PLUSS-A WELDLESS LEAKTIGHT SLEEVE FOR ALLOY 600/690 STEAM GENERATOR TUBES

Franz Pötz, Werner Bohmann
ABB Reaktor GmbH, Germany

ABSTRACT

The ABB PLUSS sleeving represents a new SG tube repair technique qualified and approved to replace in the future most of the plugging as well as welded sleeving.

Basically the advantages of an innovative combination of both alloys 600/690 and 800 are taken into consideration. The upper sleeve/SG tube-joint is hydraulically expanded stressing the SG tube only within the elastic range. The lower joint is hard rolled. The installation processes are simple and reproducible, fast, computerized and individually recorded.

The operating temperature range of the sleeved SG-tube is effectively reduced so that any further corrosion is impeded. Both, sleeve and SG tube are fully inspectable by ECT.

INTRODUCTION

As operating light water reactors getting older and some of them approaching their designed lifetime, the question of plant aging, and the determination of their potential lifetime becomes more and more important.

This calls for a better understanding of aging phenomena by an optimization of operating strategies and a development of innovative inspection and repair or replacement strategies. Definitely, this task is complex because it covers technical issues, cost, a given licensing situation and possibly, public acceptance.

From a technical point of view it seems to be a common understanding that nuclear power plants can be operated for 40, 50 or even more years today. The inspection, repair and component replacement technologies are of a very practical importance in achieving this goal.

The steam generator shall serve as an example of how we think to support utilities in the future.

Steam generators are designed to be a barrier between the primary and the secondary side in a PWR during the active life time. However, a large number of SG tubes have become defective and cannot be operated until the designed life time.

Defective tubes have to be plugged or sleeved according to current criteria. Both technologies were developed and qualified by ABB and are field proven. Another solution may be the complete replacement of a steam generator. The first option of course should be the use of all possibilities to extend the life time by economical repair solutions.

I will present you the latest developments and the operating experience we can provide already today.

SITUATION WORLDWIDE

Most of the operating steam generators in the world have tubes made from Alloy 600/690. One exception are the steam generators built in the former Soviet Union. These steam generators of the VVER type are equipped with stainless steel tubes. Alloy 800 as tube material used in Germany from the beginning is the other exception. Up to now the experience we made with alloy 800 is extraordinary. There are steam generators working in 1300 MW plants for more than twenty years literally without any apparent damage,

no tube had to be plugged because of wall degradations during operation. In many nuclear power plants in other countries the SG tube damages reached such a degree that the SG replacement is the only economically feasible solution. Figure 1 shows the mechanisms of damage for 20 years. Although the so-called wastage and denting problem dominated the seventies, the main problem today is the stress corrosion cracking of the primary as well as secondary side.

