Vent Mizer Analysis for Queen’s Physical Plant Services

APSC 400 T.E.A.M. PROJECT
April 16th 2004
Submitted to:
Mr. Eric Neuman,
Queen’s Physical Plant Services

Submitted by:
Andrew Follwell
Luke Follwell
Steve Orchard
Rob Short
Acknowledgments

Our group would like to acknowledge the support and advice of our TEAM advisor Geoff Clarkson. His wisdom and knowledge of the subject at hand was a great help to the success of our project. Without his guidance we would not have received these results. Also we would like to thank Graham Robertson and Eric Neuman for providing us with the required information about the Queen’s University Central Heating Plant. Without these numbers our analysis of the potential project would not have been possible. Other thanks go to Mike Packham of the Hamilton General Hospital for allowing us to view the Vent Mizer in action and allow us to use their collected information for our results.

Final thanks go to our project supervisors, Annette Bergeron, Barry Jackson and Dale Dilamarter for their continued support and suggestions throughout the course of this project. Their continued guidance kept us on the path to success.
Executive Summary

Our group was assigned the task to analyze the possible effects of the application of the Vent Mizer (by RCD Engineering) to the Queen’s University Central Heating Plant. This device recycles the steam which is normally expelled into the atmosphere. We found that there is no significant evidence to support that there is any damage done to the deaerator. The engineers at RCD have gone through no lengths to substantiate this claim and appear to have a limited understanding of heating plants. The proposed savings suggested by RCD have been embellished due to inaccurate feed water temperatures. Although the one Vent Mizer in operation appears to be working there is very little information available on the actual savings that this device has created. Without further research into the operational unit it is our suggestion that the Vent Mizer not be considered for installation at the Queen’s University Central Heating Plant.
# Table of Contents

**ACKNOWLEDGMENTS** .......................................................................................................................... 1

**EXECUTIVE SUMMARY** ....................................................................................................................... 11

**TABLE OF CONTENTS** ............................................................................................................................ III

1.0 INTRODUCTION ...................................................................................................................................... 1

1.1 PROJECT BACKGROUND .......................................................................................................................... 1
1.2 PROJECT MAJOR CONCERNS .................................................................................................................. 1
1.3 KEY T.E.A.M. PERSONNEL ..................................................................................................................... 2
1.4 TEAM GROUND RULES ........................................................................................................................... 2
1.5 TEAM BUDGET ......................................................................................................................................... 3
1.6 PROJECT TIMELINE ................................................................................................................................ 3

2.0 VENT MIZER .......................................................................................................................................... 5

2.1 BACKGROUND INFORMATION .............................................................................................................. 5
2.2 HEATING PLANT CYCLE ......................................................................................................................... 6
2.3 TECHNOLOGY .......................................................................................................................................... 6
2.4 WORKING ANALYSIS .............................................................................................................................. 6
2.5 BENEFITS ............................................................................................................................................... 7
2.6 PHYSICAL PLANT SERVICES APPLICATION .......................................................................................... 7

3.0 DEAERATOR ........................................................................................................................................... 10

3.1 BACKGROUND INFORMATION ............................................................................................................. 10
3.2 DEAERATION PROCEDURE .................................................................................................................... 11
3.3 ADDITIONAL INFORMATION ................................................................................................................... 12
3.4 SUMMARY ............................................................................................................................................. 13

4.0 PHYSICAL PLANT SERVICES – CENTRAL HEATING PLANT ............................................................... 14

4.1 PHYSICAL PLANT SERVICES ................................................................................................................ 14
4.2 CENTRAL HEATING PLANT OVERVIEW .............................................................................................. 14
   4.2.1 Plant History ..................................................................................................................................... 14
   4.2.2 Plant Operating Specifications ......................................................................................................... 14
   4.2.3 Plant Equipment ............................................................................................................................... 15
4.3 PLANT OPERATION ................................................................................................................................. 16

5.0 ACTIVE VENT MIZER ANALYSIS – HAMILTON GENERAL HOSPITAL ............................................. 17

5.1 BACKGROUND ....................................................................................................................................... 17
5.2 OPERATING CONDITIONS / TEST PREPARATION .............................................................................. 18
5.3 TEST CONDITION ................................................................................................................................... 18
   5.3.1 Test Result 1, 2, 3 & 4 ......................................................................................................................... 18
   5.3.2 Test result 5, 6 & 7 ............................................................................................................................ 18
   5.3.3 Test result 8 ...................................................................................................................................... 18
   5.3.4 Test result 9 ...................................................................................................................................... 19
   5.3.5 Test result 10 ................................................................................................................................... 19
5.4 DISCUSSION .......................................................................................................................................... 19
5.5 RECOMMENDATION & FOLLOW-UP ACTION ...................................................................................... 20
5.6 PROBLEMS .......................................................................................................................................... 20
5.7 CONCLUSION ........................................................................................................................................ 21

6.0 THERMODYNAMIC MODEL ANALYSIS ............................................................................................... 22

6.1 THERMODYNAMIC RESULTS ............................................................................................................... 22

7.0 ALTERNATIVES TO VENT MIZER ....................................................................................................... 23

7.1 FLU-ACE® ............................................................................................................................................. 23
7.2 HEAT EXCHANGERS ............................................................................................................................... 25
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.3 CONCERNS</td>
<td>26</td>
</tr>
<tr>
<td>8.0 CONCLUSIONS AND RECOMMENDATIONS</td>
<td>28</td>
</tr>
<tr>
<td>8.1 VENT MIZER CONCLUSIONS</td>
<td>28</td>
</tr>
<tr>
<td>8.2 RECOMMENDATIONS</td>
<td>31</td>
</tr>
<tr>
<td>9.0 REFERENCES</td>
<td>33</td>
</tr>
<tr>
<td>APPENDIX A – MEETING MINUTES</td>
<td>34</td>
</tr>
<tr>
<td>APPENDIX B – IMPORTANT DOCUMENTS</td>
<td>42</td>
</tr>
<tr>
<td>B1 – WAIVER OF LIABILITY</td>
<td>42</td>
</tr>
<tr>
<td>B2 – PROJECT PROPOSAL</td>
<td>43</td>
</tr>
<tr>
<td>APPENDIX C – ACTUAL EXPENSES</td>
<td>45</td>
</tr>
<tr>
<td>APPENDIX D – PROPOSED TIMELINE GANTT CHART</td>
<td>46</td>
</tr>
<tr>
<td>APPENDIX E - DEAERATOR COMPONENT DESCRIPTION</td>
<td>47</td>
</tr>
<tr>
<td>APPENDIX F - DEAERATOR GENERAL NOTES AND VESSEL DATA</td>
<td>48</td>
</tr>
<tr>
<td>APPENDIX G - QUEEN’S UNIVERSITY HEATING PLANT SCHEMATIC</td>
<td>50</td>
</tr>
<tr>
<td>APPENDIX H - CENTRAL HEATING PLANT IMAGES</td>
<td>51</td>
</tr>
<tr>
<td>H1 – STEAM EXHAUST IMAGES</td>
<td>51</td>
</tr>
<tr>
<td>H2 – PUMP ROOM IMAGES</td>
<td>52</td>
</tr>
<tr>
<td>APPENDIX I - SAMPLE OPERATING TABLES FOR QUEEN’S CHP</td>
<td>53</td>
</tr>
<tr>
<td>I1 – STEAM GENERATION AND WATER CONSUMPTION FOR 2002-2003</td>
<td>53</td>
</tr>
<tr>
<td>I2 – DETAILED STEAM CONSUMPTION AND PRODUCTION FROM APRIL 2003</td>
<td>54</td>
</tr>
<tr>
<td>APPENDIX J - VENT MIZER IMAGES AT HAMILTON GENERAL</td>
<td>55</td>
</tr>
<tr>
<td>APPENDIX K - QUEEN’S UNIVERSITY DEAERATOR IMAGES</td>
<td>56</td>
</tr>
<tr>
<td>APPENDIX L – PRO II OUTPUT</td>
<td>57</td>
</tr>
</tbody>
</table>
1.0 Introduction

1.1 Project Background

The task of our group was to analyze the possible effects of the application of the Vent Mizer (develop by RCD Engineering) to the Queen’s University Central Heating Plant. This device recycles the steam which is normally expelled into the atmosphere. It cleans the steam of its high oxygen content and returns this “partially cleaned steam” to the deaerator. RCD Engineering claims to be able to reduce the amount of expelled steam by as much as 90%. It is submitted by RCD Engineering that this reduction in expelled steam could result in an annual savings of approximately $90,000 for Queen’s University. There was much speculation at Queen’s that were involved with this project as to whether or not the project was too good to be true. Our task is to determine if it is in the interest of Queen’s University to install this device.

1.2 Project Major Concerns

Based on the original discussion with Mr. Eric Neuman of Physical Plant Services at Queen’s University and from the material he provided to our group, we have determined that there are a few major areas of concern that are most important:

1. That the Vent Mizer does not clean the steam thoroughly enough of oxygen in order to safely return the condensate to the deaerator. If there is too much dissolved oxygen in the returned water, the inside of the deaerator will become damaged from oxygen pitting.

2. That the actual reduction of steam exhausted and the amount of money saved has been embellished by the RCD Engineers, and

3. How the Vent Mizer performs in a real life trial situation.

These concerns will be the main focus of our project. Our goal was to collect enough information to either decide that these concerns are without warrant or to decide that these concerns are real and can not be overlooked.
1.3 Key T.E.A.M. Personnel

Our group consists of four upper year Queen’s students, 2 civil engineers, a mechanical engineer and a commerce student. Each of the group members was assigned specific roles in the project group. The members and their roles are:

Luke Follwell (Civil) – Logistics, Visual Communications Manager

Steve Orchard (Mechanical) – Client Contact, Written Communication Manager

Andrew Follwell (Commerce) – Treasurer, Documentation Manager

Rob Short (Civil) – Group Coordinator

Our client is Physical Plant Services (PPS) at Queen’s University and our contact there is Eric Neuman (engineer) and Graham Robertson (Heating plant chief of operations). Eric is our client representative who provided us with the information necessary to begin this project. Graham allowed us to tour the central heating plant and provided us with critical heating information necessary for thermodynamic analysis.

Our project supervisors are Annette Bergeron, Barry Jackson and Dale Dilamarter. They oversaw our progress during the stages of the project in order to ensure that we were on the right path towards our goals. Also our technical advisor was Geoff Clarkson a PPS specialist. He provided useful insight in ideas for further research on the Vent Mizer and offered his expert opinions about the product.

1.4 Team Ground Rules

Our group established these ground rules in order for the project to proceed efficiently and without problem.

1. Meetings will be scheduled to accommodate everyone’s schedules; therefore all members should be present at all meetings.
2. Team members will be punctual for all functions, especially for meetings with the client or outside companies.
3. Tasks will be distributed equally.
4. Each team member must fulfill the duties designated for his role to the best of his ability.
5. Team members will not discuss confidential information with any external parties.
6. No team member will incur any unnecessary expenses.

Every meeting that our group was involved in, minutes were recorded and are shown in Appendix A and all other important documents are shown in Appendix B.

1.5 Team Budget

We also discussed and proposed a realistic budget that we will be able to adhere to. We discussed what trips we will need to take and what printing and supply costs we will need to incur. The budget is shown below (figure 1.1).

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telephone Calls</td>
<td>$25</td>
<td>(10 minutes/week for 6 weeks)</td>
</tr>
<tr>
<td>Travel Expenses</td>
<td>$200</td>
<td>(meals on route)</td>
</tr>
<tr>
<td>Car Rental</td>
<td>$250</td>
<td>(1 trip to Hamilton)</td>
</tr>
<tr>
<td>Hotel</td>
<td>$125</td>
<td>(1 night in Hamilton)</td>
</tr>
<tr>
<td>Copy Cards</td>
<td>$50</td>
<td></td>
</tr>
<tr>
<td>Binders</td>
<td>$25</td>
<td></td>
</tr>
<tr>
<td>Printing Final Report</td>
<td>$250</td>
<td>(copies, colour covers, binding, folders)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$925</strong></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1.1 – Proposed Budget for the completion of the project

The actual budget incurred during the project was very close to that predicted and is shown in Appendix C.

1.6 Project Timeline

At the beginning of the project a timeline was proposed which set key dates for accomplishing major goals. This time line is shown in Table 1.1 below and in Gantt chart form in Appendix D. The timeline served as a good basis of productivity and to make sure that we did not fall behind of our deadlines.
### Table 1.1 – Proposed Timeline for Project

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Location</th>
<th>Issues</th>
</tr>
</thead>
</table>
| Tues January 13th   | 2:30 pm | Rideau Building | • Tour of building  
• Explanation of processes |
| Wed January 14th    | 3:00 pm | Dupuis 427    | • 1st Progress Reports (letter of proposal, plan of action, ground rules, and roles) |
| Mon January 26th    | 2:30 pm | Dupuis 427    | • Meeting                                                               |
| Wed February 4th    | 3:00 pm | Dupuis 427    | • Meeting                                                               |
| Thurs February 5th  | 1:00 pm | Ancaster      | • Meet with RCD Engineering                                              |
| Fri February 6th    | 9:00 am | Hamilton      | • Tour of Hospital                                                      |
| Mon February 23rd   | 3:00 pm | Dupuis 427    | • 2nd Progress Report (Draft)                                           |
| Wed March 3rd       | 3:00 pm | Dupuis 427    | • Meeting                                                               |
| Wed March 10th      | 3:00 pm | Dupuis 427    | • 3rd Progress Report (Draft)                                           |
| Wed March 17th      | 2:30 pm | Nicol Hall 321 | • MMO Presentation                                                      |
| Wed March 24th      | 3:00 pm | Dupuis 427    | • Client Presentation Rehearsals                                         |
| April               | TBD   | Kingston      | • Client Presentation                                                   |
2.0 Vent Mizer

2.1 Background Information

The specification of dissolved oxygen level from deaerator outlet water feeding steam boiler is usually less than 10 parts per billion (PPB). This tight specification is set for the deaerator alone, without relying on oxygen scavenger like sodium sulfite addition. Steam boiler deaerators are usually designed to provide around 5 PPB of dissolved oxygen. Most deaerator designs are equipped with spray nozzle and conical baffle construction in the deaerator head. Live steam is supplied to maintain operating pressure in the deaerator vessel. Other deaerator designs may be equipped with a packed column instead of the baffles, but all are designed to encourage dissolved oxygen to escape from the feed water. All deaerators operate under the concept of close to a single stage of mass transfer area, or less, with design emphasis mainly to handle feed rate changes without having to go off specification on the less than 10 PPB oxygen in the deaerator outlet water stream. Naturally, all deaerators have a purge stream that permits the dissolved oxygen in the feed to leave the deaerator.

