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# Mechanical Systems Assessment

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## Lorraine H. Morton Civic Center

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### August 26, 2019

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MECHANICAL SYSTEMS ASSESSMENT AND  
REVIEW OF UPGRADE ALTERNATIVES

Lorraine H. Morton Civic Center  
2100 Ridge Avenue  
Evanston, IL 60201

G/BA #P18-0349-00

August 26, 2019

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## Exhibits

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## EXECUTIVE SUMMARY

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This report has been prepared to establish replacement strategies and priorities for the mechanical systems and associated plumbing and electrical equipment at the Morton Civic Center in Evanston Illinois. The building's mechanical systems and equipment are a combination of older systems and equipment which predate the 1978 renovation as well as a heat pump system, installed in 1978, to provide air conditioning and mechanical ventilation to the building.

The heat pumps, piping, pumps, boilers, and controls are currently in poor condition and require significant time and effort from the building's operations staff to remain in service. This situation is exacerbated due to the condition of the circulating water system associated with the heat pumps. It is reported that water treatment of this system was neglected for many years. The system is currently treated with inhibitor and biocide, but the years of neglect have resulted in severe internal corrosion of the piping and significant quantities of precipitated products of corrosion which cause fouling of the heat pumps' internal heat exchangers.



**Figure 1 - Sediment taken from heat pump condenser coil**

Grumman/Butkus Associates (G/BA) provided a preliminary presentation to City personnel on November 15, 2018 which reviewed the findings of the investigation phase and presented five alternative strategies for the upgrade and/or replacement of the building's mechanical systems. Slides from that presentation are included in the appendix of this report. The following four strategies were selected for further development:

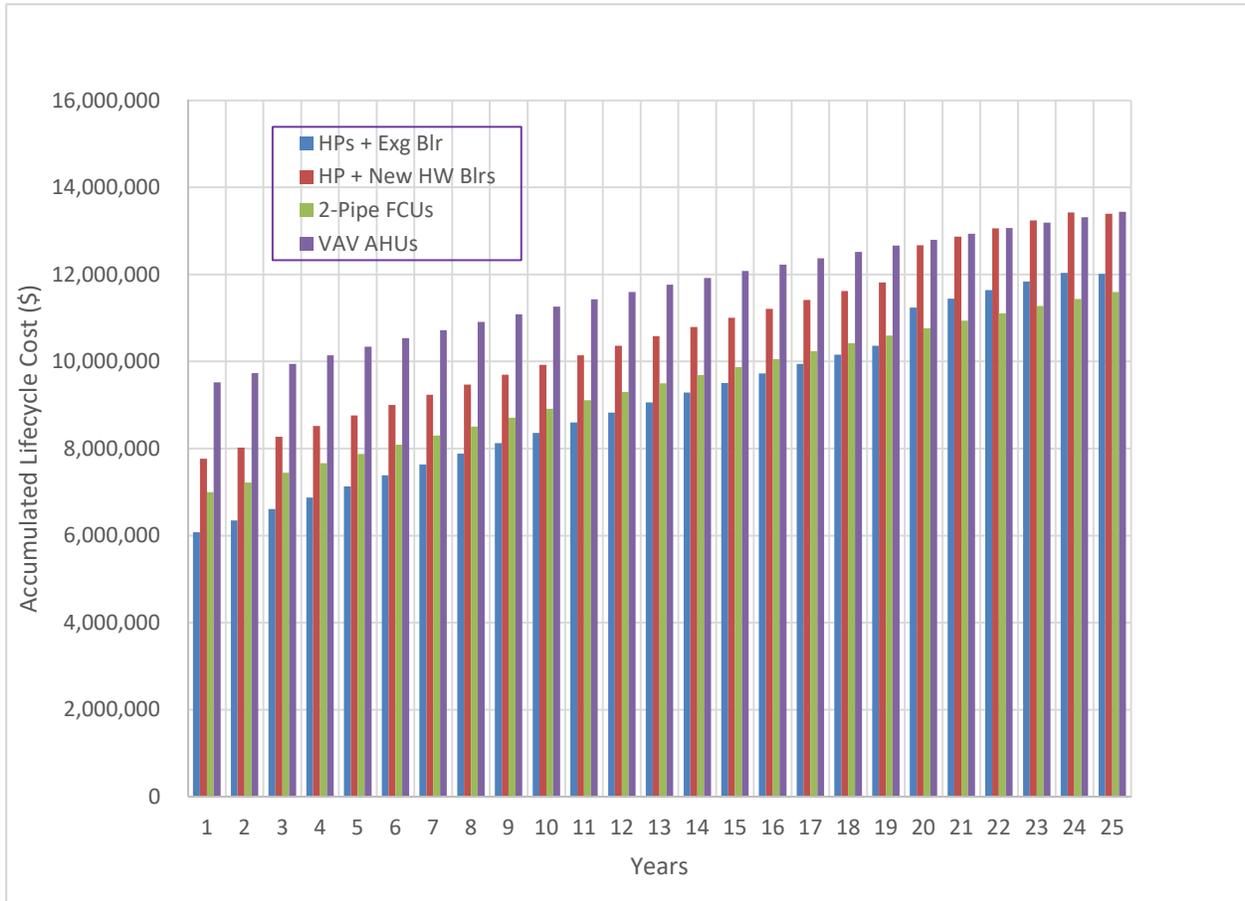
1. Sole source replacement of heat pumps in and refurbish existing piping and equipment. Replace ventilation units in attic.
2. Replace heat pumps with fan-coil units. This strategy would require a new hot water plant, chilled water plant, and replacement the neutral water piping system with a new insulated dual temperature piping system. Replace ventilation units in attic.
3. Replace heat pumps in kind and replace the entire steam heating system with a new hot water system, including boilers, pumps, piping, and convectors throughout the building. Replace ventilation units in attic.
4. Replace existing systems entirely with a new VAV air handling unit design. This strategy would require a new hot water plant, chilled water plant, and replacement of heat pumps with VAV terminal units with reheat coils.

Each of the options listed above are reviewed in this report, including a detailed description of the scope, advantages and disadvantages, an opinion of probable cost, estimated annual energy usage, and 25 year life-cycle costs. The cost estimates have been provided by Edwards Engineering working as a sub-consultant to G/BA. A 20% contingency has been added to the estimates.

A chart of the lifecycle costs associated with each option is provided below. Were the decision to be based solely upon lifecycle costs, Scheme 2 (replacement of the heat pumps with fan-coil units) would be slightly preferred. Other qualitative factors are also important, such as the extent to which periodic repairs and maintenance activities interrupt occupants and the complexity and the duration of the

construction effort necessary to implement each option. For this reason, we have developed a comparison matrix (Exhibit 13) to provide a side by side summary of the key differences among the options. An abbreviated summary matrix follows below. In light of the important economic, operations and maintenance and construction effort trade-offs, we defer to the client to decide which combination of costs and benefits best align with the project goals.

**Chart of 25 Year Lifecycle Costs for Each Scheme**



**Abbreviated Comparison Matrix**

| Scheme | Scope Description   | Pros/Cons   | Estimated Project Cost (\$) | Estimated Annual Maint. Cost (\$) | Estimated Annual Energy Cost (\$) | 25 Year Life Cycle Cost (\$) |
|--------|---|---|-----------------------------|-----------------------------------|-----------------------------------|------------------------------|
| 1      | Replace Heat Pumps<br>Refurbish Boilers<br>Replace Ventilation Units  | <b>Pro:</b> Lowest First Cost<br><b>Pro:</b> Lowest Lifecycle Cost<br><b>Pro:</b> Can heat or cool any zone at any time.<br>-----<br><b>Con:</b> Distributed system type requiring maintenance out in building.<br><b>Con:</b> Some risk associated with continued use of old steam system components | \$6,048,000                 | \$167,580                         | \$105,033                         | \$12,011,266                 |
| 2      | Install Fan-Coil Units (instead of Heat Pumps)<br>Refurbish Boilers<br>Install Air Cooled Chiller(s)<br>Replace Existing Piping with Ins'd Dual Temperature Piping. | <b>Pro:</b> Less equipment maintenance out in building.<br>-----<br><b>Con:</b> All FCUs either heat OR cool, not both.<br><b>Con:</b> Some risk associated with continued use of old steam system components.  | \$7,046,400                 | \$158,270                         | \$98,383                          | \$11,596,251                 |
| 3      | Replace Heat Pumps<br>Convert to Hot Water Htg System<br>Replace Ventilation Units  | <b>Pro:</b> Can heat or cool any zone at any time.<br><b>Pro:</b> New heating system<br>-----<br><b>Con:</b> Distributed system type requiring maintenance out in building.<br><b>Con:</b> Increased first cost   | \$7,821,600                 | \$130,340                         | \$98,951                          | \$13,392,229                 |
| 4      | Two-per-floor VAV Air Handlers<br>Terminal Units<br>replace Heat Pumps.<br>New CHW and HW Plants and Piping.  | <b>Pro:</b> Lowest expected maintenance.<br><b>Pro:</b> Equipment primarily in mech areas.<br>-----<br><b>Con:</b> Highest first cost.<br><b>Con:</b> Requires dedicated fan rooms (2-per-floor).<br><b>Con:</b> Large ducts required in corridors.   | \$9,780,000                 | \$125,685                         | \$91,811                          | \$13,437,670                 |

## INTRODUCTION

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This report has been prepared to establish replacement strategies and priorities for the mechanical systems and associated plumbing and electrical equipment at the Morton Civic Center in Evanston Illinois. The Civic Center is a five story masonry building which presently serves to house the various administrative offices of the City of Evanston, including the mayor's office, the Council Chambers, legal, administrative, accounting, planning, buildings, parks and recreation, and health and human services departments among others. The building was originally constructed in 1901 to serve as a Catholic girl's boarding school. After a period of vacancy, the building was purchased and renovated by the City of Evanston to become the Civic Center. The building's mechanical systems and equipment are a combination of older systems and equipment which predate the 1978 renovation as well as a heat pump system, installed in 1978, to provide air conditioning and mechanical ventilation to the building.

The report begins with a discussion of all major mechanical systems, together with the date installed/age, expected service life, capacity, location, energy efficiency, and assessment of overall condition. G/BA utilized several technical sub-consultants to evaluate the condition of the boilers, neutral water piping, and steam/condensate piping. The boiler assessment included visual, ultrasonic, magnetic particle and eddy current analysis methods. The neutral water piping was examined using radiographic non-destructive analysis. The steam and condensate piping was examined using ultrasonic non-destructive testing. The expected service life values are based on data from the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) service life data. Equipment service life is highly dependent on the quality of maintenance over the equipment life span and the environment within which the equipment operates, however, the ASHRAE data is the best source of information readily available describing "normal" equipment life. Used in conjunction with a study such as this one, the data is a useful tool for identifying equipment which should be replaced.

Five distinct upgrade strategies were presented during a preliminary findings review meeting held on November 15, 2019. During that meeting it was agreed to eliminate two options which were determined to be either unfeasible or impractical to implement. This report describes and compares the three selected upgrade strategies along with a fourth strategy included after the November 2018 meeting.

Each option would result in renewal or replacement of the building's HVAC systems such that no further major capital replacement is expected within the next 15-20 years, provided that diligent preventive maintenance is performed. Capital costs are provided for equipment that is recommended for replacement. The estimates have been developed by Edwards Engineering working as a sub-consultant to G/BA for this study. Energy models of each option have been developed using eQUEST software to estimate the annual energy use and costs of each scheme. Lifecycle costs are developed to compare economic performance over time.

## REVIEW OF EXISTING HVAC SYSTEMS AND EQUIPMENT

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There are several important categories of mechanical systems which serve the Civic Center. The purpose and application of each category is described below, followed by an assessment of present condition.

### **Steam Plant and Piping**

The Civic Center is primarily steam-heated with cast iron radiators located along perimeter walls under windows and near building entrances. The radiators, unit heaters, steam and condensate piping have been in service for many years, in some cases perhaps dating back to the building's original construction in 1901.

### Boiler House

**Description:** The boiler house is a separate building located approximately 200' southwest of the main building. It is a two story building with the boiler room on the ground level and an occupied dwelling unit located on the second floor.

**Present Condition:** During the survey, it was observed that the Boiler House is not equipped with a sprinkler system or fire alarm system. Both of these items are recommended as they represent good engineering practice. In addition, the fire rating of the horizontal separation between the boiler room and the dwelling unit should be confirmed.

*In all of the upgrade schemes described below, the addition of a sprinkler system and fire alarm to the Boiler House are included in the scope of work and pricing.*

### Boilers

**Description:** The building is heated by (2) fire-tube type low pressure steam boilers which are located on the boiler house, a small building that is physically separated from the main building. The boilers were manufactured in 1965.

**Present Condition:** An assessment was conducted as part of this study in order to provide information on the remaining metal thickness, physical condition, and operational status of the boilers. The assessment included visual, ultrasonic, magnetic particle and eddy current analysis methods. The results of this testing support the following conclusions:

- The front and rear tube sheets, tube sheet ligaments, circumferential and longitudinal welds appear to be in satisfactory condition.
- Both boilers had a light layer of soot throughout the fireside.
- Cracks were observed in the burner refractory of both boilers.
- The burner barrels of boiler 2 had warping and corrosion.
- There is evidence of tube leaking on the furnace sheets and combustion chambers of both boilers.
- The boilers' external and safety appurtenances appear to be in satisfactory condition, however, there is no evidence or documentation of up-to-date calibration of pressure/temperature gauges and pressure relief valves.
- In boiler 1, 35 (of a total of 72) tubes have measured wall thickness loss of more than 50%.
- In boiler 2, 45 (of a total of 72) tubes have measured wall thickness loss of more than 50%.

In summary, the boilers require new tubes and burners but are otherwise in serviceable condition.

### Radiators

**Description:** The primary means of delivering heat to spaces throughout the building remains cast iron radiators. Based on existing drawings, the building is equipped with approximately 50 radiators per floor on floors 1 through 4 for a building total of 180-200 units. The radiators have nearly all been equipped with thermostatic control valves to automatically regulate their output based on space temperature.

**Present Condition:** Cast iron radiators are heavily built and can last for many years. It is difficult to accurately estimate remaining life of these units. The operating engineer reports that they have not observed many failures of these radiators in the recent past.

### Condensate Receivers, Transfer Pumps, Feedwater Pumps, etc.

**Description:** Condensate transfer units were observed in the main building pump room, and near the main building accessible entrance. These units consist of a heavy steel or cast iron tanks and typically include two pumps and a level controller. As the tanks reach full capacity, the pumps activate to push condensate back to the main vacuum receiver/transfer unit in the boiler room. The condensate transfer units appear to be in serviceable condition. The vacuum receiver/transfer unit in the boiler house appears to be more than 50 years old but is reported to remain in serviceable condition. However, parts for the vacuum pump may no longer be available. The vacuum receiver/transfer unit pumps to the feed water tank. The feed water tank has two (2) feed water pumps, one dedicated to each boiler.

**Present Condition:** Condensate transfer units can last many years. The point of failure is typically the transfer pumps, which can be readily replaced by facility maintenance staff. The vacuum receiver/transfer set is approaching the end of its service life and should be replaced in the near future. The boiler feed water tank has recently failed due to severe corrosion of the tank. An emergency replacement of the tank prior to the next heating season is underway.



**Figure 2 - Condensate Vacuum/Transfer Pump Sets**

## Steam and Condensate Piping

**Description:** Steam and condensate piping runs throughout the building to each radiator and steam unit heater within the building. The main horizontals run at the ground floor ceiling level. These horizontals connect to the estimated 27 steam and condensate riser pairs located around the perimeter of the building. These vertical risers are typically exposed, i.e. not behind soffits. The small diameter piping connections to the radiators typically run exposed from the risers out to the radiators.

**Present Condition:** In locations where the piping runs exposed, it has typically been painted and there are no visible signs of surface corrosion. Ultrasonic testing was performed to determine the remaining wall thickness of the steam and condensate piping, see test results in Table 1 below. The results indicate that the remaining wall thickness of the piping is adequate. However, the facility maintenance staff report that the small diameter radiator connections are typically filled with debris and blockages are common.

**Table 1 – Ultrasonic Steam and Condensate Pipe Testing Results**

| Shot # | Location                 | Pipe Size | Srvc | Vert/<br>Horiz | ASME<br>thickness<br>(Std) | Minimum Measured/% Remaining |      |       |      |          |      |
|--------|--------------------------|-----------|------|----------------|----------------------------|------------------------------|------|-------|------|----------|------|
|        |                          |           |      |                |                            | 1                            |      | 2     |      | Thinnest |      |
|        |                          |           |      |                |                            | in                           | %    | in    | %    | in       | %    |
| 1      | G - Loading Dock         | 4         | Cond | H              | 0.24                       | 0.230                        | 96%  | 0.245 | 102% | 0.230    | 96%  |
| 2      | G - Loading Dock         | 2         | Cond | V              | 0.15                       | 0.160                        | 107% | 0.160 | 107% | 0.160    | 107% |
| 3      | G - Loading Dock         | 2         | Cond | H              | 0.15                       | 0.160                        | 107% | 0.159 | 106% | 0.159    | 106% |
| 4      | G - Loading Dock         | 2         | Cond | H              | 0.15                       | 0.146                        | 97%  | 0.156 | 104% | 0.146    | 97%  |
| 5      | G - Loading Dock         | 0.75      | Cond | H              | 0.11                       | 0.117                        | 106% | 0.118 | 107% | 0.117    | 106% |
| 6      | G - Pump Room            | 3         | Stm  | H              | 0.22                       | 0.217                        | 99%  | 0.232 | 105% | 0.217    | 99%  |
| 7      | G - Pump Room            | 0.75      | Cond | V              | 0.11                       | 0.110                        | 100% | 0.113 | 103% | 0.110    | 100% |
| 8      | G - Pump Room            | 4         | Stm  | H              | 0.24                       | 0.256                        | 107% | 0.253 | 105% | 0.253    | 105% |
| 9      | G - Pump Room            | 1.25      | Cond | H              | 0.14                       | 0.157                        | 112% | 0.158 | 113% | 0.157    | 112% |
| 10     | G - FM Office            | 8         | Stm  | H              | 0.32                       | 0.355                        | 111% | 0.350 | 109% | 0.350    | 109% |
| 11     | G - FM Office            | 6         | Stm  | H              | 0.28                       | 0.333                        | 119% |       | 0%   | 0.333    | 119% |
| 12     | G - FM Office            | 2         | Stm  | H              | 0.15                       | 0.176                        | 117% | 0.183 | 122% | 0.176    | 117% |
| 13     | G - FM Office            | 1         | Cond | H              | 0.13                       | 0.144                        | 111% | 0.141 | 108% | 0.141    | 108% |
| 14     | G - FM Office            | 0.75      | Cond | V              | 0.11                       | 0.118                        | 107% | 0.121 | 110% | 0.118    | 107% |
| 15     | G - Handicap<br>Entrance | 0.75      | Cond | H              | 0.11                       | 0.123                        | 112% | 0.121 | 110% | 0.121    | 110% |
| 16     | G - Handicap<br>Entrance | 2         | Cond | H              | 0.15                       | 0.154                        | 103% | 0.160 | 107% | 0.154    | 103% |
| 17     | G - Handicap<br>Entrance | 2         | Stm  | H              | 0.15                       | 0.224                        | 149% | 0.228 | 152% | 0.224    | 149% |
| 18     | G - Conf Room            | 6         | Stm  | H              | 0.28                       | 0.3                          | 107% | 0.287 | 103% | 0.287    | 103% |
| 19     | G - Conf Room            | 2         | Stm  | H              | 0.15                       | 0.157                        | 105% | 0.156 | 104% | 0.156    | 104% |
| 20     | G - Conf Room            | 1.5       | Cond | H              | 0.15                       | 0.15                         | 100% | 0.146 | 97%  | 0.146    | 97%  |
| 21     | G - Conf Room            | 1.25      | Stm  | H              | 0.14                       | 0.156                        | 111% | 0.152 | 109% | 0.152    | 109% |
| 22     | G - Conf Room            | 2         | Cond | H              | 0.15                       | 0.16                         | 107% | 0.160 | 107% | 0.160    | 107% |
| 23     | G - Conf Room            | 4         | Stm  | H              | 0.24                       | 0.23                         | 96%  | 0.251 | 105% | 0.230    | 96%  |

| Shot # | Location      | Pipe Size | Srvc | Vert/<br>Horiz | ASME<br>thickness<br>(Std) | Minimum Measured/% Remaining |      |       |      |          |      |
|--------|---------------|-----------|------|----------------|----------------------------|------------------------------|------|-------|------|----------|------|
|        |               |           |      |                |                            | 1                            |      | 2     |      | Thinnest |      |
|        |               |           |      |                |                            | in                           | %    | in    | %    | in       | %    |
| 24     | G - Conf Room | 1.25      | Stm  | H              | 0.14                       | 0.16                         | 114% | 0.168 | 120% | 0.160    | 114% |
| 25     | G - Conf Room | 8         | Stm  | H              | 0.32                       | 0.33                         | 103% | 0.328 | 103% | 0.328    | 103% |
| 26     | G - Conf Room | 2         | Cond | H              | 0.15                       | 0.178                        | 119% | 0.181 | 121% | 0.178    | 119% |
| 27     | G - Conf Room | 0.75      | Cond | H              | 0.11                       | 0.116                        | 105% | 0.116 | 105% | 0.116    | 105% |
| 28     | 1700          | 0.5       | Cond | V              | 0.11                       | 0.116                        | 105% | 0.114 | 104% | 0.114    | 104% |
| 29     | 1700          | 1         | Stm  | V              | 0.13                       | 0.129                        | 99%  | 0.130 | 100% | 0.129    | 99%  |
| 30     | 1700          | 2.5       | Stm  | V              | 0.2                        | 0.162                        | 81%  |       | 0%   | 0.162    | 81%  |
| 31     | 1700          | 0.75      | Cond | V              | 0.11                       | 0.131                        | 119% | 0.116 | 105% | 0.116    | 105% |
| 32     | 1500          | 0.75      | Cond | H              | 0.11                       | 0.12                         | 109% | 0.111 | 101% | 0.111    | 101% |
| 33     | 1500          | 1.25      | Stm  | H              | 0.14                       | 0.141                        | 101% | 0.146 | 104% | 0.141    | 101% |
| 34     | 1500          | 1         | Cond | V              | 0.13                       | 0.116                        | 89%  | 0.111 | 85%  | 0.111    | 85%  |
| 35     | 1500          | 2.5       | Stm  | V              | 0.2                        | 0.228                        | 114% | 0.208 | 104% | 0.208    | 104% |
| 36     | 1115          | 1.25      | Stm  | H              | 0.14                       | 0.152                        | 109% | 0.148 | 106% | 0.148    | 106% |
| 37     | 1115          | 0.75      | Cond | H              | 0.11                       | 0.111                        | 101% | 0.115 | 105% | 0.111    | 101% |
| 38     | 1115          | 0.75      | Cond | V              | 0.11                       | 0.111                        | 101% | 0.128 | 116% | 0.111    | 101% |
| 39     | 1115          | 2.5       | Stm  | V              | 0.2                        | 0.161                        | 81%  | 0.164 | 82%  | 0.161    | 81%  |
| 40     | 1118          | 1         | Cond | V              | 0.13                       | 0.146                        | 112% | 0.155 | 119% | 0.146    | 112% |
| 41     | 1118          | 0.75      | Cond | V              | 0.11                       | 0.128                        | 116% | 0.128 | 116% | 0.128    | 116% |
| 42     | 1118          | 2         | Stm  | V              | 0.15                       | 0.158                        | 105% | 0.160 | 107% | 0.158    | 105% |
| 43     | 3902          | 0.75      | Stm  | V              | 0.11                       | 0.121                        | 110% | 0.124 | 113% | 0.121    | 110% |
| 44     | 3902          | 0.75      | Cond | V              | 0.11                       | 0.119                        | 108% | 0.120 | 109% | 0.119    | 108% |
| 45     | 3902          | 0.75      | Cond | H              | 0.11                       | 0.126                        | 115% | 0.129 | 117% | 0.126    | 115% |
| 46     | 3902          | 2         | Stm  | V              | 0.15                       | 0.159                        | 106% | 0.161 | 107% | 0.159    | 106% |
| 47     | 3800          | 1         | Stm  | H              | 0.13                       | 0.14                         | 108% | 0.150 | 115% | 0.140    | 108% |
| 48     | 3800          | 0.75      | Cond | V              | 0.11                       | 0.12                         | 109% | 0.124 | 113% | 0.120    | 109% |
| 49     | 3800          | 1.25      | Stm  | V              | 0.14                       | 0.134                        | 96%  | 0.138 | 99%  | 0.134    | 96%  |
| 50     | 3800          | 0.5       | Cond | H              | 0.11                       | 0.11                         | 100% | 0.113 | 103% | 0.110    | 100% |
| 51     | 3501          | 0.75      | Cond | H              | 0.11                       | 0.121                        | 110% | 0.122 | 111% | 0.121    | 110% |
| 52     | 3501          | 1         | Stm  | H              | 0.13                       | 0.13                         | 100% | 0.138 | 106% | 0.130    | 100% |
| 53     | 3501          | 0.75      | Cond | V              | 0.11                       | 0.123                        | 112% | 0.129 | 117% | 0.123    | 112% |
| 54     | 3501          | 1.5       | Stm  | V              | 0.15                       | 0.157                        | 105% | 0.183 | 122% | 0.157    | 105% |
| 55     | 3106          | 1         | Stm  | H              | 0.13                       | 0.154                        | 118% | 0.156 | 120% | 0.154    | 118% |
| 56     | 3106          | 0.75      | Cond | H              | 0.11                       | 0.119                        | 108% | 0.120 | 109% | 0.119    | 108% |
| 57     | 3106          | 0.75      | Cond | V              | 0.11                       | 0.119                        | 108% | 0.128 | 116% | 0.119    | 108% |
| 58     | 3106          | 1.25      | Stm  | V              | 0.14                       | 0.134                        | 96%  | 0.138 | 99%  | 0.134    | 96%  |

### Gas booster

**Description:** The boiler plant is equipped with a gas booster to increase the gas pressure entering the burners. The operating engineer reports that this booster is not required and is no longer used.

**Present Condition:** On a recent 20°F day, a pressure gauge on the gas piping to the south boiler indicated a reading of 7 inches w.c. This is at the low end of what would be acceptable for a new high performance burner. The existing gas booster is very old and would be a candidate for replacement. However, it appears that the gas service connection to the building provides higher pressure but is reduced by a regulator prior to the gas meter located outside the boiler house. Replacement of the pressure reducing valve would likely eliminate the need for a booster.



**Figure 3 – Gas Pressure Booster Fan**

### **Heat Pump System**

Prior to 1978, the Civic Center had no centralized air conditioning system. During the 1978 renovation, a heat pump system was installed consisting of distributed air-to-water heat pump units (one per temperature control zone) connected to a circulating water loop to serve as the heat source or heat sink for the individual heat pump units. A majority of these heat pumps only operate in cooling mode and in some cases lack a reversing valve which would permit heating mode operation. This is because space heat continues to be provided by the steam fed radiators present within each zone.

### Heat Pumps

**Description:** Each area within the building is cooled by a ducted water-source heat pump. A number of these units have been replaced since the origin of the heat pump system in 1978. However, there remain a substantial number of original units which continue to rely on refrigerant R-22. After January 1, 2020, R-22 can no longer be produced in or imported to the United States. Nevertheless, reclaimed R-22 will continue to be available for many years, though its price in the future is subject to uncertainty.

**Present Condition:** The condition of the heat pump units is expected to vary as some have been replaced and the water heat exchanger coils on some of the units are known to be partially blocked with sediment. The building's engineering staff report that they spend a significant amount of time repairing or replacing these units. In addition, the staff report that many of the units perform poorly as a result of not receiving adequate flow of water for heat rejection.

The heat pumps which were installed in 1978 were manufactured by EnerCon, a division of American Air Filter which is no longer in business. These units have an inlet and outlet configuration which differs from units currently provided by major manufacturers. This is a concern because each unit has supply and return ductwork which would require substantial modification to accommodate a different unit configuration. However, a small manufacturer called Adirondack Aire, a division of Cold Point Corporation in Rome, New York, continues to supply direct replacement units which require no ductwork modification.

### Neutral Water Piping and Circulation Pumps

**Description:** Although the building presently has a qualified chemical treatment specialist managing water quality and corrosion with its steam, neutral water, and fluid cooler systems, this apparently was not the case for many of the systems years in operation. The building engineer reports that flow issues are persistent in many of the heat pump units. In some cases he has been successful in flushing the systems to permit their continued use, however, in other cases the internal heat exchangers have become fully blocked and the units have required replacement.

There are two base mounted end suction pumps mounted in the lower level pump room which circulate the neutral water system. The pumps operate lead/standby (each pump can individually provide full system flow) and were selected to provide a flowrate of 400 GPM at a pressure differential of 80 ft. w.c.

As part of this study, G/BA commissioned testing of a sample of the neutral water system and also had an evaluation performed on the composition of the sediment taken from one of the blocked heat pumps. This testing confirmed that the present condition of the water is good. The sediment was found to be composed of precipitated products of corrosion.

Given the evidence of historically unabated corrosion, G/BA hired a pipe testing company to perform non-destructive testing of the neutral water system piping in 12 locations. The results of this testing effort are provided in Table 2 below. The results indicate that the larger piping mains possess adequate remaining wall thickness and can remain in service, however inadequate wall thickness was discovered in the smaller diameter piping including the run-outs to each heat pump.

The neutral water circulation pumps were installed in 1978 and have exceeded their expected service life.



**Figure 4 - Neutral Water Pumps**



**Figure 5 - Steam to Neutral Water Heat Exchanger**

Steam to Hot Water Converter

**Description:** The heat pump units which operate in heating mode, located primarily on the lower level, draw heat from the circulating neutral water loop. A steam heat exchanger is used as the heat source to maintain a heat pump supply water temperature of 50°F or higher.

**Present Condition:** The steam heat exchanger is a shell and tube type heat exchanger. The internal tube bundle of this converter was replaced in 2018. However, the heat exchanger is piped in a manner that does not lend itself to accurate control of loop temperature.

**Table 2 – Radiographic Neutral Water Pipe Testing Results**

| Shot # | Location                                      | Pipe Size | ASME thickness (Std) | Minimum Measured/% Remaining |      |       |      |       |      |          |      | Corr. Erosion ID/OD |
|--------|---|-----------|----------------------|------------------------------|------|-------|------|-------|------|----------|------|---------------------|
|        |   |           |                      | 1                            |      | 2     |      | 3     |      | Thinnest |      |                     |
|        |   |           |                      | in                           | %    | in    | %    | in    | %    | in       | %    |                     |
| 1      | North end of NW mains on ground floor         | 3         | 0.22                 | 0.180                        | 82%  | 0.180 | 82%  | 0.193 | 88%  | 0.170    | 77%  | ID                  |
| 2      | G23 Runouts                                   | 1         | 0.13                 | 0.049                        | 38%  | 0.052 | 40%  | 0.054 | 42%  | 0.048    | 37%  | ID                  |
| 3      | O12 Runouts                                   | 1.25      | 0.14                 | 0.062                        | 44%  | 0.063 | 45%  | 0.077 | 55%  | 0.062    | 44%  | ID                  |
| 4      | O4 Runouts                                    | 1         | 0.13                 | 0.040                        | 31%  | 0.040 | 31%  | 0.047 | 36%  | 0.014    | 11%  | ID                  |
| 5      | North end of NW mains on first floor          | 1.5       | 0.15                 | 0.030                        | 20%  | 0.047 | 31%  | 0.073 | 49%  | 0.027    | 18%  | ID                  |
| 6      | Top of NW riser in attic                      | 5         | 0.26                 | 0.348                        | 134% | 0.344 | 132% | 0.35  | 135% | 0.328    | 126% | ID                  |
| 7      | South end of NW mains in attic                | 1.5       | 0.15                 | 0.070                        | 47%  | 0.080 | 53%  | 0.08  | 53%  | 0.044    | 29%  | ID                  |
| 8      | Attic?  | 3         | 0.22                 | 0.160                        | 73%  | 0.160 | 73%  | 0.17  | 77%  | 0.160    | 73%  | ID                  |
| 9      | First floor radiator runouts (1101)           | 1         | 0.13                 | 0.020                        | 15%  | 0.075 | 58%  | 0.12  | 92%  | 0.020    | 15%  | ID                  |
| 10     | First floor radiator runouts (west vestibule) | 1         | 0.13                 | 0.100                        | 77%  | 0.100 | 77%  | 0.1   | 77%  | 0.100    | 77%  | ID                  |



**Figure 6 – Closed Circuit Fluid Cooler**

Fluid Cooler

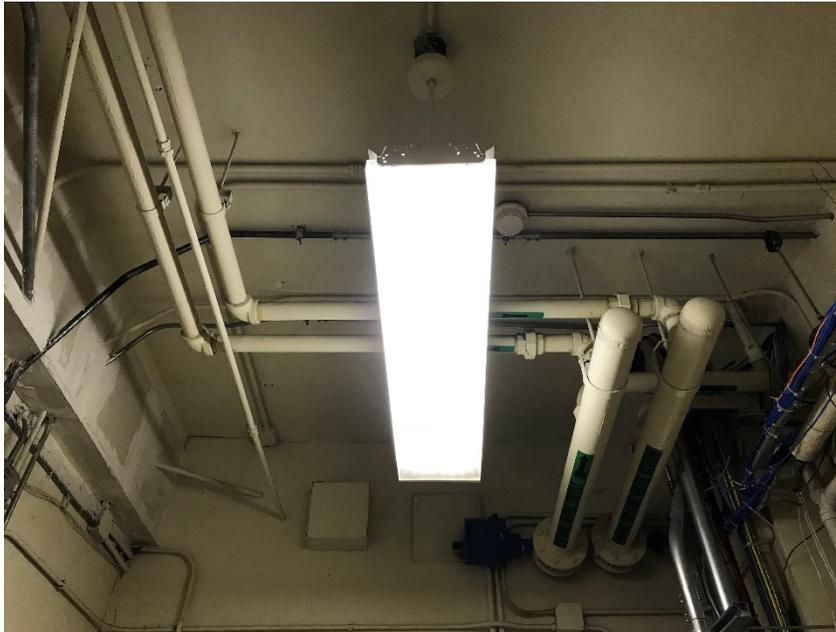
**Description:** When the heat pumps operate in cooling mode, they reject heat to the circulating neutral water loop. A fluid cooler is mounted to the south of the building which is used to maintain a heat pump supply water temperature of 90°F or lower. The unit was designed to cool a flow rate of 600 GPM from 103 to 90°F at an outdoor wet bulb temperature of 78°F.

**Present Condition:** The fluid cooler was installed in 2006. It has been in service for 12 years and appears to be in good condition, with substantial remaining service life. The fill material was replaced in recent years. The operating engineer reports that its capacity has proven adequate under periods of high cooling demand.

## Dedicated Outside Air Systems

**Description:** When centralized air conditioning was added to the building in 1978, provisions were made to add mechanical ventilation to the building. To this end, two ventilation units were installed in the north and south attic areas. The design intent was to provide tempered air in the winter and untempered air in the summer, ducted to the inlet of the distributed heat pump systems. The north unit appears to be functional, however it is not typically run due to noise complaints from building occupants. Both the north and south units includes riser ducts along with a supply and return fan, however it does not appear that the ductwork from the risers out to the heat pumps at the south end of the building or on several floors at the north end were completed. This is likely the reason why neither system can be run.

**Present Condition:** The existing dedicated outside air systems are incomplete and non-functional.



**Figure 7 – South closet with capped make-up air connection and neutral water riser connections**

## Controls

**Description:** The building does not have a digital building management system. Control of space temperatures throughout the building is provided by zone mounted thermostats associated with the distributed heat pump units and by radiator-mounted thermostatic control valves.

There is a stand-alone digital controller in the boiler house which is used to control and stage the boilers.



