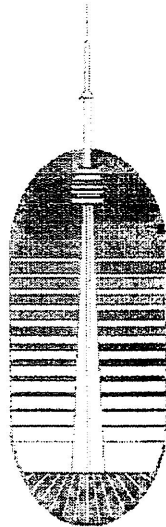


**Proceedings of the Third International Conference on
Steam Generators and Heat Exchangers**



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FOREWORD

by

R.L. Tapping
Chairman, Conference Committee

The first International Steam Generator and Heat Exchanger Conference was held in Toronto in 1990. Since then maintaining the performance of some CANDU steam generators has continued to require considerable attention. Past conferences dealt largely with operating problems and degradation of steam generators. This conference, the third, while still somewhere concerned with operating problems also addresses successful operation strategies, rehabilitation, and the performance of new designs. The theme this year was "the success of technological improvements, today and in the future".

This conference continues to provide a unique forum where all aspects of steam generator technology are discussed and an integrated approach to steam generator management can be developed. Experience gained from research and development, and operation, "lessons learned", has allowed us to more accurately predict steam generator ageing, and to develop strategies for improved operation.

This third conference was a success, and the Organizing Committee wishes to thank the presenters, both oral and poster, and the attendees for their contribution to that success.

The Organizing Committee also wishes to thank the direct supporters of the event; the CANDU Owners Group, the Canadian Nuclear Society, Siemens Canada, New Brunswick Power, and the indirect supporters, Atomic Energy of Canada Limited, Ontario Hydro, and Babcock and Wilcox International.

We look forward to seeing you at the Fourth Conference!



**THIRD INTERNATIONAL
STEAM GENERATOR AND HEAT EXCHANGER CONFERENCE**

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Mr. C.S. Welty, EPRI
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INTRODUCTION TO THE PROCEEDINGS

by

R.L. Tapping, Conference Committee Chairman

The Third International Steam Generator and Heat Exchanger conference had the objective to present the state of knowledge of steam generator performance and life management, and also heat exchanger technology. As this conference followed on from the previous conferences held in Toronto in 1990 and 1994, the emphasis was on recent developments, particularly those of the last 4 years.

The conference provided an opportunity to operators, designers and researchers in the field of steam generation associated with electricity generation by nuclear energy to present their findings and exchange ideas. The conference endeavoured to do this over the widest possible range of subject areas, including:

- General operating experience
- Life management and fitness for service strategies
- Maintenance and inspection
- Thermalhydraulics
- Vibration, fretting and fatigue
- Materials, chemistry and corrosion
- Regulatory issues

There was an excellent response world-wide to the call for papers and a total of about 155 people from 11 countries registered. They participated in lively discussions, listened to 37 oral presentations and interacted with 20 poster presentations. The Proceedings present the full refereed collection of 57 papers. These include full papers for the poster session.

The organization of the proceedings in the following two volumes generally mirrors the conference itself. Paul Spekkens' opening address precedes the papers, which are grouped into the 6 conference sessions. The Proceedings also record the discussion held following each presentation. These are then followed by the poster session papers, with the Appendices highlighting the award for the best poster, R.L. Tapping's closing address to the conference and the list of registrants.

On the technical side, management of steam generator performance and life continues to be a challenge. There are many degradation mechanisms that can afflict steam generators and finding the best life management, operations and maintenance strategy often involves many compromises. Management decisions continue to be required, while laboratory understanding of the degradation types, the influencing parameters and the degradation rate predictions are still developing. Also, from time to time, a new degradation mechanism appears on the scene (such as tube support structure degradation reported recently at several PWRs). This leaves the feeling that a full understanding of all of the ways that steam generators can degrade is still an elusive

target. The conference also heard about some of the Canadian regulatory views and approaches to steam generator degradation management.

The technological developments described at the conference provide some grounds for optimism. Significant inspection method improvements were reported in sizing cracks and considerable advances have been made in improving secondary side chemistry. However, as steam generating equipment ages, strategies have to be developed to maintain equipment performance.

On the thermohydraulics front, we heard of improvements to validate the codes used and of advances in the understanding of the complex fluid flow/tube vibration processes in AVT chemistries, and the significant advances in our ability to model tube bundle fouling.

Also, the links between chemistry, tubing material condition, and corrosion mechanisms continue to be clarified. Lead contamination is still an important issue in the chemistry control of steam generators and remains a major contribution to life management concerns.

Overall, the technical quality of the papers was excellent, and well appreciated by both the attendees and, hopefully, by the users of the Proceedings. While the credit for this goes mainly to the authors, I also thank the many individuals who contributed, via review and refereeing of the drafts. These efforts are gratefully acknowledged by the conference organizers.

Finally, the ultimate goals of designing, operating and maintaining nuclear heat exchange equipment for high reliability and extended life targets continue to be both important and challenging. If they are to be achieved, detailed discussion of the issues and reassessment of our programs by designers, operators, maintainers, inspectors and researchers is absolutely vital. International forums for these discussions, such as this conference, play an important role in stimulating progress towards these goals.

**THIRD INTERNATIONAL STEAM GENERATOR
AND HEAT EXCHANGER CONFERENCE**

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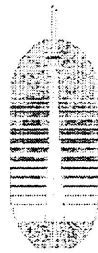
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WELCOMING ADDRESS

**DR. P. SPEKKENS
VICE PRESIDENT – TECHNICAL SUPPORT
ONTARIO HYDRO NUCLEAR**

Good morning, ladies and gentlemen. I would like to welcome you all to Toronto and to the Third International Conference on Steam Generators and Heat Exchangers. I would particularly like to welcome our visitors from outside Canada. This is truly an international gathering: we have participants from 11 countries with us this week, including more than half the speakers. To these visitors, I extend a special welcome to Canada.

