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TRANSLATION, EDITING AND DIFFUSION OF DOCUMENTS
(Results Dissemination)

TACIS R1.13/91 PROJECT
SAFETY-RELATED EQUIPMENT QUALIFICATION UNDER ACCIDENT CONDITIONS
EXECUTIVE SUMMARY

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Author(s):	C. RIEG	**(EC/JRC-IE)**
	M. MALTSEV	**(ATOMENERGOPROECT)**
Reviewed by:	R. ROUSSEAU	**(EC/JRC-IE)**
Approved by:	M. BIETH	**(EC/JRC-IE)**

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SUMMARY

The main objective of the TACIS R1.13/91 project was to define the environmental conditions occurring during design accidents for the qualification of safety-related equipment of the operating Russian VVER 440/230 NPPs (Kola 1 & 2 / Novovoronezh 3 & 4) and to propose a relevant qualification programme. External hazards, e.g. earthquake, are excluded from the scope itself. Engineering assistance for optimising the qualification programme by various means (analyses, tests, co-ordination with others qualification needs like earthquake for example) was included in the project, but no performance of any action of the proposed programme.

The three phases were successively implemented as planned, but with some delay regarding the initial time schedule. Due to time constraints and coordination arrangements with related projects, the original work plan has been adapted in order to cope with the main objective. This leads to some overlapping of working phases as well as transfer of activities from one to the other according to the project needs.

Western and Russian experts have been working in close cooperation within the frame of this project, thanks to the creation of a technical working group since the beginning of the activities. The technical cooperation allowed the experts to get familiar with the state of the art on the relevant technical areas in the each involved Country. The Russian experts could take benefit of the training courses and complementary assistance, when necessary, for the use of Western codes, in particular the WAVCO code. This code as well as computers and equipment were transferred to the Russian Beneficiary and subcontractor. Benchmarking exercises with the WAVCO and MARCH codes was very effective for improving and adapting the modelling of the local condensation phenomena in the containment compartments.

A representative model of the operating Russian VVER 440/213 NPPs was build using the layout of the Novovoronezh units, as it was shown to be typical and either conservative. The model was used for the reference analysis as well as for code comparisons. The characteristics of each compartment (volume, wall properties, connections between each compartment, …) were developed specifically and carefully reviewed.

For this project, the 32 mm primary breaks selected as the conservative accident sequences to be taken into account for the determination of the most severe environmental conditions for the safety-related equipment qualification. The corresponding mass and energy release into the containment during the accident sequence were taken from available EDO Gidropress analyses, after checking their consistency and relevance. The results obtained with the WAVCO code were considered for the following tasks of the project. Complementary analyses have shown the reliability of the output data (peak temperature, humidity and pressure) further used for the definition of the qualification conditions.

A complete reassessment of the equipment qualification policy has been prepared according to the international practice and using the upgraded environmental accident conditions. Taking into account the specific situation of these plants and the past experience at Kozloduy NPP, a list of safety-related components to be (re)qualified was proposed. Instrumentation & control equipment is the most of concern.

A relevant qualification programme has been proposed and evaluated. The global duration is estimated to be in the range of 12 to 18 months. The budget (1993 basis), needed for qualification of the equipment set[1] of the Russian VVER 440/230 NPP, is estimated to be about 2445 Millions Roubles (# 550,000 US$). The implementation of such a qualification programme into the maintenance and modernisation programme of the operating Russian VVER 440/213 NPPs makes sense, since the integration of a more extensive list of design basis accidents could appear necessary. In that case, the qualification conditions should be upgraded as well. Anyway, further financial support from the European Commission for that purpose was not foreseen.

The following recommendations have been issued in the project final report:

1. Take benefit of the transferred know-how and technology on equipment qualification,

[1] Needs due to the used of non-generic components must be specifically addressed.

2. Integrate the implementation of the proposed equipment qualification programme in the maintenance and modernisation programme of the operating Russian VVER 440/213 NPPs, after the necessary upgrading.

FOREWORD

The work was financed by the Directorate General 1A of the Commission of European Communities under the contract n° WW.910303.01B039 to Framatome S.A., heading a Consortium including Siemens KWU and Electricité de France.

The Russian beneficiary was Rosenegoatom (REA), acting as the Russian utility.

The Russian subcontractor was MOHT-OTJIG RM. Within MOHT-OTJIG RM, the main contributor was ATOMENERGOPROECT (AEP), Novovoronezh NPP staff, EDO Gidropress and RRC Kurchatov Institute experts have been involved in various technical tasks.

A working group was established, including an expert from Framatome S.A, Siemens KWU and ATOMENERGOPROECT, and assigned to take over the technical leadership of the project and its management. The Western companies made complementary expertise available according to specific consultancy and expertise needs.

The global implementation duration of the project was about 27 months. The contract was signed the 21st July 1993 and completed in October 1995. The sub-contract was signed the 7th October 1993.

The work was done according to the requirements specified in the quality assurance program, based on the relevant IAEA standards as well as other international standards, applicable for nuclear facilities.

1 INTRODUCTION

The VVER 440/230 NPPs have been designed in the 70s and are in operation in various East European countries since more than 25 years. Some have been shutdown (Armenia, Germany), but most of these are still in operation. In Russia, four units (Kola 1 & 2 / Novovoronezh 3 & 4) are still operating.

According to the applicable design codes and standards, the design of the components of the safety-related systems was based on the main results form the design basis accident analyses, which were performed at that sage using the available computer codes. Thus, the components of the safety related systems were classified according to the applicable rules. The required design margins were provided by the application of the relevant design criteria specified for each category of components.

Over the past years, more consideration has been given to the equipment qualification worldwide. Improved methodology as well as updated accident analyses using upgraded computer codes modelling more precise descriptions of the physical phenomena (steam-air mixture in containment compartments) are available nowadays.

This project was defined in order to prepare the (re)qualification of the safety-related equipment accordingly. The corresponding scope was limited to the operating Russian VVER 440/230 NPPs and the design basis accidents, excluding the external hazards (earthquake).

In order to be able to define envelope conditions for the qualification purpose, the 32 mm primary breaks were selected as the reference design basis accident, but without taking into account the upgraded accident analyses expected from the TACIS R1.3/91 project. Taking into account the limited deviations between the different layouts (Kola 1 & 2 / Novovoronezh 3 & 4) and operation conditions, Novovoronezh NPP has been considered as the reference plant. The corresponding model of the Reactor Building (containment) was built up by selecting adequate parameters to make sure that the results are conservative, whenever it was necessary. All necessary cavities and layout particularities have been represented.

Western (WAVCO) and Eastern (MARCH) code routines were first compared on some selected single models. The corresponding results showed a reasonable level of consistency, which allowed the experts to get familiar with the use of advanced codes and to identify the major deviations of simplified descriptions of the physical phenomena.