**Figure 8 – DDC boiler controller and thermostatic radiator control valve**

**Present Condition:** The radiator mounted thermostatic control valves have an expected service life of less than 20 years. It appears that many of the valves installed in 1978 have subsequently been replaced.

## Electrical System

**Description:** The main building has 2 electrical services coming from separate ComEd pad mounted transformers on the South side of the building. The incoming services come in underground to switchboards SWBD-1 and SWBD-2, located on the ground floor electrical room. The switchboard enclosures are showing signs of rust where the paint is scratched. Switch and fuse switchboards can have a long life if properly maintained, but due to the environment and maintenance record, the condition of switchboards is uncertain. Further examination and inspection by a certified testing and service company is required.



**Figure 9 - Back of SWBD-2 shows rust and signs of water damage on the floor**

Switchboard SWBD-1 is an 800A, 277/480V-3PH-4W fused switchboard manufactured by Westinghouse. The switchboard nameplate indicate that is was manufactured in 1977. Based on the age, the switchboard may be approaching the end of life, but further testing will be required. Switchboard SWBD-1 serves the fluid cooler, house pumps, elevator, power distribution to the attic, receptacle, and lighting loads throughout the building. Based on utility information, the switchboard has adequate capacity of the loads connected, but does not have any available spare switches or space for expansion.



**Figure 10 - Switchboard SWBD-1**

Switchboard SWBD-2 is an 800A, 277/480V-3PH-4W fused switchboard manufactured by Jemison Electric. Switchboard SWBD-2 was likely installed with a service upgrade to serve the heat pump system in 1978. Based on the age, the switchboard may be approaching the end of life, but further testing will be required. The switchboard enclosure does show signs of rust and damage, so special care should be provided to preserve its condition. Switchboard SWBD-2 serves heat pump branch panels throughout the building, emergency lighting and exit signs, basement heating, and the north elevator. Review of historic monthly electric demand readings confirms that the existing electric service is adequate to support all options described in this report. However, the switchboard does not have any available spare switches or space for expansion.



**Figure 11 - Switchboard SWBD-2**

## ALTERNATIVE UPGRADE OPTIONS

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The heating, cooling and ventilation systems or key components of those systems are nearing or have reached the end of their expected service lives. The building's engineering staff presently commit significant time making repairs to keep the existing equipment in operation. At this time, it is appropriate to examine a range of upgrade and replacement options so that a feasible, cost-effective upgrade strategy can be identified. In this section, a series of upgrade strategies are described. For each strategy, a discussion of implementation benefits and challenges is provided, along with an opinion of probable implementation cost, estimated annual energy costs, and differences in annual maintenance requirements.

An energy model of the building has been developed using eQUEST software to provide estimates of the annual energy usage expected for each option. Historic utility bill were reviewed to establish current per-unit energy costs. These per unit costs were used in the energy model to develop annual energy costs.

The existing system includes a substantial amount of piping and equipment which has long exceeded expected service life and the circulating water system is known to be contaminated with debris. For this reason, the existing system is very intensive to maintain and does not represent a good cost baseline for comparison of the upgrade schemes. Even Scheme 1, which is essentially replacement-in-kind, is expected to require far less effort to maintain than the existing system since the equipment would be new and the circulating water system remediated. BOMA Office, Industrial Benchmarking reports from 2017 and 2018 are used as a basis of comparison, with adjustments for differences in service and preventive maintenance requirements of each system. The BOMA data provides average values on a floor area basis for "Repair / Maintenance" costs. The values used in this analysis assume that a building's HVAC systems comprise 60% of the total repair and maintenance costs for a typical building.

Finally, 25 year lifecycle costs have been developed for each option based on the cost estimates, estimated differences in maintenance costs, and estimated annual energy costs.

## **Scheme 1 – Replace Heat Pumps in Kind and Refurbish/Repair Existing Steam and Neutral Water Systems +BAS**

Description: The boilers are currently in poor condition, however, they are structurally sound and can remain in service for another 15-20 years if the tubes and burners are replaced. The steam and condensate piping appears to have adequate remaining wall thickness, though the small diameter horizontal lines are reportedly clogged with debris. A number of the original heat pumps have been replaced. As heat pumps fail, this process of continuing to repair or replace upon failure can continue. Alternatively, all of the heat pumps can be replaced.

Maintaining a source of heat under perimeter windows is considered one of the most effective strategies to offset exterior wall/window heat losses. This strategy would continue to rely on the building's thermostatically controlled cast iron radiators for this purpose. Since the service life of thermostatic valves and radiator traps is not more than 8-10 years, both would be replaced as part of this project.

This scheme would include a new Building Automation System. All of the new heat pumps, associated pumps, boilers, heat exchangers, and the fluid cooler would be monitored and alarmed by this new BAS.

The existing system presently has no effective means to provide mechanical ventilation to the building since the attic-mounted make-up air systems are either incomplete or too noisy to operate. From a code compliance perspective, the building's operable windows can be considered an adequate means of "natural ventilation." However, ventilation through windows is unreliable, does not provide adequate control of interior humidity levels and during much of the year, perimeter zone occupants likely elect to keep the windows closed. For this reason, upgrade of the building's existing mechanical ventilation system is recommended as part of this scheme. Details of this system are provided following Scheme 3.

Given the results of the pipe testing, selective replacement of the neutral water, steam, and condensate piping is included in this option.

The existing heat pumps are served from a separate utility service than the normal service, through 800A, 277/480V-3PH-4W, switchboard SWBD-2. Since the electrical load in Scheme 1 will not be increased, switchboard SWBD-2 has adequate capacity. Due to the age of the switchboard and the environment of the electrical room, we recommend the switchboard is thermally scanned, the switchboard interior is inspected, the switches are cleaned, lubricated and exercised as part of a maintenance service on the switchboard.

Switchboard SWBD-2 feeds 277/480V-3PH-4W branch panels throughout the building to serve the existing heat pumps. Scheme 1 would require the existing heat pumps be electrically disconnected and the new heat pumps would be re-connected to the existing branch circuit. The new heat pumps would be sized to match the existing branch circuit size and voltage. Due to the age of the branch panels, we recommend the panels are thermally scanned, the panel interiors are inspected, and exercising of all circuit breakers, inspection of wiring insulation, and re-torqueing all terminations in the circuit breaker branch panels.

The existing power distribution to the attic is provided by a 400A, 277/480V-3PH-4W, panel ATTIC S MDP. Upgrades to the attic's make-up air systems can be supported by the existing panel ATTIC S MDP. New circuit breakers, conduits, and wiring will need to be provided to supply power for (2) new make-up air units.

### Scheme 1 Scope Items:

1. Re-tube both boilers
2. Replace burners on both boilers
3. Replace heat pumps in kind

4. Replace neutral temperature piping runouts from the mains to the heat pumps
5. Replace neutral water main distribution piping 2" in diameter and smaller
6. Replace neutral water circulation pumps and trim
7. Replace condensate piping runouts from the vertical risers to the radiators
8. Re-pipe steam heat exchanger and upgrade controls
9. Replace thermostatic radiator valves on an as-needed basis (primarily those valves which have been in service for more than 20 years.)
10. Install variable frequency drives to modulate speed of neutral water pumps
11. Add DDC controller to modulate pumps, monitor system differential pressure, and provide capacity control of heat exchanger and fluid cooler.
12. Provide network cabling to all new heat pumps to permit remote monitoring of each zone
13. Provide operator workstation and DDC supervisory network controller to provide for enhanced monitoring and troubleshooting of system operation and performance.
14. Electrically scan and perform maintenance to switchboard SWBD-2, and heat pump branch panels.
15. Provide power to (2) make-up air units from panel ATTIC S MDP.

Discussion: This scheme can be planned in a manner that will allow for the building to operate in a normal manner with minimal impact on occupants if the heat pumps are replaced in-kind with Adirondack-Aire units, which have the same configuration and dimensions as the existing units. However, should a decision be made to convert to side-return type heat pumps, the replacement process will require a longer duration for each unit since custom ductwork will need to be fabricated at each heat pump location, and it may be necessary to relocate the units slightly to provide clearance for the new side return duct fittings, relocate electrical conduit and junction boxes, relocate or modify ceiling mounted fire alarm conduit and devices, and modify, reroute, or extend the neutral water branch piping.

This scheme will not have significant impact to the load on the electrical system, and will not require coordination with the utility company. There will be shut down required for electrical modifications and maintenance, but downtime will not be significant.

The facility maintenance staff were queried regarding how maintenance is performed on the existing heat pumps and how that would potentially change should the existing heat pumps be replaced with side-return type units, as manufactured by Trane, Carrier and Daikin. They report that they presently have service access that is sufficient to perform minor component replacements such as contactors, transformers, and fan motors with the units remaining in place on most units. However, when they need to replace a water to refrigerant heat exchanger or a compressor, they typically disconnect the units and transport them back to their maintenance shop. They do this primarily because these efforts are lengthy and require the use of vacuum pumps, open flame brazing, and the use of loud tools which would disturb the building's occupants. They estimate that this process is necessary three to five times per year. The facility maintenance staff believe that the service strategies described herein would not change should the building convert to side-return style units.

Nevertheless, there are two important reasons why converting to side-access heat pumps would be beneficial. First, it is presumed that pricing for side return units is more competitive because there are multiple manufacturers which produce them. Second, relying on a unit which is only available from a single supplier involves the risk associated with that manufacturer going out of business or discontinuing the product line.

For the reasons described above, converting to side return configuration heat pump units would likely cost on the order of \$5,000 to \$7,000 per unit to perform the necessary ductwork modifications and relocation of other conflicting ceiling items. This cost is included in the Opinions of Probable Cost which follow for Schemes 1 and 3 below to eliminate the cost and availability risks associated with reliance on a sole source provider.



**Figure 12 – Representative Existing Heat Pump Installations**

Opinion of Probable Cost: Based on the preliminary cost estimate provided by our sub-consultant Edwards Engineering, the implementation cost for this scheme is expected to be approximately \$6,050,000, including a 20% contingency. This number includes the cost (approx. \$1,350,000) to replace the existing mechanical ventilation system along with completion of the associated ductwork.

Annual Energy Cost Estimate: \$105,033.

Annual Maintenance Cost Estimate: \$168,000. This value represents an estimate based on the range and median values associated with repair and maintenance costs for office buildings provided in the 2017 BOMA Experience Exchange Report.

### **Scheme 2 – Replace Heat Pumps with Fan-Coil Units, Replace Neutral Water System with Insulated Dual Temperature Piping System, Install Air-Cooled Chiller and Refurbish/Repair Existing Steam System + BAS**

Description: In this scheme, the heat pumps would be replaced with fan-coil units. The neutral water piping system, which is uninsulated and in poor condition, would be replaced with slightly larger insulated dual temperature piping to each new fan-coil unit. An air-cooled chiller would replace the existing fluid cooler to provide a source of chilled water during the cooling season. A steam converter would be used to provide hot water to the fan-coil units during the heating season.

This scheme would include a new Building Automation System. All of the new fan-coil units, associated pumps, chillers, and boilers would be monitored and alarmed by this new BAS.

The existing system presently has no effective means to provide mechanical ventilation to the building since the attic-mounted make-up air systems are either incomplete or too noisy to operate. From a code compliance perspective, the building's operable windows can be considered an adequate means of "natural ventilation." However, ventilation through windows is unreliable, does not provide adequate control of

interior humidity levels and during much of the year, perimeter zone occupants likely elect to keep the windows closed. For this reason, upgrade of the building's existing a mechanical ventilation system is recommended as part of this scheme. Details of this system are provided following Scheme 3.

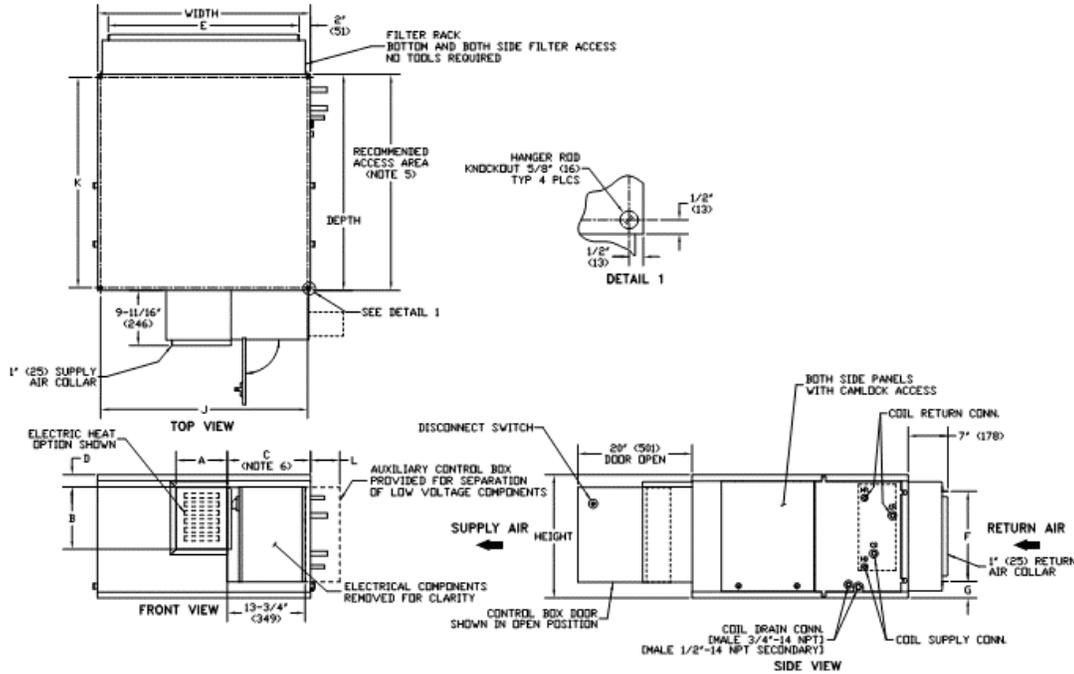
The existing heat pumps are served from a separate utility service than the normal service, through 800A, 277/480V-3PH-4W, switchboard SWBD-2. Scheme 3 will be increasing the load on the existing electrical system, but switchboard SWBD-2 appears to have adequate capacity. Switchboard SWBD-2 does not have any spare switches or physical space for expansion. Since Scheme 3 requires additional power to (2) new 80 ton air cooled chillers, the existing switchboard will need to be modified and a new distribution panel will need to be provided to support the new power requirements. Due to the age of the switchboard and the environment of the electrical room, we recommend the switchboard is thermally scanned, the switchboard interior is inspected, the switches are cleaned, lubricated and exercised as part of a maintenance service on the switchboard.

Switchboard SWBD-2 feeds 277/480V-3PH-4W branch panels throughout the building to serve the existing heat pumps. Scheme 3 would require the existing heat pumps be electrically disconnected and the circuits would be made spare for the connection of new fan-coil units. The new fan-coil units will be connected to existing branch panels that served the demolished heat pumps. The new fan-coil units will need to be specified at 277 volts to be connected to the existing branch panels. New branch circuit wiring and circuit breakers will need to be provided for the fan-coil units. Due to the age of the branch panels, we recommend the panels are thermally scanned, the panel interiors are inspected, and exercising of all circuit breakers, inspection of wiring insulation, and re-torquing all terminations in the circuit breaker branch panels.

#### Scheme 2 Scope Items:

1. Re-tube both boilers
2. Replace burners on both boilers
3. Replace heat pumps in kind
4. Replace neutral temperature piping system with new insulated dual temperature piping.
5. Replace neutral water circulation pumps and trim with new dual temperature pumps
6. Replace condensate piping runouts from the vertical risers to the radiators
7. Replace steam convertor and provide new controls
8. Replace fluid cooler with (2) new 60 ton air cooled chillers with integral primary pumps
9. Replace thermostatic radiator valves on an as-needed basis (primarily those valves which have been in service for more than 20 years.)
10. Install variable frequency drives to modulate speed of dual temperature water pumps
11. Add DDC controller to modulate pumps, monitor system differential pressure, and provide capacity control of heat exchanger and fluid cooler.
12. Provide network cabling to all new fan-coil units to permit remote monitoring of each zone
13. Provide operator workstation and DDC supervisory network controller to provide for enhanced monitoring and troubleshooting of system operation and performance.
14. Modify existing switchboard SWBD-2 and provide a new distribution panel to provide power to (2) new air cooled chillers.
15. Provide new circuit breakers and branch circuit wiring to new fan-coil units.

**Discussion:** This option requires a new set of insulated supply and return pipes to bring chilled or hot water flow to each fan-coil unit. Ideally, this new line set can be installed prior to removal of the existing neutral temperature piping. This strategy would permit essentially unit by unit change-over from heat pump to fan-coil unit once the piping mains are installed. Copper piping with press fittings or steel piping with mechanical fittings could be used to expedite the installation of the new dual temperature piping and to avoid the use of torches or welding equipment. The most significant benefit of this strategy is that fan-coil units are less complex and require less maintenance than heat pump systems.



| UNIT SIZE | FAN SIZE | DEPTH  | WIDTH | HEIGHT | SUPPLY DUCT |        |        |       | RETURN DUCT |        |       | MOUNTING HOLES |        | AUX. CTRL. BOX |
|-----------|----------|--------|-------|--------|-------------|--------|--------|-------|-------------|--------|-------|----------------|--------|----------------|
|           |          |        |       |        | A           | B      | C      | D     | E           | F      | G     | J              | K      | L              |
| 06        | 9 x 6    | 36     | 28    | 19-3/4 | 8-7/8       | 10-7/8 | 13-3/4 | 2-1/4 | 24-1/4      | 14     | 2-3/4 | 27-1/4         | 35-1/4 | 5-3/4          |
| 08        | 9 x 6    | 36     | 28    | 19-3/4 | 8-7/8       | 10-7/8 | 13-3/4 | 2-1/4 | 24-1/4      | 14     | 2-3/4 | 27-1/4         | 35-1/4 | 5-3/4          |
| 10        | 9 x 6    | 37-1/2 | 37    | 21-1/2 | 8-7/8       | 10-7/8 | 14-1/2 | 2-1/4 | 33-1/4      | 15-3/4 | 2-7/8 | 36-1/4         | 37     | 5              |
| 12        | 9 x 6    | 37-1/2 | 37    | 21-1/2 | 8-7/8       | 10-7/8 | 14-1/2 | 2-1/4 | 33-1/4      | 15-3/4 | 2-7/8 | 36-1/4         | 37     | 5              |
| 16        | 10 x 7   | 37-3/4 | 47    | 21-1/2 | 10-3/8      | 12     | 18-3/8 | 2-1/4 | 43-7/8      | 15-3/4 | 2-7/8 | 46-1/4         | 37     | 1-1/4          |
| 20/22     | 11 x 10  | 40-1/4 | 48    | 24     | 13-7/8      | 13     | 17-1/4 | 2-1/4 | 44-1/4      | 18     | 2-7/8 | 47-1/4         | 39-1/2 | 2-3/8          |
| 30        | 12 x 12  | 40-1/4 | 48    | 32-1/4 | 16-1/4      | 14     | 16     | 7-1/8 | 44-1/4      | 26-1/2 | 1-1/4 | 47-1/4         | 39-1/2 | 3-3/4          |

**NOTES:**

1. Right hand unit shown; left hand unit opposite.
2. All dimensions are  $\pm 1/4$  in.
3. Product specifications are subject to changes without notice.
4. Dimensions are in inches (mm).
5. Allow adequate spacing or maneuverability around unit to allow service through recommended access area.
6. C dimension is measured from coil side of unit.
7. Mixing box option will vary return duct dimensions, refer to mixing box drawing.

**Figure 13 - Dimensions of Typical Ducted Fan-Coil Unit**

Typical fan-coil units have a back return configuration, so only minimal modification of ductwork would be necessary. However, the fan-coil units are slightly taller, wider, and longer than the existing heat pumps, so some relocation of existing ceiling elements is anticipated.

Since this scheme will be increasing the load on the electrical system, the current demand will need to be evaluated, and the existing switchboard will need modification to provide new switches. This scheme will also require a new power distribution panel to serve new air cooled chillers and re-feed existing equipment. The switchboard modification will also require an electrical shutdown of SWBD-2, resulting in more significant downtime, and coordination of the electrical outage.

Opinion of Probable Cost: Based on the preliminary cost estimate provided by our sub-consultant Edwards Engineering, the implementation cost for this scheme is expected to be approximately \$7,050,000, including a 20% contingency. This number includes the cost (approx. \$1,350,000) to replace the existing mechanical ventilation system along with completion of the associated ductwork.

Annual Energy Cost Estimate: \$98,383.

Annual Maintenance Cost Estimate: \$130,400. This value represents an estimate based on the range and median values associated with repair and maintenance costs for office buildings provided in the 2017 BOMA Experience Exchange Report.

### **Scheme 3 – Replace Heat Pumps in Kind, Repair/Refurbish Neutral Water System and Replace Steam System with Hot Water System + BAS**

Description: This scheme is similar to scheme 1 above, however, the cast iron radiators and steam piping would be replaced with new hot water piping and convectors. The steam boilers would be replaced with hot water boilers. Hot water systems have largely displaced the use of steam in commercial and residential building due to improved energy efficiency and controllability.

This scheme would include a new Building Automation System. All of the new heat pumps, associated pumps, boilers, and the fluid cooler would be monitored and alarmed by this new BAS.

The existing system presently has no effective means to provide mechanical ventilation to the building since the attic-mounted make-up air systems are either incomplete or too noisy to operate. From a code compliance perspective, the building's operable windows can be considered an adequate means of "natural ventilation." However, ventilation through windows is unreliable, does not provide adequate control of interior humidity levels and during much of the year, perimeter zone occupants likely elect to keep the windows closed. For this reason, upgrade of the building's existing a mechanical ventilation system is recommended as part of this scheme. Details of this system are provided following Scheme 3.

In addition to the electrical work described in scheme 1, this scheme will also require power be provided for the new hot water boilers from existing branch panels in the boiler house. This scheme will also require raceways and network cabling to support the new BAS system.



**Figure 14 - Hot water baseboard radiation**

#### Scheme 3 Scope Items:

1. Demolish and remove the boilers, feed-water system, and condensate receiver in the boiler house
2. Install a new hot water heating plant within the main building.
3. Replace steam and condensate piping throughout the building with hot water supply and return piping.
4. Install hot water convectors along the base of exterior walls.
5. Replace neutral temperature piping runouts from the mains to the heat pumps
6. Replace neutral water main distribution piping 2" in diameter and smaller

7. Replace neutral water circulation pumps and trim
8. Replace steam heat exchanger with hot water heat exchanger and upgrade controls
9. Install variable frequency drives to modulate speed of neutral water pumps
10. Add DDC controller to modulate pumps, monitor system differential pressure, and provide capacity control of heat exchanger and fluid cooler.
11. Provide network cabling to all new heat pumps to permit remote monitoring of each zone
12. Provide operator workstation and DDC supervisory network controller to provide for enhanced monitoring and troubleshooting of system operation and performance.
13. Provide power to new hot water boilers from existing boiler house branch panels.

Discussion: This scheme is similar to scheme 1, but would eliminate the risk associated with continued reliance on the building's aging steam system. Replacing the steam system with hot water would result in reduced energy consumption and improved zone temperature control.

Opinion of Probable Cost: Based on the preliminary cost estimate provided by our sub-consultant Edwards Engineering, the implementation cost for this scheme is expected to be approximately \$7,820,000, including a 20% contingency. This number includes the cost (approx. \$1,350,000) to replace the existing mechanical ventilation system along with completion of the associated ductwork.

Annual Energy Cost Estimate: \$98,951.

Annual Maintenance Cost Estimate: \$158,300. This value represents an estimate based on the range and median values associated with repair and maintenance costs for office buildings provided in the 2017 BOMA Experience Exchange Report.

### Mechanical Ventilation Strategy – Schemes 1, 2 and 3

**Description:** The mechanical plans which were developed as part of the 1978 renovation of the building included the installation of two attic-mounted make-up air systems. Each system fed a vertical duct which was intended to provide approximately 1,000-1,100 CFM per floor. The intent of that design was never fully realized, however, as the ductwork associated with the systems was never completed.

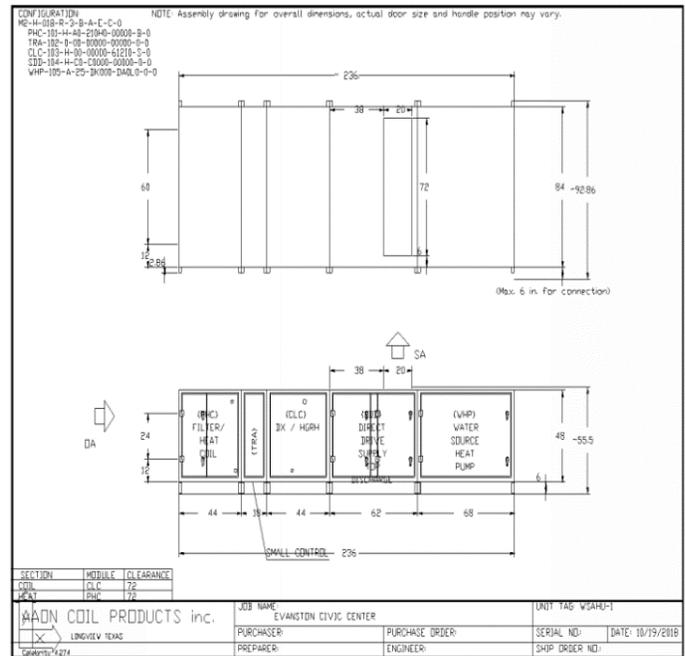
Providing a means of mechanical ventilation to the building has two important benefits. First it provides a means of ventilation which is active year-round, not just when windows may be opened. Second, it provides a means of pressurizing the building. Maintaining positive pressurization, or minimizing the degree of negative pressurization directly reduces the rate at which untempered outside air infiltrates through the exterior wall construction and through cracks in doors and windows. Reducing the infiltration rate can reduce or eliminate degradation of masonry construction which can result from the internal frosting which can occur within the masonry. Reducing the infiltration rate will also result in lower relative humidity values within the building during warm humid conditions.

**Discussion:** The design intent of the original attic make-up air systems was sound and the capacities appropriate for the size and occupancy loading of the building. Combined, those systems were intended to provide approximately 10,000 CFM of fresh air to the building.

For this scheme, the ductwork associated with the original make-up air systems would be utilized and uncompleted portions would be finished, but the air handlers would be replaced and efforts would be undertaken to isolate the building from unit generated sound.

Two new air handlers would be required. For Schemes 1 and 2, these units would be water-source heat pumps and would include a steam or hot water preheat coil, a DX cooling coil, and a hot gas reheat coil. Operation of these units will require that the neutral water piping in the attic remain in service through the winter rather than draining. To protect the piping from freeze damage, it will be necessary to insulate the exposed piping in the attic. For Scheme 3, these units would be have a single dual temperature hydronic coil.

**Opinion of Probable Cost:** Based on the preliminary cost estimate provided by our sub-consultant Edwards Engineering, the implementation cost for this scheme is expected to be approximately \$1,350,000. This includes the new DOAS units as well as the additional ductwork.



**Figure 15 - Representative Dedicated Outside Air Unit Selection**

#### **Scheme 4 – Install All-Air System with VAV boxes and Reheat Coils.**

Description: Were this building to be constructed today, it would likely be fitted with a variable air volume system to provide mechanical ventilation and space heating and cooling. Such a system would either require a single large air handling unit or perhaps one or two units on each floor.

Discussion: Conversion of the building to an all-air system would require that space be identified within the building to accommodate sizable air handling units on each floor. In addition, large medium pressure supply and return ducts would need to be installed on each floor, likely above corridor ceilings, and the heat pumps which presently serve each zone would be replaced with variable air volume (VAV) terminal units with integral reheat coils. A new building-wide system of insulated hot water supply and return piping would be required for the reheat coils. In addition, a new water chiller and piping to each air handler would be necessary.

This scheme would include a new Building Automation System. All of the new air handling units, terminal units, pumps, chillers, and boilers would be monitored and alarmed by this new BAS.

In new construction, the supply and return ducts would be mounted high in the ceiling cavity, leaving some clearance below for routing piping and conduit. In a retrofit application such as this, these ducts would likely run underneath the existing piping and conduit, which is undesirable as they would likely block access to junction boxes, pipe fittings and other ceiling mounted items which may require future access.

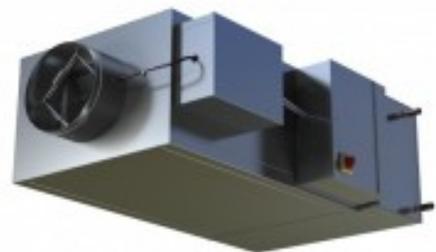
Implementation of this strategy would have a heavy impact on building occupants. Ideally, portions of the building would be vacated and the corridor ceilings removed and replaced at a lower height, resulting in reduced ceiling clearances in the corridors.

Scheme 4 would require the most work to modify the existing electrical system. In addition to all the electrical work described in Scheme 3, Scheme 4 will also require providing power to new VAV boxes and 2 additional air handling units on each floor. New branch circuits and control transformers will need to be provided to control new VAV boxes. New branch circuits will need to be provided for air handling units on each floor.

Opinion of Probable Cost: Based on the preliminary cost estimate provided by our sub-consultant Edwards Engineering, the implementation cost for this scheme is expected to be approximately \$9,780,000, including a 20% contingency.

Annual Energy Cost Estimate: \$91,811

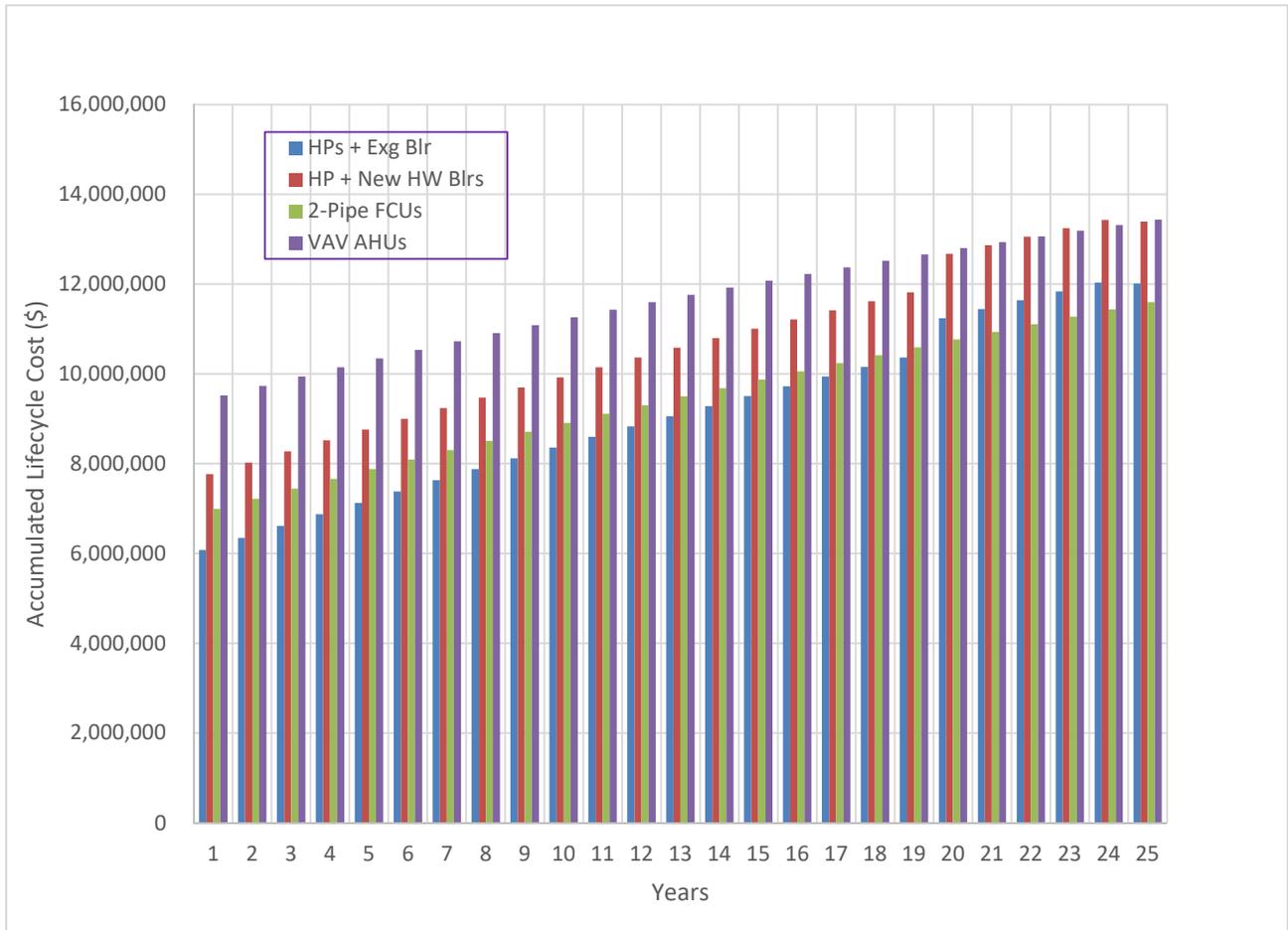
Annual Maintenance Cost Estimate: \$125,700. This value represents an estimate based on the range and median values associated with repair and maintenance costs for office buildings provided in the 2017 BOMA Experience Exchange Report.



**Figure 16 - Representative Fan-Power Box**

## RECOMMENDED UPGRADE APPROACH

Several factors should be weighed to determination which upgrade strategy best fits the City’s priorities. The alternatives described above differ in terms of first cost, impact of the construction effort on building occupants, ease of maintenance, and energy consumption. A lifecycle cost comparison has been developed, with the results presented in Figure 17 below.



**Figure 17 – 25 Year Lifecycle Costs for Each Option**

The lifecycle cost analysis indicates that the accumulated 25 year lifecycle cost of the four schemes is strongly driven by the implementation cost of each option. The differences in annual energy use of the options are relatively small. However, there are also important differences in expected service life and maintenance requirements. Packaged heat pumps have a shorter service life and require more maintenance than fan-coil units or air handling units. For this reason, the heat pumps in Schemes 1 and 3 are replaced after 20 years.

Were the decision to be based primarily on the 25 year lifecycle cost comparison, replacement of the heat pumps with 2-pipe fan-coil units would be the preferred option, though only by a narrow margin. Other qualitative factors are also important, such as the extent to which periodic repairs and maintenance activities interrupt occupants and the complexity and the duration of the construction effort necessary to implement

each option. For this reason, we have developed a comparison matrix (Exhibit 13) to provide a side by side summary of the key differences among the options.

Replacement of the heat pumps with fan-coil units would initially cost about \$1.3 million dollars more than replacing the heat pumps in kind. Over the 25 year lifecycle cost evaluation period, this difference in first cost is largely offset by reduced energy and maintenance costs. The benefit of fan-coil system type is that fan-coil units require less maintenance than a heat pump unit since they are a much simpler piece of equipment, consisting of just a fan, a coil, filter and basic controls. For this reason, the maintenance staff would spend less time working on units above ceilings or opening ceilings to remove units for remote servicing, thereby reducing disruptions to the building's occupants.

