Division Of
Construction Services

Southbury Training School
Power Plant and Alternate Heating System Study

DCS Project BI-NN-638

Prepared by

VANZELM ENGINEERS

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van Zelm #2016113.01

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I. INTRODUCTION

The Division of Construction Services retained van Zelm Engineers to provide Southbury Training School (STS) with recommendations on how best to revise or replace the power plant and steam distribution systems with a cost effective option as the facility is downsized. This study effort is directed at optimizing energy efficiency while attending to improved reliability and resiliency of the Training School's energy infrastructure. Care has been taken to ensure compatibility of proposed systems to ensure continuity of operations and allow for any re-allocation of spaces. This study also provides a guideline on which buildings should remain functional on the school's campus.

The following steps were involved in developing this report:

- Site visits were conducted to examine existing conditions.
- Input was obtained from the STS staff and management on the future needs of the facility, the ability of existing systems to serve the facility efficiently and cost effectively, resiliency of current operation and flexibility offered by the proposed replacement.
- Review of prior investigation and condition assessment of existing power house steam boilers and steam distribution.
- Analysis of the economic, physical, and operating implications of several possible options including:
  - Maintaining the existing steam distribution / hot water systems.
  - Replacing the existing equipment with distributed modular steam boilers and other energy efficiency use improvement measures.
  - Installing discrete high efficiency hot water boilers and furnaces for individual cottages
  - Retrofitting the operational buildings with high efficiency heat pumps; both air source, closed loop water source, and ground source.
- Budget estimates of overall project costs for the installation of the evaluated alternatives.
- A recommendation was made based on the results obtained from the above analysis.

II. EXECUTIVE SUMMARY

The existing central power plant and district steam distribution system has a capacity of 80 million Btus per hour, which was designed to provide heating to this 125 building campus. To date, the progressive closure of buildings has resulted in a present condition of only 45 buildings (approximately 36%) currently being heated, with a peak winter heating demand in the order of 18 million Btu per hour. This demand equates to approximately 15,000 pounds per hour of steam.

Prior investigation of the power plant and steam distribution systems have evaluated the energy conversion of input fuel, to the power plant and steam distribution system losses, resulting in the loss of approximately 85,424 MMBtu annually. This magnitude of system loss alone represents enough energy to heat 15 average residential buildings. Additionally, less than half of the steam send-out returns as condensate, so there is a continuous waste of hot water in the order of over 4 million gallons per year. During the course of our investigation, we identified several energy efficiency improvement opportunities that could significantly help reduce the natural gas and #2 oil being used on site for meeting thermal (space heating and domestic hot water) loads. Most of these measures are capital intensive and call for replacement of, modifications to, or decommissioning of existing power plant equipment. Since any new equipment installed will have a useful life of at least 20 years, we recommend that any power plant optimizations only be made if the State of Connecticut intends to keep the facility operational beyond 20 years.

However, since the current intent is for ongoing closure of buildings, utilization of the steam heating system will result in the system losses becoming even greater, its continued use resulting in a case of diminishing returns. Building closures cannot easily be conducted to create a concentration of the remaining buildings to a small footprint of this 1,600 acre campus, and this renders downsizing of the steam distribution system a significant challenge to coordinate with the preferred buildings to remain occupied.

Based on our analysis, the installation of individual boilers and hot water furnaces would be the most cost-effective solution to providing conditioning of buildings while allowing flexibility for progressive downsizing of the campus. Advantages of using these systems in individual cottages are:

- Buildings can be flexibly retrofitted with minimum disruption to current campus residents, as the existing heating system can remain in service until the new systems are fully commissioned.
- Heating efficiency and operating cost reductions will be accomplished by progressively eliminating the oversized and deteriorating steam system

A summary of the economics of the proposed conversion of the current 45 buildings to utilize individual boilers and hot water furnaces, is estimated as follows:

Budget Equipment and Installation Cost (all operational buildings)	$ 5,050,812
Estimated Annual Future Energy Costs	$733,461
15 Year Net Present Value	**$ 4,620,072**

In order to determine the 'budgeted' installed costs of the options evaluated and presented in this Report, van Zelm Engineers used experiential pricing from projects with similar mechanical system retrofit installations completed within the last ten years as well as sourcing budgetary quotes from a local contractor (All State Construction). In order to fine tune our numbers, we reached out to vendors of the evaluated equipment to verify our estimates. For items specific to this project that we did not have experiential data on, or on those where even vendors could not develop pricing (such as water tube boilers) mechanical and electrical means were used. The following table summarizes the costs associated with each measure.

Table 1: Budgeted Cost Breakdown

Measure	*Estimated OEM Equipment Cost*	*Estimated Labor Costs*	*Estimated Ancillary Costs*	*Budgeted Total Cost*
Hot Water Furnace 8,000 sq.ft. - Gas	$ 27,858	$ 41,125	$ 15,600	$ 84,583
Hot Water Furnace 18,000 sq.ft. - Gas	$ 59,192	$ 59,403	$ 20,100	$ 138,695
Hot Water Furnace 8,000 sq.ft. - Oil	$ 31,092	$ 58,489	$ 15,600	$ 105,181
Hot Water Furnace 18,000 sq.ft. - Oil	$ 54,325	$ 86,865	$ 20,100	$ 161,290
Water Tube Boilers (CB D Type)	$ 1,828,500	$ 414,000	$ 57,500	$ 2,300,000
Water Tube Boilers (B&W Hero)	$ 1,918,800	$ 442,800	$ 98,400	$ 2,460,000
Fire Tube Boilers	$ 1,466,480	$ 294,400	$ 79,120	$ 1,840,000
Modular Miura Boilers	$ 960,750	$ 411,750	$ 152,500	$ 1,525,000
Stack Heat Recovery	$ 210,600	$ 85,800	$ 93,600	$ 390,000
Boiler Combustion Optimization	$ 18,200	$ 7,150	$ 7,150	$ 32,500
VRF System	$ 7,200,000	$ 1,350,000	$ 450,000	$ 9,000,000

III. EXISTING CONDITIONS

The Southbury Training School was established in the 1930s to care for and train people with special needs. The facility has approximately 125 buildings on campus and is located in the town of Southbury, adjoining Roxbury, Connecticut.