The WAVCO code was finally used for a complete calculation of the reference accident sequence, starting from the initiation event still stable long-term parameters could be shown, reflecting the post-accident stage. The corresponding results have been made available for defining an upgraded list of safety-related equipment to be (re)qualified as well as for the definition of the relevant (conservative) qualification parameters.

The qualification programme and the corresponding time schedule and costs have been established in the frame of the project. The proposed programme was optimised within this project.

2 OBJECTIVES

The aim of TACIS R1.13/91 project was to prepare the (re)qualification of the safety-related equipment for the operating Russian VVER 440/230 NPPs according to the improved methodology and with upgraded environmental conditions. A tentative qualification programme was expected with the corresponding time schedule and costs.

The main objective of the project was to define the environmental conditions occurring during design accidents (external hazards, e.g. earthquake, are excluded) for the qualification of safety-related equipment of the operating Russian VVER 440/230 NPPs (Kola 1 & 2 / Novovoronezh 3 & 4). Therefore a 32 mm primary break accident sequence was calculated with the WAVCO code and used for the selection of the safety-related components to be qualified and the relevant conservative qualification conditions.

3 IMPLEMENTATION

According to the above-mentioned background and objective, the work plan was split in 3 phases. Table 3.1 shows the tasks arranged within the 3 phases, as specified in the contract.

Phases		Tasks
Pre-Phase (1st Phase)	a	Establishment of a working group
	b	Identification of Western and Russian requirements, including Q.A.
	c	Selection of the Western and Russian computer codes
	d	Clarification of the Russian access to the Western computer code
	e	Identification of the baseline documentation needed for the preparation of the input data for the computer codes
	f	Selection of the accidents sequences to be analysed (interface with TACIS R1.3/91)
	g	Preparation of the general input data for the Western code
	h	Preparation of the general input data for the Russian code
	i	Training of Russian experts in the use of the Western computer code
	j	Calculation of a sample problem with both Western and Russian computer codes
	k	Assistance to Russian experts in the use of Western computer codes
	l	Definition of criteria for selection of safety-related equipment
	m	Identification of the safety related equipment

Phases		Tasks
	n	Development of a qualification methodology
	o	*Reviewing of the Kozloduy programme*[2]
	p	Summary report (Pre-phase) of the findings including a detailed work plan for the next phase
Conceptual-Phase (2nd Phase)	a	Assessment of data coming from TACIS R1.3/91 project
	b	Preparation of the input data for the selected accident scenario
	c	Performance of the analysis using the Western computer codes
	d	Assistance to Russian experts in the use of Western computer codes
	e	Summary report (Conceptual-Phase) of the findings including a detailed work plan for the next phase
Confirmation-Phase (3rd Phase)	a	Review and assessment of calculated results
	b	Recalculation of some cases
	c	Estimation of schedule and cost of equipment qualification
	d	Qualification of safety-related equipment[3]
	e	Summary report (Confirmation-Phase)
	f	Final report

Table 3.1.: Reference and description of the project tasks

The three phases were successively implemented as planned, but with some delay regarding the initial time schedule:

- Pre-Phase (Phase I): from October 1993 to November 1994,
- Conceptual-Phase (Phase II): from September 1994 to December 1994,
- Confirmation-Phase (Phase III): from January 1995 to October 1995.

Due to time constraints and coordination arrangements with related projects, the original work plan has been adapted in order to cope with the main objective. This leads to some overlapping of working phases as well as transfer of activities from one to the other according to the project needs.

Training of the Russian experts on the WAVCO code took place at Siemens KWU Headquarters in Offenbach in February and March 1994. The workstations and office equipment were delivered end of August 1994 to the Beneficiary and AEP.

The first results from the TACIS 1.3/91 project were only available in May 1995 and caused some delay in this project until the decision was taken to use the available results from the EDO Guidropress accident analysis on a 32 mm primary break as input data.

Additionally, the review of the Kozloduy qualification programme was concentrating on the available information on qualification conditions and selection of components. Furthermore, the qualification programme for the selected equipment was optimised by means of engineering assistance especially. By no means, a complete qualification programme could be expected within this contract.

Progress meetings were held alternatively in Moscow (AEP), Erlangen (Siemens KWU) and Paris (Framatome). Progress reports [1, 2, 3, 5, 7 & 8] and intermediate summary reports [4 & 6] are listed in section 9. An extensive final report [8] has been established, which refers to 12 annexes.

[2] The qualification programme (equipment / conditions) was defined during the 6-month programme and was available and was expected to be available for analysis. The complementary qualification tests were planned to take place later.

[3] Engineering assistance for optimising the qualification programme by various means (analyses, tests, co-ordination with others qualification needs like earthquake for example) was intended. By no means, a complete qualification programme could be expected within this contract.

4 PRESENTATION AND DISCUSSION OF THE PROJECT RESULTS

4.1 Pre-Phase – Phase 1.

A technical working group, including representatives from the contractor's consortium and the subcontractor's leading institute, has been established (see Foreword). Its task was to take over the technical management of the project and to define step by step, the detailed technical content of the second and third phase.

The layout of the Novovoronezh NPPs, which is shown in Figure 4.1.a, has been considered for the construction of the typical VVER 440/213 unit model.

