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

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VVER-1000 NUCLEAR POWER PLANTS

SYSTEMS REQUIRED DURING AND AFTER AN EARTHQUAKE

SUMMARY REPORT

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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.O 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

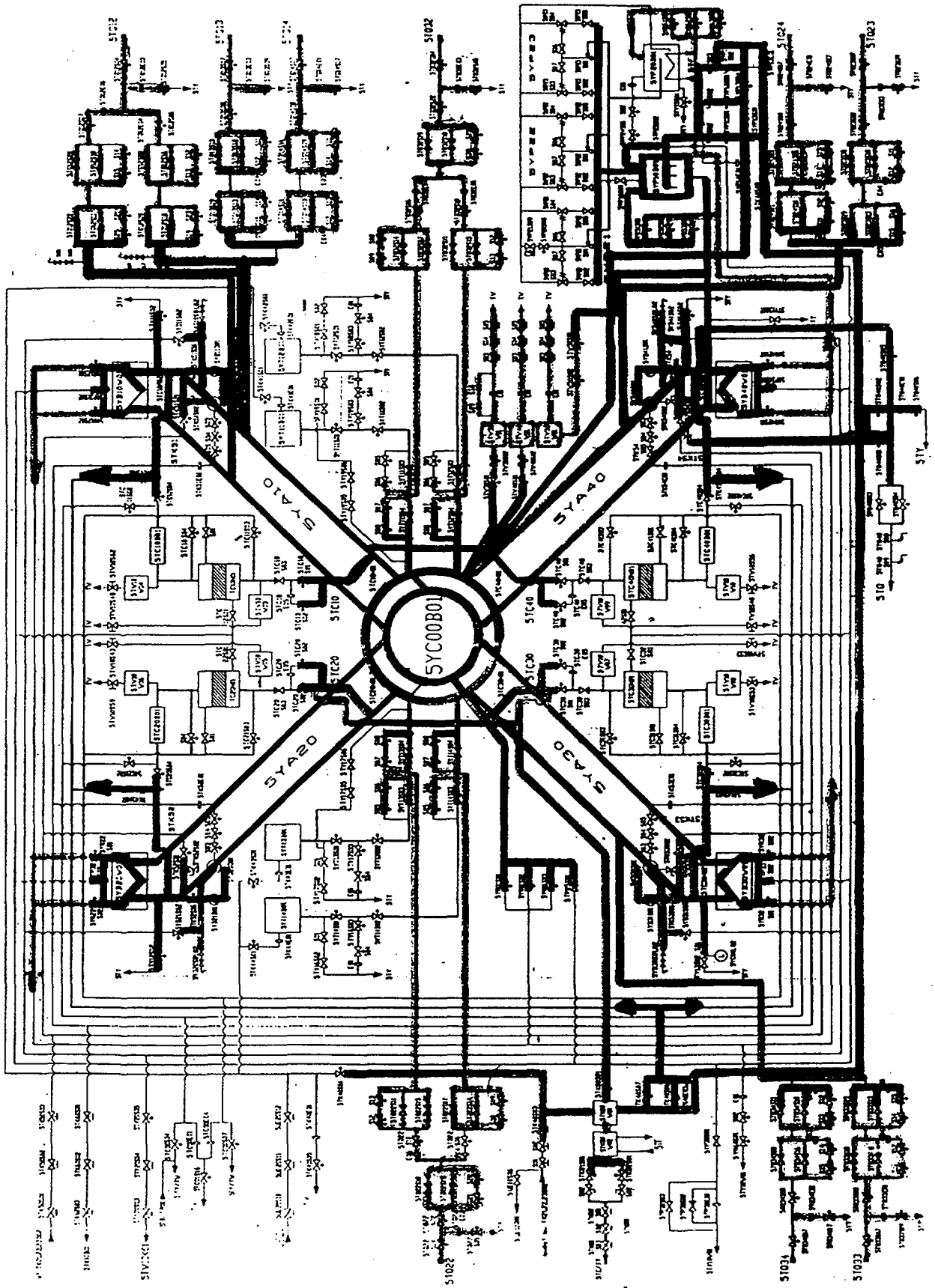
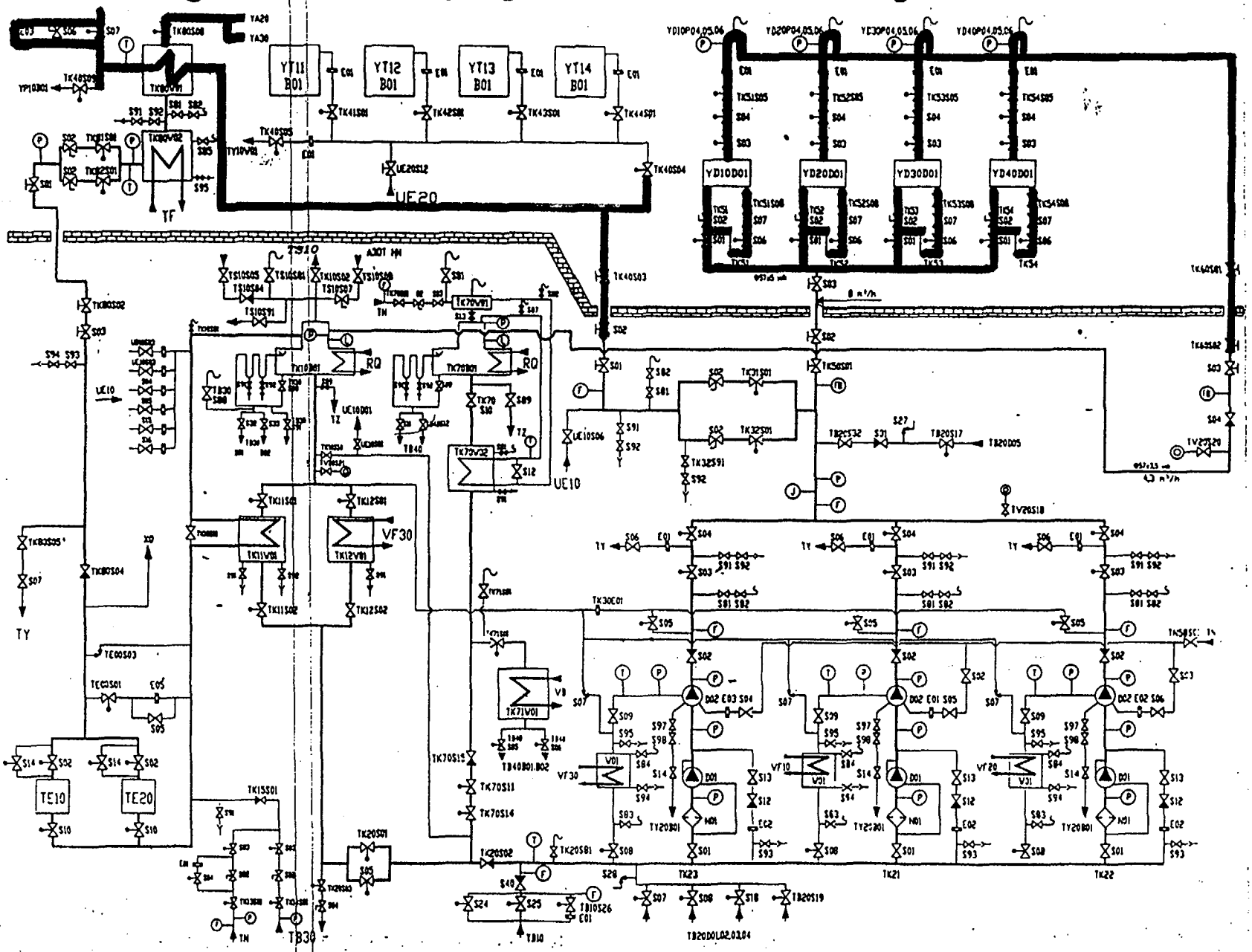


