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Cost Estimation of Implementing Safety Upgrading Measures for Khmelnitsky Unit 2 and Rovno Unit 4

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Report to the
Austrian Government

Vienna, October 1998

Risk Research Report Nr. 23

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2B.1 Introduction

2B.1.1 Modernization Project Khmelnitsky Unit 2 and Rovno Unit 4: Cost and Schedule Estimates

There have been a number of cost estimates for completion, modernization, and commissioning of Khmelnitsky Unit 2 and Rovno Unit 4 (K2/R4). These estimates are listed below in chronological order:

- **EBRD Study of Economic Aspects of Nuclear Generation and Safety Improvements in Eastern and Central Europe, June 1993, 0.92 billion USD**
- **USDOE/Minatom Study, July 1994, 0.98 billion USD**
- **Energoatom Project Presentation, August 1988, 1.25 billion USD**
- In a project presentation to the EBRD the project sponsor estimated the overall project cost (see below).
- **EBRD, September 1998, 1.725 billion USD**
  EBRD estimated the cost of completing both units and providing support to the Ukraine Nuclear Regulatory Authority at 1.725 billion USD.

2B.1.2 Cost Structure of the K2/R4 Completion Project

In the project presentation of Energoatom: "Completion of Rovno Unit 4 and Khmelnitsky Unit 2", in August 1998 the following contributors to the overall project costs were listed:

- **Completion** – the completion of the units according to the original design. This work includes outstanding construction work such as completion of plant installation; completion of partial installations; electrical wiring; instrumentation and control equipment; plant cleaninless; and equipment commissioning and functional testing.
- **Rehabilitation** – replacement of deteriorated equipment or its repair to the status good for operation. This work includes inspections to determine the equipment and civil works needing restoration to a state suitable for commissioning and startup, including repair and replacement tasks such as refurbishing, repainting, surface preservation, and repairs.
- **Modernization** – upgrading of safety, quality of operation, and the availability of the units. This work includes the modernization programme, waste processing facilities at the plants; installation of a full-scope simulator at Khmelnitsky; and improvements to the switchyard at Rovno. The modernization programme includes 148 measures, 144 of which are common to the two units and two items each which are specific to Khmelnitsky Unit 2 or Rovno Unit 4. The modernization programme is intended to eliminate deviations from current Ukrainian national safety norms; to improve the reliability of safety-related equipment by upgrading the design quality, manufacture, and installation; and to improve operation quality.
- **First Fuel Load**
- **Testing Commissioning**
- **Engineering Activities**
- **Project Management**
- **Licensing and Certification**
- **Miscellaneous Costs** like customs, insurance, financial engineer for the banks.

2B.1.3 Approach

In chapter 2 of this report we will present cost estimates which were extracted from the last update of the Modernization Programme (MP) for K2/R4 (Rev. 2, Oct. 1996). The cost estimates cover only the modernization (safety upgradings, etc.) of the reactors. Other contributors to the total costs listed above (see 1.2) are not included. Considering the time development of cost estimates for K2/R4 (see 1.1) it should also be taken into account that the costs estimates for the modernization measures presented in the Modernization Programme are from the year 1996.

In chapter 3 these modernization costs are compared with the costs for implementing a modernization programme for operating WWER-1000 units. This modernization programme and the cost estimates were set up in 1995 by the consortium of MOHT-EdF.

Chapter 4 contains a list of modernization measures which are not included in the Modernization Programme for K2/R4. An implementation of these measures, which is highly recommended by the Institute of Risk Research, results in higher costs than those estimated in the MP. An evaluation of the costs for implementing these more comprehensive list of measures is beyond the scope of this report.

Chapter 5 is an extraction of the most recent report on the status of the completion project: Temelin NPP. This report demonstrates cost overruns and time delays.

2B.2 Cost Estimation of Implementing the Safety Upgrading Measures for K2 and R4

The following table have been extracted from the Modernization Programme for Khmelnitsky 2 and Rovno 4 (Rev. 2, Oct. 1996). Table 1 provides an overview on the costs for implementing the planned measures for different areas. Attachment 1 lists the costs of all measures which are planned to be implemented before and after start-up.

Table 1: Cost Estimation of Modernization K2/R4

		K2: COSTS (USD96)	R4: COSTS (USD96)
10	GENERAL	2.000.000	2.000.000
11	REACTOR CORE AND FUEL HANDLING	1.359.430	1.359.430
12	COMPONENTS INTEGRITY	15.320.030	15.320.030
13	SYSTEMS	7.673.420	8.743.420
14	MONITORING AND CONTROL SYSTEMS	36.984.500	36.984.500
15	ELECTRICAL POWER SUPPLY	16.664.240	6.149.400
16	CONTAINMENT AND BUILDING STRUCTURES	1.993.400	1.993.400
17	INTERNAL HAZARDS	2.359.000	2.359.000
18	EXTERNAL HAZARDS	952.000	952.000
19	ACCIDENTS ANALYSIS	3.080.000	3.080.000
20	FUEL HANDLING	970.000	970.000
21	PRIMARY CIRCUIT	475.000	475.000
22	SECONDARY CIRCUIT	865.344	865.344
23	MONITORING AND CONTROL SYSTEM	105.000	105.000
24	ELECTRICAL POWER SYSTEM	19.610.219	11.568.019
25	REACTOR CORE AND FUEL	481.000	481.000
26	COMPONENTS INTEGRITY	14.350.300	14.350.300
27	SYSTEMS	785.000	785.000
28	CONTROL AND MONITORING SYSTEM	13.764.025	13.764.025
29	INTERNAL HAZARDS	1.742.900	1.742.900
30	OPERATION PROCEDURES	4.490.000	4.490.000
31	CONTROL	2.630.030	2.630.030
32	TEST AND DIAGNOSTICS	1.180.000	1.900.000
33	PERSONNEL PROTECTION AND RADIATION SAFETY	8.043.430	8.043.430
34	REPAIR AND MAINTENANCE	7.208.000	7.208.000
35	PHYSICAL PROTECTION	6.075.632	6.075.632
SUM		**171.161.900**	**155.574.860**
TOTAL SUM FOR K2 and R4: 326.736.760 USD96			

2B.3 Cost Estimates of Modernization Measures of Operating WWER-1000/320 Reactors – Extracted from the MOHT EdF Modernization Programme

The following table was extracted from the MOHT-EdF generic modernization program: MOHT-EdF, "Generic Reference Programme for the Modernization of VVER 1000"-V320, MOHT (Atomenergoprojekt, OKB Gidropress, Kurchatov Institute, VNIIAES, Zarubejatomenergostroy, Rosenergoatom, et al.) and Electricité de France (EdF), Revision 5, January 1996.

The data presented in the table were extracted from a cost estimation of MOHT-EdF for modernization of two operating WWER-1000/320 units. The data for implementing modernization measures for reactors under construction were found to be incomplete and are not quoted here.

MOHT-EDF Measures	Costs for 2 Rectors in USD95[1]
1. SAFETY	
1.1. Measures related to design and construction/installation	
1. (1.1.1.1) DECREASE IN DROP TIME OF CPS CONTROL RODS (see also 2.1.1.1.1A)	145,000
2. (1.1.1.2) REPLACEMENT OF ANALOG-DISCRETE TRANSDUCERS WITH UPGRADED UNITS, PROVIDING SIGNALLING FOR INTERLOCKING DEVICE ACTIVATION.	4,800,000
3. (1.1.1.3) MODERNIZATION OF ICIS INCLUDING REPLACEMENT OF IN CORE NEUTRON MEASURING CHANNELS (NMC) BY NFTMC AND DEVELOPMENT OF LOCAL DIAGNOSTICS SYSTEMS.	4,035,000
4. (1.1.1.4) PREVENTION OF DAMAGE OF MORE THAN ONE STEAM LINE TO EXCLUDE NUCLEAR-HAZARDOUS CONDITIONS	2,395,000
5. (1.1.1.5) DEVELOPMENT AND INTRODUCTION OF MEASURES EXCLUDING POSSIBILITY OF BREAK OF MORE THAN ONE STEAM LINE OR FEED WATER PIPING WITHIN CIVIL STRUCTURES OF REACTOR COMPARTMENT	155,400
6. (1.1.1.6) MEASUREMENT OF B-10 ISOTOPE CONCENTRATION	4,700,000
7. (1.1.1.7) NEUTRON FLUX MONITORING EQUIPMENT	3,750,000
8. (1.1.1.8) SET OF EQUIPMENT FOR DETERMINATION OF REACTIVITY EFFECTS AND EFFICIENCY OF CONTROL ROD CLUSTERS, USING IN-CORE AND EX-CORE NEUTRON DETECTORS, AND FOR ITS METROLOGICAL CERTIFICATION	63,000
9. (1.1.1.9) SEPARATION OF PRIMARY PULSE LINES TO I&C TRANSDUCERS	170,000
10. (1.1.1.10) CONTROL OF THE REACTOR CORE SUBCRITICALITY	44,000
11. (1.1.1.11) COMPACT STORAGE OF SPENT FUEL	13,536,800
12. (1.1.1.12) POST ACCIDENT MONITORING SYSTEM	250,000
13. (1.1.1.13) UPGRADING OF THE REACTOR POWER CONTROL SYSTEM	2,150,000
14. (1.1.1.14 AND 2.1.1.1.1B) IMPROVEMENT OF NOISE IMMUNITY OF CPS EQUIPMENT	152,000
15. (1.1.1.15.) SYSTEM OF SAFETY PARAMETERS PRESENTATION	4,030,000
16. (1.1.2.1.1) STANDARD SYSTEM OF REACTOR VESSEL RADIATION LOAD MONITORING	240,000