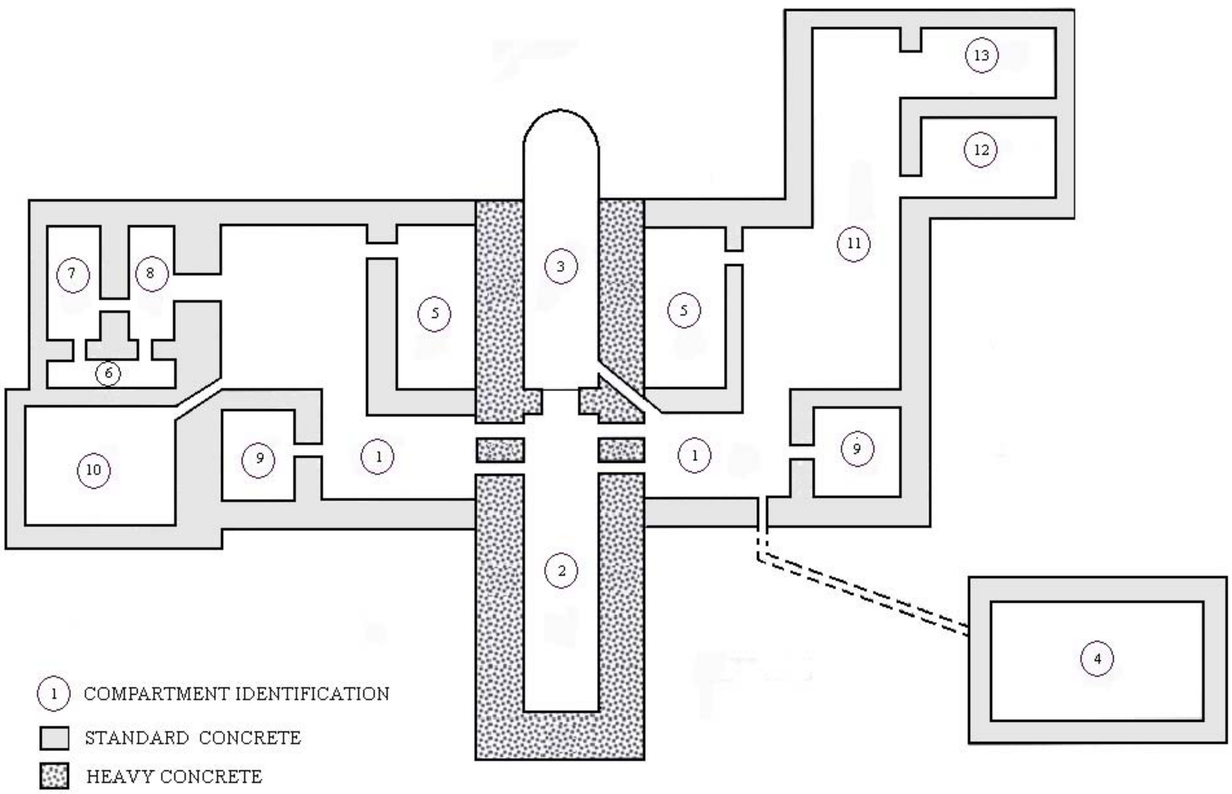


Figure 4.1.a: Novovoronezh NPP Reactor Building topological model

A short review of current Russian and French requirements for the qualification of safety-related components, during in accidental environment, was made. The comparison showed that in Russia the design criteria and the manufacturing requirements provide for the necessary quality and qualification level. This compensated for any additional functional tests.

Two computer reference have been selected for the project:

- The WAVCO code (see Annex 10 to the Final Report [9]), developed by Siemens: KWU and used for the analysis of thermodynamic phenomena, occurring during severe loss of coolant accidents, and the evaluation of their consequences in the containment of NPPs,

- The MARCH code, used by ATOMENERGOPROEKT for the analysis of thermodynamic phenomena, occurring during design as well as beyond design accidents, and the evaluation of their consequences in the containment of NPPs.

The prerequisites for the use of the WAVCO code (access, identification of the baseline documentation needed for the preparation of the input data, preparation of the general input data) were clarified during the training period of the Russian experts (see Annexes 1 & 2 to the Final Report [9]).

The connection model takes into account the different compartments of the Reactor building and 2 air-lock compartments as shown in table 4.1.a.

	Designation of the compartments
1	Steam-generator and RCP room
2	Reactor vessel and pit
3	Space under the cupola
4	Emergency boron solution reserve tank
5	RCP motor and main gate valve drives
6	CBO -1[4] venting chamber
7	CBO -1 heat exchangers room
8	CBO -1 filters room and stairs
9	Instrumentation room
10	Steam-Generator venting chamber
11	Pressurizer
12	Pressurizer venting chamber
13	Bubbler compartment
14(*)	Air lock
15(*)	Air lock

(*): The air locks are modelled as particular heat sinks

<u>Table 4.1.a</u>: List of the compartments considered in the connection scheme

The model has been establish as shown in Figure 4.1.b, including a limited number of compartments. The characteristics of each compartment (volume, wall properties, connections between each compartment, …) were developed specifically and carefully reviewed.

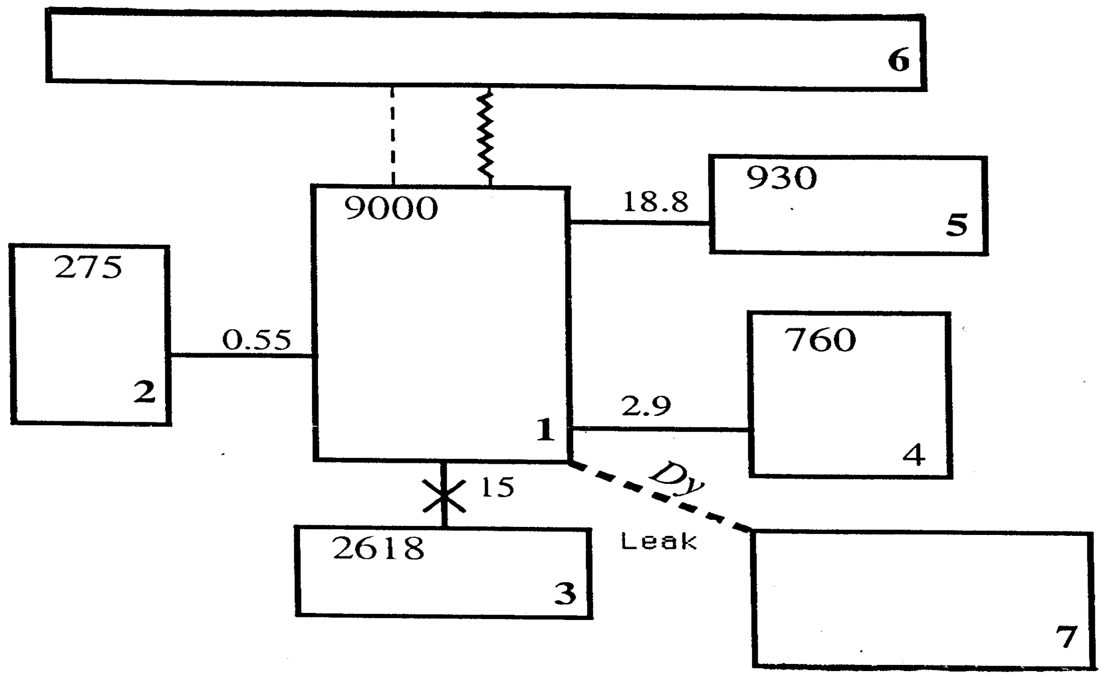
During that phase, the results of the accident analyses planned in the TACIS R1.3/91 project were not available. Therefore, the selection of the accidents sequences to be analysed did not take place at that stage.

The training programme for the Russian experts included the following steps:

- Introduction to the WAVCO Code,
- Introduction to the HP-UX Operation System,
- Introduction to the use of HP Workstations,
- Installation of the WAVCO Code on a HP Workstation,
- Introduction to the use of the WAVCO Code,
- Exercises with the WAVCO Code,

[4] Air filtering system

- Application of the WAVCO code for a Russian reactor type.



Legend: (Reference numbers are marked in bold characters)

1 Relief valves
2 Reactor Pressure Vessel and Pit
3 Reactor Coolant Pump
4 Instrumentation room
5 Pressuriser
6 Steam Generators
7 Emergency boron solution reserve tank

Figure 4.1.b: Simplified model for the reference analysis

Benchmarking of both codes on the same model was performed later (Phase II) after the choice of the reference case for the input data.