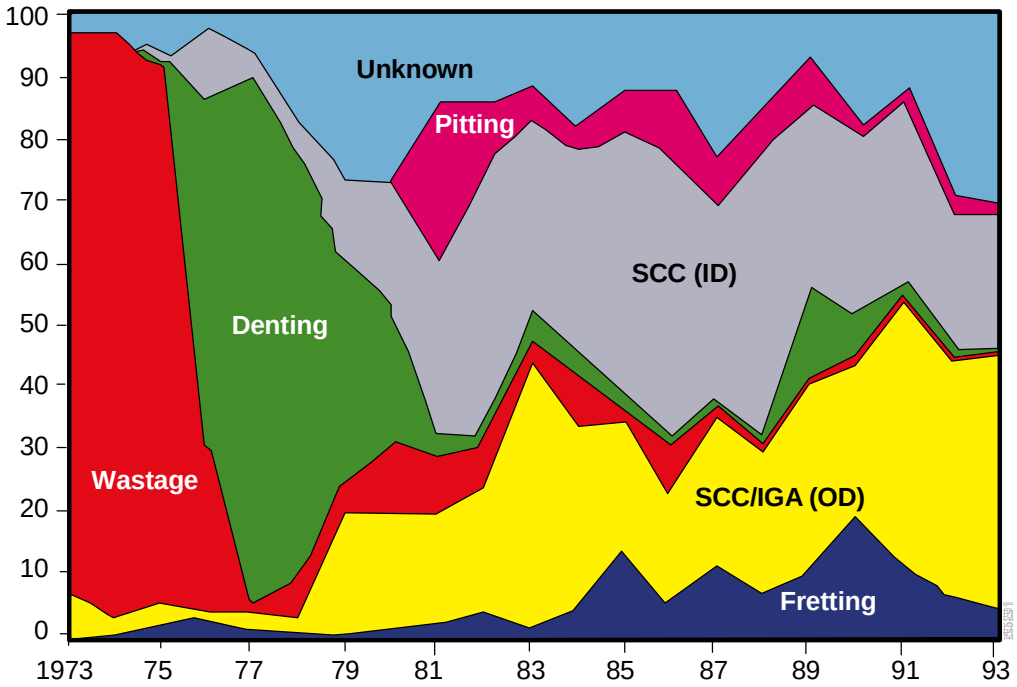

Figure 1 Causes of Tube Degradation Worldwide

ABB already developed, qualified and approved repair techniques in the past, for example a TIG welded sleeving, and installed these sleeves in different steam generator tubes widespread all over the world.

Key questions (problems) our engineers paid attention to for a long time are the following:

- Is it possible to create an innovative sleeve without the complex welded joint for optimum performance on operating and accident conditions of a nuclear power plant?
- Is it possible that, in the future, such a sleeve can replace the plugging of tubes in regard of cost and time?

TAKING INTO ACCOUNT OUR STATE OF DEVELOPMENT AND EXPERIENCE BOTH QUESTIONS CAN BE ANSWERED WITH YES!

SG REPAIR TECHNOLOGY

An extreme important question to operate a nuclear power plant is the knowledge of the condition of materials and components. The eddy current technique turned out to be the most useful technique to answer this question. Continuous improvements were made regarding detection sensitivity, inspection velocity and radiation dose reduction. A remarkable event during the last years was the development and testing of new probes enabling the detection of even smallest stress corrosion cracks with the so-called “plus point probe”. Today this is the prerequisite for the development of repair strategies.