The Nominal Vent Rate (NVR) generally regarded as an acceptable operating loss, is around half to one percent of the deaerator load. This number actually depends on a number of factors like design efficiency, flow rate to surface area, state of maintenance and most important of all, the net oxygen loading to the deaerator. A rule of thumb would be around one percent purge for every 20% to 25% of fresh make-up flow. For example, at 10% makeup (90% condensate recycled) the purge rate will be around half of one percent. For the extreme case of a once through system (all fresh makeup) the purge could be around 4% to 5% of the load. So, a nominal purge rate around one percent of boiler load is a typical rate. For a medium size boiler of 100,000 lb/hr, annual steam purge is around the 8 million lb mark.

A design has been granted a patent for virtually eliminating the generally accepted operating loss. The design essentially further concentrates the purge stream by factors of ten to twenty, or higher, to drastically lower the amount of steam required to accompany the purging of oxygen and other gases like carbon dioxide, without compromising the operation of the deaerator. The novel design helps increase existing deaerator capacity while retaining valuable heat and condensate.
2.2 Heating Plant Cycle

Steam boiler systems have long been used to supply heat to residential, industrial, commercial and other energy users. This movement of heat energy from the boiler, which supplies the heat energy, to the consumer, which receives the heat energy, is accomplished by condensation. The latent heat in the steam is dropped off to the consumer when the steam is condensed to form water, sometimes called the condensate.

Typically, condensate is returned to the boiler and heat energy is added again to boil up the condensate to make steam for re-use. This cycling of water as a heat energy carrier is called a process loop. If all the condensate streams return back to the boiler because nothing escapes the system, then water topping up is not needed. The process is a closed loop process. Some water or steam can escape from the loop and makeup is necessary in order to maintain the water inventory. In the extreme case where no condensate is returned to the boiler, the process becomes a once through system and makeup water rate matches the steam flow rate.

Since makeup water contains considerable amounts of dissolved oxygen, corrosion becomes a critical reliability concern because high heat intensity at the boiler tubes accelerates the oxidation process. Therefore, feed water to the boiler must be made oxygen free. Generally the higher the makeup water, the higher the dissolved oxygen loading.

2.3 Technology

The Vent Mizer is a patented technology invented as a result of in depth knowledge of steam boiler operation, chemical plants and oil refinery separation technology and innovative thinking. This invention provides the unique technology to selectively remove the unwanted dissolved gases like oxygen and carbon dioxide in the deaerator purge stream. This high selectivity almost completely recovers the steam portion in the purge by concentrating the unwanted gases as it passes through the Vent Mizer.

2.4 Working Analysis

The vent steam from the deaerator is fed into the bottom part of the column and about 10% of the makeup water is fed into the top part. The rising steam strips O₂ from the water, and the water in turn quenches the steam. Oxygen and carbon dioxide stay in the vapor phase and are vented with a small amount of steam from the top of the column, while water is drained as the condensate and returned to the deaerator. About 95% of the steam is recovered as
condensate. Samples of the condensate can be taken before returning to the deaerator to ensure that the strict oxygen levels are met. This can be done to guarantee that the return condensate will not corrode the very expensive and crucial deaerator. See figure 2.1 for schematic drawing of Vent Mizer.

![Figure 2.1 - Vent Mizer Schematic](image)

2.5 Benefits

The difference between pre and post Vent Mizer installation is a twenty to hundred fold reduction of the purge stream. This almost non-noticeable purge stream contains all the unwanted gases from the deaerator purge. Other benefits include increased deaerator capacity, less fresh makeup water, lower water treatment costs, and higher reliability of corrosion prevention. Installation is trouble free, fast, inexpensive and can be done on line.

2.6 Physical Plant Services Application

The objective is to reduce the current vent rate from 1500 lb/hr to 100 lb/hr; the savings are netting 1400 lb/hr. When using a cost of $8.50/1000lb steam at 8000 hours per year to come up with the monthly savings shown in Table 2.1. The installation of the VM-5, which is listed at
$72,000 CDN, would be around $15,000 or in terms of savings, 2 months worth of recoverable vented steam at 1400 lb/hr. The payout period would begin 3 months after the installation process allowing money to be paid to the contractors for the installation. The projected savings for a typical month would be $7,933. Queen’s Physical Plant Services (PPS) would share this amount with RCD for the first 3 years. Payouts to RCD would be 40% of the total savings for the 3-year period with month installments of approximately $3,173. Over the 3-year period Queen’s PPS would payout to RCD at total of $114,228. However over the same period Queen’s would see a savings of $174,533, and 5-years after installation the total savings would be $276,076.
Table 2.1 – Cash Flow Projection

<table>
<thead>
<tr>
<th>Note</th>
<th>Date</th>
<th>Pay #</th>
<th>Savings</th>
<th>Queen’s Pay Out</th>
<th>Queen’s Cash Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Completion</td>
<td>08/31/04</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pay to Contractor from savings</td>
<td>10/30/04</td>
<td>1</td>
<td>$15,867</td>
<td>$15,867</td>
<td>$0</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>11/30/04</td>
<td>2</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>12/31/04</td>
<td>3</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>01/31/05</td>
<td>4</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>03/31/05</td>
<td>5</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>04/30/05</td>
<td>6</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>05/31/05</td>
<td>7</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>06/30/05</td>
<td>8</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>07/31/05</td>
<td>9</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>08/31/05</td>
<td>10</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>09/30/05</td>
<td>11</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>10/31/05</td>
<td>12</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>11/30/05</td>
<td>13</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>12/31/05</td>
<td>14</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>01/31/06</td>
<td>15</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>02/28/06</td>
<td>16</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>03/31/06</td>
<td>17</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>04/30/06</td>
<td>18</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>05/31/06</td>
<td>19</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>06/30/06</td>
<td>20</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>07/31/06</td>
<td>21</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>08/31/06</td>
<td>22</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>09/30/06</td>
<td>23</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>10/31/06</td>
<td>24</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>11/30/06</td>
<td>25</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>12/31/06</td>
<td>26</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>01/31/07</td>
<td>27</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>02/28/07</td>
<td>28</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>03/31/07</td>
<td>29</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>04/30/07</td>
<td>30</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>05/31/07</td>
<td>31</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>06/30/07</td>
<td>32</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>07/31/07</td>
<td>33</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>08/31/07</td>
<td>34</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Share 40% with RCD</td>
<td>09/30/07</td>
<td>35</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$4,760</td>
</tr>
<tr>
<td>Last Payment</td>
<td>10/31/07</td>
<td>36</td>
<td>$7,933</td>
<td>$3,173</td>
<td>$7,933</td>
</tr>
<tr>
<td></td>
<td>11/30/07</td>
<td></td>
<td>$7,933</td>
<td>$0</td>
<td>$7,933</td>
</tr>
<tr>
<td></td>
<td>12/31/07</td>
<td></td>
<td>$7,933</td>
<td>$0</td>
<td>$7,933</td>
</tr>
<tr>
<td></td>
<td>01/31/08</td>
<td></td>
<td>$7,933</td>
<td>$0</td>
<td>$7,933</td>
</tr>
<tr>
<td></td>
<td>02/29/08</td>
<td></td>
<td>$7,933</td>
<td>$0</td>
<td>$7,933</td>
</tr>
<tr>
<td></td>
<td>03/31/08</td>
<td></td>
<td>$7,933</td>
<td>$0</td>
<td>$7,933</td>
</tr>
<tr>
<td></td>
<td>04/30/08</td>
<td></td>
<td>$7,933</td>
<td>$0</td>
<td>$7,933</td>
</tr>
<tr>
<td></td>
<td>05/31/08</td>
<td></td>
<td>$7,933</td>
<td>$0</td>
<td>$7,933</td>
</tr>
<tr>
<td></td>
<td>06/30/08</td>
<td></td>
<td>$7,933</td>
<td>$0</td>
<td>$7,933</td>
</tr>
<tr>
<td></td>
<td>07/31/08</td>
<td></td>
<td>$7,933</td>
<td>$0</td>
<td>$7,933</td>
</tr>
<tr>
<td></td>
<td>08/31/08</td>
<td></td>
<td>$7,933</td>
<td>$0</td>
<td>$7,933</td>
</tr>
<tr>
<td></td>
<td>09/30/08</td>
<td></td>
<td>$7,933</td>
<td>$0</td>
<td>$7,933</td>
</tr>
<tr>
<td></td>
<td>10/31/08</td>
<td></td>
<td>$7,933</td>
<td>$0</td>
<td>$7,933</td>
</tr>
<tr>
<td></td>
<td>11/30/08</td>
<td></td>
<td>$7,933</td>
<td>$0</td>
<td>$7,933</td>
</tr>
<tr>
<td></td>
<td>12/31/08</td>
<td></td>
<td>$7,933</td>
<td>$0</td>
<td>$4,760</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$9,520</td>
<td>1st year cash flow</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$57,120</td>
<td>2nd year cash flow</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$63,467</td>
<td>4th year cash flow</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$95,194</td>
<td>5th year cash flow</td>
</tr>
</tbody>
</table>

Cumulative Payout to RCD $114,228
3.0 Deaerator

3.1 Background Information

The function of a deaerator is to remove non-condensable gases from steam, and to heat feed water en-route to a boiler. This is accomplished by thoroughly agitating steam and water in a pressure vessel as they pass through a tray stack or scrubber. As the water temperature is increased, non-condensable gases are removed, and the effluent steam is free of potentially corrosive compounds. Without such a device in place, agents such as oxygen could cause irreparable damage to machinery and conveyance infrastructure in the form of pitting, scaling or through another failure mechanism. Queen’s Central Heating Plant uses a Double Shell (DS) model, which is manufactured by the Kansas City Deaerator Company (Kansas City Deaerator Company, 1994). The layout of this apparatus is illustrated in Figure 3.1 and is shown in Appendix K for images. Please also refer to Appendix E for detailed component descriptions.

Figure 3.1: Manufacturer’s drawing of a deaerator unit (after Kansas City Deaerator Company, 1994)
3.2 Deaeration Procedure

The deaeration procedure is based on two fundamental principles. First, since the partial pressures of oxygen and carbon dioxide in steam are very low, the solubility of gases in water can be decreased, which allows a system to be purged of undesirable gases. As well, the solubility of a gas in liquid is inversely proportional to the temperature of that liquid. As steam enters a pressure vessel, the water temperature will rise to correspond to the saturation temperature for a particular operating pressure. This process is referred to as “scrubbing” of water, which consists of an increase in temperature and a decrease in partial pressures of local gases. Subsequently, solubility is lowered (Kansas City Deaerator Company, 1994). Furthermore, water is sprayed in a thin film and scrubbed by the steam, where it is distributed to several tray channels. This increases the available surface area for gas exchange, and hence yields higher efficiency and complete oxygen and carbon dioxide removal. The proceeding steps are followed to achieve optimal results:

- Feed water is heated to the highest allowable temperature
  - This temperature corresponds to the steam pressure
- Feed water is scrubbed with steam
  - This removes O₂, CO₂ and lowers the partial pressure of the steam
- Non-condensable gases are vented
  - A vent condenser is used to concentrate vapors, thereby reducing the amount of steam wasted
  - A small amount of steam is exhausted to ensure proper venting is occurring
  - Excessive venting results in steam and energy losses, while insufficient venting yields poor O₂ removal

The pressure of water in a deaerator is another important factor in efficient operation. The water pressure must be sufficient to overcome frictional and minor losses, as well as to counteract the internal steam pressure. The normal pressure for condensate not flowing through a controller or head condenser must be equal to the internal vessel steam pressure, plus 3 psi at the heater connection, or 5 psi at the water inlet valve (Kansas City Deaerator Company, 1994) (see Figure 3.1). Moreover, inlet control valves are installed to operate within a normal range of pressures. If the water pressure is too low, insufficient water will be supplied to the heater.
Conversely, valve trouble such as vibration can result from excessive water pressure. Such effects can lead to reduced plant efficiency.

### 3.3 Additional Information

It is crucial to exercise due care when installing a deaerator’s venting pipe network. Mainly, any design element that could be a potential “gas trap” should be avoided. Ninety degree corners, long horizontal runs and dips are all conducive to gas accumulation. As well, long outside runs should be omitted to prevent condensing. It is allowable to provide a steam separator at the discharge point, provided a steam plume has been well established (Kansas City Deaerator Company, 1994).

Adequate safety measures are also necessary to reduce the risk of injury or damage to machinery. Relief valves allow steam to be purged internally from the deaerator if too much pressure has accumulated. However, these devices can only accommodate partial pressure releases, and must be accompanied by external pressure relief valves, which release steam directly from the conveyance line. These valves must be sized to allow for complete pressure release in the event of a system failure (Kansas City Deaerator Company, 1994). In addition to relief valves, vacuum breakers can be installed to protect vessel shells from outside pressure. These breakers will open if the steam influent is too low, which indicates a component malfunction. Such an occurrence can be identified by a distinct rumble and shake, in which event an operator must react immediately as feed water may be contaminated with dissolved oxygen (Kansas City Deaerator Company, 1994).