Assistance to the Russian experts in the use of the Western computer codes was provided on-line during the training and reference case calculations.

Prior to define the criteria for the selection of the safety-related equipment to be qualified, a review of the safety analyses reports for the Novovoronezh units 3 and 4 was made with the aim to identify the accident sequences which could definitively influence the qualification conditions (see Annex 3 to the Final Report [9]). Additionally, the qualification methodology and the list of the qualified equipment of the French 900 MWe series plants were provided as examples of relevant applications (see Annex 4 to the Final Report [9]). Thus, the following main parameters were identified as most important for defining the qualification needs for a safety-related equipment:

- The safety functions which are required under accidental environmental conditions (pressure, temperature, humidity, …),
- The period of time during which any safety function failure under accidental environmental conditions has to be excluded,

- The period of time during which the equipment will remain operable (performing the required safety functions) under more realistic environmental conditions than the conservative qualification conditions.

These parameters shall be considered as criteria for the selection of the safety-related equipment to be qualified.

As a result of analyses, a preliminary list of safety-related equipment to be qualified has been established:

1. *Equipment located in SG and RCP compartment (Primary Circuit Components):*

   1.1. Pipeline penetrations from the SG compartment to the emergency and normal operation make-up compartment,

   1.2. Spent fuel pond cooling circuit pipeline penetrations,

   1.3. "Confinement" isolation valves and components of its ventilation system (B-2),

   1.4. Reactor Control and Protection System and diagnostic equipment, located under the protective cupola:

   - Position indicators of the Control Rod Drive Mechanism,
   - Electrical connectors,
   - Thermocouples for active core temperature measurement,
   - Components for local (under-cupola area) dosimetry monitoring.

   1.5. Components for in- and ex-core dosimetry monitoring (ionisation chambers and counters)

   1.6. Thermocouples for MCL temperature measurement

   1.7. Level indicators in the Boron injection tank (B-8)

   1.8. Pipeline penetrations through the "confinement"

2. *RCP motor and main gate valve drives compartment:*

   2.1. Components for the water level detection at the compartment floor (sump),

   2.2. Electric motors of the air dumping valves on RPV, MCL, RCP and main gate valve,

   2.3. "Confinement" isolation valves and components of its ventilation system (B-4),

   2.4. Electric motors of the reactor coolant (RCP), circulating (ANGCN) and emergency circulating (VGCN) pumps, cables and functional parameter monitoring systems,

   2.5. Components for dosimetry monitoring in the SG and in the MCP and main gate valve motor compartments,

   2.6. Sensors, terminals and cables of accident parameters monitoring devices,

   2.7. Electric motors of the main gate valves,

   2.8. Electric motors of the recirculation-ventilation system valves (P-20),

   2.9. Electric motors of the RCP fans,

   2.10. Buttons for emergency shutdown of the electric motors of the reactor coolant (RCP), circulating (ANGCN), emergency circulating (VGCN) and the RPV shaft drainage (NDR-1) pumps

3. *Instrumentation compartments:*
   3.1. Equipment located in compartment A-004/1-3:
      - Sensors for the actuation of the pressuriser safety valve (SG 4, 5 & 6),
      - Sensors for the actuation of the emergency feed water pumps (APN 1 / 6),
      - Sensors for the actuation of the SG tubing leakage detection systems (SG 4, 5 & 6).
   3.2. Equipment located in compartment A-004/2-4:
      - Sensors for the actuation of the pressuriser safety valves (SG 1, 2 & 3),
      - Sensors for the actuation of the SG tubing leakage detection system (SG 1, 2 & 3).
4. *"Confinement" penetrations for cables.*

The bases of a methodology for qualifying the safety-related equipment have been proposed (see Annex 5 to the Final Report [9]). The proposal is derived from Western practices and complies with the relevant international requirements. The annex 5 to the Final Report [9] briefly describes the Western approach applied for safety-related equipment qualification. Taking into account that Novovoronezh units 3 and 4 are in operation, the qualification programme should take preference for any method, which could apply for "retro-active" qualification, like qualification by analysis and tests on typical spare parts.

The review of the Kozloduy qualification programme could not be performed as planned due to lack of information from the TACIS R1.3/91 project and coordination between TACIS and PHARE programmes. Consequently, only the available reports established in the frame of the WANO 6-month programme for Kozloduy NPP have been analysed during the 3rd phase (see Annex 9 to the Final Report [9]). Consequently, the qualification programme and conditions could only be evaluated, which were confirmed to be similar for both cases. For Kozloduy NPP the reference sequence for the environmental conditions was defined from the LOCA with an equivalent diameter of 45 mm. Only the qualification time (which can be understood as the period of existence of excessive environmental parameters for the particular component or the time during which this component has to fulfil its safety functions) has been given.

4.2 Conceptual Phase – Phase II

Due to time constrains, the selection of the accident sequence to be analysed was finally made on a deterministic basis and using only limited inputs from analyses performed in the TACIS R1.3/91 project. Thus, the conservative LOCA (32 mm primary break) was selected as the reference design basis accident for this project, being the most severe case for defining envelope environmental conditions inside the containment.

Additionally, input data (mass and energy discharged from the primary circuit into the containment during the accident sequence) were expected from updated accident analyses, which were planned in the frame of the TACIS R1.3/91 project. Unfortunately, this objective could not be reached, mainly for two reasons:

- First, direct use of results from the TACIS R1.3/91 project was not technically acceptable without correction. In fact in that project, the selection of the input data for accident analyses are made for maximising the consequences on the reactivity parameters. On the other hand, for defining the environmental conditions within the containment during the accident analyses the selection of the input data shall be defined for maximising the consequences outside the primary circuit.
- Second, during the development of the TACIS R1.3/91 project, it was decided to concentrate more on the beyond design accident sequences (LOCA with primary breaks

above 32 mm) in order to evaluate more realistically the available margins on the reactivity parameters. Therefore, the reference case needed for the TACIS R1.13/91 project (LOCA with 32 mm primary break) was not re-assed with the CATHARE code in the TACIS R1.3/91 project.

Therefore, a deterministic selection of input data for this project was made in coordination with the team leader of the TACIS R1.3/91 project (Siemens KWU). For this purpose, the results of the original design analysis performed by EDO Gidropress for 32 mm primary breaks were compared with those get for 64 mm primary breaks within the TACIS R1.3/91 project. This comparison showed that the mass and energy release were quite equivalent for both cases. Consequently, it was conservatively decided to use the mass and energy release given in the original EDO Gidropress analysis for 32 mm primary breaks in the cold and hot legs for the determination of the environmental conditions for equipment qualification (see Annex 6 to the Final Report [9]).