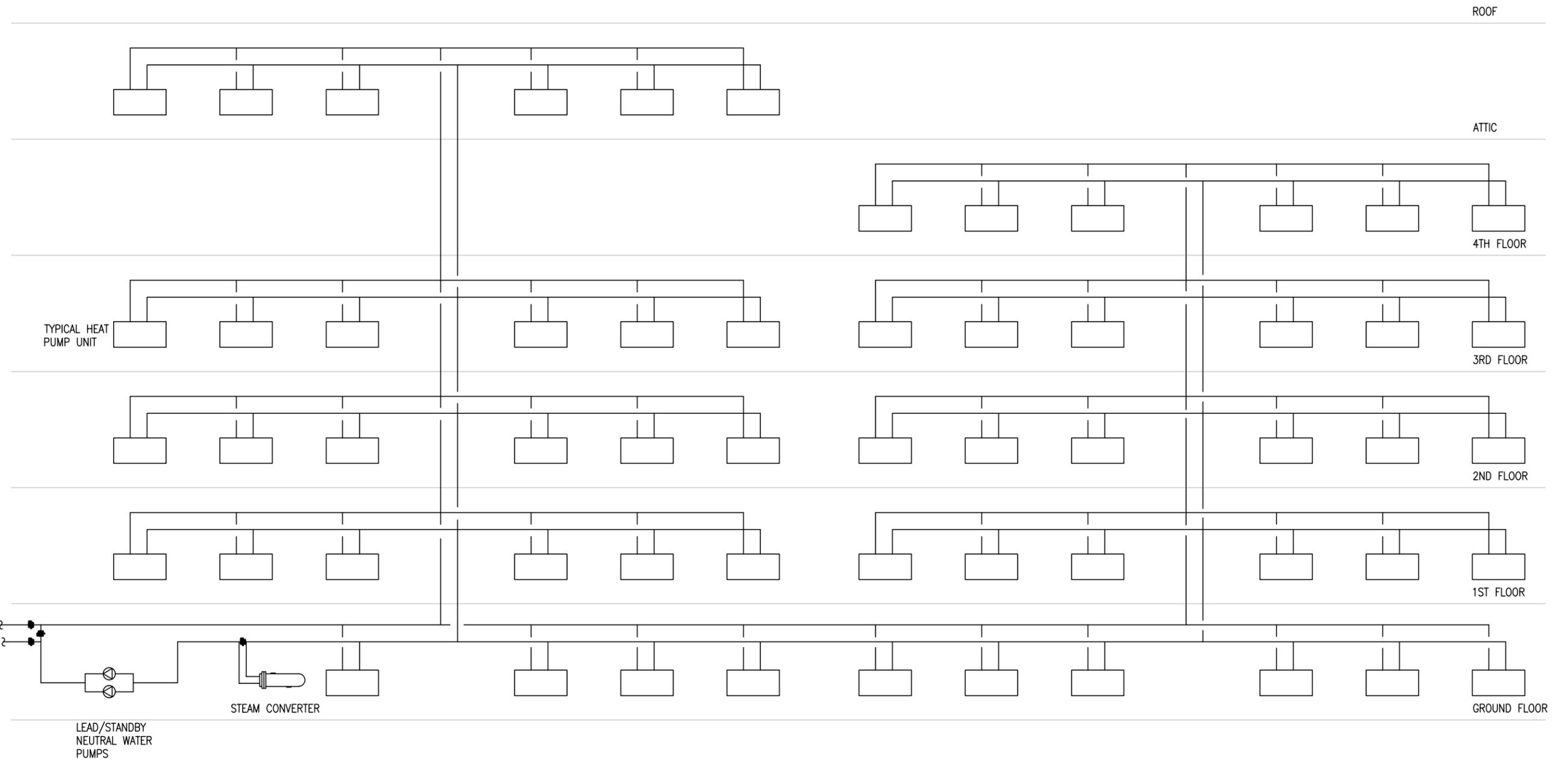
2-pipe fan-coil units can either provide cooling or heating. It would not be possible for some units to cool (sun facing zones) while other units provide heat (to shaded areas). Due to the presence of the building's perimeter heating system, which operates independently from the cooling systems, this concern is largely minimized.

Replacement of the heat pumps with VAV air handling units would cost approximately \$3.8 million dollars more than replacing the heat pumps in kind. The benefit of the VAV AHU system type is that only fan-powered boxes or VAV terminal units would be located at the zone level above ceilings. Terminal units are even simpler than fan-coil units and are far less complex than a heat pump as they consist of a motor operated damper, a flow measurement device and controller.

In light of the important economic, operations and maintenance and construction effort trade-offs, we defer to the client to decide which combination of costs and benefits best align with the project goals.

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NEUTRAL WATER SYSTEM RISER DIAGRAM

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STEVE ZEHR

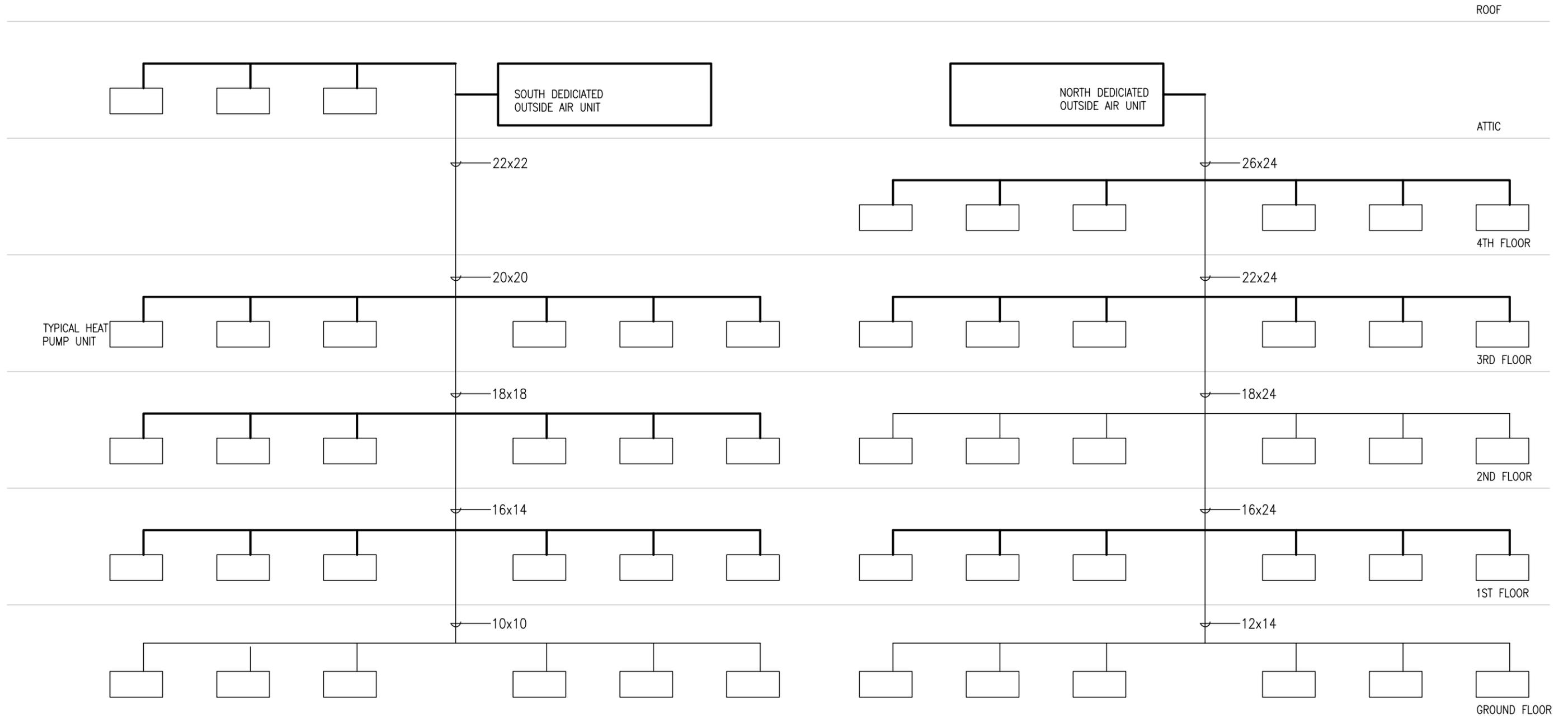
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**MECHANICAL SYSTEMS ASSESSMENT**  
 LORRAINE H. MORTON CIVIC CENTER  
 EVANSTON, IL

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|-------------|----------|
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| APPROVED    | JET      |
| SCALE       | NTS      |
| PROJECT NO. | P18-0349 |

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**DEDICATED OUTSIDE AIR SYSTEM RISER DIAGRAM**

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STEVE ZEHR

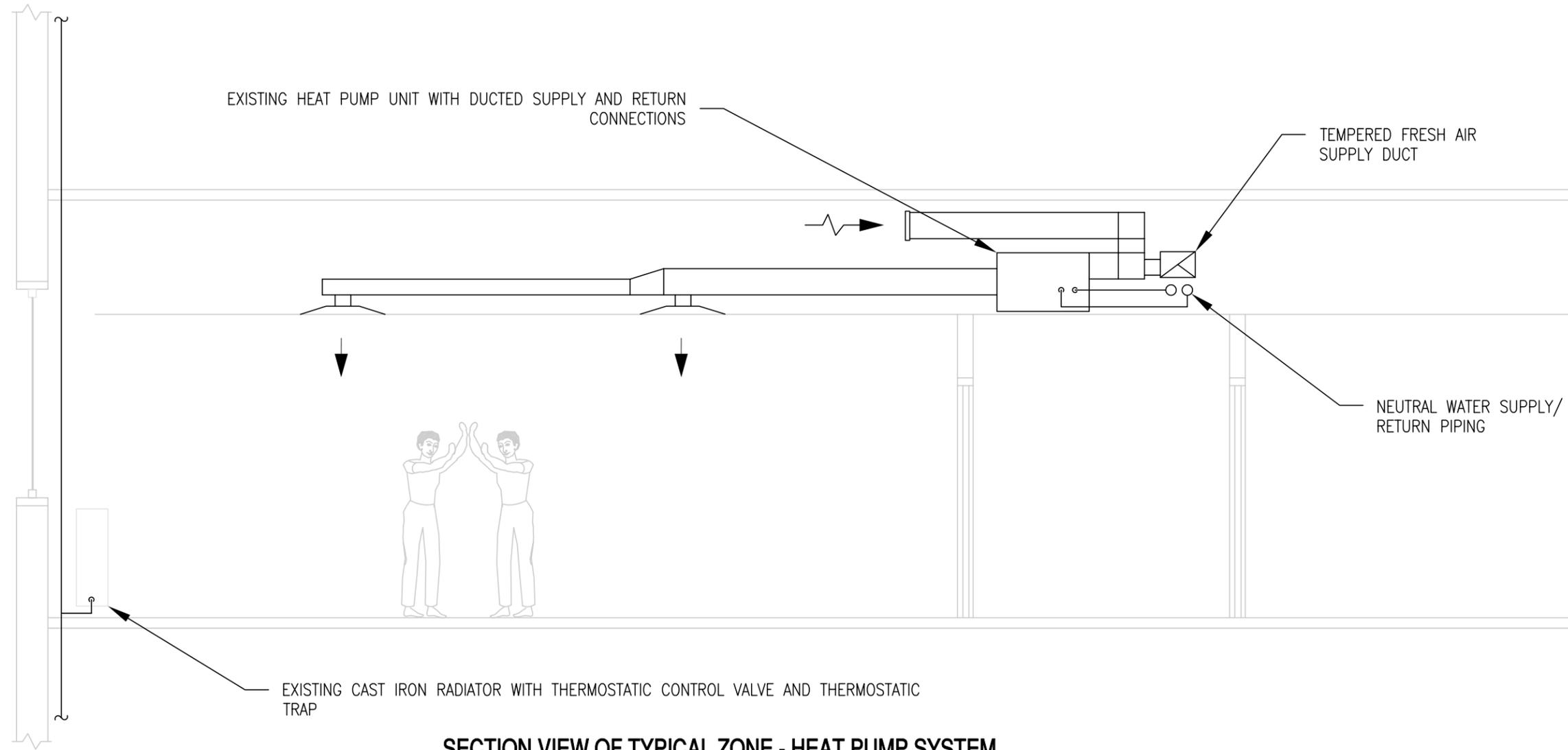
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**SECTION VIEW OF TYPICAL ZONE - HEAT PUMP SYSTEM**

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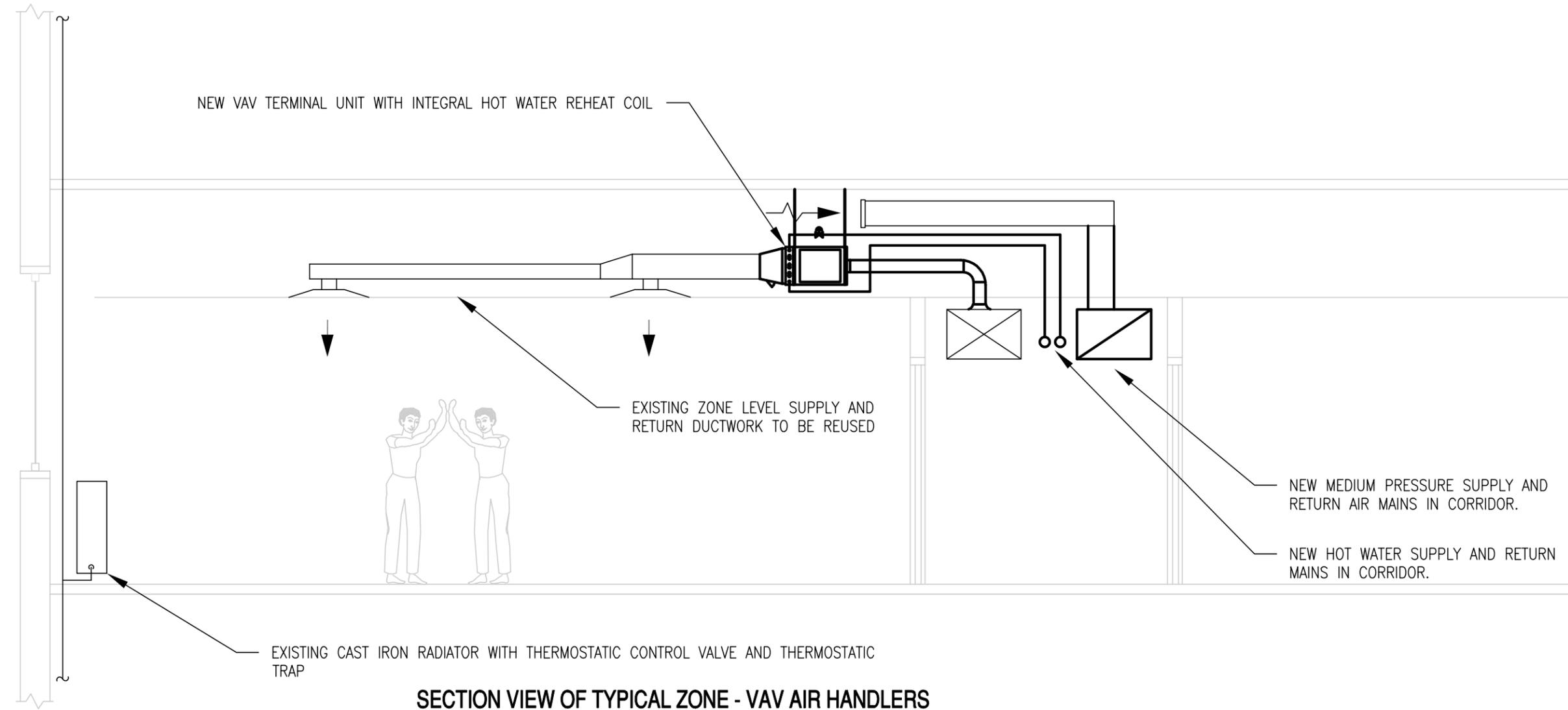
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Fax: (630) 510-3261  
www.boilerinspection.com

**BOILER TUBE CONDITION ASSESSMENT  
BOILER NOS. 1 & 2  
FOR  
EVANSTON CIVIC CENTER  
EVANSTON, ILLINOIS**

**SUBMITTED BY:**

**BOILER INSPECTION SERVICES COMPANY  
1755 S. Naperville Rd., Suite 100  
Wheaton, IL 60189**

**Dated: August 2018**

**\*\*\* THE BOILER & PRESSURE VESSELS EVALUATION SPECIALISTS \*\*\***

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| RECOMMENDATIONS .....    | 9  |
| CALCULATIONS .....       | 12 |

### APPENDICES

ULTRASONIC THICKNESS TESTING RESULTS

MAGNETIC PARTICLE TESTING RESULTS

REMOTE FIELD EDDY CURRENT TESTING RESULTS

PHOTOGRAPHIC DOCUMENTATION

## INTRODUCTION

On August 24, 2018, Boiler Inspection Services Company performed a Boiler Tube Condition Assessment on Boilers #1 and #2 for Evanston Civic Center, located in Evanston, Illinois. The objectives of the evaluation are to provide information on the remaining metal thickness, physical condition, identify any current operational and maintenance deficiencies, and determine the cause of any deficient conditions.

The boiler's physical condition, description and evaluation are based upon information obtained through visual inspection, nondestructive examination (NDE) including ultrasonic thickness testing (UT), magnetic particle testing (MT), remote field eddy current testing (RFEC), and an assessment of previous operation, maintenance and repair data.

Subsequent portions of this report contain a description of the boiler, an evaluation of the existing physical condition and the inspection techniques utilized. Calculations addressing the original design are given and where applicable, current conditions and projected working pressures and depletion rates are also included when required. Preceding the survey text is a summary of our inspection findings and corresponding suggestions for corrections of observed discrepancies.

These boilers are identified by Evanston Civic Center as Boiler #1 and #2, and display National Board Nos. 1996 and 1995, respectively. Both boilers were built in 1965 and are rated at 15 psi steam.

An exit meeting was held on August 24, 2018, with Mr. Steve Zehr of Grumman Butkus Consulting Company, to relate the preliminary results of the inspection and to discuss various operational and maintenance deficiencies noted during the evaluation.

This evaluation was performed by Ron Avalos, Project Manager, and assisted by Katreena Avalos, NDE Level II, Jacob Johnson, NDE Level II, and Casimir Soczyk, NDE Level I.

If there are any questions regarding this report or the services offered by Boiler Inspection Services Company, please contact the Operations Manager, at (630) 510-3223.

## OBJECT DESCRIPTION

### BOILER #1 AND #2

|                        |   |                 |
|------------------------|---|-----------------|
| Boiler Type            | - | Firetube Boiler |
| Year Built             | - | 1965            |
| MAWP                   | - | 15 psi steam    |
| Tube Size              | - | 3"              |
| Tube Nominal Thickness | - | .110"           |

### Safety Relief Valves

|              |   | <u>Boiler #1</u> |              | <u>Boiler #2</u> |              |
|--------------|---|------------------|--------------|------------------|--------------|
|              |   | <u>RV A</u>      | <u>RV B</u>  | <u>RV A</u>      | <u>RV B</u>  |
| Manufacturer | - | Apollo Valve     | Apollo Valve | Apollo Valve     | Apollo Valve |
| Size         | - | 2 x 2            | 2 x 2        | 2 x 2            | 2 x 2        |
| Set          | - | 15 psi           | 15 psi       | 15 psi           | 15 psi       |
| Capacity     | - | 3,150 lbs/hr     | 3,150 lbs/hr | 3,150 lbs/hr     | 3,150 lbs/hr |
| Date         | - | Unknown          | Unknown      | Unknown          | Unknown      |

## **SUMMARY**

### **WATERSIDE**

**Visual inspection of the waterside in Boilers #1 and #2 revealed the following:**

- A) Scale and tubercles were observed on the accessible tubes, boiler shell, and furnace sheet throughout both boilers. Heavy under deposit pitting and corrosion were observed in the tubes. Light pitting was noted on the accessible furnace sheets. (See photos)
  
- B) Old cut-out tubes were noted at the bottom of the shell in both boilers. A moderate accumulation of sediment and debris were observed at the bottom of the boilers. (See photos)

### **FIRESIDE**

**Visual inspection of the fireside in Boilers #1 and #2 revealed the following:**

- A) A light layer of black soot was observed throughout the fireside on both boilers. (See photos)
  
- B) No indication of pitting was noted on the front and rear tubesheets in both boilers. (See photos)

- C) The tubesheet ligaments and accessible stud welds, circumferential welds, and longitudinal welds appeared to be in satisfactory condition. (See photos)
- D) Watermark discoloration was noted on the inner rear tubesheets in both boilers, likely caused by condensation during the start/stop operation of the boilers. (See photos)
- E) Waterlines were noted on the furnace sheets and combustion chambers, indicative of previous tube leakage. (See photos)
- F) Light corrosion and pitting were observed on the furnace sheets. (See photos)
- G) Soot build-up was noted near the burner in both boilers. (See photos)
- H) Cracks in the burner refractory in both boilers were observed. Corrosion and warping of the burner barrels were noted in Boiler #2. (See photos)
- I) Accumulation of debris was observed at the bottom of the combustion chamber and beneath the burner in both boilers. (See photos)

## **EXTERNAL AND SAFETY APPURTENANCES**

### **Visual inspection of the boiler's external revealed the following:**

- A) No indication of up-to-date calibration was observed on the pressure/temperature gauges and pressure relief valves on both boilers.  
(See photos)
  
- B) The low water fuel cut-off devices were newly installed. (See photos)
  
- C) The water level sight glasses appeared to be in satisfactory condition.  
(See photos)
  
- D) Indications of past leakage was noted on the main steam isolation valves.  
(See photos)
  
- E) Gaps in the casing seams were noted on both boilers. (See photos)
  
- F) Staining, corrosion, and deterioration were observed on the casing beneath the boilers. Corrosion around the handholes was also noted. (See photos)
  
- G) The support structures appeared to be in satisfactory condition.  
(See photos)

## **NONDESTRUCTIVE TESTING (NDE)**

- A) Ultrasonic thickness testing (UT) on Boilers #1 and #2 of the front tubesheet, inner rear tubesheet, furnace sheet, and combustion chamber showed no significant wall loss. The least thickness measured is still appropriate for the design pressure of the boiler at this time. (See UT results)
  
- B) Magnetic particle testing (MT) on Boilers #1 and #2 of the tubesheet ligaments and selected circumferential and longitudinal welds on the boiler's fireside revealed no relevant indications. (See MT results)
  
- C) Remote field eddy current (RFEC) testing of seventy-two (72) tubes in each boiler revealed the following: (See the color code diagrams for more details)

### **BOILER #1**

- a) Thirty-five (35) tubes have a wall thickness loss of 51% and above.
- b) Eighteen (18) tubes have a wall thickness loss of 41% and up to 50%.
- c) Nineteen (19) tubes have a wall thickness loss of 31% and up to 40%.

(See RFEC results)

### **BOILER #2**

- a) Forty-five (45) tubes have a wall thickness loss of 51% and above.

- b) Twenty-seven (27) tubes have a wall thickness loss of 41% and up to 50%. (See RFEC results)

## RECOMMENDATIONS

Relative to the boilers' life, the most critical components are the shell, front and rear tubesheets and furnace sheet with the tubes being considered replaceable. Of additional concerns are boiler appurtenances (low water cut-offs, sight glass, safety valves, isolation valves and others). The basis for the evaluation of the current condition is the original thickness and the presence of defects/conditions, which may be deleterious. However, the following recommendations should be scheduled and/or performed:

1. Consideration should be given to completely re-tube Boiler #1 and Boiler #2 due to the present deleterious condition of the tubes prior to the operation of the boilers. At 50% wall loss, the tubes can still theoretically operate at the design pressure of the boilers, however, the State/Jurisdictional authority recommends to start replacing the tubes when the wall loss approaches 50%. A significant portion of tubes in Boiler #1 (49%) and Boiler #2 (63%) have a wall loss of 51% or above, with the remaining tubes nearing 50%. The replacement tubes should be at least equal to or greater than the original material specification. The company that will perform the tube replacement should have a valid "R" stamped from the National Board.

2. The waterside of the boilers should be pressure washed and/or a more aggressive method of scale removal (acid wash) utilized to dislodge and dissolve the heavy build-up of scale. Any accumulation of sediment and debris at the bottom of the boilers should be cleaned out. The build-up of scale or tubercles tends to accelerate corrosion on the shell and tubes by means of oxygen entrapment, as well as decrease the efficiency of the boiler. The potential for overheating of the tubes and furnace sheet also increases due to the insulating effect of the scale. Power washing of the boilers' waterside should be performed annually and incorporated into the boilers' annual maintenance program.
  
3. The fireside of the boilers (furnace sheet, and tubesheets) should be cleaned and free of fireside scale and deposits to prevent masking of surface defects and improve the efficiency and fuel consumption of the boiler.
  
4. The boilers' burner should be tuned-up by a qualified and experienced burner repair company prior to the operation of the boilers to prevent flame impingement and ensure the correct fuel to air ratio for proper combustion and boiler efficiency. The black soot currently on the shell of the furnace sheets should be cleaned to better serve as an indicator for the tuning of the burners.

5. The cracks in the burner refractory in both boilers should be repaired prior to the operation of the boilers. The boilers' refractory should be monitored and repaired as needed every shutdown.
6. The main pressure gauge and auxiliary pressure gauges should be calibrated every year to a master gauge traceable to the National Standard. Frequency of calibration should be incorporated into the boilers' preventative maintenance program.
7. The safety relief valves should be calibrated every three (3) years, or replaced.
8. The float bowl of the low water fuel cut-off devices should be cleaned annually to prevent restriction on the float chamber during boiler operation.
9. The insulation and casing on the boilers should be repaired at the next available boiler opportunity and continuously monitored for moisture entrapment to prevent external corrosion of the boiler's shell.
10. Consult with a water treatment company to adjust the water chemistry and reduce the build-up of scale throughout the boiler's waterside.

## CALCULATIONS

### BOILER #1 AND #2

|                      |   |          |
|----------------------|---|----------|
| Year Built           | - | 1965     |
| MAWP                 | - | 15 psi   |
| Tube Size            | - | 3" OD    |
| Boiler Tube Material | - | SA-178-A |

|   |   |       |
|---|---|-------|
| Nominal thickness   | - | .110" |
| Lowest thickness measured at 50% wall loss<br>(Excluding tubes above 50% wall loss)             | - | .055" |
| Minimum required thickness @ 15 psi:  | - | .018" |
| Remaining Actual Thickness @ 50% wall loss<br>[Thickness measured – minimum required thickness] | - | .037" |

#### **Note:**

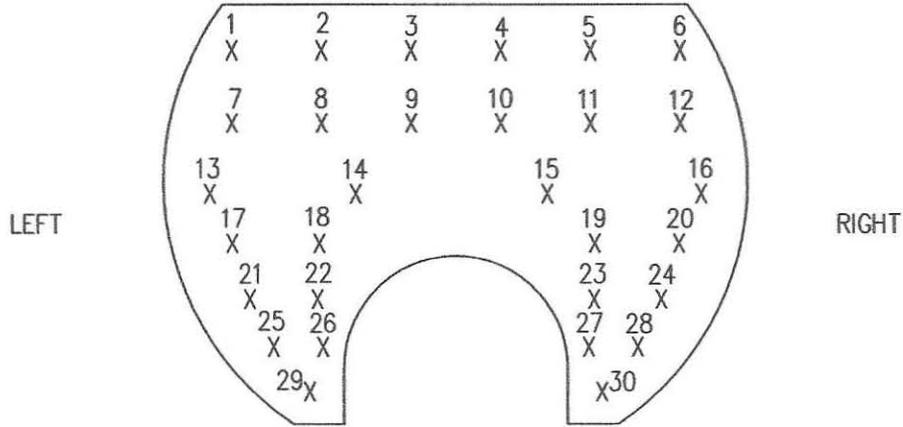
At 50% wall loss, the tubes can still theoretically operate at the design pressure of the boiler, however, the State/Jurisdictional authority recommends to start replacing the tubes when the wall loss approaches 50%.

\* Calculations are only theoretical ASME Section IV, 1965 edition.

## **ULTRASONIC THICKNESS TESTING RESULTS**

**BOILER #1**

EVANSTON CIVIC CENTER  
 EVANSTON, ILLINOIS  
 BOILER NO.1  
 ULTRASONIC THICKNESS READINGS  
 FRONT TUBESHEET



ULTRASONIC THICKNESS READINGS  
 BOILER #1 - FRONT TUBESHEET

LOCATIONS

|          |       |           |       |           |       |           |       |           |       |
|----------|-------|-----------|-------|-----------|-------|-----------|-------|-----------|-------|
| <b>1</b> | 0.451 | <b>7</b>  | 0.454 | <b>13</b> | 0.474 | <b>19</b> | 0.445 | <b>25</b> | 0.465 |
| <b>2</b> | 0.448 | <b>8</b>  | 0.464 | <b>14</b> | 0.514 | <b>20</b> | 0.457 | <b>26</b> | 0.465 |
| <b>3</b> | 0.473 | <b>9</b>  | 0.457 | <b>15</b> | 0.459 | <b>21</b> | 0.450 | <b>27</b> | 0.462 |
| <b>4</b> | 0.453 | <b>10</b> | 0.466 | <b>16</b> | 0.438 | <b>22</b> | 0.454 | <b>28</b> | 0.456 |
| <b>5</b> | 0.454 | <b>11</b> | 0.482 | <b>17</b> | 0.447 | <b>23</b> | 0.463 | <b>29</b> | 0.462 |
| <b>6</b> | 0.454 | <b>12</b> | 0.457 | <b>18</b> | 0.444 | <b>24</b> | 0.457 | <b>30</b> | 0.462 |

CLIENT:  
 EVANSTON CIVIC CENTER

TITLE:  
 BOILER NO.1

INSPECTION  
 ENGINEER:

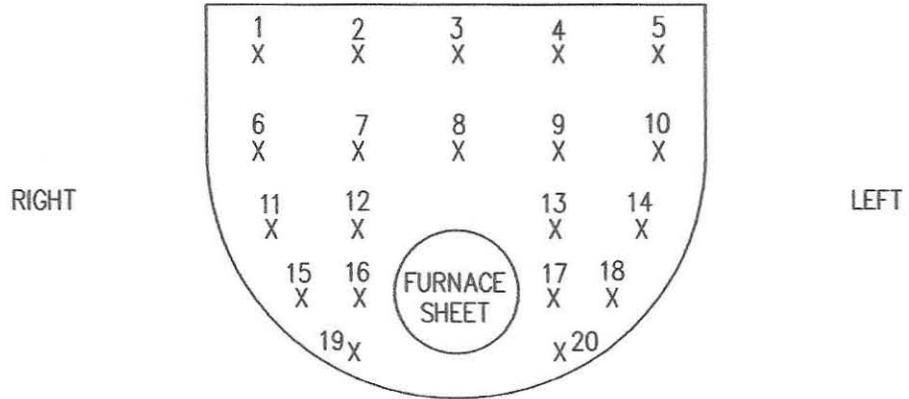
DRAWN  
 BY: A. NOBLE JR.

CAD  
 SUPER: D. JIMENEZ

SCALE: NONE

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 Wheaton, Illinois 60187

EVANSTON CIVIC CENTER  
 EVANSTON, ILLINOIS  
 BOILER NO.1  
 ULTRASONIC THICKNESS READINGS  
 INNER REAR TUBESHEET



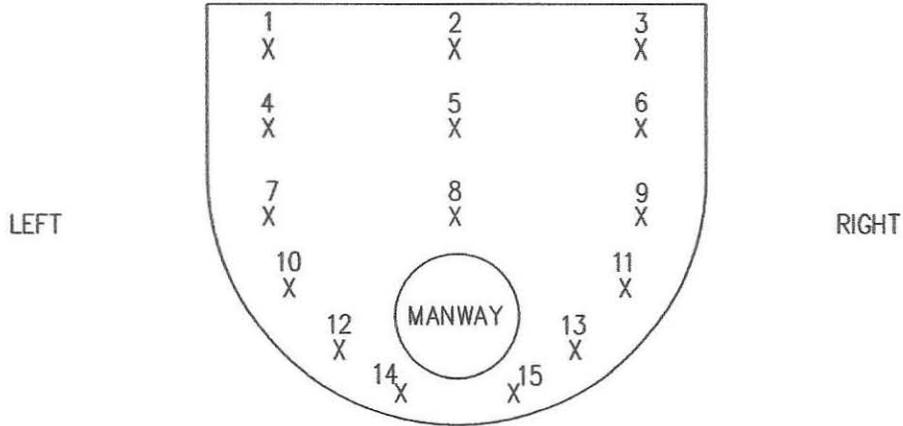
ULTRASONIC THICKNESS READINGS  
 BOILER #1 - INNER REAR TUBESHEET

LOCATIONS

|          |       |           |       |           |       |           |       |
|----------|-------|-----------|-------|-----------|-------|-----------|-------|
| <b>1</b> | 0.510 | <b>6</b>  | 0.477 | <b>11</b> | 0.450 | <b>16</b> | 0.474 |
| <b>2</b> | 0.451 | <b>7</b>  | 0.459 | <b>12</b> | 0.443 | <b>17</b> | 0.456 |
| <b>3</b> | 0.454 | <b>8</b>  | 0.456 | <b>13</b> | 0.452 | <b>18</b> | 0.457 |
| <b>4</b> | 0.457 | <b>9</b>  | 0.456 | <b>14</b> | 0.453 | <b>19</b> | 0.459 |
| <b>5</b> | 0.453 | <b>10</b> | 0.459 | <b>15</b> | 0.454 | <b>20</b> | 0.457 |

|                                  |  |   |
|----------------------------------|--|---|
| CLIENT:<br>EVANSTON CIVIC CENTER | INSPECTION ENGINEER:<br>DRAWN BY: A. NOBLE JR. | <b>BOILER INSPECTION SERVICES COMPANY</b><br>1755 S. Naperville Rd. Suite #100<br>Wheaton, Illinois 60187 |
| TITLE:<br>BOILER NO.1            | CAD SUPER: D. JIMENEZ                          |   |
| SCALE: NONE                      |  |   |

EVANSTON CIVIC CENTER  
 EVANSTON, ILLINOIS  
 BOILER NO.1  
 ULTRASONIC THICKNESS READINGS  
 INNER REAR WALL



ULTRASONIC THICKNESS READINGS  
 BOILER #1 - INNER REAR WALL

LOCATIONS

|          |       |           |       |           |       |
|----------|-------|-----------|-------|-----------|-------|
| <b>1</b> | 0.374 | <b>6</b>  | 0.388 | <b>11</b> | 0.378 |
| <b>2</b> | 0.384 | <b>7</b>  | 0.365 | <b>12</b> | 0.414 |
| <b>3</b> | 0.385 | <b>8</b>  | 0.208 | <b>13</b> | 0.381 |
| <b>4</b> | 0.387 | <b>9</b>  | 0.381 | <b>14</b> | 0.353 |
| <b>5</b> | 0.387 | <b>10</b> | 0.367 | <b>15</b> | 0.357 |

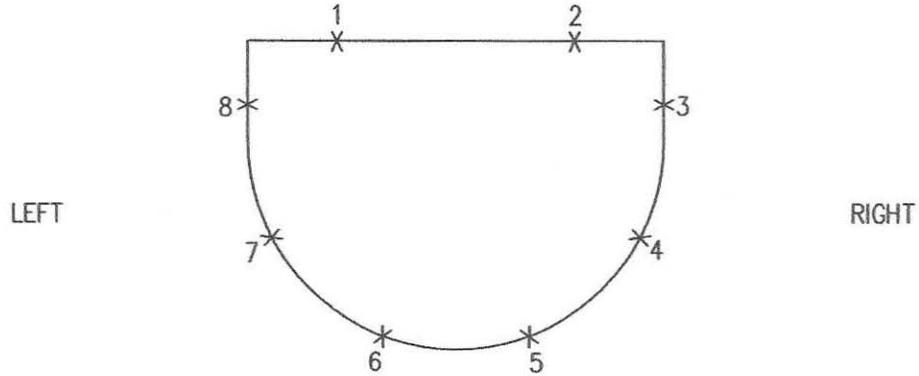
CLIENT:  
 EVANSTON CIVIC CENTER

TITLE:  
 BOILER NO.1

INSPECTION  
 ENGINEER:  
 DRAWN BY: A. NOBLE JR.  
 CAD SUPER: D. JIMENEZ  
 SCALE: NONE

**BOILER INSPECTION  
 SERVICES COMPANY**  
 1755 S. Naperville Rd, Suite #100  
 Wheaton, Illinois 60187

EVANSTON CIVIC CENTER  
 EVANSTON, ILLINOIS  
 BOILER NO.1  
 ULTRASONIC THICKNESS READINGS  
 COMBUSTION CHAMBER



ULTRASONIC THICKNESS READINGS  
 BOILER #1 - COMBUSTION CHAMBER

LOCATIONS

|   |       |   |       |   |       |
|---|-------|---|-------|---|-------|
| 1 | 0.412 | 4 | 0.378 | 7 | 0.390 |
| 2 | 0.384 | 5 | 0.383 | 8 | 0.374 |
| 3 | 0.380 | 6 | 0.387 |   |       |

