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Three Steam Generator Replacement Projects in 1995

Consortium Siemens Framatome is Well Prepared to Contribute its Experience to the SGR at the Krško NPP

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Since the companies Siemens AG and Framatome S.A. joined their experience and efforts in the field of steam generator replacements and formed a consortium in 1991, the following projects were performed in 1995: Ringhals 3, Tihange 3 and Ascó 1. Further projects will follow in 1996, i. e., Doel 4 and Ascó 2. Currently, this European consortium is bidding for the contract to replace the steam generators at the Krško NPP and hopes to be awarded in 1996.

An overview of the way the Consortium Siemens and Framatome approaches SG replacement projects is given based on the projects performed in 1995. Various aspects of project planning, management, licensing, personnel qualification and techniques used on site will be discussed.

Planning, Engineering Phase of the Project

Very exact and detailed planning is required for such a project because plant downtime due to the replacement must be kept as short as possible (minimizing electricity production outages), because the procedures involved are complex and varied, and because local companies are to be included in the effort.

Country-specific and international codes and standards (e.g., ASME, DIN, ISO or IAEA) can be readily applied owing to the experience Siemens and Framatome have had with them over many years. The quality management system employed by Siemens and Framatome has been certified by numerous institutions in Germany, France and abroad.

Project Structuring

As the first step toward efficient processing, the entire project is broken down into job packages, the most important of which are listed below. The structure of the projects is of fundamental importance to subsequent phases of the project. The project team is formed based on this structure (with the appointment of the specialists required), and project schedules (engineering schedules) are prepared which embrace the entire preparatory phase up to the commencement of work at the plant.

The most important job packages for a steam generator replacement are:

- Design, design calculation and licensing activities
- Disposal of radioactive waste, general decontamination
- Decontamination of the reactor coolant lines
- Optical survey of the reactor coolant lines
- Machining of the reactor coolant lines

- Steam generator transport and rigging
- Fit-up and alignment of the reactor coolant lines
- Welding of the reactor coolant lines
- Activities at the primary and secondary piping systems
- Civil engineering (opening of the containment, construction of the storage facility,for old SGs and other buildings)
- Replacement of thermal insulation
- Radiation protection (ALARA considerations)
- Risk analysis, licensing
- Temporary facilities, site infrastructure
- Scaffolding, radiation shielding
- Construction of steam generator mock-up, qualification of personnel and equipment using the mock-up

Putting the Project Team Together

All specialists required for the individual job packages form an organizational unit under the coordination of a project manager who becomes their direct superior for the duration of the project and coordinates all activities within Siemens and Framatome. Processing of projects in this manner has proven extremely effective for the following reasons:

Communication and information pathways are short and the number of interfaces is minimized, allowing the team to respond rapidly to special customer requests.

Efficiency is high because there is a direct link between work activities and the decision-making process within the team.

Motivation is high and team members identify with their assigned task because they are only involved in a single project.

Project Schedules

Project schedules are prepared for all job packages. They have a standardized arrangement and contain the following sections:

- project preparations,
- design, engineering, licensing
- order processing and manufacturing,
- qualification of personnel and equipment,
- site planning, and
- preparation for work at the power plant

These schedules are an important basis for high-quality project processing. They are used to coordinate the activities of all participants, including subcontractors, and are presented along with a monthly status report to the customer so that he is always fully informed and integrated into the project.

Each schedule contains approximately 100 activities. These activities are included in condensed form in a higher-level schedule (the main engineering time schedule).

Documentation for Work at the Power Plant

One of the most important planning steps is a complete visual inspection of the steam generator during one of the refueling outages prior to replacement. This inspection also includes the secondary piping, the steam generator support structure and the reactor coolant line. All potential interferences must be recorded, the rigging paths measured and openings checked by using mock-ups. In preparation for this visual inspection, a plant *walkdown list* is drawn up showing all activities which must be performed during the plant outage prior to replacement of the steam generators.

The "*general work sequence plan*" is the main document for all activities on site. It lists in a logical sequence all work that is to be performed. It includes approximately 15,000 activities indicating the steps involved in each, and makes reference to all applicable documents such as drawings, work procedures, system descriptions, etc.

Another important document is the *inspection plan* which is the official quality management document. It contains all necessary inspection steps and is prepared in accordance with project-specific requirements and country-specific standards which regulate all activities concerned with quality management, nondestructive examinations and other tests and also specifies who shall witness each (Consortium, the supplier, the customer, the licensing authority).

A *site schedule* is prepared for the replacement work. Independent of their association with the job packages, the required activities are planned chronologically and incorporated by the customer into the overall outage planning. The site schedule comprises about 6,000 separate activities, with one hour being the smallest unit of time assigned.