Proper maintenance and operational procedures will greatly prolong the service life of a deaerator. Please refer to Appendix F: General Notes and Vessel Data for system specifications. The following is a partial list of situations that should be avoided, as dictated by the manufacturer:

- Excessive cold make-up water
  - This leads to higher steam velocities and subsequent erosion
- Shocking with cold water
  - Rapid heating and cooling could result in failure of internal parts
- Excessively high steam temperatures
  - This increases stress on the unit
- Excessive cycling
Deaerators are meant to operate within steady state conditions with minimal fluctuation

- Vibration
  - Internal damage may result
- Poor water quality
  - Chlorides and other dissolved ions can cause stress corrosion and cracking

### 3.4 Summary

Although deaerators require relatively little maintenance, annual inspections should be conducted to ensure proper functionality. Operators should look for evidence of scaling and corrosion, and should check the condition of spray valves, trays, control valves, gauges and shell insulation. More frequent testing, however, is required to monitor oxygen levels in exhaust fumes.
4.0 Physical Plant Services – Central Heating Plant

4.1 Physical Plant Services

The Queen’s University Physical Plant Services (PPS) is located in the Rideau building at 207 Stuart St. PPS is responsible for campus construction, engineering, grounds, parking, utilities and major capital projects. For this project the major departments of concern are that of engineering and utilities. It operates the Central Heating Plant (CHP) located on King St.

4.2 Central Heating Plant Overview

4.2.1 Plant History

The original plant was constructed in 1922 to serve Queen’s University and Kingston General Hospital (KGH). The plant was subsequently upgraded and expanded from 1969 to 1972. It now serves Queen’s Main and West campuses, KGH, St. Mary’s by the Lake and Hotel Dieu Hospitals. The heating plant schematic is shown in Appendix G.

4.2.2 Plant Operating Specifications

The CHP’s operating specifications are shown below in table 2.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Capacity</td>
<td>530,000 pounds per hour (pph)</td>
</tr>
<tr>
<td>Average Winter Load</td>
<td>150,000 pph</td>
</tr>
<tr>
<td>Average Summer Load</td>
<td>24,000 pph</td>
</tr>
<tr>
<td>Peak Load</td>
<td>200,000 pph</td>
</tr>
<tr>
<td>Steam Production (2001-2002)</td>
<td>576,608,300 pounds</td>
</tr>
<tr>
<td>Oil Consumption (2001-2002)</td>
<td>17,275,607 litres</td>
</tr>
<tr>
<td>Cost of steam distributed (2001-2002)</td>
<td>$11.87 per thousand pounds</td>
</tr>
<tr>
<td>Current oil costs</td>
<td>$0.28 per litre</td>
</tr>
</tbody>
</table>
4.2.3 Plant Equipment

The CHP contains a variety of essential equipment required to produce the steam needed to heat the buildings. The plant equipment is as follows (Physical Plant Services, 25402014.doc):

- Boiler #4 – Foster Wheeler, D type, water tube, gas and oil fired, rated at 30,000 pounds of steam per hour at 125 P.S.I.G., installed 1962
- Boiler #5 – Foster Wheeler, D type, water tube, gas and oil fired, rated at 50,000 pounds of steam per hour at 125 P.S.I.G., installed 1963
- Boiler #6 – Vickers Keeler, D type, water tube, gas and oil fired, rated at 150,000 pounds of steam per hour at 275 P.S.I.G., installed 1969
- Boiler #7 – Foster Wheeler, D type, water tube, oil fired, rated at 150,000 pounds of steam per hour at 125 P.S.I.G., installed 1973
- Boiler #8 – Foster Wheeler, D type, water tube, gas and oil fired, rated at 150,000 pounds of steam per hour at 125 P.S.I.G., installed 1974
- Boilers #1, 2 and 3 were coal fired units which were scrapped in 1974
- Boiler feed water is supplied by three 1100 foot head, 360 gallons per minute centrifugal pumps, one of which is turbine driven. The feed water is softened by use of a split stream sodium and acid softener system
- Control Air Supply
  - One Joy 100 CFM compressor
  - Two Broomwade 215 CFM compressors
  - One Gardner Denver 435 CFM compressor
- Emergency Power Supply
  - Two 450 kilowatt, 600 volt diesel driven generators
  - One 60 kilowatt 600 volt diesel driven U.P.S. system serving the boiler control systems
- Oil tank farm capacity
  - 635,600 litres of No. 6 oil
  - 113,500 litres of No. 2 oil
4.3 Plant Operation

The plant operates year round providing heat and hot water for the Kingston buildings listed in the previous sections. Images of the steam venting at the CHP and the pump room of the CHP are found in Appendix H. Tables of steam generation and water consumption for the 2003-2003 year and a detailed steam consumption and production summary from the month of April 2003 are shown in Appendix I.
5.0 Active Vent Mizer Analysis – Hamilton General Hospital

*** From Hamilton General Vent Mizer Testing Report with input from Mike Packham

5.1 Background

The prototype unit installed at the Hamilton General Hospital is a 6-inch diameter unit, VM-1 (for images see Appendix J). The rated design capacity is 200 lb/hr of vent steam handling, suitable for a 20,000 lb/hr deaerator venting at 1.0%. It is designed to recover 95% of the vented steam using cold quench water (temperature no higher than 125 °F) and returns the condensate to the deaerator top hatch. This patented technology enables the deaerator outlet water quality to be equivalent to or better than prior to the Vent-Mizer installation. The plume size (% of prior deaerator vent rate) is based on visual judgment, referencing to 1% of 15,000 lb/hr deaerator operating capacity before VM-1 was installed. Figure 5.1 below shows the variables which are mentioned in the tests. According to the Chief Engineer at Hamilton General (Mike Packham), the Vent Mizer was installed prematurely. There was pressure from authorities above him to proceed with the installation when he insisted more research needed to be done. The pressure came from the drive for more money for their department which they could obtain when citing the savings induced by the deaerator.

![Diagram](image)

**Figure 5.1 - Variables used in the test situations at Hamilton General Hospital**
5.2 Operating Conditions / Test Preparation

Sulfite injection was cut off 24 hours before the scheduled test. The vent from VM-1 has been kept to a minimum (5% of usual venting) since installation June 26, 2002. The deaerator has been operating in summer load conditions and the quench water has been running at no higher that 1.0 USGPM at any time because of low makeup water requirement. One hour prior to the test, and during the test, the quench water was increased to 3 USGPM and the sample line was opened to give a continuous flash. A sample cooler was designed and installed by Chief Stationary Engineer Mike Packham at the Hamilton General Hospital approximately one week prior to the test. Betz-Dearborn did the testing on August 9, 2002.

5.3 Test Condition

5.3.1 Test Result 1, 2, 3 & 4

Vent valve $V$ as shown in figure 5.1 was left open at the usual amount (5% venting) and quench water $Q$ as shown in drawing was running at 3 USGPM, 3 times higher that the usual rate of 1 USGPM. Four samples from the sample connection, stream $R$ as shown on drawing, were tested for dissolved oxygen and the reading were all above 40 parts per billion. The reason for repeating the test 4 times was to clear the suspicion that there could be an oxygen leak into the sample line somewhere. Many flushes were done in between the tests.

5.3.2 Test result 5, 6 & 7

Three separate samples from the deaerator outlet, stream $D$ as shown on drawing, were taken and tested for dissolved oxygen. All three readings were less than 10 parts per billion, meeting boiler feed water standard. We felt confident that the sample line had no oxygen leak and that the sample line was adequately flushed and the readings of tests 1 through 4 were reliable.

5.3.3 Test result 8

The vent valve, $V$, was opened up to give the same amount of venting as before the installation of VM-1. Sample from stream $R$ was tested again for dissolved oxygen and the reading was less than 10 parts per billion. This confirms our reference point.
5.3.4 Test result 9

The vent valve, \( V \), was completely closed. Sample from stream \( R \) was tested again for dissolved oxygen and the reading was above 40 parts per billion.

5.3.5 Test result 10

The vent valve, \( V \), was opened to give 20% of the amount of venting as before the installation of VM-1. Sample from stream \( R \) was tested again for dissolved oxygen and the reading was less than 10 parts per billion. All ten sample tubes were used up by that time.

5.4 Discussion

Table 5.1 summarizes the test conditions. The amount of steam being quenched by the

<table>
<thead>
<tr>
<th>Test conditions</th>
<th>Test Result #1,2,3,4</th>
<th>Test Result #5,6,7</th>
<th>Test Result #8</th>
<th>Test Result #9</th>
<th>Test Result #10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure, psig</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>( S ) temperature deg F</td>
<td>221</td>
<td>221</td>
<td>221</td>
<td>221</td>
<td>221</td>
</tr>
<tr>
<td>( S ) latent heat BTU/lb</td>
<td>964</td>
<td>964</td>
<td>964</td>
<td>964</td>
<td>964</td>
</tr>
<tr>
<td>( Q ) usgpm / deg F</td>
<td>3.0/80</td>
<td>3.0/80</td>
<td>3.0/80</td>
<td>3.0/80</td>
<td>3.0/80</td>
</tr>
<tr>
<td>( Q ) lb/hr</td>
<td>1,500</td>
<td>1,500</td>
<td>1,500</td>
<td>1,500</td>
<td>1,500</td>
</tr>
<tr>
<td>Steam quenched by ( Q ) lb/hr</td>
<td>220</td>
<td>220</td>
<td>220</td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td>Design capacity of Vent-Mizer, 1% of 20klb/hr DA</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>% design at test conditions</td>
<td>110</td>
<td>110</td>
<td>110</td>
<td>110</td>
<td>110</td>
</tr>
<tr>
<td>Normal vent, 1% of 15klb/hr</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>( V ) % of usual vent</td>
<td>5.0</td>
<td>5.0</td>
<td>100.0</td>
<td>0.0</td>
<td>20.0</td>
</tr>
<tr>
<td>( V ) vented steam in lb/hr</td>
<td>7.5</td>
<td>7.5</td>
<td>150</td>
<td>0.0</td>
<td>30</td>
</tr>
<tr>
<td>( S ) actual = ( Q ) + ( V )</td>
<td>227.5</td>
<td>227.5</td>
<td>375</td>
<td>220</td>
<td>250</td>
</tr>
<tr>
<td>% design at test condition</td>
<td>114</td>
<td>114</td>
<td>188</td>
<td>110</td>
<td>125</td>
</tr>
<tr>
<td>% recovery of vent actual</td>
<td>96.7</td>
<td>96.7</td>
<td>60.0</td>
<td>100.0</td>
<td>88.0</td>
</tr>
<tr>
<td>% recovery of vent SAVINGS</td>
<td>95.0</td>
<td>95.0</td>
<td>0</td>
<td>100.0</td>
<td>80.0</td>
</tr>
<tr>
<td>( R ) measured dissolved O2 ppb</td>
<td>&gt;40</td>
<td>N/A</td>
<td>&lt;10</td>
<td>&gt;40</td>
<td>&lt;10</td>
</tr>
<tr>
<td>( D ) measured dissolved O2 ppb</td>
<td>N/A</td>
<td>&lt;10</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
quench water is based on heat transfer from the latent heat of steam to raise the quench water to the boiling point of water at the operating pressure of 3.0 psig. Since the steam handled by the Vent-Mizer is the sum of quenched steam plus the vented steam, VM-1 has been operating at 110% to 188% of design capacity.

Based on the above capacity reference point, the recovery rate (test point #10) is at 88% with dissolved oxygen at VM-1 outlet less than 10 parts per billion, at 125% of design operating capacity. This is measured at the outlet of the VM-1 drain, not at the deaerator outlet. At the deaerator outlet, the level of dissolved oxygen has to be even lower still since the condensate gets deaerated again as it passes through the deaerator baffles.

5.5 Recommendation & Follow-up Action

In order to determine more precisely the upper limit of VM-1 performance, we should repeat the tests at a prorated quench water flow of 2.0 USGPM. This quench flow corresponds to 1% vent rate of 15,000 lb/hr deaerator capacity. For this specific installation, vent plume size should be referenced to the above operating capacity. We can then adjust the venting from 5% to 20% so that we can map out the performance. In other words, we are interested to find out at what vent rate we will begin to detect higher than 10 ppb oxygen from VM-1. The reasoning is quite simple. We would no longer require secondary deaerating through the baffles as part of the specifications. Any increased deaeration would be regarded as bonus on additional steam savings.

5.6 Problems

After a long discussion with engineer Mike Packham, a number of problems arose that had complicated the use of the Vent Mizer. The first problem was that luckily the spray heads in the Hamilton General deaerator were not spring loaded. Mr. Packham was never asked by RCD about their spray heads. Had they been spring loaded spray heads, as most spray heads in deaerators are, then the Vent Mizer would not have worked. Since the Vent Mizer is operated purely by gravity insufficient head would have built up in the return condensate in order to activate the spray heads. This would have lead to the Vent Mizer just filling with water. This fortunately was not a problem for Hamilton General, however never was the question even posed regarding their spray heads.
The second problem was that the Vent Mizer required 2 GPM of quench water at all times of the year. Normally this would not be a problem, however during the reduced load summer months enough water would not have been flowing through it. Mike Packham was forced to design an automatic flow adjustment device in order to maintain the required operating parameters.

### 5.7 Conclusion

The above analysis and test data confirmed that the VM-1 is operating well within the design range and is meeting the intended steam savings. Once the 2.0 USGPM tests results are in, we can be even more confident in determining the actual steam savings without relying on the polishing step of running VM-1 outlet through the deaerator baffles. Based on the results to date, we can guarantee a minimum of 80% savings. A more typical steam vent recovery is 90% and above.

The engineers at Hamilton General have not received any visual information regarding the condition of the interior of their deaerator. Photographs should have been taken at the beginning of the installation and an inspection should have been done every year after in order to determine if this device is causing damage to the deaerator. The RCD Engineers could be approached in order to share the costs of these inspections so that RCD can obtain some concrete evidence that no damage is done to the deaerator by their device.
6.0 Thermodynamic Model Analysis

6.1 Thermodynamic Results

Several attempts were made using the Pro II software in order to determine the operating parameters of the Vent Mizer theoretically. We used the model shown below in figure 7.1.