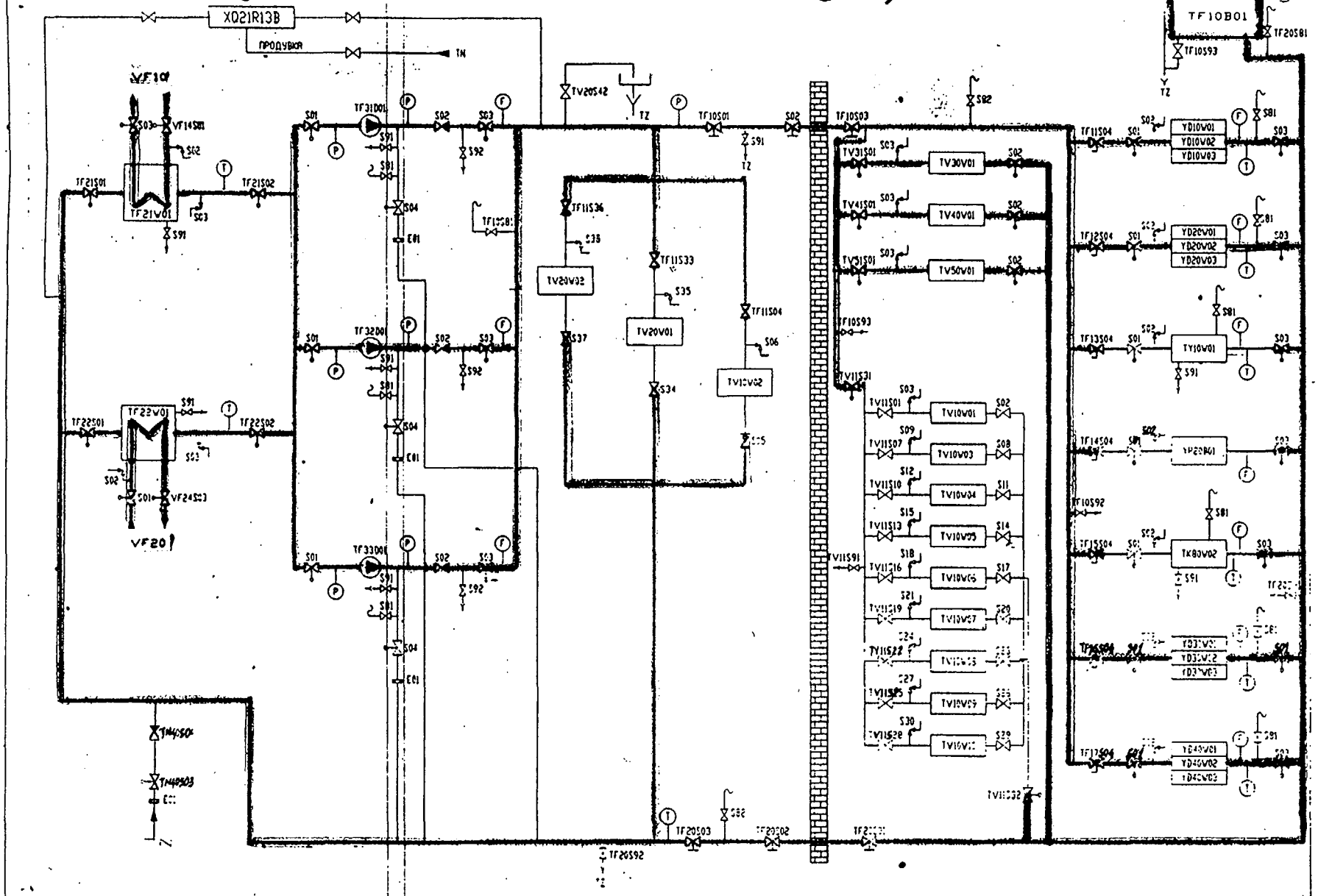
Figure 1 : RCS and YR

Figure 2: charging/letdown & seal injection return



3
TK

Figure 3 : intermediate cooling system TF



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Гл. инженер				Межцинен контур	Т
Р-л напр.					
Н. к. отд.	Чертил		35. РЦ.ТГ.ТС.07	АЕЦ Козлодуй V-стопанска	
	Провер.				