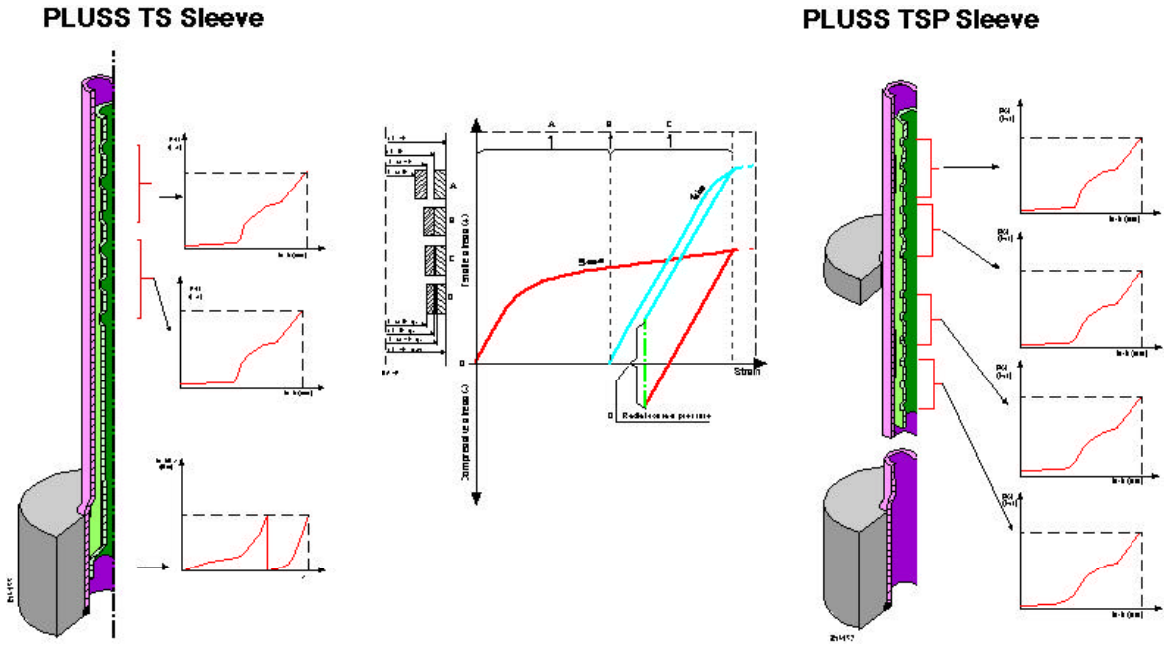

Figure 2 : Advantage Taken of Different Material Characteristics

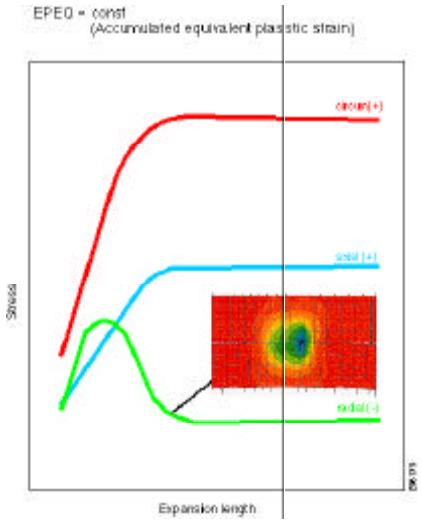

Figure 3: Theoretical Investigation on Optimum Expansion Length

Let me now present our new sleeving product, the so-called PLUSS Sleeve. The basic idea was to take the advantage of different material characteristics between sleeve and SG tube (see Figure 2). Because of the different spring back characteristics a contact pressure appears after the hydraulic expansion process, which creates a leak tight upper joint PLUSS TS sleeve or both joints of the PLUSS TSP sleeve. The lower joint of the PLUSS TS sleeve is a hard rolled one with a microlock similar to that of the plug. On the left side of the Figure you see a mother tube repaired in the TSP region with a PLUSS TSP sleeve. The right side shows a mother tube repaired in the TS region by a PLUSS TS sleeve. All hydraulic expansions are so-called 0%-expansion, that means no significant stresses are remaining after the expansion process. This

is very important for SG tubing of material susceptible to stress corrosion cracking, like Alloy 600, during longterm usage.

Further potential of optimisation was in the area of the expansion length (see Figure 3). Elastoplastic finite element analysis proved evidence that a certain optimized expansion length leads to maximum radial stresses and decreasing axial and circumferential stresses. The radial stresses are directly responsible for the sealing function. The results achieved during the qualification testing confirmed this calculation.

Another advantage can be seen in the next Figures 4 and 5. The sleeving process leads to a material temperature decrease of approximately 30°C on the primary tube surface in the PLUSS sleeved range. This is very important with regard to the crack initiation and propagation, as shown in EPRI research papers, see Figure 6.