[1] Comparison of average USD96 and USD95: 1 USD96 = 1.049 USD95

MOHT-EDF Measures	Costs for 2 Rectors in USD95[1]
17. (1.1.2.1.2). TO MODERNIZE RADIATION MONITORING WITHIN THE SCOPE OF THE EXISTING PROGRAMME OF SURVEILLANCE SPECIMENS. TO PERFORM ANALYSIS OF THE RESULTS OF SURVEILLANCE SPECIMENS TESTS TAKING ACCOUNT OF REVISIONS OF RADIATION MONITORING CHARACTERISTICS.	380,000
18. (1.1.2.1.3). TO ELABORATE AND IMPLEMENT A NEW PROGRAMME OF SURVEILLANCE-SPECIMENS OF THE VESSEL MATERIAIL	670,000
19. (1.1.2.1.4). TO DEVELOP AND INTRODUCE THE STANDARD PROCEDURE FOR DETERMINATION OF THE CURRENT RESIDUAL RADIATION LIFE OF SAFE OPERATION OF THE REACTOR	70,000
20. (1.1.2.1.5) VERIFICATION OF THE DESIGN SERVICE LIFE OF THE REACTOR VESSEL	70,000
21. (1.1.2.2) STEAM DETECTOR FOR RPV HEAD	300,000
22. (1.1.2.3) ASSURANCE OF LONG-TERM REMOVAL OF REACTOR RESIDUAL HEAT	5,634,800
23. (1.1.2.4) REDUNDANCY OF A GROUP SERVICE WATER SUPPLY FOR SEALING OF ECCS PUMPS	293,000
24. (1.1.2.5) MODERNIZATION IN-CORE INSTRUMENTATION FOR TEMPERATURE CONTROL	460,000
25. (1.1.2.6 AND 1.1.2.20) MODERNIZATION OF REACTOR VESSEL HEAD SEALING (MAIN SEALING AND SEALING OF PENETRATIONS)	220,000
26. (1.1.2.7) MEASURES THAT EXCLUDE UNAUTHORIZED OVERFILL OF A GROUP SERVICE WATER TANKS IN THE EVENT OF FAILURE OF CHECK VALVE	738,000
27. (1.1.2.8) IMPROVEMENT OF OPERATING RELIABILITY OF STEAM GENERATORS AND BLOWDOWN SYSTEM	2,074,000
28. (1.1.2.9) IMPLEMENTATION OF THE “LEAK-BEFORE-BREAK” CONCEPT	25,150,000
29. (1.1.2.10 AND 1.2.2.1) HYDROGEN REMOVAL FROM THE REACTOR PLANT PRIMARY EQUIPMENT AND ANALYSES OF HYDROGEN SAFETY	573,000
30. (1.1.2.11A) ON-LINE DIAGNOSTICS SYSTEM FOR PRIMARY CIRCUIT OF NPPS IN SERVICE	
31. (1.1.2.11B) SYSTEM FOR PERIODICAL INSPECTION OF REACTOR EQUIPMENT (EXCEPT REACTOR VESSEL) AND PIPELINE METAL INTEGRITY	
32. (1.1.2.11B) SYSTEM FOR PERIODICAL INTERNAL IN-SERVICE INSPECTION OF RPV METAL INTEGRITY	Sum 30-32: 20,133,900
33. (1.1.2.12) FIRE PROTECTION SYSTEM	846,400
34. (1.1.2.13) PROTECTION OF PRIMARY CIRCUIT AGAINST COLD	10,500
35. (1.1.2.14 AND 1.1.2.15) ASSURANCE OF DESIGN LIFE OF THE REACTOR VESSEL – HEATING OF ECCS WATER	1,195,000
36. (1.1.2.16) ORGANIZATIONAL-ENGINEERING MEASURES FOR THE MANAGEMENT OF ACCIDENTS INVOLVING PRIMARY-TO-SECONDARY COOLANT LEAK UP TO DNOM 100 MM.	768,000
37. (1.1.2.17) UPDATING OF PRESSURISER PSD TO IMPLEMENT “FEED AND BLEED” PROCEDURE	180,000
38. (1.1.2.18) SYSTEM TO ENSURE SPENT FUEL POND COOLING AT FALSE CLOSING OF ISOLATING VALVE	535,000
39. (1.1.2.19) SEPARATION OF THE MAIN CONTROL ROOM (MCR) AND RESERVE CONTROL ROOM (RCR) VENTILATION SYSTEMS	117,800

MOHT-EDF Measures	Costs for 2 Rectors in USD95[1]
40. (1.1.2.21) EXTENSION OF THE TIME OF STEAM GENERATORS MAKE-UP (SAFETY UPGRADING FOR BEYOND-DESIGN ACCIDENTS)	52,500-751,500
41. (1.1.2.22) UPGRADING OF INFORMATION SYSTEMS AND CONTROL SYSTEMS TO PROVIDE AUTOMATIC AND/OR AUTOMATED DIAGNOSIS OF THE STATE OF HARDWARE	14,300,000
42. (1.1. 2.23) NPP LOCAL CRISIS CENTRE	6,400,000
43. (1.1.2.24) INCREASE OF BATTERIES DISCHARGE TIME.	175,000
44. (1.1.2.25) INTEGRATION OF GENERAL PLANT DIESEL GENERATOR	7,383,600
45. (1.1.2.26) CONTROL OF INDICATION OF POSITION OF THE MAIN VALVE OF THE PRESSURIZER	380,000
46. (1.1.2.27.1 AND 2.1.1.2.1) PROPOSALS FOR ARRANGING CONNECTIONS BETWEEN POWER UNITS BY 6 KV NETWORK PROVIDING FIRE PROTECTION OF ONE POWER UNIT WHEN FIRE OCCURS ON THE OTHER ONE.	5,100,000
47. (1.1.2.27.2) UPGRADE THE FIRE EMERGENCY DOORS	940,000
48. (1.1.2.27.3) REACTOR COOLANT PUMP FIRE DETECTION SYSTEM	600,000
49. (1.1.2.27.4) INSTALLATION OF FIRE GATE VALVES IN VENTILATION DUCTS.	885,000
50. (1.1.2.27.5) IMPROVEMENT OF FIRE SAFETY OF CABLE EQUIPMENT.	1,635,000
51. (1.1.2.27.6) ENHANCEMENT OF FIRE SAFETY OF DIESEL-GENERATORS OF RELIABLE POWER SUPPLY	44,000
52. (1.1.2.27.7) THE SMOKE REMOVAL SYSTEM	909,400
53. (1.1.2.27.8) THE GAS FIRE EXTINGUISHING SYSTEMS IN ROOMS WITH ELECTRONIC EQUIPMENT	466,400
54. (1.1.2.28) CABLE ROUTING AND PENETRATIONS.	1,750,000
55. (1.1.2.29 AND 2.1.1.6.2) IMPROVEMENT OF BRU-A RELIABILITY	100,000 + costs to be determined later
56. (1.1.2.30) PROVISION OF CONTROL OF EQUIPMENT MOVEMENT	347,000
57. (1.1.2.31 AND 2.1.1.4.1) UPDATING OF GTSN-195M RCP	1,343,500
58. (1.1.2.32 AND 2.1.1.9.2) REPLACEMENT OF INVERTERS	1,520,000
59. (1.1.2.33 AND 2.1.1.9.4) REPLACEMENT OF 6 KV BREAKERS	13,400,000
60. (1.1.2.34 AND 2.1.1.12.1) UPGRADING OF EMERGENCY AND SCHEDULED COOL DOWN PUMP TSNR800-230	455,000
61. (1.1.2.35 AND 2.1.1.12.2) UPGRADING OF SPRINKLER PUMP TSNSA700-140	395,000
62. (1.1.2.36 AND 2.1.1.12.3) UPGRADING OF EMERGENCY BORON INJECTION PUMP TSN150-110	395,000
63. (1.1.3.1) SYSTEM FOR CONTROL AND REMOVAL OF HYDROGEN	970,000
64. (1.1.3.2) INSPECTION OF INTEGRITY OF COLLECTORS AND HEAT EXCHANGING TUBES OF STEAM GENERATORS	580,000
65. (1.1.3.3) AUTOMATIC SYSTEM FOR RADIATION SITUATION MONITORING (ASKRO)	4,900,000
66. (1.1.3.4) PREVENTION OF RADIOACTIVITY RELEASE OUTSIDE THE CONTAINMENT DURING ENCLOSURE UNSEALING OF HEAT EXCHANGER OF RCP SELF-CONTAINED SYSTEM	51,800

MOHT-EDF Measures	Costs for 2 Rectors in USD95[1]
67. (1.1.3.5) IMPROVEMENT OF RELIABILITY OF THE PROCEDURES OF REFUELLING	215,000
68. (1.1.3.6) REMOVAL OF RADIOACTIVE WASTE FROM THE REACTOR HALL	a) 530,000 b) 1,550,000
69. (1.1.3.7) IMPROVEMENT OF REFUELLING PROCEDURE RELIABILITY	540,000
70. (1.1.3.8) WITHDRAWAL OF DROPPED FUEL ASSEMBLY	590,000
1.2. Analysis and Expert Assessment	
71. (1.2.1.1 AND 1.2.2.3) QUALIFICATION OF EQUIPMENT	1,750,000
72. (1.2.1.2) FIRE SAFETY ENHANCEMENT	260,000
73. (1.2.1.3 AND 1.2.2.5) ANALYSIS OF NPP SEISMIC STABILITY	1,500,000
74. (1.2.1.4) TO COMPILE SAFETY ANALYSIS REPORT (SAR) WITH CONSIDERATION OF MEASURES IMPLEMENTED BEFORE UNIT COMMISSIONING	
75. (1.2.1.5) TO ELABORATE PROBABILISTIC SAFETY ANALYSIS (PSA) WITH CONSIDERATION OF MEASURES IMPLEMENTED BEFORE UNIT	
76. (1.2.1.6) OVERALL ANALYSIS OF INTERNAL FLOODING IN THE REACTOR BUILDINGS AND TURBINE HALL	12,000
77. (1.2.1.7) ANALYSIS OF FEASIBILITY OF INTRODUCTION OF ADDITIONAL SYSTEMS FOR MANAGEMENT OF BEYOND-DESIGN BASIS ACCIDENTS	
78. (1.2.1.8) STRENGTH RECALCULATION OF SAFETY RELEVANT PIPELINES	320,000
79. (1.2.1.9 AND 1.2.1.14) DESIGN ACCIDENT ANALYSIS	1,900,000
80. (1.2.1.10.) TO PERFORM THE ANALYSIS AND TO IMPLEMENT THE REQUIRED MEASURES FOR THE ELIMINATION OF INADVERTENT DECREASE OF ABSORBER CONCENTRATION IN THE PRIMARY CIRCUIT	200,000
81. (1.2.1.11) ASSESSMENT OF THE CONTAINMENT ABILITY TO WITHSTAND POSSIBLE AIRPLANE CRASH LOADS UP TO 20T	85,000
82. (1.2.1.12) ELABORATE DESIGN CRITERIA ON PROTECTION OF CONTAINMENT SHUT-OFF VALVES AGAINST INTERNAL MISSILES	25,000
83. (1.2.1.13) ADDITIONAL SAFETY ANALYSES FOR BEYOND-DESIGN BASIS ACCIDENTS	840,000
84. (1.2.1.15) MONITORING OF THE CORROSION-PROOF PROTECTION STATE FOR THE CONTAINMENT PRESTRESSING SYSTEM AT OPERATIONAT. NPPS EQUIPPED WITH WER-1000	90,000
85. (1.2.1.16 AND 1.2.2.7) SUBSTANTIATION OF REACTOR TOP HEAD RELIABILITY	575,000
86. (1.2.1.17A) EXPERIMENTAL-CALCULATIONAL ANALYSIS OF STRENGTH OF STRESS-RELIEVED COLLECTORS TO-MCP AND TO-PGV-lOOOM STEAM GENERATOR VESSEL WELDS	120,000
87. (1.2.1.17B) CALCULATION OF MAXIMUM PERMISSIBLE MOMENT ON THE WRENCH DURING THE REMOVAL OF STUD FROM THREADED FLANGE JOINTS OF STEAM GENERATOR	120,000
88. (1.2.1.18) ANALYSIS OF ULTIMATE STRENGTH OF THE CONTAINMENT STRUCTURE AND ITS PENETRATIONS DEPENDING ON INTERNAL PRESSURE	150,000
89. (1.2.1.19) TO PERFORM ANALYSIS AND TO IMPLEMENT, IF NECESSARY, MEASURES FOR SAFETY IMPROVEMENT OF CONNECTION OF SCHEDULE COOLDOWN LINE OVER THE PRIMARY CIRCUIT.	140,000
90. (1.2.1.20) LIST OF NUCLEAR-HAZARDOUS WORK	25,000