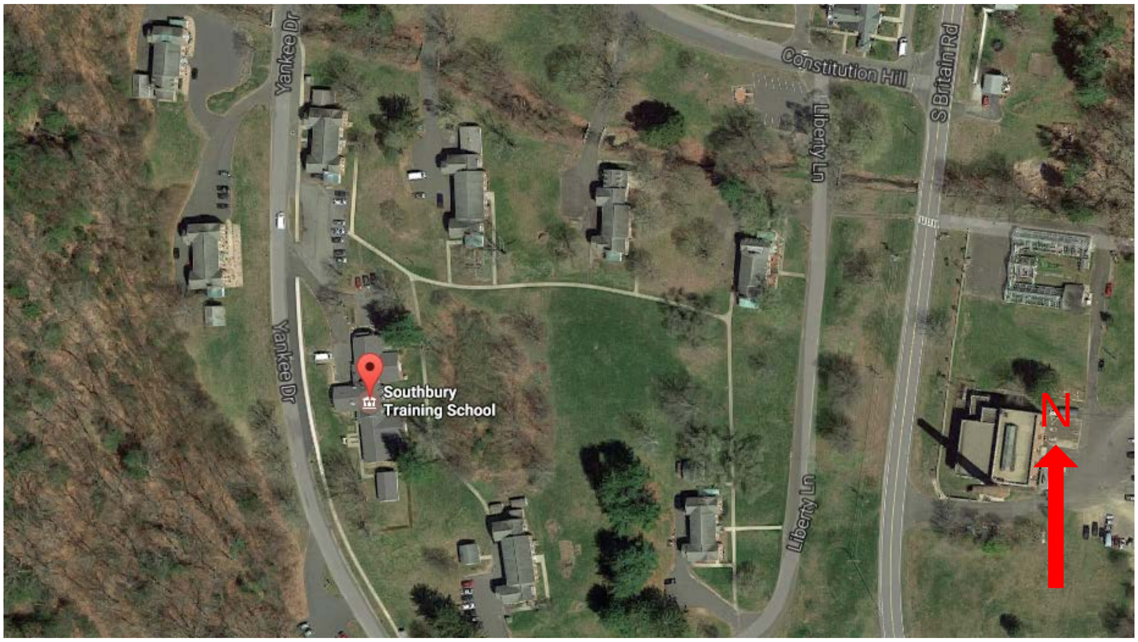


Figure 1: Portion of Southbury Training School with its Power House to the right

The School is spread over a very large area and has several administrative buildings. The school derives its primary heating from its central power plant. The main usage of occupied space is in the residential and training buildings which are spread over a large portion of the campus. There are approximately 45 residential buildings currently in use on campus. This number is a fraction of the 125 buildings constructed for use originally in the 1930's. The buildings are heated by a central district steam system originating from the Power House. The Power House is located across Route 172 and housed in its own building. This provides for a sufficient buffer zone between the Power House and the Campus in case of any unforeseen emergency, but it does increase the distance thermal energy has to cover from its generation source to the point of utilization, resulting in an increase in the energy consumption, especially due to distribution heat losses. Steam most commonly provides building heating by indirect heat exchangers that convert this steam to hot water for hydronic heating of the buildings.

During recent years, the facility has been downsizing and not accepting applications from potential new residents. As a result, several buildings have been evacuated and comfort conditions are not being maintained in these buildings in order to save energy. However, a few buildings, even though unoccupied, do maintain comfort conditions so as to ensure operability during any unforeseen events. The typical residential buildings surveyed consisted of living and common spaces for the tenants, some class rooms, some private offices and residential bedrooms, as well some kitchens and mechanical rooms for mechanical equipment.

We have also made an attempt at determining the most optimal use of buildings on the campus to save energy and reduce maintenance costs. Further details can be found in other sections of this report.

Figure 2: Typical common space within Building 18

Mechanical equipment in most buildings, even though functional and in relatively good shape, is approaching, if not beyond, the end of useful life. Most mechanical interconnections and delivery systems were installed when the facility was constructed several decades ago, circa 1930. In recent years, the facility has incurred significant charges in order to maintain these legacy systems that were designed, installed and commissioned for a large campus. Most buildings comprise one or two floors and have inclined roofs. The buildings have a masonry brick exterior. The windows appear to be in good shape with some infiltration issues. We estimate the existing buildings to have a roof insulation value of R-20 with a wall insulation value of R-15, which were typical and reasonable for the time of construction. In addition to the residential and administrative buildings, there are also a few maintenance buildings on campus such as the machine shop, welding shop, etc.

As the facility downsizes, the investment required to maintain these systems loses its economy of scale, resulting in exorbitant costs for maintenance with a limited window available to recoup the investment. The primary purpose of this study is to determine a best fit solution to provide heating and cooling within the occupied spaces, at minimum cost to the State.

The power plant serving the facility is located across the street (South Britain Road) in the Power House building and is in very good operating condition. The facilities staff at the training school deserve a significant portion of the credit for its operating condition, cleanliness, reliability and functionality. The central power plant consists of 3 back up emergency generators and 4 boilers that are rated for 250 psig, with capacity of 20,000 and 25,000 pounds per hour. A backup generator provides power in the event of a loss of utility. A separate study was previously performed that evaluated various options for optimization of the Power House. This study focuses on various buildings and optimization of providing heating for a progressively decreasing amount of residential spaces, with some options evaluated for the Power House.

Figure 3: Mechanical Equipment Room (Building 18)

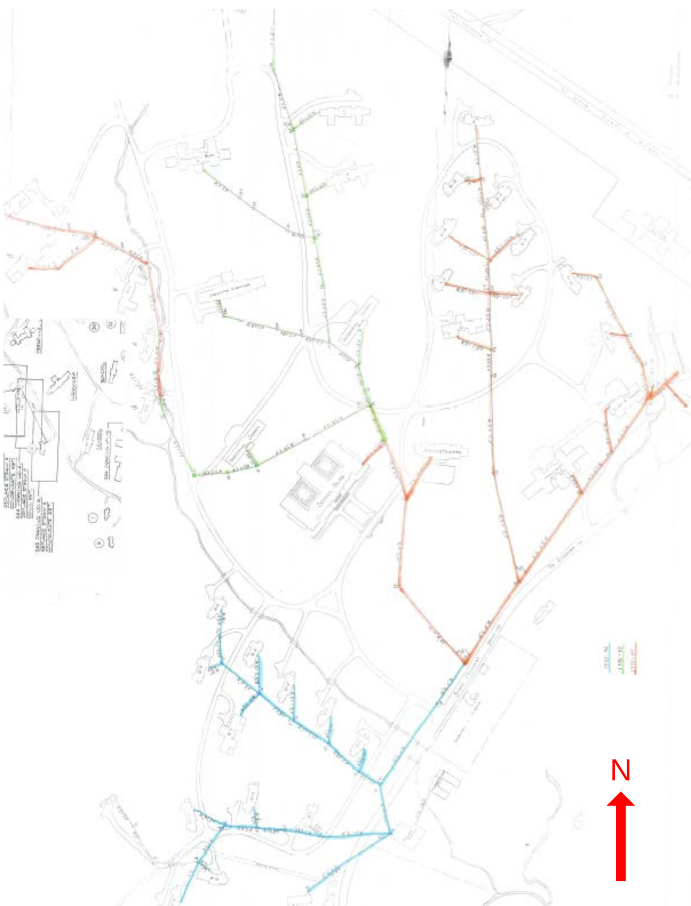


Figure 4: Southbury Training School Steam Distribution System[1]

[1] Figure provided previously by Southbury Training School

IV. POWER PLANT EFFICIENCY IMPROVEMENT

Currently, the facility produces steam using four boilers from the Power House across the street. This steam is generated at high pressure at up to 250 PSI and through pressure reducing valves sent out at 30 PSI and delivered to each of the buildings on the loop. Indirect heat exchangers and other equipment convert this to hot water which is then pumped up the building for heating. Most of the boilers in the plant are original equipment and were installed circa 1930. Boilers 1, 2, and 4 were installed in the 1930's and have a nameplate capacity of 20,000 lbs per hour. They have thus outlasted expectations for service life. Boiler 3 was installed in 1999 and has a nameplate capacity of 25,000 lbs per hour.

Additionally, the boilers appear to be oversized and as the campus decreases its occupied footprint, this system no longer offers an energy efficient solution. The boilers are dual fuel and can operate on natural gas or number 2 fuel oil.

The steam distribution system appears to be in disrepair in several locations, leading to significant maintenance costs and leakage losses of steam and condensate.

Figure 5: Existing boiler #4

Figure 6: Generation and consumption pressures #4

The existing boilers appear to be well maintained and in good operating condition. However, the older of these are now almost ninety years old and suffer from inefficiencies due to age. van Zelm Engineers analyzed several approaches to try and make the existing boiler plant more efficient to serve the remaining buildings on campus.

In order to determine the 'budgeted' installed costs of the options evaluated and presented in this Report, van Zelm Engineers co-ordinated its efforts with All State Construction, Inc. a local contractor. Additionally, experiential pricing from projects with similar mechanical system retrofit installations completed within the last ten years was utilized for some measures. In order to fine tune our numbers, we reached out to vendors of the evaluated equipment to verify our estimates.