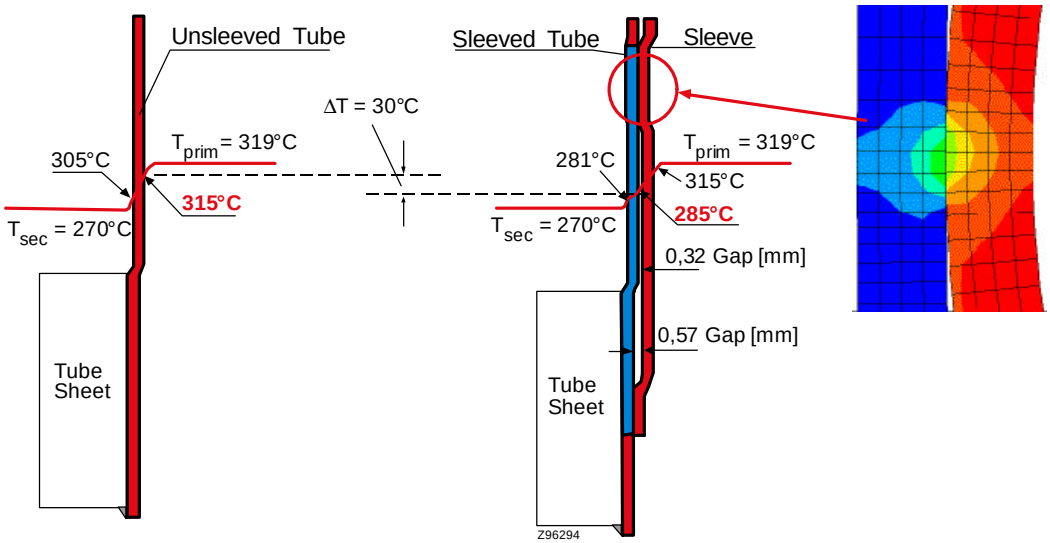

Figure 4: Theoretical Temperature Investigation

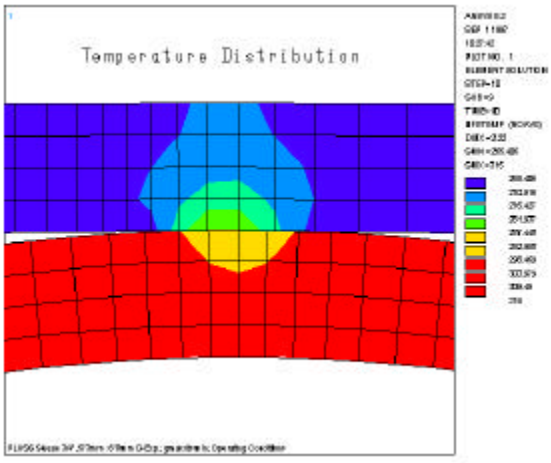

Figure 5: Temperature Distribution on PLUSS Sleeved SG Tube

The mentioned temperature decrease of 30°C reduces the crack initiation and the crack propagation roughly by a factor of 10. In other words, a defective tube that will be PLUSS sleeved according to the valid criteria, will need for example 10 years before failing under operating conditions instead of 1 year in not sleeved condition.

To this day we installed 1339 sleeves in 3 plants which are operating successfully, two of them for more than two years. The achieved production rate was approximately 50 sleeves per SG and day.

