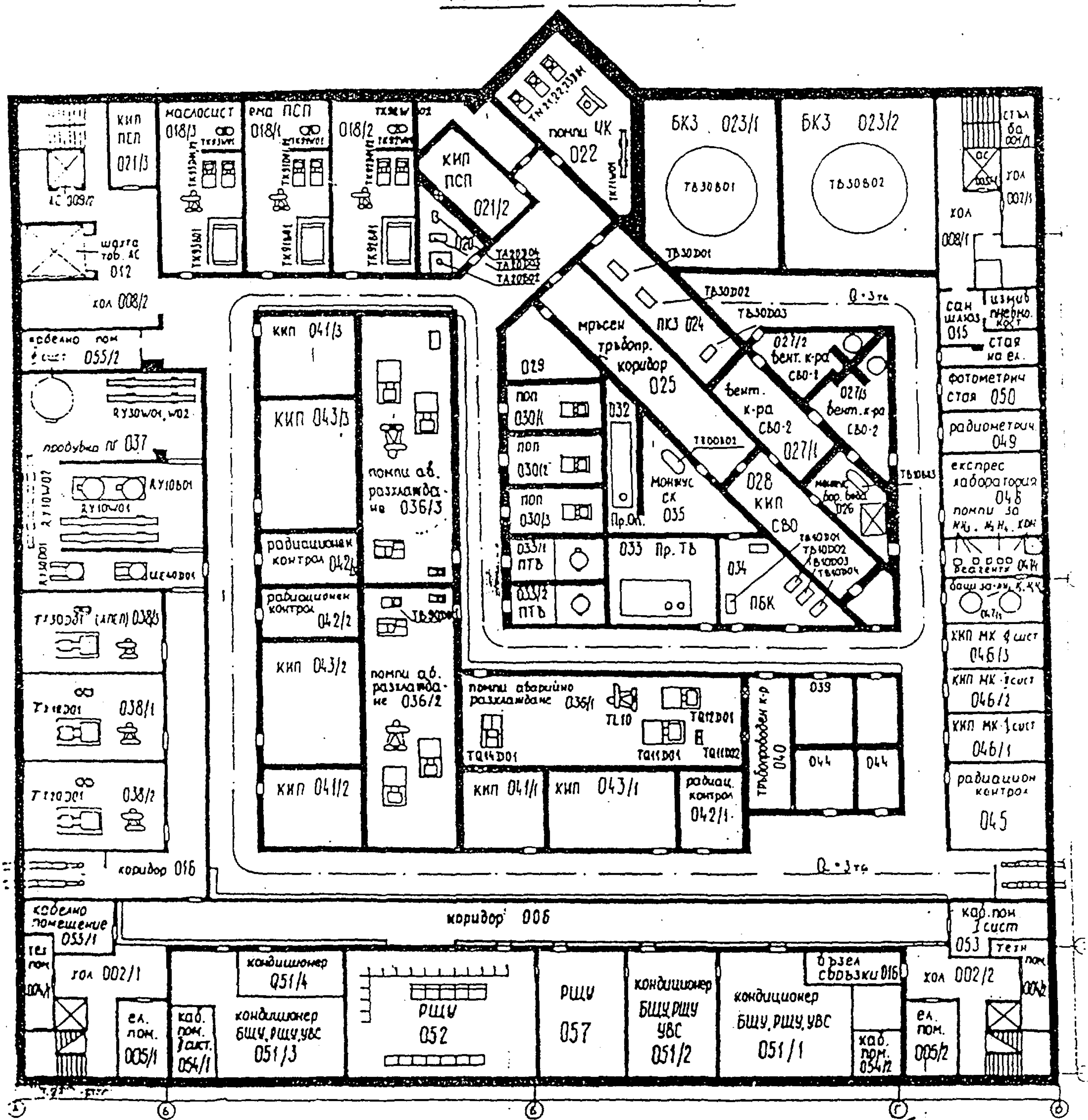

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/инж. Вл. Евбчев/

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/инж. Ив. Ге...