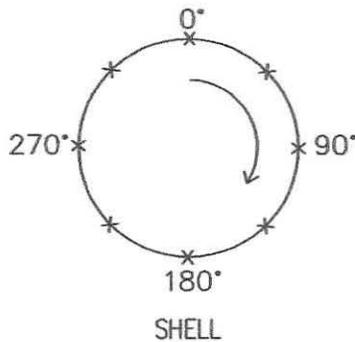
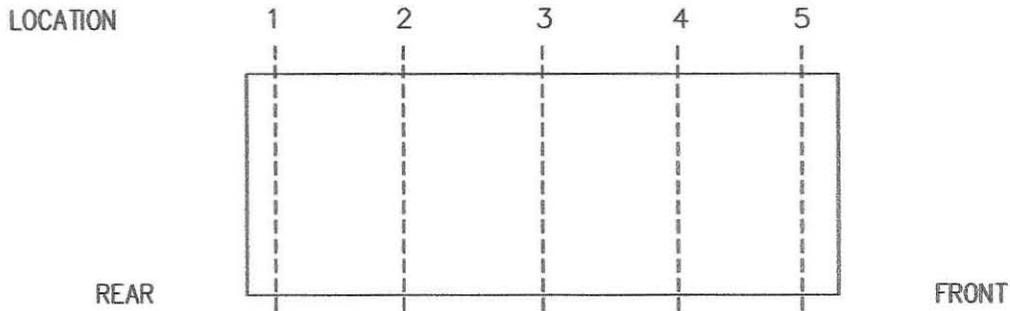
CLIENT:  
 EVANSTON CIVIC CENTER

TITLE:  
 BOILER NO.1

INSPECTION  
 ENGINEER:  
 DRAWN  
 BY: A. NOBLE JR.  
 CAD  
 SUPER: D. JIMENEZ  
 SCALE: NONE

BOILER INSPECTION  
 SERVICES COMPANY  
 1755 S. Naperville Rd. Suite #100  
 Wheaton, Illinois 60187

EVANSTON CIVIC CENTER  
EVANSTON, ILLINOIS  
BOILER NO.1  
ULTRASONIC THICKNESS READINGS  
FURNACE SHEET



ULTRASONIC THICKNESS READINGS  
BOILER #1 - FURNACE SHEET

LOCATIONS

|      | 1     | 2     | 3     | 4     | 5     |
|------|-------|-------|-------|-------|-------|
| 0°   | 0.388 | 0.396 | 0.398 | 0.404 | 0.409 |
| 45°  | 0.403 | 0.400 | 0.423 | 0.406 | 0.403 |
| 90°  | 0.401 | 0.397 | 0.423 | 0.406 | 0.399 |
| 135° | 0.409 | 0.405 | 0.398 | 0.404 | 0.398 |
| 180° | 0.409 | 0.406 | 0.398 | 0.403 | 0.405 |
| 225° | 0.402 | 0.394 | 0.398 | 0.405 | 0.395 |
| 270° | 0.405 | 0.416 | 0.399 | 0.401 | 0.393 |
| 315° | 0.404 | 0.405 | 0.424 | 0.432 | 0.397 |

CLIENT:  
EVANSTON CIVIC CENTER

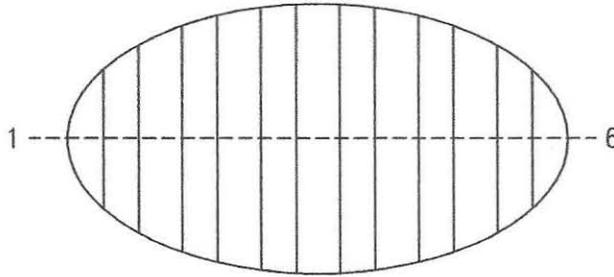
TITLE:  
BOILER NO.1

INSPECTION ENGINEER:  
DRAWN BY: A. NOBLE JR.  
CAD SUPER: D. JIMENEZ  
SCALE: NONE

**BOILER INSPECTION  
SERVICES COMPANY**  
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Wheaton, Illinois 60187

EVANSTON CIVIC CENTER  
 EVANSTON, ILLINOIS  
 BOILER NO.1  
 ULTRASONIC THICKNESS READINGS  
 TOP TUBES

FRONT



REAR

ULTRASONIC THICKNESS READINGS  
 BOILER #1 - TOP TUBES

LOCATIONS

|   |       |   |       |
|---|-------|---|-------|
| 1 | 0.116 | 4 | 0.107 |
| 2 | 0.119 | 5 | 0.107 |
| 3 | 0.111 | 6 | 0.111 |

CLIENT:  
 EVANSTON CIVIC CENTER

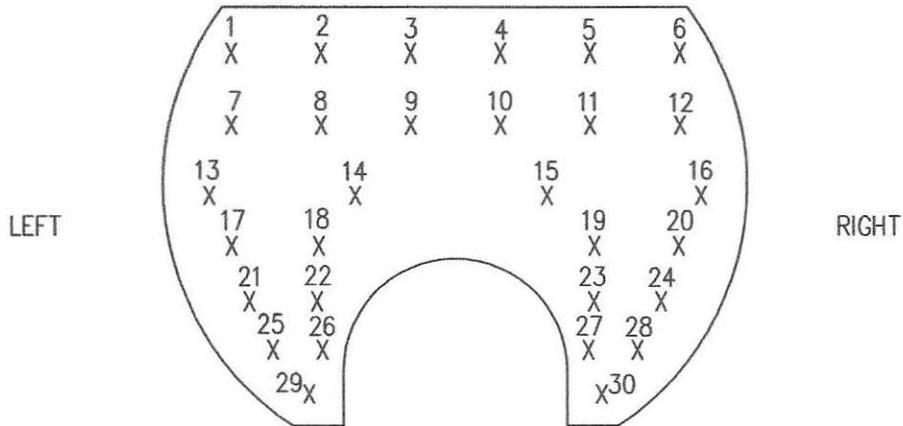
TITLE:  
 BOILER NO.1

INSPECTION  
 ENGINEER:  
 DRAWN  
 BY: A. NOBLE JR.  
 CAD  
 SUPER: D. JIMENEZ  
 SCALE: NONE

BOILER INSPECTION  
 SERVICES COMPANY  
 1755 S. Naperville Rd, Suite #100  
 Wheaton, Illinois 60187

**BOILER #2**

EVANSTON CIVIC CENTER  
 EVANSTON, ILLINOIS  
 BOILER NO.2  
 ULTRASONIC THICKNESS READINGS  
 FRONT TUBESHEET



ULTRASONIC THICKNESS READINGS  
 BOILER #2- FRONT TUBESHEET

LOCATIONS

|   |       |    |       |    |       |    |       |    |       |
|---|-------|----|-------|----|-------|----|-------|----|-------|
| 1 | 0.442 | 7  | 0.448 | 13 | 0.452 | 19 | 0.446 | 25 | 0.448 |
| 2 | 0.443 | 8  | 0.449 | 14 | 0.452 | 20 | 0.446 | 26 | 0.463 |
| 3 | 0.445 | 9  | 0.447 | 15 | 0.452 | 21 | 0.448 | 27 | 0.454 |
| 4 | 0.446 | 10 | 0.447 | 16 | 0.449 | 22 | 0.454 | 28 | 0.457 |
| 5 | 0.444 | 11 | 0.455 | 17 | 0.438 | 23 | 0.442 | 29 | 0.448 |
| 6 | 0.449 | 12 | 0.455 | 18 | 0.438 | 24 | 0.448 | 30 | 0.448 |

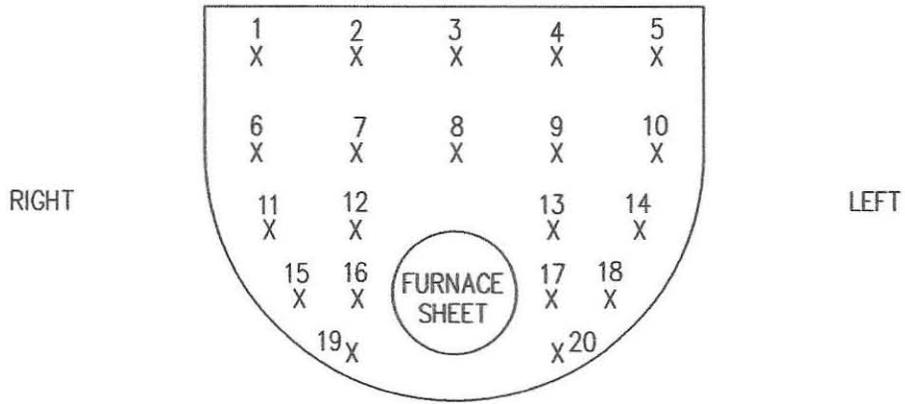
CLIENT:  
 EVANSTON CIVIC CENTER

TITLE:  
 BOILER NO.2

INSPECTION  
 ENGINEER:  
 DRAWN  
 BY: A. NOBLE JR.  
 CAD  
 SUPER: D. JIMENEZ  
 SCALE: NONE

**BOILER INSPECTION  
 SERVICES COMPANY**  
 1755 S. Naperville Rd. Suite #100  
 Wheaton, Illinois 60187

EVANSTON CIVIC CENTER  
 EVANSTON, ILLINOIS  
 BOILER NO.2  
 ULTRASONIC THICKNESS READINGS  
 INNER REAR TUBESHEET



ULTRASONIC THICKNESS READINGS  
 BOILER #2 - INNER REAR TUBESHEET

LOCATIONS

|          |       |           |       |           |       |           |       |
|----------|-------|-----------|-------|-----------|-------|-----------|-------|
| <b>1</b> | 0.456 | <b>6</b>  | 0.458 | <b>11</b> | 0.440 | <b>16</b> | 0.454 |
| <b>2</b> | 0.459 | <b>7</b>  | 0.458 | <b>12</b> | 0.440 | <b>17</b> | 0.456 |
| <b>3</b> | 0.458 | <b>8</b>  | 0.457 | <b>13</b> | 0.440 | <b>18</b> | 0.454 |
| <b>4</b> | 0.460 | <b>9</b>  | 0.463 | <b>14</b> | 0.458 | <b>19</b> | 0.458 |
| <b>5</b> | 0.462 | <b>10</b> | 0.454 | <b>15</b> | 0.452 | <b>20</b> | 0.458 |

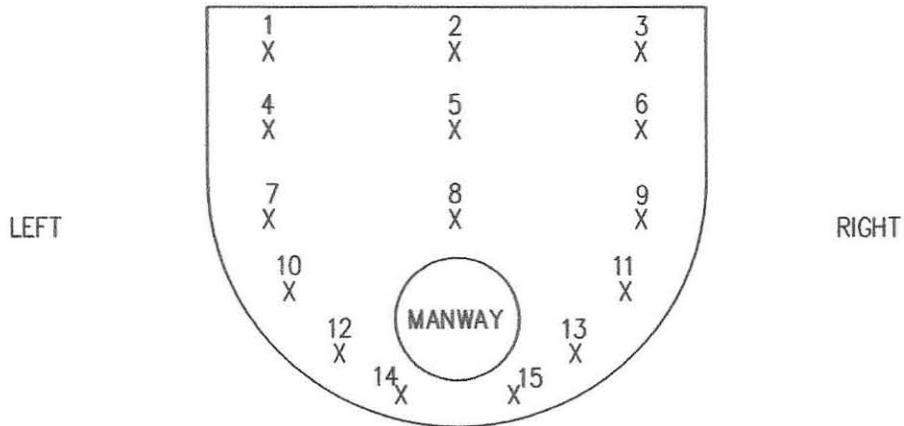
CLIENT:  
 EVANSTON CIVIC CENTER

TITLE:  
 BOILER NO.2

|                      |              |
|----------------------|--------------|
| INSPECTION ENGINEER: |              |
| DRAWN BY:            | A. NOBLE JR. |
| CAD SUPER:           | D. JIMENEZ   |
| SCALE: NONE          |              |

**BOILER INSPECTION  
 SERVICES COMPANY**  
 1755 S. Naperville Rd. Suite #100  
 Wheaton, Illinois 60187

EVANSTON CIVIC CENTER  
 EVANSTON, ILLINOIS  
 BOILER NO.2  
 ULTRASONIC THICKNESS READINGS  
 INNER REAR WALL



ULTRASONIC THICKNESS READINGS  
 BOILER #2 - INNER REAR WALL

LOCATIONS

|          |       |           |       |           |       |
|----------|-------|-----------|-------|-----------|-------|
| <b>1</b> | 0.382 | <b>6</b>  | 0.384 | <b>11</b> | 0.406 |
| <b>2</b> | 0.357 | <b>7</b>  | 0.384 | <b>12</b> | 0.387 |
| <b>3</b> | 0.382 | <b>8</b>  | 0.357 | <b>13</b> | 0.401 |
| <b>4</b> | 0.384 | <b>9</b>  | 0.386 | <b>14</b> | 0.391 |
| <b>5</b> | 0.384 | <b>10</b> | 0.385 | <b>15</b> | 0.385 |

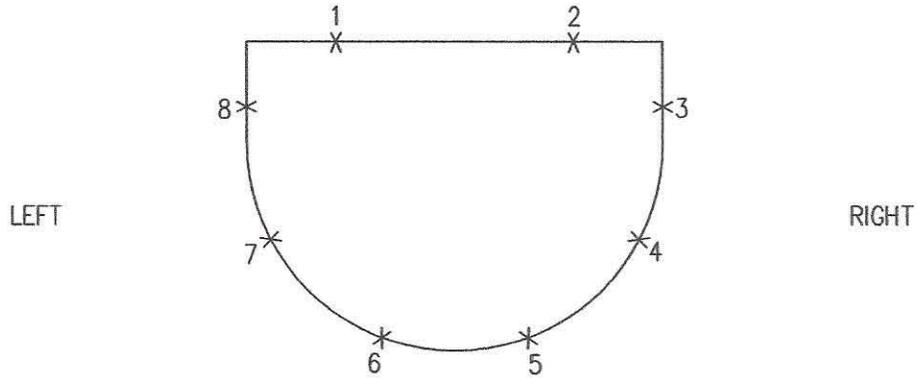
CLIENT:  
 EVANSTON CIVIC CENTER

TITLE:  
 BOILER NO.2

INSPECTION  
 ENGINEER:  
 DRAWN  
 BY: A. NOBLE JR.  
 CAD  
 SUPER: D. JIMENEZ  
 SCALE: NONE

**BOILER INSPECTION  
 SERVICES COMPANY**  
 1755 S. Naperville Rd. Suite #100  
 Wheaton, Illinois 60187

EVANSTON CIVIC CENTER  
 EVANSTON, ILLINOIS  
 BOILER NO.2  
 ULTRASONIC THICKNESS READINGS  
 COMBUSTION CHAMBER



ULTRASONIC THICKNESS READINGS  
 BOILER #2 - COMBUSTION CHAMBER

LOCATIONS

|          |       |          |       |          |       |
|----------|-------|----------|-------|----------|-------|
| <b>1</b> | 0.378 | <b>4</b> | 0.380 | <b>7</b> | 0.379 |
| <b>2</b> | 0.376 | <b>5</b> | 0.379 | <b>8</b> | 0.377 |
| <b>3</b> | 0.371 | <b>6</b> | 0.378 |          |       |

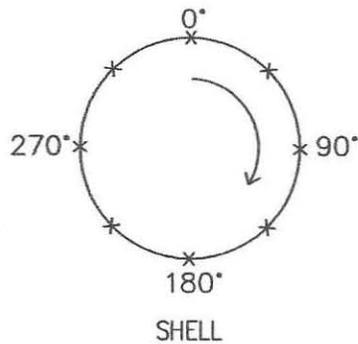
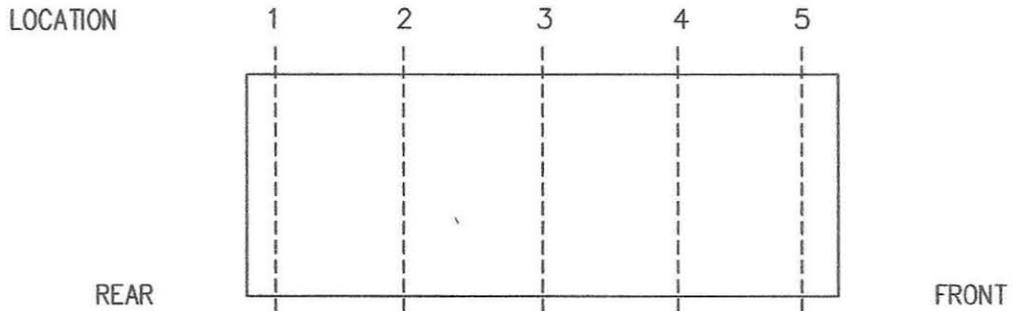
CLIENT:  
 EVANSTON CIVIC CENTER

TITLE:  
 BOILER NO.2

|                      |              |
|----------------------|--------------|
| INSPECTION ENGINEER: |              |
| DRAWN BY:            | A. NOBLE JR. |
| CAD SUPER:           | D. JIMENEZ   |
| SCALE:               | NONE         |

**BOILER INSPECTION  
 SERVICES COMPANY**  
 1755 S. Naperville Rd. Suite #100  
 Wheaton, Illinois 60187

EVANSTON CIVIC CENTER  
 EVANSTON, ILLINOIS  
 BOILER NO.2  
 ULTRASONIC THICKNESS READINGS  
 FURNACE SHEET



ULTRASONIC THICKNESS READINGS  
 BOILER #2 - FURNACE SHEET

LOCATIONS

|      | 1     | 2     | 3     | 4     | 5     |
|------|-------|-------|-------|-------|-------|
| 0°   | 0.387 | 0.392 | 0.412 | 0.394 | 0.421 |
| 45°  | 0.390 | 0.392 | 0.384 | 0.397 | 0.389 |
| 90°  | 0.388 | 0.386 | 0.395 | 0.396 | 0.392 |
| 135° | 0.380 | 0.405 | 0.395 | 0.400 | 0.420 |
| 180° | 0.382 | 0.405 | 0.430 | 0.421 | 0.420 |
| 225° | 0.385 | 0.390 | 0.396 | 0.422 | 0.418 |
| 270° | 0.387 | 0.385 | 0.390 | 0.424 | 0.418 |
| 315° | 0.386 | 0.390 | 0.389 | 0.395 | 0.424 |

CLIENT:  
 EVANSTON CIVIC CENTER

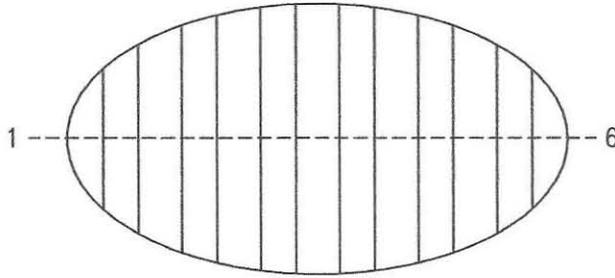
TITLE:  
 BOILER NO.2

INSPECTION ENGINEER:  
 DRAWN BY: A. NOBLE JR.  
 CAD SUPER: D. JIMENEZ  
 SCALE: NONE

**BOILER INSPECTION  
 SERVICES COMPANY**  
 1755 S. Naperville Rd. Suite #100  
 Wheaton, Illinois 60187

EVANSTON CIVIC CENTER  
 EVANSTON, ILLINOIS  
 BOILER NO.2  
 ULTRASONIC THICKNESS READINGS  
 TOP TUBES

FRONT



REAR

ULTRASONIC THICKNESS READINGS  
 BOILER #2 - TOP TUBES

LOCATIONS

|   |       |   |       |
|---|-------|---|-------|
| 1 | 0.108 | 4 | 0.116 |
| 2 | 0.112 | 5 | 0.116 |
| 3 | 0.121 | 6 | 0.117 |

CLIENT:  
 EVANSTON CIVIC CENTER

TITLE:  
 BOILER NO.2

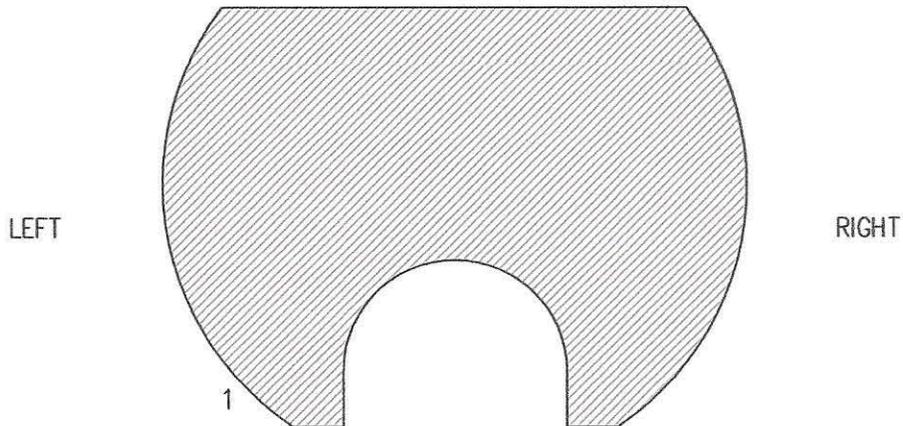
INSPECTION  
 ENGINEER:  
 DRAWN  
 BY: A. NOBLE JR.  
 CAD  
 SUPER: D. JIMENEZ  
 SCALE: NONE

BOILER INSPECTION  
 SERVICES COMPANY  
 1755 S. Naperville Rd. Suite #100  
 Wheaton, Illinois 60187

## **MAGNETIC PARTICLE TESTING RESULTS**

**BOILER #1**

EVANSTON CIVIC CENTER  
 EVANSTON, ILLINOIS  
 BOILER NO.1  
 MAGNETIC PARTICLE TESTING  
 FRONT TUBESHEET



INDICATES MT LOCATIONS

| LOCATION | REMARKS | TEST BY:  |
|----------|---------|-----------|
| 1        | **      | J JOHNSON |

\*\* - NO RELEVANT INDICATIONS FOUND

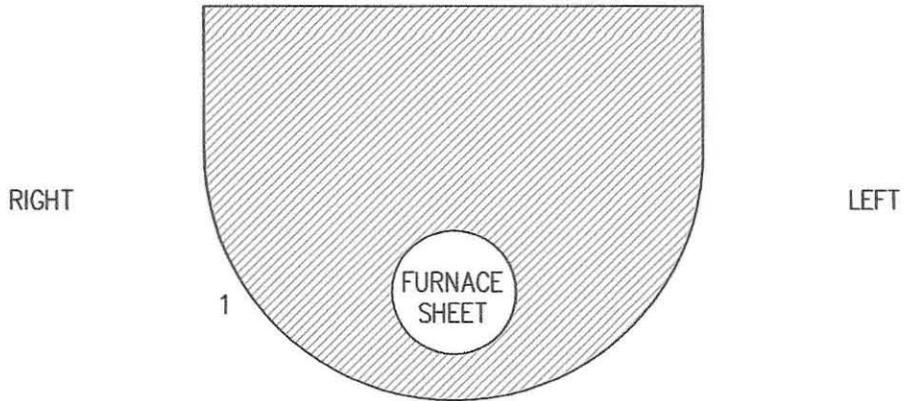
CLIENT:  
 EVANSTON CIVIC CENTER

TITLE:  
 BOILER NO.1

INSPECTION  
 ENGINEER:  
 DRAWN  
 BY: A. NOBLE JR.  
 CAD  
 SUPER: D. JIMENEZ  
 SCALE: NONE

**BOILER INSPECTION  
 SERVICES COMPANY**  
 1755 S. Naperville Rd. Suite #100  
 Wheaton, Illinois 60187

EVANSTON CIVIC CENTER  
 EVANSTON, ILLINOIS  
 BOILER NO.1  
 MAGNETIC PARTICLE TESTING  
 INNER REAR TUBESHEET



INDICATES MT LOCATIONS

| LOCATION | REMARKS | TEST BY:   |
|----------|---------|------------|
| 1        | **      | J. JOHNSON |

\*\* - NO RELEVANT INDICATIONS FOUND

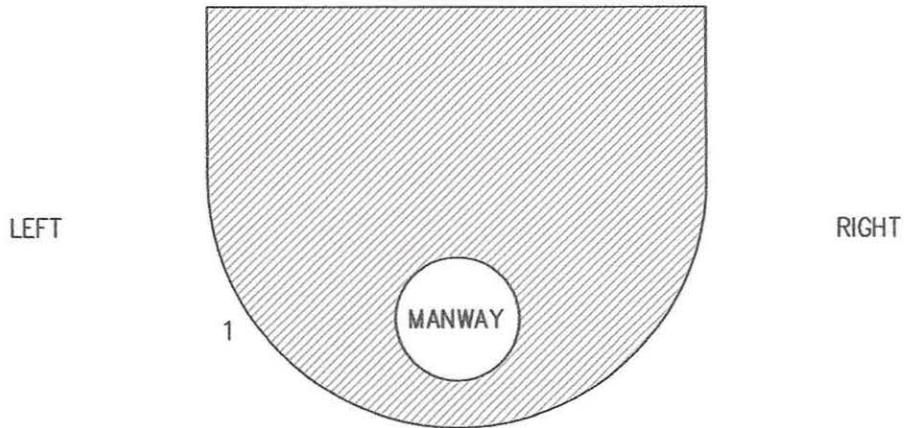
CLIENT:  
 EVANSTON CIVIC CENTER

TITLE:  
 BOILER NO.1

INSPECTION ENGINEER:  
 DRAWN BY: A. NOBLE JR.  
 CAD SUPER: D. JIMENEZ  
 SCALE: NONE

**BOILER INSPECTION SERVICES COMPANY**  
 1755 S. Naperville Rd. Suite #100  
 Wheaton, Illinois 60187

EVANSTON CIVIC CENTER  
 EVANSTON, ILLINOIS  
 BOILER NO.1  
 MAGNETIC PARTICLE TESTING  
 INNER REAR WALL



INDICATES MT LOCATIONS

| LOCATION | REMARKS | TEST BY:   |
|----------|---------|------------|
| 1        | **      | J. JOHNSON |

\*\* - NO RELEVANT INDICATIONS FOUND

CLIENT:  
 EVANSTON CIVIC CENTER

TITLE:  
 BOILER NO.1

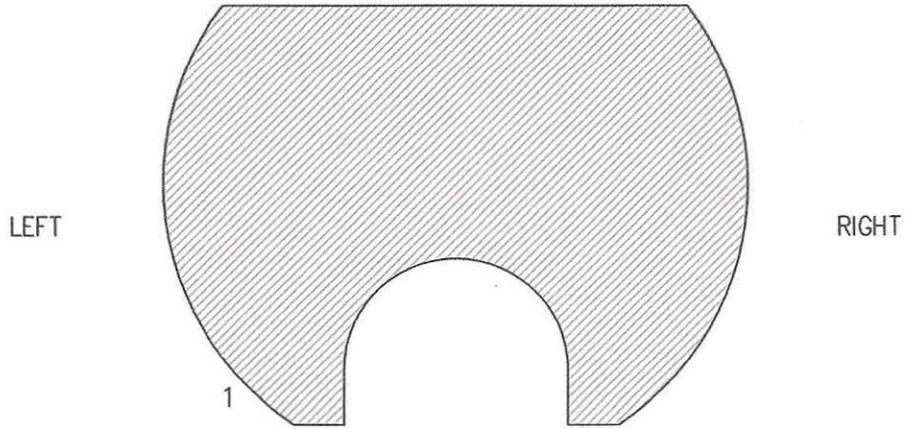
INSPECTION  
 ENGINEER:  
 DRAWN  
 BY: A. NOBLE JR.  
 CAD  
 SUPER: D. JIMENEZ  
 SCALE: NONE

BOILER INSPECTION  
 SERVICES COMPANY  
 1755 S. Naperville Rd. Suite #100  
 Wheaton, Illinois 60187



**BOILER #2**

EVANSTON CIVIC CENTER  
 EVANSTON, ILLINOIS  
 BOILER NO.2  
 MAGNETIC PARTICLE TESTING  
 FRONT TUBESHEET



INDICATES MT LOCATIONS

| LOCATION | REMARKS | TEST BY:  |
|----------|---------|-----------|
| 1        | **      | J JOHNSON |

\*\* - NO RELEVANT INDICATIONS FOUND

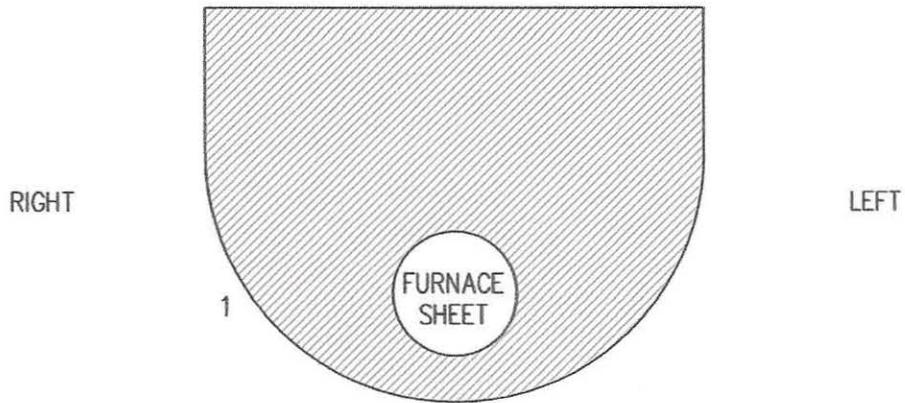
CLIENT:  
 EVANSTON CIVIC CENTER

TITLE:  
 BOILER NO.2

INSPECTION  
 ENGINEER:  
 DRAWN  
 BY: A. NOBLE JR.  
 CAD  
 SUPER: D. JIMENEZ  
 SCALE: NONE

**BOILER INSPECTION  
 SERVICES COMPANY**  
 1755 S. Naperville Rd. Suite #100  
 Wheaton, Illinois 60187

EVANSTON CIVIC CENTER  
 EVANSTON, ILLINOIS  
 BOILER NO.2  
 MAGNETIC PARTICLE TESTING  
 INNER REAR TUBESHEET



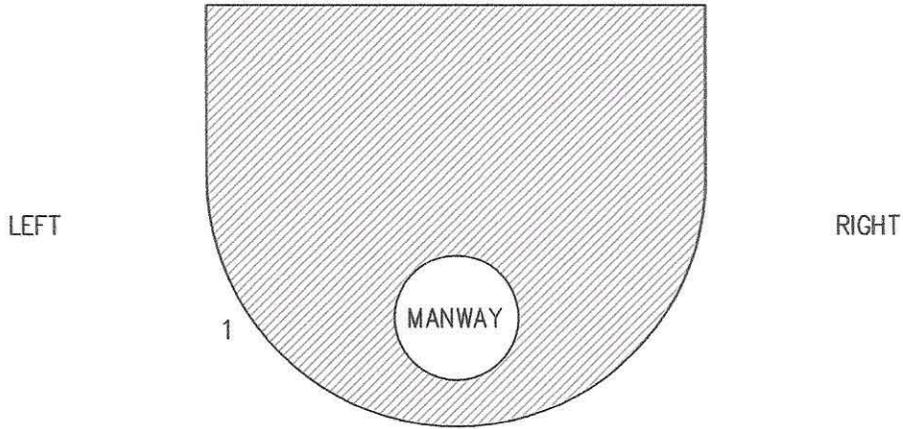
INDICATES MT LOCATIONS

| LOCATION | REMARKS | TEST BY:   |
|----------|---------|------------|
| 1        | **      | J. JOHNSON |

\*\* - NO RELEVANT INDICATIONS FOUND

|                                  |  |   |
|----------------------------------|--|---|
| CLIENT:<br>EVANSTON CIVIC CENTER | INSPECTION ENGINEER:<br>DRAWN BY: A. NOBLE JR.<br>CAD SUPER: D. JIMENEZ<br>SCALE: NONE | <b>BOILER INSPECTION SERVICES COMPANY</b><br>1755 S. Naperville Rd. Suite #100<br>Wheaton, Illinois 60187 |
| TITLE:<br>BOILER NO.2            |  |   |

EVANSTON CIVIC CENTER  
 EVANSTON, ILLINOIS  
 BOILER NO.2  
 MAGNETIC PARTICLE TESTING  
 INNER REAR WALL



 INDICATES MT LOCATIONS

| LOCATION | REMARKS | TEST BY:   |
|----------|---------|------------|
| 1        | **      | J. JOHNSON |

\*\* - NO RELEVANT INDICATIONS FOUND

|                                  |  |   |
|----------------------------------|--|---|
| CLIENT:<br>EVANSTON CIVIC CENTER | INSPECTION ENGINEER:<br>DRAWN BY: A. NOBLE JR. | <b>BOILER INSPECTION SERVICES COMPANY</b><br>1755 S. Naperville Rd. Suite #100<br>Wheaton, Illinois 60187 |
| TITLE:<br>BOILER NO.2            | CAD SUPER: D. JIMENEZ                          |   |
|                                  | SCALE: NONE                                    |   |



## **REMOTE FIELD EDDY CURRENT TESTING RESULTS**

## **Description of the Ferroscope System**

Boiler Inspection Services Company is presently using the Ferroscope System of Inspection as a method of inspection for ferritic tubing in boilers and other equipment. The availability of worldwide information and data obtained through numerous uses allows Boiler Inspection Services Company and its customers the satisfaction of knowing that this is the best method of inspection presently available, thereby providing the most reliable and accurate results.

The Ferroscope System was developed in response to a need in several industries for a reliable method of testing ferritic tubing. Carbon steel, nickel and magnetic stainless steels can be successfully inspected using the Ferroscope.

The Ferroscope System is based on the principles of "Remote Field Eddy Current." A low frequency AC signal is sent to an exciter coil that creates an alternating magnetic field. The signal penetrates the tube wall where it is picked up by one or more detector coils in the probe. The time required for the signal to go from the exciter to the detector(s) varies depending upon the amount of material the signal must penetrate. Time is measured as a "phase shift" and is translated by the instrument into an excursion on a chart recording. The technician interprets the excursion as a percentage of wall loss.

The Ferroscope probes are less affected by “fill factor” than are conventional Eddy Current probes. Typically, Ferroscope probes are made 0.050 to 0.075 inches smaller than the tube ID.

The Ferroscope probes are equipped with one exciter coil and one or more detector coils. Single channel probes (for 5/8 inch to 1.250 inch diameters) have as many as eight detectors.

The detector coil(s) measure(s) the volume of metal in the portion of the tube wall in its vicinity. For a single channel probe, the detector measures the volume of metal averaged around the entire tube circumference. For a multi-channel probe, the circumferential extent of the tube wall inspected by each detector is determined by a number of detectors (i.e.: for a 4-channel probe, each detector inspects one-quarter of the tube). The multi-channel probe has the advantage of revealing the circumferential extent of a discontinuity.

Prior knowledge of the discontinuity geometry inspected in the tube bundle is an important aid to a successful inspection. This information is used to assist in fabricating a similar discontinuity in a calibration tube. The technician can then predict discontinuity size in the tube bundle chart recording. This procedure is especially important in the smaller tube diameters as it assists in determining the circumferential extent of discontinuity.

The system's proven measurement accuracy is plus or minus five percent for a wall loss of 10% and more. Accuracy is greater for a larger magnitude discontinuity.

The Ferroscope System is somewhat sensitive to ferromagnetic scale build-up. Magnetite build-up of the tubes is detected as an apparent wall increase on the chart recordings and can cause a noisy base line. It is therefore, more difficult to resolve a small discontinuity in the presence of magnetic scale. Greater accuracy can be achieved if this magnetic scale is removed. The Ferroscope can detect a 1/32 inch through hole in a clean, otherwise defect free tube.