![Figure 7.1 – Pro II model used for analysis](image)

Due to our lack of understanding of the program and the inability to find anyone with good knowledge of the program the data obtained, shown in Appendix L, is not useful. The amount of steam entering and leaving is approximately the same as is the water. Also there is very little temperature difference between the inlets and exits in each state. Since the operational Vent Mizer does not produce results close to this, we can only assume that we have made some error in one of our assumptions or in the calibrations of the program. Unfortunately the thermodynamic analysis was unable to be completed.
7.0 Alternatives to Vent Mizer

7.1 FLU-ACE®

A possible alternative to the Vent Mizer system is the FLU-ACE® Condensing Heat Recovery System, which is a product of Thermal Energy Solutions. This device is depicted in Figure 7.1.

![FLU-ACE® system](image)

The following testimonial was retrieved from the Industry Canada web page (Thermal Solutions, 2004), and outlines the apparent capabilities of the FLU-ACE® system:

…it recovers 80-90% of the heat in the flue gas presently exhausted into the atmosphere. This results in reduction of energy consumption of gas and oil fuelled burners by 15-25% and in having more heat available for sale.
In effect, the capabilities of an Electro-static Precipitator, Scrubber, Waste Heat Recovery Unit and Smoke Stack are replaced with one FLU-ACE® tower thus achieving significant savings in capital costs and operating and maintenance costs. The energy savings from waste heat recovery enables the FLU-ACE® System to pay for the control of the dirtiest flue gases.

The result was a high performance system which virtually eliminates air pollutant emissions from biomedical waste incinerators, while at the same time, paying for itself through energy recovery savings. The HP FLU-ACE® will capture and remove particulate (90-99%), SOx (over 95%), HCl, HF, and HBr (up to 99%), VOCs, and Patt's (up to 99%). HP FLU-ACE® will effectively control emissions from "dirty" flue including municipal waste, biomedical waste, biomass, coal, hog fuel, and wood waste. Similarly Hybrid FLU-ACE® will effectively control emissions from bark, biomass, etc. combustion.

It recovers 3 to 4 times more heat than conventional indirect economizer systems. It also provides large quantities of water for recycling. Simple payback on capital investment is usually between three (3) and six (6) years, depending on the size, flue, operation time and design complexity, utilization of the recovered waste heat.

To date, there are currently six different FLU-ACE® products and integrated systems have been proven and developed through thirteen different installations. All of the FLU-ACE® products and solutions accomplish the combined benefit of efficient heat recovery and effective air pollution control from hot waste gas streams (Thermal Solutions, 2004). Currently, there have been more than two dozen FLU-ACE® designs that have been tested using computer modeling. The FLU-ACE® efficiently removes multiple pollutants at the same time - including fine particulates (i.e. fly ash, dust, soot, and heavy metals), hydrocarbons and toxic volatile organic compounds (VOCs), acid gases (i.e. SOx, NOx, HCl), and greenhouse gases (i.e. CO2) (Thermal Solutions, 2004).

Typically, the FLU-ACE® has been installed as a replacement for a conventional smoke stack or chimney in industrial and institutional central heating plants. Also the FLU-ACE® has been used for combined heat recovery (HR) and air pollutant control (APC) from hot gases that have been emitted from burning natural gas and fuel oils. In this "clean stack" application, the FLU-ACE® has proven to recover up to 90% of the waste heat which translates into fuel savings from 15% to 50%, while at the same time removing from 90% to 99% of a wide variety of air pollutants (Thermal Solutions, 2004). An example of a FLU-ACE® is shown in figure 7.2 below installed in a heating plant system.
7.2 Heat Exchangers

The University of Guelph had considered installation of the Vent Mizer, and the FLU-ACE® a number of years ago, but the notion was subsequently rejected. According to Dan MacLachlan of Guelph Physical Resources, this decision was based on equipment costs and the logistics associated with setting-up elaborate pipe networks. In lieu of the FLU-ACE® system, Guelph elected to acquire two heat exchangers; one to preheat the boiler feed water and one to provide heat to classroom complex adjacent to the heating plant. The total initial cost was about $800,000, but the system incurred annual savings of $200,000. Since the payback period is less than five years and heat exchangers will likely pose no threat to existing infrastructure, this is a solution that Queen’s Physical Plant Services should consider.
The system of quenching the steam and returning the condensate with the Vent Mizer has the possibility to corrode the very expensive deaerator. To avoid this possible disaster the use of heat exchangers for the heating plant was investigated. Instead of quenching the steam vent from the deaerator, the steam would be redirected to preheat the makeup water for the boilers. This would reduce the amount of natural gas needed to bring the boilers to the correct temperature. Natural gas accounts for the largest cost at the heating plant and by using the steam to preheat the water it will be possible to reduce the amount of gas required. Figure 7.3 shows an example of a plate heat exchanger that will receive the steam and with the use of a plate system allow the boiler water to be heated before entering the boiler. The steam will then exit as condensate and be used as makeup water for the deaerator. Thus reusing all of the available elements in the system and increasing the efficiency of the heating plant.

![Figure 7.3 - Example of heat exchanger](image)

**7.3 Concerns**

Energy efficient plants often employ this energy for preheating boiler feed water (BFW). There are two basic types of BFW heating that can be done:

1. Heating of un-deaerated water entering the deaerator
2. Heating of BFW being delivered to the boiler
Preheating the boiler feed water prior to entering the deaerator minimizes the use of low-pressure steam in the deaerator. There are some important points to remember when specifying a system to preheat un-deaerated boiler feed water.

If too much preheating is done this may cause problems in the operation of the deaerator. The supply of stripping and heating steam to the deaerator is done under pressure control. If the boiler feed water is heated to its saturation point the pressure controller may reduce or cut-off the supply of steam to the deaerator, reducing its ability to strip oxygen and carbon dioxide from the water. The exit temperature from the boiler feed water heater should not approach the deaerator operating temperature by more than 17°C (30°F).
8.0 Conclusions and Recommendations

8.1 Vent Mizer Conclusions

To determine what course of action should be followed with respect to the Vent Mizer the initial three questions posed by Physical Plant Services must be revisited. These questions are:

1. That the Vent Mizer does not clean the steam of thoroughly enough of oxygen in order to safely return the steam to the deaerator. If there is too much dissolved oxygen in the returned water, the inside of the deaerator will become damaged from oxygen pitting.

2. That the actual reduction of steam exhausted and the amount of money saved has been embellished by the RCD Engineers, and

3. How the Vent Mizer performs in a real life trial situation.

The first concern is a very important issue and was the main focus of the research. Have our group findings enabled us to conclude without reasonable doubt that there will be no damage to the deaerator? The answer to this question is no.

After all of our research there was no convincing information that anyone could provide that showed a proven record of the Vent Mizer not damaging the deaerator. This is due to the fact that there is only one Vent Mizer currently in operation and that the company who manufactures them has not gone through any lengths in order to obtain substantial concrete evidence in support of their device. Our group has found it difficult to understand why the engineers at RCD have not entered in a partnership with Hamilton General in order to use them as their test case to collect data that will enhance the credibility of their product. It was not plausible for our group to conduct any tests on the working model because after discussions with Mike Packham at Hamilton General he informed us that the equipment needed to do proper testing costs hundreds of thousands of dollars. He also claimed that this was one reason that RCD has not proceeded with any testing of its own due to their limited financial standing. Why would RCD not seem interested in collecting any information in order to help justify to potential clients that their product does indeed possess the benefits they claim it does? There is not even any substantial hard information available other than the company’s claims.
Aside from RCD’s lack of interest in collecting information, damage to the deaerator can not be taken lightly. Queen’s University Central Heating Plant prides itself in its maintenance and operating standards. Investing in a device that could cause an essential piece of equipment to fail that would cost $300,000 to replace would be out of the question. The only information that was available was from Hamilton General Hospital that the feed water returning to the boiler remained below the 10 ppb dissolved oxygen criteria. This shows that the deaerator is still able to remove enough oxygen to allow for safe boiler operation; however it does not show anything regarding the inside of the deaerator. The increased level of oxygen in the deaerator may not immediately hinder its performance but it may be causing increased oxygen pitting inside which will cause severe problems a few years down the road.

The next question relates to savings associated with the installation of the Vent Mizer. RCD has provided an estimate of savings based of the operating conditions at Queen’s CHP. These were shown in table 2.1 previously. At a first glance these numbers appear to be very inviting to the installation of the deaerator estimating a savings of $7,933 per month. With these reported savings the Vent Mizer would pay for itself in just over a year. How can these numbers be so certain that a pay period be associated with them? These numbers have been offered when no actual working information has been used to tabulate them. They are purely hypothetical. Hamilton General has not been able to calculate their exact savings too date due to lack of resources. RCD is asking Queen’s to pay them according to this chart with no working analysis used in calculating these values.

Along with the uncertainty of the savings the Chief Engineer at Guelph University found a discrepancy in their calculations for savings. In their savings calculations RCD assumed a feed water temperature of 180 °F. However, the actual feed water temperature is closer to 220 °F. When the feed water temperature was corrected to this value their savings were much lower than stated. This is important in the savings calculations because they were assuming that the boilers were bringing 180°F to a boil when in fact they were bringing 220 °F to a boil. With the Vent Mizer in place the feed water temperature will be higher because the recaptured steam is being used instead of much colder make-up water. This will cause the water exiting the deaerator to be at an even higher temperature. Adding warmer water into the boilers will require less fuel energy because the water does not need to be heated as much. Their under estimation of the feed water temperature will result in a larger savings because it will consider the heating of 180°F water as a base.
The final question is related to the Vent Mizer already in operation at Hamilton General Hospital. The major concern is how this unit is performing. Problems began with this unit immediately after the installation. There was a major oversight on the part of RCD engineers during installation. The oversight was that RCD did not research the type of deaerator used at Hamilton General. This older type of deaerator has an unconventional type of spray head that is not spring loaded. This was fortunate because the Vent Mizer is operated completely by gravity and would not have developed enough head in the line returning to the deaerator in order to open spring loaded spray heads. This was a small oversight on the part of RCD; however it shows that they may not be as well informed as they should be. In order for Queen’s to install the Vent Mizer, due to their spring loaded spray heads, the unit must be installed a minimum of 20 feet above the deaerator. This would not be a large inconvenience, however if this was not discovered then the installation would need to have been done twice.

Another issue that arose from the working unit is the fact that it requires 2 gallons per minute (gpm) to flow through the unit at all times. During the high load winter months this is no problem. However, a problem does arise during the summer months where the load on the system is significantly less. Typically in the summer only 1 gpm was needed by the plant at Hamilton. In order for the 2 gpm to be maintained automatically a network of piping designed by Mike Packham had to be installed. This network is shown below in figure 8.1. This was another issue that was not discovered until after the installation. Our group tested the Vent Mizer while on the roof to see the difference in its plume compared to the plume of steam when the inlet valve is opened and the steam directly from the deaerator was observed. The plume from the deaerator was approximately 80-90% larger. This demonstrates that the steam is in fact being recaptured.

With all the information collected not one of the concerns originally posed by PPS can be neglected. There is not enough information available yet in order to make a decision that will be safe and economical. The savings are not necessarily what they seem to be and there is no concrete evidence that the deaerator will not be damaged from the installation of the Vent Mizer.
8.2 Recommendations

After careful consideration of all the facts, it is our suggestion not to install the Vent Mizer from RCD. The risks associated with possible deaerator malfunction greatly outweigh the possible benefits of this project. Since the returns may not be as high as predicted and RCD engineers seem to lack a basic understanding and knowledge of deaerators we also do not suggest that the installation be pursued.

One recommendation is to talk with Hamilton General and engage in a study headed by Queen’s University. Since the savings will not only benefit Queen’s University but also the government, due to the sharing of costs, funding could come from government sources. The research project should include a complete financial assessment of the Hamilton General heating plant expenses for the last 10-15 years. This will enable the researchers to compare present expenses with past expenses in order to determine the savings that have been created by the installation of the Vent Mizer. Along with the financial side of the research the researchers will also investigate the effects of the Vent Mizer on the deaerator. Queen’s, the government and Hamilton General and even possibly RCD could share the costs of the annual cleaning and inspection of the deaerator. If any past maintenance information and photographs are available from Hamilton General then these can be compared. If these are not available then the study can be conducted over a period of a few years in order to determine if there is an increase in oxygen pitting. The cost of this study over the few years will be a worthwhile expense. If the Vent Mizer is shown to function as well as RCD claims then the installation of the Vent Mizer will result in savings that will pay for the costs of the study in a year. If the Vent Mizer was found to
be damaging then Queen’s has saved themselves from destroying their expensive deaerator and could publish papers reporting their results.

Another recommendation that we are suggesting is the exploration of other technologies available. Further investigation of heat exchangers should be conducted to study the possibility of preheating the boiler water. The application of a plate heat exchanger will reduce the amount of time and natural gas required to heat the boiler water. This can be accomplished by using the vent steam from the deaerator. The water can then also be used as makeup water for the deaerator.
9.0 References

Industry Canada, Canadian Environmental solutions.  
[www.strategis.ic.gc.ca/Ces_Web/_display_air_agriculture_prob_info_cfm?problemId=79&targe
t=english](http://www.strategis.ic.gc.ca/Ces_Web/_display_air_agriculture_prob_info_cfm?problemId=79&targe


Fax: (519) 837-0581  
danma@pr.uoguelph.ca


Physical Plant Services, “Queen’s University Central Heating Plant” 25402014.doc, September 30, 2002

Appendix A – Meeting Minutes

Minutes of Meeting, December 6th 2003
Meeting with Eric Neuman

Present:
Andrew Follwell
Luke Follwell
Rob Short
Steve Orchard
Eric Neuman

Opening the meeting: The meeting began at 2:30 p.m. at Eric Neuman’s office in the Physical Plant Services building.

Agenda: A brief overview of what the “Vent Mizer” is and what its functions are.

Meeting Points:

1) What the actual technical functions of the “Vent Mizer” are and how it works. Mr. Neuman outlined what he knew about the technical functions of the “Vent Mizer”.