Figure 4 : organized leakage / YA interconn

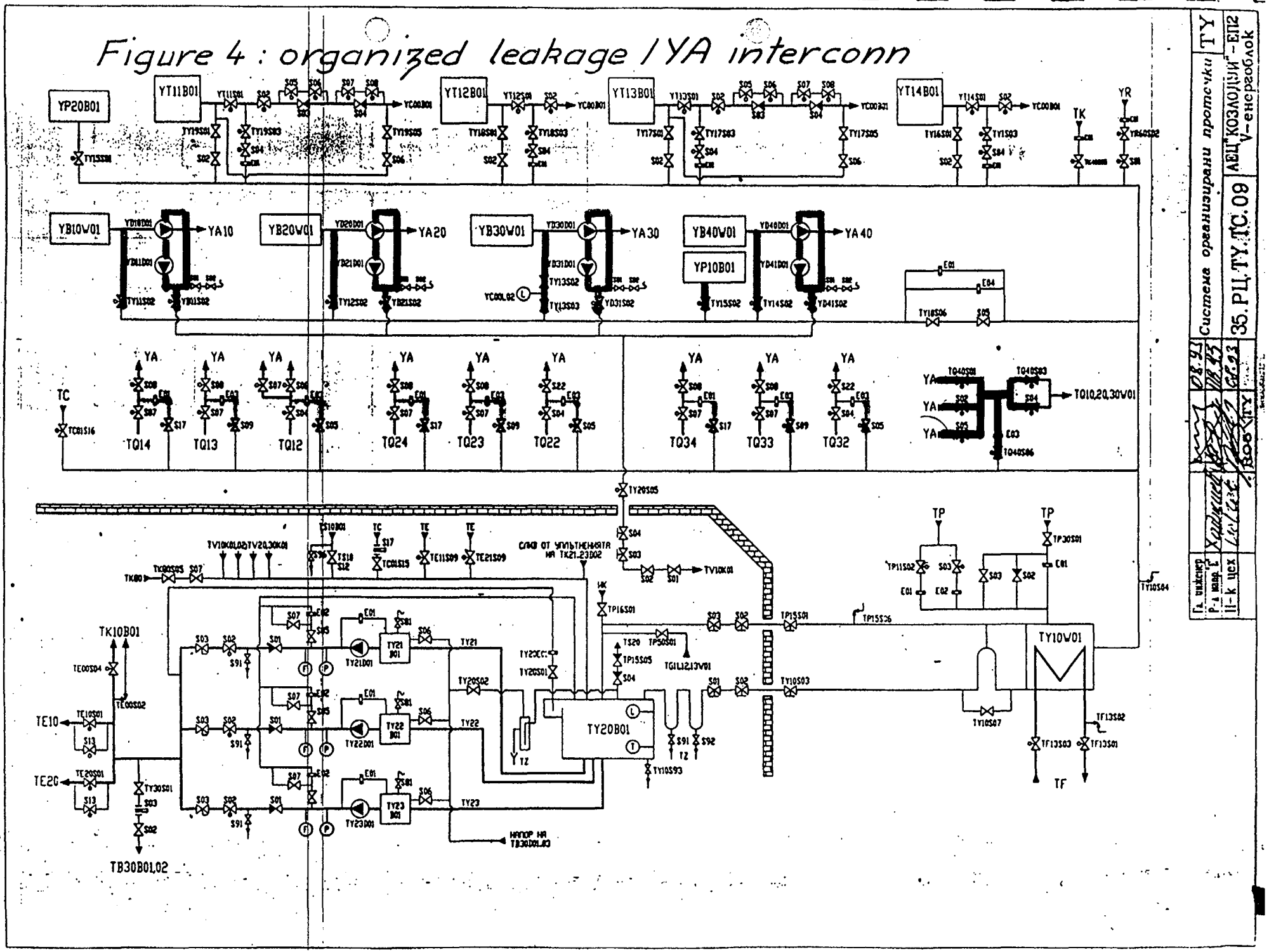

Figure 5: emergency steam gas mixture removal system / interc. with YA

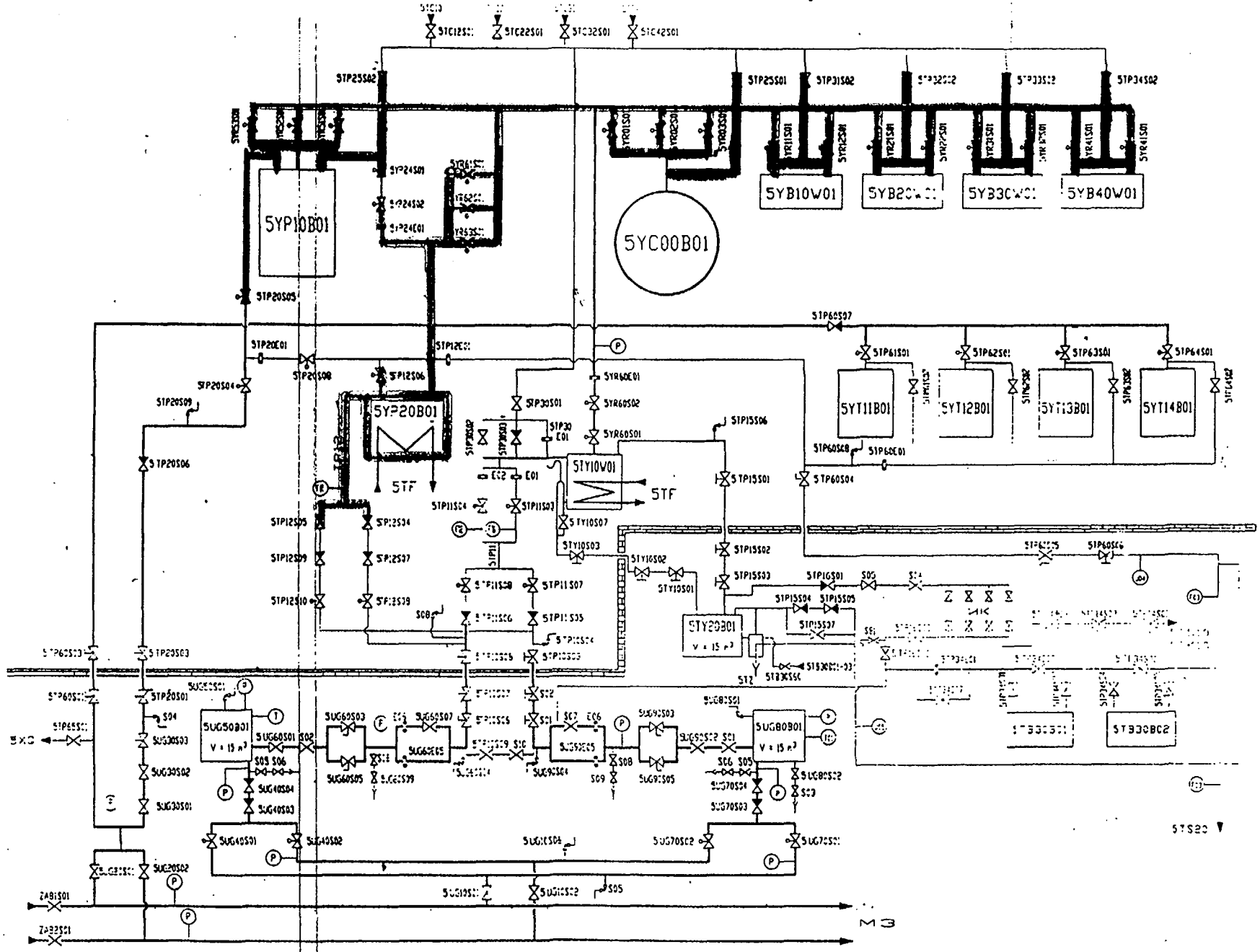

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Figure 6 : essential service water VF10/20/30 (example: VF10)