The data gathered by the Ferroscope System is recorded on an analogue chart recorder, thermal printer, or can be transmitted to a computer.

The Ferroscope System gives a linear response for circumferential defects. For example, a series of three circumferential grooves having depths of 20%, 40%, and 60% will give a response similar to that illustrated on the graph entitled "Excursion Size Chart Recordings vs. Wall Loss in Calibration Tube."

Wall loss excursions on the chart recordings go to the left (see Figure 1). Wall increase indications (such as baffles or magnetic scale) go to the right. Figure 1 shows how defect size is determined by measuring the length of the excursions on the chart recordings.

Figure 2 illustrates a chart recording for a calibration tube. Note that the technician has chosen a “base line” that may shift slightly from tube to tube due to permeability differences and slight differences in the tubes’ nominal thickness (mill tolerances). For seamless tubes, the wall thickness can also vary slightly due to eccentricity of the bore.

Because of these differences the technician must choose a base line, representing nominal wall thickness, which may be at a slightly different position on each chart recording.

## Instrumentation

Ferroscope Model 308

Laptop computer

Adept Pro RFEC analysis software

2 channel, Absolute Detector Probe: Serial Number F308-ADA-0364

Frequency: 50/50 Hz

Channel: Two

Nominal/Offset: Varies

## Items Inspected and General Comments

The items inspected were the firetubes in Boiler #1 (NB #1996) and Boiler #2 (NB #1996), for Evanston Civic Center. The tubes for both boilers are 3" diameter, 0.110" nominal thickness, and SA-178-A material, which extend from the front tubesheet to the rear tubesheet. A total of seventy-two (72) tubes were examined for each boiler. See the tubesheet diagram for the specific tubes inspected.

### **BOILER #1** – *A total of 72 tubes were inspected*

- A) Thirty-five (35) tubes have a wall thickness loss of 51% and above.
- B) Eighteen (18) tubes have a wall thickness loss of 41% and up to 50%.
- C) Nineteen (19) tubes have a wall thickness loss of 31% and up to 40%.

(See RFEC results)

### **BOILER #2** – *A total of 72 tubes were inspected*

- D) Forty-five (45) tubes have a wall thickness loss of 51% and above.
- E) Twenty-seven (27) tubes have a wall thickness loss of 41% and up to 50%.

(See RFEC results)

## **ANALYSIS OF INSPECTION**

Number of tubes inspected: 72 for each boiler

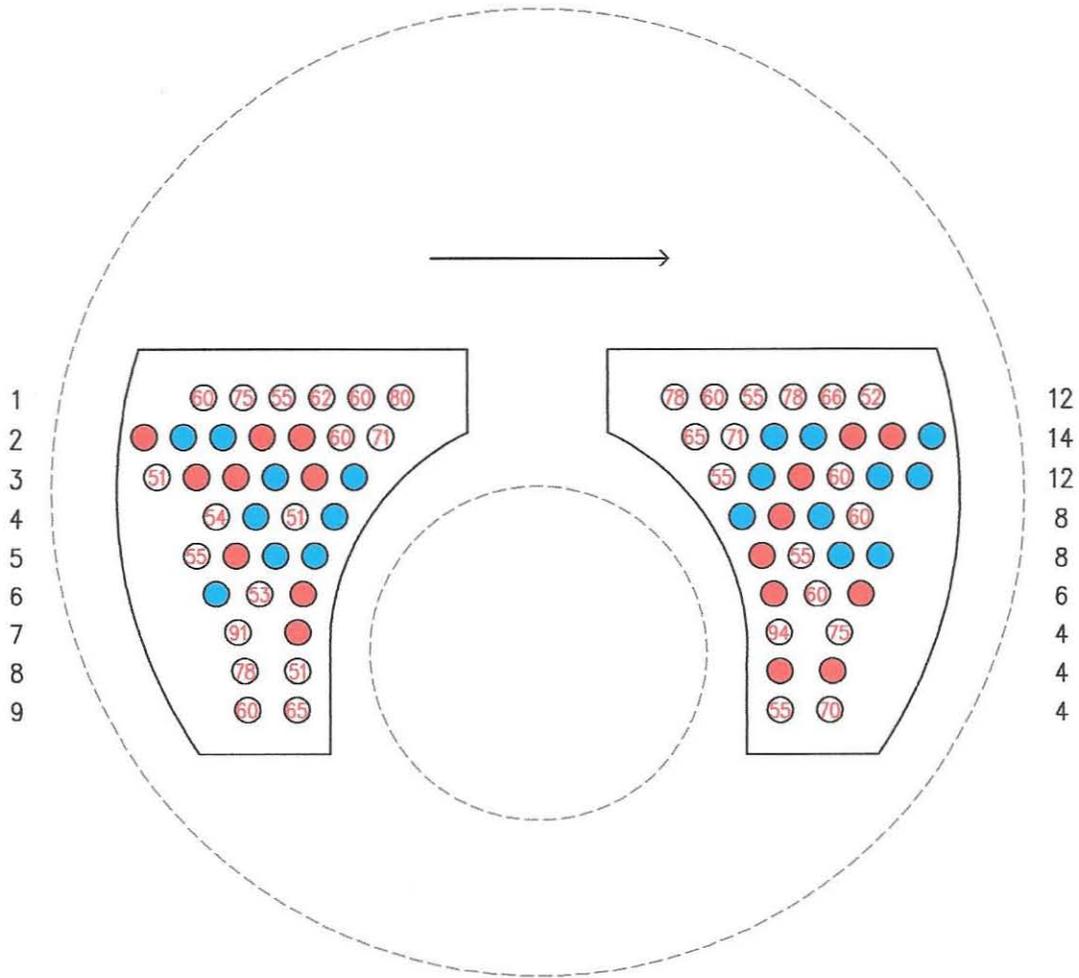
The number of tubes inspected in each category of wall loss is tabulated in the "Analysis of Tubes Inspected."

A tube sheet diagram shows an overview of these categories. Only tubes marked were inspected.

**BOILER #1**



EVANSTON CIVIC CENTER  
 EVANSTON, ILLINOIS  
 BOILER NO.1  
 TUBESHEET DIAGRAM



- LEGEND:
- 1-10% W.L.
  - 11-20% W.L.
  - 21-30% W.L.
  - 31-40% W.L.
  - 41-50% W.L.
  - # % W.L.

|                                  |                        |   |
|----------------------------------|------------------------|---|
| CLIENT:<br>EVANSTON CIVIC CENTER | INSPECTION ENGINEER:   | <b>BOILER INSPECTION SERVICES COMPANY</b><br>1755 S. Naperville Rd. Suite #100<br>Wheaton, Illinois 60187 |
|                                  | DRAWN BY: A. NOBLE JR. |   |
| TITLE:<br>BOILER NO.1            | CAD SUPER: D. JIMENEZ  |   |
|                                  | SCALE: NONE            |   |



# Boiler Inspection Services Company

Engineering & Inspection Services

1755 S. Naperville Rd.  
Suite # 100  
Wheaton, IL. 60187  
Tel: (630) 510-3223  
Fax: (630) 510-3261  
www.boilerinspection.com

## FERROSCOPE FIELD DATA REPORT

Customer: Evanston Civic Center Plant: Evanston, IL Date: August 24, 2018

Frequency: 50/50 Hz Current: 5/7 v No. of Channel(s): 2 Sensitivity: 50

Boiler No. 1 Tube Size: 3" Gauge: .110" Material: SA-178-A

| Row No. | Tube No. | Plugged | OBSTRUCTED |  | % of Wall Loss |        |        |        |        | Location | Remarks |
|---------|----------|---------|------------|--|----------------|--------|--------|--------|--------|----------|---------|
|         |          |         | RESTRICTED |  | 1-10%          | 11-20% | 21-30% | 31-40% | 41-50% |          |         |
| 1       | 1        |         |            |  |                |        |        |        |        |          | 60%     |
|         | 2        |         |            |  |                |        |        |        |        |          | 75%     |
|         | 3        |         |            |  |                |        |        |        |        |          | 55%     |
|         | 4        |         |            |  |                |        |        |        |        |          | 62%     |
|         | 5        |         |            |  |                |        |        |        |        |          | 60%     |
|         | 6        |         |            |  |                |        |        |        |        |          | 80%     |
|         | 7        |         |            |  |                |        |        |        |        |          | 78%     |
|         | 8        |         |            |  |                |        |        |        |        |          | 60%     |
|         | 9        |         |            |  |                |        |        |        |        |          | 55%     |
|         | 10       |         |            |  |                |        |        |        |        |          | 78%     |
|         | 11       |         |            |  |                |        |        |        |        |          | 66%     |
|         | 12       |         |            |  |                |        |        |        |        |          | 52%     |
| 2       | 1        |         |            |  |                |        |        |        | •      |          |         |
|         | 2        |         |            |  |                |        |        | •      |        |          |         |
|         | 3        |         |            |  |                |        |        | •      |        |          |         |
|         | 4        |         |            |  |                |        |        |        | •      |          |         |
|         | 5        |         |            |  |                |        |        |        | •      |          |         |
|         | 6        |         |            |  |                |        |        |        |        |          | 60%     |
|         | 7        |         |            |  |                |        |        |        |        |          | 71%     |
|         | 8        |         |            |  |                |        |        |        |        |          | 65%     |
|         | 9        |         |            |  |                |        |        |        |        |          | 71%     |
|         | 10       |         |            |  |                |        |        | •      |        |          |         |
|         | 11       |         |            |  |                |        |        | •      |        |          |         |
|         | 12       |         |            |  |                |        |        |        | •      |          |         |
|         | 13       |         |            |  |                |        |        |        | •      |          |         |
|         | 14       |         |            |  |                |        |        | •      |        |          |         |



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## FERROSCOPE FIELD DATA REPORT

Customer: Evanston Civic Center Plant: Evanston, IL Date: August 24, 2018

Frequency: 50/50 Hz Current: 5/7 v No. of Channel(s): 2 Sensitivity: 50

Boiler No. 1 Tube Size: 3" Gauge: .110" Material: SA-178-A

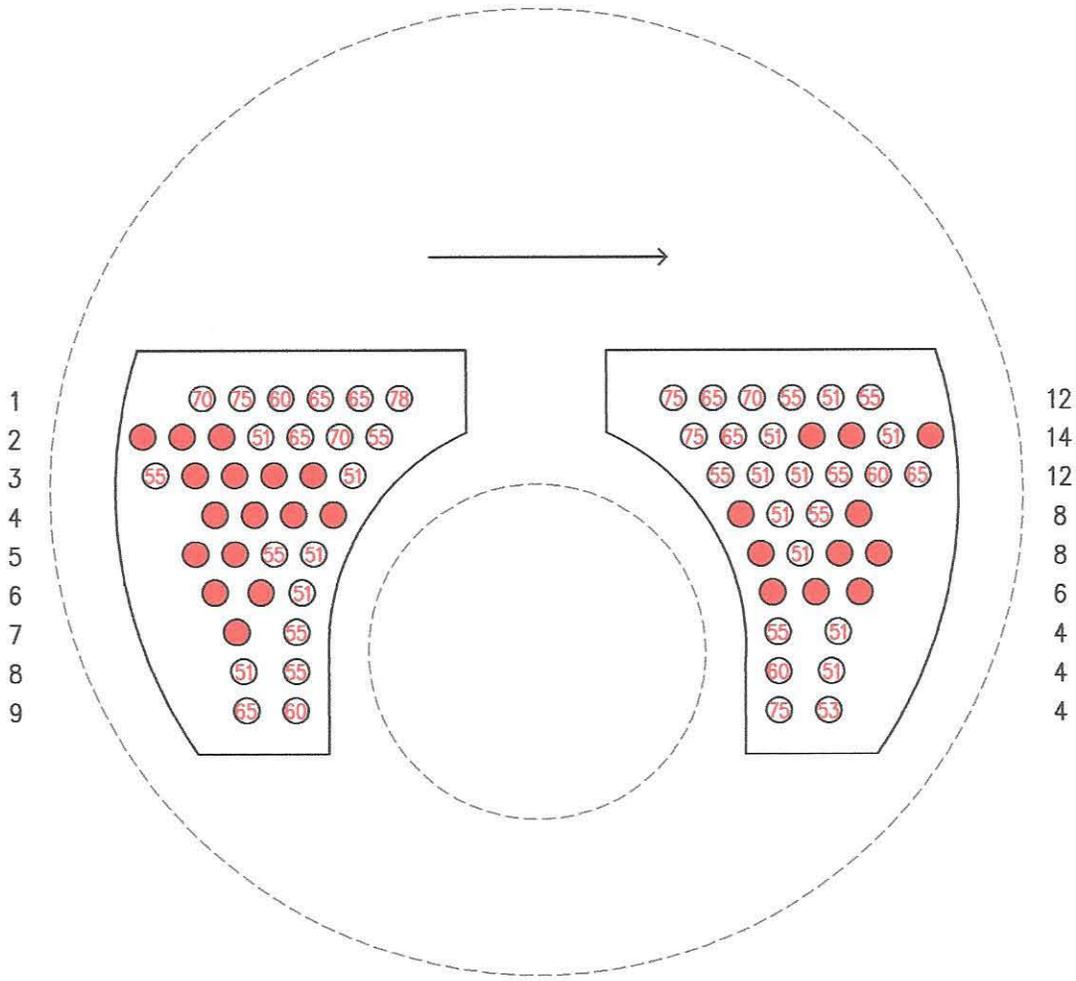
| Row No. | Tube No. | Plugged | OBSTRUCTED |  | % of Wall Loss |        |        |        |        | Location | Remarks |
|---------|----------|---------|------------|--|----------------|--------|--------|--------|--------|----------|---------|
|         |          |         | RESTRICTED |  | 1-10%          | 11-20% | 21-30% | 31-40% | 41-50% |          |         |
| 3       | 1        |         |            |  |                |        |        |        |        |          | 51%     |
|         | 2        |         |            |  |                |        |        |        |        |          |         |
|         | 3        |         |            |  |                |        |        |        | •      |          |         |
|         | 4        |         |            |  |                |        |        | •      |        |          |         |
|         | 5        |         |            |  |                |        |        |        | •      |          |         |
|         | 6        |         |            |  |                |        |        | •      |        |          |         |
|         | 7        |         |            |  |                |        |        |        |        |          | 55%     |
|         | 8        |         |            |  |                |        |        | •      |        |          |         |
|         | 9        |         |            |  |                |        |        |        | •      |          |         |
|         | 10       |         |            |  |                |        |        |        |        |          | 60%     |
|         | 11       |         |            |  |                |        |        | •      |        |          |         |
|         | 12       |         |            |  |                |        |        | •      |        |          |         |
| 4       | 1        |         |            |  |                |        |        |        |        |          | 54%     |
|         | 2        |         |            |  |                |        |        | •      |        |          |         |
|         | 3        |         |            |  |                |        |        |        |        |          | 51%     |
|         | 4        |         |            |  |                |        |        | •      |        |          |         |
|         | 5        |         |            |  |                |        |        | •      |        |          |         |
|         | 6        |         |            |  |                |        |        |        | •      |          |         |
|         | 7        |         |            |  |                |        |        | •      |        |          |         |
|         | 8        |         |            |  |                |        |        |        |        |          | 60%     |
| 5       | 1        |         |            |  |                |        |        |        |        |          | 55%     |
|         | 2        |         |            |  |                |        |        |        | •      |          |         |
|         | 3        |         |            |  |                |        |        | •      |        |          |         |
|         | 4        |         |            |  |                |        |        | •      |        |          |         |
|         | 5        |         |            |  |                |        |        |        | •      |          |         |
|         | 6        |         |            |  |                |        |        |        |        |          | 55%     |
|         | 7        |         |            |  |                |        |        | •      |        |          |         |
|         | 8        |         |            |  |                |        |        | •      |        |          |         |



**BOILER #2**



EVANSTON CIVIC CENTER  
 EVANSTON, ILLINOIS  
 BOILER NO.2  
 TUBESHEET DIAGRAM



- LEGEND:
- 1-10% W.L.
  - 11-20% W.L.
  - 21-30% W.L.
  - 31-40% W.L.
  - 41-50% W.L.
  - ⊕ # % W.L.

CLIENT:  
 EVANSTON CIVIC CENTER

TITLE:  
 BOILER NO.2

INSPECTION ENGINEER:  
 DRAWN BY: A. NOBLE JR.  
 CAD SUPER: D. JIMENEZ  
 SCALE: NONE

**BOILER INSPECTION SERVICES COMPANY**  
 1755 S. Naperville Rd. Suite #100  
 Wheaton, Illinois 60187







## **FIELD DATA**

Technicians: Ron Avalos, Katreena Avalos, Jacob Johnson, and Casimir Soczyk

Number of tubes inspected: 72 for each boiler

## **PHOTOGRAPHIC DOCUMENTATION**

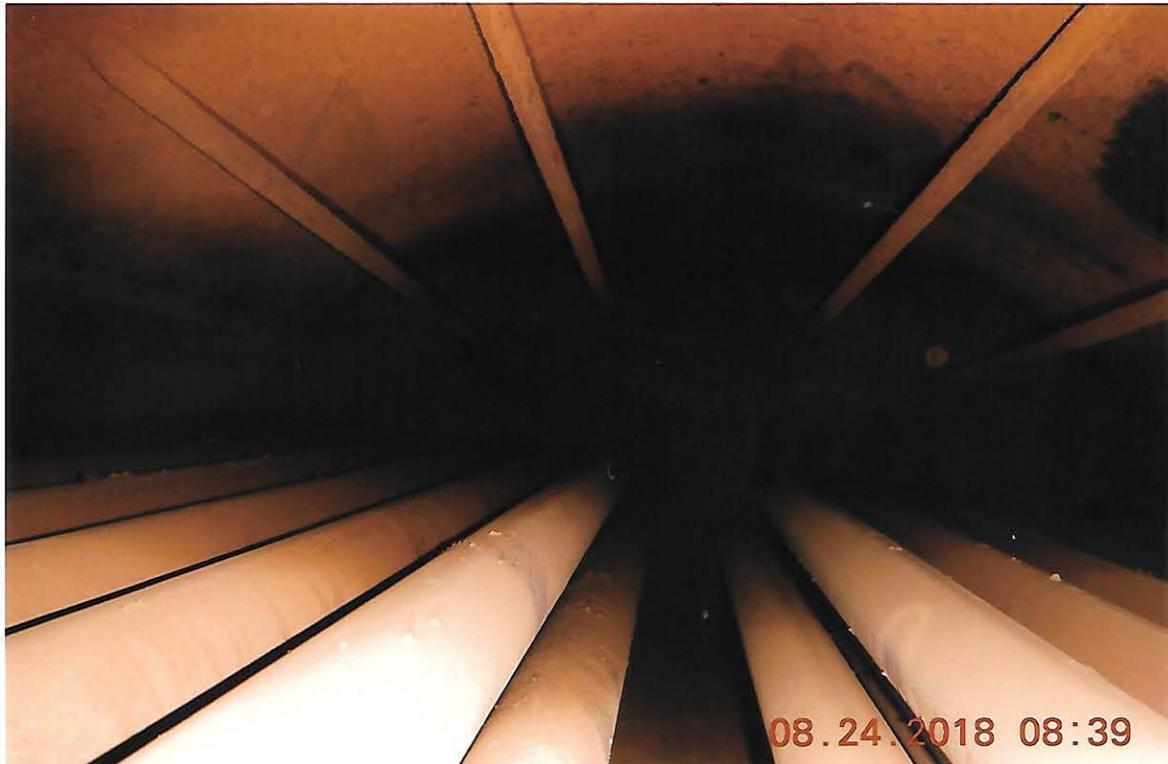
**BOILER #1**

The following ten (10) photos show the condition of the boiler's waterside as viewed from the top manway. Scale and tubercles were observed on the accessible tubes, boiler shell, and furnace sheet. Heavy under deposit pitting and corrosion were observed in the tubes. Light pitting was noted on the accessible furnace sheet.

1)



2)

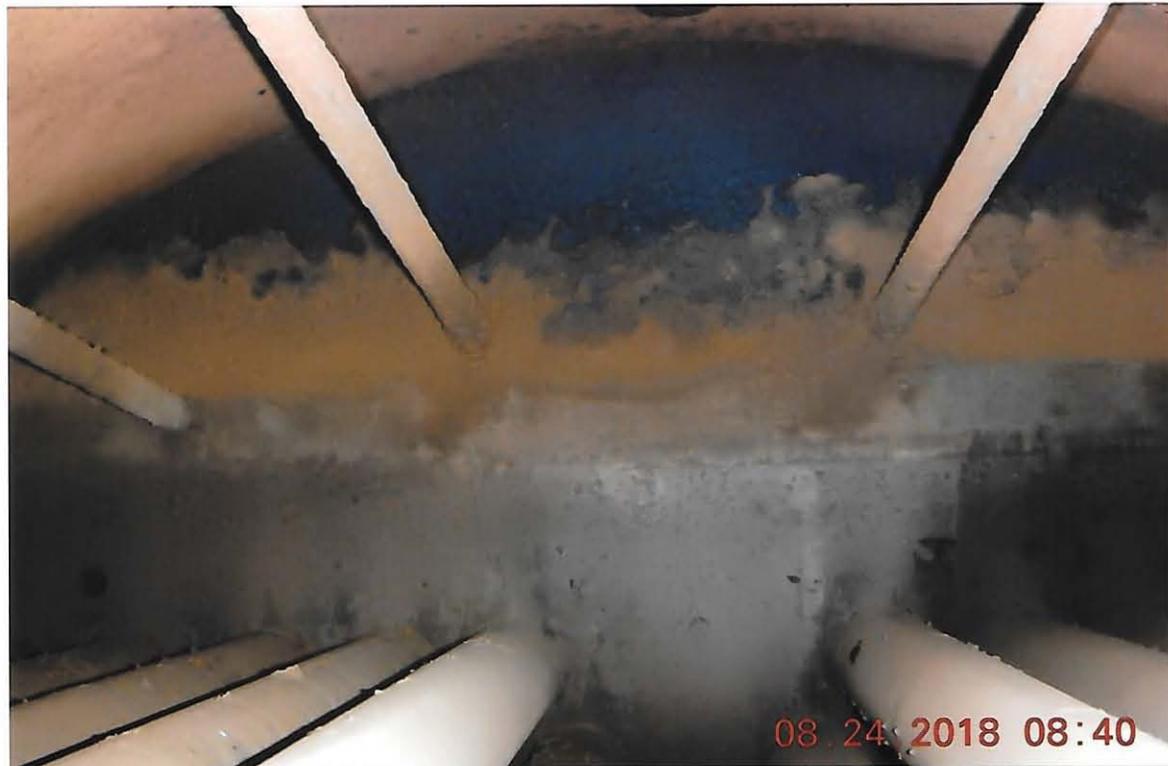


The following ten (10) photos show the condition of the boiler's waterside as viewed from the top manway. Scale and tubercles were observed on the accessible tubes, boiler shell, and furnace sheet. Heavy under deposit pitting and corrosion were observed in the tubes. Light pitting was noted on the accessible furnace sheet.

3)



4)



The following ten (10) photos show the condition of the boiler's waterside as viewed from the top manway. Scale and tubercles were observed on the accessible tubes, boiler shell, and furnace sheet. Heavy under deposit pitting and corrosion were observed in the tubes. Light pitting was noted on the accessible furnace sheet.

5)



6)



The following ten (10) photos show the condition of the boiler's waterside as viewed from the top manway. Scale and tubercles were observed on the accessible tubes, boiler shell, and furnace sheet. Heavy under deposit pitting and corrosion were observed in the tubes. Light pitting was noted on the accessible furnace sheet.

7)



8)



The following ten (10) photos show the condition of the boiler's waterside as viewed from the top manway. Scale and tubercles were observed on the accessible tubes, boiler shell, and furnace sheet. Heavy under deposit pitting and corrosion were observed in the tubes. Light pitting was noted on the accessible furnace sheet.

9)



10)



The following ten (10) photos show the condition of the boiler's waterside as viewed from the lower handholes. Scale and tubercles were observed on the accessible tubes, boiler shell, and furnace sheet. An old cut-out tube was noted at the bottom of the shell. A moderate accumulation of sediment and debris was observed at the bottom of the shell.

1)



2)



The following ten (10) photos show the condition of the boiler's waterside as viewed from the lower handholes. Scale and tubercles were observed on the accessible tubes, boiler shell, and furnace sheet. An old cut-out tube was noted at the bottom of the shell. A moderate accumulation of sediment and debris was observed at the bottom of the shell.

3)



4)



The following ten (10) photos show the condition of the boiler's waterside as viewed from the lower handholes. Scale and tubercles were observed on the accessible tubes, boiler shell, and furnace sheet. An old cut-out tube was noted at the bottom of the shell. A moderate accumulation of sediment and debris was observed at the bottom of the shell.

5)



6)



The following ten (10) photos show the condition of the boiler's waterside as viewed from the lower handholes. Scale and tubercles were observed on the accessible tubes, boiler shell, and furnace sheet. An old cut-out tube was noted at the bottom of the shell. A moderate accumulation of sediment and debris was observed at the bottom of the shell.

7)



8)



The following ten (10) photos show the condition of the boiler's waterside as viewed from the lower handholes. Scale and tubercles were observed on the accessible tubes, boiler shell, and furnace sheet. An old cut-out tube was noted at the bottom of the shell. A moderate accumulation of sediment and debris was observed at the bottom of the shell.

9)



10)



The following six (6) photos show the condition of the front tubesheet and associated smokebox. A light layer of black soot was observed on the front tubesheet, smokebox walls, and ID of the tubes. No indication of pitting was noted. The accessible welds and tubesheet ligaments appeared to be in satisfactory condition.

1)



2)



The following six (6) photos show the condition of the front tubesheet and associated smokebox. A light layer of black soot was observed on the front tubesheet, smokebox walls, and ID of the tubes. No indication of pitting was noted. The accessible welds and tubesheet ligaments appeared to be in satisfactory condition.

3)



4)



The following six (6) photos show the condition of the front tubesheet and associated smokebox. A light layer of black soot was observed on the front tubesheet, smokebox walls, and ID of the tubes. No indication of pitting was noted. The accessible welds and tubesheet ligaments appeared to be in satisfactory condition.

5)



6)

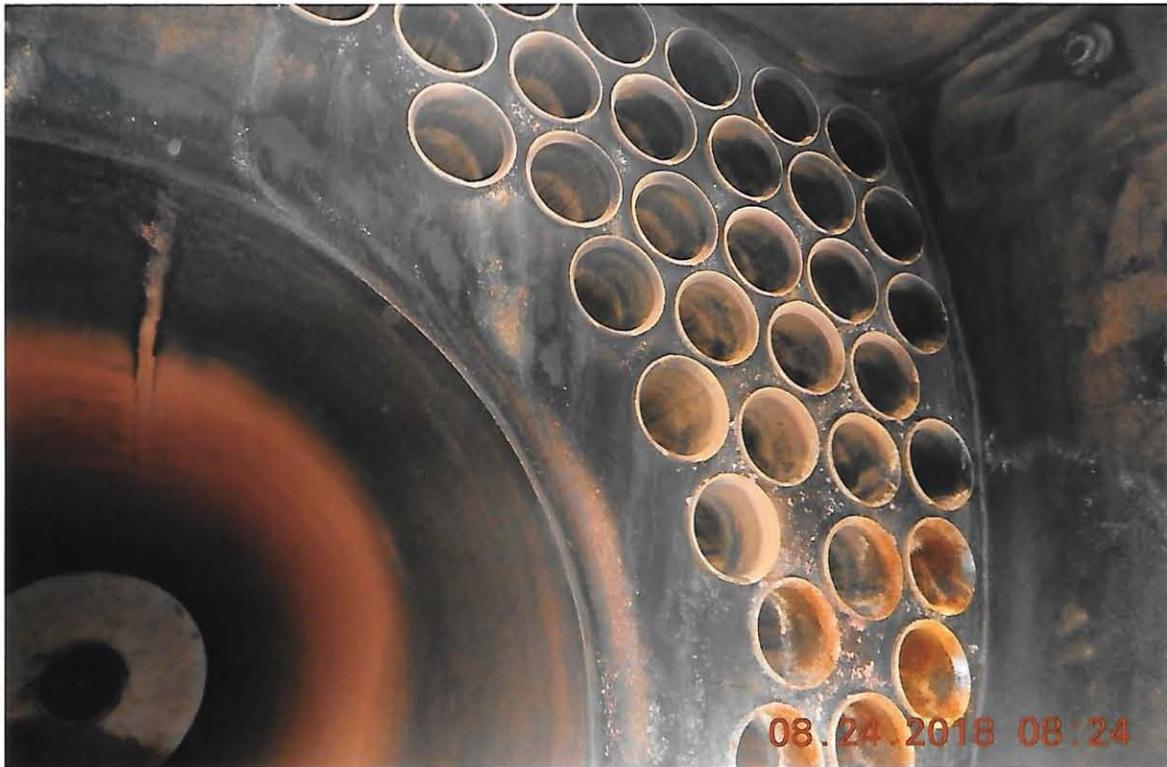


The following six (6) photos show the condition of the inner rear tubesheet and combustion chamber. A light layer of black soot was noted on the rear tubesheet, combustion chamber walls, and ID of the tubes. No indication of pitting was observed. Watermark discoloration was noted on the tubesheet and at the bottom of the combustion chamber. Accumulation of debris was observed at the bottom of the combustion chamber. The accessible welds and tubesheet ligaments appeared to be in satisfactory condition.

1)



2)

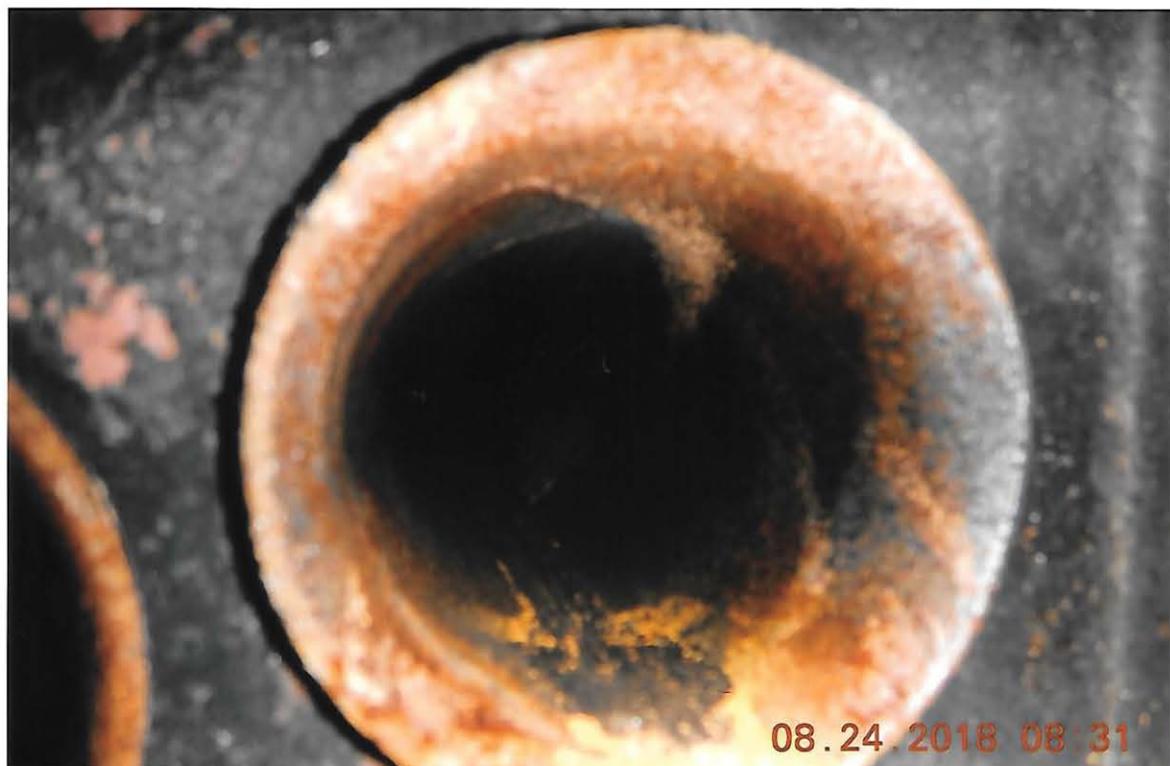


The following six (6) photos show the condition of the inner rear tubesheet and combustion chamber. A light layer of black soot was noted on the rear tubesheet, combustion chamber walls, and ID of the tubes. No indication of pitting was observed. Watermark discoloration was noted on the tubesheet and at the bottom of the combustion chamber. Accumulation of debris was observed at the bottom of the combustion chamber. The accessible welds and tubesheet ligaments appeared to be in satisfactory condition.

3)



4)



The following six (6) photos show the condition of the inner rear tubesheet and combustion chamber. A light layer of black soot was noted on the rear tubesheet, combustion chamber walls, and ID of the tubes. No indication of pitting was observed. Watermark discoloration was noted on the tubesheet and at the bottom of the combustion chamber. Accumulation of debris was observed at the bottom of the combustion chamber. The accessible welds and tubesheet ligaments appeared to be in satisfactory condition.

5)



6)



The following six (6) photos show the condition of the furnace sheet and burner. Light corrosion and pitting were observed on the furnace sheet. Soot build-up was noted near the burner. Watermark discoloration and accumulation of debris were noted at the bottom of the furnace sheet. Cracks in the burner refractory were observed. The longitudinal weld appeared to be in satisfactory condition.

1)



2)

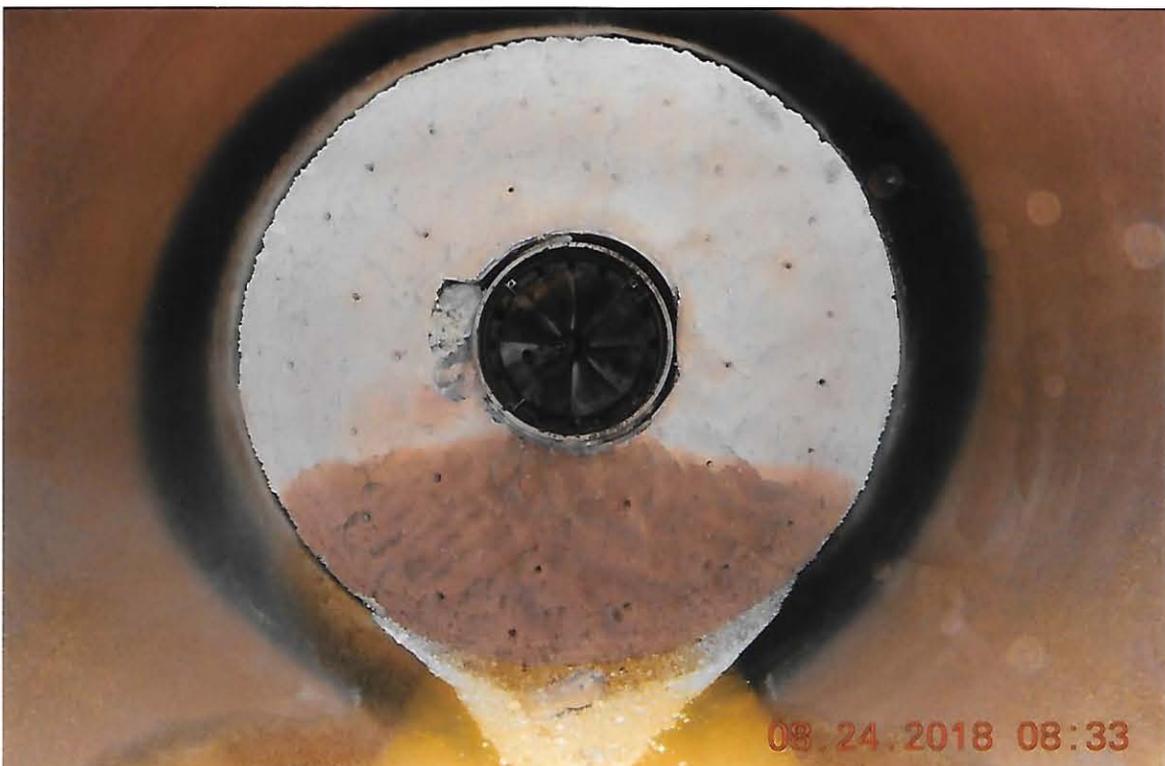


The following six (6) photos show the condition of the furnace sheet and burner. Light corrosion and pitting were observed on the furnace sheet. Soot build-up was noted near the burner. Watermark discoloration and accumulation of debris were noted at the bottom of the furnace sheet. Cracks in the burner refractory were observed. The longitudinal weld appeared to be in satisfactory condition.

