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Projekt zamenjave uparjalnikov jedrske elektrarne Krško

Steam-Generators Replacement at the Krško Nuclear Power Plant

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V prispevku smo predstavili osnovne opravke pri projektu zamenjave uparjalnikov, ki obsegajo vse transportne in logistične dejavnosti kakor tudi vse trajne spremembe, potrebne zaradi prilagoditve novih uparjalnikov na sedanje sisteme in načrtovanega povečanja moči. Vse dejavnosti se izvajajo tako, da bodo doseženi osnovni nameni zamenjave:1. zagotoviti zamenjavo znotraj vseh pogodbenih obveznosti, 2. kolektivna doza izpod 1,4 Sv, 3. nobenih izgubljenih dni zaradi poškodb pri delu.

(Ključne besede: transport, sistemi dvižni, meritve optične, dekontaminacija)

The paper covers all the basic techniques of the steam-generator replacement (SGR) project including all rigging /handling and other logistical activities as well as all the permanent modifications required to adapt systems for the new steam generators and the corresponding power increase. All activities will be performed in a way which ensures that the following main project goals will be met: 1. all work will be done within contractual obligations; 2. collective dose below 1.4manSv; 3. zero lost working days due to personal injury.

(Keywords: transport, lifting systems, optical survey, decontamination)

0 UVOD

Jedrska elektrarna Krško je s Konzorcijem Siemens/Framatome februarja 1998 sklenila pogodbo o zamenjavi uparjalnikov, ki je eden izmed projektov modernizacije elektrarne. Članek obravnava različne vidike projekta: obseg, načrtovanje, inženiring, pripravo spreminjevalnih paketov za pridobitev dovoljenj, vodenje, pomembnejše uporabljene tehnike itn. in prikazuje dejavnosti, ki so načrtovane od aprila do junija 2000.

Projekt poteka po sistemu "ključ v roke", kar pomeni, da Konzorcij izvaja vsa inženirska dela, pripravlja dokumentacijo projektnih sprememb in izvaja dejavnosti na objektu. JE Krško pridobiva dovoljenja in skrbi za vse dejavnosti, ki zahtevajo sodelovanje elektrarne ali zadevajo preostale projekte posodobitve.

1 OBSEG PROJEKTA

1.1 Priprava in transport uparjalnikov

Ta paket obsega vse dejavnosti, ki so potrebne za pripravo in transport starih in novih

0 INTRODUCTION

The Krško nuclear power plant (NPP) awarded the contract for the Steam-Generator Replacement Project, which is one of the modernization projects at Krško, to the Consortium Siemens - Framatome in February 1998. This paper deals with the various aspects of the project: scope, planning, engineering, preparation of the modification packages for licensing, management, major techniques used, etc., showing also the status of the activities for the project which are scheduled to be performed in April - June 2000.

The project is being performed on a "turnkey" basis, which means the Consortium is performing all the engineering, preparation of the modification packages and site activities; Krško NPP is dealing with the licensing of the project and all the activities interfacing with the plant and other modernization projects.

1 PROJECT SCOPE

1.1 Steam-Generator Rigging and Handling

The rigging package comprises all the activities which are required for handling and trans-

uparjalnikov med zunanjim odlagališčem v večnamenski stavbi in njunim prostorom v reaktorski zgradbi. Značilni podatki uparjalnikov so:
- dva stara uparjalnika, mase 321 ton, dolžine 20,65 m, največjega premera 4474 mm, je treba prepeljati iz reaktorske zgradbe do končnega odlagališča v večnamenski stavbi,
- dva nova uparjalnika, mase 337 ton, dolžine 20,85 m, največjega premera 4474 mm, je treba prepeljati iz začasnega skladišča v večnamenski stavbi v reaktorsko poslopje.

1.1.1 Postopek ravnanja in transporta

Transport uparjalnika zajema naslednje glavne korake (sl. 1):
- transport med večnamensko in reaktorsko zgradbo na višini 100 m
- dvigovanje med elevacijo 100 m in obratovalno ploščadjo – višna 115 m
- vodoraven premik v reaktorsko zgradbo in iz nje skozi odprtino za opremo na obratovalni ploščadi – višina 115 m
- dvigovanje iz obratovalne ploščadi – višine 115 do prostora uparjalnikov na višini 108 m

1.1.2 Oprema pri ravnanju in transportu

Sistemi, ki se uporabljajo za te naloge, temeljijo na posebej prilagojeni opremi - za dviganje težkega bremena. Sestavljajo jo naslednje glavne komponente:

Vozilo za težki tovor

Zunanji prevoz uparjalnikov poteka na samopogonskem 14-osnem vozilu. Izbrani sistem je za takšne transportne naloge značilen. Uporabili so ga že pri izvedenih zamenjavah uparjalnikov (Ringhals 3, Švedska).

Vozilo omogoča dviganje bremena z začasnega skladišča z vgrajeno hidravlično dvižno ploščadjo (Δh = +/-300 mm). Zato pri natovarjanju in raztovarjanju niso potrebna dodatna dvigala.

Zunanji dvižni sistem

Za dviganje uparjalnikov z višine 100 m na 115 je nameščen zunanji dvižni sistem, ki omogoča navpično dviganje in vodoravno obračanje bremena. Po prevzemu uparjalnika s transporterja v vodoravni legi, se uparjalnik dvigne, s štirimi 200-tonskimi hidravličnimi dvigali. Ko uparjalnik doseže obratovalno ploščad, višino 115 m, se s pomočjo drsnega sistema potisne do reaktorske zgradbe. Podporni okvir dvižnega sistema sestavljata dva stebra, dva nosilca (dolžine

portation of the old and new steam generators (SGs) between the outside storage location in the multi purpose building (MPB) and the SG cubicles in the reactor building (RB). The characteristic data of the steam generators are:
- two old SG, weight: 321 tons; length: 20,65 m; max. diameter: 4474 mm to be transported from RB to final storage in MPB.
- two new SG, weight: 337 tons; length: 20,85 m max. diameter: 4474 mm to be transported from temporary storage in MPB into the RB.