MOHT-EDF Measures	Costs for 2 Rectors in USD95[1]
91. (1.2.1.21) IN ORDER TO CLASSIFY NPP COMPONENTS, SYSTEMS AND STRUCTURES AS TO THEIR EFFECT ON SAFETY	35,000
92. (1.2.1.22) SEISMIC STABILITY CALCULATIONS FOR COMPONENTS OF THE DECONTAMINATION SYSTEM OF RADIOACTIVE AEROSOLS	15,000
93. (1.2.1.23) TO PERFORM ADDITIONAL SUBSTANTIATION OF SVO-1 FILTER STRENGTH	85,000
94. (1.2.1.24) CONSIDERATION OF POSSIBILITY OF IMPLEMENTING A “TUBE IN TUBE” STRUCTURE (“DOUBLE ENVELOPE”) FOR PIPELINE TO REMOVE COOLANT FROM CONTAINMENT SUMP.	15,000
95. (1.2.1.25) STUDIES TO SHORTEN THE CABLING LENGHT FROM DIESEL GENERATOR	
96. (1.2.1.26) DETERMINATION OF CRITERION FOR STEAM GENERATOR UTUBES PLUGGING	270,000
97. (1.2.1.27) SAFETY ENGINEERING FACTOR	200,000
98. (1.2.1.28) DESIGNING OF CONTAINMENT BUILDING. DESIGN CALCULATIONS	190,000
99. (1.2.1.29) DESIGNING OF CONTAINMENT BUILDING. DESIGN AND PROCESS IMPROVEMENTS	70,000
100. (1.2.1.30) SAFETY LIMITS FOR THE CONTAINMENT BUILDING. MONITORING OF THE BUILDING	150,000
101. (1.2.1.31) SAFETY LIMITS FOR THE CONTAINMENT BUILDING. MONITORING SEQUENCE	115,000
102. (1.2.2.2) PROBABILISTIC SAFETY ANALYSIS	8,645,000
103. (1.2.2.4) DETERMINATION OF THE EFFECT OF A PRZ PULSE-SAFETY DEVICE (PSD) OPENING ON PRZ EQUIPMENT AND PIPELINES	60,000
104. (1.2.2.6) PROBABILISTIC ASSESSMENT OF FIRE SAFETY	1,200,000
105. (1.2.2.8, 1.3.5 AND 1.3.2.5.2C) DECREASE OF PRIMARY CIRCUIT LEAKS PROBABILITY	121,000
106. (1.2.2.9) DRAW UP A LIST OF PERSONNEL ERRORS ON THE BASIS OF STATISTICAL DATA. REVISE DESIGN OPTIONS AND OPERATING PROCEDURES AS PER RESULTS OF ANALYSIS, IF NECESSARY	15,000
107. (1.2.2.10) ANALYSIS OF EFFECT OF BUILDINGS AND STRUCTURES DISPLACEMENT ON SAFETY SYSTEMS OPERATION	120,000
108. (1.2.2.11) ANALYSIS OF TIME DURING WHICH SPRAY PONDS MAINTAIN SERVICEABILITY IN THE CASE OF FAILURE OF A MAKE-UP SYSTEM FAILURE	135,000
109. (1.2.2.12) SEVERE ACCIDENT ANALYSES FOR WER 1000 NPP’S	later
110. (1.2.2.13) CORRECTION OF CRITERIA FOR INTRODUCTION OF THE EMERGENCY ACTION PLAN	100,000
111. (1.2.2.14) PERFORM A COMPREHENSIVE ANALYSIS OF ACCIDENTS WITH PRIMARY LEAKS INVOLVING A POSSIBLE RADIOACTIVITY RELEASE BEYOND THE CONTAINMENT BOUNDARIES (CONTAINMENT BYPASS).	85,000
1.3. Operating Upgrading	
112. (1.3.1.1 AND 1.3.1.2) DEVELOPMENT OF NORMAL AND OF STATEORIENTED REACTOR EMERGENCY PROCEDURES	8,020,000
113. (1.3.1.3, 1.3.5.5 AND 1.3.5.6) MAINTENANCE AND REPAIR	1,769,800
114. (1.3.2.1) STAFFING AND TRAINING	75,000

MOHT-EDF Measures	Costs for 2 Rectors in USD95[1]
115. (1.3.2.2) SYSTEM (SET) FOR HUMAN RELIABILITY ASSURANCE DURING NPP OPERATION	490,000
116. (1.3.3.1) DEVELOPMENT OF A QUALITY ASSURANCE SYSTEM (3-5 YEAR PROGRAMME)	380,000
117. (1.3.4.1) SYSTEMS FOR ECCS HEAT EXCHANGERS MONITORING AND CLEANING FROM THE SERVICE WATER SIDE	250,000
118. (1.3.4.2) OPTIMIZATION OF METHODS AND FREQUENCY OF PRESSURIZER PSD INSPECTIONS	780,000
119. (1.3.4.3) REGISTRATION OF EMERGENCY EVENTS	530,000
120. (1.3.4.3 AND 2.1.1.8.1C) REVAMPING OF THE SYSTEM FOR SG LEVEL VARIATION	1,255,000
121. (1.3.4.5A) MULTICHANNEL SYSTEM FOR RECORDING AND ANALYZING ELECTRICAL TRANSIENTS DURING EMERGENCY SITUATIONS	135,000
122. (1.3.4.5B) STATIONARY AUTOMATIC MONITORING SYSTEM FOR THE MAIN ELECTRICAL EQUIPMENT	82,000
123. (1.3.4.6) RECORDING DEVICES IN THE MAIN CONTROL ROOM.	200,000
124. (1.3.4.7) UPDATING OF EMERGENCY LIGHTING (EMERGENCY EXITS DURING PERFORMANCE OF EMERGENCY WORK).	115,000
125. (1.3.4.8) IDENTIFICATION OF EMERGENCY POWER SUPPLY EQUIPMENT	200,000
126. (1.3.5.2A) ELABORATION OF TECHNOLOGICAL DESIGN DOCUMENTATION “RESTORATION OF THE CLADDING OF PGV-1OOOM STEAM GENERATORS SEALING SURFACES “	230,000
127. (1.3.5.2B) SPECIFICATION FOR TEMPORARY SEALING OF THE SG PRIMARY COLLECTOR WITH THE WATER-FILLED REACTOR REFUELLING POOL	235,000
128. (1.3.5.3) REPLACEMENT OF WIRING UNIT ELECTRICAL EQUIPMENT AND MODERNIZATION OF ELECTROTECHNICAL SYSTEMS	2,450,000
129. (1.3.5.4) IMPLEMENTATION METHODOLOGY TO DETERMINE THE CORRESPONDING REFERENCE ISOTOPES BETWEEN DAMAGED FUEL OPERATIONAL LIMIT AND PRIMARY COOLANT ACTIVITY	950,000
130. (1.3.5.7, 1.3.5.8, 2.3.1.2 AND 2.1.1.9.1) WRITING A SET OF DOCUMENTATION FOR MAINTENANCE AND REPAIR OF POWER TRANSFORMERS, MOTOR 6 KV, UKTS CUBICLES ETC	602,000
131. (1.3.6.1A, 1.3.6.1B AND 1.3.6.1C) OPTIMIZATION OF FUEL LOADS	240,000
132. (1.3.6.2) OPTIMIZATION OF POWER UNIT OPERATION UNDER TRANSIENTS WITH VARIATION OF LOAD	2,600,000
133. (1.3.6.3) OPTIMIZATION OF FUEL CYCLES MANAGEMENT FOR JOINT POWER UNITS	60,000
134. (1.3.7.1) REVISION OF THE LIST OF MEANS FOR PERSONNEL PROTECTION	30,000
135. (1.3.7.2) REVISION OF THE INSTRUCTIONS FOR PERFORMANCE OF RADIOLOGICALLY HAZARDOUS WORKS	40,000
136. (1.3.7.3) REVISION OF THE DUTY INSTRUCTIONS FOR THE RADIOLOGICAL SAFETY SERVICES	30,000
137. (1.3.7.4) IMPLEMENTATION OF PERSONAL DOSIMETERS WITH AUDIBLE AND VISUAL SIGNALLING	20,000
138. (1.3.7.5) MEASURES FOR IMPROVING THE QUALITY OF THE BREATHING DEVICES USED ON SITE	20,000

MOHT-EDF Measures	**Costs for 2 Rectors in USD95**[1]
139. (1.3.8.1, 1.3.8.2, 1.3.8.3, 1.3.8.4 AND 2.1.1.10.1) WATER CHEMISTRY OF PRIMARY AND SECONDARY CIRCUITS	470,000
140. (1.3.9.1) DEVELOPMENT OF DATA SHEETS ON EQUIPMENT FAILURES	10,000
141. (1.3.9.2 AND 2.3.4.1) DEVELOPMENT OF “HISTORY OF NPP EQUIPMENT OPERATION” INFORMATION SYSTEM	100,000
142. (1.3.10.1) INSPECTIONS AND TESTS SPECIFICATION FOR REACTOR SYSTEMS AND EQUIPMENT IMPORTANT FOR SAFETY	310,000
143. (1.3.11.1) UPGRADING OF COMMUNICATIONS	500,000
2. AVAILABILITY	
2.1 Measures related to Design and Construction/Installation	
144. (2.1.1.1.1A) TO REPLACE THE CPS DRIVE AND POSITION INDICATOR WITH A DRIVE PROVIDING LARGE PULL FORCE AND A SERVICE LIFE OF AT LEAST 30 YEARS	10,660,000
145. (2.1.1.1.2A) MODERNIZATION OF I&C. PROCESS SIGNAL COMMUTATION DEVICES (UKTS)	20,000,000
146. (2.1.1.1.2B) MODERNIZATION OF I&C SYSTEMS. MECHANICAL PART	890,000
147. (2.1.1.1.2C) MODERNIZATION OF I&C SYSTEMS. ELECTRIC PART (CCS)	1,600,000
148. (2.1.1.1.2D) MODERNIZATION OF I&C SYSTEMS. SECONDARY INSTRUMENTS AND TRANSDUCERS	19,800,000
149. (2.1.1.1.2E) UPDATING OF SYSTEMS AND DEVELOPMENT OF BLOWDOWN PROCEDURE FOR MEASURING SET PULSE LINES IN TURBINE PLANT EQUIPMENT	43,000
150. (2.1.1.3.1) MODERNIZATION OF THE MAIN TURBINE CONDENSERS. STUDY OF TUBES DAMAGE AND DEVELOPMENT OF MEASURES TO IMPROVE OPERATIONAL RELIABILITY	10,320,000
151. (2.1.1.3.2) UPDATING OF THE GENERATOR PARAMETER MONITORING SYSTEM	203,000
152. (2.1.1.3.3) PERFORMANCE OF ANALYSIS AND DEVELOPMENT OF MEASURES TO DECREASE THE BEARING VIBRATION LEVEL IN TURBINE K1000-60/1500	132,000
153. (2.1.1.4.2) UPGRADING OF THE RCP MOTOR COOLING SYSTEM	100,000
154. (2.1.1.5.1) UPGRADING OF CONDENSER PUMP KSA 1500-240	95,000
155. (2.1.1.5.2) UPGRADING OF CONDENSATE PUMP KSVA 1500-120	130,000
156. (2.1.1.5.3) UPGRADING OF CONDENSATE PUMP KSVA 360-160	242,000
157. (2.1.1.5.4) UPGRADING OF CONDENSATE PUMP KSVA 630-125	190,000
158. (2.1.1.6.1) UPGRADING OF HIGH PRESSURE HEATERS OF PV-2500 TYPE 245	680,000
159. (2.1.1.6.3) UPDATING AND ELABORATION OF A SET OF nor:iTMF`NTATION ON FAST-ACTING ISOLATION VALVE OF BABCOCK TYPE 246	76,000
160. (2.1.1.6.4) UPDATING AND ELABORATION OF A SET OF DOCUMENTATION ON MAINTENANCE AND REPAIR OF THE 960-300/350-E TYPE ISOLATION THROTTLE VALVE	301,000
161. (2.1.1.7.1) UPDATING OF BOOSTER FEED WATER PUMP PTA3800-20	398,000
162. (2.1.1.7.2) UPDATING OF MAIN FEED WATER PUMP PTA 3750-75	703,000
163. (2.1.1.8.1A) DEVICE FOR ISOLATION OF DEFECTIVE STEAM GENERATORS FROM THE MAIN COOLANT PIPELINE (MCP)	65,000