For items specific to this project that we did not have experiential data on, mechanical and electrical means were used.

A. REPLACE BOILERS #2 AND #4

Water Tube Boilers

The existing boilers were designed to meet loads of the entire campus when it was occupied originally in the 1930's. Southbury Training School stopped accepting new residents several decades ago and has adopted the policy of consolidating its residents into buildings clustered together while mothballing the other buildings. This has significantly decreased:

- The heated and conditioned square footage.
- The number of people needing to be served by the boiler plant.

Both of the above reasons have decreased the load on the power plant. According to our calculations, and from interviews with the facilities staff at STS, we estimate that one 20,000 pph boiler, with an efficient steam delivery system, will be capable of handling all of the training school's heating load. We recommend replacing boilers number 2 and number 4 with two Cleaver Brooks 'D' style water tube boilers rated at 20,000 pph each. These boilers are significantly more efficient than the existing ones were at the time of initial installation and can provide annualized efficiencies as high as 78%. One boiler will be used to serve the facility while the other will be on standby. Boiler #1 can be removed and scrapped. The economics of this project can be summarized as follows:

- Installed costs: $2,300,000
- Annual energy savings: $89,836

Alternatively, these boilers can also be replaced with two Babcock and Wilcox "Hero" series boilers rated at 20,000 pph. These boilers are slightly more expensive to install, but offer comparable operational efficiencies. The project economics of this are as follows:

- Installed costs: $2,460,000
- Annual energy savings: $89,836

The above costs have been estimated based on similar projects of comparable sized developed by van Zelm Engineers and published vendor data. These costs can be confirmed should the project be pursued further. Given that water tube boilers can provide reasonably efficient service for over 50 years, we recommend investigating this option further only after the Southbury Training School ameliorates its budgetary constraints. Additionally, these boilers are typically built on site and will require OEM manufacturers from the Midwest to visit the site to confirm pricing. Long lead times and high maintenance costs add to the complexities posed by this option.

Fire Tube Boilers

Fire tube boilers and water tube boilers represent designs diametrically opposite of each other. The fire tube boiler passes combustion gas inside a series of tubes surrounded by water in a vessel to produce steam, while a water tube boiler instead sends water through a series of tubes surrounded by combustion gas used to transfer heat energy and produce steam. The type of boiler chosen depends upon the operating pressures, type and nature of fuel supply, associated thermal delivery, and distribution systems and end use of thermal energy. The key differences can be summarized as follows:

Fire tube Boilers	***Water Tube Boilers***
• Compact Construction • Typically have higher efficiencies • Typically have a lower cost of total ownership • Easier access and maintenance • Good load head surge handling at operating pressure • Simpler operational sequences	• Higher operating pressure • Higher temperature output • Precise load fluctuation handling • Superheated steam generation • Better heat recovery • Better turn down

The operating parameters of the Southbury Training School allow for it to be serviced by either a fire tube or a water tube boiler. In order to compare costs, we also evaluated replacing boilers 2 and 4 with fire tube boilers. Cleaver brooks CBEX DryBack Elite 600 series is a fire tube boiler best suited for the needs of STS. These boilers can provide annualized efficiencies as high as 82% and are slightly more cost effective to install and operate than water tube boilers. The project economics for this installation are as follows:

- Installed costs: $1,840,000
- Annual energy savings: $116,787

The above costs have been provided by a local general contractor All State Construction on a budgetary ideal. These costs can be confirmed should the project be pursued further. Given that fire tube boilers can provide reasonably efficient service for over 50 years, we recommend investigating this option further only after the Southbury Training School ameliorates its budgetary constraints.

B. STACK HEAT RECOVERY

During the site visit, it was observed that the boiler stack flue gas temperature was 390°F. This temperature is within the normal range of operating conditions for boilers of this size. Additional heat can be recovered by utilizing the economizers to extract heat from the exhausted flue gas. The recovered heat will be used to pre-heat the makeup water going into the boiler. This will allow for greater efficiency by offsetting the amount of energy the boiler has to input into the water to bring it up to operating temperature for conversion to steam. Several boiler manufacturers such as Cleaver Brooks™ and Babcock and Wilcox™ offer packaged stack economizing solutions.

These can either be retrofitted onto each individual boiler, or the exhausts from all three boilers can be ducted together through a stack economizer. This measure has a budgetary installed cost of approximately **$390,000.** This cost has been estimated by All State Construction for Cleaver Brooks CRE 36H economizers.

This measure will save approximately **269,200** Ccf of natural gas and **$215,613** annually.

C. LOWER STEAM GENERATION AND DISTRIBUTION PRESSURE

Currently, the facility produces steam using four boilers from the Power House across the street. This steam is generated at high pressure, up to 270 PSI and 450^0F, and through pressure reducing valves sent out at 30 psig and delivered to each of the buildings on the loop. Indirect heat exchangers and other equipment convert this to hot water which is then pumped up the building for heating. Most of the boilers in the plant are original equipment and were installed circa 1930. Boilers 1, 2, and 4 were installed in the 1930's and have a nameplate capacity of 20,000 lbs per hour. They have thus outlasted expectations for service life. Boiler 3 was installed in 1999 and has a nameplate capacity of 25,000 lbs per hour. Additionally, the boilers appear to be oversized and as the campus decreases its occupied footprint, this system no longer offers an energy efficient solution. The boilers are dual fuel and can operate on natural gas or number 2 fuel oil. The boilers are well maintained and in good operating condition.

As stated above, the boilers are currently set to generate steam at 270 PSI and 450^0F. Most of the Training School's needs can be met by generating steam at 75 PSI. We also recommend reducing the steam distribution pressure to 20 PSI. This will result in lower steam loss due to leaks while maintaining comfort conditions. However, we recommend lowering these pressures in 10 PSI increments over a period of a few weeks during the heating season. This will allow plenty of time for remedial action to be taken in case lowering the pressure has unforeseen consequences, such as loss of total steam pressure at the ends of steam supply runs.

The higher the pressure at which steam is generated, the more energy is required for its generation per pound. Decreasing the steam generation pressure to 75 PSI and the distribution pressure to 20 PSI will maintain operability of the system while saving the facility approximately **60,774 therms** of natural gas and **$48,619** annually. This measure has almost no installation costs associated with it.

D. BOILER COMBUSTION OPTIMIZATION

This measure calls for further optimization of the percent of excess air being supplied to the boiler for combustion. When boiler burners are tuned on a periodic basis, they are typically adjusted to about 3% excess oxygen which is about 15% excess air. This is because there are many ambient and atmospheric conditions that can affect oxygen/air supply. For example, colder air is denser and contains more oxygen than warm air; wind speed affects every chimney/flue/stack differently; and barometric pressure further affects draft. Therefore, an excess oxygen/air setting at the time of tuning assumes there will still be enough oxygen available for complete combustion when conditions worsen.

From an efficiency standpoint, the excess O_2 means there is more air in the combustion stream than needs to be. That air also contains moisture, and it all is heated and then lost up the stack. The amount of excess O_2 is almost directly proportional to the efficiency lost. Thus, the amount of O_2 supplied should be continuously monitored and adjusted to ensure optimal operability. Several commercial systems are available to modulate the amount of O_2 being provided to the boiler. This measure will save approximately **171,342 therms** and **$118,226** annually. The price for installing this measure was estimated by the in-house Commissioning group at van Zelm Engineers.