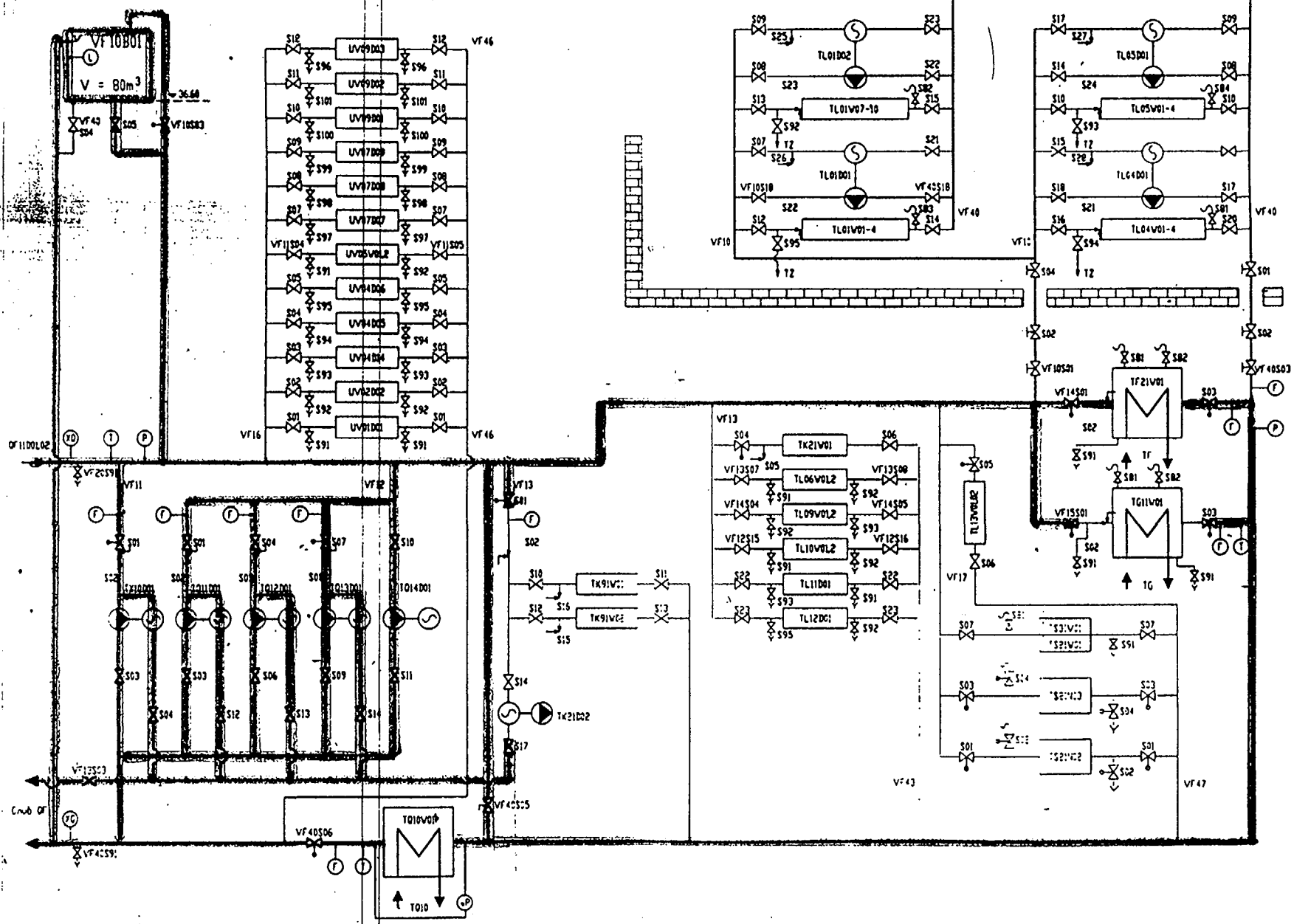
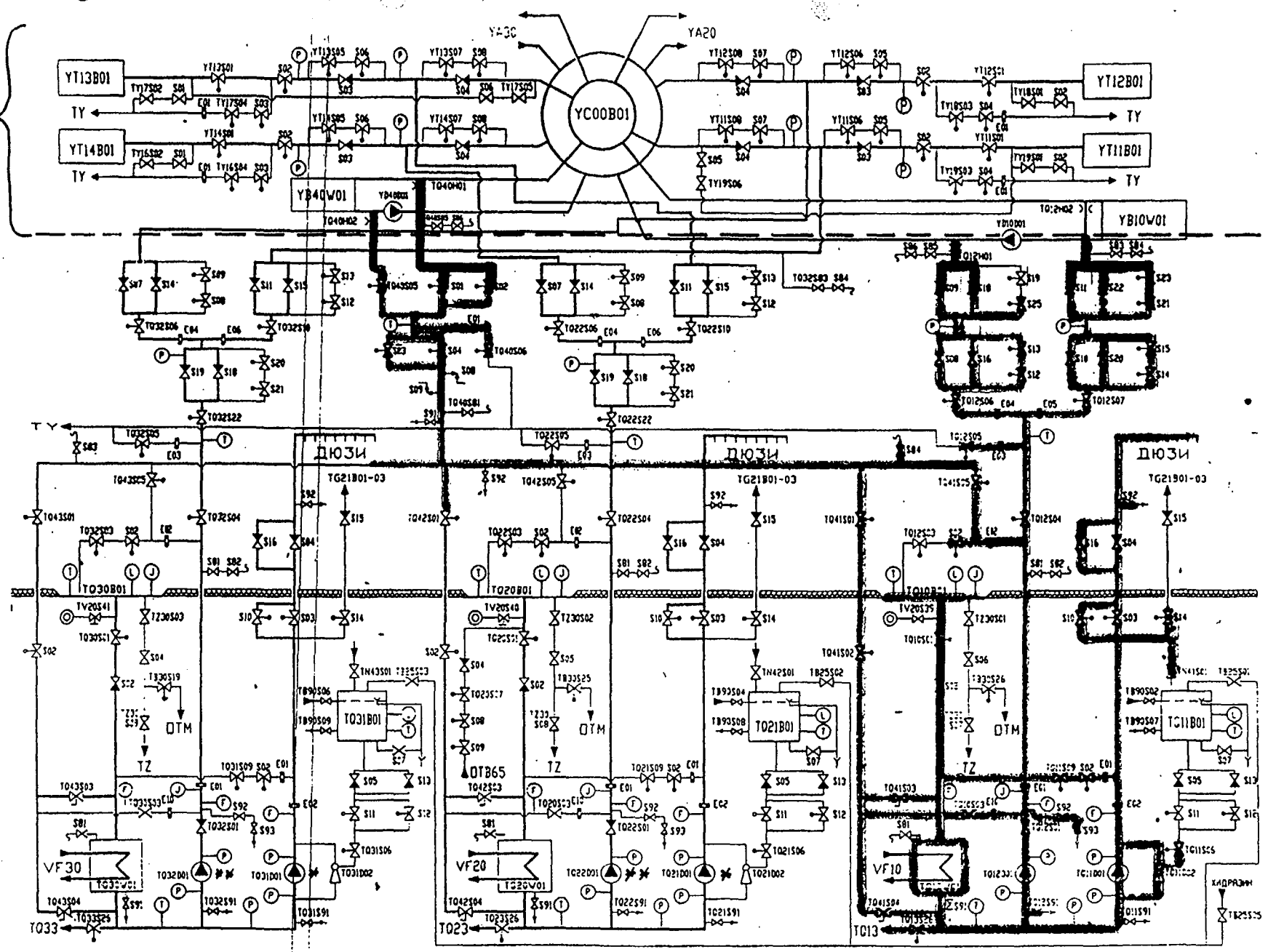