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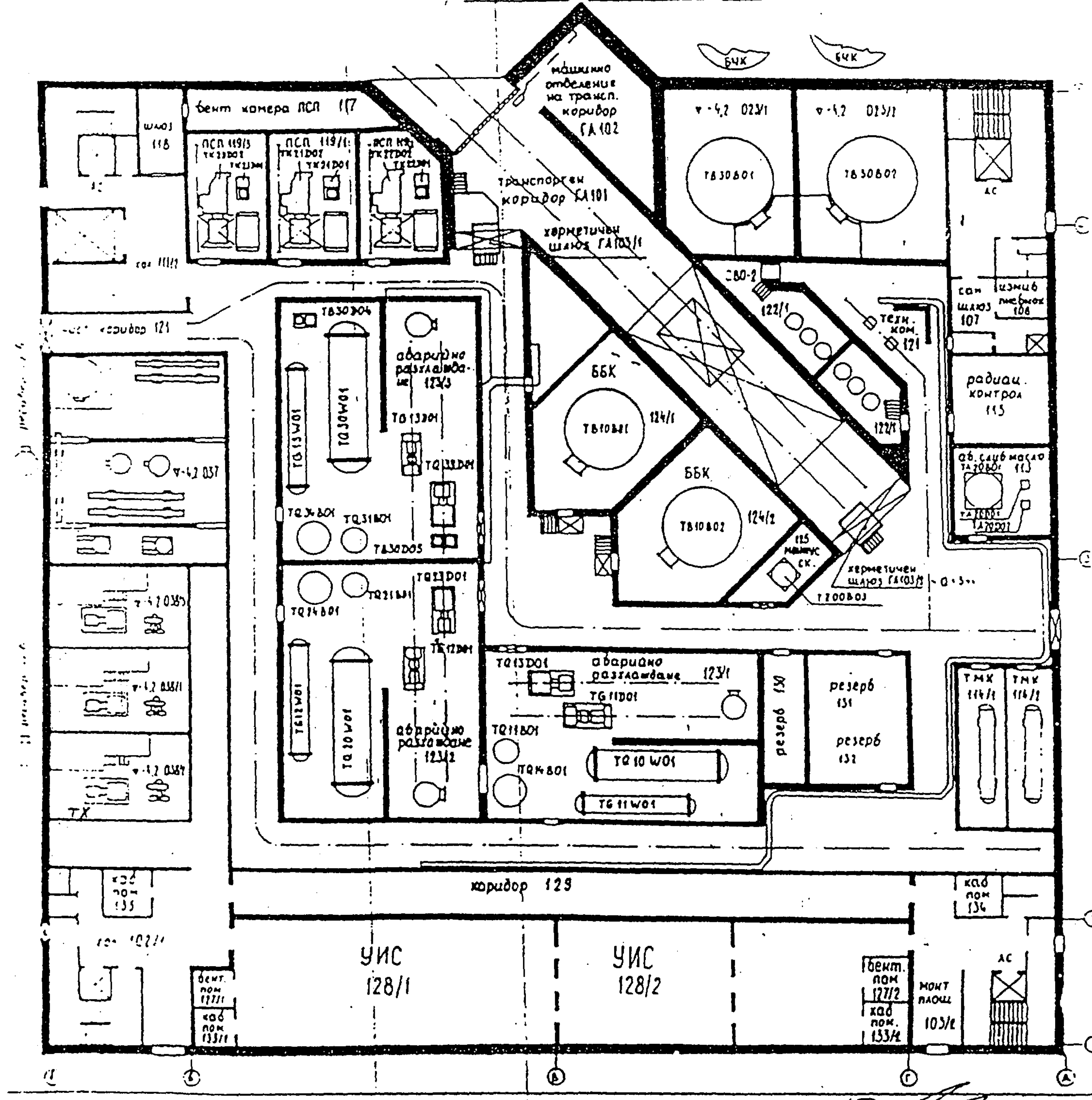
ПЛАН на ∇ 0,00