3)



4)



The following six (6) photos show the condition of the furnace sheet and burner. Light corrosion and pitting were observed on the furnace sheet. Soot build-up was noted near the burner. Watermark discoloration and accumulation of debris were noted at the bottom of the furnace sheet. Cracks in the burner refractory were observed. The longitudinal weld appeared to be in satisfactory condition.

5)



6)



The following six (6) photos show the condition of the various safety appurtenances. No indication of up-to-date calibration was observed on the pressure/temperature gauges and pressure relief valves. The low water fuel cut-off devices were newly installed. The water level sight glass appeared to be in satisfactory condition. Indications of past leakage were noted on the main steam isolation valve.

1)

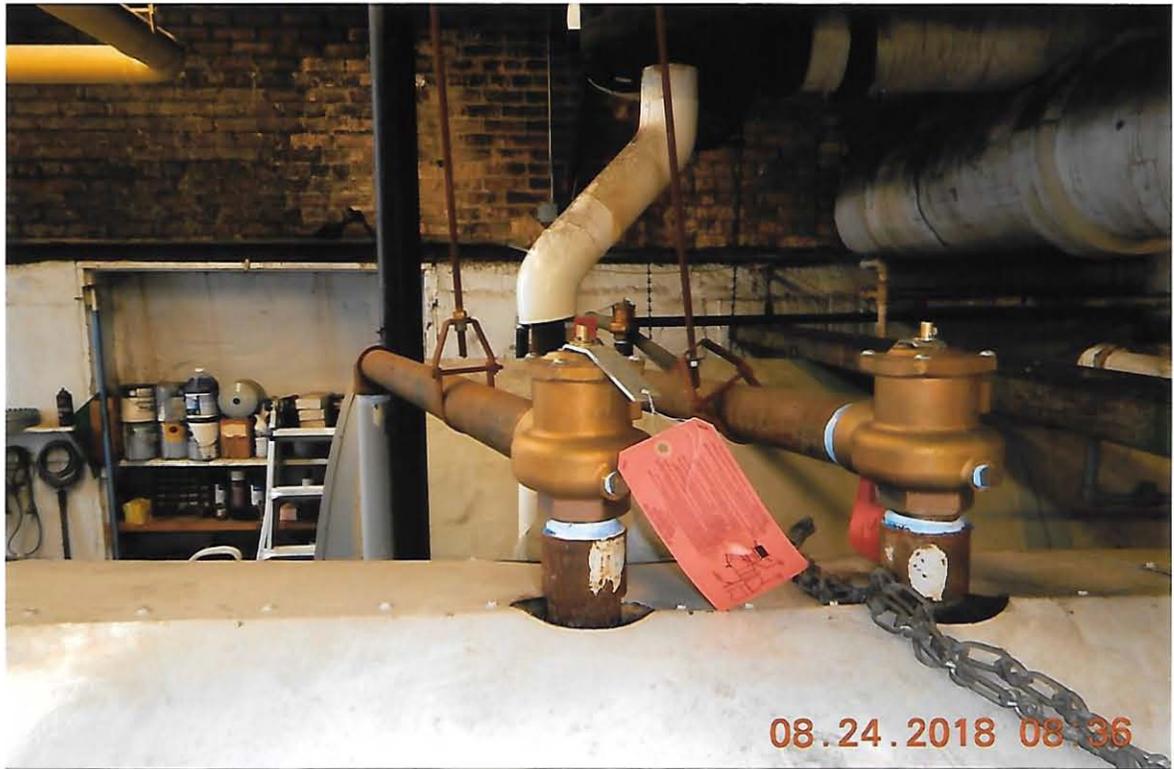


2)



The following six (6) photos show the condition of the various safety appurtenances. No indication of up-to-date calibration was observed on the pressure/temperature gauges and pressure relief valves. The low water fuel cut-off devices were newly installed. The water level sight glass appeared to be in satisfactory condition. Indications of past leakage were noted on the main steam isolation valve.

3)



4)



The following six (6) photos show the condition of the various safety appurtenances. No indication of up-to-date calibration was observed on the pressure/temperature gauges and pressure relief valves. The low water fuel cut-off devices were newly installed. The water level sight glass appeared to be in satisfactory condition. Indications of past leakage were noted on the main steam isolation valve.

5)



6)



The following eight (8) photos show the external condition of the boiler. Gaps in the casing seams were noted. Staining, corrosion, and deterioration were observed on the casing beneath the boiler. Corrosion around the handholes was noted. The support structure appeared to be in satisfactory condition.

1)



2)



The following eight (8) photos show the external condition of the boiler. Gaps in the casing seams were noted. Staining, corrosion, and deterioration were observed on the casing beneath the boiler. Corrosion around the handholes was noted. The support structure appeared to be in satisfactory condition.

3)



4)



The following eight (8) photos show the external condition of the boiler. Gaps in the casing seams were noted. Staining, corrosion, and deterioration were observed on the casing beneath the boiler. Corrosion around the handholes was noted. The support structure appeared to be in satisfactory condition.

5)



6)



The following eight (8) photos show the external condition of the boiler. Gaps in the casing seams were noted. Staining, corrosion, and deterioration were observed on the casing beneath the boiler. Corrosion around the handholes was noted. The support structure appeared to be in satisfactory condition.

7)



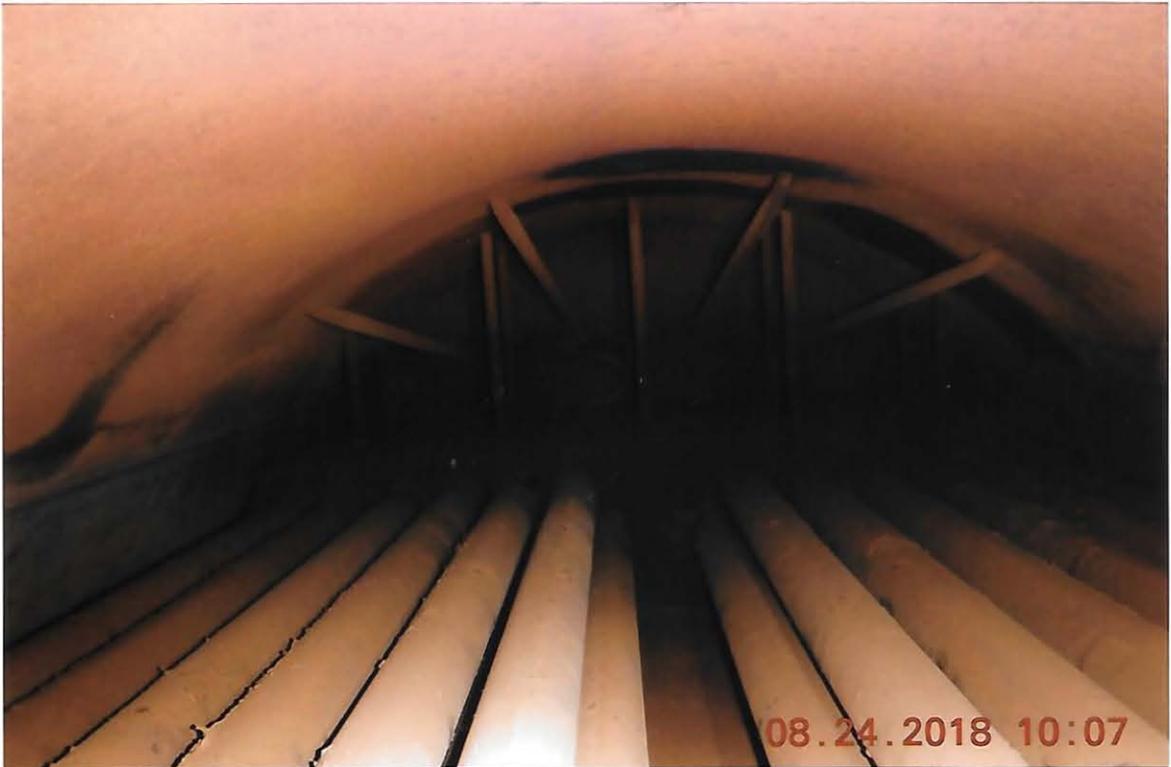
8)



**BOILER #2**

The following ten (10) photos show the condition of the boiler's waterside as viewed from the top manway. Scale and tubercles were observed on the accessible tubes, boiler shell, and furnace sheet. Heavy under deposit pitting and corrosion were observed in the tubes. Light pitting was noted on the accessible furnace sheet.

1)



2)



The following ten (10) photos show the condition of the boiler's waterside as viewed from the top manway. Scale and tubercles were observed on the accessible tubes, boiler shell, and furnace sheet. Heavy under deposit pitting and corrosion were observed in the tubes. Light pitting was noted on the accessible furnace sheet.

3)



4)



The following ten (10) photos show the condition of the boiler's waterside as viewed from the top manway. Scale and tubercles were observed on the accessible tubes, boiler shell, and furnace sheet. Heavy under deposit pitting and corrosion were observed in the tubes. Light pitting was noted on the accessible furnace sheet.

5)



6)



The following ten (10) photos show the condition of the boiler's waterside as viewed from the top manway. Scale and tubercles were observed on the accessible tubes, boiler shell, and furnace sheet. Heavy under deposit pitting and corrosion were observed in the tubes. Light pitting was noted on the accessible furnace sheet.

7)



8)



The following ten (10) photos show the condition of the boiler's waterside as viewed from the top manway. Scale and tubercles were observed on the accessible tubes, boiler shell, and furnace sheet. Heavy under deposit pitting and corrosion were observed in the tubes. Light pitting was noted on the accessible furnace sheet.

9)



10)



The following eight (8) photos show the condition of the boiler's waterside as viewed from the lower handholes. Scale and tubercles were observed on the accessible tubes, boiler shell, and furnace sheet. Two old cut-out tubes were noted at the bottom of the shell. A moderate accumulation of sediment and debris was observed at the bottom of the shell.

1)



2)



The following eight (8) photos show the condition of the boiler's waterside as viewed from the lower handholes. Scale and tubercles were observed on the accessible tubes, boiler shell, and furnace sheet. Two old cut-out tubes were noted at the bottom of the shell. A moderate accumulation of sediment and debris was observed at the bottom of the shell.

3)



4)



The following eight (8) photos show the condition of the boiler's waterside as viewed from the lower handholes. Scale and tubercles were observed on the accessible tubes, boiler shell, and furnace sheet. Two old cut-out tubes were noted at the bottom of the shell. A moderate accumulation of sediment and debris was observed at the bottom of the shell.

5)



6)



The following eight (8) photos show the condition of the boiler's waterside as viewed from the lower handholes. Scale and tubercles were observed on the accessible tubes, boiler shell, and furnace sheet. Two old cut-out tubes were noted at the bottom of the shell. A moderate accumulation of sediment and debris was observed at the bottom of the shell.

7)



8)



The following six (6) photos show the condition of the front tubesheet and associated smokebox. A light layer of black soot was observed on the front tubesheet, smokebox walls, and ID of the tubes. No indication of pitting was noted. The accessible welds and tubesheet ligaments appeared to be in satisfactory condition.

1)



2)



The following six (6) photos show the condition of the front tubesheet and associated smokebox. A light layer of black soot was observed on the front tubesheet, smokebox walls, and ID of the tubes. No indication of pitting was noted. The accessible welds and tubesheet ligaments appeared to be in satisfactory condition.

3)



4)



The following six (6) photos show the condition of the front tubesheet and associated smokebox. A light layer of black soot was observed on the front tubesheet, smokebox walls, and ID of the tubes. No indication of pitting was noted. The accessible welds and tubesheet ligaments appeared to be in satisfactory condition.

5)



6)



The following eight (8) photos show the condition of the inner rear tubesheet and combustion chamber. A light layer of black soot was noted on the rear tubesheet, combustion chamber walls, and ID of the tubes. No indication of pitting was observed. Watermark discoloration was noted on the tubesheet and at the bottom of the combustion chamber. Accumulation of debris was observed at the bottom of the combustion chamber. The accessible welds and tubesheet ligaments appeared to be in satisfactory condition.

1)



2)



The following eight (8) photos show the condition of the inner rear tubesheet and combustion chamber. A light layer of black soot was noted on the rear tubesheet, combustion chamber walls, and ID of the tubes. No indication of pitting was observed. Watermark discoloration was noted on the tubesheet and at the bottom of the combustion chamber. Accumulation of debris was observed at the bottom of the combustion chamber. The accessible welds and tubesheet ligaments appeared to be in satisfactory condition.

3)

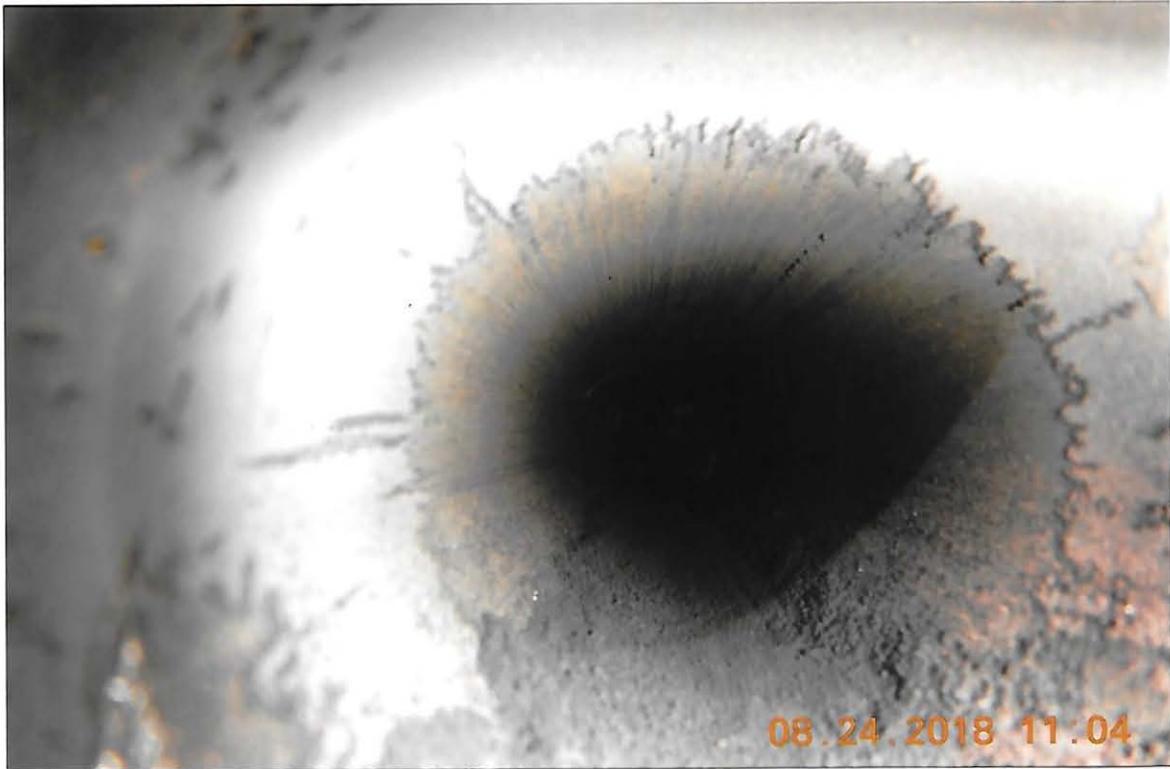


4)



The following eight (8) photos show the condition of the inner rear tubesheet and combustion chamber. A light layer of black soot was noted on the rear tubesheet, combustion chamber walls, and ID of the tubes. No indication of pitting was observed. Watermark discoloration was noted on the tubesheet and at the bottom of the combustion chamber. Accumulation of debris was observed at the bottom of the combustion chamber. The accessible welds and tubesheet ligaments appeared to be in satisfactory condition.

5)



6)



The following eight (8) photos show the condition of the inner rear tubesheet and combustion chamber. A light layer of black soot was noted on the rear tubesheet, combustion chamber walls, and ID of the tubes. No indication of pitting was observed. Watermark discoloration was noted on the tubesheet and at the bottom of the combustion chamber. Accumulation of debris was observed at the bottom of the combustion chamber. The accessible welds and tubesheet ligaments appeared to be in satisfactory condition.

7)



8)



The following six (6) photos show the condition of the furnace sheet and burner. Light corrosion and pitting were observed on the furnace sheet. Soot build-up was noted near the burner. Watermark discoloration and accumulation of debris were noted at the bottom of the furnace sheet. Corrosion and warping of the burner barrels were noted. Cracks in the burner refractory were observed. The longitudinal weld appeared to be in satisfactory condition.

1)



2)



The following six (6) photos show the condition of the furnace sheet and burner. Light corrosion and pitting were observed on the furnace sheet. Soot build-up was noted near the burner. Watermark discoloration and accumulation of debris were noted at the bottom of the furnace sheet. Corrosion and warping of the burner barrels were noted. Cracks in the burner refractory were observed. The longitudinal weld appeared to be in satisfactory condition.

3)



4)



The following six (6) photos show the condition of the furnace sheet and burner. Light corrosion and pitting were observed on the furnace sheet. Soot build-up was noted near the burner. Watermark discoloration and accumulation of debris were noted at the bottom of the furnace sheet. Corrosion and warping of the burner barrels were noted. Cracks in the burner refractory were observed. The longitudinal weld appeared to be in satisfactory condition.

5)



6)

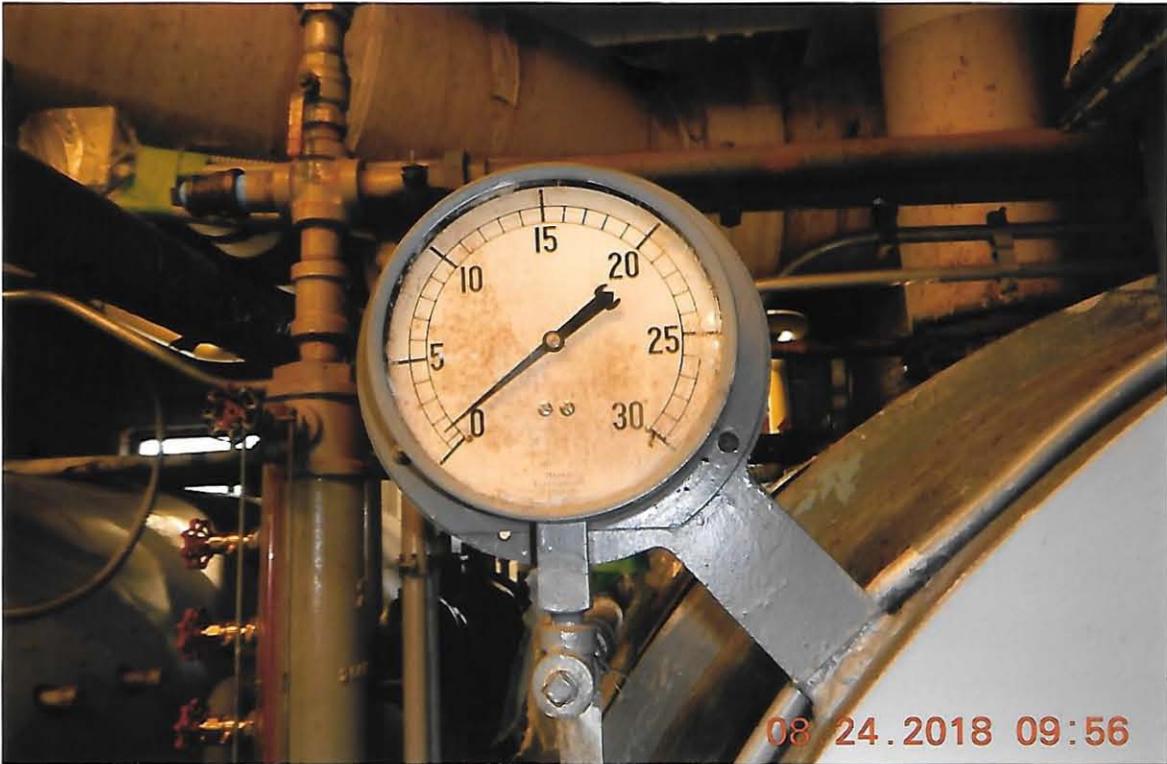


The following five (5) photos show the condition of the various safety appurtenances. No indication of up-to-date calibration was observed on the pressure/temperature gauges and pressure relief valves. The low water fuel cut-off devices were newly installed. The water level sight glass appeared to be in satisfactory condition.

1)



2)



The following five (5) photos show the condition of the various safety appurtenances. No indication of up-to-date calibration was observed on the pressure/temperature gauges and pressure relief valves. The low water fuel cut-off devices were newly installed. The water level sight glass appeared to be in satisfactory condition.

3)



4)



The following five (5) photos show the condition of the various safety appurtenances. No indication of up-to-date calibration was observed on the pressure/temperature gauges and pressure relief valves. The low water fuel cut-off devices were newly installed. The water level sight glass appeared to be in satisfactory condition.

5)



The following eight (8) photos show the external condition of the boiler. Gaps in the casing seams were noted. Staining, corrosion, and deterioration were observed on the casing beneath the boiler. Corrosion around the handholes was noted. The support structure appeared to be in satisfactory condition.

1)



2)



The following eight (8) photos show the external condition of the boiler. Gaps in the casing seams were noted. Staining, corrosion, and deterioration were observed on the casing beneath the boiler. Corrosion around the handholes was noted. The support structure appeared to be in satisfactory condition.

3)

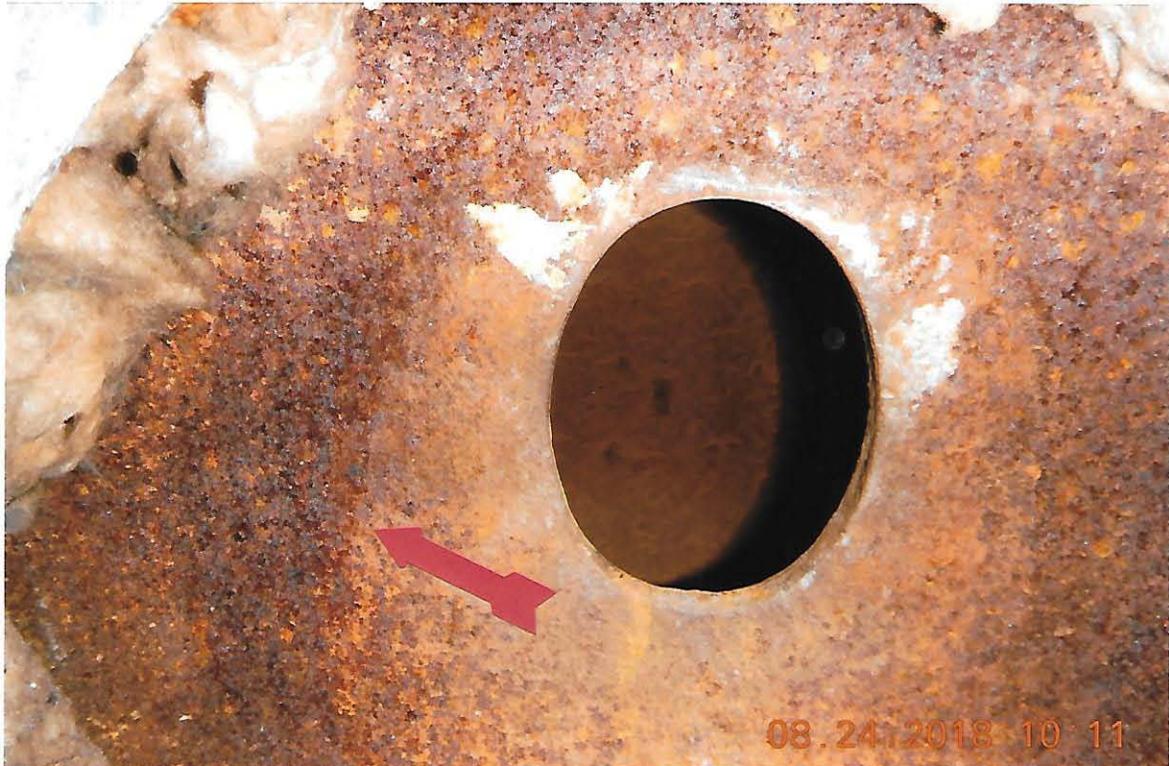


4)



The following eight (8) photos show the external condition of the boiler. Gaps in the casing seams were noted. Staining, corrosion, and deterioration were observed on the casing beneath the boiler. Corrosion around the handholes was noted. The support structure appeared to be in satisfactory condition.

5)



6)

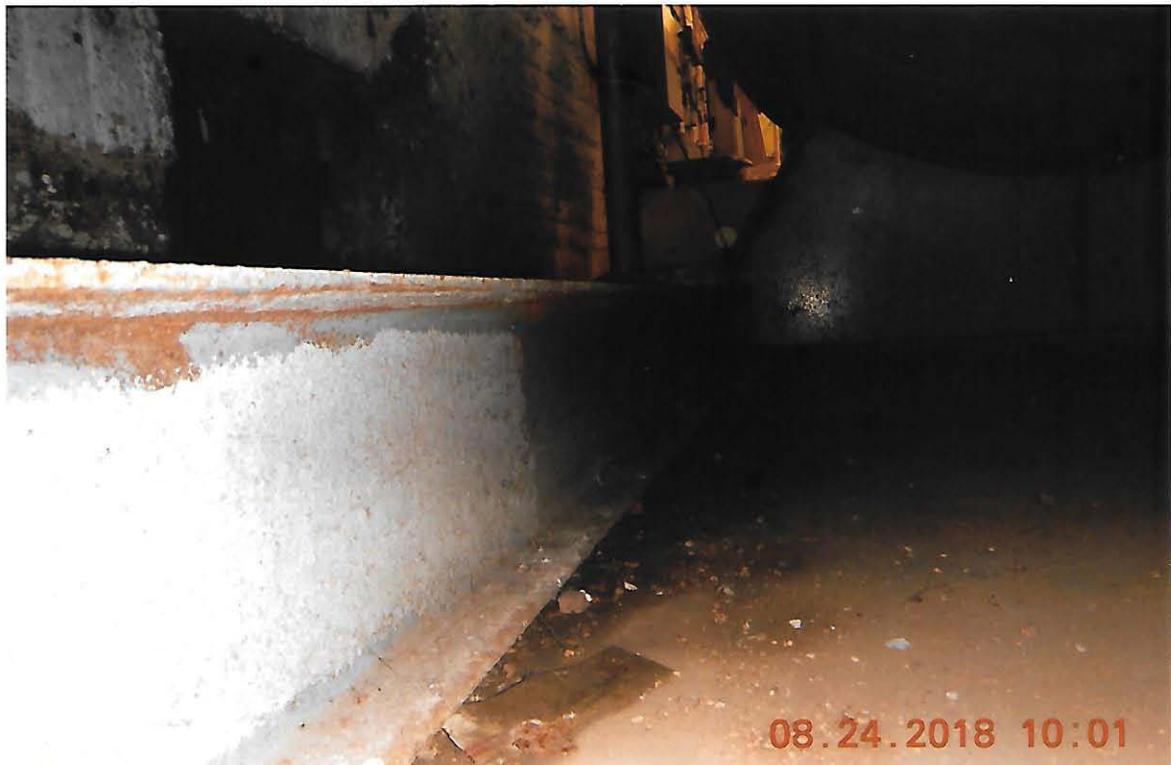


The following eight (8) photos show the external condition of the boiler. Gaps in the casing seams were noted. Staining, corrosion, and deterioration were observed on the casing beneath the boiler. Corrosion around the handholes was noted. The support structure appeared to be in satisfactory condition.

7)



8)







|   |                                       |
|---|---------------------------------------|
| DATE: 12-21-18                            | CLIENT: Grumman Butkus                |
| REPORT No: 1 of 3                         | JOB LOCALE- CITY, STATE: Evanston, IL |
| CLIENT PO No:                             | JANX JOB No:                          |
| CLIENT W/O No: 2100 Ridge Ave in Evanston | JANX PROCEDURE No:                    |
| CLIENT JOB No:                            | ACCEPTANCE CRITERIA: API 1104 20th ED |

**ULTRASONIC THICKNESS TESTING TECHNIQUE**

|  |   |  |                           |
|--|---|--|---------------------------|
| Instrument Mfg: <u>Landmark</u>  | Model: <u>UMap-1D</u>   | Serial No: <u>5103116</u>                      | Cal. Date: <u>3-27-18</u> |
| Transducer Mfg: <u>Landmark</u>  | Transducer Frequency: <u>10</u> MHz   | Due Date: <u>3-27-19</u>                       |                           |
| Transducer Size: <u>5 mm</u>   | Transducer Type: <input checked="" type="checkbox"/> Dual Element <input type="checkbox"/> Single Element | <input type="checkbox"/> Delay Line            |                           |
| <input checked="" type="checkbox"/> Contact <input checked="" type="checkbox"/> Angle 0° to Surface <input type="checkbox"/> Straight Beam | <input checked="" type="checkbox"/> Spot Thickness Readings Only  | <input type="checkbox"/> Area Scan (see below) |                           |
| Scan Description: <u>Spot thickness</u>  | Max. Scan Rate (in./sec.): _____  | Scan Overlap %: _____                          |                           |
| Couplant Brand or Type: <u>CSF</u>   | Remarks:  |  |                           |

|  |                  |                                    |  |                     |             |
|--|------------------|------------------------------------|--|---------------------|-------------|
| <b>PART DESCRIPTION</b>  |                  | Calibration Block No: <u>SP191</u> |  | Material: <u>CS</u> |             |
| Material: <u>Steel</u>   | Thickness: _____ | Step 1                             | Step 2   | Time                |             |
| Inspection Area Description: <u>Steam lines</u>                                    |                  | Cal Block Actual Thickness:        | <u>.100"</u>                                       | <u>.500"</u>        |             |
| Surface Condition: <u>Clean</u>  |                  | Cal. Reading at Start:             | <u>.100"</u>                                       | <u>.500"</u>        | <u>7:00</u> |
| Surface Preparation: <u>Wire brush</u>   |                  | Cal. Reading at End:               | <u>.100"</u>                                       | <u>.500"</u>        | <u>1:30</u> |
| Temp. of Part and Cal. Block within ± 25°F of each other: <input type="checkbox"/> |                  | Gate Height: _____ %               | <input checked="" type="checkbox"/> Not Applicable |                     |             |
|  |                  | Gain: _____ dB                     | <input checked="" type="checkbox"/> Not Applicable |                     |             |

| THICKNESS READINGS |  |    |  |    |  |    |  |     |
|--------------------|--|----|--|----|--|----|--|-----|
| 1                  |  | 21 |  | 41 |  | 61 |  | 81  |
| 2                  |  | 22 |  | 42 |  | 62 |  | 82  |
| 3                  |  | 23 |  | 43 |  | 63 |  | 83  |
| 4                  |  | 24 |  | 44 |  | 64 |  | 84  |
| 5                  |  | 25 |  | 45 |  | 65 |  | 85  |
| 6                  |  | 26 |  | 46 |  | 66 |  | 86  |
| 7                  |  | 27 |  | 47 |  | 67 |  | 87  |
| 8                  |  | 28 |  | 48 |  | 68 |  | 88  |
| 9                  |  | 29 |  | 49 |  | 69 |  | 89  |
| 10                 |  | 30 |  | 50 |  | 70 |  | 90  |
| 11                 |  | 31 |  | 51 |  | 71 |  | 91  |
| 12                 |  | 32 |  | 52 |  | 72 |  | 92  |
| 13                 |  | 33 |  | 53 |  | 73 |  | 93  |
| 14                 |  | 34 |  | 54 |  | 74 |  | 94  |
| 15                 |  | 35 |  | 55 |  | 75 |  | 95  |
| 16                 |  | 36 |  | 56 |  | 76 |  | 96  |
| 17                 |  | 37 |  | 57 |  | 77 |  | 97  |
| 18                 |  | 38 |  | 58 |  | 78 |  | 98  |
| 19                 |  | 39 |  | 59 |  | 79 |  | 99  |
| 20                 |  | 40 |  | 60 |  | 80 |  | 100 |

**SKETCH / PICTURE / REMARKS - AS NEEDED**

BILLING 820 Davis St.  
ADDRESS: Suite 300 Evanston, IL 60201

|                                |                         |                           |                     |                         |
|--------------------------------|-------------------------|---------------------------|---------------------|-------------------------|
| CLIENT SIGNATURE               | JANX LEVEL II SIGNATURE |                           | LEVEL II TECHNICIAN | OTHER EMPLOYEES & LEVEL |
|                                |                         |                           | Todd Jessup         | Dan Cordova - Level I   |
| CLIENT REP NAME & PHONE NUMBER | TRAVEL MILES            | TOTAL HOURS TRAVEL & WORK | UNIT NUMBER         | PER DIEM APPLICABLE     |
| <b>Steve Zehr</b>              | 125                     | 10                        | 670                 | No                      |
|                                |                         |                           |                     | TOTAL ITEMS INSPECTED   |
|                                |                         |                           |                     | 58                      |

|   |                                       |   |
|---|---------------------------------------|---|
| DATE: 12-21-18                            | CLIENT: Grumman Butkus                |  |
| REPORT No: 2 of 3                         | JOB LOCALE- CITY, STATE: Evanston, IL |   |
| CLIENT PO No:                             | JANX JOB No:                          |   |
| CLIENT W/O No: 2100 Ridge Ave in Evanston | JANX PROCEDURE No:                    |   |
| CLIENT JOB No:                            | ACCEPTANCE CRITERIA: API 1104 20th Ed |   |

| ITEM ID | ITEM TYPE / SIZE / THICKNESS / MATERIAL | IN CODE |   | LOCATION          | REMARKS / WELDER ID          |
|---------|---|---------|---|-------------------|------------------------------|
|         |   | Y       | N |                   |                              |
| UTT-1   | .230", .245", .256"                     |         |   | Loading dock      | Horizontal 4" condensate     |
| UTT-2   | .160", .160"                            |         |   | Loading dock      | Vertical 2" condensate       |
| UTT-3   | .160", .159"                            |         |   | Loading dock      | Horizontal 2" condensate     |
| UTT-4   | .146", .156"                            |         |   | Loading dock      | Horizontal 2" condensate     |
| UTT-5   | .117", .118"                            |         |   | Loading dock      | Horizontal 3/4" condensate   |
| UTT-6   | .217", .232"                            |         |   | Pump Room         | Horizontal 3" steam          |
| UTT-7   | .110", .113"                            |         |   | Pump Room         | Vertical 3/4" condensate     |
| UTT-8   | .256", .253                             |         |   | Pump Room         | Horizontal 4" steam          |
| UTT-9   | .157", .158"                            |         |   | Pump Room         | Horizontal 1 1/4" condensate |
| UTT-10  | .355", .350"                            |         |   | FM office         | Vertical 8" steam            |
| UTT-11  | .333"                                   |         |   | FM office         | Vertical 6" steam            |
| UTT-12  | .176", .183"                            |         |   | FM office         | Vertical 2" steam            |
| UTT-13  | .144", .141"                            |         |   | FM office         | Vertical 1" condensate       |
| UTT-14  | .118", .121"                            |         |   | FM office         | Vertical 3/4" condensate     |
| UTT-15  | .123", .121"                            |         |   | Handicap entrance | Horizontal 3/4" condensate   |
| UTT-16  | .154", .160"                            |         |   | Handicap entrance | Horizontal 2" condensate     |
| UTT-17  | .224", .228"                            |         |   | Handicap entrance | Horizontal 2" steam          |
| UTT-18  | .300", .287"                            |         |   | Ground level room | Horizontal 6" steam          |
| UTT-19  | .157", .156"                            |         |   | Ground level room | Horizontal 2" steam          |
| UTT-20  | .150", .146"                            |         |   | Ground level room | Horizontal 1 1/2" condensate |
| UTT-21  | .156", .152"                            |         |   | Ground level room | Horizontal 1 1/4" steam      |
| UTT-22  | .160", .160"                            |         |   | Ground level room | Horizontal 2" condensate     |
| UTT-23  | .230", .251"                            |         |   | Ground level room | Horizontal 4" steam          |
| UTT-24  | .160", .168"                            |         |   | Ground level room | Horizontal 1 1/4" steam      |
| UTT-25  | 330", .328"                             |         |   | Ground level room | Horizontal 8" steam          |
| UTT-26  | 178", .181"                             |         |   | Ground level room | Horizontal 2" condensate     |
| UTT-27  | .116", .116"                            |         |   | Ground level room | Horizontal 3/4" condensate   |
| UTT-28  | .116", .114"                            |         |   | Room 1700         | Vertical 1/2" condensate     |
| UTT-29  | .129", .130"                            |         |   | Room 1700         | Vertical 1" steam            |
| UTT-30  | .162"                                   |         |   | Room 1700         | Vertical 2 1/2" steam        |
| UTT-31  | .131", .116"                            |         |   | Room 1700         | Vertical 3/4" condensate     |
| UTT-32  | .120", .111"                            |         |   | Room 1500         | Horizontal 3/4" condensate   |
| UTT-33  | .141", .146"                            |         |   | Room 1500         | Horizontal 1 1/4" steam      |
| UTT-34  | .116", .111"                            |         |   | Room 1500         | Vertical 1" condensate       |
| UTT-35  | .228", .208"                            |         |   | Room 1500         | Vertical 2 1/2" steam        |
| UTT-36  | .152", .148"                            |         |   | Room 1115         | Horizontal 1 1/4" steam      |
| UTT-37  | .111", .115"                            |         |   | Room 1115         | Horizontal 3/4" condensate   |
| UTT-38  | .111", .128"                            |         |   | Room 1115         | Vertical 3/4" condensate     |
| UTT-39  | .161", .164"                            |         |   | Room 1115         | Vertical 2 1/2" steam        |

Note: Continuation Page Signatures Required. See Preceding Page(s) for Technique(s) and Billing Information.

|   |                         |                  |                         |
|---|-------------------------|------------------|-------------------------|
| CUSTOMER SIGNATURE  | JANX LEVEL II SIGNATURE | LEVEL II ON UNIT | OTHER EMPLOYEES & LEVEL |
|  | Todd Jessup             | Todd Jessup      | Dan Cordova - Level 1   |





**Grumman/Butkus Associates**  
Energy Efficiency Consultants and Sustainable Design Engineers



# HVAC Upgrade Study Morton Civic Center

Date: November 15, 2018

## Project Objectives



- Investigate operational status and remaining service life of existing systems and equipment.
- Identify 2-3 feasible HVAC upgrade/replacement strategies for the building.
- Analyze each upgrade option in terms of energy performance, maintenance burden, and implementation cost.
- Provide recommendations and a detailed scope of work to execute the project.