MOHT-EDF Measures	Costs for 2 Rectors in USD95[1]
164. (2.1.1.8.1B) DOCUMENTATION FOR TIGHTNESS CHECK OF SG HEAT EXCHANGING BUNDLE BY PNEUMO-AQUARIUM METHOD	5,000
165. (2.1.1.9.3.) REPLACEMENT OF 24 KV BREAKER	3,740,000
166. (2.1.1.10.1) UPGRADING OF CIRCULATING WATER PUMP 170 DPV12/22EG-1	340,000
167. (2.1.1.10.2) UPGRADING OF CIRCULATING WATER PUMP OPV10-185EG	275,000
168. (2.1.1.13.1) INTEGRATION OF LEAK CHECK SIPPING METHOD IN THE FUEL HANDLING MACHINE MAST (FHM)	
169. (2.1.2.1) COLLECTION OF BORON-CONTAMINATED WATER LEAKS FROM THE REACTOR CONTAINMENT	see item 1.3.8.4
170. (2.1.2.2) SYSTEM OF MECHANICAL ALIGNMENT FOR THE INTERNALS INSPECTION WELL	
171. (2.1.2.3) INFORMATION SYSTEM “TITAN-2”	25,920,000
172. (2.1.2.4) REPLACEMENT OF – 220 V DC SWITCHES	90,000
173. (2.1.2.5) SELECTIVITY OF PROTECTIVE DEVICES	80,000
174. (2.1.2.6) DETECTION OF GROUND FAULT IN 220 V D.C. MAINS	346,000
175. (2.1.2.7) UNINTERRUPTED ELECTRIC POWER SUPPLY OF COMPUTER CONTROL SYSTEM AND RADIOLOGICAL SAFETY MONITORING EQUIPMENT	54,500
176. (2.1.2.8) REMOVAL OF «LOUVRES» STEAM SEPARATOR FROM STEAM GENERATOR	10,000
2.2. Ananlysis and Expert Assessment	
177. (2.2.1) DYNAMIC UNIT STABILITY IMPROVEMENT	130,000
178. (2.2.2) SUBSTANTIATION OF SECONDARY PIPELINE STRENGTH WITHIN THE BOUNDARIES OF THE TURBINE HALL	135,000
179. (2.2.3) POWER DISTRIBUTION SYSTEM -ANALYSIS OF CHANGE OVER FROM MAIN -ELECTRICAL POWER SUPPLY TO STANDBY SUPPLY	65,000
180. (2.2.4) GROUNDING SYSTEM DESIGN	10,000
181. (2.2.5) ANALYSIS OF ROUTING OF THE TURBINE DRAINING AND BLEEDING PIPELINES	8,000
2.3. Operation Upgrading	
182. (2.3.1.1) ELABORATION OF THE DOCUMENTATION FOR MAINTENANCE AND REPAIR OF DRIVING TURBINE TYPE OKA-12A	51,000
183. (2.3.1.5) SCHEDULING OF THE PREVENTIVE REPLACEMENT OF THE GENERATOR AUXILIARY SYSTEM COMPONENTS	27,000
184. (2.3.2.1A AND 2.3.2.2) STATIONARY AUTOMATIC MONITORING SYSTEM PDA-1GMSM OF NPP UNIT	95,000
185. (2.3.2.1B) CONTROL SYSTEM OF INSULATION RESISTANCE OF GENERATOR VOLTAGE CIRCUITS GROUNDING	207,000
186. (2.3.2.1C) A SET OF TECHNICAL MEASURES TO ENHANCE THE FIRE AND EXPLOSION SAFETY OF HYDROGEN COOLED TURBO-GENERATOR	80,000
187. (2.3.2.3) AUTOMATED INFORMATION-SERVICE SYSTEM FOR CONTROL AND DIAGNOSIS OF UKTS (ASKD) BLOCKS	95,000

MOHT-EDF Measures	Costs for 2 Rectors in USD95[1]
188. (2.3.3.1) REVISION OF SERVICE MANUALS FOR EQUIPMENT AND TURBINE PLANT SYSTEM	800,000
189. (2.3.3.2) DEVELOPMENT OF SCHEDULED PULSE LINE BLOW DOWN IN THE TURBO-PLANT EQUIPMENT MEASURING SETS	40,000
190. (2.3.3.3) IMPROVEMENT OF IN-SERVICE INSPECTION OF TURBINE PIPELINE METAL	182,000
191. (2.3.3.4) CONTROL OF RESIDUAL LIFE OF NPP CABLES	1,600,000
ADDITIONAL MEASURES: REDUCTION OF PROBABILITY OF LEAKAGE FROM MAIN JOINT SEALS IMPROVING RELIABILITY OF AIR DUCT BEND	 220,000 85,000
SUM:	**314,338,100 USD95**

2B.4 Safety Measures Not Included in the Modernization Programme for K2/R4

2B.4.1 Safety issues which require more comprehensive safety measures than the MP

The Institute of Risk Research has identified important safety relevant issues which require more comprehensive measures than those proposed in the Modernization Programme (MP) for Khmelnitsky 2 and Rovno 4 (Rev. 2, Oct. 1996).

A solution of these safety relevant issues results in higher costs than those evaluated in the MP. An evaluation of the costs for implementing more comprehensive measures is beyond the scope of this report.

Important safety relevant issues not adequately addressed in the MP

AREA: 1. General
Preservation and Mothballing
Qualification of Equipment
Post-TMI Requirements (NUREG-0737)

AREA: 2. Reactor Core Issues
Control Rod Insertion Reliability/Fuel Assembly Deformation
Xenon Oscillations and Power Density Control System

AREA: 3. Component Integrity Issues
Reactor Pressure Vessel Embrittlement
Steam Generator (SG) Collector Integrity and Non-Destructive Testing (NDT)
Reactor Coolant Pump (RCP) Seals

AREA: 4. Systems Issues
ECCS Sump Screen Blocking
SG Safety and Relief Valves Qualification for Two-Phase and Water Flow
SG Feedwater Capacity
ECCS Sump Capacity

AREA: 5. Instrumentation and Control Issues
Reactor Vessel Head Leak Monitoring System
Instrumentation & Control Replacement

AREA: 6. Electrical Power Supply Issues
Emergency Battery Discharge Time
Replacement of 6 kV Switchgear

AREA: 7. Containment Issues
Containment Structure and Containment Bypass Accidents
Containment Ultimate Capacity
Pneumatic Containment Isolation Valves

AREA: 8. nternal Hazards Issues
Fire Prevention
Pipeline Break Impacts Inside the Reactor Building and Turbine Building

AREA: 9. External Hazards Issues
Extreme Weather Conditions, Low Temperatures
Man-Induced External Hazards
Seismicity and Geological Hazards

AREA: 10. Accident Analysis Issues
Probabilistic Safety Assessment (PSA)
Rapid Reactivity Increase/Control Rod Ejection

AREA: 11. Spent Fuel and Radioactive Waste Management Issues
Spent Fuel Management Risks for WWER-1000 Reactors
(Spent Fuel Pools Inside Containment)

AREA: 12. Operating Procedures Issues
Implementation of symptom-oriented emergency operating procedures (EOPs)

AREA: 13. Logistics and Infrastructure Issues
Financial and infrastructural preconditions for implementation of the MP

AREA: 14. Additional Safety Issues
Attempted Application of Leak-Before-Break (LBB)
to Secondary PipingComplete Loss of Heat Sink (Loss of ESW)

2B.4.2 Safety measures identified by MOHT-EdF not included in the MP

The MOHT-EDF consortium identified two groups of proposed upgrades based on PSA and severe accident insights for VVER-1000/320 reactors, most of which are **not** included in the K2/R4 upgrade programmes. The items recommended by MOHT are as follows (MOHT- EdF, "Generic Reference Programme for the Modernization of VVER 1000"-V320, MOHT (Atomenergoprojekt, OKB Gidropress, Kurchatov Institute, VNIIAES, Zarubejatomenergostroy, Rosenergoatom, et al.) and Electricité de France (EdF), Revision 5, January 1996: Part 1/A2, pp. 2-4; Part 3, pp. 132-139):

- Upgrade pressurizer relief valves for two-phase and water flow to allow for performing feed and bleed (i.e., removal of decay heat from the primary system by “bleeding” primary coolant from the pressurizer relief valves and providing makeup with the high pressure injection system). [Included in the upgrade programme as technical measure 13411, with implementation before startup; KIEP 1996:67-68.]

- Development and implementation of additional means of steam generator supply from reliable sources (due to the limited capacity of the emergency feedwater system, which in the basic design is limited to 8-10 hours of heat removal). [Included in the upgrade programme as technical measure 13311, but only **after** startup; KIEP 1996:63-64.]
- Provision of an additional common diesel generator. [Included in the upgrade programme as technical measure 24411, with implementation before startup; KIEP 1996:203-204.]
- Provision of an automated algorithm of protective actions in case of large primary-to-secondary leak.
- Upgrading of the suction pipelines of the primary circuit heat removal system to improve its reliability. [Included in the upgrade programme.]
- Introduction of a passive decay heat removal system (SPOT; consisting of a heat exchanger to dump steam to the environment via natural circulation with the primary circuit intact).
- Implementation of additional, higher pressure (15 bar), hydroaccumulators to provide for extended (several hours) passive injection in case of failure of active emergency core cooling system.
- Modernization of the area under the reactor vessel to accommodate core melt accidents, and provision of additional borated water inventory to flood the area under the reactor vessel in case of core melt.
- Implementation of filtered vented containment for severe accidents.
- Installation of passive hydrogen recombiners for severe accident hydrogen loads. [Included in the upgrade programme as technical measure 16211, but only analysis is included before startup; equipment installation is **after** startup; KIEP 1996:118-119.]
- Implementation of containment penetration room leakage collection system, processed through the filtered venting system.

2B.5 Temelin – Example for a WWER-1000/320 Reactor Completion Project with Delay in Schedule and Costoverruns

The following text has been extracted from a report which was presented by the Czech minister Karel Kühnl in August 1998:

2B.5.1 Date and cost of completion of Temelin construction

According to the current calculations, the cost of Temelin NPP construction will reach 98.6 billion Czech crowns and the date of completion of Unit 1 – fuel load to the reactor – was set to the end of August year 2000. If this date is met, the first Unit of Temelin NPP could be commercially operating in the beginning of May 2001.