2) Concerns – There are concerns about what may happen to the existing equipment if the “Vent Mizer” is installed. Primarily, the main concern is that with the instillation of the “Vent Mizer” it is going to wear out the existing equipment, especially the deaerator.

3) Another concern that was raised surrounds the actual process of the “Vent Mizer” and if it will do what they say it will do. Currently there is little know about what the “Vent Mizer” can and will do as there are currently no studies being conducted on the operations of a “Vent Mizer” anywhere.

4) A discussion on any tests that can prove that the “Vent Mizer” can do what they claim it can do may be a good idea.

5) Discussions of what alternatives exist to the process that the “Vent Mizer” performs.

6) Talk to other companies that have actually installed a “Vent Mizer” and ask them the results of their “Vent Mizer”

Adjournment: The meeting concluded shortly after 3:45 p.m.

Minutes of Meeting, January 5th, 2004

Present:
Andrew Follwell
Luke Follwell
Rob Short
Steve Orchard

Opening the Meeting: The meeting took place at 489 Johnson St, where two group members live. The meeting began at 5:00 p.m.

Agenda: A discussion of what roles each member of the team will be taking on as well as setting up any meetings that we may want to conduct with people involved with the “Vent Mizer” Project.

Meeting Points:

1) Delegation of Roles
a. Steve Orchard – Team Leader
b. Andrew Follwell – Secretary
c. Luke Follwell – Treasurer
d. Rob Short – Client Contact

2) Developing of time line. Discussion of ideas of who and when we need to meet people as well as developed a list of what information we need to gather from each party that we are interviewing.

3) Developed a list of things that needed to be completed for next meeting.  
   a. Client contacted  
   b. List of questions developed  
   c. Project binder assembled

4) Review the actual product and what it does. Discuss the possible negative effects of implementing one at Queens.

5) Set next meeting time

Adjournment: The meeting adjourned at 7:00 p.m.

Minutes of Meeting, January 12th, 2004

Present:
Andrew Follwell
Luke Follwell
Rob Short
Steve Orchard

Opening the Meeting: The meeting took place at 489 Johnson Street. The meeting began at 6:00 p.m.

Agenda: A discussion of how we should proceed with the project.

Meeting Points:

1) Review of Last meeting

2) Discussion of Possible client contacts and who we can talk to about the “Vent Mizer”

3) Develop a list of who we need to meet
   a. RCD Engineering
   b. Guelph heating plant supervisor
   c. GM heating plant supervisor

4) Update on how the progress is coming thus far. See if anyone needs help on any areas of the project

5) Discussion of setting up a business meeting wit RCD Engineering to discuss the project.

6) Set next meeting

Adjournment: The meeting adjourned at 7:30 p.m.

Minutes of Meeting, January 13th, 2004

Meeting with Graham Robertson

Present:
Andrew Follwell
Luke Follwell
Steve Orchard
Rob Short  
Graham Robertson

**Opening the Meeting:** The meeting began at 2:30 p.m. at Graham Robertson’s offices located at the Heating Plant on Kings St.

**Agenda:** A brief overview of the heating plant functions as well as a tour of the plant.

**Meeting Points:**

1) Discussion of the maintenance of a deaerator. Opened and maintained every 12 months.

2) Need at least one year to tell if the “Vent Mizer” is actually functioning the way that it should be.

3) Noted that the saving calculated by the “Vent Mizer” are based on a water temperature of 180F, water at the plant is held at 232F.

4) Contact chief engineer at University of Guelph heating plant where they were approached with the possibility of getting a “Vent Mizer” and turned it down.

5) Contact chief engineer at GM where they were approached with the possibility of getting a “Vent Mizer” and turned it down.

6) Discussed the importance of the heating plant. Especially the fact that it heats all of the hospital’s as well as well of the residences.

7) Negative Effects of a broken deaerator
   a. $300,000 replacement cost
   b. Long term shut down of plant
   c. Idle time very expensive

**Adjournment:** The meeting concluded shortly after 3:45 p.m.

Minutes of Meeting, January 14th, 2004  
Meeting with B.W. Jackson & A.M. Bergeron

**Present:**
Andrew Follwell  
Luke Follwell  
Steve Orchard  
Rob Short  
Dr. Jackson  
Dr. Bergeron

**Opening the Meeting:** The meeting began at 3:00 p.m. in Dupuis Hall Conference Room 427.

**Agenda:** Our first progress meeting

**Meeting Points:**

8) Discussion and background information was provided to the course coordinators. The various positive and negative issues were discussed.

9) We discussed our role as a team in this project. We need to determine if this Vent Mizer will actually work and if the information provided from RCD Engineering is accurate.

10) It was pointed out by Dr. Jackson that if the Vent Mizer was to be used in Kingston that it will not be easy to compare with the Hamilton Hospital. The Hospital only uses 2% of the capacity of the Kingston plant
11) We discussed our Progress Memo, Budget, and Timeline. It was noted by Dr. Bergeron that we should use a Gantt chart for our timeline.

12) For more information on the bids put in by GM Dr. Jackson noted that he could contact the MMO for more resources.

13) We should discuss with Eric Neuman the need of a confidentiality agreement.

14) It was noted that we did not have an advisor and that an Engineer from Barrie could be a good fit to our team.

Adjournment: The meeting concluded at 3:30 pm

Minutes of Meeting, January 26th, 2004

Present: Andrew Follwell, Luke Follwell, Steve Orchard, Rob Short, Dr. Jackson, Dr. Bergeron, Dale Dilamarter

Opening the Meeting: The meeting began at 3:00 p.m. in Dupuis Hall Conference Room 427.

Agenda: 2nd Meeting

Meeting Points:

15) Discussed our meeting/email with Geoff Clarkson and his outlook on the project.

16) Discussed RCD claims and that all this Vent Mizer does is act as an additional deaerator.

17) Dr. Jackson suggested that we use the Vent Mizer as a black box and then set up a thermal dynamic schematic. Use the theories of heat transfer and this should result in a simple mass balance equation.

18) This idea just seems to be a little “Mickey Mouse” and might just end up in the “Bone Yard” in no time.

19) We need to update our Timeline and turn it into a Gantt Chart.

20) Set up meeting with Dr. Jackson to go over the PROII software to set up a model of the Vent Mizer.

21) Send Dr. Bergeron an email about rescheduling our Mar 5th – 10th Meeting.

Adjournment: The meeting concluded at 3:30 pm

Minutes of Meeting, February 4th, 2004

Present: Andrew Follwell, Luke Follwell, Steve Orchard, Rob Short, Dr. Jackson, Dale Dilamarter
Opening the Meeting: The meeting began at 3:00 p.m. in Dupuis Hall Conference Room 427.

Agenda: 3rd Meeting

Meeting Points:
1) Discussion of model that was simulated after the last meeting and its outputs.

2) Discussion of Trip Planned
   a. Meet Advisor
   b. Meet Superintendent of Hamilton Hospital
      i. Advised on some of the questions that need to be asked
      ii. Temperatures, pressures and flows?
      iii. Dimensions of Vent Mizer
   iv. Heat Loss?
   v. Insulation?

3) Discussion of Client
   a. What do they really want?
   b. They do not want to be the guinea pig

4) Discussion of only real way to test this system is to condense a sample of steam going in and to monitor the output.

5) Discussion of simple thermodynamics
   a. You cant wash oxygen out of steam
   b. You cannot selectively wash steam

6) Insulation of Vessel
   a. How does this work in the frigid Canadian winter?

7) Savings – if we monitor the amount of steam going in and coming out and it is different from what is predicted, then do we save money on this project when we purchase it?

Adjournment: The meeting concluded at 3:30 pm

Minutes of Meeting, February 5th, 2004

Hamilton

Present:
Luke Follwell
Steve Orchard
Rob Short
Mike Packham – Chief Engineer at the Hamilton General Hospital

Opening the Meeting: The meeting began at 1:00 pm in Mike’s office at the HGH.

Agenda: Discuss the pros and cons of his Vent Mizer to see how it operates.

Meeting Points:

8) The group met with Mike in his office and then proceeded to the roof to have a close up look at his Vent Mizer.
9) When talking with Mike he mentioned that his boss didn’t ask any questions of the claims that RCD was proposing, but that was just to install the system.

10) The following observations were made when on the roof

   a. The system seems very basic, Mike described the middle of the tube to contain small pop can lids that allows the steam from the bottom to be washed by the water coming in from the top.
   b. The quenching water is piped into the system at 2 gallons per minute through at ¾ inch copper pipe.
   c. The steam is piped into the system through at 1 ½ inch pipe but the rate is still unknown and would be different for our application.
   d. The system does not appear to have any insulation.

11) The following items were later discovered by Mike

   a. During the summer they still need to supply the Vent Mizer with 2 gallons of water per minute. This required some rework of his piping in the boiler room to make sure that the system always had enough water.
   b. The condensate coming off the Vent Mizer could be returned to the deaerator but was gravity feed. In Mike’s case it was adequate because he didn’t have spring-loaded spray heads within the deaerator. For our application we have spring loaded spray heads so a secondary pump would need to be installed to allow this water to return to the deaerator.

12) While on the roof we took video of the Vent Mizer when opened a relief valve prior to entering the bottom of the system and it was very noticeable that something was actually happening inside the tube.

13) Mike gave us some information on testing that has been done on his Vent Mizer for us to look at for analysis.

Adjournment: The meeting concluded at 2:00 pm

Minutes of Meeting, February 5th, 2004

Hamilton

Present:
Luke Follwell
Steve Orchard
Rob Short
Geoff Clarkson – Team advisor

Opening the Meeting: The meeting began at 2:00 pm at the Howard Johnson in Hamilton

Agenda: Introduction to group and what we have completed so far

Meeting Points:

14) We made the proper introductions and proceeded to discuss our up to date work on this project.

15) Geoff had a few questions about the systems application:

   a. Could we instead of capturing the condensate use the steam to preheat the make-up water?
   b. Look at the cost of the feed water. Do we use de-mineralized water? What is the cost of the treated water?
   c. They determine how much head is required to heat up the make up water.
   d. Could we use a different type of heat exchanger? Possibly use a plate system that allows the steam to flow through one side and water through the other. Would this be more useful in our application?
16) Geoff suggested that we produce an excel spreadsheet using the steam table values and perform a mass balance.

17) He also mentioned that we should be doing a mass balance around the deaerator as well.

18) He suggested a method of getting some values from our vent to determine some flows and temperatures. This involved using a pail and capturing steam and taking temperatures before and after a certain time.

19) He also questioned what would happen if we reduced the pressure inside the deaerator.

20) He suggested that the Vent Mizer could be used as a steam injector.

21) We also need to know the pressure drop across the Vent Mizer. We know that the pressure leaving the deaerator must be the same as the pressure entering the Vent Mizer. And the pressure leaving the Vent Mizer is 0 because it is exposed to the atmosphere.

22) The issue of using returning the condensate into the deaerator with little to no pressure resulted in raising the Vent Mizer to height of 15 feet above the deaerator to achieve a pressure of approximately 5 psi. This be an adequate pressure to allow the water to flow through the spring loaded spray heads.

Adjournment: The meeting concluded at 4:00 pm

Minutes of Meeting, February 23rd, 2004
Meeting with B.W. Jackson and A.M. Bergeron

Present:
Dr. Bergeron
Dr. Jackson
Rob Short

Opening the Meeting: The meeting began at 15:00 in Ellis Hall Conference Room 212.

Agenda: Discussion of the Hamilton General Hospital visit and the meeting with Geoff Clarkson.

Meeting Points:

1) The high cost of water treatment
   a. Water into the boiler must be pure
   b. Steam is re-circulated to boiler
   c. Presence of a condensate condenser

2) Obtain overall steam and water balance from Physical Plant Services

3) Improve Gantt Chart: “More meat,” not just dates of meeting times

4) Air cooler versus cooling water: no hot water is deposited into the environment

Adjournment: The meeting concluded at 15:30.

Minutes of Meeting, March 3rd, 2004
Meeting with B.W. Jackson, A.M. Bergeron and D. Dilamarter

Present:
Dr. Bergeron
Dr. Dilamarter
Dr. Jackson
Rob Short
Opening the Meeting: The meeting began at 15:00 in the Dupuis Conference Room.

Agenda: Discussion of progress since February 23rd.

Meeting Points:

1) Touch base with Geoff Clarkson to schedule meeting or teleconference.
2) Use Dupuis cluster to fabricate a Pro II simulation for the heating system with a Ventmizer employed.
3) Have a draft of the final report prepared for March 10th.
4) Prepare a black and white copy of the final for the TEAM advisors a week before due date.
5) Ensure that there will be sufficient content in the report.
6) Prepare for MMO presentation - team dynamics only.
7) Want to schedule QPPS presentations on same day as solar group.
8) Confer with solar team to determine exam dates and determine a suitable presentation date.
9) Final presentation dates are posted on course website

Adjournment: The meeting concluded at 15:15.

Minutes From Meeting With Eric Neuman – Mar/11/2004

1) General Overview of what is happening
2) Discussion of Hamilton General Hospital
   - Dearrator different from the one at Queen’s
   - Must have two gallons per minute running through it for it to function
3) Alternatives – Flu Ace
   - acts similar to Vent Mizer
   - want to recover heat, not steam
4) Need to have control to monitor and all us to make accurate conclusions
5) Set date of the 16th of April for our presentation
6) Outlined how the presentation should go
7) Eric needs two copies in colour and three in black and white of the report for the 16th
8) Eric needs a black and white copy of report on e week before presentation
9) Don’t wear a suit to the presentation
Appendix B – Important Documents

B1 – Waiver of Liability

Queen’s Physical Plant Services (the Client) understands that the purpose of Technology, Engineering and Management (the Program) is to provide students with a unique educational experience and the Client is willing to participate in that experience by providing students in the Program with an opportunity to analyze problems in its workplace and develop solutions. The Client waives any and all claims it may have against Queen's University, its students, agents and staff (Queen's) for losses or damages it may incur due to its participation in the Program and releases Queen's from all liability for any such damage.