1.1.1 Rigging tasks

The SG transport consists of the following main steps (see figure 1):
- Ground transportation between MPB and RB on ground elevation (EL) 100 m
- SG lifting operation between EL 100 m and operation floor level EL 115 m
- SG horizontal transfer into and out of RB through equipment hatch on operation floor EL 115 m
- SG lifting from operation floor EL 115 into the SG housings on EL 108 m

1.1.2 Rigging Equipment

The systems employed for these tasks are mainly based on equipment used in heavy lifting, specially adapted for this purpose. The main components are:

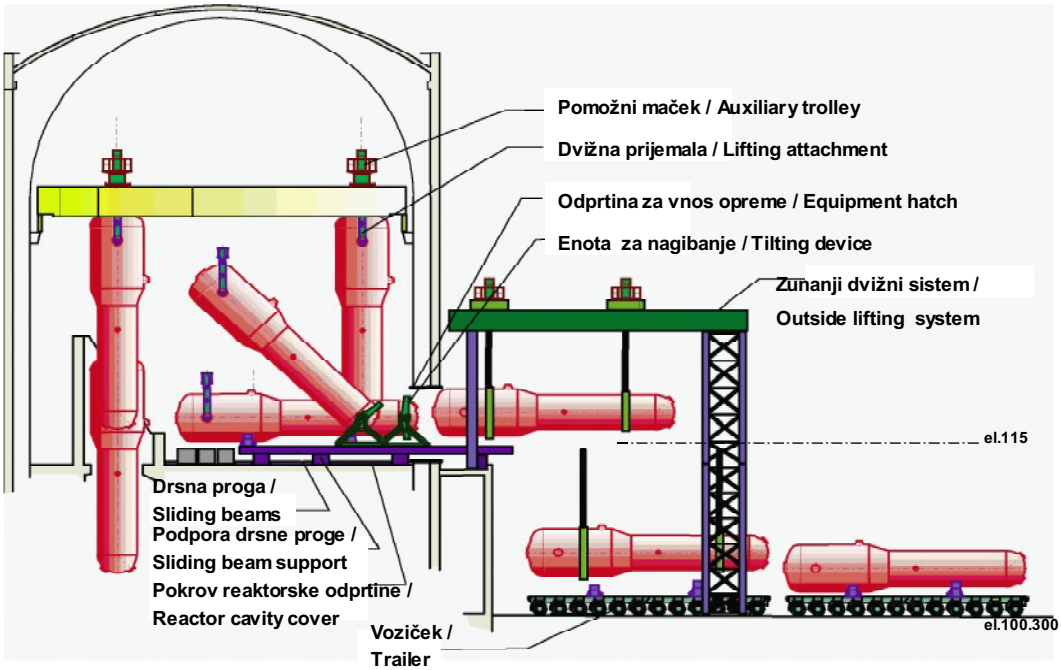
Heavy-load trailer

The ground transportation is performed by a self-propelled 14 axle heavy-load trailer. The chosen trailer is typical for this kind of transport task. The trailer to be used has already been employed for previous steam-generator replacements (Ringhals 3, Sweden).

The trailer allows the transfer of loads from storage supports with its integrated hydraulic lifting platform (Δh = +/-300mm). Therefore no additional cranes are required for loading and unloading of the trailer.

Outside Lifting System

For the SG lifting from ground level EL 100 m to operation floor level EL 115 m an outside lifting gantry is installed. The lifting system enables vertical hoisting and horizontal shifting of loads. After take-over of the steam generator from the transport trailer in the horizontal position the SG is lifted by 4 x 200 ton wire jacks. When the steam generator has reached the upper level, it is shifted towards the sliding system at EL 115 m on which the SG is moved into the RB. The support frame of the lifting system consists of two towers, two heavy



Sl. 1. *Ravnanje z uparjalnikom*
Fig.1. *Steam-generator rigging*

34 m) in nosilni okvir pred odprtino za vnos opreme. Stebra sta izdelana iz modularnih jeklenih elementov, nosilci in vhodni okvir pa kot standardni jekleni sestavi.

Vozička sta nameščena na nosilcih, vsak pa ima po dve 200-tonski hidravlični dvigali. Vodoravno premikanje vozičkov se doseže s pomočjo vodoravno nameščenih hidravličnih valjev, ki omogočajo vzporedno ali neodvisno premikanje obeh vozičkov.

Drsni sistem

Odprtina reaktorske stavbe za vnos opreme ima premer 6,95 m, kar zadošča za transport uparjalnika skoznjo.

Vodoraven premik uparjalnika skozi odprtino se izvede z drsnim sistemom, ki leži pod zunanjim dvižnim sistemom na višini 115 m. Nato se uparjalnik z dvema podporama namesti na drsni sistem: ena podpora je na strani priključka parnega voda ob drsnem sedlu in druga na strani primarne komore ob enoti za nagibanje.

Uparjalnik se potisne v reaktorsko stavbo s parno kupolo naprej. Znotraj reaktorske stavbe se ta postavi v pokončno lego z uporabo polarnega žerjava. Pri tem posegu deluje enota za nagibanje kot tečaj, ki dovoljuje nadzorovano dvigovanje uparjalnika ob hkratnem nagibanju.

Spremembe polarnega žerjava

Polarni žerjav v sedanji obliki ne zmore potrebne dvižne višine. Najvišja dvižna višina žerjava ne zadostuje, da bi se lahko pomaknil prek sten

load girders (lengths 34 m) and one portal frame in front of the equipment hatch. The towers are built from modular steel elements. The girders and the portal frame are fabricated as standard steel structures.

Two cross beams are installed on top of the girder, each equipped with two 200 ton hydraulic wire jacks. The horizontal sliding of the cross beams is achieved by horizontally installed wire jacks which allow moving both in parallel, or independently from each other.

Sliding System

The equipment hatch in the RB has a diameter of 6.95 m. This is sufficient to allow the SG transport into the RB through this opening.

The steam generator's horizontal transfer through the equipment hatch is performed by a sliding system resting below the outside lifting system at EL 115 m. The SG is carried by two supports when set onto the sliding system: one at the steam-dome side by a sliding saddle and at the channelhead side by the so-called tilting device.

The SG is moved into the RB with the steam dome entering first. When inside the RB the SG body is brought to the vertical position by means of the polar crane. For this operation the tilting device acts as a bearing to allow for controlled raising of the SG.

Polar-crane modifications

The polar crane in the existing configuration does not allow handling of the SG as required in terms of lifting height and trolley capacity. The maxi-

prostora uparjalnika s pričvrščenim uparjalnikom – potrebna bi bila obsežna gradbena dela v reaktorski zgradbi.

Zmogljivost polarnega žerjava je 320 ton, masa novega uparjalnika pa 337 ton. Obe omenjeni zahtevi sta rešeni z vgradnjo pomožne dvigovalne naprave na dvigalu. Ta nadomesti sedanjega mačka, ki ga umaknemo na skrajno točko mostu. Problem nezadostne dvižne višine je rešen z ustrezno obliko pomožne dvigalne naprave in optimalno dolžino plošč za pritrditev uparjalnika.