The last official fuel load date accepted by the whole system of suppliers was September 1997 and the cost of Temelin NPP construction completion was given in the amount of 76.2 billion Czech crowns.

As of June 30, 1998, of the total budget of 98.6 billion crowns, 63.3 billion crowns was spent for the supplied equipment and work. Another 35.3 billion Czech crowns is still to be expended for the completion of construction.

2B.5.2 Main causes of delay in the schedule

The main cause for delays in completion of construction are the accepted changes in the design of Temelin NPP. These changes which are continuously being incorporated in the design of Temelin NPP are divided into three categories.

a) **System changes accepted with the objective to enhance technical, operational and safety level of the power plant**. These changes were recommended by international institutions, by Czech State Office for Nuclear Safety and also by CEZ, a.s. experts. As an example we could mention substitution of the original instrumentation and control system for Westinghouse system.

b) **Changes which inevitably resulted from the changes of category one**. Example is modification of electric parts, HVAC system or fundamentally more rigid requirements for implementation of cabling caused by a substitution of the instrumentation and control system.

c) **Changes caused by close down of production of certain equipment or change of production programme of some suppliers**. Equipment not delivered for these reasons must have been substituted by another piece of equipment which is more modern but require a change in the original design.

2B.5.2.1 Process of prolongation of construction due to design changes

Each additional equipment or more modern equipment (with other parameters) must be incorporated in the power plant design, including a new design of instrumentation and control system provided by Westinghouse. A major part of the delay in the date of construction completion is therefore attributed to design work resulting from the changes described above.

One of the direct causes of delay of final date is the delay of cabling (design and physical cable pulling) which is impacted by a majority of changes and where it is most complicated to incorporate the changes.

Delay in cable pulling (stop of pulling for the reason of completion of the design change or its slow progress for the reason of complicated design) is directly reflected in the date of power plant completion (cabling is on so-called critical path of the construction schedule).

2B.5.2.2 Elimination of the causes of construction delay

The number of accepted changes which may provoke major intervention in the design, is strictly limited during the change proceedings in the scope of which it is assessed whether the proposed change is inevitably necessary for bringing of the power plant to a safe operation. If not, the change is rejected.

Main design changes implemented from 1990 to 1998

Year	Changes influenced by	Note
1990	Decision about substitution of cables for non-flammable and fire-superior cables	Impact on changes from 1996 to 1998 (cable supports, penetrations)
1991, 1992	Russian design – change of supplies – substitute deliveries	
1992, 1993	Enhancement of nuclear safety on the basis of international audits	IAEA, NUS Halliburton ...
1994, 1995	Calculations of strength and lifetime	
1994, 1995 – to this date	Substitution of instrumentation and control system – Westing-house	
1994-1996	Seismic calculations	
1994	Enhancement of fire protection in the Russian design zone, change of fire sections	
1995 to the beginning of 1998	Segregation and separation of cabling	End of extreme growth of the number of change proceedings-maximum at the turn of 96-97
1998	Extension of number of changes for Unit 2, civil completion, changes from start-up of the individual systems start to show their impact	

Note: *Most significant increase of the number of design changes occurred in late 1996 when there were approximately 22 process changes a week. Most of them were important changes impacting the work schedule. In the second quarter of 1998 there were about 4 changes a week. These were less important changes resulted especially from testing during start-up of the individual systems.*

2B.5.2.3 Individual dates for start up of Temelin NPP

Activity	Date
Preparedness of the instrumentation and control system for test of technology from the control room	June 30, 1999
Start of fuel loading (start of physical testing)	August 31, 2000
Start of complex testing – successful test of 144 hours is followed by commercial operation of unit	April 30, 2001

2B.5.2.4 Sources of possible jeopardising of the date of construction completion

1. Other changes in the power plant design (risk declines with a decreasing number of significant changes).
2. Possibility of delay of suppliers´ work which are on the critical path of power plant construction completion (Westinghouse, Elektromontážní závody Praha).
3. Necessity of implementation of partial changes which might result from the results of tests conducted during commissioning of the power plant.
4. Other requirements of supervisory bodies which might prolong the approval proceedings for start of operation of the power plant.

2B.5.3 Increase of cost of construction

2B.5.3.1 Table providing cost comparison
(all prices are given in million of Czech crowns)

1 Cost	2 SR 95	3 SR 12/97	4 SR 03/98	5 Difference 98-95
Cost of research and design work	2 108	3 128	3 655	1 547
Cost of technological supplies	39 963	41 799	54 799	14 836
Cost of civil supplies	13 718	14 990	16 462	2 744
Other cost including interest	15 533	16 347	21 061	5 528
Reserve	4 943	1	2 603	- 2 340
Total	**76 265**	**76 265**	**98 580**	**22 315**
SR without a reserve	71 322	76 264	95 977	24 655

Column 2 shows division of total cost of the budget accepted in 1995.
Column 3 shows in which way the reserve of 1995 was used from 1995 to 1997.
Column 4 shows assumed total cost for completion of both Temelin NPP units (March 1998).
Column 5 shows the total increase of cost.

2B.5.3.2 Cost indirectly related to start of operation of Temelin NPP (million of CZK):

Liquidation of site facilities with a subsequent technical recultivation.............................. 2 169
Procurement of fixed assets in reserve 340
Total **2 509**

Cost of liquidation of site facilities was not taken into account in the budget for 1995.

2B.5.3.3 Causes and amount of budget increase as against year 1995

Extension of supply	**13.7 billion CZK (98)**
SÚJB, IBP	2.3 billion CZK
IAEA, OSART, NUS	1.9 billion CZK
CEZ	2.8 billion CZK
Westinghouse*	6.3 billion CZK
Expertise	0.4 billion CZK
Prolongation of construction	**5.2 billion CZK**
Price escalation	**5.7 billion CZK**
Total	**24.6 billion CZK**

* *This supply reflects all three causes of increase of budget, including the change of Czech crown exchange rate.*

Causes of increase of budget for Temelin NPP construction are directly related with the described mechanism of its prolongation. Most significant increase of cost was caused by changes accepted for enhancement of safety and reliability of power plant operation and changes resulting therefrom. Extension of the supply by the additionally ordered pieces of equipment and work increased the total cost by an amount of 13.7 billion Czech crowns. The amount can be divided between companies and institutions which provoked the changes by their recommendation (IAEA, OSART) or requirement (SÚJB, IBP). To this category we can also include increase of the price of Westinghouse supply caused by additional changes in the design and prolongation of the construction. A number of changes which caused the increased of cost were provoked also by CEZ by its own decision to improve a certain part of power plant.

Examples of extension of supplies:
Requirements of SÚJB and other legislative requirements

Examples of the most important projects:

- preparation of independent verification and validation of safety software of instrumentation and control system of Westinghouse
- demonstration of safety and lifetime of steam generators and reactor pressure vessels
- preparation of safety evaluation of containment
- preparation of conclusive documentation of calculation of strength and lifetime

Recommendations of international and Czech bodies (Audit of company Halliburton NUS, recommendation of IAEA, OSART mission, ...). Examples of the most important ones are as follows:

- substitution of instrumentation and control system
- building of the system of emergency accident facilities
- adding of filtration stations into the HVAC system
- preparation of probabilistic safety analysis
- preparation of analysis of design basis and beyond design basis accidents

Improvement based upon the decision of CEZ, a.s.

The most important improvements are as follows:

- implementation of group control of voltage
- preparation of analysis for modification of steam generators
- preparation of programmes of controlled ageing of selected components
- evaluation of calculations of strength and lifetime

Other causes of increase of budget are extra costs related to control of construction and preparation of power plant operation and increase of prices of supply of equipment and services which occurs as the time goes by.

Increase of cost of construction completion was also caused by exchange rate changes of Czech crown against USD (in 1995 the exchange rate was 28 CZK/USD, in 1998 it is 36 CZK/USD). As a consequence of that, the cost was increased by 2.5 billion Czech crowns and their hedging was not possible. This increase of cost is not given separately, it is contained in the cost contained in the Table.

2B.6 Conclusions

1. The cost estimates of the modernization measures to be implemented at K2/R4 NPPs were presented in the MP in the year 1996 and they cover only modernization upgradings.
2. The cost estimates quoted in the MP (327 million USD96) are in the same range as cost estimates for the modernization of operating WWER-1000 reactors (314 million USD95 or 330 million USD 96) presented by MOHT-EdF in 1995.
3. Significant safety issues, which have been identified by IRR (see above) are not adequately addressed in the K2/R4 Modernization and Upgrade Program. A comprehensive treatment of these issues is a precondition to reach the minimum acceptable safety level, formulated by IAEA in the INSAG-3 goals for core damage frequency and frequency of large releases or in NUSS codes. Implementation of measures to solve these issues and additional measures proposed by MOHT-EdF will result in higher costs than quoted in the present MP.
4. Technical and organisational problems in the Temelin completion project caused considerable costoverruns and time delays in this project. A similar development could be expected for K2/R4.
5. Up to now no information about cost estimates of completion and rehabilitation of K2/R4 is available. Attachment 1

Attachment – Table 1: Costs of all modernization measures planned in the Modernization Programme for K2 and R4

All costs quoted in this table are costs in USD 96.

Preliminary developments	Main design and specifications	Equipment supplies	Construction assembling and testing	Sum	
10 GENERAL					
10.1 Components Qualification					
11011 Develop materials on equipment qualification					
19 month	30 month			49 month	
	(correction required)				
400.000 USD96	1.600.000 USD96				2.000.000 USD96
			TOTAL	**49**	**2.000.000**
11 REACTOR CORE AND FUEL HANDLING					
11.1 Neutronic characteristics of the core					
11111 Equip the reactor power unit with technical devices for control of subcriticality of reactor core					
3			equipment have been taken into account in measures 14211 and 14221	3	
65.000					65.000
11.2 Core structure					
11211 Study of a new controll strategy and replacement of control rods: improve Xe and power distribution control system					
6				6	
130.000					130.000
11212 Study of a new controll strategy and replacement of control rods: increase service life and enhance control rods efficiency					
6		During normal cyclic replacement of control rods.	During normal cyclic replacement of control rods.	6	
520.000					520.000
11221 To provide design drop time of CPS control rods. Estimate loads onto supporting frame of FA.					
1	1	3	During preventive maintenance	5	
5.000	20.000	25.000	225.000		275.000
11222 To provide design drop time of CPS control rods. Introduce "heavy weight" control rod of FA.					
1	2	9	6	18	
		The cost of a component of the new heavy shafts; the price ignores the cost of the heavy CPS AR´s.	(the cost deals with operation expenses)		
2.530	6.700	355.000	5.200		369.430
			TOTAL	**38**	**1.359.430**