E. CONDENSATE RECOVERY

Condensate from a steam boiler system is hot mineral-free water. Improving condensate recovery also decreases the amount of makeup water injected into the system. Heating makeup water consumes significantly more energy than converting hot condensate to steam. In the calendar year analyzed, it is estimated that the Southbury Training School lost 4,000,000 gallons of condensate. Implementing a program to isolate and then eliminate steam and condensate leaks, implementing a steam trap survey, and examining heating supply lines for leaks will help return a higher percentage of condensate back into the system and reduce the amount of makeup water utilized. An added benefit will be the decreased use of chemicals and improved boiler surfaces. This will reduce corrosion (which can lead to early failure) and/or the buildup of scale (which can hurt boiler efficiency).

A 50% improvement in condensate return will result in saving approximately **16,000 therms** of natural gas and at least **$12,800** annually. This measure does not have any direct costs, but a few indirect variable costs which can be incorporated into routine maintenance costs.

F. INSTALL MODULAR BOILERS

Currently, the facility uses three boilers rated for 20,000 pph each. These boilers appear to be significantly oversized for the existing load, especially since a major portion of the campus has been taken offline. We estimate that just one boiler alone can carry the entire campus load in the dead of winter, while in the summer months only a quarter of the existing capacity of a single boiler is needed, primarily for producing domestic hot water. Keeping a large, high-pressure boiler operational during the summer consumes a lot of energy and is significantly under-utilized.

This measure calls for the installation of four smaller modular boilers to produce steam for use in the summer and turning the bigger boilers off. This will allow for production of smaller amounts of steam and domestic hot water at higher efficiency as well as saving energy by not having to operate a significantly larger boiler. Miura LX-150 is a commercially available modular steam boiler that can be used to operate at between 30 **M**aximum **A**llowable **W**orking **P**ressure (MAWP) and 15 MAWP. These boilers supply just over 5,000 pounds per hour of steam and can be staged in series to allow for taking boilers offline during the summer, and only running those that are required in the swing seasons. Installing modular boilers also allows for added redundancy.

Installing these boilers without improving the existing thermal delivery and recovery infrastructure will lead to inaccurate sizing and unnecessary capital expenditure. We recommend the following course of action prior to implementing this measure:

- Fix all steam, condensate and domestic hot water leaks in the existing system
- Project campus usage, occupancy and funding available over the next 15 years
- Install data loggers to measure actual amounts of domestic hot water consumed on a daily, weekly and monthly basis over an entire calendar year and
- Determine appropriate boiler sizing and quantities based on data collected.

According to current estimates, based on existing energy consumption and occupancy, this measure will save the School approximately **59,821 therms** and **$47,856** annually. Installing these boilers will cost approximately $**1,525,000**. The cost of the OEM boilers is significantly lower than those of larger steam boilers. However, the associated piping, valves, plumbing, control system and affiliated sensors, etc. drive up the cost of installation. The pricing for this measure was provided on a budgetary basis by All State Construction, Inc.

V. OPTIMIZATION OF STAGED BUILDING CLOSURES

The Southbury Training School was built in the 1930's and was dedicated to providing care for people with special needs. The campus consists of 125 buildings spread over 1,600 acres. STS stopped accepting new residents several decades ago, and ever since then the State of Connecticut has been faced with the issue of which buildings to decommission as the population continues to decrease naturally. This is primarily driven by the costs of operating and maintaining an oversized central utilities plant that provides heat and electricity to the campus.

Installing the central plant was the prudent thing to do when the campus was opened and fully occupied. However, as the population has decreased, along with budget cuts, an optimal solution needs to be found to maintaining operating and livable conditions for the occupied buildings while saving on scarce funds by decreasing operating costs of the central utilities plant.

A key factor in determining this optimal solution is the length of time for which the State of Connecticut intends to keep the campus open. Any solution presented in this report will have to be analyzed based on the decisions made by the State going forward. As things stand, there are two primary approaches:

- Option A: Disable the central plant and replace the existing heating, ventilating and air-conditioning infrastructure, as well as domestic hot water infrastructure, with newer systems and take the central plant offline. This option is discussed in detail in the following sections of this report.

- Option B: Move the remaining residents closer to the central plant in a staged manner and shut down the farthest corners of the steam and thermal loop. This will save significantly on thermal losses due to leaks, enable a drastic reduction in steam generation and supply pressure, reduce maintenance costs, and reduce labor costs while providing comfortable living conditions for the residents. The following map was furnished by Southbury Training School. The cottages highlighted in yellow represent those that are still occupied.

In order to determine an optimum strategy for space allocation van Zelm Engineers took into consideration the following factors:

- Estimated current occupancy levels
- Proximity to the Power House

It is understood that programmatic needs of the Southbury Training School ultimately will dictate which buildings will be utilized. However, the following represents the buildings that if maintained in service would represent the best case for utilizing the existing central steam system.

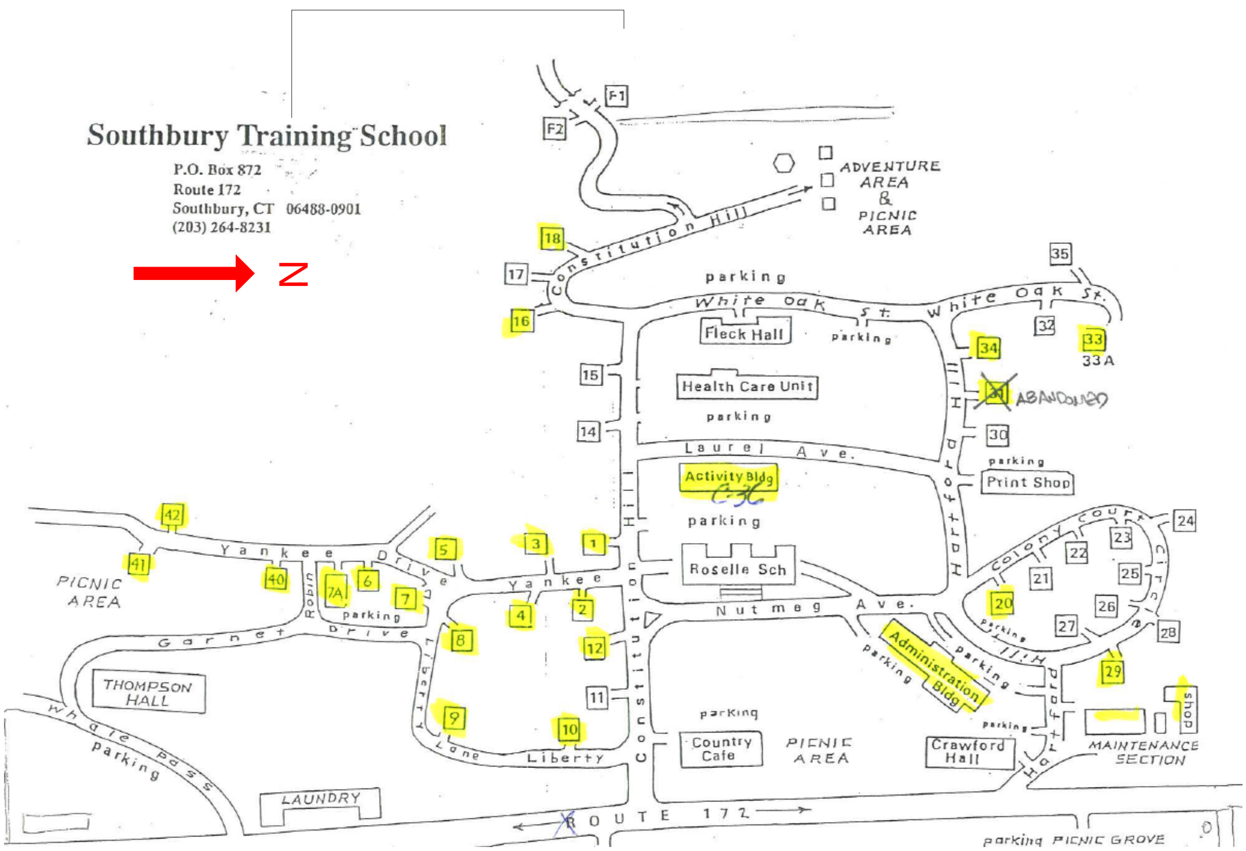


Figure 7: Current Campus Occupancy

Option B involves the following steps:

- Step 1: Develop a count of the total number of current residents.
- Step 2: Move residents from Cottages 40, 41 and 42 to Cottages 21, 22, 23 and 24 over the next 3 years.
  - The part of the thermal delivery system beyond Cottage 7A on Yankee Drive can then be valved off.
- Step 3: Move residents from Cottage 16 and Cottage 18 to Cottages 25 and 26 over the next 5 years.
  - The thermal delivery system can then be valved off beyond Laurel Drive.
- Step 4: Move residents from Cottages 33 and 34 to Cottages 27 and 28 over the next 10 years.
  - The thermal delivery system beyond colony court can then be valved off.