The site schedule and the general work sequence plan are also used in resources planning, i.e., in deciding which personnel, equipment, and machinery to use, and in estimating radiation dose.

Personnel Training

Experience with such replacement projects has shown that personnel training contributes enormously to optimum performance in terms of work quality, meeting deadlines, and minimizing the radiation exposure of the personnel. Hence, comprehensive theoretical and practical training programs were developed for the most important work steps. Consortium and subcontractor employees are given specialized training for the tasks and conditions of the steam generator replacement at hand.

All personnel training programs are performed using a full-scale mock-up of the lower section of the steam generator (primary channel head with a section of the reactor coolant line and the steam generator nozzles) including the interferences in this area.

Training and qualification are performed for the following main activities

- welding of the reactor coolant line,
- cutting and machining of the reactor coolant line,

- decontamination of the remaining ends of the reactor coolant line
- mounting of special shielding devices,
- video inspections inside the reactor coolant line and the primary channel head.

Activity description	Early start	Early finish	RESP
Preliminary	01FEB94A		SIE
Review by REX	10MAR94		REX
Final	07APR94A		SIE
Submit to REX		01MAY94A	SIE
DESIGN:	01FEB94A	17JAN95	
Flow diagram	01MAY94A		SIE
Isometrics	15MAR94	04NOV94A	SIE
Support concept	01FEB94A		SIE
Support drawings	01APR94A		SIE
Platform drawings	15NOV94	14JAN95	BRB
Wall penetration drawings	01JUN94A	15DEC94	SIE
Material test sheets for PIPING	01MAR94	31MAY94A	SIE
Material test sheets for SUPPORTS	01JUN94A	02DEC94	BRB
Review by REX/SA (prel.)	01JUL94A	03DEC94	R/S
Final revision by Siemens	15AUG94	17JAN95	SIE
Submit to REX/SA		17JAN95A	SIE
FIPs FOR PROCUREMENT	01MAY94A	26NOV94	
Preparation for PIPING	01MAY94A	12JUN94A	SIE
Preparation for SUPPORTS	15MAY94A	26NOV94	BRB
Review by REX/SA prel (Piping and supports)	23JUN94A	23NOV94	SIE
Final revision by Siemens (Piping and supports)	22JUL94A	17NOV94	SIE
Submit to REX/SA (Piping and supports)		26NOV94A	SIE
MANUFACTURING DOCUMENTS	01MAY94A	03DEC94	SIE

Expenditure: ■ Previous, ▒ Still Planned
Deadline for milestone: ■ Actual, □ Planned
SIE, SIEMENS
REX, Project code/customer
BRB, Subsupplier
SA, Authorized inspection agency

Excerpt from a project schedule

Design, design calculation, licensing

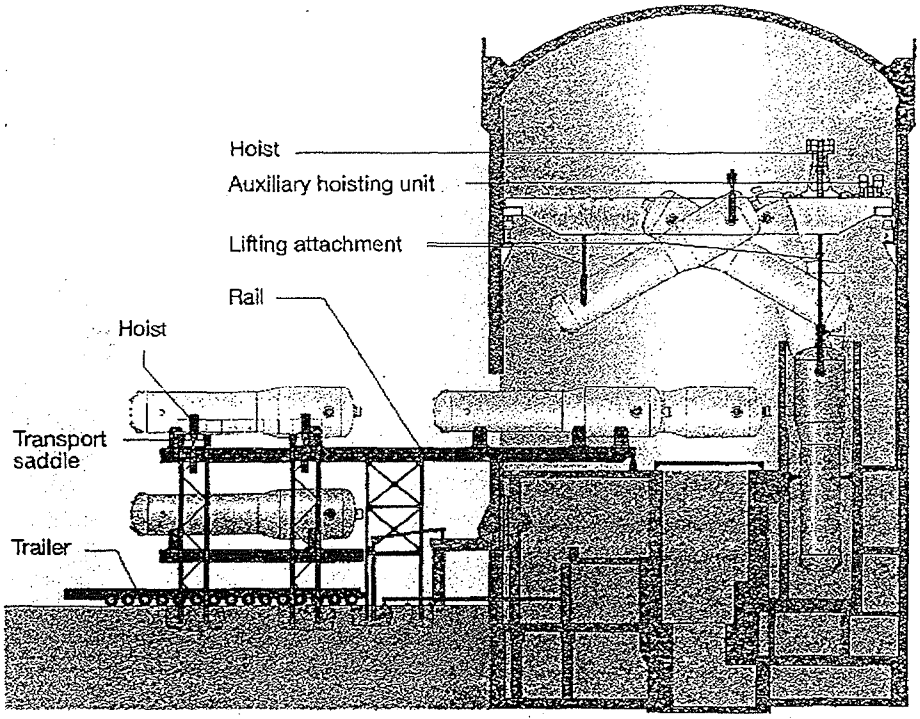
In SG replacements the tasks of special importance are design and design calculation. These activities apply for temporary equipment (such as SG rigging, devices for piping, etc.) and for permanent plant equipment including all related modifications (such as rerouting of piping, thermal insulation, steel liner of containment opening). Piping design covered rerouting of feedwater and auxiliary feedwater, adaptation of instrumentation piping, main steam, blow-down, reactor temperature detection, drain, sampling. Design calculation basically covered analyses of structural, seismic and fluid dynamic data.