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/инж. Вл. Стойчев/

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/инж. Ив. Генов/

Гл. инж. (подпис)
/инж. И.В. Тризан/

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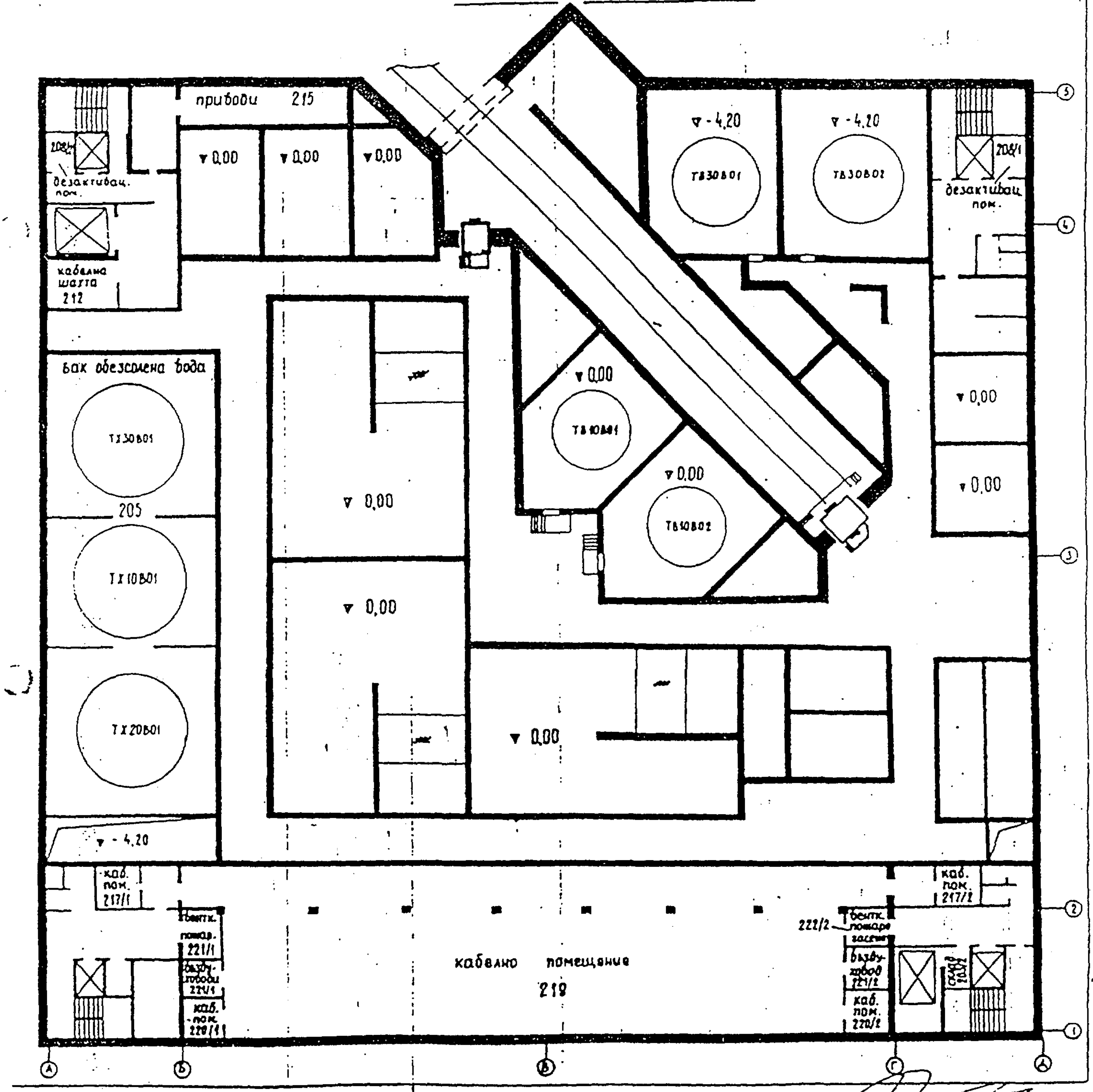
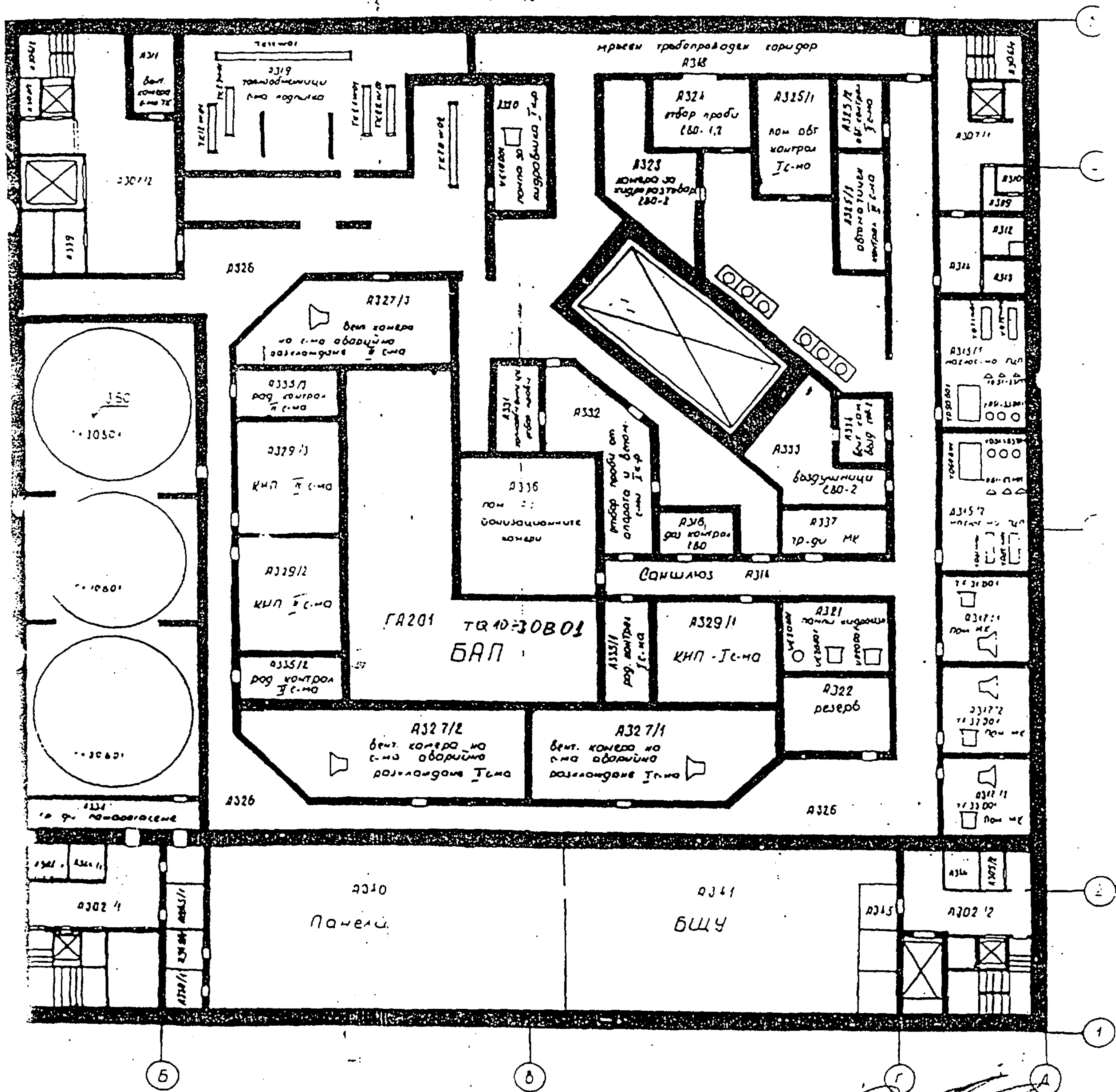