After the adoption of this decision, analyses with the WAVCO and the MARCH codes were performed on a generic and conservative model, representing the four operating Russian VVER 440/230 NPPs. These analyses were performed for the purpose of comparison of particular aspects of both computer codes. The objective was to help the Russian experts to get familiar with the use of “advanced” codes and to identify the major deviations of “simplified descriptions” of the physical phenomena.

Particular emphasis was put on the manner the steam-air mixture phenomena, occurring in the containment compartments during a LOCA including the hydrogen behaviour, are modelled in the computer codes by relevant physical or analytical descriptions. In the WAVCO code, the steam condensation phenomena on spray drops are modelled by a thermodynamic balance equation, which includes two main parameters to be manually set with the input data. Additionally, it appeared necessary to correct the spray system model in the different containment compartments in order to represent correctly its effectiveness by the WAVCO code.

The comparison of the results obtained from both codes showed some evidence of discrepancies on the speed of pressure decrease during operation of the spray system, due to the complexity of the condensation phenomena of steam-air mixture on spray drops and the reliability of their modelling. Despite these facts, the major outcomes, provided by both codes on the reference case, and needed for the definition of conservative environmental conditions (maximum pressure, humidity, temperature, …) were found in good qualitative and quantitative accidental environmental conditions agreement (see Annex 8 to the Final Report [9]).

The steam-air mixture behaviour during the accident sequences have been analysed in the different compartments, taking into account the local spray conditions. The corresponding absolute and partial steam pressures and the temperature, given by the WAVCO code, are reported in annex 7 of the Final Report [9]. The maximum values of these parameters are keys data for our purpose; they are given in table 4.2.

Compartments	Maximum value of parameters		
	Absolute pressure (MPa)	Partial steam pressure (MPa)	Temperature (^{0}C)
Reactor vessel and cavity	0.1344	0.01236	62.7
RCP compartment	0.1342	0.01413	65.9
Boron solution storage tank	0.1343	0.01245	60.7
Pressuriser compartment	0.1342	0.01209	62.0
Steam-generator compartment	0.1343	0.04163	76.9
Instrumentation room	0.1343	0.01232	62.8

<u>Table 4.2</u>: WAVCO analysis: maximum values of pressure and temperature in the compartments

Obviously, assistance to Russian experts in the use of Western computer codes was provided during the preparation of the model and input data as well as for carrying out the analysis.

4.3 Confirmation Phase – Phase III

The results of the reference case have been carefully reviewed. The benchmarking of both codes (see $ 4.1) has given the possibility to evaluate the quality and the reliability of the way of modelling the physical phenomena.

Complementary analyses were performed for some extend for the justification of the first results obtained with a preliminary version of the WAVCO code. The results obtained with the modified code, which integrated a better description of the local physical phenomena, did not reveal significant differences on the main parameters and their maximum values.

A complete reassessment of the equipment qualification policy has been prepared according to the international practice and using the upgraded environmental accidental conditions.

First of all main safety functions have been recalled as shown in table 4.3.a. As a first step towards the application of a structured selection process (see $ 4.1), the required ones have been identified for each component.

	Designation of the safety function
1	Maintaining of reactor sub-criticality
2	Cooling of reactor core
3	Heat removal from primary side by secondary side
4	Provision of primary circuit integrity
5	Provision of confinement integrity
6	Decrease of accidental radioactive releases to the environment

Table 4.3.a: Main safety functions to be considered for the equipment selection

Thus, the table 4.3.b details for each pre-selected components (see $ 4.1), the number of components implemented in one unit, the location in the plant, the original manufacturer, the availability of spare parts or not and the required safety functions. The availability of representative spare parts is valuable information regarding the possibility for possible experimental qualification. The detailed list of components has been established regarding the needs for the proper management of the accident sequence chosen for the determination of the conservative qualification conditions. The corresponding required safety functions are indicated for each component.

From the information collected in table 4.3.c, one can see that for the selected safety-related components the conservative environmental conditions for the 32 mm primary break (LOCA), as calculated by using the WAVCO code (see table 4.2), are exceeding those specified in the operational technical specifications. Note that the design basis values are exceeding the calculated one except for some cases (see Annex 11 to the Final Report [9]).

A list of a limited number of components has been established as shown in table 4.3.d and is proposed for further (re)qualification. This list comprises the components for which the calculated environmental conditions during the 32 mm primary break exceed those specified during the design stage. The final number of components to be qualified excludes components on an engineering basis in order to concentrate on the most safety-relevant ones showing not only the largest deviations, but also those, which are essential from the practical point of view.

Identification	Number per unit	Location	Original Manufacturer	Spare parts	Safety functions
Reactor Pressure Vessel	1	A-001	Izorskie Zavody, Kolpino	No	2, 4
Steam Generators	6	A-001	Izorskie Zavody, Kolpino	No	3
Reactor Cooling Pump	6	A-001	«Kirov» Factory, Sankt-Petersburg	No	3
Pipeline penetrations from Steam Generators compartment to emergency and normal operation make-up compartment	17	A-001	Manufactured during installation on site	No	5
Spent fuel pond cooling circuit pipeline penetrations	8	A-001	Manufactured during installation on site	No	5
B-2 ventilation system fans	2	B-303	Factory in Nicolaev-20	No	6
B-2 ventilation system filters (Petryanov type)	2	A-001	Factory in Tallinn	Yes	6
B-2 ventilation system carbon filters	3	A-001	Electromechanical factory, Electrostal	No	6
B-2 ventilation system air ducts	10	A-001	Manufactured during installation on site	No	5, 6
P-20 valves	1	A-102	Tulaprivod	No	2
Main Gate Valves	12	A-102	Vanykovsky valves factory, Chekhov	No	2, 3
B-4 ventilation system fans	2	A-102	«Marx» Mechanical-Engineering factory	No	6
B-4 ventilation system filter (Petryanov type)	5	A-102	Factory in Tallinn	Yes	6
B-4 ventilation system air ducts	2	A-102	Manufactured during installation on site	No	6
Pipeline penetrations through the “confinement”	225	A-102	Manufactured during installation on site	No	5
GCEN 310 type electric motor of MCP	6	A-102	«Kirov» Factory, Sankt-Petersburg	Yes	2, 3
VCEN 315 type electric motor of ANGCN	6	A-102	«Kirov» Factory, Sankt-Petersburg	Yes	2, 3
VGCN 138 type electric motor of VGCN fan	6	A-102	«Kirov» Factory, Sankt-Petersburg	Yes	2, 3
Type KSG1(2)-21 emergency cut-off buttons of electric motors of the RCP, ANGCN, VGCN & NDR-1 pumps	6	A-102	«REOSTAT», Velikie Lyki	Yes	2, 3
Power and instrumentation cables for electric motors and emergency cut-off buttons	21 power 19 control	A-102	«Kamkabel», Perm, «Moskabel», Podolsk «Sevkabel»,Sankt-Petersburg	Yes	1-2-3-4-5
Control Rod Drive Mechanisms: - Internal volume of the drive - Outside surface of the drive - Electric connectors	 73 73 146	A-001	Izorskie Zavody, Kolpino	 Yes Yes Yes	

