BOILER PLANT REPLACEMENT AND RETROFIT CASE STUDIES©

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1.0 CASE STUDY NO. 1 <u>HAMILTON CIVIC HOSPITALS - HENDERSON GENERAL DIVISION</u>

1.1 <u>Original Boiler Plant Description</u>

- The original Henderson Hospital boiler plant was constructed approximately sixty-four years ago and had been built directly into the face of the Niagara Escarpment. A busy city street, Mountain Park Avenue, crosses over the roof of this structure.

- The City of Hamilton was concerned about the stability on this face of the escarpment and several of the reinforced concrete roof beams were exhibiting spalled concrete and exposed, badly corroded reinforcing. In addition, cracks had developed in the concrete on the plant's lower floors

- The boiler plant was originally designed for a total capacity of 70,000 lb/hr of 125 psig saturated steam.

- At the time of the replacement feasibility study in December, 1993, the boiler plant contained:

  a) two (2) “A” type package watertube boilers manufactured by Leonard-Badenhouse and installed in 1951, each rated at 20,000 lb/hr.

  b) one (1) “O” type package water tube boiler manufactured by John Inglis Co., installed in 1963, and rated at 30,000 lb/hr.

- The boiler controls were pneumatic-based. Spare part to maintain the controls were becoming increasingly hard to obtain. In some cases, used parts from other installations had been installed.

- The boiler plant contained steam flow meters using Le Doux Bell technology. These meters held 15 to 18 pounds of mercury, which is now classified as a hazardous waste.

- In 1986, the boiler had been retrofitted with dual fuel (natural gas and No. 2 oil) burners. However, at the time of the replacement study, the oil firing capability of the boilers was considered to be at best 60% of boiler capacity. The boilers were also only considered to be capable of 85% of rated output on natural gas. Based on testing in 1990, the efficiency of Boilers 1 and 2 was estimated at 76% on natural gas.

1.2 <u>New Boiler Plant</u>

- Based upon a study of the existing hospital steam load profiles, plus projected expansion, Gryphon estimated a maximum hourly demand of 52,000 lb/hr of steam in the winter and 15,000 lb/hr in the summer.

- The Ministry of Health (MOH) requires that upon failure of one boiler, the remaining boiler or boilers must be capable of meeting 70% of maximum demand.

- It was decided to utilize three boilers; one each of 15,000, 25,000 and 30,000 lb/hr capacity. This would require only the smallest boiler to operate in order to meet the summer demand while ensuring the MOH requirement would be met even if the largest boiler failed.

- The client did not want to consider the use of either coil-tube or fire-tube boilers.

- The client selected a location for the new boilerhouse that was situated in an enclosed courtyard which formed a quadrangle and which was surrounded on all sides by existing buildings. This made access to the site for construction and materials laydown very difficult.

- The new boilerhouse was designed as a steel frame structure, with concrete floors and brick walls, which were selected to blend in with adjacent existing structures. The brick walls also assisted in reducing noise transmission from the new boilerhouse to the surroundings.

- Three “D” type packaged water tube boilers were supplied by Nebraska Boiler Company. The boilers utilize a “finned tube” or “welded water wall” design that provides for a gastight furnace enclosure.

- The boiler pressure parts were completely assembled and mounted on a structural steel support frame. The burners and windboxes were shop-assembled to the boilers front walls but the burner throats, which are of refractory construction, were installed after the boilers had been set.

- Separate fin tube economizers were also supplied by the boiler manufacturer. These were installed on the mezzanine floor above the main operating level. The addition of economizers improved the boiler efficiency to about 82.4% on natural gas fuel and 86.4% on No. 2 fuel oil.

- The burners supplied with the boilers were Todd Combustion “LINFLO”, parallel flow, low excess air, low NOx burners. The burners are designed to operate with Induced Flue Gas Recirculation (IFGR), but this was not initially installed.

- The burners are dual fuel burners, namely natural gas and No. 2 fuel oil. Without flue gas recirculation, the burners are guaranteed to meet 0.10 lb/MMBTU or 80 ppmv on natural gas and 0.2 lb/MMBTU or 160 ppmv on No. 2 fuel oil. In the future, if emission limits change, the IFGR system would be commissioned, and then NOx emissions of 50% of the above numbers are guaranteed.