Nosilnost mostu polarnega žerjava je izboljšana z novo, lažjo dvigalno napravo in ugodno porazdelitvijo bremena. Dodatni preveritveni izračuni za vse obremenjene sestave potrjujejo sprejemljivost te rešitve. Polarni žerjav je s temi ukrepi zmožen premikati uparjalnik brez sprememb nosilnih delov.

Uparjalnik se dvigne s 400-tonskim hidravličnim dvigalom, podprtim z osnim ležajem, ki omogoča nagibanje visečega uparjalnika okoli njegove navpične osi. To je potrebno zaradi številnih kotnih prilagoditev uparjalnika med različnimi fazami vgradnje.

Hidravlične dvižne naprave

Hidravlične dvižne naprave uporabljamo za ravnanje s težkimi bremeni, npr. dvigovanje in vodoravne premike. Združujejo prednosti hidravličnih dvižnih naprav s prožnostjo kabelskih vitlov in zagotavljajo močne hidravlične sile z neomejenimi premiki. Premikajo se gladko in so zaradi svojega načina delovanja varni tudi v primeru okvare oz. odpovedi.

1.1.3 Posebne zahteve

Celoten postopek transporta in ravnanja z uparjalnikom je bil obdelan z vidika jedrskega in ekonomskega tveganja. Ker se večina aktivnosti zamenjave izvede po zaustavitvi elektrarne in brez gorivnih elementov v reaktorju, obravnavajo varnostna vrednotenja jedrskega tveganja predvsem zahtevo, da gorivo v bazenu za izrabljeno gorivo ne pomeni nevarnosti.

Tudi običajna ekonomska tveganja morajo biti minimalna. To pomeni, da morajo biti tudi sestave, ki niso v varnostnem razredu, dokazane kot varne. Presegati morajo torej običajne zahteve.

Pri sedanjih zamenjavah uparjalnikov so zunanji dvižni sistem praviloma postavili pred zaustavitvijo elektrarne. Tak postopek je v Krškem – glede na rezultate varnostnega vrednotenja – nemogoč. Ugotovljeno je, da bi namestitev zunanjega dvižnega sistema lahko vplivala na varnostne sisteme, kakor so zbiralnik vode za menjavo goriva, zbiralnik kondenzata in zbiralnik reaktorske dodajne vode.

mal lifting height of the crane trolley is not sufficient to cross the walls of the SG housings with the attached steam generator and would require extensive civil engineering works inside the RB.

The polar crane has an original capacity of 320 tons. But the weight of the new Steam Generator is 337 tons. These two deficiencies are remedied by the installation of a special auxiliary lifting gantry which provides the required properties. This gantry substitutes the existing trolley which is parked at one end of the bridge. The problem of insufficient lifting height is solved by a suitable design of the hoisting unit and the SG attachment plates with optimised length.

The load bearing capacity of the polar-crane bridge is improved by the new gantry's lightweight design and an advantageous load distribution. Additional verification calculations for all loaded structures prove this is an acceptable solution. With these measures the polar-crane bridge is capable of handling the SG load without structural modifications.

SG lifting is achieved by a 400 ton wire jack. This wire jack is supported by an axial bearing which allows rotation of the hanging steam generator about its vertical axis. This is necessary for the several angular adjustments of the SG during the different rigging phases.

Hydraulic Wire Jacks

Wire jacks are employed within the rigging package in several applications for the handling of heavy loads. Hoisting and horizontal shifting is powered by wire jacks. Wire jacks combine the advantages of hydraulic jacks with the flexibility of cable winches. They provide high hydraulic forces with an unlimited lifting stroke. The movements are smooth and they are fail safe under accident conditions due to their working principle.

1.1.3 Specific Requirements

The entire process of SG rigging and handling was investigated in view of nuclear and economic risk. As most of the SGR activities are performed after shutdown of the plant with an unloaded core, safety evaluations for nuclear risk deal mainly with the requirement that the fuel in the spent fuel pool is not a danger.

Conventional risks are also to be minimised. This means that structures which are not nuclear-safety related also have to be demonstrated as safe, above normal requirements.

According to a typical SG replacement schedule the outside lifting system is erected prior to the shut down of the plant. According to the results of the safety evaluation this is, in practise not possible at Krško. It was determined that the safety related systems RWST (Refuelling Water Storage Tank), CST (Condensate Tanks) and Reactor Makeup Water Storage Tank may be affected by the outside

Ker bi namestitev in ravnanje s težkimi bremeni v bližini omenjenih zbiralnikov lahko pomenila zmanjšanje varnosti elektrarne, mogoči nadomestni ukrepi pa niso na voljo, zgodnja postavitev zunanjega dvižnega sistema praktično ne pride v poštev. Torej je prestavljena na čas po zaustavitvi elektrarne.

Običajno razmeroma nepomembna dejavnost postavitve zunanjega dvižnega sistema lahko tako postane dejavnost na kritični poti projekta, ki vpliva na izvedbo celotnega projekta. Da bi kar najbolj zmanjšali možne negativne posledice, poteka zelo natančno načrtovanje vseh dejavnosti sestavljanja.

1.2 Dejavnosti na ceveh reaktorskega hladiva

1.2.1 Optične meritve, učvrstitve in prilagoditve

Delovni paket obravnava prilagoditev novih uparjalnikov na sedanji sistem reaktorskega hladila. Uparjalnik se odmakne od sistema reaktorskega hladila z rezanjem primarnih cevovodov ob priključkih na stara uparjalnika. Načrtovanje prilagoditev mora omogočiti natančno prilagoditev novega uparjalnika, upoštevaje odstopanja dimenzij in posebne zahteve za vzpostavitev prvotnega stanja. Te dejavnosti potekajo v tesni povezavi z optičnimi meritvami. Na podlagi zahtev za prilagoditev se rezultati optičnih meritev uporabijo