Н-к РЦ (подпис) /инж. Вл. Славчев/

Р-л напр. „Е" (подпис)

Гл. инж.:
инж. Ив. Призанов

План на кота 6.60



Н-к РЦ:
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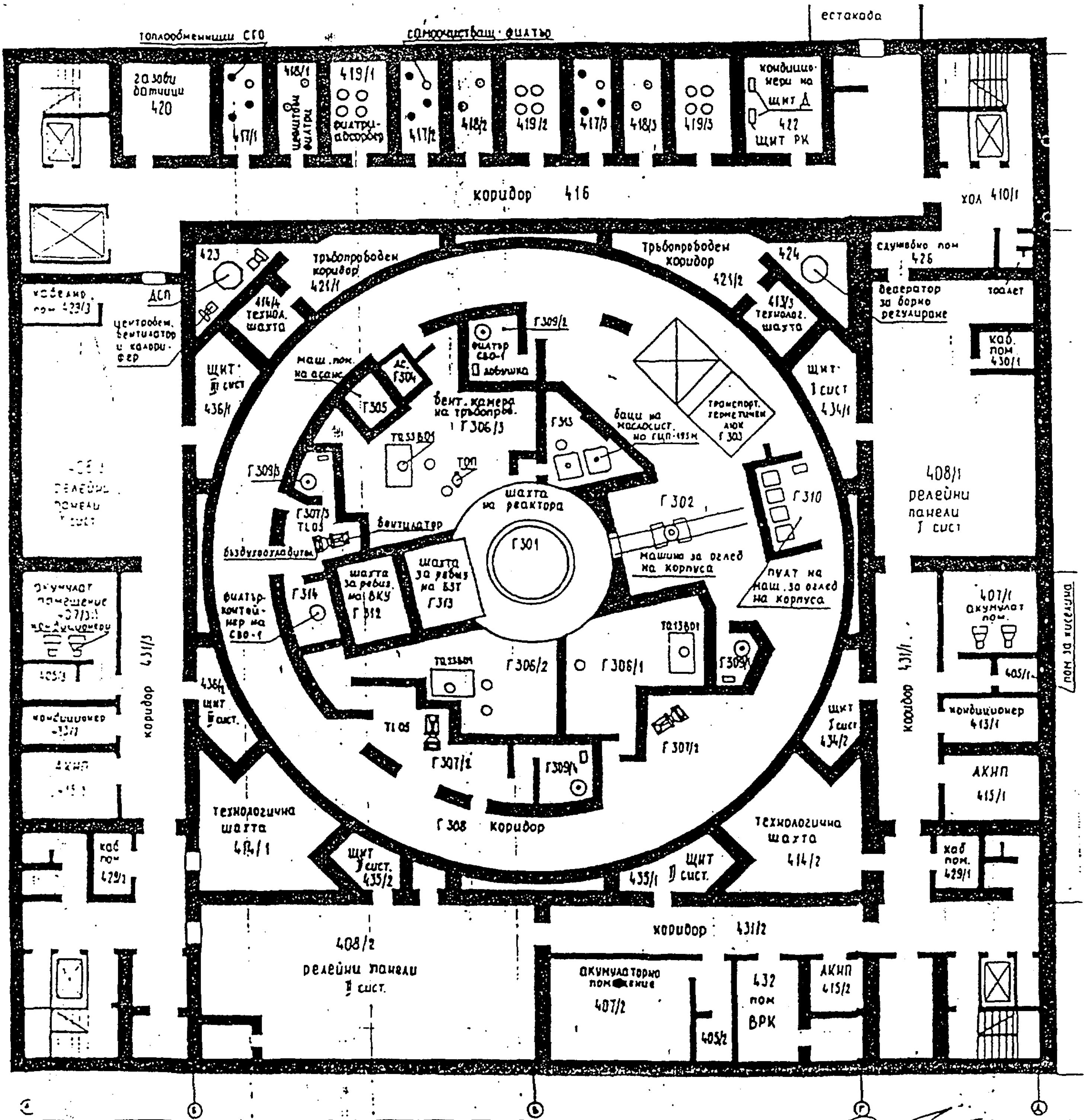
Гл. инж.
/инж. Ив. Гризон/