This can enable the shutting down of the steam supply for spaces that will no longer be occupied, resulting in significant energy savings due to:

- Reduced usage from lower demand.
- Slightly reduced steam generating pressure due to a decrease in the length of the steam supply and condensate return loop.
- Significantly lowered leakage losses.

In the figure below, the newly occupied buildings have been highlighted in blue, while those decommissioned have been highlighted in red.

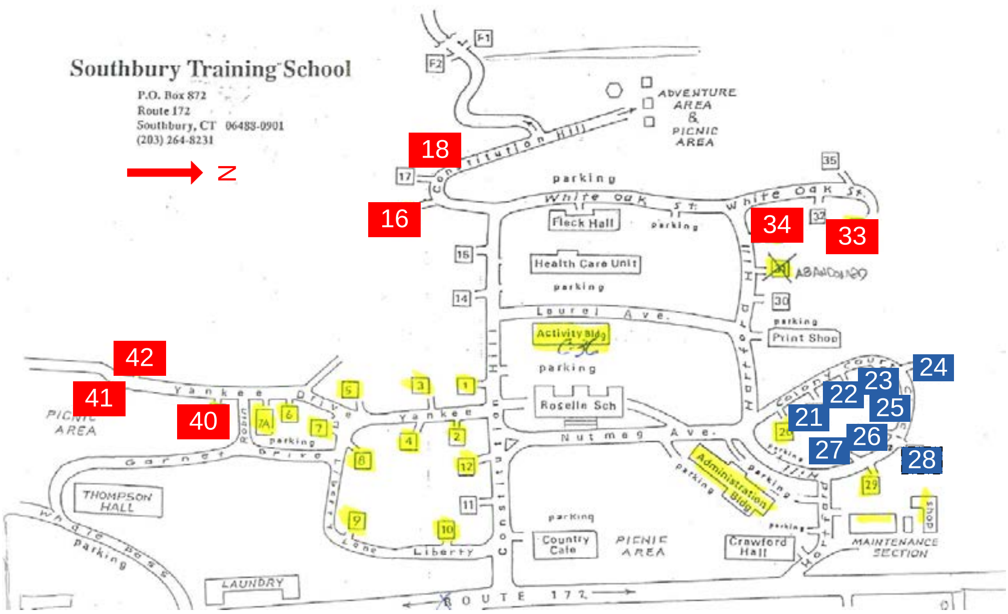


Figure 8: Suggested Future Campus Occupancy

VI. REVIEW OF EXISTING INFORMATION

van Zelm Engineers conducted a thorough review of information provided by the Department of Construction Services and the Department of Administrative Services for the State of Connecticut. The information reviewed included:

- A site steam distribution plan
    - This plan highlighted the steam network serving all the buildings on campus.
    - This plan also referenced other drawings (drawings #3 - #8) that detailed steam supply and condensate return piping for replacement.
- A campus reprogramming map
    - This map highlighted those locations on campus that are currently occupied.
    - This map is used in the above figures to denote existing and suggested future campus occupancy.
- Drawing #9
    - This drawing provides the architectural floor plan for Cottage 16.
    - This drawing also enabled van Zelm Engineers to estimate cooling loads per floor and zone in Cottage 16 for replacement options.
    - Additionally, this drawing also provides some detail on architectural elements in these 'Cottages' such as doors and window frames.
- Drawing #A-2
    - This drawing provides the architectural floor plan for Cottage 18.
    - This drawing also enabled van Zelm Engineers to estimate cooling loads per floor and zone in Cottage 18 for replacement options.
- Drawing #A-5
    - This drawing provides the architectural floor plan for Cottage 33.
    - This drawing also enabled van Zelm Engineers to estimate cooling loads per floor and zone in Cottage 33 for replacement options.
    - Additionally, this drawing also provides some detail on architectural elements such as doors.
    - This drawing also provides us with some detail on the basement within the building.
- Drawing #A-9
    - This drawing provides the architectural floor plan for Cottage 34.
    - This drawing also enabled van Zelm Engineers to estimate cooling loads per floor and zone in Cottage 34 for replacement options.
    - This drawing also provides us with detail on the basement within the building.

- Drawing #A-29
    - This drawing provides the architectural floor plan for Cottage 36.
    - This drawing also enabled van Zelm Engineers to estimate cooling loads per floor and zone in Cottage 36 for replacement options.

- Master Plan – Final Submission: RMF Engineers, Dated October 2009
    - van Zelm Engineers also reviewed a Campus Master Plan and Boiler Study prepared by RMF Engineers.
    - van Zelm Engineers concurs with most of the recommendations made by this study; however:
        - The study was conducted ten years ago, and hence some key factors that would affect the conclusions of the study have changed:
            - The campus is more lightly occupied now
            - The clustering of occupied buildings has changed
        - Utility rates have changed significantly. This is a key point since the options for the Southbury Training School going forward hinge on the fuel source and associated costs as well occupancy and longevity

- Field Surveys and Site visits
    - van Zelm Engineers verified existing conditions and those mapped on the drawings provided by conducting several site visits.
        - The first site visit was performed circa June 2016
        - Additional site visits were performed in November 2016 and March 2017
    - The steam distribution network was surveyed and its efficacy estimated.
    - The electrical distribution network was surveyed as well with special focus being given to back up generation options.

VII. EVALUATED REPLACEMENT SYSTEMS

A. EXISTING SYSTEM (BASE CASE)

Currently, the facility produces steam using four boilers from the Power House across the street. This steam is generated at high pressure and through pressure reducing valves sent out at 30 psig and delivered to each of the buildings on the loop. Indirect heat exchangers and other equipment convert this to hot water which is then pumped up the building for heating. Most of the boilers in the plant are original equipment and were installed circa 1930. Boilers 1, 2, and 4 were installed in the 1930's and have a nameplate capacity of 20,000 lbs per hour. They have thus outlasted expectations for service life. Boiler 3 was installed in 1999 and has a nameplate capacity of 25,000 lbs per hour. Additionally, the boilers appear to be oversized and as the campus decreases its occupied footprint, this system no longer offers an energy efficient solution. The boilers are dual fuel and can operate on natural gas or number 2 fuel oil.

The steam distribution system appears to be in disrepair in several locations, leading to significant maintenance costs and leakage losses of steam and condensate. Maintaining this legacy system's functionality over the next few years will require a significant (continuous) investment. Making any further investments in this system beyond maintaining day to day operability should only be considered if the campus is likely to remain open beyond the next 20 years.

In order to analyze the impacts and relative costs of each of the options considered, we estimated the conditioned floor area to be approximately 450,000 square feet of conditioned space used currently.