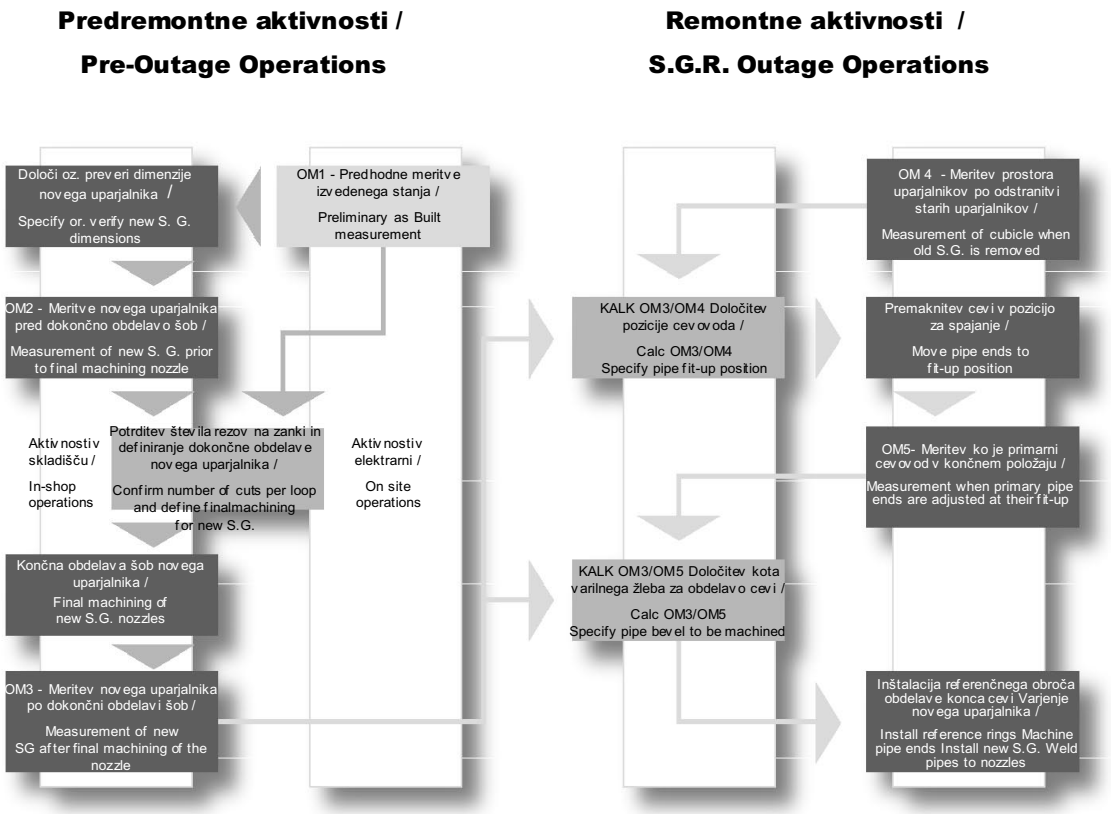
lifting system during its installation. As heavy-load rigging activities in the vicinity of these tanks would be a potential risk to the nuclear safety of the plant and feasible substitution measures are not available, the early erection of the lifting system is practically ruled out. Therefore, the erection activities have to be postponed until after the shut down.

The normally non-critical erection of the outside lifting system may become a critical activity with an impact on the overall project time schedule. To minimise the negative consequences as much as possible, very detailed planning of all erection activities is in progress.

1.2 Activities at the reactor coolant pipe

1.2.1 Optical survey, clamping and fit-up

This work package deals with the adaptation of the new steam generators to the existing reactor coolant system (RCS). The SG is separated from the remaining RCS by cuts at the primary nozzles. The fit-up engineering has to provide the basis for the accurate fit-up of the new SG, taking into account the dimensional deviations and the specific requirements of the restoration process. The fit-up activities are performed in close co-operation with the optical survey task. Based on fit-up requirements the optical measurement results are used to determine optimised fit-



Sl. 2. *Zaporedje optičnih meritev*
Fig.2. *Sequence of optical measurements*

za določitev optimalnih leg za nova uparjalnika. Da bi izpolnili te zahteve, obsega delovni paket naslednje naloge (sl. 2):
- natančno prilagoditev dimenzij novih uparjalnikov in sedanjega sistema reaktorskega hladiva,
- kompenzacijo krčenja novega zvara,
- določitev dovoljenih napetosti v sistemu reaktorskega hladila s preveritvenimi izračuni,
- dimenzijsko prilagoditev podpor uparjalnika.

Postopek prilagoditev pri zamenjavi uparjalnika z metodo dveh rezov zahteva merjenja v naslednjem zaporedju (OM = optične meritve):
- OM 1 izvedbene meritve sedanjega sistema reaktorskega hladiva,
- OM 2 meritve novih uparjalnikov pred pripravo zvarnega roba,
- OM 3 meritve novih uparjalnikov po pripravi zvarnega roba,
- OM 4 meritve cevnih koncev reaktorskega hladiva po rezanju v blokirani legi,
- OM 5 meritve cevnih koncev v legi namestitve pred obdelavo,
- OM 6 meritve po varjenju.

Uporabljena merilna tehnika

Osnovna tehnika za optične meritve je določitev koordinat prostorskih predmetnih točk z optičnim osredotočenjem in trikotnimi izračuni. Pri teh meritvah je uporabljen industrijski merilni sistem z elektronskimi teodoliti.

Merilni sistem sestavljajo elektronsko povezani teodoliti in prenosni računalnik s posebnim računalniškim programom. Med eno meritvijo ob zamenjavi uparjalnika se uporabijo skupno eden do štirje teodoliti. Vzporedno z izvajanjem meritev potekajo tudi preverjanja izračunov, da bi odkrili vprašljive rezultate. Ti se med samimi meritvami uporabljajo za preveritev ali popravke dobljenih podatkov.

Preverjanje podatkov poteka zunaj reaktorske zgradbe. Izračuni prilagajanj se izvajajo s posebnim programskim orodjem, ki je bilo uspešno uporabljeno že med do tedaj izvedenimi zamenjavami uparjalnikov.

1.2.2 Rezanje, brušenje, priprava zvarnega roba

Rezanje cevi sistema reaktorskega hladila se izvaja z uporabo mehanskega postopka.
To mehansko rezanje omogoča:
- rezanje cevi iz nerjavnega jekla (zunanjega premera do 1 m in debeline do 100 mm),
- rez z zunanje strani brez vstopa v primarno komoro starega uparjalnika,
- delo znotraj omejenega prostora okoli spoja med cevjo in šobo.

Rezalni stroj je vpet na cevi sistema reaktorskega hladila. Pogon je hidravličen. Rezanje se izvaja v dveh glavnih korakih:

up positions for the new steam generators. To fulfil these requirements the following tasks have to be considered in this work package (Figure 2):
- accurate dimensional adaptation of the new SG and existing RCS;
- compensation of the weld shrinkage of the new welds;
- determination of allowable stresses in the RCS by verification calculations;
- dimensional adaptation of SG supports.

The fit-up process within a 2-cut steam generator replacement requires the following measurement steps (OM = Optical Measurement):
- OM 1 as-built survey of the existing RCS,
- OM 2 survey of new SGs prior to weld-edge preparation,
- OM 3 survey of new SGs after weld-edge preparation,
- OM 4 survey of RC pipe ends after cutting in blocked position,
- OM 5 survey of RC pipe ends in fit-up position prior to machining,
- OM 6 survey after welding.