Identification	Number per unit	Location	Original Manufacturer	Spare parts	Safety functions
Ionisation chambers and counters for in- and ex-core dosimetry monitoring	18	A-001	Zaprudnenskiy electrolamp factory	Yes	1
Thermo-electrical transducers TXK of the Reactor Temperature Control System	343	A-001	Scientific-technical laboratory «Pribor», NIIAT, Moscow	Yes	2, 3, 4
Manometers MED, MID	8	A-001, A-102, A-004/1,2	«MANOMETR», Moscow	Yes	4, 5
Electrical contact manometers	21	A-001, A-102, A-004/1,2	«MANOMETR», Moscow	Yes	4, 5
Instrumentation and power cables of the valves' motors	425	A-001, A-102, A-004/1,2	«Moskabel», Podolsk	Yes	1, 2, 3, 4, 5
Electric motors of the main gate and P-20 valves	13	A-001, A-102	«Electroprivod», Tula	No	2, 3
«Sapfir» and MPE-MI type pressure sensors	18	A-001, A-004/1,2	«MANOMETR», Moscow	Yes	4
Cables of 22 BP-36 power supply units for «Sapfir»	18	A-001, A-004/1,2	Device-Engineering factory, Ivano-Frankovsk	Yes	4
DM 3564, 3566 & 3583 type differential manometers	3	A-001, A-102, A-004/1,2	Device-Engineering factory, Ivano-Frankovsk	No	2, 3
Components for the water level detection at the compartment floor (sump),	1	A-001	«TENZOR», Kolpino	No	4

Table 4.3.b: Identification of the selected safety-related components

Identification	Nominal values according to operational technical specifications			Normal operation conditions			Design basis accident conditions			Maximum values for the 32 mm primary break (LOCA) calculated using the WAVCO code		
	T (°C)	H (%)	P (bar)	T (°C)	H (%)	P (bar)	T (°C)	H (%)	P (bar)	T (°C)	H (%)	P (bar)
Reactor Pressure Vessel	**80**	**90**	**1.0**	40/65	40/90	1*	120	100	2.0			
Steam Generators	**80**	**90**	**1.0**	40/65	40/90	1*	120	100	2.0	**76.9**	**100**	**1.343**
Reactor Cooling Pump	**80**	**90**	**1.0**	40/65	40/90	1*	120	100	2.0	**76.9**	**100**	**1.343**
Pipeline penetrations from the SG compartment to the emergency and normal operation make-up compartment.				30/65	40/90	1*	120	100	2.0	**76.9**	**100**	**1.343**
Spent fuel pond cooling circuit pipeline penetrations				25/65	30/60	1*	120	100	2.0	**76.9**	**100**	**1.343**
B-2 ventilation system fans	**-40/+40**	**45**		40/65	40/90		100	100	2.0	**76.9**	**100**	**1.343**
B-2 ventilation system filters	**30**	**95**	**0.03**	40/65	40/90		60			**76.9**	**100**	**1.343**
B-2 ventilation system carbon filters				40/65	40/90			80		**76.9**	**100**	**1.343**
B-2 ventilation system air ducts				40/65	40/90		100	100	2.0	**76.9**	**100**	**1.343**
P-20 valves	**40/90**			25/40	40/90	1*		100	2.0	**65.9**	**100**	**1.342**
Main gate valves	**40/90**			25/40	40/90		120	100	2.0	**65.9**	**100**	**1.342**
B-4 ventilation system fans	**40/90**			25/40	40/90			100		**65.9**	**100**	**1.342**
B-4 ventilation system filter	**30**	**95**	**0.03**	25/40	40/90		60			**65.9**	**100**	**1.342**
B-4 ventilation system air ducts				25/40	40/90		60			**65.9**	**100**	**1.342**
Pipeline penetrations through the "confinement"				40/65	40/90	1*	120	100	2.0	**65.9**	**100**	**1.342**
GCEN 310 type electric motor of MCP	**40**	**100**	**1**							**65.9**	**100**	**1.342**
VCEN 315 type electric motor of ANGCN	**40**	**100**	**1**	25/40	40/90	1*	120	100	2.0	**65.9**	**100**	**1.342**
VGCN 138 type electric motor of VGCN fan	**40**	**100**	**1**	25/40	40/90	1*	120	100	2.0	**65.9**	**100**	**1.342**
Type KSG1(2)-21 emergency cut-off buttons of electric motors of the RCP, ANGCN, VGCN & NDR-1 pumps	**40**	**100**	**1**	25/40	40/90	1*	120	100	2.0	**65.9**	**100**	**1.342**
Power and instrumentation cables for electric motors and emergency cut-off buttons	**-50/+50**	**98**		25/40	40/90	1*	120	100	2.0	**65.9**	**100**	**1.342**

Identification	Nominal values according to operational technical specifications			Normal operation conditions			Design basis accident conditions			Maximum values for the 32 mm primary break (LOCA) calculated using the WAVCO code		
	T (°C)	H (%)	P (bar)	T (°C)	H (%)	P (bar)	T (°C)	H (%)	P (bar)	T (°C)	H (%)	P (bar)
Control Rod Drive Mechanisms:						1*				**76.9**	**100**	**1.343**
- Internal volume of the drive	**100**	**100**	**125**	60/80	100		200	>100	140.0			
- Outside surface of the drive	**100**	**100**	**125**	60/80	100		120	100	2.0			
- Electric connectors	**100**	**100**	**0.55/1.6**	25/40			120	100	2.0			
Ionisation chambers and counters for in- and ex-core dosimetry monitoring	**200**			55/70			120	100	0.0	**76.9**	**100**	**1.0**
Thermo-electrical transducers TXK of the Reactor Temperature Control System	**60**	**90**	**0.85/ 1.03**	25/40	40/90		120	100.0	2.0	**76.9**	**100**	**1.343**
Manometers MED, MID	**50**	**80**		25/40	40/90		120	100.	2.0	**76.9**	**100**	**1.343**
Electrical contact manometers	**50**	**80**		25/40	40/90		120	100	2.0	**76.9**	**100**	**1.343**
Instrumentation and power cables of the valves' motors					40/90		120	100	2.0	**76.9**	**100**	**1.343**
Electric motors of the main gate and P-20 valves	**50**	**95**		25/40	40/90		120	100	2.0	**76.9**	**100**	**1.343**
«Sapfir» and MPE-MI type pressure sensors	**60**	**95**	**0.85/ 1.1**	25/40	40/90		120	100	2.0	**76.9**	**100**	**1.343**
Cables of 22 BP-36 power supply units for «Sapfir»				25/40	40/90		120	100	2.0	**76.9**	**100**	**1.343**
DM 3564, 3566 & 3583 type differential manometers	**50**	**80**		25/40	40/90		120	100	2.0	**76.9**	**100**	**1.343**
Components for the water level detection at the compartment floor (sump)	**200**	**100**	**25.0**	35/60	40/90		200	100	2.0	**76.9**	**100**	**1.343**