ПЛАН на ∇ 13.20 и 13.70



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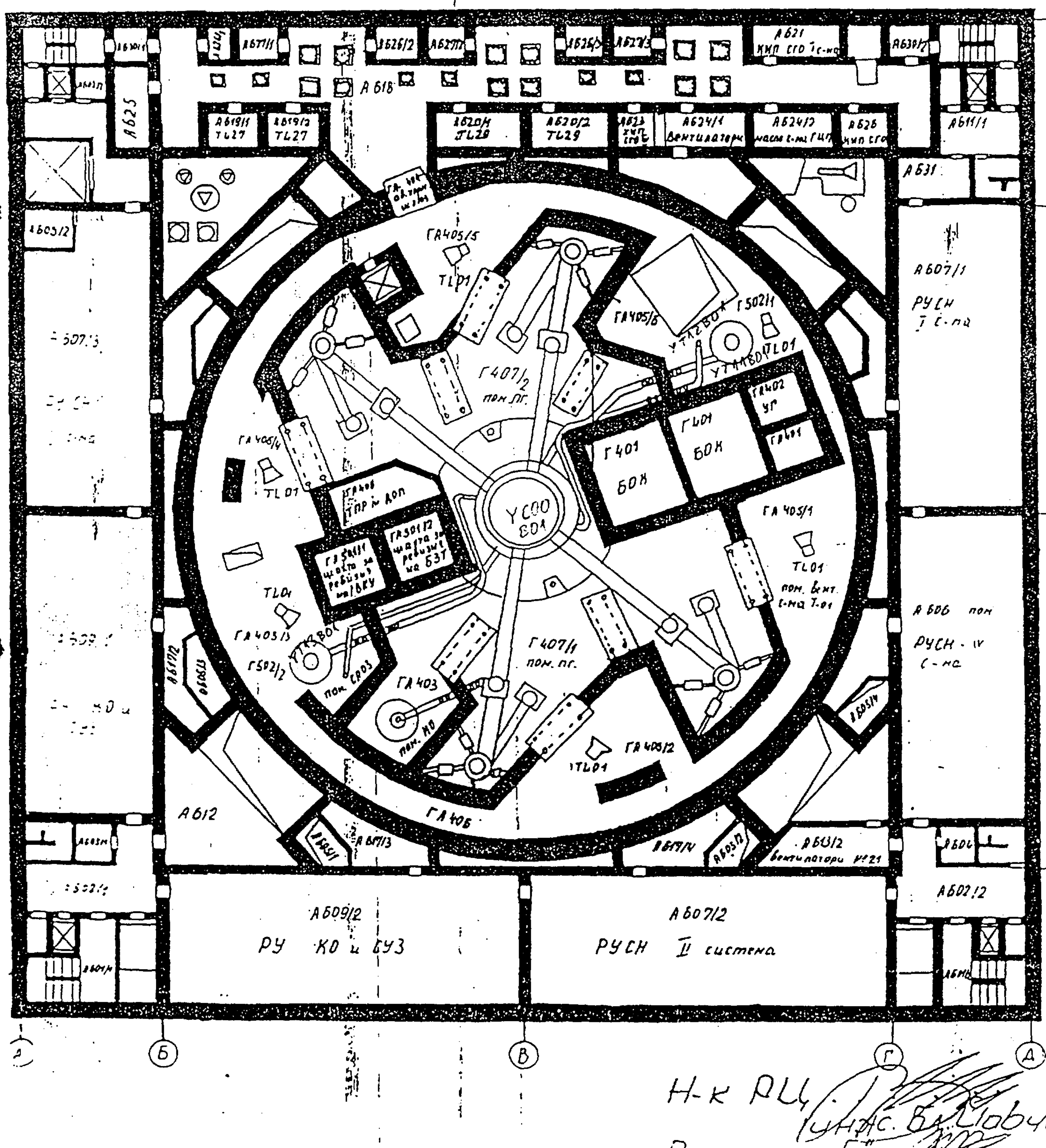
Гл. инж. ... инж. Гриза