In parallel with basic engineering, the safety of all activities leading to modification of plant equipment or activities introducing a specific risk, such as handling, rigging, transportation, waste handling, is evaluated for review by the licensing authorities. These evaluations are in accordance with 10CFR50.59.

Ringhals 3, in Sweden

At Ringhals 3 the Siemens Framatome Consortium joined forces for the first time. Particular to Ringhals 3 were:

- The necessity of cutting an opening into the reactor building wall for removing the old SGs and bringing in the new ones.
  The opening was 6m x 7m. This "door", a 140 metric ton block of concrete, had to be handled 15m above ground. Cutting the concrete and subsequent closing off were both on the critical path, a tight 44-day schedule for the SG replacement.



Rigging Inside/Outside Containment of Steam Generators at Ringhals 3

- SG handling kinematics, especially adapted to cylindrical shape of the Ringhals SG cubicles which tightly and at full length "imprison" the steam generators.
  This was possibly the most spectacular aspect of the SGR. It meant removal of the old SGs from their cylindrical cubicles and bringing in the new ones without destroying existing civil work structures and staying within the 390 metric tons, maximum load capacity of the polar crane. This required an aerial ballet that involved pivoting the SGs from a vertical position to a horizontal position and a rotation of up to 180° as the clearance between the SG outlines and the concrete cubicles was only 20 cm. Due to the loading limit of the polar crane and the lifting height required additionally, an extra gantry crane was constructed and mounted on traveling crane beams.

Remaining operations including techniques for working on the reactor coolant system did not pose any particular problems. Operational delivery, the transfer of responsibility for activities within reactor building from the Consortium to the customer Vattenfall took place on August 9, 95 - five days earlier than required under the contract. Reconnection to the Swedish power grid was on August 29, 95, 90 days precisely after insertion of the shutdown control rods. Overall collective dose for the SGR was 1290 mSv constituting the best performance to date for a steam generator replacement.

Tihange 1, in Belgium

The real challenge was not only in the replacement as such, but also in the work environment as for this second 10-year in-service inspection at Tihange 1 other work was scheduled, such as:

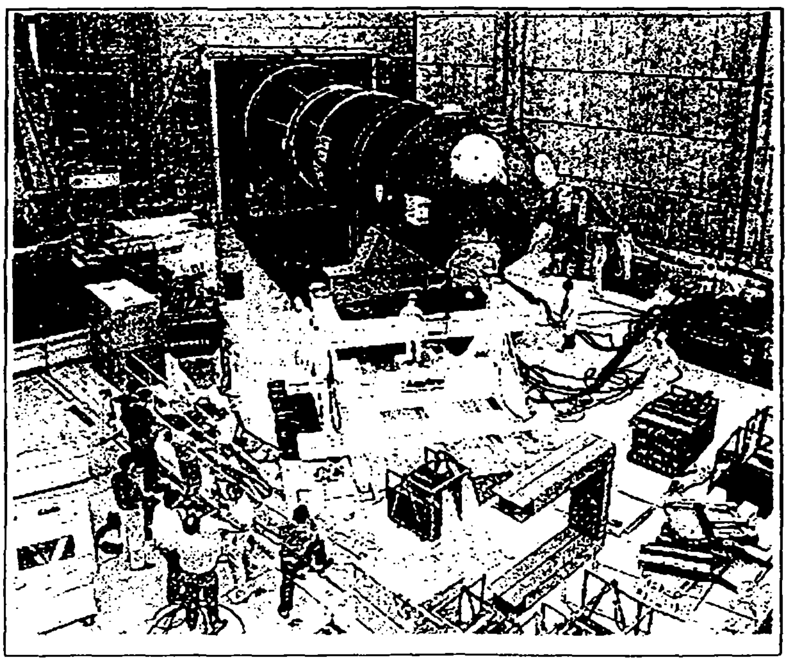
Reactor vessel inspection
Inspection of bolts of reactor internals and replacement of 10% of them
Replacement of all pressurizer heaters
Overall replacement of reactor protection system
Replacement of turbine low-pressure rotors
Renovation of cover gasket of equipment hatch in reactor building.