Preliminary developments	Main design and specifications	Equipment supplies	Construction assembling and testing	Sum	
12 COMPONENTS INTEGRITY					
12.1 Primary circuit system					
12111 Carry out measures to protect primary circuit from excessive moulding under cooldown conditions via ECCS and primary circuit from excessive pressure in cold conditions					
12	4	8	4	28	
		To be defined more exactly by result study	To be defined more exactly by result study corrected to finished		
3.000	5.300	20.000	5.830		34.130
12.2 Safety important systems under pressure					
12211 Providing "rigid" embedding of steam and feedwater pipelines and the outlet of reactor compartment					
1	8	6	4	19	
3.800	92.200	50.000	10.000		156.000
12221 To develop and implement the necessary means and systems for realization of LBB concept.					
10	16	4	6	36	
1.410.500	1.690.000	4.550.000	1.300.000		8.950.500
12.3 Reactor (with vessel)					
12311 Insufficient accuracy on assessment of fluence build-up by critical zones of reactor vessel. To design and introduce standard system for continous monitoring of radiation load (accumulated fluence) in order to estimate the residual life of the reactor vessel. The scope of the work is the following: - calculational and experimantal studies; – development of the monitoring methodology; – development of the design and manufactoring the system; – delivera of the NPP; – pilot operation; – turning over the system for commercial operation.					
18	4	12		34	
including 374,400 – experimental verifivcation			Assembling during adjustment works. Pilot operation: 1 to 2 life times		
647.400	72.000	751.000	15.600		1.486.000
12321 Implement preheating up to 55° C of water supplied to reactor by ECCS passive accumulator tanks					
		The cost shown are included into the price of the unit completion	The cost shown are included into the price of the unit completion		
0	0	0	0		0
12331 Implement preheating up to 20° C of water supplied to reactor by ECCS active part.					
	6	12	4	22	
			During maintenance outage		
0	100.000	160.000	250.000		510.000
12341 To modernize radiation control, within the scope of present programme of surveillance-specimens with the purpose of enhancing representativeness of test results of surveillance-specimens: - to develop and substantiate calculational- and experimantal methods for determination of irradiation conditions and radiation load of surveillance-specimens.					
6		3		9	
175.000		5.200			180.200

Preliminary developments	Main design and specifications	Equipment supplies	Construction assembling and testing	Sum	
12351 To develop and introduce a new programme of surveillance-specimens of vessel material: – to perform a calculational- and experimental verification and develop a design of modernization of container assemblies and surveillance-specimens; – to develop and substantiate methods and means for determination of irradiation conditions of surveillance-specimens and fluence accumulated by them in the modernized container assemblies; – to develop a shedule of irradiation of surveillance-specimens and programme of tests; – to develop a system of archiving test results; – to manufacture and assemble modernized container assemblies and specialingging;					
	8	12		20	
			Assembling during adjustment works, tests – in line with programme (cost is included in operation expenses)		
	422.500	201.500			624.000
12352 To develop and implement the standard procedure for determination of current residual radiation life of safe operation of the reactor vessel with regard for actual reactor state and conditions of its operation, indication of vessel radiation load monitoring system, results of radiation monitoring experiments at reactors and mock-ups of VVER-1000, results of tests of surveillance specimens.					
3	3			6	
40.000	19.500				59.500
12361 To determine a current residual radiation life of safe operation of vessel with due account of actual: – state of station systems; – diagrams of fuel loading; – power generation; – properties of vessel materials; – test results of surveillance-specimens; – indications of monitoring system of radiation load of vessel					
	9			9	
	80.200				80.200
12371 Develop, manufacture and implement a set of equipment for qualitative manufacture and annealing of gaskets of the main joint.					
	11	22	2	35	
			(during adjustments works)		
	550.000	1.380.000	260.000		2.190.000
12391 Perform more accurate strength calculations of the reactor air duct. Use calculation results for making decisions concerning the necessity of appropriate redesign.					
3	9	12	2	26	
	(in case of reconstruction)	(in case of reconstruction)	During preventive maintenance		
13.000	78.000	9.750	9.750		110.500
12.4 Miscellaneous					
12411 Develop organizational and technical measures for accident management. leak from primary circuit to secondary circuit with nominal cross-section dia. 100					
y	14	6		20	
	(both stages) Term: 4 month (phase 1) Term:10 month (phase 2)	No equipment required in phase 1			
	223.000	300.000			523.000

Preliminary developments	Main design and specifications	Equipment supplies	Construction assembling and testing	Sum	
12431 To correct strength calculations of the reactor vessel head to bring them into a line with PNAE G 7 002 86.					
3	18			21	
26.000	104.000				130.000
12441 Scientific and research, experimental and design engeneering works are required for determination of criterion of SG U-tube plugging.					
3	9	3	3	18	
65.000	91.000	65.000	65.000		286.000
			TOTAL	**303**	**15.320.030**
13 SYSTEMS					
13.1 Reactivity maintenance					
13111 Positioning of boron – 10 new monitoring points					
3	11	9	7	30	
10.000	116.000	512.000	100.000		738.000
13.2 Primary circuit coolant margin maintenance					
13211 Analysis of insulation material behavior under LOCA conditions.					
				0	
	to be defined				
					0
13213 Implementation of selected technical solution on NPPs. Ensure residual heat removal under LOCA.					
	16	10	4	30	
	Schedule and cost shall be defined after design development.				
	430.000	3.900.000	450.000		4.780.000
13.3 Primary circuit cooling					
13311 Develop and implement additional facilities for steam generator makeup from reliable supplies.					
4	3	6	3	16	
		To be defined from result of detailed drawings	To be defined from result of detailed drawings		
7.800	18.940	100.000	20.000		146.740
13321 Replace steam generator safety valves with safety devices meeting requirements of normative documentation.					
	10	12	4	26	
	to be defined				
	135.680	1.140.000	100.000		1.375.680

Preliminary developments	Main design and specifications	Equipment supplies	Construction assembling and testing	Sum	
13.4 Primary circuit pressure maintenance					
13411 To use the pulse safety device on the pressuriser to lower the primary pressure so as to achieve "feed and bleed" procedure in the primary circuit.					
3	6			9	
		to be defined after technical project have been designed	to be defined after technical project have been designed		
13.000	220.000				233.000
13.6 Auxilary system					
13611 Implement upgraded tightness diagnosis system for ECCS heat exchangers.					
	22	4	2	28	
	150.000	150.000	100.000		400.000
			TOTAL	**139**	**7.673.420**
14 MONITORING AND CONTROL SYSTEMS					
14.1 Informationsystem					
14111 To redesign temperature monitoring racks for the protective tube units with introduction of modernized temperature transducers and compensation devices.					
3	3	6	2	14	
			(during adjustment works)		
32.500	245.000	305.000	45.500		628.000
14.2 Reactor control and protection system					
14211 Replacement of existing NFMS hardware with new equipment featuring improved reliability, performance parameters, and meeting modern requirements.					
3	4	12	6	25	
500.000	150.000	1.760.000	225.000		2.635.000
14221 Provide power units with regular facilities for reactivity measurement complete with metrological support.					
3	6	6	6	21	
3.000	10.000	85.000	20.000		118.000
14231 Ensure the partitioning impulse lines to I & C safety system sensors for emergency protection system.					
6	8	6	2	22	
			(stage-by-stage during maintenance outages)		
30.000	40.000	70.000	30.000		170.000

Preliminary developments	**Main design and specifications**	**Equipment supplies**	**Construction assembling and testing**	**Sum**	
14241 Redesign of the system for measuring level in steam generators.					
	3	6	2	11	
			(During preventive maintenance)		
	40.000	84.500	19.500		144.000
14251 To develop and implement at NPP a system for control of gas-steam volume under the reactor vessel head for indirect coolant level measurement inside the RV.					
3	18	24	2	47	
			(During adjustment works)		
65.000	325.000	208.000	52.000		650.000
14261 To develope and introduce: – equipment including software meeting up-to-date requirements of precision,reliability fast action,reliability and ergonomic principles during NPP operation. Instead of obsolete and out-of-date instrumentation and computer facilities("Hindukush, SM-2M) – electronic equipment meeting up-to-date requirements of precision, reliability, fastaction and diagnosis to ensure control and monitoring of control rod positions instead of obsolete and out-of-date electronics; – measuring probes with thermocouples at inlet and outlet of the reactor core immerses in the coolant ("wet" of traditional "dry" design against the degree of readiness of the development).					
	12	24	24	60	
	1.084.000	5.530.000	1.190.000		7.804.000
14271 To carry out analysis of noise in CPS circuits and to develop measures on improvement of noise immunnity.					
3	3	3	12	21	
			(with regard for the cost of implementation of measures)		
4.000	30.000	32.000	10.000		76.000
14281 To replace the CPS drives, including their position indicators by drives which have greater pulling force and a service life of not less than 30 years.					
	9	15	6	30	
	390.000	6.900.000	130.000		7.420.000
14.3 Control system					
14321 Replace with a more reliable, NPP-classified device of the electronic part turbine regulating system ref. K-1000-60/3000					
	3	12	3	18	
	50.000	1.000.000	50.000		1.100.000
14331 Replace power unit control computer system (upper level) with modern, high-performance workstation integrated into the common data network at power unit level, and with advanced data output display.					
	3	12	3	18	
	60.000	12.000.000	150.000		12.210.000

Preliminary developments	Main design and specifications	Equipment supplies	Construction assembling and testing	Sum	
14.4 Monitoring system					
14411 Provide power unit with data storage equpment for beyond design-basis accidental conditions ("black box").					
3	10	24	3	40	
60.000	200.000	1.000.000	60.000		1.320.000
14421 Replace and add sensors, transducers, and secondary instruments that fail to meet modern requirements (operational experience)					
	14	16	5	35	
	70.000	2.500.000	139.500		2.709.500
			TOTAL	**362**	**36.984.500**
15 ELECTRICAL POWER SUPPLY					
15.1 Electrical Power generation and transformation					
15111 Replace UPSU. (Operational experience).					
	5	6	4	15	
	40.000	3.500.000	370.000		3.910.000
15121 Increase storage capacity of batteries.					
	6	4	5	15	
	61.440	757.200	80.000		898.640
15131 Perform analysis of additional sources of energy for safety systems.					
4	6			10	
23.040	37.120				60.160
15132 Development of measures directed to improvment of existing SDGS reliability.					
2	5	6	3	16	
8.000	42.000	1.000	2.000		53.000
15.2 ELECTRICAL POWER DISTRIBUTION					
15211 Replace 6 kV switches					
	3	2	3	8	
	67.600	1.080.000	80.000		1.227.600
15221 Exchange of sealed cable penetrations.					
	1	2	3	6	
	14.840	9.900.000	600.000		10.514.840
			TOTAL	**70**	**16.664.240**
16 CONTAINMENT AND BUILDING STRUCTURES					
16.1 Containment bypass risk					
16111 Develop design solutions to prevent loss-of-integrity of independent MCP circuit and blowing aftercooler heat exchanger.					
	5		4	9	
	12.000		58.400		70.400