План на ▼ 19,20; 20,40



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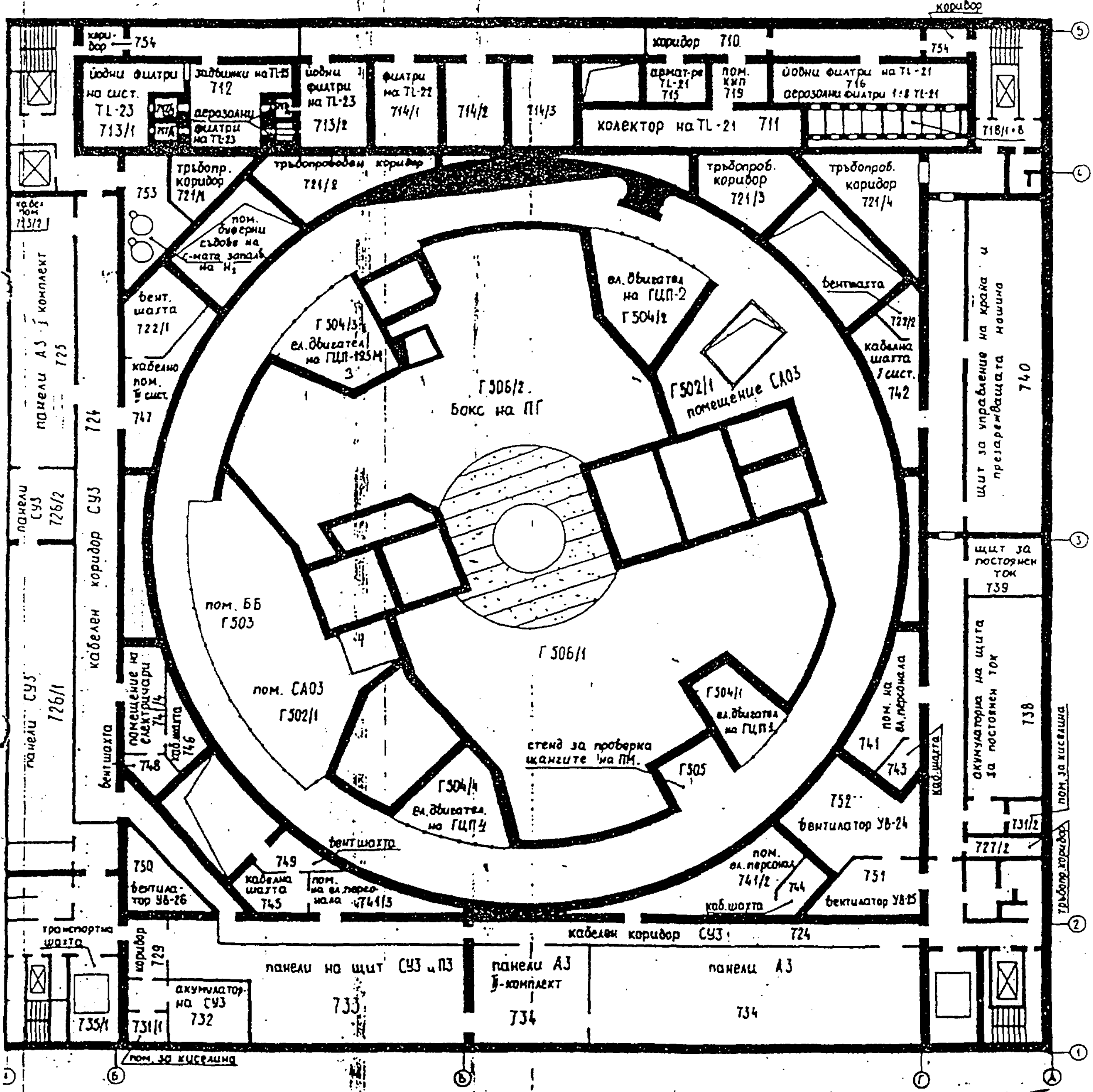
ПЛАН на ▼ 24,60 , 25,70