B. HOT WATER BOILERS AND FURNACES (Recommended Option)

Installing dual fuel hot water furnaces and boilers in each of the cottages provides the most cost-effective solution that meets all the needs of the Southbury Training School. These systems will have the lowest installation costs of any discrete system evaluated to serve each cottage separately, while providing the flexibility desired by the campus to be able to salvage equipment from buildings to be mothballed to re-allocate towards other sites. The steady state efficiencies of these system approach 85% and they can be controlled to provide optimal comfort for tenants. The dual fuel option provides a built-in redundancy.

All State Construction, Inc. provided budgetary pricing which has been included in the appendices.

C. WATER SOURCE UNITARY HEAT PUMP SYSTEM

This system would utilize heat pump technology to condition multiple spaces using one system per building. However, instead of direct heat exchange to outside air, a closed loop water system is set up to be an intermediate source of heating or cooling, and this is piped up to individual heat pumps distributed throughout the different building areas.

A hydronic hot water boiler adds heat to the loop in the winter, and an evaporative cooling tower indirectly cools the water source loop in the summer. Even though this system has some benefits in terms of better operational efficiency and lower cooling costs, the need to provide either natural gas service or fuel oil systems will not justify the required initial investment for this system to pay back its incremental installation costs over discrete buildings.

Installing this system would also enable buildings to be independent of the steam distribution system, and also provide new reliable equipment that would reduce or eliminate the need for unoccupied buildings to be held in a heated condition due to reliability concerns.

SYSTEMS EVALUATED BUT NOT RECOMMENDED

Grouped steam boilers for multiple buildings

Though this would require fewer boilers than the individual boilers at each building, the added scope of separating and isolating areas of steam distribution would make its cost unattractive, and since it would also require significant architectural re-fit work to repurpose buildings that otherwise would be abandoned, this option was excluded.

Individual location-hot water boilers

Adding individual boilers to generate heating hot water at each of the facility's occupied buildings was also examined. However, this would also require a significant capital investment in purchasing new boilers and some infrastructure and code required modifications to the spaces. This system will also require the piping of natural gas or fuel oil storage tanks with enough capacity for heating to each of the individual sites, making it cost prohibitive. Installation of this system is also hindered by the uncertainty of the Training School's future beyond the next ten years or so.

Geothermal Heat Pump System

Geothermal heat pumps (GHPs), sometimes referred to as GeoExchange, earth-coupled or ground-source heat pumps, use the constant temperature of the earth as the exchange medium instead of the outside air temperature. Although Connecticut experiences seasonal temperature extremes, a few feet below the earth's surface the ground remains at a relatively constant temperature. Ground temperatures range from 45°F to 65°F.

Ground temperatures in the winter are warmer than the air above it, and during the summer cooler than the air above. The GHP takes advantage of this by exchanging heat with the earth through a ground heat exchanger. As with any heat pump, geothermal heat pumps are able to heat, cool, and, if so equipped, supply hot water.

Some models of geothermal systems are available with two-speed compressors and variable fans for more comfort and energy savings. Relative to air-source heat pumps, they are quieter, last longer, need little maintenance, and do not depend on the temperature of the outside air.

However, this system requires a significant capital investment to conduct a feasibility study as well as the actual design and installation of the system itself. Installing this system separately across each occupied location will be cost prohibitive. Hence, this system was evaluated but eliminated from final consideration.

Variable Refrigerant Flow (VRF) Systems

High efficiency heat pumps are suited for applications that require installation of HVAC systems in distinct locations. These heat pumps are inverter driven and can operate when the outdoor air temperature is as low as -15 ºF.

These systems are ductless split systems and have an outdoor condensing unit that can be coupled to several indoor units. A typical heat pump system design will involve locating an indoor unit in each of the spaces, with refrigerant lines leading out to a condensing unit.

The units have the ability to transfer heat from one portion of the building to another. In other words, if one occupant is feeling hot while another is feeling cold, the heat pumps can transfer the heat from one room to the other using refrigerant lines, satisfying both demands as opposed to heating and cooling them separately, thus saving energy.

Installing this system shifts a significant portion of the heating load from fossil fuels to electricity. This will require additional backup generators totaling one megawatt to be installed. Currently, backup generators of 100 kW each serve most buildings.

We estimate installing these generators will cost approximately **$725,000.** This pricing is estimated on a similar installation executed in New York City. However, the installation quotes receives from the State on these systems independently from contractors, makes this option cost prohibitive.

UTILITY AND GOVERNMENTAL INCENTIVES

Since the Southbury Training School is an entity operated by the State of Connecticut, it is ineligible to receive State incentives for energy efficiency improvements. Utility incentives can be pursued under a custom program. Since these incentives vary annually, and are based on the amount of funds available at any given time, we excluded them from our analysis.

VIII. ECONOMIC ANALYSIS

This economic analysis compares the replacement option recommended to the existing conditions. Additional modifications to the existing plant should be undertaken on a simple cost-benefit aspect. The prediction of economic performance for disparate mechanical systems is a relatively complicated process, as it must consider the implication of energy displaced and utilized throughout the year. An annual monthly spreadsheet model was developed after using state of the art energy simulation software to predict annual operating costs, fuel consumption and cost savings.

A 15 year life cycle cost analysis was performed to further evaluate the project economics. The basic operating condition assumptions for both Year 1 and the life cycle cost analysis are:

- Approximately 450,000 square feet of space will be allocated to the new mechanical systems.
- Year 1 for the economic performance analysis is 2019 since that is the earliest that the recommended systems could be made operational post permitting.
- All systems considered operate year round from January 1 through December 31 on an annual basis.
- Gas, electric and other utility as well as maintenance labor costs are inflated by 3% annually over the 15 year life cycle. This represents a realistic inflation rate.
- A discount rate of 4% has been utilized to estimate Net Present Values in today’s dollars of Life Cycle Costs.
- Gas costs were calculated to be $0.80 per therm based on the local utility data, while electric costs were estimated to be $0.14 per kWh.
- Maintenance costs for evaluated options were determined based on data provided by respective vendors and were escalated at an inflation rate of 3%.
- The Power House Heating plant efficiency is assumed to be at 73%.

- The economic performance analysis is based on equipment performance, budget pricing and other relevant data provided by OEM vendors for equipment evaluated. This ensures a higher level of accuracy, as opposed to basing these factors on standardized rates.

The economic analysis for disparate mechanical systems estimates the thermal and electrical operating costs, along with the additional costs for maintenance to operate the systems. Net annual savings are then compared to the Base Case (Existing Conditions) costs in order to develop the Net Present Values in today's dollars, over fifteen years, for the evaluated options. A spreadsheet program was developed to carry out the analysis.

The base case is the cost to operate the Southbury Training School's Campus without adding any new equipment; i.e. continue operating as is. Annual costs for the year 2019 and going forward were estimated by projecting and escalating existing annual utility costs at the rates stated above.

A similar calculation was done for each of the other options. Additionally, budgeted OEM equipment and other installation costs were estimated to determine the financial burden of installation in 2019. The economics are highly sensitive to energy rates. We expect them to continue to rise at approximately 3%. We have used this figure as an inflation adjuster for both fuel and maintenance costs.

Table 3: Economic Performance Summary

	Base Case (Do Nothing Option)	***Recommended Option: Hot Water Boilers and Furnaces***
Total Project Installation Costs (all 45 operational buildings)		$ 5,050,812
Year 3 Cash Flow	$(1,533,340)	$(788,154)
Yr 3 Benefit Relative to Base Case (Do Nothing)	-	$745,186
Year 5 Cash Flow	$(1,626,720)	$(836,153)
Yr 5 Benefit Relative to Base Case (Do Nothing)	-	$790,568
Year 10 Cash Flow	$(1,885,815)	$(969,330)
Yr 10 Benefit Relative to Base Case (Do Nothing)	-	$916,485
NPV of Cash Flow Relative to Base Case (15 Years)	-	$ 4,620,072

A positive Net Present Value denotes a favorable project. Our findings suggest that the Southbury Training School should proceed with the installation of the Recommended Option i.e. Hot Water Boilers and Furnaces.

