Steam Generators for CANDU

Engineering Memoirs by John M. Dyke

John Dyke is a retired engineer from Babcock & Wilcox Canada Ltd. (Cambridge, Ontario), the company that manufactures most CANDU steam generators, as well as supplying the PWR and fossil-fuel market. Mr. Dyke was personally involved in the early assessments and design decisions that lead to current CANDU steam generator technology. He has written the following summary of those important days.

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In the beginning, I worked for Dominion Bridge. While there, Atomic Energy Canada Limited (AECL) offered courses on nuclear power to get industry involved in the new technology. I was elected to attend. We were immersed in things Nuclear.

Following this, AECL set up a boiler design competition amongst Canadian boiler companies to design a boiler unique to the Heavy Water Reactor (HWR) vs. the US Pressurized (light) Water Reactor (PWR).

Specifications were issued for the design competition and we all began in earnest to design boilers of our own making, with reviews and input from time to time by AECL. Dominion Bridge Co. Ltd. (DB) reasoned that Babcock Wilcox Canada Ltd. (BWC), Combustion Engineering Ltd. (CE), and Foster Wheeler Ltd. (FW) had US designs to back them up, and that it would be wasting time for DB to re-invent the wheel by offering a natural circulation boiler design. Instead, since they had considerable expertise in designing forced-circulation boilers, they chose to investigate this alternative - if only to eliminate it from consideration.

The competition was won by CE. AECL subsequently modified this design and issued specs for Douglas Point, a 200 MW plant, the first commercial Nuclear Station in Canada. Montreal Locomotive Works Co. Ltd . (MLW) won the order to build the boilers.

I joined BWC in 1964 to become project engineer for the 500MW fossil-fired plants that Ontario Hydro (OH) was going to build for the future expansion of the province. In 1967 OH made the decision to drop fossil fuels in favour of uranium; Ontario Hydro h ad gone Nuclear, and I was out of a career! However, as I had the AECL course at Chalk River and had done some nuclear work at DB, I was elected to head up the newly formed, nuclear section of BWC.

I began by reviewing Chalk River and World Wide Nuclear Steam Generators data. In addition, since BWC were sales agents for YUBA, a USA Heat Exchanger manufacturer, we were privy to their design data. I had access to a very large data base of information . This composed of: Feed Water Heaters design data, criteria for tube failures, allowable fluid velocities, water chemistry effects, heat treating of tubing, manufacturing processes, and tube failures in nuclear steam generators world-wide from AECL Chalk River publications and the US BW Research

Labs at Alliance, Ohio.

Specifications for Pickering-A, AECL's pro-rated Douglas Point design, were finally issued to OH. BWC management discussed this turn of events with their US management, as to what support we could expect, etc. The US parent said that, where possible, they would support BWC with the US PWR technology and US Naval experience. The US PWR Steam generators, I knew, would not evaluate favourably in the CANDU system which uses heavy water (the US system does not). At the proposal review meeting I stated my ca se, and the committee gave instructions to design a boiler suitable to the Canadian Heavy Water Cycle.

Thus, I had to process two bids; one to specifications as required by the bidding rules and the alternate design from scratch.. As it happened, the support we received from the US during the bidding process was a photograph of lattice bars, a tube support system which eventually played a very important role in the success of CANDU boilers. A photograph was the only type of document which could evade Adm. Rickover's (US NAVY) security control system; drawings could not be released as they were marked secret and tightly controlled.

We proceeded on our own to design a boiler to meet the requirements. As it happened, due to my stint at the Royal Canadian Navy Research Establishment (NRE) in Halifax, NS, I was able to compare all systems in use by others to US Navy lattice bars tube support systems - which were suggested to BWC as a method of supporting the tubes for Pickering-A (we were not told that these had failed in marine service). Exposure to this experimental work enable me to make a valid judgement to use lattice bars as an acceptable method of supporting the tubes.

While at NRE I had designed a device to control the acoustic decoy, which had vibrating bars to attract the German Acoustic Torpedo away from a target ship. The control allowed the bars, on demand, to vibrate on or off at will, which made the Cat a useful tactical device. The CAT GEAR MK III decoy employed all of the same principles (except only as single phase flow) with the flow of water impinging on two steel bars which made them vibrate (or not). This phenomenon was basically the same as what the tubes experienced in the support system designed for the US Navy Vertical Boilers (but with two-phase flow - a mixture of steam and saturated water). As it turned out, Lattice Bar failure in submarine service was a result of damage caused by depth-charge explosions.