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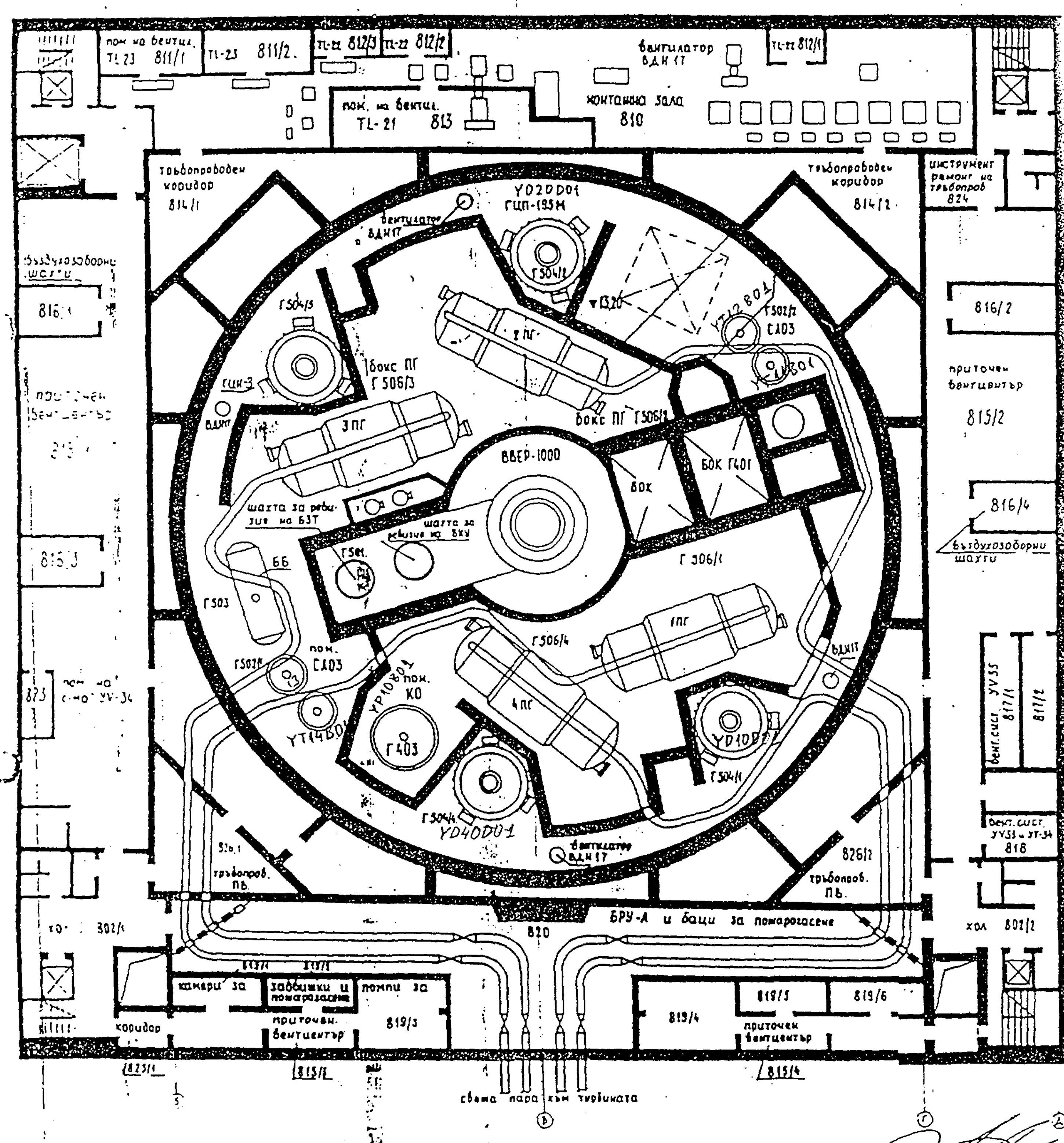
Гл. инж.:
инж. Ив. Грозан

ПЛАН на ▽25,70 и 28,80



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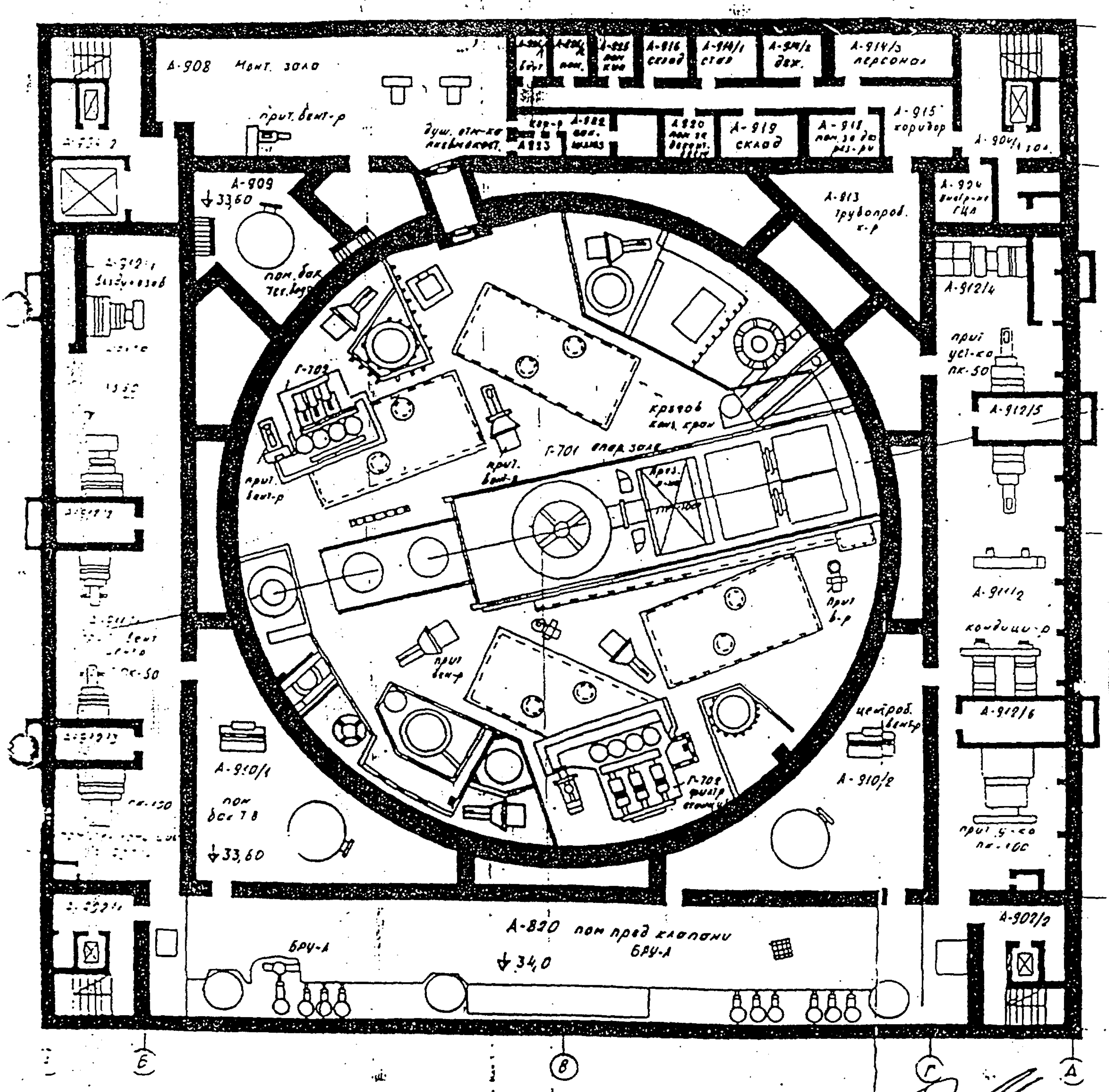
План на ▼36,9