ERIC NEUMANN

Client Representative (please print):

Signature:

JAN 14/04

Date:
Dear Mr. Neuman,

In order to fulfill the requirements of the APSC 400 course, our team, whose members are Andrew Follwell, Luke Follwell, Steve Orchard, and Rob Short, will be working in conjunction with Queen’s Physical Plant Services to evaluate the feasibility of a “Vent Mizer” system for the Central Heating Plant. Our principal objectives will be to determine if this device will cause damage to existing equipment, and if not, the amount of steam it will recover and the savings incurred.

Any information that you disclose will be kept confidential, unless you specify otherwise. Similarly, we will provide you with all new information that we obtain from the “Vent Mizer” designer, RCD Engineering, as well as from their customers and any other relevant sources.

We have already initiated several steps necessary to achieving our objectives. We have conferred with Graham Robertson, who gave us a tour of the Central Heating Plant, and explained its operation in detail. We are in the process of arranging a meeting with Peter Tung, the President of RCD Engineering, or with one of his associates, to obtain additional background, to observe how calculations were conducted and how conclusions were reached. We also intend to contact the Hospital in Hamilton where a “Vent Mizer” has been installed and the Chief Engineer at the University of Guelph, who declined to implement the system. Furthermore, there may be a brewery that is equipped with “Vent Mizer”, and we will contact the appropriate person if in fact the device is in use. We will also speak to representatives from any other companies or institutions that we discover who have, or have considered installing a “Vent Mizer” system. After analyzing the evidence presented to us, we will recommend to Queen’s Physical Plant Services whether or not they should purchase the mechanism.

This venture will be supervised by the Department of Chemical Engineering, mainly by Ms. Annette Bergeron and Dr. Barrie Jackson. If you wish to get in touch with us please contact Steve Orchard by email, 9so@qlink.queensu.ca, or by phone, (613) 546-5449. With regard to finances, we ask that Queen’s Physical Plant Services cover any costs incurred by providing an up front payment. Our projected budget for travel, communications, report and presentation preparation, and program expense is about $925. Andrew Follwell will serve as team treasurer, and he will provide you with a tax number to allow Queen’s Physical Plant Services to claim this fee as a charitable donation.

We also wish to request your participation in this project. We encourage you to provide input, to raise questions or concerns you may have, and also to allot time for us to present our findings. We would also appreciate access to any relevant material that you have available.

January 14, 2004

B2 – Project Proposal

Attn: Mr. Eric Neuman, MSc, PEng
Physical Plant Services
Rideau Building, 207 Stuart Street
Queen’s University
Kingston, ON
K7L 3N6

January 14, 2004

Dear Mr. Neuman,

In order to fulfill the requirements of the APSC 400 course, our team, whose members are Andrew Follwell, Luke Follwell, Steve Orchard, and Rob Short, will be working in conjunction with Queen’s Physical Plant Services to evaluate the feasibility of a “Vent Mizer” system for the Central Heating Plant. Our principal objectives will be to determine if this device will cause damage to existing equipment, and if not, the amount of steam it will recover and the savings incurred.

Any information that you disclose will be kept confidential, unless you specify otherwise. Similarly, we will provide you with all new information that we obtain from the “Vent Mizer” designer, RCD Engineering, as well as from their customers and any other relevant sources.

We have already initiated several steps necessary to achieving our objectives. We have conferred with Graham Robertson, who gave us a tour of the Central Heating Plant, and explained its operation in detail. We are in the process of arranging a meeting with Peter Tung, the President of RCD Engineering, or with one of his associates, to obtain additional background, to observe how calculations were conducted and how conclusions were reached. We also intend to contact the Hospital in Hamilton where a “Vent Mizer” has been installed and the Chief Engineer at the University of Guelph, who declined to implement the system. Furthermore, there may be a brewery that is equipped with “Vent Mizer”, and we will contact the appropriate person if in fact the device is in use. We will also speak to representatives from any other companies or institutions that we discover who have, or have considered installing a “Vent Mizer” system. After analyzing the evidence presented to us, we will recommend to Queen’s Physical Plant Services whether or not they should purchase the mechanism.

This venture will be supervised by the Department of Chemical Engineering, mainly by Ms. Annette Bergeron and Dr. Barrie Jackson. If you wish to get in touch with us please contact Steve Orchard by email, 9so@qlink.queensu.ca, or by phone, (613) 546-5449. With regard to finances, we ask that Queen’s Physical Plant Services cover any costs incurred by providing an up front payment. Our projected budget for travel, communications, report and presentation preparation, and program expense is about $925. Andrew Follwell will serve as team treasurer, and he will provide you with a tax number to allow Queen’s Physical Plant Services to claim this fee as a charitable donation.

We also wish to request your participation in this project. We encourage you to provide input, to raise questions or concerns you may have, and also to allot time for us to present our findings. We would also appreciate access to any relevant material that you have available.

January 14, 2004

Dear Mr. Neuman,

In order to fulfill the requirements of the APSC 400 course, our team, whose members are Andrew Follwell, Luke Follwell, Steve Orchard, and Rob Short, will be working in conjunction with Queen’s Physical Plant Services to evaluate the feasibility of a “Vent Mizer” system for the Central Heating Plant. Our principal objectives will be to determine if this device will cause damage to existing equipment, and if not, the amount of steam it will recover and the savings incurred.

Any information that you disclose will be kept confidential, unless you specify otherwise. Similarly, we will provide you with all new information that we obtain from the “Vent Mizer” designer, RCD Engineering, as well as from their customers and any other relevant sources.

We have already initiated several steps necessary to achieving our objectives. We have conferred with Graham Robertson, who gave us a tour of the Central Heating Plant, and explained its operation in detail. We are in the process of arranging a meeting with Peter Tung, the President of RCD Engineering, or with one of his associates, to obtain additional background, to observe how calculations were conducted and how conclusions were reached. We also intend to contact the Hospital in Hamilton where a “Vent Mizer” has been installed and the Chief Engineer at the University of Guelph, who declined to implement the system. Furthermore, there may be a brewery that is equipped with “Vent Mizer”, and we will contact the appropriate person if in fact the device is in use. We will also speak to representatives from any other companies or institutions that we discover who have, or have considered installing a “Vent Mizer” system. After analyzing the evidence presented to us, we will recommend to Queen’s Physical Plant Services whether or not they should purchase the mechanism.

This venture will be supervised by the Department of Chemical Engineering, mainly by Ms. Annette Bergeron and Dr. Barrie Jackson. If you wish to get in touch with us please contact Steve Orchard by email, 9so@qlink.queensu.ca, or by phone, (613) 546-5449. With regard to finances, we ask that Queen’s Physical Plant Services cover any costs incurred by providing an up front payment. Our projected budget for travel, communications, report and presentation preparation, and program expense is about $925. Andrew Follwell will serve as team treasurer, and he will provide you with a tax number to allow Queen’s Physical Plant Services to claim this fee as a charitable donation.

We also wish to request your participation in this project. We encourage you to provide input, to raise questions or concerns you may have, and also to allot time for us to present our findings. We would also appreciate access to any relevant material that you have available.

January 14, 2004

Dear Mr. Neuman,

In order to fulfill the requirements of the APSC 400 course, our team, whose members are Andrew Follwell, Luke Follwell, Steve Orchard, and Rob Short, will be working in conjunction with Queen’s Physical Plant Services to evaluate the feasibility of a “Vent Mizer” system for the Central Heating Plant. Our principal objectives will be to determine if this device will cause damage to existing equipment, and if not, the amount of steam it will recover and the savings incurred.

Any information that you disclose will be kept confidential, unless you specify otherwise. Similarly, we will provide you with all new information that we obtain from the “Vent Mizer” designer, RCD Engineering, as well as from their customers and any other relevant sources.

We have already initiated several steps necessary to achieving our objectives. We have conferred with Graham Robertson, who gave us a tour of the Central Heating Plant, and explained its operation in detail. We are in the process of arranging a meeting with Peter Tung, the President of RCD Engineering, or with one of his associates, to obtain additional background, to observe how calculations were conducted and how conclusions were reached. We also intend to contact the Hospital in Hamilton where a “Vent Mizer” has been installed and the Chief Engineer at the University of Guelph, who declined to implement the system. Furthermore, there may be a brewery that is equipped with “Vent Mizer”, and we will contact the appropriate person if in fact the device is in use. We will also speak to representatives from any other companies or institutions that we discover who have, or have considered installing a “Vent Mizer” system. After analyzing the evidence presented to us, we will recommend to Queen’s Physical Plant Services whether or not they should purchase the mechanism.

This venture will be supervised by the Department of Chemical Engineering, mainly by Ms. Annette Bergeron and Dr. Barrie Jackson. If you wish to get in touch with us please contact Steve Orchard by email, 9so@qlink.queensu.ca, or by phone, (613) 546-5449. With regard to finances, we ask that Queen’s Physical Plant Services cover any costs incurred by providing an up front payment. Our projected budget for travel, communications, report and presentation preparation, and program expense is about $925. Andrew Follwell will serve as team treasurer, and he will provide you with a tax number to allow Queen’s Physical Plant Services to claim this fee as a charitable donation.

We also wish to request your participation in this project. We encourage you to provide input, to raise questions or concerns you may have, and also to allot time for us to present our findings. We would also appreciate access to any relevant material that you have available.
We will contact you promptly by telephone to confirm that you are satisfied with our proposal, and that we have a mutual understanding of the objectives for this investigation. We will do our best to exceed your expectations, and we look forward to working with you.

Sincerely,

Andrew Follwell       Luke Follwell       Steve Orchard       Rob Short
Appendix C – Actual Expenses

Stationary and other Supplies January 2003

Travel Expenses from Feb 5-6 in Hamilton

<table>
<thead>
<tr>
<th>Food</th>
<th>$163.33</th>
<th>Hotel</th>
<th>$100.67</th>
<th>Gas</th>
<th>$56.49</th>
<th>Parking</th>
<th>$13.50</th>
</tr>
</thead>
<tbody>
<tr>
<td>McDonalds</td>
<td>$16.96</td>
<td>Hojo</td>
<td>$100.67</td>
<td>Napanee</td>
<td>$47.27</td>
<td>Toronto</td>
<td>$1.50</td>
</tr>
<tr>
<td>Hamilton General</td>
<td>$6.63</td>
<td></td>
<td></td>
<td>kingston</td>
<td>$9.22</td>
<td>Hamilton Hospital</td>
<td>$6.00</td>
</tr>
<tr>
<td>Subway</td>
<td>$25.49</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Misc</td>
<td>$6.00</td>
</tr>
<tr>
<td>Hooters</td>
<td>$70.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Esso</td>
<td>$10.91</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>McDonalds</td>
<td>$23.72</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pizza Pizza</td>
<td>$9.62</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total $34.26

Total 333.99
Appendix D – Proposed Timeline Gantt Chart
Appendix E - Deaerator Component Description
# Appendix F - Deaerator General Notes and Vessel Data

## KSANS CITY DEAERATOR COMPANY
### MODEL DS
#### General Notes & Vessel Data

<table>
<thead>
<tr>
<th>Project Name:</th>
<th>Queen's University</th>
<th>KCD Job #:</th>
<th>981332</th>
<th>Doc. Name:</th>
<th>GA13321</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Location:</td>
<td>Kingston, Ontario</td>
<td>Designed By:</td>
<td>DS</td>
<td>Date:</td>
<td>3-17-98</td>
</tr>
<tr>
<td>Customer Name:</td>
<td>Thermal &amp; Hydraulic Equipment</td>
<td>Project Number:</td>
<td>2952</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### REVISIONS

<table>
<thead>
<tr>
<th>Rev. #</th>
<th>Date</th>
<th>Description of Change</th>
<th>By</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4-20-98</td>
<td>REVISED SUPPORT DETAIL DRAWING 2</td>
<td>BA</td>
</tr>
<tr>
<td>2</td>
<td>5-14-98</td>
<td>REVISED NOTE 14 &amp; 35, DELETED NOTE 16</td>
<td>BA</td>
</tr>
</tbody>
</table>

### VESSEL DESIGN

<table>
<thead>
<tr>
<th>DESIGN</th>
<th>HEATER</th>
<th>STORAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODEL</td>
<td>DS300</td>
<td>5017.83</td>
</tr>
<tr>
<td>ASME CODE</td>
<td>SECTION VIII, DIV 1</td>
<td>SECTION VIII, DIV 1</td>
</tr>
<tr>
<td>T.E.L</td>
<td>HEI 1963 EDITION</td>
<td>HEI 1963 EDITION</td>
</tr>
</tbody>
</table>

| DESIGN PRESS (psig) | 30 | 30 |
| VACUUM DESIGN | PV | PV |
| DESIGN TEMP (F) | 370 | 390 |
| G. A. PRESS (in) | 0.125 | 0.125 |
| G. A. VAC. (in) | 0.125 | 0.125 |
| SEISMIC (UBC) | UBC | UBC |
| WIND LOAD (UBC) | UBC | UBC |
| SADDLE EXP. (in) | NA | 0.246 |

### TESTING

<table>
<thead>
<tr>
<th>TESTING</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>HYDRO PRESS (psig)</td>
<td>45</td>
</tr>
<tr>
<td>PWP</td>
<td>1 STAGE</td>
</tr>
<tr>
<td>WMP</td>
<td>INT. WELDS (SEE NOTE 35)</td>
</tr>
<tr>
<td>XRAY (U.E) SHELL</td>
<td>RT-3</td>
</tr>
<tr>
<td>XRAY (U.E) HEAD</td>
<td>RT-3</td>
</tr>
</tbody>
</table>

### MISCELLANEOUS DETAILS

<table>
<thead>
<tr>
<th>MISCELLANEOUS DETAILS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SURFACE PREP INT.</td>
<td>SP-3</td>
</tr>
<tr>
<td>INTERNAL</td>
<td>NONE</td>
</tr>
<tr>
<td>SURFACE PREP EXT.</td>
<td>SP-5</td>
</tr>
<tr>
<td>EXTERNAL</td>
<td>RED OXIDE PRIME</td>
</tr>
</tbody>
</table>