Besides this, numerous other maintenance tasks and modifications were called for after 20 years of operating Tihange 1. The SGR scope was similar to that of an EDF NPP in France. Nevertheless, the new steam generators from Mitsubishi Heavy Industries in Japan for their installation required special interface management. The very different design of the horizontal SG supports (a system of swiveling tie rods under tension) called for special methods during disassembly and reassembly.

Scheduled overall duration of SGR was 38 days counting from start of cutting primary piping to primary and secondary systems' readiness for refilling - all work was on the critical path. In this especially tight schedule and under difficult working situations, Framatome and Siemens completed the assigned tasks in 33 days to the satisfaction of the customer. The unit was reconnected to the Belgian power grid on September 16, 96 - just 93 days after shutdown.

Ascó 1, in Spain

In the January '93 contract with Asociación Nuclear de Ascó (ANA) the Consortium had agreed to provide a turnkey project, with a very large scope of supply which included major civil work inside the reactor building on account of size and positioning of SG cubicles.



During the outage other major tasks were performed. ANA replaced the LP turbine, eliminated temperature-measuring bypasses of the reactor coolant system, installed a digital measuring system of SG levels and implemented the concept "Leak Before Break".

Prior to the SGR, the Consortium

- constructed a "mausoleum" for storing the old steam generators on site,

- installed a laundry facility in the auxiliary buildings
- constructed a decontamination workshop
- installed a new waste-compacting machine and
- constructed an access building for use during the SGR

At Ascó 1 an opening was cut into the SG bunker facing the equipment hatch which produced four concrete blocks weighing a total of 310 metric tons. The "conventional" steps of SG handling and work on primary piping posed no particular problems and went much faster than expected:

- Bringing in and positioning three new SGs in 4.5 days,
- Welding the primary system in only 8 days.

After rebuilding the SG cubicles and completing work on the secondary piping, reactor pit and polar crane were returned to the operator's control one day earlier than originally scheduled. Total dose rate for the outage was 2,440 mSv which exceeded our objectives by far and resulted from the protective measures taken.

Replacement of steam generators in Ascó 2 is currently (August 96) under way, and is scheduled to be finished in October 1996. Ambitious objectives resulting from SGR in Ascó 1 are now being integrated into SGR in Ascó 2.

Work Performed on the Reactor Coolant Pipes during the SGRs in Ringhals, Tihange 1 and Ascó 1

The work performed on reactor coolant pipes is one of the most important tasks of the SG replacement and was quite the same for all three projects. The objective of all the activities on reactor coolant pipes is to obtain the required fit-up tolerances between the new SG and the existing loops with the following requisites:

- Perform 2-cut method without replacing elbows.
- Minimize residual stresses after welding
- Reduce accumulated radiation dose
- Optimize the schedule

Optical survey

The optical survey was performed by applying a combination of photogrammetry and industrial optical technique using electronic theodolites. The process was previously proven in terms of accuracy, reproducibility, radiation exposure and speed of use.

This technique was also used during previous outages to determine the geometry of the existing reactor coolant pipes which allowed machining the new SG nozzle during the manufacturing phase.

Cutting/Machining

Specifically developed portable machines were used

- for cutting old SG nozzles. This machine was designed with a cutting wheel to keep chips from entering the pipe.

- for machining of pipe elbows at a position previously determined by optical measurement to obtain a fit-up tolerance of less than 1 mm.

Welding

Main target of the activities performed on the reactor coolant pipes was to achieve a proper fit-up of the new steam generators to the reactor coolant pipes and to minimize the residual stresses after welding. This was achieved by using a special installation sequence and the GTA narrow gap welding technique.

The special configuration of the welding edge in connection with the equipment provides the following advantages:

- Smaller weld volume which resulted in reduced welding time,
- Remote-controlled, TV-monitored process contributed to a reduction of the accumulated radiation dose.
- Due to sequence of weld fabrication lower residual stresses were produced in the welds (length allowance for shrinkage), thus residual stresses in piping system were minimized.

Decontamination

The purpose of this process is to reduce radiation dose in the area of reactor coolant pipe ends, and to achieve local cleanliness of pipe interiors there. This process was performed in two steps:

Blasting by electrocorundum to remove the oxide layer, followed by blasting with glass beads to improve the superficial stress conditions and to smoothe the surface. Use of a closed-circuit system with subatmospheric pressure prevented abrasive particles and dust from escaping into the atmosphere (aerosol build-up is avoided) keeping radioactive waste build-up to a minimum.

Steam Generator Replacement - Duration and Dose Applied