I realized that this tube support system provided excellent geometry to avoid chemical attack of the tubes and that the system could be designed so that the tubes would not vibrate. It is also interesting to note that BWC designed the tube bundle to include an internal "economizer" section, whose characteristics were the same as feedwater heaters. Since BWC had complete design data from YUBA, the arrangement included their proven design details and gave excellent service life. The inclusion of an intern al economizer reduced the heating surface significantly and thus the cost of heavy water in the CANDU system. In addition, because it improved the Log Mean Temperature Difference (LMTD) it raised the steam pressure of the cycle and improved its efficiency.

Having received the order for the Pickering-A boilers, BWC entered the nuclear market in earnest. In fact, BWC built all but one set of boilers for Canada's CANDU plants, up to 1980 (Pickering-A&B, Bruce-A&B, Darlington, Gentilly-2, and Pt. Lepreau).

As nuclear plants came into service world wide, failures were monitored very carefully throughout the world. Since nuclear boilers were so large only commercial installations were a suitable test bed for proof of their adequacy. Most failures in large capacity heat exchangers were due to very high velocities, dry out, fretting, poor water chemistry, and improperly designed tube support systems. All laboratories in North America researched the problems in depth and at top priority - particularly fretting failures. The conclusions of the latter experiments were, in general, misinterpreted. It should be noted that the Canadian Electrical Association published an article by this author in 1970 stating that tube supports employing drilled holes with tight clearances was a poor choice, and that such an arrangement would lead to a short life of the boilers. Thus, because of the research published to the contrary, improved lattice bars were not approved for Bruce-A and beyond, until Darlington. Since the Pickering-A lattice bars were too weak, they did not stand up to handling in the shop or in the field. Some of the bars were bent and this caused doubts that they would give adequate service, and OH/AECL abandon their use.

This change from lattice bars to broached hole plates was made after the contract for Bruce-A was finally awarded and the changes had to be made quickly. As a result, mistakes were made. The change resulted in a mismatch between the flexibility of the lattice bars and the rigid broached-hole plates. The temperatures gradients, as a result of the heat treating process, caused bending of the internals. Thus, the tubes were damaged.

The decision was made that all the tubes had to be replaced in all generators in the shop and in the field. This was a very expensive fix, and serious delays occurred. This turn of events caused a major shake-up at BWC and management and staff were imported from BW (US) to handle the work load. Since I could not agree with the conclusions of the design review committee's findings of how the boilers should be rebuilt, I took early retirement in 1980. The fixes for the rebuild program generally followed the US design features and manufacturing processes of the very expensive Once-Through Steam Generator (OTSG).

As these rebuilt boilers matured, service results showed that the life of the boilers was shortened and concerns arose as to the suitability of the design employing broached hole plates. The new (Canadian) management which followed believed a change in design was necessary for the next generation of boilers on the drawing boards. McMaster University (Hamilton, Ont.) was hired to run an experiment to prove that flat bar U-bend supports would work (the writer took a part in making this happen). The experimental results also convinced OH that a change was necessary . This small change would have eliminated the damage to the tubes in the first place, without any other significant changes. The experiment also showed the value of lattice bars, which McMaster reported but no further research was done.

In contrast, the Pickering A boilers (with suspect lattice bars) under the worst water chemistry treatment control had one of the best in service records of any boilers in North America[*] - evidence that improved lattice bars would work. With this information and the results of the McMaster experiment at hand, it was possible to convince OH to reverse their decision, and improved lattice bars were fitted to Darlington. Also, with this turn of events BWC entered the USA replacement steam generator market, and was able to offer a proven record and the best-supported guarantee. The resulting orders kept the shops busy for over 10 years.

As mentioned above I took early retirement in 1980. I spent a year at AECL Sheridan Park and then returned to working on fossil plants, and my own consulting business, for about five years. In this capacity I did some nuclear work .

In the early 1990's a consortium of power utilities sued Westinghouse (W) for improperly designed units . As a result, Westinghouse subpoenaed BW to show that they, Westinghouse, were no worse than any other boiler manufacturers. BWC, being a subsidiary, had to support the parent. This was thought to be many man-years of work.. BWC hired the writer to do the work for them and in about six months time, based upon my research of the files "for disclosure", I was asked to prepare a White Paper to summarize the findings to date. As a result of this report and the evidence presented Westinghouse agreed to settle out of court!

At this point in time I retired from "things nuclear", except to think about what happened and to write about the events for others to read as time passes.

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*KARACHI Pakistan - these boilers have a better record than Pickering-A

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