Applied measurement technique

The basic technique for the optical survey is the determination of 3-D coordinates of the object points by optical focusing and triangular calculations. For these measurements an industrial measurement system with electronic theodolites is used.

The measuring system consists of electronically combined theodolites and a notebook PC for data processing with specific measuring software. For SG replacement surveys, normally 1 to 4 theodolites are used together within one survey. In parallel with the taking of measurements, verification calculations are automatically performed to detect questionable results. These indications are used during the running measurement session, to verify or to correct the received measurement data.

The data evaluation is performed outside the RB. The fit-up calculations are performed with specific software tools which were successfully used in previous steam-generator replacements.

1.2.2 Cutting and beveling

The RCS pipe cutting is performed using a mechanical process.
This mechanical cutting allows:
- cutting of stainless steel pipes (external diameter up to 1m and thickness up to 100 mm);
- outside cut without entering the old SG channelhead;
- operation within the limited space around the pipe / nozzle junction.

The cutting machine is supported on the RCS pipe. A hydraulic power unit drives the machine. The RCS cutting is performed in two main steps:

– rezanje do 90 odstotkov debeline cevne stene; globina rezila se spremeni samodejno pri vsakem obratu,
– preden zunanja rezilna orodja prerežejo v notranjost cevi, se rezila zamenjajo z rezalnimi kolesi, ki odrežejo cev, ne da bi opilki padli v cev.

Zvarni rob cevi sistema reaktorskega hladiva se pripravi po dekontaminaciji in optičnih meritvah.

Rezkalni stroj se osredišči na cevi in namesti z obročem, ki se že prej nastavi z optičnimi merjenji. Kroglasti zgib in mehanske prižeme na stroju omogočajo natančne prilagoditve rezkalnega stroja glede sosrednosti in nivoja.

Po nastavitvi se rezkalni stroj uporablja z veliko natančnostjo za strojno obdelavo novega zvarnega roba na točno določenem mestu na cevi.

Geometrijska oblika zvarnega roba in njegova natančnost sta v skladu s postopkom argonskega varjenja v ozkem žlebu.

Ista oprema se bo uporabila pri pripravi zvarnega roba na priključkih novih uparjalnikov.

1.2.3 Dekontaminacija

Namen tega postopka, prikazanega na sliki 3, je zmanjšati sevalne doze v področju cevnih

– Using blade cutters, up to 90% of the pipe wall is cut. The re-indexing of the blade cutter depth is achieved automatically after each rotation
– Before the external cutting tools break through the interior of the pipe, the blade cutters are replaced by cutting wheels, which separate the pipe from the old SG without introducing debris into the pipe.

The RCS pipe beveling is performed after decontamination and an optical survey.

The beveling machine is centered in the pipe and adjusted with the reference ring previously set by the optical survey. A spherical ball joint and mechanical jacks installed on the machine allow a fine adjustment of the beveling machine in concentricity and planeity.

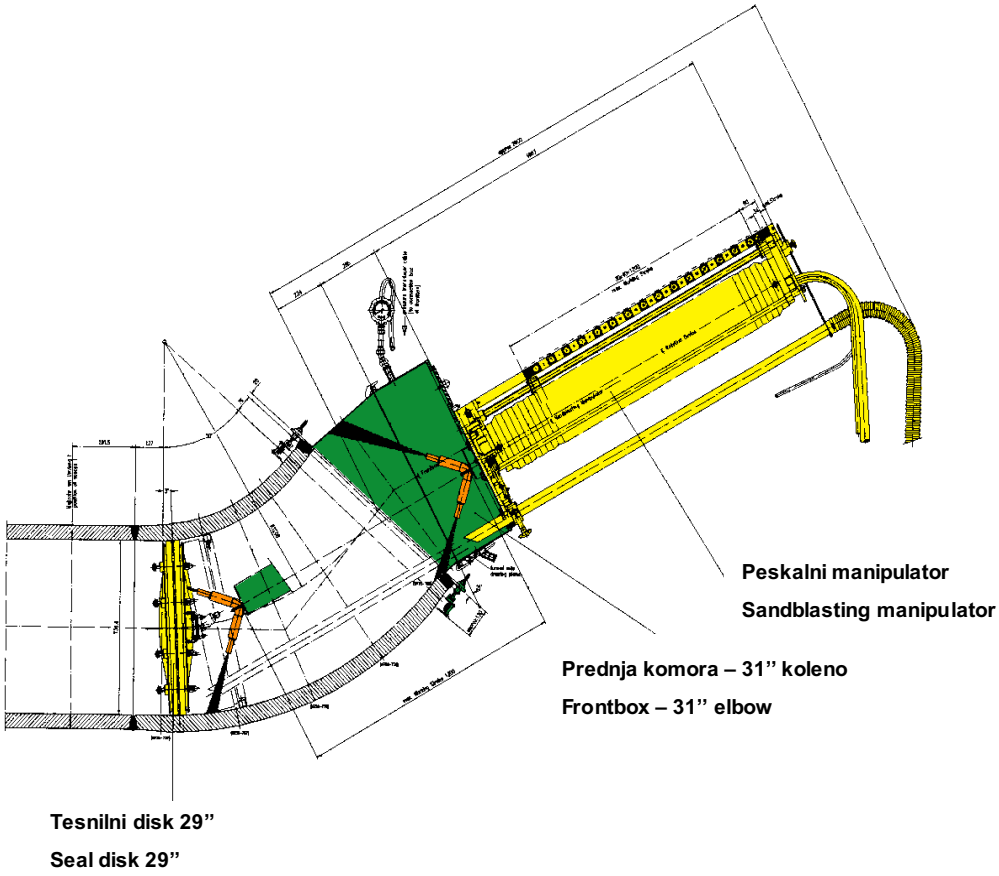
Once adjusted, the beveling machine is used for machining the new bevel, with a great accuracy, at its exact position on the pipe .

The bevel geometry and its accuracy are in accordance with the gas tungsten arc welding (GTAW) narrow-gap process.

The same equipment will be used to perform the bevel on the new SG nozzles.

1.2.3 Decontamination

The purpose of this decontamination shown in Fig.3 is to reduce the radiation dose in the area of



Sl. 3. *RC-L dekontaminacija konca cevi: oprema za dekontaminacijo / vroči krak*
Fig.3. *RC-L pipe ends decontamination: decontamination equipment assembly / hot leg*

koncev sistema reaktorskega hladiva in doseči lokalno čistočo notranjosti cevi. Postopek se doseže v dveh korakih: z uporabo peskanja z elektrokorundom, ki odstrani oksidne obloge in nato pršenja s steklenimi delčki, da bi zmanjšali površinsko napetost in zgladili površino; z uporabo zaprtega sistema s podtlakom, kar prepreči uhajanje abrazivnih delcev in prahu v ozračje (prepreči se razvitje aerosolov) in zagotovi najmanjšo količino nastalih radioaktivnih odpadkov.