Preliminary developments	Main design and specifications	Equipment supplies	Construction assembling and testing	Sum	
16121 Develop and substanciate complementary methods for non-destructive control over base metal and welds that allow to timely detect defects being developed and undertake the measures on their prevention from.					
	3		13	16	
	To be defined				
	40.000		160.000		200.000
16131 To perform analysis and calculations of hydrogen accumulations inside the reactor plant and its release to the outside for MDBA.					
20				20	
123.000					123.000
16.2 Integrity					
16211 Installation of a hydrogen detection and ignition system within containment reactor compartments.					
	6	15	4	25	
		(igniters) From 1996 (igniters) Sensors schould be purchased in Western Countries	During maintenance outage		
	100.000	1.350.000	150.000		1.600.000
			TOTAL	**70**	**1.993.400**
17 INTERNAL HAZARDS					
17.1 Fire hazard protection					
17111 Carry out fire safety analysis for all power unit rooms following AIEA procedures and requirements.					
6	24			30	
200.000	150.000				350.000
17112 Analyse the possibility of maintaining safe reactor shutdown and maintaining long-term subcriticality of the reactor in the cable comparment under MCR and ECR and 6.0 kV switchgear.					
	24			24	
	150.000				150.000
17121 Replace combustible petroleum oil with incombustible lubricating fluids in the lubrication system.					
	12	12	6	30	
	5.000	50.000	10.000		65.000
17131 Replacement of existing input switching devices of RTZO type switchboards.					
	2	2	10	14	
	15.000	65.000	15.000		95.000
17132 Coat the cables bundles with fire-resistant coating.					
		10	10	20	
		630.000	100.000		730.000

Preliminary developments	**Main design and specifications**	**Equipment supplies**	**Construction assembling and testing**	**Sum**	
17141 Develop and implement, in the reconstruction design, FAS equipment meeting specific requirements for NPP equipment and instrumentation.					
	6	12	6	24	
	Cost: design: 15.000 working docum.: 35.000				
	50.000	314.000	115.000		479.000
17151 Replace existing fire resistant doors in the rooms containing safety system trains.					
6	6			12	
		Schedule and cost have to be defined together with supplier of standard devices	Schedule and cost have to be defined together with supplier of standard devices		
10.000	30.000	75.000	20.000		135.000
17161 Install fire protection valves in air conduits according to normative documentation.					
	4	10	2	16	
			(in stages during maintenance out-ages)		
	40.000	120.000	55.000		215.000
17.2 Flooding protection					
17211 Perform a complete analysis of internal flood in reactor compartment and machine hall rooms.					
	12	15	4	31	
	(complete analysis)				
	90.000				90.000
17.3 Hazards due to pipes rupture and flying fragments					
17311 Develop draft design criteria for shut-off valves protection against internal missiles.					
	6			6	
	15.000				15.000
17321 Carry out special analysis to determine the extent of pipeline breaks impact inside the reactor building, and probable consequences of secondary effects.					
	9			9	
	35.000				35.000
			TOTAL	**216**	**2.359.000**
18 EXTERNAL HAZARDS					
18.1 Seismic					
18111 Additional instrumental seismic observations and geophysical studies.					
	24			24	
	700.000				700.000

Preliminary developments	Main design and specifications	Equipment supplies	Construction assembling and testing	Sum	
18.2 Natural external conditions					
18211 Carry out risk assessment, – define shock wave loads and their impact on building structures; design justification of building structures bearing capacity considering foreign procedures.					
	5			5	
	30.000				30.000
18212 Carry out risk assessment, – define wind storms loads and its impact on building structures; design justification of building structures bearing capacity considering foreign procedures.					
	5			5	
	30.000				30.000
18221 Carry out and analysis on possibility of ensuring the normal air conditions inside the rooms of safety system at lower ambient temperature.					
7	8			15	
60.000	102.000				162.000
18.3 Main induced external events					
18311 Carry out analysis of possibility of airplane crash with the help of wertern firms procedures and experience.					
	4			4	
	30.000				30.000
18321 Carry out estimation of risc impact on MCR(ECR) personnel of toxic gases arising at man induced external events. Develop measures excluding risc of personnel damage.					
	to be defined				
					0
			TOTAL	**53**	**952.000**
19 ACCIDENTS ANALYSIS					
19.1 Design basis accident					
19111 Prepare a complete list and scenarios of design basis accidents considering international practice on the list of initiating events.					
	6			6	
	30.000				30.000
19112 Carry out analysis of selected accidents using modern codes.					
	24			24	
	130.000				130.000
19121 Carry out of analysis of reactivity accidents, including unpredicted decrease of absorber concentration in the primary circuit, and identifying necessary measures.					
	24			24	
	120.000				120.000
19.2 Beyond the design basis accident					
19211 Carry out analysis of NPP behavior in case of beyond the design-basis accidents.					
	48			48	
	460.000				460.000

Preliminary developments	Main design and specifications	Equipment supplies	Construction assembling and testing	Sum	
19.3 Additional safety analysis					
19311 Carry out, based on elaborated initiating events list, analysis of accidents that have not been reviewed in Technical Report on Safety Substantiation (TO5).					
	24			24	
	140.000				140.000
19.4 Probalistic safety analysis					
19411 Perform probalistic safety analysis. Develop based on probalistic safety analysis, list of beyond the design-basic accidents. Carry out R and D works on substantiation and implementation of methods and technical means to manage beyond the design basis accidents.					
	48			48	
	(whole scope of PSA including R&D and the list of beyond design-basic accidents). The price depends on the result of R&D program progress.				
	2.200.000				2.200.000
			TOTAL	**174**	**3.080.000**
20 FUEL HANDLING					
20.1 Fuel handling control					
20111 Development and introduction of equipment and methodology for sipping procedure of FFD conducted in the refuelling machine mast during fuel assembly transportation (FFDRM method).					
3	6	3	5	17	
26.000	340.000	97.500	84.500		548.000
20121 To develop equipment for completing fuel assembly placing procedures in the event of loss of power supply to the refuelling machine.					
6	6	6	3	21	
24.000	71.000	100.000	10.000		205.000
20131 To develop equipment for lifting the fuel assembly dropped into the reactor or into the spent fuel pool.					
12	6	6	3	27	
26.000	74.000	100.000	17.000		217.000
			TOTAL	**65**	**970.000**
21 PRIMARY CIRCUIT					
21.1 Main circulation pumps					
21111 Modernize thermal barriers to improve operational reliability and safety of TUH – 195 M;					
	4	12	3	19	
	5.600	281.600	12.800		300.000

Preliminary developments	Main design and specifications	Equipment supplies	Construction assembling and testing	Sum	
21114 Develop a procedure for the determination of allowable defects in body components of TUH – 195M;					
	6			6	
	41.500				41.500
21115 Develop documentation and carry out auxiliary systems reconstruction to increase the time of interruption in supply of blocking water to sealings of TUH – 195M;					
		21	5	26	
		87.500	15.000		102.500
21.2 Integrity					
21211 Carry out strength analysis of welded assembly of makeup nozzle protective jacket (since the distance between welds attaching the thermal shield to makeup nozzle protective jacket, and the welding joint protective jacket with Dnom 850 dia. pipe (cadding) is less than 3h (leg height).					
	8			8	
	(cost of calculation)				
	31.000				31.000
			TOTAL	**59**	**475.000**
22 SECONDARY CIRCUIT					
22.1 Steam generators					
22111 Modernization of steam generators blowdown.					
	6	12	4	22	
	The costs shown are included into the price of the unit completion for RNPP	The costs shown are included into the price of the unit completion for RNPP	The costs shown are included into the price of the unit completion for RNPP		
	121.344	140.000	100.000		361.344
22.2 Other component					
22351 Replace built-in air conditioners that do not meet operational requirements (operational experience).					
	6	7	6	19	
	50.000	135.000	90.000		275.000
22.4 Steam and water system					
22441 Retrofit balanced (disk) steam generator feed control valves.					
	3	6	3	12	
	5.500	200.000	23.500		229.000
			TOTAL	**53**	**865.344**

Preliminary developments	Main design and specifications	Equipment supplies	Construction assembling and testing	Sum	
23 MONITORING AND CONTROL SYSTEM					
23.1 Diagnostic systems					
23111 Modernization of the system monitoring generator process parameters, combined with implementation of diagnosis tasks (operational experience).					
	3	12	6	21	
		(including software)			
	5.000	80.000	20.000		105.000
			TOTAL	**21**	**105.000**
24 ELECTRICAL POWER SYSTEM					
24.1 Diagnostic facilities					
24111 Implement a multi-channel system "Regina" type for recording and analysis of electrical transients during emergency situations.					
2	6	3	6	17	
31.232	190.464	117.740	68.320		407.756
24121 Computerized monitoring system of turbine generator stator windings insulation state from partial discharges.					
8	5	6	6	25	
			(to be determined in distinct specifications)		
3.000	7.500	15.500	10.500		36.500
24122 Computerized monitoring system of 6 kV motors stator winding insulation condition from partial discharges.					
8	5	6	6	25	
			(to be determined in distinct specifications)		
1.500	2.050	24.000	9.000		36.550
24131 Develop a permanent monitoring system of generator voltage insulation.					
3	7	9	6	25	
1.500	4.500	16.850	8.000		30.850
24.2 Electrical Power distribution					
24211 Develop procedures and hardware to assess residual lifetime of NPP cables.					
15	6	3	5	29	
226.600	90.620	400.000	50.000		767.220
24221 Fit additional self-contained emergency lighting fixtures.					
3	3	2	3	11	
15.000	15.000	49.000	10.000		89.000

Preliminary developments	**Main design and specifications**	**Equipment supplies**	**Construction assembling and testing**	**Sum**	
24.3 Electrical power output systems					
24311 Carry out analysis of external supply systems (power grid).					
5	5			10	
67	76				143
24.4 Electric power generation and transformation					
24411 Design and implement a power and Diesel-generator station. Supply make up pumps from Diesel-generator station.					
				0	
			From 1994		
					0
24421 High-voltage transformers buchings, replacement. (operational experience).					
	10	6	6	22	
	100.000	10.000.000	100.000		10.200.000
24441 Install group 2 stand-by transformers of plant services (PTCH-2).					
2	10	5	4	21	
30.200	512.000	6.000.000	1.500.000		8.042.200
			TOTAL	**185**	**19.610.219**
25 REACTOR CORE AND FUEL					
25.1 Neutronic design of core					
25111 To provide transition of the power units to the strategy of refuelling with low neutron leakage.					
9	3			12	
	(preliminary design)				
235.000	26.000				261.000
25131 Analysis of components of engineering safety factor and revision of engineering documentation. Work is planned in 2 phases. *Phase 1:* To perform analysis of components of engineering safety factor taking into account advanced fuel manufacture technology and actual errors of neutron and physical parameters calculation. Engineering margin factor. *Phase 2:* Introduction of modifications to technical design of reactor plant, documentation on fuel manufacture, and technical justification of NPP safety.					
12				12	
220.000					220.000
			TOTAL	**24**	**481.000**
26 COMPONENTS INTEGRITY					
26.1 Chemistry conditions					
26131 Improve and automate chemical water treatment of secondary circuit.					
4	11	8	7	30	
96.000	205.000	9.200.000	321.000		9.822.000