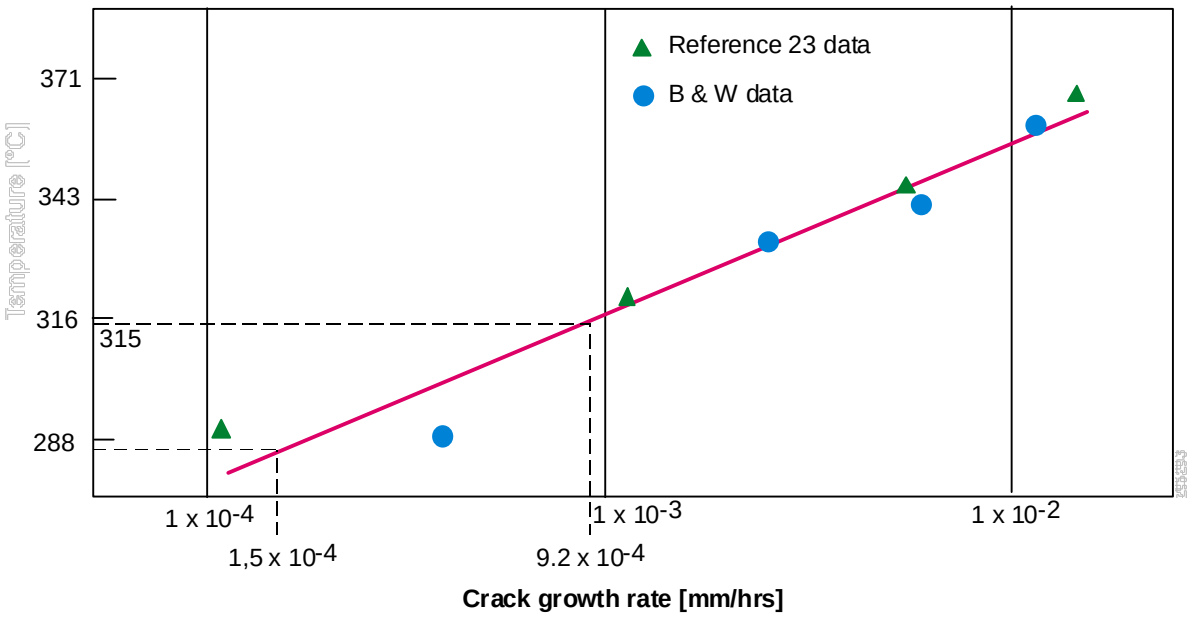

Figure 6: EPRI Corrosion Test Results

FIELD SERVICE HARDWARE AND SOFTWARE

The equipment and tooling utilized for the remote-controlled PLUSS sleeve installation consists of proven basic systems for

- manipulation
- tool delivery
- tube cleaning and air flushing (Figure 7)
- volume controlled hydraulic expansion (Figure 8)
- torque controlled hard rolling
- non-destructive examination by ECT.

The PLUSS sleeving is controlled with high accuracy via the ABB multiprocessor control system DAMS 2000. The PLUSS sleeving software allows and renders

- operation and supervision of the system according to specified criteria on a graphic screen device
- detection of certain check points and on-line calculation of limits
- system shut-down on target
- recording and hard-copying of significant procedure data and graphs.

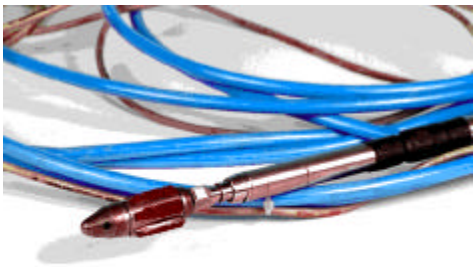

Figure 7: Tube Cleaning and Air Flushing Tool

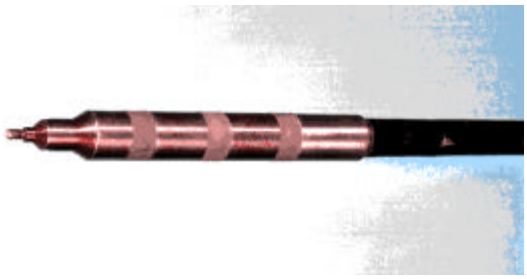

Figure 8: Sleeve Expansion Tool

CONCLUSION

From our point of view the presented development and qualification of the new SG tube repair technique will replace most of the plugging processes of steam generator tubes in the future. The inspection of the mother tube as well as the sleeve is very well feasible with qualified eddy current methods. The key features and their advantages are summarized in Table 9.

Innovative economical solutions cannot be developed by one lonely party. On the contrary we need the cooperation and willingness of our customers and authorities to pave the way for innovative solutions.

We strongly believe that innovative solutions are of considerable importance for a safe and economic operation of nuclear power plants in the future.

Table 9 Key Features of PLUSS Sleeves

Design	Material Zero expansion of SG-tube SG tube stresses due to installation Potential for leakage •Tubes with non wall through defects	Alloy 800-qualified industrial production No heat treatment None compressive due to installation process leak tight; crack growth drastically reduced due to reduction in SG tube surface temperature
Installation	3 simple steps Controlled steps Application Accessibility	Cleaning of SG tube, hydraulic expansion of upper and hard rolling of lower joint of TS sleeve or hydraulic expansion of upper and lower joint of TSP sleeve Low risk of procedure deviations Tob of tube sheet / support plates Up to 98 % of tube sheet area
Results	SG tube inspection Production rates Removal of sleeve	Complete inspectability of sleeved area 40 to 60 per day and SG Possible