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Illinois Professional Registration #184-000926

## Existing Systems – Steam Plant and Piping



### Boilers

Boiler specialist was engaged to conduct a thorough condition assessment of both boilers. The assessment included visual, ultrasonic, magnetic particle and eddy current analysis methods.



### Findings

- The front and rear tube sheets, tube sheet ligaments, circumferential and longitudinal welds appear to be in satisfactory condition.
- Both boilers had a light layer of soot throughout the fireside.
- Cracks were observed in the burner refractory of both boilers.
- The burner barrels of boiler 2 had warping and corrosion.
- There is evidence of tube leaking on the furnace sheets and combustion chambers of both boilers.
- The boilers' external and safety appurtenances appear to be in satisfactory condition, however, there is no evidence or documentation of up-to-date calibration of pressure/temperature gauges and pressure relief valves.
- **In boiler 1, 35 (of a total of 72) tubes have measured wall thickness loss of more than 50%.**
- **In boiler 2, 45 (of a total of 72) tubes have measured wall thickness loss of more than 50%.**

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## Existing Systems – Steam Plant and Piping



### Radiators

Cast iron radiators are heavily built and can last for many years. It is difficult to accurately estimate remaining life of these units. The operating engineer reports that they have not observed many failures of these radiators in the recent past. There are approximately 50 radiators per floor on levels 1-4, for a building total of approximately 200.

### Steam and Condensate Piping

Initial pipe testing of small bore radiator connection piping raised concerns. Further investigation is needed. There are no existing drawings which indicate the sizes and configuration of the steam and condensate piping system. It is estimated that there are 20-24 steam supply/condensate risers in the building with main horizontal piping running at ceiling level of the ground floor.



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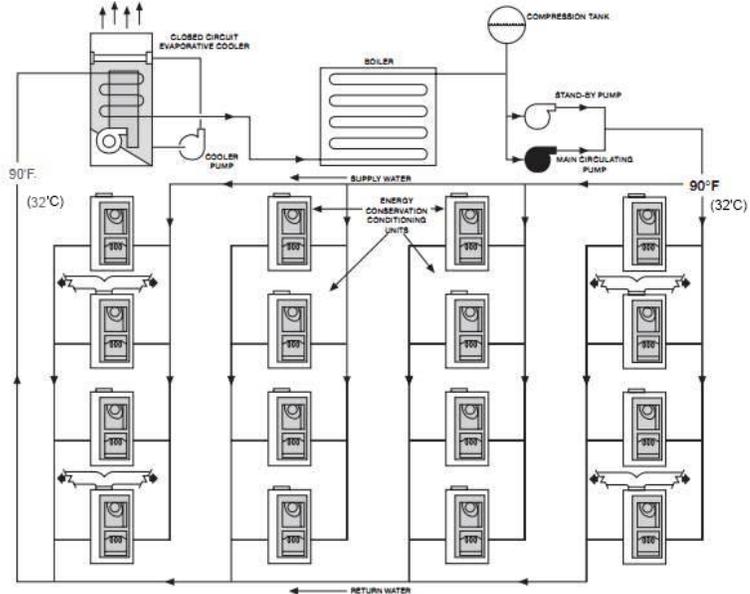
Illinois Professional Registration #184-000926

## Existing Systems – Heat Pumps



**Air-conditioning (and heating in select areas) is provided by the building's water-source heat pump system.**

- Each temperature control zone within the building is equipped with a ceiling mounted heat pump with supply and return duct connections.
- The heat pumps reject heat into the circulating water loop when operating in cooling mode and draw heat from the loop in heating mode.
- A steam heat exchanger adds heat to the loop to maintain a minimum loop temperature.
- A closed loop fluid cooler is used to reject heat to maintain the water temperature entering the heat pumps at or below 90°F.



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## Existing System – Heat Pumps



### Heat Pumps

The building has an inventory of replacement units in attic storage.

|                                  |    |                      |
|----------------------------------|----|----------------------|
| Ground Level Unit Count          | 25 |                      |
| 1 <sup>st</sup> Floor Unit Count | 18 |                      |
| 2 <sup>nd</sup> Floor Unit Count | 20 |                      |
| 3 <sup>rd</sup> Floor Unit Count | 16 |                      |
| 4 <sup>th</sup> Floor Unit Count | 16 | Building Total = 95* |

### Steam Converter

The steam converter (shell-tube type steam to water heat exchanger) is piped using a bridge connection at the main return line. Flow is induced through the converter by throttling the butterfly valve located between the tees. The converter is not intended to receive full system flow. The existing converter was installed in 1979 and is approaching the end of its service life.

### Fluid Cooler

The fluid cooler was replaced in 2006. It appears to be in good condition. The fill material has recently been replaced.

### Circulation Pumps

The circulation pumps were installed in 1979. They are beyond their expected service life.



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## Existing Systems – Heat Pumps

### Neutral Water Piping System

The heat pumps all receive flow from a “neutral” water loop. The term “neutral” is used to refer to its temperature – which is neither hot nor cold, typically operating within the range of 65-90°F. This piping requires no insulation or vapor barrier.

### History Of Water Quality Issues

The engineer expressed concerns about this piping, and reported that for much of its service life the water chemistry within the piping may not have been carefully managed. He reports that a number of the heat pumps appear to be receiving inadequate flow. In addition, he reports that there have been issues with fouling within the coiled, concentric heat exchangers

### Analysis of Water Quality and Sediment Composition

G/BA had a water sample and a sample of the sediment taken from a fouled heat pump analyzed by a chemist.

### Analysis of Remaining Pipe Wall Thickness

G/BA commissioned radiographic (x-ray) testing of pipe wall thickness in a number of locations throughout the building, focused primarily on the neutral water piping system.



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## Existing Systems – Heat Pumps



### Water Chemistry Testing Results



Fehr Solutions, LLC

Water Treatment Services and Consulting

The water in the ECC system has low corrosion products and proper pH. The evidence of boron and small amounts of tolyltriazole and nitrite shows that there was treatment but levels are low.

The solid sample is primarily iron and calcium. The iron is primarily from old corrosion product.

|                               | ECC Water Sample | ECC SOLID Sample |
|-------------------------------|------------------|------------------|
|                               | 9/20/18          | 9/20/18          |
| Conductivity                  | 630              | N/A              |
| pH                            | 9.15             | N/A              |
| Magnesium (as ppm CaCO3)      | 16.90            | 2.44             |
| Calcium (as ppm CaCO3)        | 12.66            | 17.77            |
| Ca/Mg Ratio                   | 0.75             |                  |
| Iron (as ppm Fe)              | 0.02             | 71.71            |
| Copper (as ppm Cu)            | 0.03             | 3.84             |
| Total Phosphorus (as ppm PO4) | 0.02             | 1.46             |
| Zinc (as ppm Zn)              | 0.02             | 0.22             |
| Sodium (as ppm Na)            | 106.19           | 0.11             |
| Molybdate (as ppm Mo)         | 0.12             | 0.00             |
| Silicate (as ppm SiO2)        | 0.22             | 1.40             |
| Boron (as ppm B)              | 30.33            | 0.00             |
| Aluminum (as ppm Al)          | 0.01             | 0.18             |
| Sulfur (as ppm SO4)           | 18.90            | 0.46             |
| Manganese (as ppm Mn)         | 0.01             | 0.40             |
| Total Hardness (as ppm CaCO3) | 29.56            | N/A              |
| Tolyltriazole (TT)            | 1.7              | N/A              |
| Sodium Nitrite (as ppm NO2)   | 80               | N/A              |

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## Existing Systems – Heat Pumps



### Pipe Wall Thickness Testing Results

Results indicate that significant internal corrosion has transpired within the neutral water system. Due to the initially lesser wall thickness of small diameter piping, the end of main runs and the runouts from the mains to the heat pumps are the main areas of concern.

| Shot # | Location                                      | Pipe Size | ASME thickness (Std) | Minimum Measured/% Remaining |      |       |      |       |      |          |      | Corr. Erosion ID/OD |
|--------|---|-----------|----------------------|------------------------------|------|-------|------|-------|------|----------|------|---------------------|
|        |   |           |                      | 1                            |      | 2     |      | 3     |      | Thinnest |      |                     |
|        |   |           |                      | in                           | %    | in    | %    | in    | %    | in       | %    |                     |
| 1      | North end of NW mains on ground floor         | 3         | 0.22                 | 0.180                        | 82%  | 0.180 | 82%  | 0.193 | 88%  | 0.170    | 77%  | ID                  |
| 2      | G23 Runouts                                   | 1         | 0.13                 | 0.049                        | 38%  | 0.052 | 40%  | 0.054 | 42%  | 0.048    | 37%  | ID                  |
| 3      | O12 Runouts                                   | 1.25      | 0.14                 | 0.062                        | 44%  | 0.063 | 45%  | 0.077 | 55%  | 0.062    | 44%  | ID                  |
| 4      | O4 Runouts                                    | 1         | 0.13                 | 0.040                        | 31%  | 0.040 | 31%  | 0.047 | 36%  | 0.014    | 11%  | ID                  |
| 5      | North end of NW mains on first floor          | 1.5       | 0.15                 | 0.030                        | 20%  | 0.047 | 31%  | 0.073 | 49%  | 0.027    | 18%  | ID                  |
| 6      | Top of NW riser in attic                      | 5         | 0.26                 | 0.348                        | 134% | 0.344 | 132% | 0.35  | 135% | 0.328    | 126% | ID                  |
| 7      | South end of NW mains in attic                | 1.5       | 0.15                 | 0.070                        | 47%  | 0.080 | 53%  | 0.08  | 53%  | 0.044    | 29%  | ID                  |
| 8      | Attic?  | 3         | 0.22                 | 0.160                        | 73%  | 0.160 | 73%  | 0.17  | 77%  | 0.160    | 73%  | ID                  |
| 9      | First floor radiator runouts (1101)           | 1         | 0.13                 | 0.020                        | 15%  | 0.075 | 58%  | 0.12  | 92%  | 0.020    | 15%  | ID                  |
| 10     | First floor radiator runouts (west vestibule) | 1         | 0.13                 | 0.100                        | 77%  | 0.100 | 77%  | 0.1   | 77%  | 0.100    | 77%  | ID                  |

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## Existing Systems – Ventilation Units

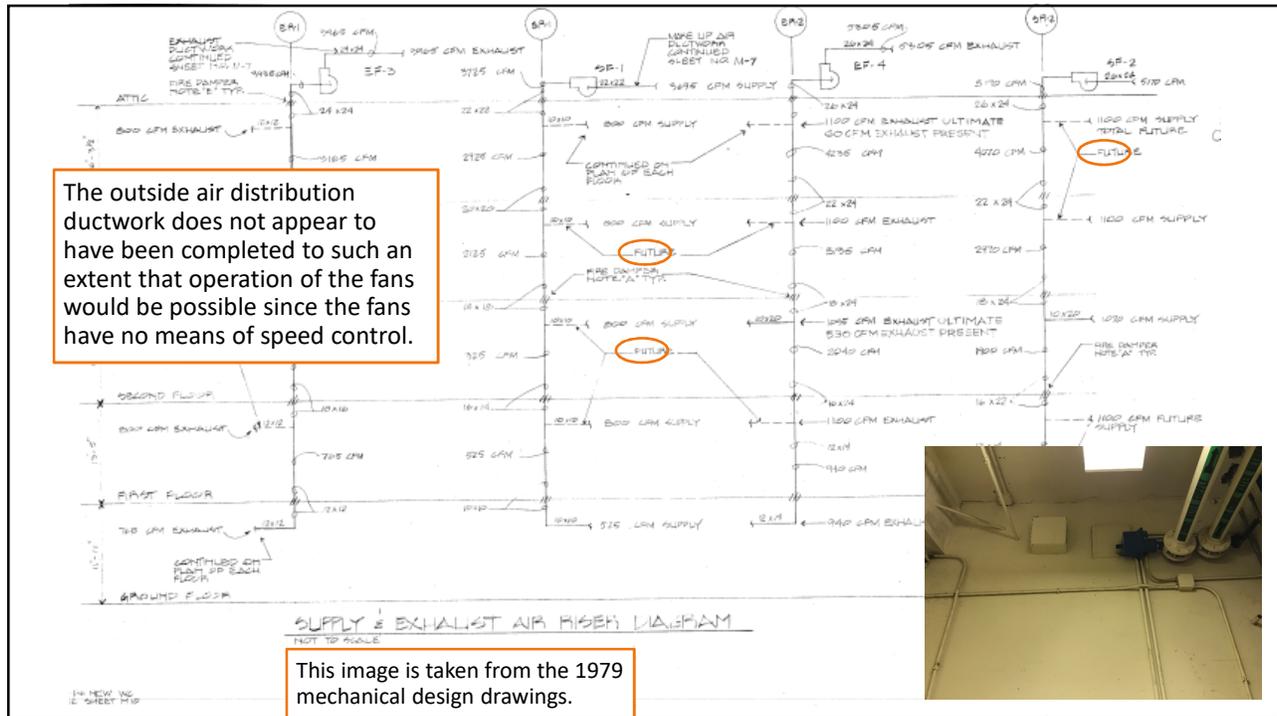


### Description

- There are two ventilation units located in the north and south ends of the attic. The units were originally rated to “temper” 5,170 and 3,695 CFM of outside air, respectively. The units connect to vertical ducts which are intended to direct airflow down into the building, delivering approximately 900-1,100 CFM per floor.
- While this building technically meets ventilation code due to its operable windows, there are two reasons why a Dedicated Outdoor Air System (DOAS) is recommended.
  1. During a high percentage of hours annually, building occupants are unlikely to open windows for comfort reasons.
  2. Operation of a DOAS system can cause the building to be positively (or less negatively) pressurized, effectively reducing the rate at which unconditioned outside air infiltrates into the building.

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### Summary of Findings

1. The boilers are in need of new burners and tube replacement.
2. Further testing is planned to gather more data on the condition of the steam and condensate piping.
3. The small diameter neutral water piping has lost a significant percentage of wall thickness due to internal corrosion. It is recommended that this piping be replaced.
4. The neutral water piping system appears to have significant amounts of precipitated corrosion product within the piping. We will recommend efforts to install a dirt separator or filter along with a segment by segment high velocity flushing of each branch of the system, perhaps with a portable flush kit to purge the individual heat pumps.



## Preliminary Upgrade Strategies



- Option 1 [Heat Pumps Remain]
  - Refurbish existing systems, incl. boilers, neutral water piping and pumps
  - Install new DOAS Units and Complete Ventilation Ductwork System
- Option 1 + Replace Condensate Piping
  - Option 1 items
  - Replace vertical condensate risers and radiator run-out piping throughout building
- Option 1 + Hot Water Conversion
  - Replace steam boilers with hot water boilers
  - Replace all steam and condensate piping with insulated hot water supply and return lines throughout building
  - Replace radiators with cabinet convectors or baseboard radiation



Adirondack-Aire HW

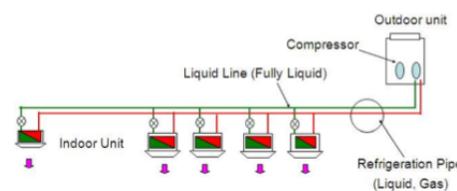
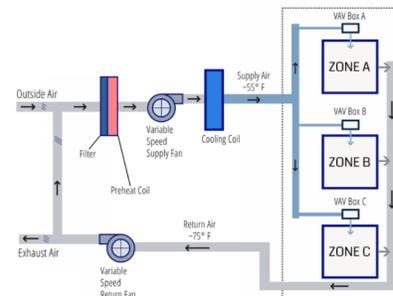
Replaces American Air Filter / Enercon HW ducted horizontal water source heat pumps

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## Preliminary Upgrade Strategies (continued)



- Option 2 [Distributed VAV Air Handlers]
  - Would require approximately 80,000 CFM of capacity.
  - Heat pumps and neutral water piping would be removed.
  - Install Variable Air Volume (VAV) Air Handling Units (probably 2 per floor – for reasons we can discuss)
  - Provide VAV terminal units – one per zone, may be possible to reuse zone ductwork after heat pumps.
  - Heating to each zone provided by hydronic reheat coils.
  - Significant construction effort
- Option 3 [VRF]
  - Replace heat pumps with distributed variable refrigerant flow (VRF) fan-coil units
  - Ventilation strategies same as with heat pumps
  - Zone-based radiators or convectors needed for heating as heating capability inadequate at low ambient conditions.



Cooling Mode : Expansion = Indoor Unit    Liquid Line = Condensed Liquid  
 Heating Mode : Expansion = Outdoor unit    Liquid Line = Condensed Liquid

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## Next Steps

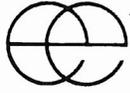


- Our focus now turns to conceptual design and cost estimating for implementation of each option. As that task reaches completion we will issue a report on our findings and recommendations.
- Follow-up testing of steam and condensate piping.
- We anticipate that the differences in implementation costs among the options will greatly exceed differences in annual operating costs and that the decision will likely be cost driven.

## Preliminary Order of Magnitude Scope Pricing



| Scheme  | ROM Project Cost |
|---|------------------|
| Option 1 (Stay with HPs – includes replacement)     | \$ 1,500,000     |
| Option 1 + Replace Cond Piping                      | \$ 2,000,000     |
| Option 1 + HW Conversion                            | \$ 3,600,000     |
| Option 2 VAV AHUs (Includes HW Conversion)          | \$ 7,300,000     |
| Option 3 Variable Refrigerant Flow (Supp Htg Req'd) | \$ 3,600,000     |
| Option 3 + Replace Cond Piping                      | \$ 4,100,000     |
| Option 3 + HW Conversion                            | \$ 5,200,000     |



# edwards engineering, inc.

1000 TOUHY AVENUE ELK GROVE VILLAGE, IL 60007-4922  
 TELEPHONE: (847) 364-8100 FAX: (847) 364-0188

## CONTRACTORS / ENGINEERS

- AIR CONDITIONING • HEATING
- REFRIGERATION • VENTILATION
- PIPING • SHEET METAL
- SERVICE

January 15, 2019

Mr. Steve Zehr  
**Grumman/Butkus Associates**  
 820 Davis Street, Suite 300  
 Evanston, IL 60201

szehr@grummanbutkus.com

**Subject: Evanston Civic Center  
 Budgetary Pricing**

Dear Mr. Zehr:

Listed below are our budgetary prices you requested for the above project. As with any budget pricing our assumed work conditions and restrictions for a municipal civic center in continuous use will impact our budgets.

Budget 1A: Replace the existing horizontal heat pumps with new:

- Ceiling removal and re-installation
- Dust partitions as required
- Disconnect ductwork piping and wiring from approximately ninety five (95) horizontal heat pumps
- Replace heat pumps with new including control valves, new thermostats using existing wiring, hose kits
- Reconnect new heat pumps to existing ductwork, piping, and wiring
- Start-up, test & balance, and first year warranty

**Budget 1A: \$1,405,000 for this scope of work**

Assumptions:

- All work during normal working hours
- Phasing of this work is by floor
- Owner to assist in gaining access to heat pump locations by relocating furniture, equipment, etc.

Budget 1B: Remove and replace in kind existing condenser water piping from existing risers to heat pump:

- Removal and re-installation of the existing ceiling for pipe access
- Allowances for visqueen barriers/partitions
- Demo existing pipe and replace with new
- Reconnect pipe to heat pumps

**Budget 1B: \$670,000 for this scope of work**

January 15, 2019

Page 2

Budget 1C: Install new 100% make-up air units in attic:

- Furnish and install two (2) new 100% outside air water cooled make-up air units in the north and west ends of the attic
- Install new OA intake louvers in existing attic window and roof cupola
- Connect new make-up air supply duct to existing risers located in attic
- Run new condenser water piping from ground floor pump room up to units in attic
- Furnish booster pumps at each unit
- Duct insulation
- Power wiring allowance
- Stand alone temperature controls
- Hoisting equipment through attic window
- Air balancing

**Budget 1C: \$796,000 for this scope of work**

Exclusions: Structural analysis of floor for west MAU

Budget 1D: Complete dedicated OA ductwork not previously installed:

- Remove and re-install existing ceilings
- Dust partitions as required
- Extend make-up air ductwork from existing duct shafts to return air ductwork on each existing heat pump on floors 1, 2, 3 & 4 as directed
- Duct insulation
- Air balancing

**Budget 1D: \$550,000 for this scope of work**

Assumptions:

- See Budget 1A

Budget 1E: Replace two (2) existing condenser water pumps with new:

- Drain down existing condenser water piping
- Demo existing base mounted pumps and replace with same
- Install new variable frequency drives and reconnect existing power wiring
- Install new isolation valves and hydronic accessories

**Budget 1E: \$65,000 for this scope of work**

Assumptions:

- All existing isolation valves hold
- No chemical treatment
- Owner drains/fills existing system

January 15, 2019

Page 3

Budget 1F: Re-tube and replace burners on existing steam boilers (two total boilers)

**Budget 1F: \$148,000 for this scope of work**

Assumptions:

- No work on existing condensate or vacuum pumps

Budget 1G: Replace condensate piping and thermostatic control valves on existing radiators

- Ceiling removal and replacement
- Dust partitions as required
- Demo steam condensate risers back to maintenance office area
- Run new SCH 80 steam condensate pipe in original pipe location
- Re-insulate pipe
- Remove and replace existing steam thermostatic control valves
- Firestop openings

**Budget 1G: \$624,000 for this scope of work**

Assumptions:

- No wall removal or replacements to gain access to hidden piping
- Owner assists in allowing access where required

Budget 1H: Niagara BAS control system

**Budget 1H: \$356,000 for this scope of work**

Budget 2A/B: New boilers, pumps, HW fin tube, HW pipe, demo

- Demo existing steam boilers and piping in boiler room
- Demo existing steam and condensate, piping and radiators in building as required
- Install three (3) new hot water boilers, pumps, pipe and HW specialties and flues in boiler house
- Install new underground insulated hot water pipe from boiler room to interior of the building including all excavation and backfill
- Install new hot water distribution pipe throughout the building
- New hot water fin tube baseboard with covers and thermostatic control valves in place of old steam radiators
- Ceiling removal/replace as required
- Firestopping
- Insulation
- Stand alone boiler controls
- Water balancing
- Power wiring

January 15, 2019

Page 4

**Budget 2A/B: \$2,250,000 for this scope of work**

Budget 3: New VAV AHU's fan powered boxes, boilers, chillers, pumps, piping, ductwork, insulation, controls:

- Demo steam boilers, piping, radiators
- Install new hot water boilers, pumps, piping insulation, controls in boiler room
- New underground hot water pipe to building and to new fan powered boxes located throughout the building
- Install new VAV air handling units on north and west end of each floor
- Install grade mounted chillers
- Install chilled water pumps
- Install new chilled water pipe to each air handling unit
- Install new distribution duct down main corridors for each floor
- Insulation
- Temperature controls
- Test and balance

**Budget 3: \$8,100,000 for this scope of work**

As an overall review of our budgets, we are basing these numbers on the following assumptions:

- All work on straight time
- Work is assumed to begin in 2020
- Permits, fees, and bonds are excluded
- All abatement has been accomplished by others prior to the start of the project
- We assume entire floors will be available for these modifications
- Owner responsible for moving office equipment/desks for our needs
- Budget prices have some redundancies due to shopping list presentation

Please contact us with any questions you may have.

Sincerely,

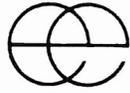
EDWARDS ENGINEERING, INC.



Scott Lieske  
President

Cc: R. Larson

SL:dkf


**edwards engineering, inc.**

1000 TOUHY AVENUE ELK GROVE VILLAGE, IL 60007-4922  
 TELEPHONE: (847) 364-8100 FAX: (847) 364-0188

## CONTRACTORS / ENGINEERS

- AIR CONDITIONING • HEATING
- REFRIGERATION • VENTILATION
- PIPING • SHEET METAL
- SERVICE

February 8, 2019

Mr. Steve Zehr  
**Grumman/Butkus Associates**  
 820 Davis Street, Suite 300  
 Evanston, IL 60201

szehr@grummanbutkus.com

**Subject: Evanston Civic Center – Scheme #3  
 Budgetary Pricing**

Dear Mr. Zehr:

Listed below are our budgetary prices for the above project. We have incorporated all items for Scheme #3 as listed on your e-mail dated 1/22/19.

We include the following scope of work for this Scheme:

- Retube existing boilers including new burners and controls (previous Budget 1F)
- Replace horizontal heat pumps with new dual temp fan coil units (previous Budget 1A)
- Demo existing condenser water piping in its entirety and install new insulated dual temp steam and condensate return piping.
- Demo existing condenser water pumps, fluid coolers, and steam heat exchanger. Install new Aquasnap air-cooled chillers, pumps, VFD's, and all required accessories.
- Provide new exterior chiller pads.
- Provide new steam to hot water heat exchanger.
- Replace steam radiator valves and condensate pipe from existing risers (previous Budget 1G).
- Provide network cabling for new FCU's, network controls, and workstations (previous Budget 1H).
- Additional electrical allowance.
- Additional ceiling removal and replace allowance.
- Air & water balancing.

**Scheme #3 Budget: \$4,450,000**

**Add \$796,000** (previous Budget 1C) for new DOAS units in attic.

The following exclusions apply:

- No phasing allowance has been included. Building occupancy will be compromised under this option.
- All work assumed to begin in 2020.
- Sales tax.
- Permits, fees, bond.
- Cutting/patching/painting.

February 8, 2019

Page 2

- Furniture or equipment relocation.
- Overtime.

Please call with any questions you may have.

Sincerely,

EDWARDS ENGINEERING, INC.

A handwritten signature in black ink, appearing to read "Scott Lieske", written in a cursive style.

Scott Lieske  
President

Cc: R. Larson, EEI

SL:dkf

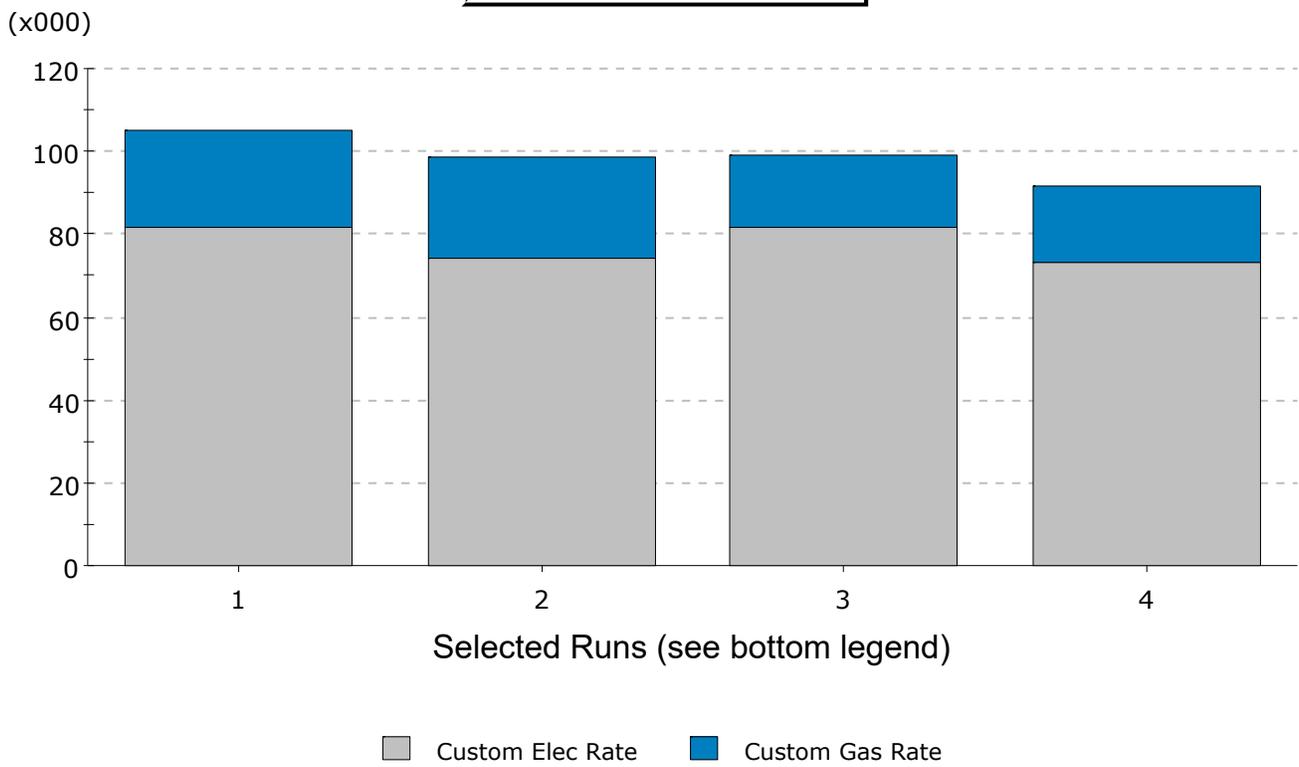
Scheme Comparison Matrix

| Scheme | Description   | Installation Considerations   | Maintenance Requirements  | Estimated Annual System Maintenance Cost Difference (\$) <sup>1</sup> | Estimated Annual Elec Use (kWh) | Estimated Annual NG Use (Therms) | Estimated Annual Energy Cost (\$) | Estimated Project Cost (\$) | 25 Year Life Cycle Cost (\$) |
|--------|---|---|---|---|---------------------------------|----------------------------------|-----------------------------------|-----------------------------|------------------------------|
| 1      | Replace Heat Pumps in kind and Refurbish Boilers. Replace attic ventilation units and complete OA ductwork.   | Would isolate piping on half of a floor. All heat pumps and piping connections would be rebuilt and new OA ductwork added where required. Existing ceilings would remain. Boiler refurbishmen to occur during the summer. Attic OA units would be replaced. Estimated duration of construction per wing = 8-12 weeks.   | Heat pumps represent a "distributed" system type, with motors, compressors, heat exchangers, and controls located above ceilings in numerous (approx 95) locations throughout the building. Maintenance of distributed systems is more challenging and disruptive to building occupants relative to centralized system types. This is exacerbated by poor service access above the ceiling in some locations. | \$ 167,580  | 1,275,000                       | 2,581                            | \$ 105,033                        | \$ 6,048,000                | \$ 12,011,266                |
| 2      | Replace Heat Pumps with 2-Pipe Fan-Coil Units and Refurbish Boilers. Requires new chilled water plant and replaces neutral water piping with insulated dual temperature piping. | Would isolate piping on half of a floor. All heat pumps would be replaced with fan-coil units. Piping would be replaced with larger sized insulated piping. New OA ductwork added where required. Existing ceilings would likely remain. Boiler refurbishmen to occur during the summer. Attic OA units would be replaced. Estimated duration of construction per wing = 12-16 weeks. | This is a "centralized" system type. Fan-coil units are located above ceilings in occupied areas, however, they require less maintenance than heat pumps since they are comprised of a single heat exchanger, a fan motor, and basic controls.  | \$ 130,340  | 1,179,000                       | 2,706                            | \$ 98,383                         | \$ 7,046,400                | \$ 11,596,251                |
| 3      | Replace Heat Pumps in kind and Replace Steam Boilers with Hot Water Boilers. Replace attic ventilation units and complete OA ductwork.  | Would isolate piping on half of a floor. All heat pumps and piping connections would be rebuilt and new OA ductwork added where required. Existing ceilings would remain. Boiler replacement would occur during the summer. Attic OA units would be replaced. Estimated duration of construction per wing = 8-12 weeks.   | Heat pumps represent a "distributed" system type, with motors, compressors, heat exchangers, and controls located above ceilings in numerous throughout the building. Maintenance of distributed systems is more challenging and disruptive to building occupants relative to centralized system types. This is exacerbated by poor service access above the ceiling in some locations.                       | \$ 158,270  | 1,273,000                       | 1,915                            | \$ 98,951                         | \$ 7,821,600                | \$ 13,392,229                |
| 4      | Install Floor-by-floor VAV Air Handling Systems and Terminal Units. Requires new chilled water and hot water plants and distribution piping.                                    | Would build out in half-floor increments. Corridor ceilings would need to be removed to permit installation of new ductwork. A fan room would need to be created on each wing of each floor. Estimated duration of construction per wing = 16-20 weeks.   | This is a "centralized" system type. The primary equipment which requires service (AHU's, chillers, boilers) would be located in mechanical rooms. Units can generally be serviced without entering occupant areas. VAV terminal units, which are located above ceilings, typically require little maintenance.   | \$ 125,685  | 1,158,000                       | 2,078                            | \$ 91,811                         | \$ 9,780,000                | \$ 13,437,670                |

Notes:

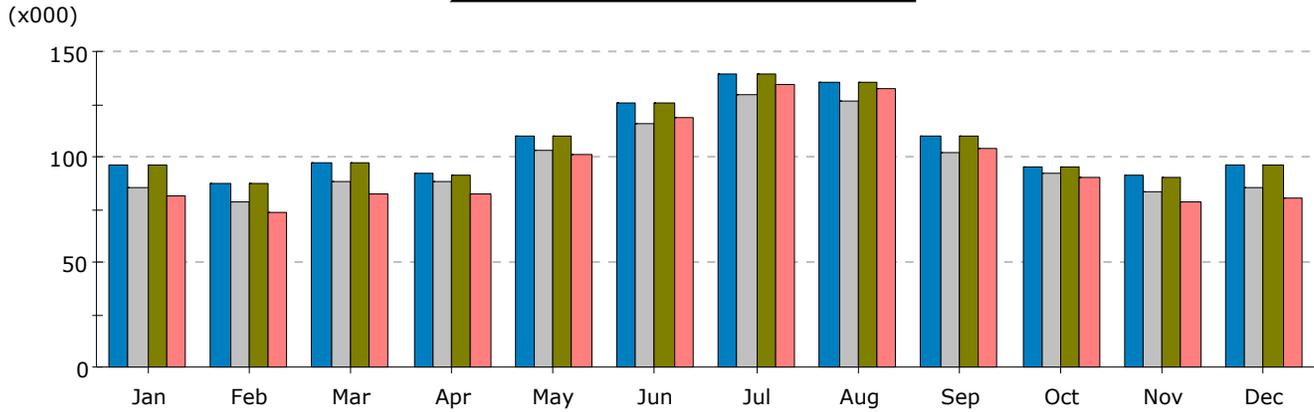
1) Maintenance costs are derived based on median repair/maintenance costs for office building provided by the 2017 BOMA Exerience Exchange Report.