- Although it is normal with packaged burners and boilers to mount the fuel train to the front of the windbox, it was decided in this installation to mount the fuel trains on structural steel racks located at the side of the boilers. While this had a cost premium associated with it, the access to the burner front was dramatically improved.

- The breeching from the three boilers were discharged into one common, free standing stack. The stack is insulated and is 100 feet high and three feet in diameter.

- The deaerator is a spray type unit operating at a pressure of 5 psig. It is located on top of a horizontal storage tank that provides for 10 minutes of storage for full boilerhouse capacity.

- To provide redundancy in case of a pump failure and to attempt to match minimum pump flow requirements with the steam demand pattern, three 50% boiler feed pumps were supplied.

- A new condensate receiving tank of 1000 US gallon capacity was installed and piped in series with an existing receiver of the same capacity. Together, the two tanks provide for a condensate storage of 14 minutes at full boilerhouse output.

- Using similar reasoning as that employed for the boiler feed pumps, three 50% condensate return pumps were installed to forward condensate from the new receiver to the deaerator.

- Make-up water treatment consists of Strong Acid Cation (sodium zeolite) softening and chloride anion dealkalization. Source of make-up water is potable water.

- A new aboveground storage tank of 16,500 Imperial gallons (75,000 litres) was installed outside the new boilerhouse. The tank is remotely filled because its location precludes tanker access to permit direct filling. The tank is, therefore, equipped with an electronic overfill protection system that provides tank high level indication at the remote filling station.

- Adjacent to the oil storage tank is a new duplex pumping and straining set that forwards oil to the fuel oil supply header in the boilerhouse.

- Steam supply and condensate return piping exist and enter the northeast corner of the new boilerhouse and travel through a new section of underground service tunnel. The new tunnel section connects with the existing underground tunnel system. The new sections of steam and condensate piping tie into existing piping located in the previously constructed tunnels.

- The new boilerhouse was equipped with a Bailey “Infi 90” Distributed Control System (DCS) to handle all plant controls. Both the Burner Management Systems (BMS) and the combustion controls utilize the integrated digital control logic contained within the DCS. The combustion controls are fully metered, cross-limited controls.

- Each boiler was assigned a “Process Control Unit” (PCU) cabinet. Within each PCU redundant control modules were utilized. Each control module can supervise both the Burner Management and the Combustion Controls. The rest of the plant controls, such as drum level, furnace pressure, steam pressure, deaerator level, etc. are also handled in the control modules.

- The control room houses an operator interface unit, consisting of computer, CRT screen and keyboard, as well as a printer for hard copy. The CRT displays three boiler graphics with live information on all the process variables, as well as pop-ups for control purposes. The operator can control firing rates, change set points, start and stop feedwater pumps and FD fans, etc. The operator has complete control of the plant from the CRT display and the capability of printing shift logs and trends as required. In the control room area, there are also three (3) guarded pushbuttons used for tripping each boiler from this remote area.

2.0 CASE STUDY No. 2 CORNELL UNIVERSITY - BOILER PLANT REPLACEMENT and ADDITIONS TO CENTRAL UTILITIES STEAM PLANT

2.1 Existing Boiler Plant

- Cornell University has a large Central Heating Plant (CHP) which, at the time of the original feasibility study in early 1989, contained six boilers; two of which supplied steam to a 400 psig steam header system and four of which supplied steam to a 200 psig header system. The combined nameplate capacity of the higher pressure boilers was 280,000 lb/hr while that for the lower pressure boilers was 380,000 lb/hr for a total plant nameplate rating of 660,000 lb/hr.

- A cogeneration plant containing two backpressure steam turbine generators had been established in a building adjacent to the CHP. Steam turbine/generator TG-1 has a throttle flow of 75,000 lb/hr of steam at 400 psig and 600 deg. F with an electrical output of 1810 kW, while steam turbine/generator TG-2 has a throttle flow of 180,000 lb/hr with an electrical output of 5778 kW.