1.2.4 Varjenje

Varjenje na cevovodih sistema reaktorskega hladiva bo potekalo s postopkom argonskega varjenja.

Konci priključkov uparjalnika in sedanja kolena bodo strojno obdelani na posebno geometrijsko obliko za varjenje v ozkem žlebu, kakor je prikazano na sliki 4.

Zvari na spojih bodo narejeni z daljinsko upravljano napravo. Izdelani bodo v večslojni tehniki in z nespremenljivimi parametri varjenja po obodu zvara. V primeru razlik v zunanjem premeru se končni nanos izvede avtomatsko ali ročno, odvisno od velikosti odstopanj.

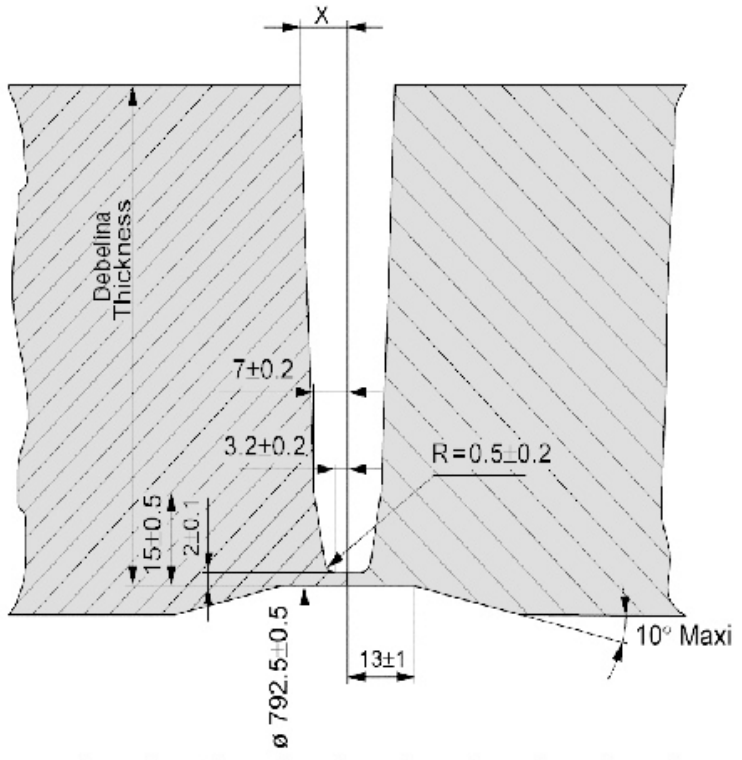
the reactor coolant pipe ends, and to achieve local cleanliness of pipe interiors . This process is performed in two steps. First, blasting by electrocorundum to remove the oxide layer, followed by blasting with glass beads to improve the superficial stress conditions and to smooth the surface. Use of a closed-circuit system with sub-atmospheric pressure prevents abrasive particles and dust from escaping into the atmosphere (aerosol build-up is avoided) keeping radioactive waste build-up to a minimum.

1.2.4 Welding

The welds in the RCS piping system will be performed with the mechanized GTAW process.

The SG nozzle ends and the existing elbows will be machined to a specific narrow-gap weld geometry as shown in Figure 4.

The weld joints will be made using a remote-controlled narrow-gap orbital welding unit. The welds will be performed using a layer-by-layer technique and with constant welding parameters around the weld circumference. In case of differences in outside diameter, overlay welding could be carried out either automatically or manually, depending on the height of the weld builtup.



debelina thickness	64 to 65.9	66 to 67.9	68 to 69.9	70 to 71.9	72 to 73.9	74 to 75.9	76 to 77.9	78 to 79.9	80 to 81.9	82 to 83.9
X (+0.3; -0.3)	9.3	9.4	9.5	9.6	9.7	9.8	9.9	10	10.1	10.2

Sl. 4. *Priprava zvarnega roba*
Fig.4. *Weld edge preparation*

Zaradi velike kakovosti zvarov, ki so posledica optimalne tehnike varjenja in ponovljivosti postopka, je možnost napake zelo majhna. Vseeno pa bo pripravljen tudi popravni postopek varjenja. Glede na naravo napake bo omogočen daljinski postopek strojne obdelave za argonsko varjenje ali ročni postopek varjenja.

Na koncu bodo zvari (zunaj cevi) zbrušeni. Na celotnem zvaru se bodo izvedli naslednji neporušni preskusi:
– test s tekočimi penetranti,
– rentgenski test,
– ultrazvočna preskušanja.

1.3 Sekundarni in pomožni cevovodi, instrumentacija in nadzor ter spremembe, povezane s povečanjem moči

Med zamenjavo uparjalnika bo veliko dejavnosti potekalo na sekundarnih sistemih. Predstavljamo najpomembnejše:

Sistem glavne pare

Odstranitev dela cevi in kolena glavnega parnega voda je potrebna zaradi odstranitve starega uparjalnika in ponovna vgradnja po namestitvi novega uparjalnika.

Sistem glavne napajalne vode

- Preusmeritev cevovoda glavne napajalne vode zaradi priključitve na priključek novega uparjalnika (nova lokacija),
– odstranitev in ponovna namestitev instrumentacijskih cevi (zaradi proste poti in lokacij novih instrumentacijskih priključkov),
– odstranitev obvoda predgrelnika, grelnih cevovodov in priključene instrumentacije (nova uparjalnika nimata predgrelnika),
– zamenjava rotorja črpalke napajalne vode in vgradnja novih notranjih delov v regulacijske ventile napajalne vode, ki se jim poveča gib (večji pretoki in zato povečani padci tlaka, povezani s povečanjem moči, zahtevajo večji pretok črpalke in večjo zmogljivost regulacijskih ventilov),
- omogočeno delovanje s tremi črpalkami napajalne vode.

Sistem za kaluženje uparjalnikov

- Odstranitev sedanjih cevi za kaluženje znotraj prostora za uparjalnik,
– vgradnja spremenjenih cevi za kaluženje v prostoru za uparjalnik, ki bodo uravnavale pretok iz dveh priključkov novega uparjalnika in omogočile 5-odstotni imenski pretok napajalne

Due to the high quality of welds resulting from the optimized welding technique and the reproducibility of the mechanized process, the risk of defects is very low. However, repair welding procedures will also be prepared. Depending on the nature of the defects involved, either the mechanized remote-controlled GTAW process or a manual welding process will be used.