### PERFORMANCE

<table>
<thead>
<tr>
<th>PERFORMANCE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPACITY (MMH)</td>
<td></td>
</tr>
<tr>
<td>OUTLET</td>
<td>300,000</td>
</tr>
<tr>
<td>STEAM (MAX)</td>
<td>30,000</td>
</tr>
<tr>
<td>INLET FLOW</td>
<td>266,372</td>
</tr>
</tbody>
</table>

### CAPACITY (GAL)

<table>
<thead>
<tr>
<th>STORAGE (GAL)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>OVERFLOW LEVEL AT 83 INCHES</td>
<td>6,972</td>
</tr>
<tr>
<td>HIGH HIGH LEVEL AT 78 INCHES</td>
<td>6,678</td>
</tr>
<tr>
<td>NORMAL LEVEL AT 60 INCHES</td>
<td>5,952</td>
</tr>
<tr>
<td>LOW LEVEL AT 19 INCHES</td>
<td>1,028</td>
</tr>
</tbody>
</table>

### PERFORMANCE GUARANTEE

<table>
<thead>
<tr>
<th>PERFORMANCE GUARANTEE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>OXYGEN EFFLUENT</td>
<td>0.5 co</td>
</tr>
<tr>
<td>FREE CO2</td>
<td>2</td>
</tr>
<tr>
<td>SPRAY VALVES</td>
<td>8</td>
</tr>
<tr>
<td>PRESSURE DROP</td>
<td>2.3 psi</td>
</tr>
</tbody>
</table>

### TRAYS

<table>
<thead>
<tr>
<th>TRAYS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SIZE</td>
<td>50</td>
</tr>
<tr>
<td>NO. OF ASSEMBLIES</td>
<td>60</td>
</tr>
<tr>
<td>NO. OF CHANNELS</td>
<td>640</td>
</tr>
<tr>
<td>TRAY VOLUME (IN PER 1992 HEI)</td>
<td>105,690</td>
</tr>
<tr>
<td>TRAY CONFIGURATION</td>
<td>2x3x8</td>
</tr>
</tbody>
</table>
**VESSSEL DATA (CONTINUED)**

<table>
<thead>
<tr>
<th>PHYSICAL DATA</th>
<th>DRAWING REFERENCES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HEATER</strong></td>
<td><strong>DRAWING NO.</strong></td>
</tr>
<tr>
<td><strong>STORAGE</strong></td>
<td></td>
</tr>
<tr>
<td>DIAMETER (in)</td>
<td>9.00</td>
</tr>
<tr>
<td>SHELL LENGTH (ft)</td>
<td>7.00</td>
</tr>
<tr>
<td>TYPE OF HEADS</td>
<td>FLD</td>
</tr>
<tr>
<td>HEAD THICKNESS</td>
<td>1/2</td>
</tr>
<tr>
<td>SHELL THICKNESS</td>
<td>1/2</td>
</tr>
<tr>
<td>VACUUM RINGS</td>
<td>0</td>
</tr>
<tr>
<td>LIFTING LUGS</td>
<td>INCLUDED</td>
</tr>
<tr>
<td>INSULATION CUPS</td>
<td>NONE</td>
</tr>
<tr>
<td>WEIGHTS (lb)</td>
<td></td>
</tr>
<tr>
<td>EMPTY</td>
<td>11,500</td>
</tr>
<tr>
<td>OPERATING</td>
<td>14,000</td>
</tr>
<tr>
<td>FLOODED</td>
<td>49,000</td>
</tr>
<tr>
<td>TOTAL FLOODED</td>
<td>152,000</td>
</tr>
</tbody>
</table>

**MATERIALS**

<table>
<thead>
<tr>
<th>VESSEL</th>
<th>SADDLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRAYS</td>
<td>A-516-70</td>
</tr>
<tr>
<td>430 SS 16 GAUGE</td>
<td>3/6 or SA-516-70</td>
</tr>
<tr>
<td>TRAY ENCLOSURE</td>
<td>VENT CONDENSER AREA</td>
</tr>
<tr>
<td>1/8&quot; 304 L SS</td>
<td>6&quot; 304 L SS</td>
</tr>
<tr>
<td>HEADER</td>
<td>PIPE / NOZZLES</td>
</tr>
<tr>
<td>1/4&quot; 304 SS 6&quot; DIAMETER</td>
<td>1/4&quot; x 1/2 &quot;</td>
</tr>
<tr>
<td>SPRAY VALVES</td>
<td>A-516-70</td>
</tr>
<tr>
<td>316 SS</td>
<td></td>
</tr>
</tbody>
</table>

**GENERAL NOTES**

1. If any discrepancy arises within the Kansas City Desalinator drawings/documents or between KCD drawings/documents and any customer specifications, the vessel fabricator is to inform KCD, in writing, of such a discrepancy. Customer specifications shall govern except where KCD requirements are more stringent. The vessel fabricator is to obtain written approval from KCD to clarify the discrepancy.

2. Unless noted otherwise, all flange bolting shall straddle natural centerline. All fabrication is to be within +/- 1/8" tolerance unless otherwise required per customer specification.

3. All pressure-retaining welds are to be full penetration.

4. The fabricator is to clean the interior of the vessel thoroughly after surface preparation.

5. All manway gaskets are to be provided by the shop prior to shipment. Asbestos and rubber gaskets are prohibited.

6. All nozzles and openings are to be properly sealed prior to shipment to prevent moisture intrusion.

7. All accessories and materials that are to be supplied by Kansas City Desalinator Company and the KCD fabricator are listed on the KCD bill of materials.
Appendix G - Queen’s University Heating Plant Schematic
Appendix H - Central Heating Plant Images

H1 – Steam Exhaust Images

A

B

C

D

E

F
H2 – Pump Room Images

A

B

C

D

E

F
# Appendix I - Sample Operating Tables for Queen’s CHP

## Central Heating Plant -113

<table>
<thead>
<tr>
<th>Date</th>
<th>Meter Readings</th>
<th>Consumption</th>
<th>Service Charges ($)</th>
<th>Total ($)</th>
<th>Unit ($/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>02 Apr</td>
<td>525,495</td>
<td>Yr. Mo.</td>
<td>52 30</td>
<td>52,495</td>
<td>1.04</td>
</tr>
<tr>
<td>02 May</td>
<td>532,036</td>
<td>02 Apr-30</td>
<td>53 31</td>
<td>53,203.6</td>
<td>1.04</td>
</tr>
<tr>
<td>02 Jun</td>
<td>533,762</td>
<td>02 May-31</td>
<td>54 31</td>
<td>53,376.2</td>
<td>1.04</td>
</tr>
<tr>
<td>02 Jul</td>
<td>536,445</td>
<td>02 Jun-31</td>
<td>55 31</td>
<td>53,644.5</td>
<td>1.04</td>
</tr>
<tr>
<td>02 Aug</td>
<td>538,063</td>
<td>02 Jul-31</td>
<td>56 31</td>
<td>53,806.3</td>
<td>1.04</td>
</tr>
<tr>
<td>02 Sep</td>
<td>544,338</td>
<td>02 Aug-31</td>
<td>57 31</td>
<td>544,338</td>
<td>1.04</td>
</tr>
<tr>
<td>02 Oct</td>
<td>553,172</td>
<td>02 Sep-31</td>
<td>58 31</td>
<td>553,172</td>
<td>1.04</td>
</tr>
<tr>
<td>02 Nov</td>
<td>556,983</td>
<td>02 Oct-31</td>
<td>59 31</td>
<td>556,983</td>
<td>1.04</td>
</tr>
<tr>
<td>02 Dec</td>
<td>566,368</td>
<td>02 Nov-31</td>
<td>60 31</td>
<td>566,368</td>
<td>1.04</td>
</tr>
<tr>
<td>03 Jan</td>
<td>572,616</td>
<td>02 Dec-31</td>
<td>61 31</td>
<td>572,616</td>
<td>1.04</td>
</tr>
<tr>
<td>03 Feb</td>
<td>603,140</td>
<td>03 Jan-31</td>
<td>62 31</td>
<td>603,140</td>
<td>1.04</td>
</tr>
<tr>
<td>03 Mar</td>
<td>611,831</td>
<td>03 Feb-31</td>
<td>63 31</td>
<td>611,831</td>
<td>1.04</td>
</tr>
<tr>
<td>03 Apr</td>
<td>622,442</td>
<td>03 Mar-31</td>
<td>64 31</td>
<td>622,442</td>
<td>1.04</td>
</tr>
<tr>
<td>Total</td>
<td>367</td>
<td>03 Apr-31</td>
<td>65 31</td>
<td>367,000</td>
<td>1.04</td>
</tr>
<tr>
<td>2002</td>
<td>41,070</td>
<td>03 Apr-31</td>
<td>66 31</td>
<td>41,070</td>
<td>1.04</td>
</tr>
<tr>
<td>2003</td>
<td>55,074</td>
<td>03 Apr-31</td>
<td>67 31</td>
<td>55,074</td>
<td>1.04</td>
</tr>
<tr>
<td>May-Oct</td>
<td>27,677</td>
<td>03 Apr-31</td>
<td>68 31</td>
<td>27,677</td>
<td>1.04</td>
</tr>
<tr>
<td>Nov-April</td>
<td>69,274</td>
<td>03 Apr-31</td>
<td>69 31</td>
<td>69,274</td>
<td>1.04</td>
</tr>
<tr>
<td>Average</td>
<td>7,996</td>
<td>03 Apr-31</td>
<td>70 31</td>
<td>7,996</td>
<td>1.04</td>
</tr>
</tbody>
</table>

**NOTES:**

1. Meter Number W20805
2. Meter Size = 6" (150 mm)
3. Commercial Rates
4. Water Rate Block 1 50 0.4300
5. Water Rate Block 2 850 0.3250
6. Sewer Rate Block 1 50 0.4102
7. Sewer Rate Block 2 850 0.3821
8. Water Basic Charge 2.497 vbca $2.78
9. Sewer Basic Charge 10.157 sbca 18.97133
### I2 – Detailed Steam Consumption and Production from April 2003

<table>
<thead>
<tr>
<th>FOR April 2003</th>
<th>This Month’s Statistics</th>
<th>Year To Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Condensate Return</td>
<td>Steam Distributed</td>
</tr>
<tr>
<td></td>
<td>(pounds)</td>
<td>(%)</td>
</tr>
<tr>
<td><strong>WEST LINE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. Mary's Hosp.</td>
<td>1</td>
<td>2,173,000</td>
</tr>
<tr>
<td>Queen's West</td>
<td>2</td>
<td>17,375,584</td>
</tr>
<tr>
<td><strong>Total West Line</strong></td>
<td>3</td>
<td>19,548,584</td>
</tr>
<tr>
<td><strong>EAST LINE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waldron Towers</td>
<td>4</td>
<td>600,600</td>
</tr>
<tr>
<td>Louise D. Acton</td>
<td>5</td>
<td>281,700</td>
</tr>
<tr>
<td>Cancer Research</td>
<td>6</td>
<td>460,300</td>
</tr>
<tr>
<td>Botterell Hall</td>
<td>7</td>
<td>2,405,000</td>
</tr>
<tr>
<td>Biosciences Line</td>
<td>8</td>
<td>2,531,000</td>
</tr>
<tr>
<td>Burr Wing</td>
<td>9</td>
<td>622,436</td>
</tr>
<tr>
<td>Hotel Dieu Hosp.</td>
<td>10</td>
<td>3,870,336</td>
</tr>
<tr>
<td><strong>Total East Line</strong></td>
<td>11</td>
<td>10,771,372</td>
</tr>
<tr>
<td><strong>CENTRAL</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Queen's</td>
<td>12</td>
<td>10,307,460</td>
</tr>
<tr>
<td>K.G.H.</td>
<td>13</td>
<td>8,429,000</td>
</tr>
<tr>
<td><strong>K.G.H. Total = 9 + 13</strong></td>
<td>14</td>
<td>9,051,436</td>
</tr>
<tr>
<td>Queen's Total = 2+4+5+6+7+8+12</td>
<td>15</td>
<td>33,961,644</td>
</tr>
<tr>
<td><strong>Total Distributed = 3+11+12+13</strong></td>
<td>16</td>
<td>49,056,416</td>
</tr>
<tr>
<td><strong>Total Produced</strong></td>
<td>17</td>
<td>66,473,984</td>
</tr>
<tr>
<td>Efficiency</td>
<td>18</td>
<td>86.1</td>
</tr>
</tbody>
</table>

### FUEL CONSUMPTION

<table>
<thead>
<tr>
<th></th>
<th>This Year</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Consumed</td>
<td>755</td>
<td>9,860</td>
</tr>
<tr>
<td>No. 2 Oil Consumed</td>
<td>(m³)</td>
<td>(m³)</td>
</tr>
<tr>
<td>No. 4 Oil Delivered</td>
<td>2,089,690</td>
<td>-</td>
</tr>
<tr>
<td>MAKE UP WATER ADDED</td>
<td>11.3</td>
<td>%</td>
</tr>
</tbody>
</table>

### HEATING DEGREE DAYS (Below 18°C)

<table>
<thead>
<tr>
<th>Year</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>This Year</td>
<td>425.5</td>
</tr>
<tr>
<td>Normal</td>
<td>343.3</td>
</tr>
</tbody>
</table>

1. Heating Value for #4 Oil = 178,000 BTU/IG = 39,207 BTU/L
2. Heating Value for Gas = 1,000 BTU/cf = 35,314 BTU/cu.m.
3. 1,000 BTU's required to produce 1 pound of steam
4. Plant Efficiency 15/16 X 100
5. St. Mary's steam is based on condensate returns + 15% as per contract
6. Waldon Tower, Botterell Hall and LD Acton and Cancer Research steam consumption is based on condensate return
7. Burr Wing meters 0.0.0 - steam and condensate estimated
Appendix J - Vent Mizer Images at Hamilton General

A

B

C

D

E

F
Appendix K - Queen’s University Deaerator Images

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>E</td>
<td>F</td>
</tr>
</tbody>
</table>
Appendix L – Pro II Output