- All heating steam supplied by the CHP to the campus distribution system comes from a nominal 100 psig steam header system. The two steam turbine generators exhaust to this header. A number of turbine drives for boiler feedwater pumps and existing boiler fans also discharge to the 100 psig export steam header.

- Two of the boilers numbered 6 and 7 respectively which supplied steam to the 200 psig steam header system and which were both rated at 100,000 lb/hr had developed serious pressure part corrosion and the client had decided that to assure reliable steam supply, they should be replaced.

- At the time of the replacement feasibility study, peak steam demand was approximately 375,000 lb/hr (winter heating season) and this was expected to increase to approximately 450,000 lb/hr, within the lifetime of the two new boilers. Additionally, the CHP had an internal auxiliary steam usage of up to 50,000 lb/hr.

2.2 Modified Boiler Plant

- It was decided that the two new boilers would be rated for 110,000 lb/hr each of steam at 400 psig and 650 deg. F. The higher final steam temperature (i.e. 650 deg. F vs. 600 deg. F) than that produced from the existing boilers supplying the 400 psig header system was selected to improve dryness at the turbine exhaust of the two steam turbine generators. This required ensuring that the existing piping system was suitable for the higher temperature.

- With the two new boilers generating steam at the higher pressure, this left only two boilers to produce steam at the 200 psig level. These two boilers were then delegated as backup to the boilers generating steam at 400 psig.

- The existing boiler feed pumps for the 200 psig boilers were removed and replaced by a new steam turbine driven feed pump that could supply the feedwater header for the 400 psig boilers. This resulted in a feedwater system consisting of two steam turbine driven and one electric motor driven feed pump, all capable of supplying water to the higher pressure boilers.

- The feedwater pump control logic was modified so that the feedwater header pressure setpoint is generated from the boiler requiring the highest feedwater pressure.

- New feedwater regulating valves were installed on the two lower pressure (backup) boilers to accommodate the increased pressure drop that would now be required.

- The two new boilers were of the packaged, water tube "D" type and were manufactured by Foster Wheeler Limited. The boilers they replaced were of the "O" type and it is thought that the new "D" type boilers will not be as susceptible to the corrosion that the existing "O" type boilers had suffered.

- As were the boilers they replaced, the new boilers are equipped to fire either natural gas or No. 6 oil. The burners were supplied by John Zink Company and are of the register type. They are designed to accept future flue gas recirculation.

- The existing stack for the original boilers No. 6 and 7 was reused.

- A new 400 to 100 psig pressure reducing/desuperheating station was installed to supplement an existing station. These stations are normally only used in the case of a steam turbine trip. The campus heating demand only exceeds the steam turbine/generator and steam turbine drive steam demand for short durations during the winter heating season.

- The existing boilerhouse required extensive modifications, which included demolishing portions of existing exterior walls and extending the building approximately 12 feet to the east. The new corner of the building has a full basement and operating floor, as well as economizer and fan floors located above the operating floor.

3.0 RETROFIT POTENTIAL

- From a technical viewpoint, almost any retrofit that can be envisioned is possible. Whether the retrofit is feasible will depend more on other factors such as economics, i.e. cost of a new boiler versus a retrofit, the estimated remaining service life of the boiler, project schedule requirements and ability of the retrofitted boiler to meet process requirements.

- In addition to improving boiler efficiency, today there are two other major reasons behind many of the retrofits that are carried out, namely, the requirement to meet new, more stringent emission regulations and a desire to improve flexibility of fuel supply.

- Examples of retrofits that have been carried out on boilers include:

  - Burner replacements; in some cases requiring modification or complete replacement of the windbox or windboxes.

  - Removal of grates and modification of lower furnace waterwalls on boilers firing coal, bark or other solid fuels.

  - Installation or modification of overfire air systems.

  - Installation of additional sootblowers due to a change in fuel or degradation of fuel quality.

  - Modification of pressure parts (heat absorbing surfaces) to improve efficiency or correct performance shortfalls.

  - There have even been cases where the furnace height of large field erected, top supported boilers has been increased. This required engineering of temporary support structures for the steam drum and upper portion of the furnace.