The welds will be ground (outside the pipe) after completion. The following non-destructive examination (NDE) will be performed on the entire completed weld:
– liquid penetrant test,
– X-ray,
– pre-service inspection ultrasonic test .

1.3 Secondary and auxiliary piping, instrumentation and control, uprating related modifications

During the SGR, a lot of activities are performed on the secondary systems. The main ones are described below.

Main steam system

Removal, for clearance purposes, of a section of main steam pipe for removal of existing steam generator and reinstallation, once new steam generator is installed.

Main feedwater system

– Re-routing of the feedwater pipe to attach to the replacement steam-generator nozzle (new location),
– removal and reinstallation of the steam generator instrumentation pipe and tubing (clearance purposes and new instrument tap locations),
– removal of the preheater bypass and warm-up piping and associated I&C (no preheater bypass required for the replacement steam generator),
– replacement of the feedwater pump impellers and installation of new trim in the feedwater control valves with increased stem travel (higher feedwater flows and resulting increased pressure drops associated with the uprating require increased pump performance and control valve capacity),
- enable operation with 3 FW pumps.

Blowdown system

- Dismantling of the existing blowdown (BD) pipes inside the steam generator cubicle,
- installation of a revised blowdown piping in the steam generator compartment to balance the flow from the two blowdown connections provided on the replacement steam generator and to get a flow

vode v novem cevovodu pri spoju s sedanjim cevovodom (mogoče poznejše spremembe sistema za kaluženje za večji pretok brez posegov v prostoru za uparjalnik),
– vgradnja odzračevalnih priključkov na visokih točkah cevovoda za kaluženje in priključka kondenzatnega sistema za polnjenje sistema za kaluženje, da se prepreči vodni udar pri ponovnih zagonih sistema.

Sistem pomožne napajalne vode

- Odstranitev dela cevovoda in kolena pomožne napajalne vode zaradi odstranitve starega uparjalnika in ponovna vgradnja po namestitvi novega uparjalnika,
– zamenjava notranjih delov regulacijskih ventilov pomožne napajalne vode, da bi omogočili dodatno rezervo za obratovanje črpalk pomožne napajalne vode.

Sistem drenaže grelnikov

– zamenjava cevi drenaže grelnikov št. 2 iz 12" na 24" (sedanja velikost cevi je komaj zadostna za zahtevani samoodzračevalni pretok).

Kondenzatni sistem

– Zamenjava sesalne cevi kondenzatnih črpalk iz 24" na 30", da bi se zmanjšal padec tlaka ob povečanih pretokih,
– delovanje s tremi kondenzatnimi črpalkami, da bi omogočili ustrezen tlak in prilagodljivost ob povečanih pretokih.

1.4 Večnamenska stavba

V sklop projekta zamenjave uparjalnikov je vključena tudi večnamenska stavba, prikazana v tlorisu na sliki 5, ki je namenjena za:
– shranjevanje starih uparjalnikov,
– shranjevanje nizko- in srednjeradioaktivnih odpadkov, ki nastanejo pri zamenjavi,
– prostor za dekontaminacijo,
– prostor za urjenje,
– prostor za osebje radiološke zaščite.

Objekt je dovolj močan, da se ne bi porušil ob hipotetičnem potresu varne zaustavitve elektrarne. Izvedba objekta tudi zagotavlja, da nivo sevanja ob ograji, predpisan v lokacijskem dovoljenju, v nobenem primeru ne bo presežen.

Projekt je bil izdelan v skladu s slovenskim zakonom o graditvi objektov; zato je bil predložen PGD (projekt za pridobitev gradbenega dovoljenja) ter podprt z ustreznim projektom za izvedbo – PZI.

Za pridobitev dovoljenj je bil PGD osnova v

equal to 5% of nominal feedwater flow in the new piping at the connection with the existing piping (possible later modifications of BD system for higher flow, without any works in the cubicles),
– installation of vents at high points in the blowdown piping and provision of a connection to fill the blowdown system from the condensate system in order to prevent the water-hammer effect when restarting the system.

Auxiliary feedwater system

– Removal, for clearance purposes, of a section of auxiliary feedwater pipe for removal of existing steam generator and reinstallation once the new steam generator is installed,
– replacement of the auxiliary feedwater-control valve trims to provide additional margin for AF pump operation.

Heater drain system

– Replacement of the number 2 heater drain pipe, increasing the size from 12" to 24" (the existing pipe size is marginal for the required self-venting flow).

Condensate system

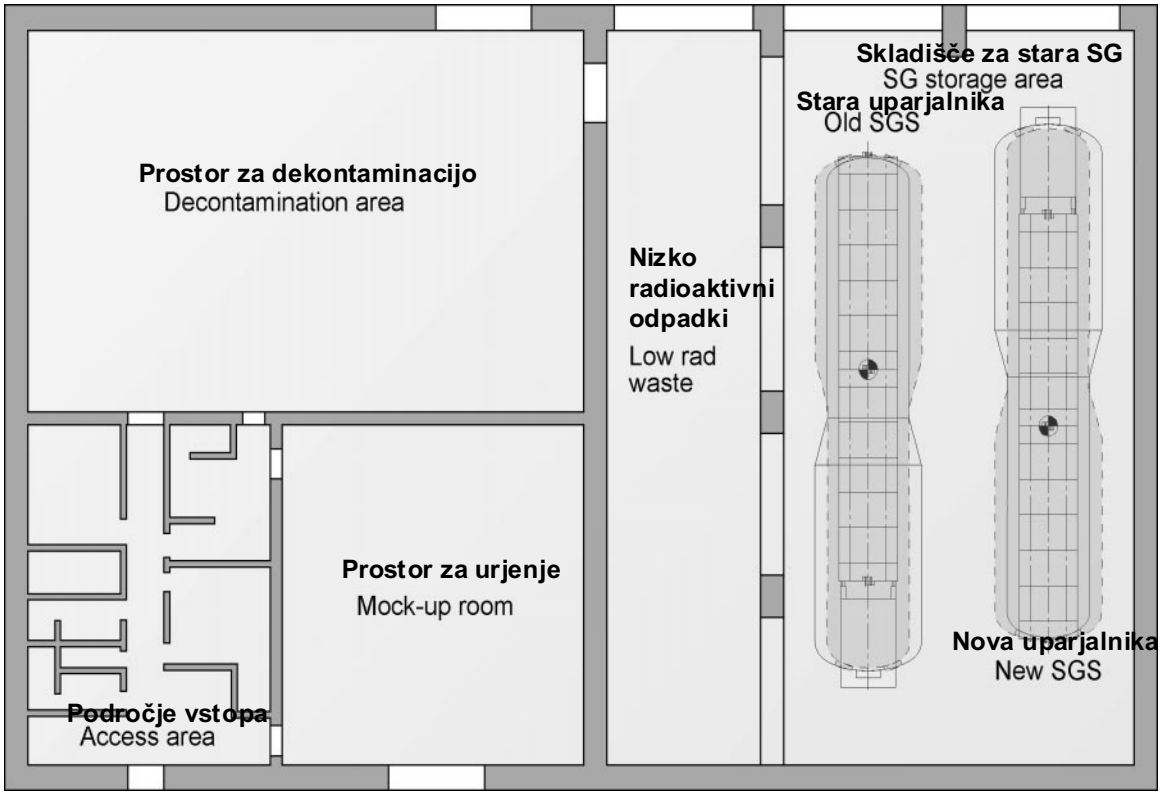
– Replacement of the condensate pump suction pipe, increasing the size from 24" to 30" in order to reduce pressure drop at uprate flows,
– operation with three CY pumps to provide adequate pressure and flexibility at uprate flows.