IX. CONCLUSIONS AND RECOMMENDATIONS

Given the uncertain long-term future of the campus and the decreasing number of residential occupants, we recommend that the Southbury Training School should proceed with the installation of the Recommended Option, i.e. Hot Water Boilers and Furnaces, as it will provide significant cost savings in addition to the flexibility required by the training school at this juncture.

T:\2016\2016113.01\Study\Southbury Training School-power plant-alternate heating study\2018-12-07 Southbury Training School Report.doc

Appendix

PRICING

September 17, 2018

Tanay Bapat
van Zelm Heywood & Shadford, Inc.
10 Talcott Notch Road
Farmington, CT 06032

RE: SPB18-095 – Budgetary Pricing for Typical Building Heating Hot Water Furnace Installations

Tanay,

Thank you for the opportunity to provide this budgetary estimate for typical building heating hot water furnace installations. These prices are provided site unseen and have several assumptions incorporated which will be detailed below and in the attached estimate summary tables. If you would like any alternate budgetary proposals or additional detail please feel free to ask.

- Pricing assumes CT DOL wage rates for Southbury effective July 1, 2018.
- Pricing assumes an existing gas line is available to branch off of within 40 FT of the new gas furnace locations. A new PRV and plug valves have been included.
- Pricing assumes a suitable oil tank location is available within 40 FT of the new oil furnace locations.
- Pricing assumes hot water distribution systems exist in the buildings and can be tied into within 60 FT of the new furnace locations.
- Pricing does not include new radiators or distribution piping throughout the buildings.
- Pricing includes the following hydronic accessories: air separator, wye strainer, circulator pump, pressure reducing valve, automatic air vents, temperature gauges, and pressure gauges.
- Pricing includes fiberglass insulation and ASJ on all hot water piping.
- Pricing includes system commissioning and balancing.
- Pricing includes allowances for asbestos abatement assuming only removal of material to make tie-ins to existing hot water piping.
- Pricing includes new house-keeping pads for all equipment.
- Pricing does not include demolition, removal, or disposal of existing equipment except to the extent necessary to facilitate new work.
- Pricing includes allowance for standalone controls or integration into an existing BMS if applicable.
- Pricing includes allowance for supplying power to new circulator pump and furnace(s).
- Pricing includes condensate neutralization kit and pump.

Building Size	Fuel	Price
8,000 SQ FT	Gas	$84,583
18,000 SQ FT	Gas	$138,695
8,000 SQ FT	Oil	$105,181
18,000 SQ FT	Oil	$161,290

Sincerely,

Ryan Morley
Project Manager
All State Construction, Inc.
Cell: (860) 914-8918
Office: (860) 678-0678 x3040

*Phone (860) 678-0678 * 449 Cooke Street, P.O. Box 805 * Farmington, Connecticut 06034 * Fax (860) 676-8910*

8,000 SQ FT GAS	**$84,583.01**
1 - Labor	**$41,124.85**
3 – Material (QTY 1 KBN501)	**$27,858.17**
406,000 BTU Output Knight XL High Efficiency Boiler KBN501	$12,405.54
Condensate	$360.91
Gas Supply	$3,284.89
Hydronic Piping	$8,904.31
New Pad	$360.00
Vent	$2,542.51
4 – Subcontract	**$15,600.00**
Asbestos Abatement	$6,000.00
Electrical – Controls	$6,000.00
Electrical – Power	$3,600.00

18,000 SQ FT GAS	**$138,694.60**
1 – Labor	**$59,402.55**
3 - Material (QTY 2 KBN701)	**$59,192.05**
574,000 BTU Output Knight XL High Efficiency Boiler KBN701	$34,074.59
Condensate	$721.82
Gas Supply	$6,569.78
Hydronic Piping	$12,020.82
New Pads	$720.00
Vent	$5,085.02
4 - Subcontract	**$20,100.00**
Asbestos Abatement	$7,500.00
Electrical - Controls	$7,200.00
Electrical - Power	$5,400.00

*Phone (860) 678-0678 * 449 Cooke Street, P.O. Box 805 * Farmington, Connecticut 06034 * Fax (860) 676-8910*

8,000 SQ FT OIL	**$105,181.14**
1 - Labor	**$58,488.67**
3 – Material (QTY 1 G315)	**$31,092.47**
454,000 BTU Burderus G315/6 with Beckett CF800 Burner	$10,419.84
Drain	$360.91
Hydronic Piping	$8,904.31
New Pads	$1,080.00
Oil Piping	$3,284.89
Oil Tanks	$4,500.00
Vent	$2,542.51
4 - Subcontract	**$15,600.00**
Asbestos Abatement	$6,000.00
Electrical - Controls	$6,000.00
Electrical - Power	$3,600.00

18,000 SQ FT OIL	**$161,290.29**
1 - Labor	**$86,864.81**
3 – Material (QTY 2 G315)	**$54,325.48**
454,000 BTU Burderus G315/6 with Beckett CF800 Burner	$20,839.68
Drain	$721.82
Hydronic Piping	$11,130.39
New Pads	$1,800.00
Oil Piping	$5,748.56
Oil Tanks	$9,000.00
Vent	$5,085.02
4 - Subcontract	**$20,100.00**
Asbestos Abatement	$7,500.00
Electrical - Controls	$7,200.00
Electrical - Power	$5,400.00

ALL STATE
CONSTRUCTION, INC.
*Phone (860) 678-0678 * 449 Cooke Street, P.O. Box 805 * Farmington, Connecticut 06034 * Fax (860) 676-8910*

December 6, 2018

Tanay Bapat
van Zelm Heywood & Shadford, Inc.
10 Talcott Notch Road
Farmington, CT 06032

RE: SPB18-142 – Budgetary Pricing for Boiler Replacement Options

Tanay,

Thank you for the opportunity to provide this budgetary estimate for various boiler replacement options at the Southbury Training School. These prices are provided site unseen and with no design drawings. Several assumptions have been incorporated which will be detailed below. Final pricing is subject to detailed engineering design (by others), site condition review, selected equipment options, and equipment pricing at time of order.

Replace (2) Existing Water Tube Boilers with (2) New Fire Tube Boilers
- Pricing assumes CT DOL wage rates for Southbury effective July 1, 2018
- Pricing includes demolition of existing equipment and allowance for asbestos abatement
- Pricing includes (2) new Cleaver Brooks CBEX Elite-200-600-150ST(460/3/60) boilers with CRE-36H economizers
- Pricing includes all pipe, valves, fittings, and standard trim
- Pricing includes new feedwater pumps, deaerator tank, condensate receiver, condensate pumps
- Pricing includes new 24" diameter stacks and supports
- Pricing includes service platform and ladder
- Pricing assumes an existing gas line or oil tank with adequate capacity is available within 100 FT of the new boiler locations
- Pricing assumes steam distribution system exists with a header that can be tied into within 100 FT of the new boiler locations
- Pricing assumes boiler location has sufficient access to rig new equipment into place. A packaged boiler is quoted, not field erected
- Pricing does not include new distribution piping throughout the campus or buildings
- Pricing includes fiberglass insulation with ASJ covering for heat conservation per IECC and personnel protection
- Pricing includes system start-up and commissioning
- Pricing includes electrical power and controls
- Pricing includes new house-keeping pads for all equipment.
- Pricing includes standalone controls