Figure 7: containment spray (TQ 11*) & low head SI (TQ 12**)

details
: Figure 1



* IDEM TQ11D01

** IDEM TQ12 D01

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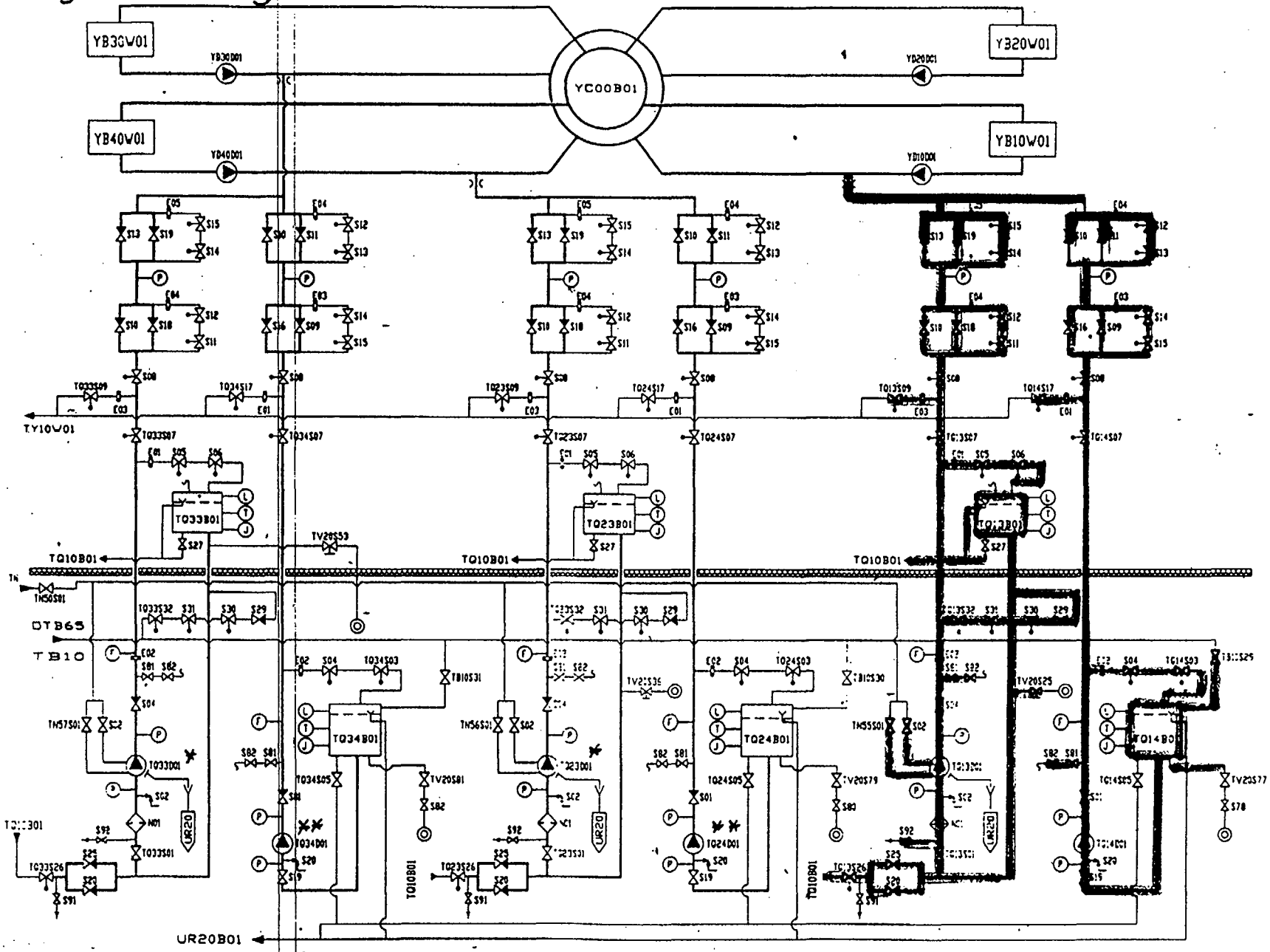
Гл. инженер			Сплинкерна система и планово аварийно разхлаждане	TQ
Р-л напр. Т				TQ
Н-к цех		28.93	35. РЦ. TQ1,2. TC. 19	АЕЦ "КОЗЛОДУЙ" - ЕГ V-енергоблок

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.)