*: +/- 30 mm of water column

Table 4.3.c: Comparison of the different environmental conditions defined for the selected safety-related components

	Designation of the safety-related equipment
1	Pipeline penetrations from the SG compartment to the emergency and normal operation make-up compartment
2	Spent fuel pond cooling circuit pipeline penetrations
3	Pipeline penetrations through the “confinement”
4	Thermo-electrical transducers TXK of Reactor Temperature Control System
5	Manometers MED, MID
6	Electrical contact manometers
7	«Sapfir» and MPE-MI type pressure sensors
8	Instrumentation and power cables of the valves’ motors
9	Cables of 22 BP-36 power supply units for «Sapfir».
10	Electric motors of P-20 valves
11	Electric motors of the main gate valves
12	DM 3564, 3566 & 3583 type differential manometers

Table 4.3.d: List of the safety-related equipment proposed for (re)qualification

According to international requirements and taking benefit of the available experience within the group of experts, a qualification programme has been proposed. Depending on the type of equipment a specific qualification methodology has been proposed, taking into account the possibility to do partial or more extensive tests on spare parts or on removed components, on site or at a certified laboratory in Russia.

Therefore, the components have been classified into four groups, according to their functional role and technology:

- Group I: Various pipe penetrations,
- Group II: Thermo-electric transducers,
- Group III: Manometers,
- Group IV: Cables (control & power).

For each group of components, the most appropriate qualification methodology was proposed. Preference was given to on-site tests involving installed equipment, when possible. Other methods (laboratory tests on spare parts or removed components, analytical evaluations) have been proposed alternatively. The proposal can be summarised as follows:

- Group I equipment (penetrations) should be qualified by strength calculations prior testing (justifying that the penetration is capable to withstand the accidental thermal and pressure loads) and random individual tightness tests (10% of each penetration type) on-site during a specific shutdown for maintenance. Specific test configuration has to be arranged for that purpose;
- Group II and III equipment is suggested to be qualified at a laboratory on removed representative components. A 10% random sample per type has been proposed;
- Group IV equipment (all types of instrumentation and power cables) is suggested to be qualified at a laboratory on representative spare parts, in order to limit the expenses for removal.

A separate group V contains all equipment, which cannot be qualified by any of the above proposed methodology and need to be replaced by new ordered and qualified components. This situation occurs for components for which spare parts are not available and which cannot be removed without dismounting.

Russian Experts from ATOMENERGOPROEKT and Novovoronezh NPP have performed preliminary cost and test duration estimation, taking into account some prerequisites:

- Single tests shall include a 24 hour step at simulated conservative environmental conditions (expected to be equivalent to exposure to conditions occurring during the whole accident sequence till restoration of normal conditions can be managed);
- Pipeline penetration tests shall be performed during a specific shutdown for maintenance;
- 1993 Russian costs basis has been considered for the evaluations;
- The costs for the procurement of new spare parts replacing those who will be implemented in place of the original components to be tested at a laboratory are not included in the evaluation.

Table 4.3.e summarises the information giving, for each safety-related equipment proposed for (re)qualification, the relevant group, the proposed qualification method as well as the corresponding costs and duration estimates.

As shown in table 4.3.e, the global duration of the proposed qualification programme is estimated to be in the range of 12 to 18 months. The budget (1993 basis), needed for qualification of the equipment set of the Russian VVER 440/230 NPP, is estimated to be about 2445 Millions Roubles (# 550,000 US$).

The proposed qualification programme (see Annex12 to the Final Report [9]) was not performed within the R1.13/91 project, due lack of budget as well as the impossibility to extend this project to the suitable duration.

It was recommended to implement that programme as part of the maintenance and modernisation programme, which shall take place at the operating Russian VVER 440/213 NPPs to adapt their safety level according to international requirements. The integration of a more extensive list of design basis accidents could appear necessary. In that case, the qualification conditions should be upgraded as well.

Anyway, further financial support from the European Commission for that purpose was not foreseen. Therefore it was recommended that the Russian Beneficiary should take over the responsibility for its implementation in that frame as well as taking care on the necessary financial resources.

5 Overview of the project results

5.1. Fulfilled scope

Some coordination difficulties with related PHARE and TACIS projects needed compensatory measures to be able to cope with the main objective of the project. Thus, the review of the qualification programme performed within the 6 month WANO programme for Kozloduy NPP was restricted to a report survey. To compensate the delivery of updated input data (mass and energy release into the containment) from the TACIS R1.3/91 project, it was decided to use available Russian data, after checking their consistency and relevance.

Engineering assistance for optimising the qualification programme by various means (analyses, tests, co-ordination with others qualification needs like earthquake for example) was included in the project, but no performance of any action of the proposed programme. The contractor considers necessary to perform the proposed programme in the frame of the maintenance and modernisation programme of the Russian VVER 440/213 NPPs to adapt their safety level according to international requirements for further safe operation.

	Designation of the safety-related equipment	Qualification Group	Methods	Costs (Million Roubles)	Duration	Notes
1	Pipeline penetrations from the Steam Generators compartment to the emergency and normal operation make-up compartment.	I	Strength calculations prior testing Random (10% per type) individual on-site tightness tests	50	3 months	Duration is indicative and should be considered for or each type of penetration (position 1,2,3)
2	Cooling pond pipeline penetrations			450	During a specific maintenance shutdown	
3	Pipeline penetrations through the "confinement"					
4	Thermo-electrical transducers TXK of Reactor Temperature Control System.	II	Random (10% per type) laboratory tests of removed representative components	775	3 months	
5	Manometers MED, MID	III		540	2 months	
6	Electrical contact manometers					
7	«Sapfir» and MPE-MI type pressure sensors					
8	Instrumentation and power cables of the valves' motors	IV	100% laboratory tests of representative spare parts	630	2 months	
9	Cables of 22 BP-36 Power supply units for «Sapfir»					
10	Electric motors of P-20 valves	V	Replacement by replaced by new ordered and qualified components			The cost and duration will be defined after the selection of the new equipment
11	Electric motors of main gate valves					
12	DM 3564, 3566, 3583 type differential manometers					

Table 4.3.e: Proposed qualification programme for the identified safety-related components including costs and duration estimation

5.2. Discussion

Western and Russian experts have been working in close cooperation within the frame of this project, thanks to the creation of a technical working group since the beginning of the activities. The technical cooperation allowed the experts to get familiar with the state of the art on the relevant technical areas in the each involved Country. The Russian experts could take benefit of the training courses and complementary assistance, when necessary, for the use of Western codes, in particular the WAVCO code. This code as well as computers and equipment were transferred to the Russian Beneficiary and subcontractor. Benchmarking exercises with the WAVCO and MARCH codes was very effective for improving and adapting the modelling of the local condensation phenomena in the containment compartments.