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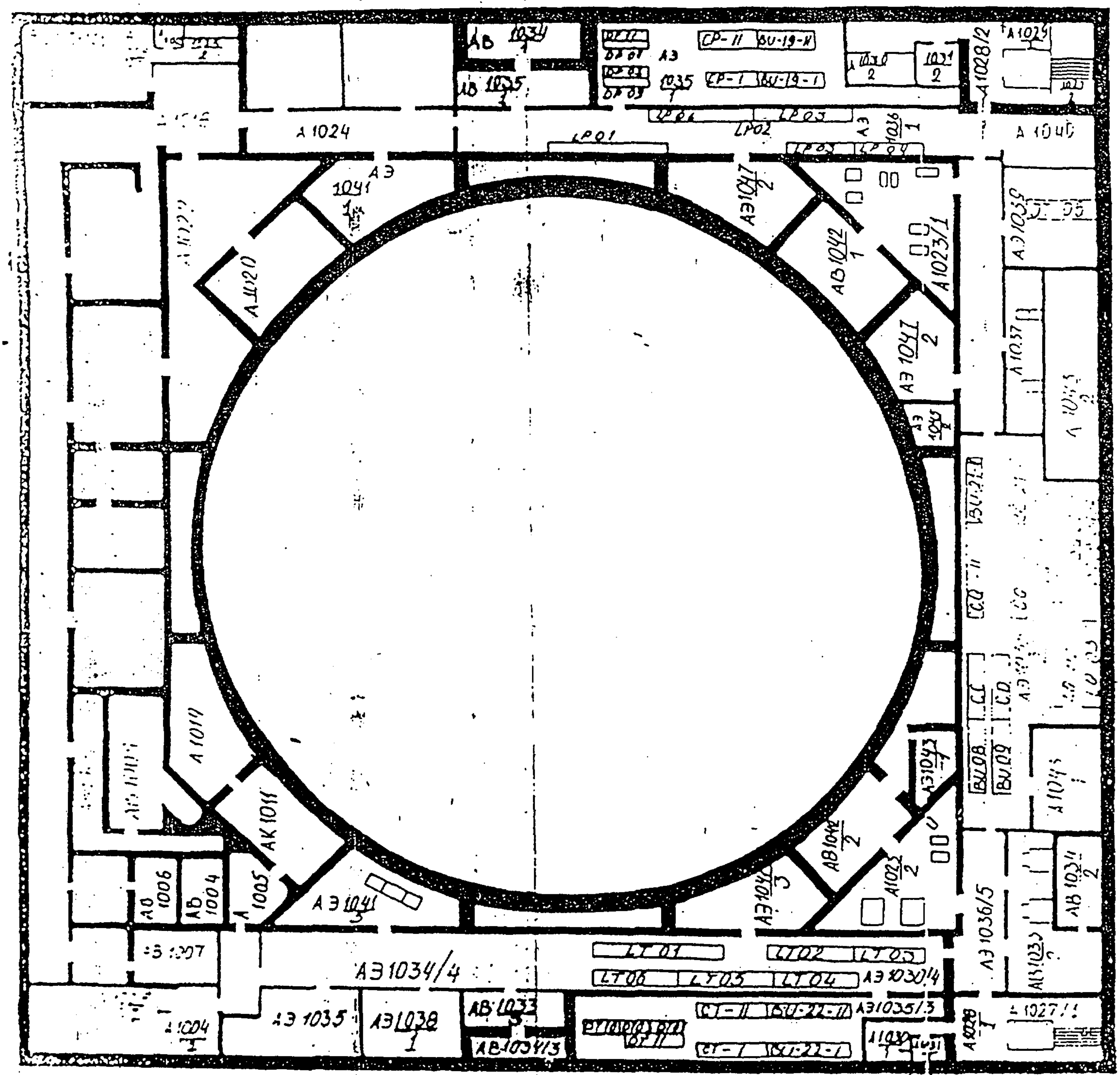

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