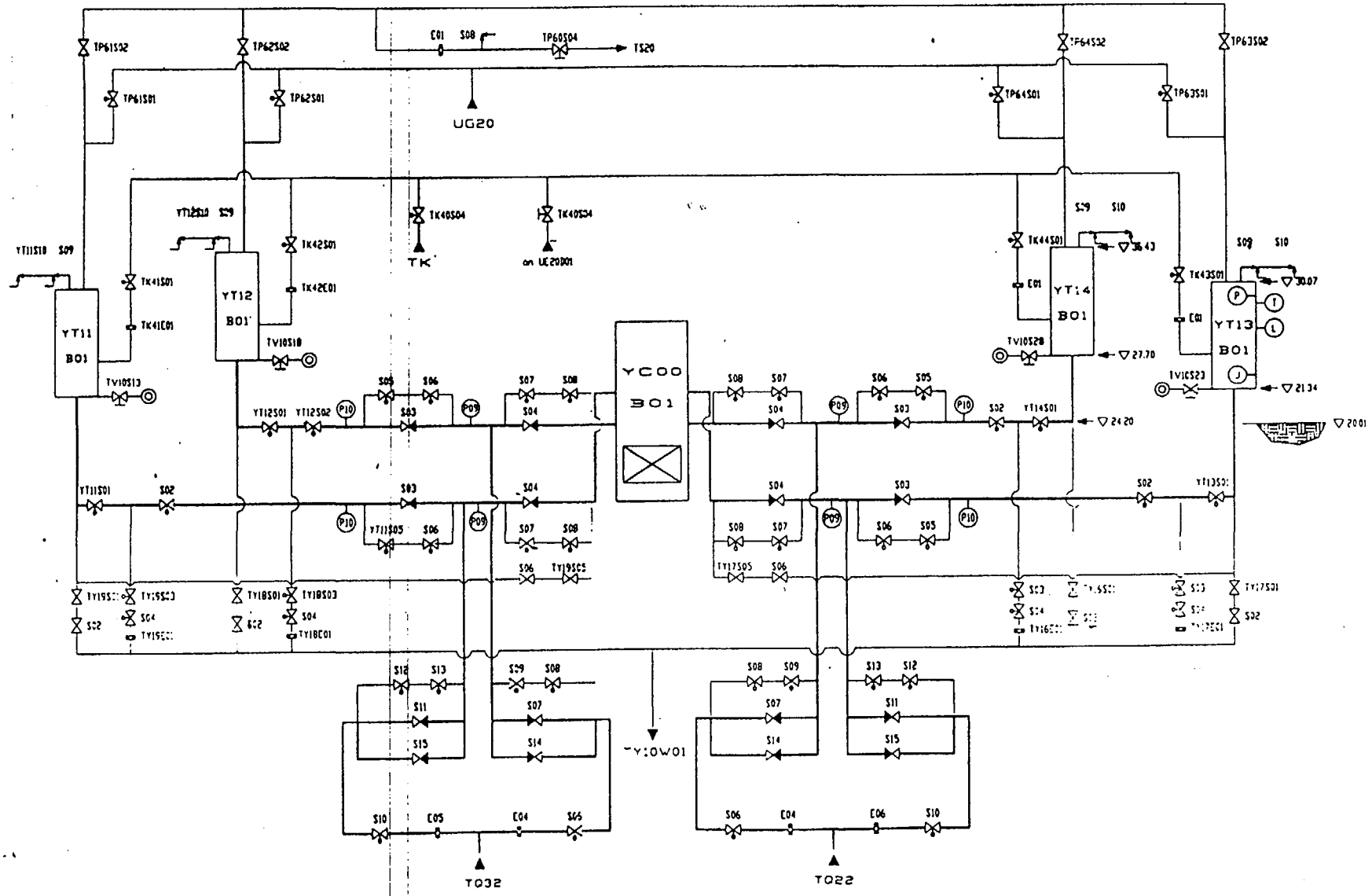


Figure IV.: TC high pressure purification
• not required ○ • see Figure 1.