**Annual Utility Bills (\$)**



1. Evanston Civic Center - Baseline Design (05/14/19 @ 10:47) (annual bill: \$ 105,033)
2. Evanston Civic Center - FCUs - Baseline Design (02/12/19 @ 15:49) (annual bill: \$ 98,383)
3. Evanston Civic Center-HW - Baseline Design (05/02/19 @ 11:18) (annual bill: \$ 98,951)
4. Evanston Civic Center - VAV - Baseline Design (02/12/19 @ 15:50) (annual bill: \$ 91,811)

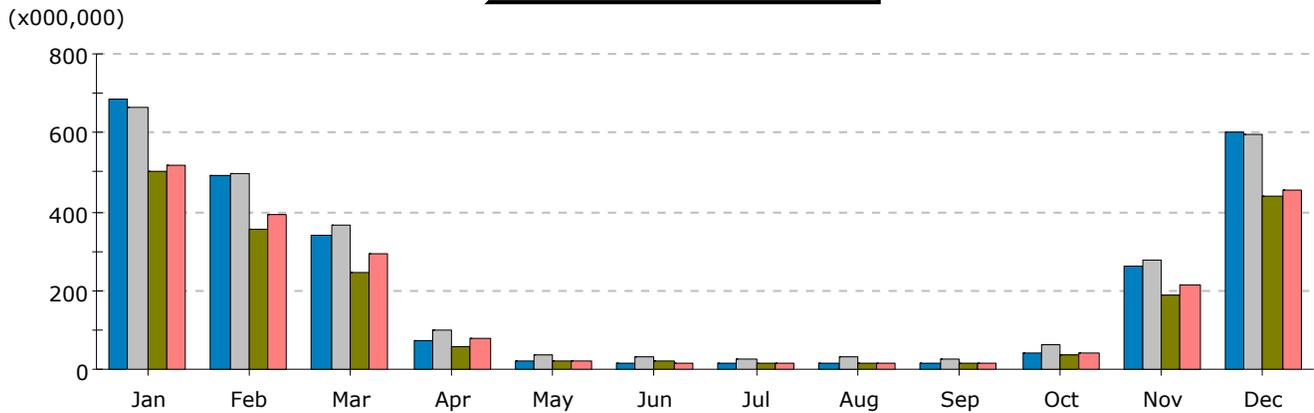
### Electric Consumption (kWh)



|        | Jan  | Feb  | Mar  | Apr  | May   | Jun   | Jul   | Aug   | Sep   | Oct  | Nov  | Dec  | Total   |
|--------|------|------|------|------|-------|-------|-------|-------|-------|------|------|------|---------|
| Run 1. | 96.3 | 87.6 | 97.4 | 91.7 | 109.5 | 125.2 | 139.4 | 135.8 | 110.3 | 95.4 | 90.7 | 96.1 | 1,275.1 |
| Run 2. | 85.6 | 78.4 | 88.2 | 88.6 | 102.8 | 116.0 | 129.7 | 126.6 | 102.3 | 92.6 | 83.0 | 85.6 | 1,179.4 |
| Run 3. | 96.0 | 87.4 | 97.2 | 91.5 | 109.3 | 125.0 | 139.2 | 135.6 | 110.1 | 95.2 | 90.5 | 95.8 | 1,273.2 |
| Run 4. | 81.2 | 73.9 | 82.5 | 82.7 | 100.7 | 118.7 | 134.3 | 132.0 | 103.6 | 89.7 | 78.0 | 80.7 | 1,158.1 |
| Run 5. |      |      |      |      |       |       |       |       |       |      |      |      |         |

- 1. Evanston Civic Center - Baseline Design (05/14/19 @ 10:47)
- 2. Evanston Civic Center - FCUs - Baseline Design (02/12/19 @ 15:49)
- 3. Evanston Civic Center-HW - Baseline Design (05/02/19 @ 11:18)
- 4. Evanston Civic Center - VAV - Baseline Design (02/12/19 @ 15:50)

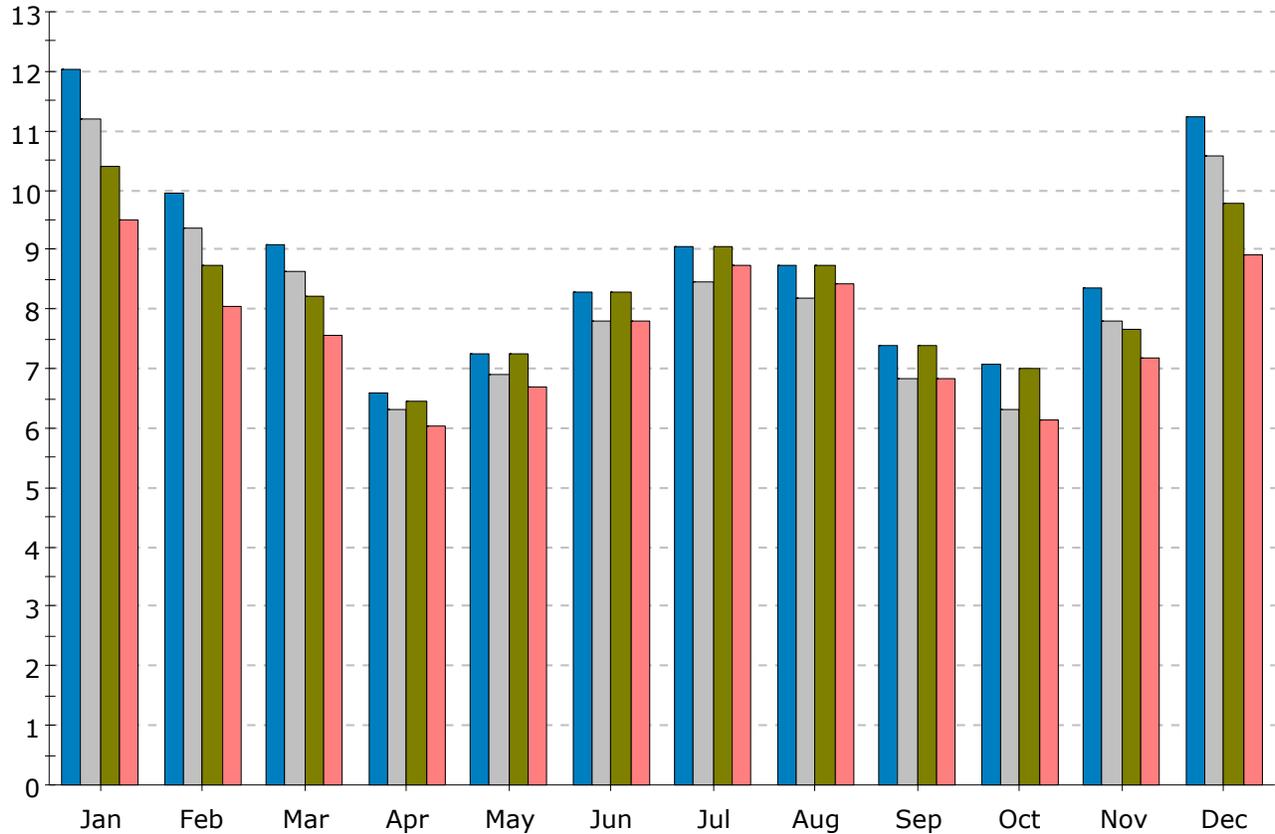
### Gas Consumption (Btu)



|        | Jan   | Feb   | Mar   | Apr   | May  | Jun  | Jul  | Aug  | Sep  | Oct  | Nov   | Dec   | Total   |
|--------|-------|-------|-------|-------|------|------|------|------|------|------|-------|-------|---------|
| Run 1. | 682.6 | 491.0 | 342.4 | 73.1  | 20.2 | 17.8 | 17.1 | 16.9 | 14.7 | 42.3 | 261.0 | 601.5 | 2,580.8 |
| Run 2. | 666.3 | 496.3 | 366.7 | 100.0 | 34.2 | 29.3 | 27.7 | 29.9 | 24.8 | 60.9 | 275.7 | 594.3 | 2,706.0 |
| Run 3. | 502.7 | 358.0 | 246.5 | 57.8  | 20.4 | 18.3 | 17.8 | 17.5 | 15.0 | 35.1 | 186.7 | 439.4 | 1,915.2 |
| Run 4. | 517.0 | 391.7 | 294.3 | 77.8  | 20.0 | 17.3 | 16.7 | 16.4 | 14.8 | 42.2 | 216.7 | 453.3 | 2,078.2 |
| Run 5. |       |       |       |       |      |      |      |      |      |      |       |       |         |

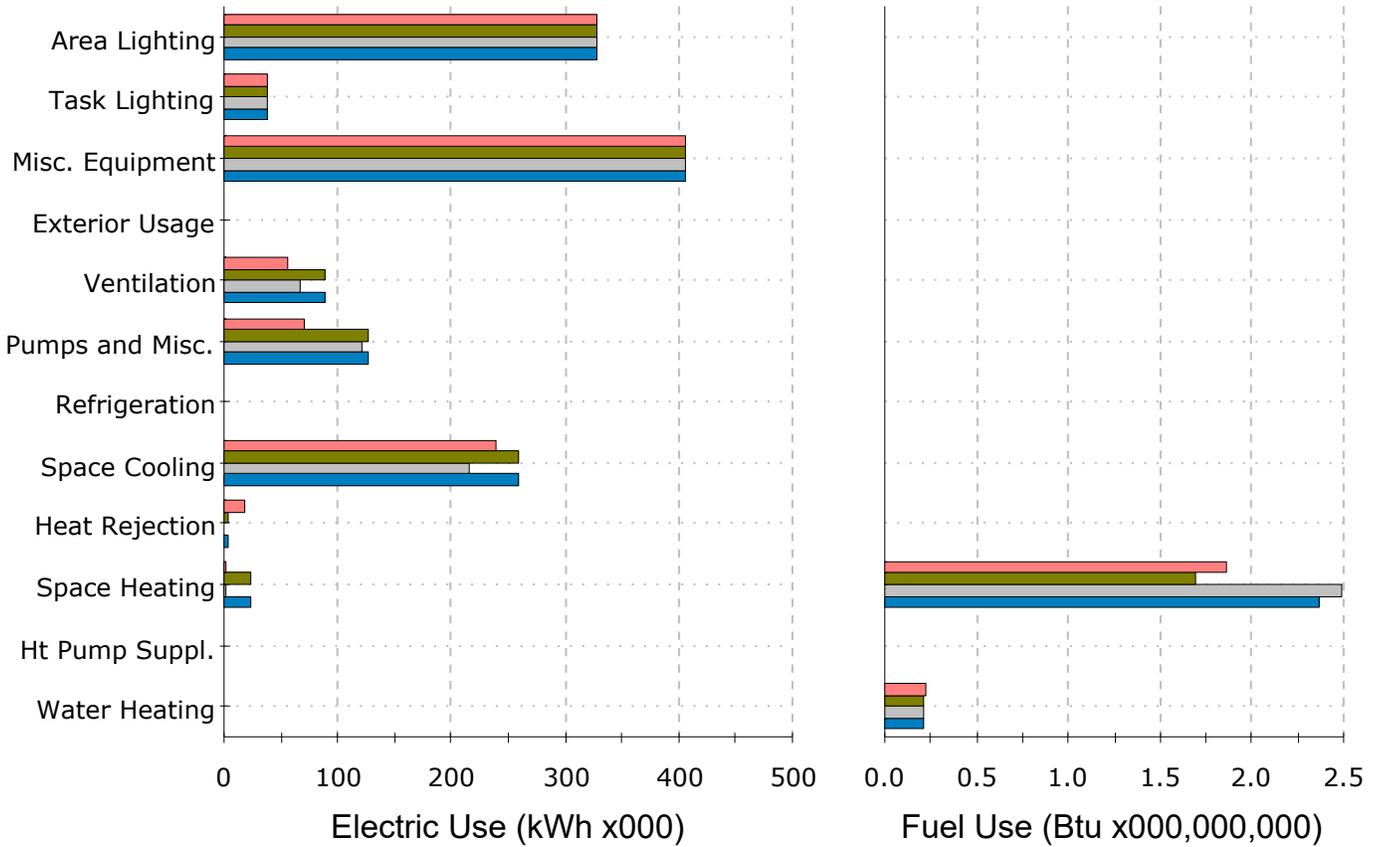
### Monthly Utility Bills (\$)

(x000)



- Evanston Civic Center - Baseline Design (05/14/19 @ 10:47)
- Evanston Civic Center - FCUs - Baseline Design (02/12/19 @ 15:49)
- Evanston Civic Center-HW - Baseline Design (05/02/19 @ 11:18)
- Evanston Civic Center - VAV - Baseline Design (02/12/19 @ 15:50)

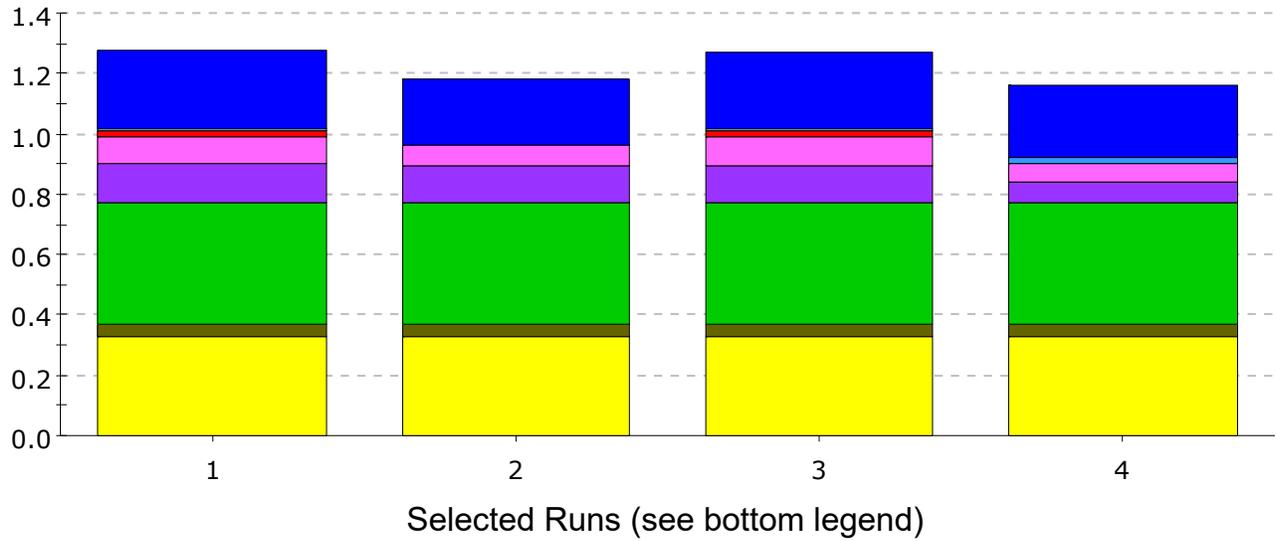
## Annual Energy Consumption by Enduse



- Evanston Civic Center - Baseline Design (05/14/19 @ 10:47)
- Evanston Civic Center - FCUs - Baseline Design (02/12/19 @ 15:49)
- Evanston Civic Center-HW - Baseline Design (05/02/19 @ 11:18)
- Evanston Civic Center - VAV - Baseline Design (02/12/19 @ 15:50)

### Annual Electric Consumption (kWh)

(x000,000)



- |   |   |   |  |
|---|---|---|--|
| <span style="display: inline-block; width: 15px; height: 15px; background-color: yellow; border: 1px solid black;"></span> Area Lighting  | <span style="display: inline-block; width: 15px; height: 15px; background-color: grey; border: 1px solid black;"></span> Exterior Usage   | <span style="display: inline-block; width: 15px; height: 15px; background-color: orange; border: 1px solid black;"></span> Water Heating  | <span style="display: inline-block; width: 15px; height: 15px; background-color: cyan; border: 1px solid black;"></span> Refrigeration     |
| <span style="display: inline-block; width: 15px; height: 15px; background-color: brown; border: 1px solid black;"></span> Task Lighting   | <span style="display: inline-block; width: 15px; height: 15px; background-color: purple; border: 1px solid black;"></span> Pumps & Aux.   | <span style="display: inline-block; width: 15px; height: 15px; background-color: darkred; border: 1px solid black;"></span> Ht Pump Supp. | <span style="display: inline-block; width: 15px; height: 15px; background-color: blue; border: 1px solid black;"></span> Heat Rejection    |
| <span style="display: inline-block; width: 15px; height: 15px; background-color: green; border: 1px solid black;"></span> Misc. Equipment | <span style="display: inline-block; width: 15px; height: 15px; background-color: pink; border: 1px solid black;"></span> Ventilation Fans | <span style="display: inline-block; width: 15px; height: 15px; background-color: red; border: 1px solid black;"></span> Space Heating     | <span style="display: inline-block; width: 15px; height: 15px; background-color: darkblue; border: 1px solid black;"></span> Space Cooling |

1. Evanston Civic Center - Baseline Design (05/14/19 @ 10:47)
2. Evanston Civic Center - FCUs - Baseline Design (02/12/19 @ 15:49)
3. Evanston Civic Center-HW - Baseline Design (05/02/19 @ 11:18)
4. Evanston Civic Center - VAV - Baseline Design (02/12/19 @ 15:50)

**Option 1 - Heat Pumps, Refurbish Existing Boiler**

|                          |                          |                                    |
|--------------------------|--------------------------|------------------------------------|
|                          | <u>Escalation Rates:</u> | <u>First Year Operating Costs:</u> |
| <b>4% Discount Rate</b>  | 20 Nat. Gas:             | 2.5%                               |
| Discount Rate:           | 4.0% Elec:               | 2.5% NG/Elec                       |
| Year 1 Installation Cost | \$ 6,048,000 Maint:      | 2.5% Maintenance:                  |
|                          |                          | \$ 105,033                         |
|                          |                          | \$ 167,580.00                      |

| Period | Capital Costs | OPERATING COSTS |                  |         |         | Total Annual Own&Oper Costs | Present Value | Cummulative LCC |
|--------|---------------|-----------------|------------------|---------|---------|-----------------------------|---------------|-----------------|
|        |               |                 | NG + Electricity | O/M     | Total   |                             |               |                 |
| 1      | 6,048,000     | 0               | 105,033          | 167,580 | 272,613 | 6,320,613                   | 6,077,513     | 6,077,513       |
| 2      |               | 0               | 107,659          | 171,770 | 279,428 | 279,428                     | 268,681       | 6,346,194       |
| 3      |               | 0               | 110,350          | 176,064 | 286,414 | 286,414                     | 264,806       | 6,610,999       |
| 4      |               | 0               | 113,109          | 180,465 | 293,574 | 293,574                     | 260,987       | 6,871,986       |
| 5      |               | 0               | 115,937          | 184,977 | 300,914 | 300,914                     | 257,222       | 7,129,208       |
| 6      |               | 0               | 118,835          | 189,601 | 308,437 | 308,437                     | 253,512       | 7,382,721       |
| 7      |               | 0               | 121,806          | 194,341 | 316,148 | 316,148                     | 249,856       | 7,632,577       |
| 8      |               | 0               | 124,851          | 199,200 | 324,051 | 324,051                     | 246,252       | 7,878,829       |
| 9      |               | 0               | 127,973          | 204,180 | 332,152 | 332,152                     | 242,701       | 8,121,530       |
| 10     |               | 0               | 131,172          | 209,284 | 340,456 | 340,456                     | 239,200       | 8,360,730       |
| 11     |               | 0               | 134,451          | 214,517 | 348,968 | 348,968                     | 235,750       | 8,596,480       |
| 12     |               | 0               | 137,812          | 219,879 | 357,692 | 357,692                     | 232,350       | 8,828,829       |
| 13     |               | 0               | 141,258          | 225,376 | 366,634 | 366,634                     | 228,999       | 9,057,828       |
| 14     |               | 0               | 144,789          | 231,011 | 375,800 | 375,800                     | 225,696       | 9,283,524       |
| 15     |               | 0               | 148,409          | 236,786 | 385,195 | 385,195                     | 222,441       | 9,505,964       |
| 16     |               | 0               | 152,119          | 242,706 | 394,825 | 394,825                     | 219,232       | 9,725,197       |
| 17     |               | 0               | 155,922          | 248,773 | 404,696 | 404,696                     | 216,070       | 9,941,267       |
| 18     |               | 0               | 159,820          | 254,993 | 414,813 | 414,813                     | 212,954       | 10,154,221      |
| 19     |               | 0               | 163,816          | 261,368 | 425,183 | 425,183                     | 209,882       | 10,364,103      |
| 20     | 1,400,000     | 0               | 167,911          | 267,902 | 435,813 | 1,835,813                   | 871,355       | 11,235,458      |
| 21     |               | 0               | 172,109          | 274,599 | 446,708 | 446,708                     | 203,872       | 11,439,330      |
| 22     |               | 0               | 176,412          | 281,464 | 457,876 | 457,876                     | 200,931       | 11,640,261      |
| 23     |               | 0               | 180,822          | 288,501 | 469,323 | 469,323                     | 198,033       | 11,838,294      |
| 24     |               | 0               | 185,342          | 295,713 | 481,056 | 481,056                     | 195,177       | 12,033,471      |
| 25     | (550,000)     | 0               | 189,976          | 303,106 | 493,082 | (56,918)                    | (22,205)      | 12,011,266      |

**Uniform Annual Cost** **\$826,725**

**10 Year Discounted Lifecycle Co \$ 8,360,730**

**15 Year Discounted Lifecycle Co \$ 9,505,964**

**20 Year Discounted Lifecycle Co \$ 11,235,458**

**Option 2 - 2-Pipe Fan-Coil units**

|                          |                          |                                    |
|--------------------------|--------------------------|------------------------------------|
|                          | <u>Escalation Rates:</u> | <u>First Year Operating Costs:</u> |
| <b>4% Discount Rate</b>  | 20 Nat. Gas:             | 2.5%                               |
| Discount Rate:           | 4.0% Elec:               | 2.5% NG/Elec                       |
| Year 1 Installation Cost | \$ 7,046,400 Maint:      | 2.5% Maintenance:                  |
|                          |                          | \$ 98,383                          |
|                          |                          | \$ 130,340.00                      |

| Period | Capital Costs | OPERATING COSTS |                  |         |         | Total Annual Own&Oper Costs | Present Value | Cummulative LCC |
|--------|---------------|-----------------|------------------|---------|---------|-----------------------------|---------------|-----------------|
|        |               |                 | NG + Electricity | O/M     | Total   |                             |               |                 |
| 1      | 7,046,400     | 0               | 98,383           | 130,340 | 228,723 | 7,275,123                   | 6,995,311     | 6,995,311       |
| 2      |               | 0               | 100,843          | 133,599 | 234,441 | 234,441                     | 225,424       | 7,220,735       |
| 3      |               | 0               | 103,364          | 136,938 | 240,302 | 240,302                     | 222,173       | 7,442,907       |
| 4      |               | 0               | 105,948          | 140,362 | 246,310 | 246,310                     | 218,968       | 7,661,876       |
| 5      |               | 0               | 108,596          | 143,871 | 252,467 | 252,467                     | 215,810       | 7,877,686       |
| 6      |               | 0               | 111,311          | 147,468 | 258,779 | 258,779                     | 212,698       | 8,090,384       |
| 7      |               | 0               | 114,094          | 151,154 | 265,249 | 265,249                     | 209,630       | 8,300,013       |
| 8      |               | 0               | 116,946          | 154,933 | 271,880 | 271,880                     | 206,606       | 8,506,620       |
| 9      |               | 0               | 119,870          | 158,807 | 278,677 | 278,677                     | 203,626       | 8,710,246       |
| 10     |               | 0               | 122,867          | 162,777 | 285,644 | 285,644                     | 200,689       | 8,910,936       |
| 11     |               | 0               | 125,939          | 166,846 | 292,785 | 292,785                     | 197,795       | 9,108,730       |
| 12     |               | 0               | 129,087          | 171,017 | 300,104 | 300,104                     | 194,942       | 9,303,673       |
| 13     |               | 0               | 132,314          | 175,293 | 307,607 | 307,607                     | 192,130       | 9,495,803       |
| 14     |               | 0               | 135,622          | 179,675 | 315,297 | 315,297                     | 189,359       | 9,685,162       |
| 15     |               | 0               | 139,013          | 184,167 | 323,180 | 323,180                     | 186,628       | 9,871,790       |
| 16     |               | 0               | 142,488          | 188,771 | 331,259 | 331,259                     | 183,936       | 10,055,727      |
| 17     |               | 0               | 146,050          | 193,490 | 339,541 | 339,541                     | 181,283       | 10,237,010      |
| 18     |               | 0               | 149,701          | 198,328 | 348,029 | 348,029                     | 178,669       | 10,415,679      |
| 19     |               | 0               | 153,444          | 203,286 | 356,730 | 356,730                     | 176,092       | 10,591,771      |
| 20     |               | 0               | 157,280          | 208,368 | 365,648 | 365,648                     | 173,552       | 10,765,323      |
| 21     |               | 0               | 161,212          | 213,577 | 374,789 | 374,789                     | 171,049       | 10,936,372      |
| 22     |               | 0               | 165,242          | 218,917 | 384,159 | 384,159                     | 168,582       | 11,104,954      |
| 23     |               | 0               | 169,373          | 224,390 | 393,763 | 393,763                     | 166,150       | 11,271,104      |
| 24     |               | 0               | 173,608          | 229,999 | 403,607 | 403,607                     | 163,754       | 11,434,858      |
| 25     |               | 0               | 177,948          | 235,749 | 413,697 | 413,697                     | 161,392       | 11,596,251      |

**Uniform Annual Cost** **\$792,131**

**10 Year Discounted Lifecycle Co \$ 8,910,936**

**15 Year Discounted Lifecycle Co \$ 9,871,790**

**20 Year Discounted Lifecycle Co \$ 10,765,323**

**Option 3 - Heat Pumps, New HW Boiler**

|                          |                          |                                    |
|--------------------------|--------------------------|------------------------------------|
|                          | <u>Escalation Rates:</u> | <u>First Year Operating Costs:</u> |
| <b>4% Discount Rate</b>  | 20 Nat. Gas:             | 2.5%                               |
| Discount Rate:           | 4.0% Elec:               | 2.5% NG/Elec                       |
| Year 1 Installation Cost | \$ 7,821,600 Maint:      | 2.5% Maintenance:                  |
|                          |                          | \$ 98,951                          |
|                          |                          | \$ 158,270.00                      |

| Period | Capital Costs | OPERATING COSTS |                  |         |         | Total Annual Own&Oper Costs | Present Value | Cummulative LCC |
|--------|---------------|-----------------|------------------|---------|---------|-----------------------------|---------------|-----------------|
|        |               |                 | NG + Electricity | O/M     | Total   |                             |               |                 |
| 1      | 7,821,600     | 0               | 98,951           | 158,270 | 257,221 | 8,078,821                   | 7,768,097     | 7,768,097       |
| 2      |               | 0               | 101,425          | 162,227 | 263,652 | 263,652                     | 253,511       | 8,021,608       |
| 3      |               | 0               | 103,960          | 166,282 | 270,243 | 270,243                     | 249,855       | 8,271,463       |
| 4      |               | 0               | 106,559          | 170,439 | 276,999 | 276,999                     | 246,251       | 8,517,714       |
| 5      |               | 0               | 109,223          | 174,700 | 283,924 | 283,924                     | 242,699       | 8,760,413       |
| 6      |               | 0               | 111,954          | 179,068 | 291,022 | 291,022                     | 239,199       | 8,999,612       |
| 7      |               | 0               | 114,753          | 183,545 | 298,298 | 298,298                     | 235,749       | 9,235,361       |
| 8      |               | 0               | 117,622          | 188,133 | 305,755 | 305,755                     | 232,349       | 9,467,709       |
| 9      |               | 0               | 120,562          | 192,837 | 313,399 | 313,399                     | 228,997       | 9,696,707       |
| 10     |               | 0               | 123,576          | 197,658 | 321,234 | 321,234                     | 225,695       | 9,922,402       |
| 11     |               | 0               | 126,666          | 202,599 | 329,265 | 329,265                     | 222,439       | 10,144,841      |
| 12     |               | 0               | 129,832          | 207,664 | 337,496 | 337,496                     | 219,231       | 10,364,072      |
| 13     |               | 0               | 133,078          | 212,856 | 345,934 | 345,934                     | 216,069       | 10,580,141      |
| 14     |               | 0               | 136,405          | 218,177 | 354,582 | 354,582                     | 212,953       | 10,793,094      |
| 15     |               | 0               | 139,815          | 223,631 | 363,447 | 363,447                     | 209,881       | 11,002,975      |
| 16     |               | 0               | 143,311          | 229,222 | 372,533 | 372,533                     | 206,854       | 11,209,829      |
| 17     |               | 0               | 146,893          | 234,953 | 381,846 | 381,846                     | 203,871       | 11,413,700      |
| 18     |               | 0               | 150,566          | 240,827 | 391,392 | 391,392                     | 200,930       | 11,614,630      |
| 19     |               | 0               | 154,330          | 246,847 | 401,177 | 401,177                     | 198,032       | 11,812,663      |
| 20     | 1,400,000     | 0               | 158,188          | 253,018 | 411,206 | 1,811,206                   | 859,675       | 12,672,338      |
| 21     |               | 0               | 162,143          | 259,344 | 421,487 | 421,487                     | 192,361       | 12,864,699      |
| 22     |               | 0               | 166,196          | 265,827 | 432,024 | 432,024                     | 189,587       | 13,054,286      |
| 23     |               | 0               | 170,351          | 272,473 | 442,824 | 442,824                     | 186,852       | 13,241,138      |
| 24     |               | 0               | 174,610          | 279,285 | 453,895 | 453,895                     | 184,157       | 13,425,295      |
| 25     | (550,000)     | 0               | 178,975          | 286,267 | 465,242 | (84,758)                    | (33,066)      | 13,392,229      |

**Uniform Annual Cost** **\$932,453**

**10 Year Discounted Lifecycle Co \$ 9,922,402**

**15 Year Discounted Lifecycle Co \$ 11,002,975**

**20 Year Discounted Lifecycle Co \$ 12,672,338**

**Option 4 - VAV AHUs**

|                          |                          |                                    |
|--------------------------|--------------------------|------------------------------------|
|                          | <u>Escalation Rates:</u> | <u>First Year Operating Costs:</u> |
| <b>8% Discount Rate</b>  | 20 Nat. Gas:             | 2.5%                               |
| Discount Rate:           | 5.0% Elec:               | 2.5% NG/Elec                       |
| Year 1 Installation Cost | \$ 9,780,000 Maint:      | 2.5% Maintenance:                  |
|                          |                          | \$ 91,811                          |
|                          |                          | \$ 125,685.00                      |

| Period | Capital Costs | OPERATING COSTS |                  |         |         | Total Annual Own&Oper Costs | Present Value | Cummulative LCC |
|--------|---------------|-----------------|------------------|---------|---------|-----------------------------|---------------|-----------------|
|        |               |                 | NG + Electricity | O/M     | Total   |                             |               |                 |
| 1      | 9,780,000     | 0               | 91,811           | 125,685 | 217,496 | 9,997,496                   | 9,521,425     | 9,521,425       |
| 2      |               | 0               | 94,106           | 128,827 | 222,933 | 222,933                     | 212,318       | 9,733,742       |
| 3      |               | 0               | 96,459           | 132,048 | 228,507 | 228,507                     | 207,262       | 9,941,005       |
| 4      |               | 0               | 98,870           | 135,349 | 234,219 | 234,219                     | 202,328       | 10,143,332      |
| 5      |               | 0               | 101,342          | 138,733 | 240,075 | 240,075                     | 197,510       | 10,340,842      |
| 6      |               | 0               | 103,876          | 142,201 | 246,077 | 246,077                     | 192,808       | 10,533,650      |
| 7      |               | 0               | 106,473          | 145,756 | 252,229 | 252,229                     | 188,217       | 10,721,867      |
| 8      |               | 0               | 109,134          | 149,400 | 258,534 | 258,534                     | 183,736       | 10,905,602      |
| 9      |               | 0               | 111,863          | 153,135 | 264,998 | 264,998                     | 179,361       | 11,084,963      |
| 10     |               | 0               | 114,659          | 156,963 | 271,623 | 271,623                     | 175,090       | 11,260,054      |
| 11     |               | 0               | 117,526          | 160,887 | 278,413 | 278,413                     | 170,922       | 11,430,975      |
| 12     |               | 0               | 120,464          | 164,910 | 285,374 | 285,374                     | 166,852       | 11,597,827      |
| 13     |               | 0               | 123,476          | 169,032 | 292,508 | 292,508                     | 162,879       | 11,760,707      |
| 14     |               | 0               | 126,562          | 173,258 | 299,821 | 299,821                     | 159,001       | 11,919,708      |
| 15     |               | 0               | 129,727          | 177,590 | 307,316 | 307,316                     | 155,216       | 12,074,924      |
| 16     |               | 0               | 132,970          | 182,029 | 314,999 | 314,999                     | 151,520       | 12,226,444      |
| 17     |               | 0               | 136,294          | 186,580 | 322,874 | 322,874                     | 147,912       | 12,374,356      |
| 18     |               | 0               | 139,701          | 191,245 | 330,946 | 330,946                     | 144,391       | 12,518,746      |
| 19     |               | 0               | 143,194          | 196,026 | 339,220 | 339,220                     | 140,953       | 12,659,699      |
| 20     |               | 0               | 146,774          | 200,926 | 347,700 | 347,700                     | 137,597       | 12,797,296      |
| 21     |               | 0               | 150,443          | 205,950 | 356,393 | 356,393                     | 134,321       | 12,931,616      |
| 22     |               | 0               | 154,204          | 211,098 | 365,302 | 365,302                     | 131,122       | 13,062,739      |
| 23     |               | 0               | 158,059          | 216,376 | 374,435 | 374,435                     | 128,001       | 13,190,739      |
| 24     |               | 0               | 162,011          | 221,785 | 383,796 | 383,796                     | 124,953       | 13,315,692      |
| 25     |               | 0               | 166,061          | 227,330 | 393,391 | 393,391                     | 121,978       | 13,437,670      |

**Uniform Annual Cost                      \$1,026,888**

**10 Year Discounted Lifecycle Co \$ 11,260,054**

**15 Year Discounted Lifecycle Co \$ 12,074,924**

**20 Year Discounted Lifecycle Co \$ 12,797,296**