1.4 Multi-purpose building

Within the scope of activities for the steam generator replacement, a multi-purpose building with the layout shown in figure 5 has also been included for the following purposes:
– storage of old steam generators,
– storage of low and intermediate-level waste from the SG replacement,
– decontamination area,
– mock-up and training area,
– personnel radiation-health area.

The facility has been designed as a non-safety related building but calculated for non-collapse in the case of an SSE. Furthermore the radiation level at the site fence established in the site permit shall not be surpassed.

The design was performed according to the Slovenian construction regulations, for which purpose a design for construction permit (PGD) was granted, supported later on for construction purposes with the corresponding design for construction performance (PZI) documents.



Sl. 5. *Večnamenska stavba*
Fig.5. *Multi-purpose building*

skladu z običajnim gradbenim dovoljenjem ter oceno jedrskih vidikov.

Stavba je opremljena s sistemom HVAC, ki vključuje filter HEPA, da bi preprečeval uhajanje radioaktivnosti in znotraj stavbe vzdrževal podtlak ter primerne okoliščine za osebje. Prostor za dekontaminacijo se bo uporabljal za dekontaminacijo, v njem bo 5-tonsko dvigalo, povezano s sistemom demineralizirane vode in neodvisnim sistemom stisnjenega zraka. Monitorji sevanja z lokalnimi alarmi bodo vgrajeni v prostorih za shranjevanje in dekontaminacijo in povezani z glavno kontrolno sobo elektrarne. Stavba je bila uporabljena tudi kot prostor za shranjevanje novih uparjalnikov med zimo 1999-2000. Nova uparjalnika sta bila v elektrarno pripeljana v septembru 1999.

2 DOKUMENTACIJA ZA PROJEKT IN PRIDOBITEV DOVOLJENJ

V pripravljalni fazi projekta je treba pripraviti veliko dokumentov. Pripraviti je treba naslednje glavne kategorije dokumentov:

– dokumentacijske pakete za trajne in začasne spremembe. Poleg projekta in projektnih izračunov vsebujejo varnostno presojo in varnostno oceno. Ti paketi so podlaga za proces pridobivanja dovoljenj. Ko vse te dokumente natančno pregleda JEK (SSP – Strokovni svet pogona in VS –

For the licensing, the PGD was the basis according to the normal construction license which joined an assessment with regard to the nuclear application, having received the construction permit in this way.

The whole building is equipped with a nuclear HVAC system comprising a HEPA filter to avoid the emission of radioactivity and to maintain a sub-pressure inside the building, as well as for personnel comfort. The decontamination area will be used for decontamination activities and is also equipped with a 5 ton crane. It also has a connection to the de-mineralized water system and an independent compressed air system. Radiation monitors with local alarms are connected to the control room and installed in the storage and decontamination rooms. The building has also served as a storage place for the new steam generators during the winter 1999 / 2000. The new steam generators arrived on site in September 1999.

2 DOCUMENTATION FOR ENGINEERING AND LICENSING

During the preparatory/engineering phase of the project, numerous documents have to be prepared. The following main categories of documents are to be prepared:

– document packages for permanent and temporary modifications. Besides all the design and design calculation aspects these documents include the safety evaluation screening and safety evaluation. These packages are the basis of the licensing process. After a detailed review of these documents by NEK (by

Varnostni svet), jih pošlje na Upravo RS za jedrsko varnost. Metodologija za pridobitev dovoljenj je v skladu z zahtevami Zvezne jedrske upravne komisije ZDA (10CFR50.59),
- dokumentacijo za kvalifikacijo posebnih postopkov, opreme in osebja,
- dokumentacija za nakup začasne in trajne opreme,
- dokumentacijske pakete za vgradnjo,
- dokumentacijo izvedenih del.

Upoštevati je potrebno tudi ustrezno slovensko zakonodajo.

3 ORGANIZACIJA IN ČASOVNI NAČRT PROJEKTA

Projektno skupino konzorcija sestavljata podjetje Siemens v Erlangnu v Nemčiji in Framatome v Chalonu v Franciji. Tudi JEK ima zelo dobro projektno organizacijo, da bi se lahko odzvala na vse zahteve projekta. Zaradi neposrednega stika ima Konzorcij svojega zastopnika v elektrarni med celotno dobo zamenjave. Le-ta je vključen tudi v poslovanje s slovenskimi podjetji.

Zaustavitev elektrarne zaradi zamenjave uparjalnikov se prične 15. aprila 2000; zamenjava naj bi po načrtu trajala 28 dni, celoten remont pa približno dva meseca.

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KOC-Krško Operating Committee and KSC-Krško Safety Committee) these documents will be forwarded to the Slovenian Nuclear Regulatory Body (URSJV). The methodology for licensing is in accordance with the US NRC (10CFR50.59),
- documents for the qualification of special processes, equipment and personnel,
- documents for the procurement of temporary and permanent equipment,
- document packages for site implementation (installation packages),
- as-built documentation.

Applicable Slovenian legislation shall also be respected.

3 PROJECT ORGANIZATION AND SCHEDULE

The Consortium project team includes Siemens located in Erlangen, Germany and Framatome located in Chalon, France. Krško NPP also has a very good project organization in order to be able to react to the requirements of the project. For interface purposes the Consortium has a representative on site during the whole engineering phase, who is also involved in dealing with Slovenian companies.

The shut down for the steam generator replacement starts on April 15, 2000. The replacement window is scheduled for a period of 28 days, and the entire outage for approximately two months.

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