A representative model of the operating Russian VVER 440/213 NPPs was build using the layout of the Novovoronezh units, as it was shown to be typical and either conservative. The model was used for the reference analysis as well as for code comparisons. The characteristics of each compartment (volume, wall properties, connections between each compartment, …) were developed specifically and carefully reviewed.

For this project, the 32 mm primary breaks selected as the conservative accident sequences to be taken into account for the determination of the most severe environmental conditions for the safety-related equipment qualification. The corresponding mass and energy release into the containment during the accident sequence were taken from available EDO Gidropress analyses, after checking their consistency and relevance. The results obtained with the WAVCO code were considered for the following tasks of the project. Complementary analyses have shown the reliability of the output data (peak temperature, humidity and pressure) further used for the definition of the qualification conditions.

A complete reassessment of the equipment qualification policy has been prepared according to the international practice and using the upgraded environmental accident conditions. Taking into account the specific situation of these plants and the past experience at Kozloduy NPP, a list of safety-related components to be (re)qualified was proposed. Instrumentation & control equipment is the most of concern.

A relevant qualification programme has been proposed and evaluated. The global duration is estimated to be in the range of 12 to 18 months. The budget (1993 basis), needed for qualification of the equipment set of the Russian VVER 440/230 NPP, is estimated to be about 2445 Millions Roubles (# 550,000 US$). The proposed programme could not be carried out within this project. The implementation of such a qualification programme into the maintenance and modernisation programme of the operating Russian VVER 440/213 NPPs makes sense, since the integration of a more extensive list of design basis accidents could appear necessary. In that case, the qualification conditions should be upgraded as well. Anyway, further financial support from the European Commission for that purpose was not foreseen.

6 RECOMMENDATIONS

The following recommendations have been issued in the project final report:

1. **Take benefit of the transferred know-how and technology on equipment qualification:**

   The results of the project in terms of transfer of expertise and equipment have a universal character. Appropriate adaptation can be managed by Russian experts in order to prepare application for equipment of any other NPPs series or specific case.

2. **Integrate the implementation of the proposed equipment qualification programme in the maintenance and modernisation programme of the operating Russian VVER 440/213 NPPs, after the necessary upgrading:**

The modernisation of the operating Russian VVER 440/213 NPPs is prepared under the responsibility of REA in order to cope with the required international safety level for further safe operation. In that frame, new design basis accidents should be integrated, according to the “Requests for technical re-equipment and modernisation of the 3rd and 4th units of the Novovoronezh NPP”, published in 1994. Therefore, the qualification conditions should first be upgraded before the qualification programme is being implemented.

7 ABBREVIATIONS

NPP	Nuclear Power Plant
VVER	Russian type Pressurised Water Reactor type
PWR	Pressurised Water Reactor
RPV:	Reactor Pressure Vessel
MCL	Main Coolant Lines
RCP	Reactor Coolant Pump
SG	Steam Generator
CRDM	Control Rod Drive Mechanism
ANGCN	Circulation pump (part of the RCP support system)
VGCN	Auxiliary circulation pump (part of the RCP support system)
NDR	Drainage pump of the RPV shaft
APN	Emergency feed water pump
CBO	Special water treatment system
GCEN, VCEN	Motor type references
TXK	Chromel-Alumel thermocouple
MED, MID, MPE-MI	Pressure sensor (manometer) type references
DM	Differential Manometer
ECCS	Emergency Core Cooling System
LOCA	LOss of Coolant Accident
MARCH AEP	Computer code for thermodynamic phenomena assessment in the containment (developed by ATOMENERGOPROEKT)
WAVCO	Computer code for thermodynamic phenomena assessment in the containment (developed by Siemens KWU)
CATHARE	Computer code for accident analyses is PWR systems (developed by CEA, Framatome & EDF)
TOR	Terms of Reference
FRA	Framatome S.A. (Framatome ANP = Framatome Advanced Nuclear Power)
Siemens KWU	Siemens Kraftwerkunion (Nowadays “Framatome ANP“)
EDF	Electricité de France
REA	Rosenergoatom (Russian Utility)
MOHT-OTJIG RM	Russian economical corporate company for the development and application of annealing technology, backfitting and modernization of NPPs
AEP	ATOMENERGOPROEKT
EDO Gidropress	Experimental and Design Organisation “Gidropress”
RRC KI	Russian Research Centre Kurchatov Institute
GAN	Gosatomnadsor (Russian Regulatory Body)

IAEA	International Atomic Energy Agency
CEC	Commission of European Communities
TACIS	Technical Assistance for the Commonwealth of Independent States
PHARE	Poland Hungary Assistance in Reconstruction of the Economy
WANO	World Association of Nuclear Operators

8 REFERENCES

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9. NVOD NT 95 2365 Rev. A – TACIS 91-1.13 – Final Report – Safety-related equipment qualification – July 1993 / October 1995, with:
   - Annex 1: Modelling and data for calculations – VVER 440-V 179 project – Units 3 and 4 of Novovoronezh NPP
   - Annex 2: Information on description of VVER 440-179 Project – Units 3 and 4 of Novovoronezh NPP
   - Annex 3: Revue of Safety Analyses Reports for 3 and 4 units of Novovoronezh NPP
   - Annex 4: Qualification methodology and qualified equipment list of the French 900 MWe series plant (FRA ET/SS/DC 638 A)
   - Annex 5: Safety-related equipment qualification method proposed for equipment qualifications (NVOD NT 94.2049 B)
   - Annex 6: Listing of 32 mm hot and cold legs LOCA input data for WAVCO programme
   - Annex 7: Calculation results of the 32 mm LOCA for 3rd and 4th units of Novovoronezh NPP
   - Annex 8: Comparison between the results of the WAVCO programme and the MARCH-AEP programme for the sample problem
   - Annex 9: Analysis of the Kozloduy qualification report in the PHARE programme (NVOD NT 95.1173 B)
   - Annex 10: Aim and description of the WAVCO programme
   - Annex 11: Safety-related equipments - Main technical specimens and environmental operation conditions VVER 440-V179 units 3 and 4 of Novovoronezh NPP
   - Annex 12: Qualification methodology qualification programme schedule and cost estimation VVER 440-V179 units 3 and 4 of Novovoronezh NPP