This is the third conference in this series, the previous ones having been held in 1990 and 1994. What keeps bringing us together is a shared interest in and, in many cases, frustration with the behaviour of these very important components of pressurized water reactors, namely, steam generators. In spite of almost two decades of effort around the world, steam generator problems are still responsible for a great deal of work by nuclear power plant operators, including ongoing inspection, repairs, cleaning and increasingly, replacement of the component entirely. In Ontario Hydro Nuclear, we have undergone the same pattern as much of the rest of the industry, albeit at a slightly displaced schedule. In the first conference of this series in 1990, we reported that our large fleet of nuclear steam generators had operated for almost two decades with relatively few steam generator problems. As a consequence, we had paid relatively little attention to them throughout this period. During this same time, the rest of the PWR community had already experienced major steam generator degradation and was devoting considerable attention to monitoring the health of their steam generators. Many plants were upgrading their inspection programs, and changing chemistry and other plant conditions that could improve the situation.

By the next conference, four years later in 1994, Ontario Hydro's experience had suffered a rapid reversal. We had encountered major problems at our Bruce A plant with stress corrosion cracking in the U-bend; at our Pickering plant with pitting; and at our Bruce B plant with fretting in the U-bend. In effect, our experience had caught up very rapidly with that of the rest of the world in the previous decade. In response, Ontario Hydro Nuclear undertook corrective maintenance activities at all of its plants: enhanced inspection, chemical cleaning to remove sludge loadings, installation of anti-vibration bars to control fretting and fatigue. And, for a time, the results in our stations indicated that the programs we had undertaken were starting to pay off. Our forced outage rate due to steam generators declined steadily and reached a very low level in 1996. We did not suffer any leaker outages in 1996, and it looked like we were winning on steam generators. Even though we still had a lot of work to carry out, the reliability of the components was falling into line with the targets that we had set for ourselves. It was starting to look as if we had our steam generator situation finally under control. Well, ladies and gentlemen, I tell you now that the steam generators at Ontario Hydro Nuclear had a few more surprises to spring on us. 1997 was a disastrous year for us. At our Bruce A plant, we were overwhelmed by top-of-tubesheet circumferential cracking at both the OD and the ID. This attack, particularly the

PWSCC on the ID, was something which we had not expected. We were so busy looking at the U-bend region that the top-of-tubesheet surprised us. In retrospect we should not have been caught off guard. A colleague of mine in Ontario Hydro Nuclear from Pickering had a favourite expression whenever we were trying to understand what our inspection results meant and what we should do about them. He would say, "*the boilers are talking to us.*" (We Canadians call steam generators "boilers" - probably a throw-back to our fossil origins.) "*The boilers are talking to us, we need to listen to them.*" A romanticized concept perhaps but one that has some validity. In the case of Bruce A, the boilers had talked to us, at least whispered to us a few years earlier that there was degradation at the top of tubesheet. But we had been so focused on managing the degradation that we already knew about that we failed to heed the warning that the boilers had whispered in our ear. As a result, we were surprised and overwhelmed when the top-of-tubesheet cracking problem came into full view in the spring of '97. And the surprises aren't finished yet. Since then, we have encountered new forms of degradation, fretting at Bruce B in the pre-heaters, fretting at Darlington, steam separator thinning at Bruce B, broached hole erosion at Pickering. And again we're feeling overwhelmed by the unexpected findings.

This leads me to the message I want to leave with you. Ontario Hydro recognized in 1996 that its nuclear program was underperforming. As a result, it commissioned a major study of what would be required to put the corporation's nuclear program back into a position of being among the top performers. This study, the so-called IIPA, identified weaknesses in all aspects of the Ontario Hydro nuclear program, including deficiencies in its management of steam generator issues. A symptom of these weaknesses was that we were constantly in a reactive mode, fighting fires as they arose but never really getting ahead of the problem.

At the same time, the electricity sector in Ontario is undergoing rapid change. We are moving towards a deregulated marketplace with competition in the generation sector.

For a utility to be successful in a competitive environment, it must be able to operate its facilities in a safe, reliable manner. We cannot expect to be competitive if we are constantly coping with surprises. In fact, this is one of the main tenets of effective life cycle management - avoiding surprises! We may have to accept that components degrade with time and need to be maintained or replaced. As long as this happens in a predictable fashion, it can be managed. But if we are going to be continuously surprised when events arise, it will be difficult to survive in a competitive environment that values predictability and reliability. Our job, if we are to be successful, will be to learn enough about our steam generators to start to reduce the number of times we're surprised.

Part of the answer is enhanced inspection. One of the improvement initiatives we're undertaking is to enhance the amount of routine inspection we are going to carry out on our steam generators. In effect, we want to "listen to the boilers" much more attentively than before. Another part of the answer is more effective life cycle management. This is where conferences such as this one play an important role.

By sharing our operating experiences and technology developments with each other, we all gain a better understanding of what can happen to our steam generators and what we can do about it.

And that understanding is at the heart of the life cycle management that we all need to carry out in order to be able to operate our steam generators safely, reliably and competitively.

I hope that you all have a productive few days here, and that you gain new insights that you can put to use to help your companies thrive in the increasingly competitive environment that surrounds us all.

Thank you for your attention, and have an interesting conference.