$ Generated by PRO/II Keyword Generation System <version 6.01>
$ Generated on: Thu Apr 15 17:26:16 2004
TITLE
PRINT STREAM=ALL, RATE=M
SEQUENCE SIMSCI
COMPONENT DATA
LIBID 1,OXYGEN/2,WATER
THERMODYNAMIC DATA
METHOD SYSTEM=SRK, SET=SRK01
METHOD SYSTEM(VLLE)=SRKK, SET=SRKK01
METHOD SYSTEM=SRK, SET=SRK02
METHOD SYSTEM=NRTL, HENRY, SET=NRTL01, DEFAULT
STREAM DATA
PROPERTY STREAM=WATER, TEMPERATURE=39.999, PRESSURE=20, PHASE=M, &
COMPOSITION(LV,FT3/H)=2,5
PROPERTY STREAM=LPSTEAM, PRESSURE=25, PHASE=V, RATE(WT)=1000, &
COMPOSITION(M)=1,0.005/2,999.005, NORMALIZE
UNIT OPERATIONS
COLUMN UID=T1
PARAMETER TRAY=5,IO
FEED WATER,1/LPSTEAM,5, SEPARATE
PRODUCT OVHD(M)=VENT,25, BTMS(M)=CONDENSATE,395
DUTY 1,3,0.05, SIDEHC1
PSPEC PTOP=15
PRINT PROPTABLE=PART
END

=== PROBLEM SOLUTION BEGINS ===
FEED FLASH    COMPLETE
*** PROBLEM SOLUTION REACHED

*** THIS RUN USED 11.31 PRO/II SIMULATION UNITS

*** RUN STATISTICS
STARTED  17:26:01 04/15/04       NO ERRORS
FINISHED  17:26:14 04/15/04       NO WARNINGS
RUN TIMES
INTERACTIVE  0 MIN, 12.00 SEC
CALCULATIONS  0 MIN, 0.37 SEC
TOTAL       0 MIN, 12.37 SEC
COMPONENT DATA

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>COMP. TYPE</th>
<th>PHASE</th>
<th>MOL. WEIGHT</th>
<th>API</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>OXYGEN</td>
<td>LIBRARY</td>
<td>VAP/LIQ</td>
<td>31.999</td>
</tr>
<tr>
<td>2</td>
<td>WATER</td>
<td>LIBRARY</td>
<td>VAP/LIQ</td>
<td>18.015</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>NBP</th>
<th>CRIT. TEMP.</th>
<th>CRIT. PRES.</th>
<th>CRIT. VOLM.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>OXYGEN</td>
<td>-297.364</td>
<td>-181.120</td>
<td>736.266</td>
</tr>
<tr>
<td>2</td>
<td>WATER</td>
<td>212.000</td>
<td>705.560</td>
<td>3208.117</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>ACEN. FACT.</th>
<th>HEAT FORM.</th>
<th>G FORM.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>OXYGEN</td>
<td>0.01900</td>
<td>0.00</td>
</tr>
<tr>
<td>2</td>
<td>WATER</td>
<td>0.34800</td>
<td>-104039.98</td>
</tr>
</tbody>
</table>

CALCULATION SEQUENCE

SEQ | UNIT ID | UNIT TYPE
--- | -------- | -------
1   | T1       | COLUMN
UNIT 1, 'T1'

TOTAL NUMBER OF ITERATIONS

IN/OUT METHOD 5

COLUMN SUMMARY

<table>
<thead>
<tr>
<th>TRAY</th>
<th>TEMP (DEG F)</th>
<th>PRESSURE (PSIA)</th>
<th>LIQUID (LB-MOL/HR)</th>
<th>VAPOR (LB-MOL/HR)</th>
<th>FEED (LB-MOL/HR)</th>
<th>PRODUCT (LB-MOL/HR)</th>
<th>HEATER (MM BTU/HR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>213.0</td>
<td>15.00</td>
<td>20.4</td>
<td>17.3L</td>
<td>55.8V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>213.0</td>
<td>15.00</td>
<td>20.4</td>
<td>58.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>213.0</td>
<td>15.00</td>
<td>17.5</td>
<td>58.9</td>
<td></td>
<td>0.0500</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>213.0</td>
<td>15.00</td>
<td>17.5</td>
<td>56.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>213.0</td>
<td>15.00</td>
<td>56.0</td>
<td>55.5V</td>
<td>17.0L</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FEED AND PRODUCT STREAMS

<table>
<thead>
<tr>
<th>TYPE</th>
<th>STREAM</th>
<th>PHASE</th>
<th>FROM TRAY</th>
<th>TO TRAY</th>
<th>LIQUID FRACTION</th>
<th>LIQUID FLOW RATES (LB-MOL/HR)</th>
<th>HEAT RATES (MM BTU/HR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEED</td>
<td>WATER</td>
<td>LIQUID</td>
<td>1</td>
<td>1</td>
<td>1.0000</td>
<td>17.30</td>
<td>0.0025</td>
</tr>
<tr>
<td>FEED</td>
<td>LPSTEAM</td>
<td>VAPOR</td>
<td>5</td>
<td>0</td>
<td>0.0000</td>
<td>55.51</td>
<td>1.1609</td>
</tr>
<tr>
<td>PROD</td>
<td>VENT</td>
<td>VAPOR</td>
<td>1</td>
<td></td>
<td></td>
<td>55.82</td>
<td>1.1580</td>
</tr>
<tr>
<td>PROD</td>
<td>CONDENSATE</td>
<td>LIQUID</td>
<td>5</td>
<td></td>
<td></td>
<td>16.99</td>
<td>0.0554</td>
</tr>
</tbody>
</table>

OVERALL MOLE BALANCE, (FEEDS - PRODUCTS) -2.4094E-14
OVERALL HEAT BALANCE, (H(IN) - H(OUT)) 1.4674E-06
**UNIT 1, 'T1' (Cont)**

### TRAY NET VAPOR RATES AND DENSITIES

<table>
<thead>
<tr>
<th>TRAY</th>
<th>MW</th>
<th>ACTUAL DENS</th>
<th>Z FROM</th>
<th>STANDARD</th>
<th>ACTUAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LB/FT³</td>
<td>DENSITY</td>
<td>M LB/HR</td>
<td>M FT³/HR</td>
</tr>
<tr>
<td>1</td>
<td>18.015</td>
<td>0.03743</td>
<td>1.00000</td>
<td>1.006</td>
<td>21.184</td>
</tr>
<tr>
<td>2</td>
<td>18.015</td>
<td>0.03743</td>
<td>1.00000</td>
<td>1.061</td>
<td>22.355</td>
</tr>
<tr>
<td>3</td>
<td>18.015</td>
<td>0.03743</td>
<td>1.00000</td>
<td>1.061</td>
<td>22.355</td>
</tr>
<tr>
<td>4</td>
<td>18.015</td>
<td>0.03743</td>
<td>1.00000</td>
<td>1.010</td>
<td>21.270</td>
</tr>
<tr>
<td>5</td>
<td>18.015</td>
<td>0.03743</td>
<td>1.00000</td>
<td>1.010</td>
<td>21.270</td>
</tr>
</tbody>
</table>

### TRAY NET LIQUID RATES AND DENSITIES

<table>
<thead>
<tr>
<th>TRAY</th>
<th>MW</th>
<th>ACTUAL DENS</th>
<th>Z FROM</th>
<th>STD LIQ</th>
<th>ACTUAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LB/FT³</td>
<td>DENSITY</td>
<td>FT³/MIN</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>18.015</td>
<td>59.803</td>
<td>6.26E-04</td>
<td>0.367</td>
<td>5.892</td>
</tr>
<tr>
<td>2</td>
<td>18.015</td>
<td>59.803</td>
<td>6.26E-04</td>
<td>0.367</td>
<td>5.891</td>
</tr>
<tr>
<td>3</td>
<td>18.015</td>
<td>59.803</td>
<td>6.26E-04</td>
<td>0.316</td>
<td>5.065</td>
</tr>
<tr>
<td>4</td>
<td>18.015</td>
<td>59.803</td>
<td>6.26E-04</td>
<td>0.316</td>
<td>5.065</td>
</tr>
<tr>
<td>5</td>
<td>18.015</td>
<td>59.803</td>
<td>6.26E-04</td>
<td>0.306</td>
<td>4.909</td>
</tr>
</tbody>
</table>

**STREAM ID**

<table>
<thead>
<tr>
<th>NAME</th>
<th>CONDENSATE</th>
<th>LPSTEAM</th>
<th>VENT</th>
<th>WATER</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHASE</td>
<td>LIQUID</td>
<td>VAPOR</td>
<td>VAPOR</td>
<td>LIQUID</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FLUID RATES, LB-MOL/HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 OXYGEN</td>
</tr>
<tr>
<td>2 WATER</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TOTAL RATE, LB-MOL/HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.9873</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TEMPERATURE, F</th>
</tr>
</thead>
<tbody>
<tr>
<td>213.0201</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PRESSURE, PSIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.0000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ENTHALPY, MM BTU/HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0554</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MOLECULAR WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.0150</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MOLE FRAC VAPOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MOLE FRAC LIQUID</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0000</td>
</tr>
</tbody>
</table>
### STREAM SUMMARY

<table>
<thead>
<tr>
<th>STREAM ID</th>
<th>CONDENSATE</th>
<th>LPSTEAM</th>
<th>VENT</th>
<th>WATER</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHASE</td>
<td>LIQUID</td>
<td>VAPOR</td>
<td>VAPOR</td>
<td>LIQUID</td>
</tr>
<tr>
<td>-----  TOTAL STREAM -----</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RATE, LB-MOL/HR</td>
<td>16.987</td>
<td>55.509</td>
<td>55.824</td>
<td>17.302</td>
</tr>
<tr>
<td>M LB/HR</td>
<td>0.306</td>
<td>1.000</td>
<td>1.006</td>
<td>0.312</td>
</tr>
<tr>
<td>STD LIQ RATE, FT3/HR</td>
<td>4.909</td>
<td>16.041</td>
<td>16.132</td>
<td>5.000</td>
</tr>
<tr>
<td>TEMPERATURE, F</td>
<td>213.020</td>
<td>240.064</td>
<td>213.020</td>
<td>40.000</td>
</tr>
<tr>
<td>PRESSURE, PSIA</td>
<td>15.000</td>
<td>25.000</td>
<td>15.000</td>
<td>20.000</td>
</tr>
<tr>
<td>MOLECULAR WEIGHT</td>
<td>18.015</td>
<td>18.015</td>
<td>18.015</td>
<td>18.015</td>
</tr>
<tr>
<td>ENTHALPY, MM BTU/HR</td>
<td>5.541E-02</td>
<td>1.161</td>
<td>1.158</td>
<td>2.498E-03</td>
</tr>
<tr>
<td>BUTU/LB</td>
<td>181.055</td>
<td>1160.941</td>
<td>1151.504</td>
<td>8.013</td>
</tr>
<tr>
<td>MOLE FRACTION LIQUID</td>
<td>1.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>REDUCED TEMP (KAYS RULE)</td>
<td>0.5773</td>
<td>0.6005</td>
<td>0.5773</td>
<td>0.4288</td>
</tr>
<tr>
<td>PRES (KAYS RULE)</td>
<td>4.6756E-03</td>
<td>7.7928E-03</td>
<td>4.6757E-03</td>
<td>6.2342E-03</td>
</tr>
<tr>
<td>ACENTRIC FACTOR</td>
<td>0.3480</td>
<td>0.3480</td>
<td>0.3480</td>
<td>0.3480</td>
</tr>
<tr>
<td>WATSON K (UOPK)</td>
<td>8.762</td>
<td>8.761</td>
<td>8.761</td>
<td>8.762</td>
</tr>
<tr>
<td>SPECIFIC GRAVITY</td>
<td>0.9996</td>
<td>0.9996</td>
<td>0.9996</td>
<td>0.9996</td>
</tr>
</tbody>
</table>

--------  VAPOR --------

| RATE, LB-MOL/HR | N/A | 55.509 | 55.824 | N/A |
| M LB/HR | N/A | 1.000 | 1.006 | N/A |
| M FT3/HR | N/A | 16.673 | 26.866 | N/A |
| STD VAP RATE(1), M FT3/HR | N/A | 21.065 | 21.184 | N/A |
| SPECIFIC GRAVITY (AIR=1.0) | N/A | 0.622 | 0.622 | N/A |
| MOLECULAR WEIGHT | N/A | 18.015 | 18.015 | N/A |
| ENTHALPY, BTU/LB | N/A | 1160.941 | 1151.504 | N/A |
| CP, BTU/LB-F | N/A | 0.336 | 0.361 | N/A |
| DENSITY, LB/M FT3 | N/A | 59.976 | 37.432 | N/A |
| Z (FROM DENSITY) | N/A | 1.0000 | 1.0000 | N/A |

--------  LIQUID --------

| RATE, LB-MOL/HR | 16.987 | N/A | N/A | 17.302 |
| M LB/HR | 0.306 | N/A | N/A | 0.312 |
| FT3/HR | 5.117 | N/A | N/A | 4.986 |
| GAL/MIN | 0.638 | N/A | N/A | 0.622 |
| STD LIQ RATE, FT3/HR | 4.909 | N/A | N/A | 5.000 |
| SPECIFIC GRAVITY (H2O=1.0) | 0.9996 | N/A | N/A | 0.9996 |
| MOLECULAR WEIGHT | 18.015 | N/A | N/A | 18.015 |
| ENTHALPY, BTU/LB | 181.055 | N/A | N/A | 8.013 |
| CP, BTU/LB-F | 1.007 | N/A | N/A | 1.001 |
| DENSITY, LB/FT3 | 59.803 | N/A | N/A | 62.509 |
| Z (FROM DENSITY) | 6.2593E-04 | N/A | N/A | 1.0749E-03 |

(1) STANDARD VAPOR VOLUME IS 379.49 FT3/LB-MOLE (60 F AND 14.696 PSIA)