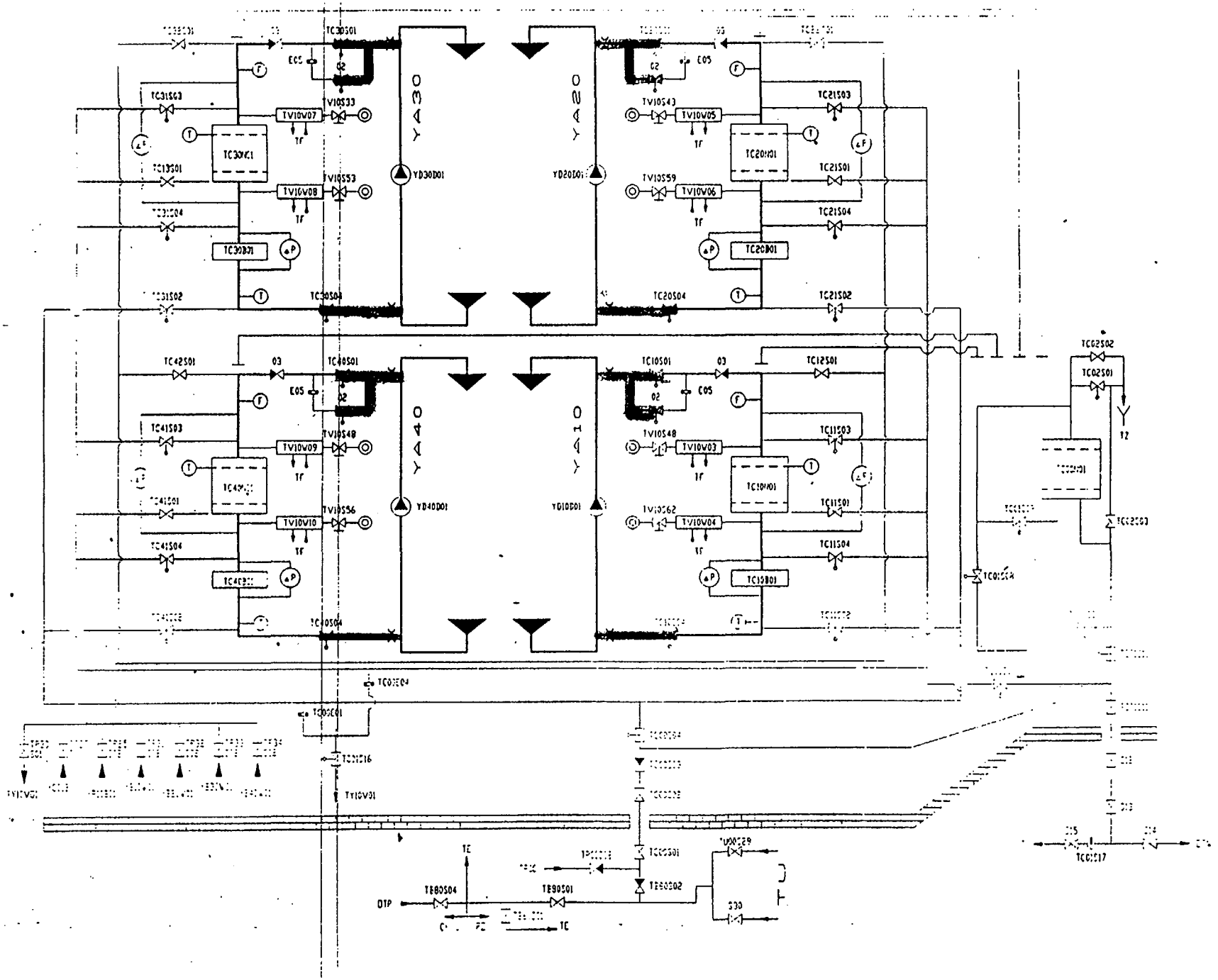


Figure 11: TB reagent tanks - not required

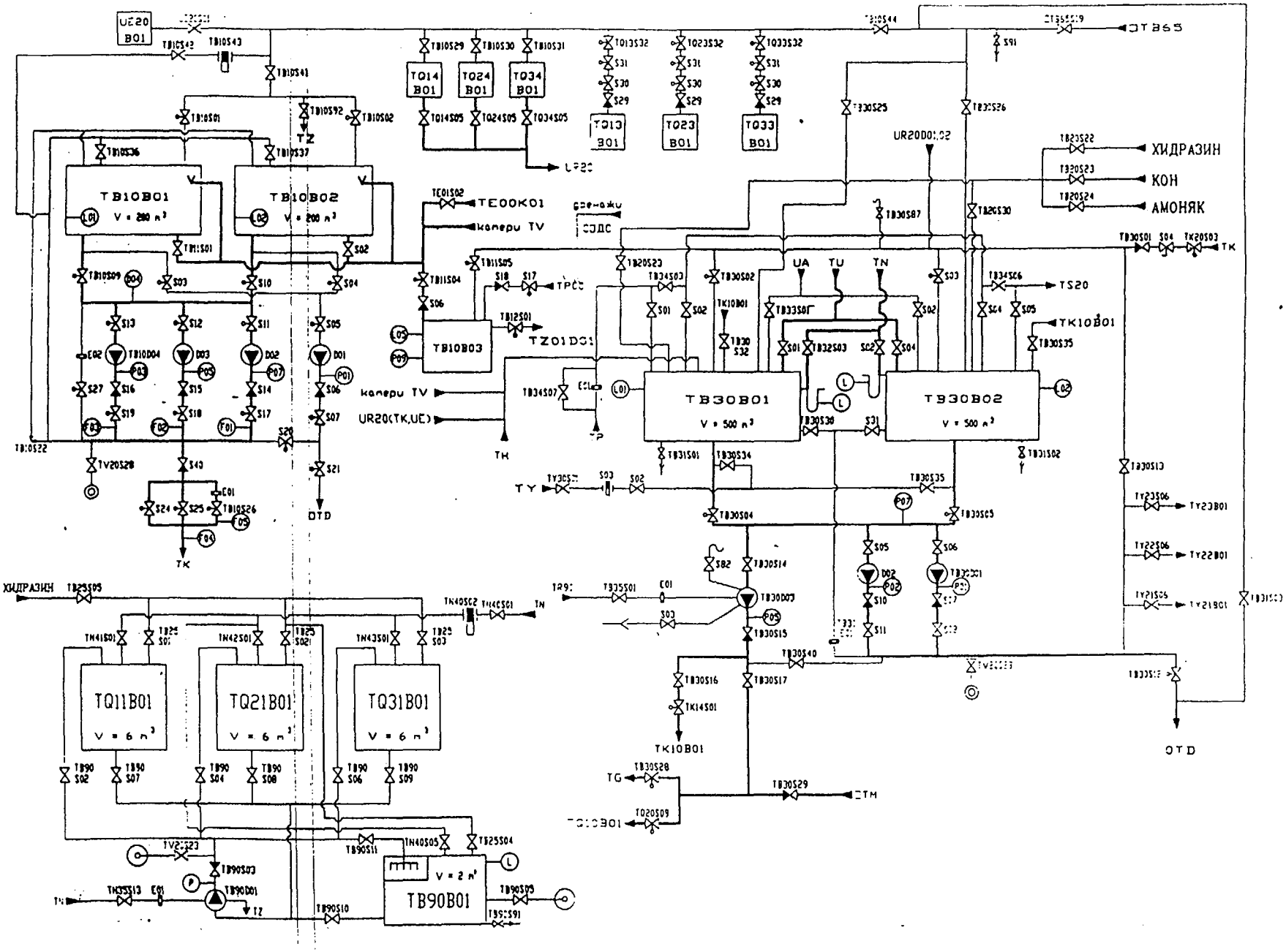


Figure 12: emergency feedwater TX & YB MSIV's & safety