Preliminary developments	Main design and specifications	Equipment supplies	Construction assembling and testing	Sum	
26132 Involvement a system for continous and automatic monitoring of primary circuit coolant parameters (pH, Xe, H2) in normal operating conditions.					
4	8	20	12	44	
50.000	45.000	3.500.000	194.000		3.789.000
26.2 Miscellaneous					
26211 Carry out strength recalculations for safety-related pipings (according to OPB-88).					
5	15			20	
28.000	532.000				560.000
26212 Following results of above recalculations, implement measures for additional piping attachments.					
	19	6	2	27	
	(including preparation of modified working drawings)	The period and costs are being made precise by calculations.	The period and costs are being made precise by calculations.		
	179.300				179.300
			TOTAL	**121**	**14.350.300**
27 SYSTEMS					
27.1 Containment integrity					
27211 Perform the analysis of the building structures on the containment, especialy in the places of the penetrations.					
	5			5	
	30.000				30.000
27212 Perform the analysis of the existence and adequacy of structures, including modern diagnostics.					
	5			5	
	70.000				70.000
27213 Develop the procedure of the containment state assessment during unit operation and the assessment of its life term taking into account the consenescence of the constructive materials.					
	20			20	
	600.000				600.000
27214 Prepare calculated groundings of containment reliability using complete models and codes proposed by wertern companies.					
	10			10	
	85.000				85.000
			TOTAL	**40**	**785.000**
28 CONTROL AND MONITORING SYSTEM					
28.1 Monitoring and diagnostic system					
28111 Develop and implement a full-diagnosis system.					
	12			12	
	50.000				50.000

Preliminary developments	Main design and specifications	Equipment supplies	Construction assembling and testing	Sum	
28112 Develop and implement computerized network for diagnosis and monitoring at VVER-1000 NPP´s.					
9	12	18	6	45	
60.000	297.888	595.791	148.878		1.102.557
28113 Develop and implement vibration diagnosis system for reactor plants.					
3	9	9	6	27	
25.600	123.510	300.000	80.000		529.110
28114 Develop and implement system for detection of loose parts and inadequate fixing.					
5	9	9	6	29	
25.600	332.800	486.400	153.600		998.400
28115 Develop and implement system for noise diagnosis of steam generators headers.					
3	6	6	4	19	
25.600	111.220	96.000	40.000		272.820
28116 Develop and implement system for primary coolant leakage detection.					
5	9	9	6	29	
38.400	467.200	627.200	217.600		1.350.400
28117 Develop and implement system for residual fatigue diagnosis.					
6	6	12	6	30	
60.000	304.500	364.000	129.100		857.600
28118 Develop and implement system for MCP vibration monitoring and diagnosis.					
6	6	9	6	27	
25.600	111.220	1.013.000	86.000		1.235.820
28119 Develop and implement system for mode diagnosis.					
6	12	6	6	30	
25.600	345.000	371.200	140.800		882.600
28121 Develop and implement of in-core noise diagnostic system.					
6	6	12	6	30	
60.000	231.200	439.075	272.867		1.003.142
28122 Develop and implement of system for diagnostic of back pressure valves.					
6	12	12	6	36	
50.000	204.040	200.000	184.000		638.040
28123 Develop and implement of system for diagnostic air-operated valves.					
	8	10	6	24	
	119.808	40.000	100.000		259.808
28124 Develop and implement of industrial television system for NPP´s closed premises.					
	3	5	4	12	
	73.728	400.000	110.000		583.728

Preliminary developments	Main design and specifications	Equipment supplies	Construction assembling and testing	Sum	
28.4 Information system					
28411 Develop and implement for each power unit a system displayingg generalized safety parameters and critical safety functions (SPDS).					
	18	8	4	30	
	400.000	1.100.000	200.000		1.700.000
28.5 Operators support system					
28511 Developing, at each power unit or at two adjacent power units, a Technical Support Center for MCR operators in emergency situations.					
	24	24	6	54	
	800.000	1.200.000	300.000		2.300.000
			TOTAL	**434**	**13.764.025**
29 INTERNAL HAZARDS					
29.1 Fire prevention					
29111 Improve resistance rate of turbine hall steel structures by means of application of fire resistance compound.					
	3	3	3	9	
	7.000	375.000	37.500		419.500
29112 Develop and implement measures of automatic hydrogen dumping from generator housing outside the limits of turbine hall on "fire" alarm actuation.					
6	12	12	6	36	
5.000	10.000	10.000	1.000		26.000
29121 Develop and implement the smoke prevention system of room and corridors used for personnel evacuation of reactor building (RB) which freely connected with envirement.					
6	9	10	2	27	
			stage by stage in preventive maintenance period. (in stages, during maintenance outages)		
50.000	170.000	620.000	170.000		1.010.000
29131 Develop and implement design of gas fire extinguishing system in NPP rooms containing safety control systems and monitoring and control systems.					
6	9	18	3	36	
		development and testing			
50.000	73.400	104.000	60.000		287.400
			TOTAL	**108**	**1.742.900**

Preliminary developments	Main design and specifications	Equipment supplies	Construction assembling and testing	Sum	
30 OPERATION PROCEDURES					
30.1 Normal operation procedures					
30111 Improve technical instructions and normal operation procedures an reactor equipment and systems.					
	24			24	
	550.000				550.000
30112 Improvement of maintenance and repair procedures for reactor equipment and systems.					
	24			24	
	975.000				975.000
30121 Providing, in the technical design for reactor unit, a list of neclear-hazardous works.					
	4			4	
	25.000				25.000
30131 To assure hydrogen removal from the primary circuit equipment in the process of the cooldown and "cold" shutdown.					
2	10	12	2	26	
			during adjustment works		
26.000	221.000	78.000	65.000		390.000
30141 To develop and implement methodology for setting up correspondence between operational limit of fuel element defects and primary coolant activity by reference isotopes.					
	6			6	
	50.000				50.000
30.2 Accident operation procedures					
30211 Develop emergency procedures based on approach-oriented at core state.					
	36			36	
	2.500.000				2.500.000
			TOTAL	**120**	**4.490.000**
31 CONTROL					
31.1 Use of operation experience and data base					
31111 Develop and implement an information system "Computer-aided history of NPP equipment operation".					
6	15	6	4	31	
30	300.000	50.000	100.000		450.030
31.2 Quality assurance program					
31211 To develop and implement the "NPP Quality Assurance Programm" which would include all the NPP living cycle stages.					
	40			40	
	1.797.000				1.797.000

Preliminary developments	Main design and specifications	Equipment supplies	Construction assembling and testing	Sum	
31.3 Documents development					
31351 To develop the programme and methodology (technical process) for replacement of electrical wiring out unit equipment to have worked out its service life.					
3	6			9	
32.000	351.000				383.000
			TOTAL	**80**	**2.630.030**
32 TEST AND DIAGNOSTICS					
32.1 Periodic test programme					
32111 Improve operation procedure for safety-related reactor systems.					
	12			12	
	160.000				160.000
32112 Improve verification and testing procedure of safety-related reactor systems.					
	18			18	
	160.000				160.000
32.2 Monitoring and diagnostic system					
32231 Develop proposals of diagnosis of forces in fitting cables of SPZO (CN30) (containment prestressing system).					
	7	8	3	18	
	(analysis)				
	30.000	350.000	30.000		410.000
32241 Develop measures to improve existing containment state monitoring.					
	13			13	
	80.000				80.000
32251 Develop and implement equipment for containment vacuum tests. Justify and work out a program.					
	15			15	
	370.000				370.000
			TOTAL	**76**	**1.180.000**
33 PERSONNEL PROTECTION AND RADIATION SAFETY					
33.1 Wastes and discharges					
33111 To develop equipment for transportation of the spent CPS AR clusters from the reactor and for their burial at the NPP site (with compacting). This measure will help to free the storage tanks in the fuel cooling pond racks for the spent fuel asseemblies.					
12	6	6	3	27	
38.000	90.000	117.000	20.000		265.000
33112 To develop equipment for transportation of the spent CPS AR clusters from the reactor and for their burial at the NPP site (without compacting). This measure will help to free the storage tanks in the fuel cooling pond racks for the spent fuel asseemblies.					
12	6	6	3	27	
38.000	78.000	117.000	20.000		253.000

Preliminary developments	Main design and specifications	Equipment supplies	Construction assembling and testing	Sum	
33.2 Monitoring system equipment					
33211 Enhance the function of the existing radiation protection monitoring system AKP5-03 according to NTD requirements.					
1	2	6	2	11	
10.000	20.000	400.000	30.000		460.000
33212 Replace the radiation protection monitoring system AKP5-03 with a new system ensuring the monitoring of more functions according to NTD requirements.					
2	4	24	4	34	
20.000	100.000	2.000.000	150.000		2.270.000
33221 Install standard devices to monitor pipings displacement and ensure recording of maximum deflection values. For piping located in unattended rooms, deflection recordings shall be carried out remotely.					
4	6	10	6	26	
		Schedule and cost are too be defined with participation of standard devices supplier	Schedule and cost are too be defined with participation of standard devices supplier		
19.200	46.080	150.000	80.000		295.280
33231 Development and implementation of automatic radiation monitoring system.					
4	10	12	8	34	
150	220.000	3.680.000	600.000		4.500.150
			TOTAL	**159**	**8.043.430**
34 REPAIR AND MAINTENANCE					
34.1 Metal inspection					
34111 To develop, purchase and implement a set of systems for internal periodical monitoring of reactor vessel metal: – Set of inspection systems for reactor vessel and core barrel internal inspection by means of ultrasonic examination, eddy currents, TV-surveillance, radiographic inspections.					
		18		18	
		7.000.000			7.000.000
34.2 Equipment and tools					
34221 To develop stands and methodology for adjustment and specified inspections of the pressuriser pulse safety devices without real pressure increasing in order to reduce additional loading to equipment and pipelines and to eliminate non-design primary pressure decrease in the case of the main valve fit failure. To optimize the content, scope and frequency of inspection taking into account operating experience.					
3	6			9	
		to be defined after technical project have been designed	to be defined after technical project have been designed		
13.000	195.000				208.000
			TOTAL	**27**	**7.208.000**

Preliminary developments	Main design and specifications	Equipment supplies	Construction assembling and testing	Sum	
35 PHYSICAL PROTECTION					
35.1 NPP physical protection					
35111 Implementation of access management system.					
2	6	6	5	19	
49.152	276.480	4.000.000	1.750.000		6.075.632
			TOTAL	**19**	**6.075.632**

Table 2: Costs of all modernization measures planned in the Modernization Programme for R4

The planned measures and costs in the Modernization Programme for R4 (Rev. 2, Oct. 1996) are identical to K2, except the following 4 modifications:

The following 2 measures are not included in the Modernization Programme for R4:

Preliminary developments	Main design and specifications	Equipment supplies	Construction assembling and testing	Sum	
15.2 Electrical Power distribution					
15221 Exchange of sealed cable penetrations.					
	1 (month)	2	3	6	
	14.840 (USD96)	9.900.000	600.000		10.514.840
24.4 Electric power generation and transformation					
24441 Install group 2 stand-by transformers of plant services (PTCH-2).					
2	10	5	4	21	
30.200	512.000	6.000.000	1.500.000		8.042.200

Two new measures are planned for R4:

Preliminary developments	Main design and specifications	Equipment supplies	Construction assembling and testing	Sum	
13.5					
13521 Installation of hermetic valves Dia 1600 for localizing groups of repairing ventilation.					
	2 (month)	6	2	10	
	20.000 (USD96)	1.000.000	50.000		1.070.000
32.2 Monitoring and Diagnostic System					
32211 The indication of the position of the gate of main IPU KD valve have to be installed in the control room.					
	6	6	7	19	
	90.000	260.000	370.000		720.000