Total Budgetary Estimate: **$1,840,000**

Replace (2) Existing Water Tube Boilers with (4) New Miura LX-150 Boilers
- Pricing assumes CT DOL wage rates for Southbury effective July 1, 2018
- Pricing includes demolition of existing equipment and allowance for asbestos abatement
- Pricing includes (4) new Miura LX-150 boilers with economizers and standalone controls
- Pricing includes all pipe, valves, fittings, and standard trim
- Pricing includes new feedwater pumps, deaerator tank, condensate receiver, condensate pumps
- Pricing includes new 20" diameter stacks and supports
- Pricing assumes an existing gas line or oil tank with adequate capacity is available within 100 FT of the new boiler locations
- Pricing assumes steam distribution system exists with a header that can be tied into within 100 FT of the new boiler locations
- Pricing assumes boiler location has sufficient access to rig new equipment into place. A packaged boiler is quoted, not field erected
- Pricing does not include new distribution piping throughout the campus or buildings
- Pricing includes fiberglass insulation with ASJ covering for heat conservation per IECC and personnel protection
- Pricing includes system start-up and commissioning
- Pricing includes electrical power and controls
- Pricing includes new house-keeping pads for all equipment.
- Pricing includes standalone controls

Total Budgetary Estimate: **$1,525,000**

Install (2) Stack Economizers on Existing 20,000 lb/h Steam Boilers
- Pricing assumes CT DOL wage rates for Southbury effective July 1, 2018
- Pricing includes (2) new Cleaver Brooks CRE-36H economizers
- Pricing includes new structural supports as required for economizer and for stack above economizer
- Pricing includes transitions and expansion joints as required to accommodate economizer into existing stacks
- Pricing includes new circulator pump and water piping from existing header within 100 FT of existing stack locations
- Pricing includes new flue gas and liquid thermometers
- Pricing includes new pressure relief valves
- Pricing includes automatic soot blower and stack corrosion control options with associated controllers and control/power wiring

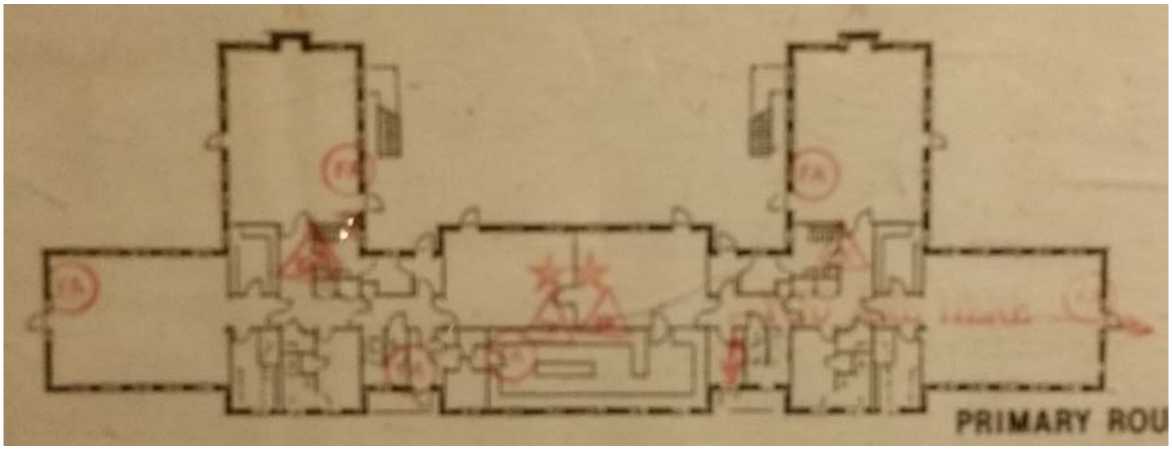
Total Budgetary Estimate: **$390,000**

Sincerely,

Ryan Morley
Project Manager
All State Construction, Inc.
Cell: (860) 914-8918
Office: (860) 678-0678 x3040

Appendix

PHOTOS



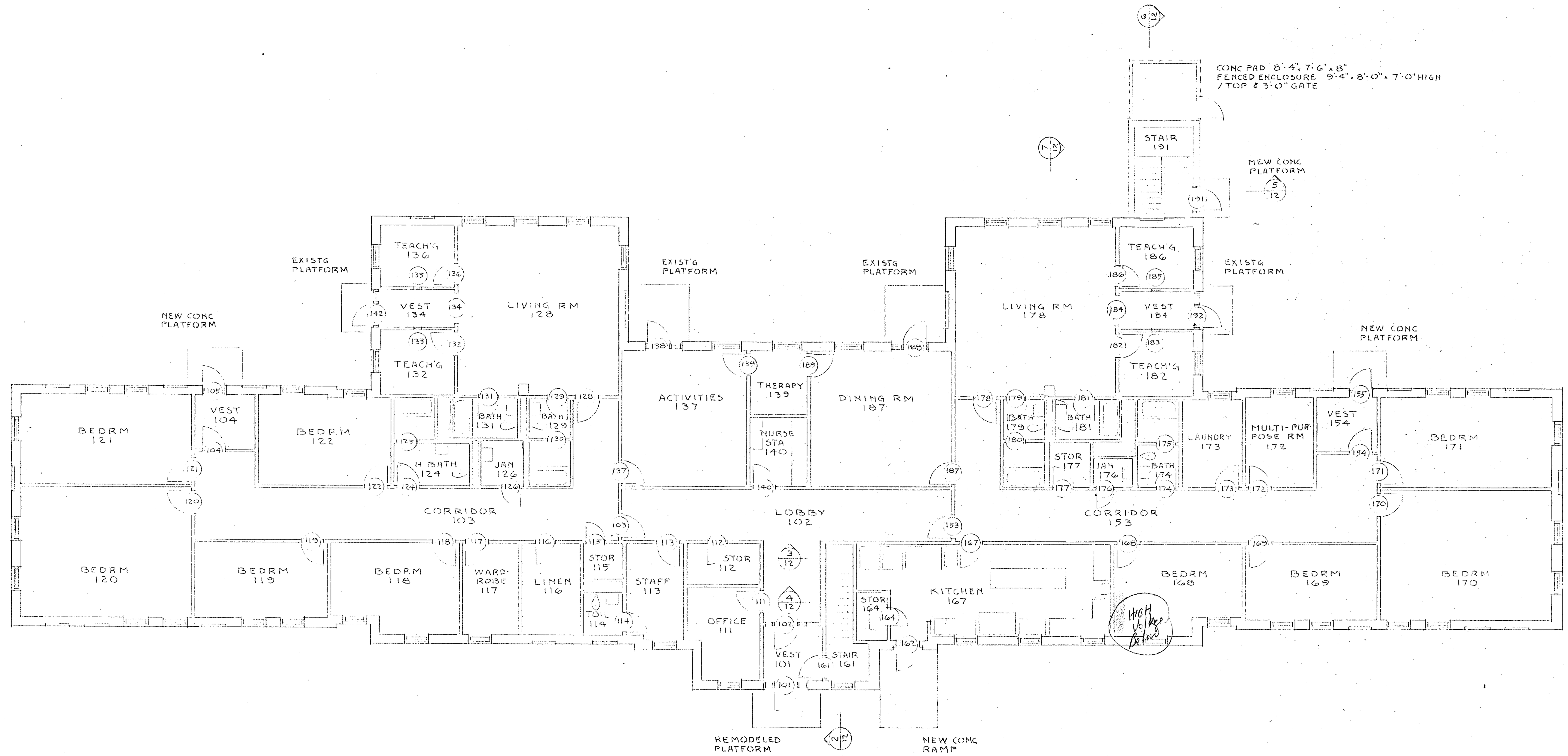
Typical Floor Plan for a Residential Building

Typical Mechanical Room (Building 18)

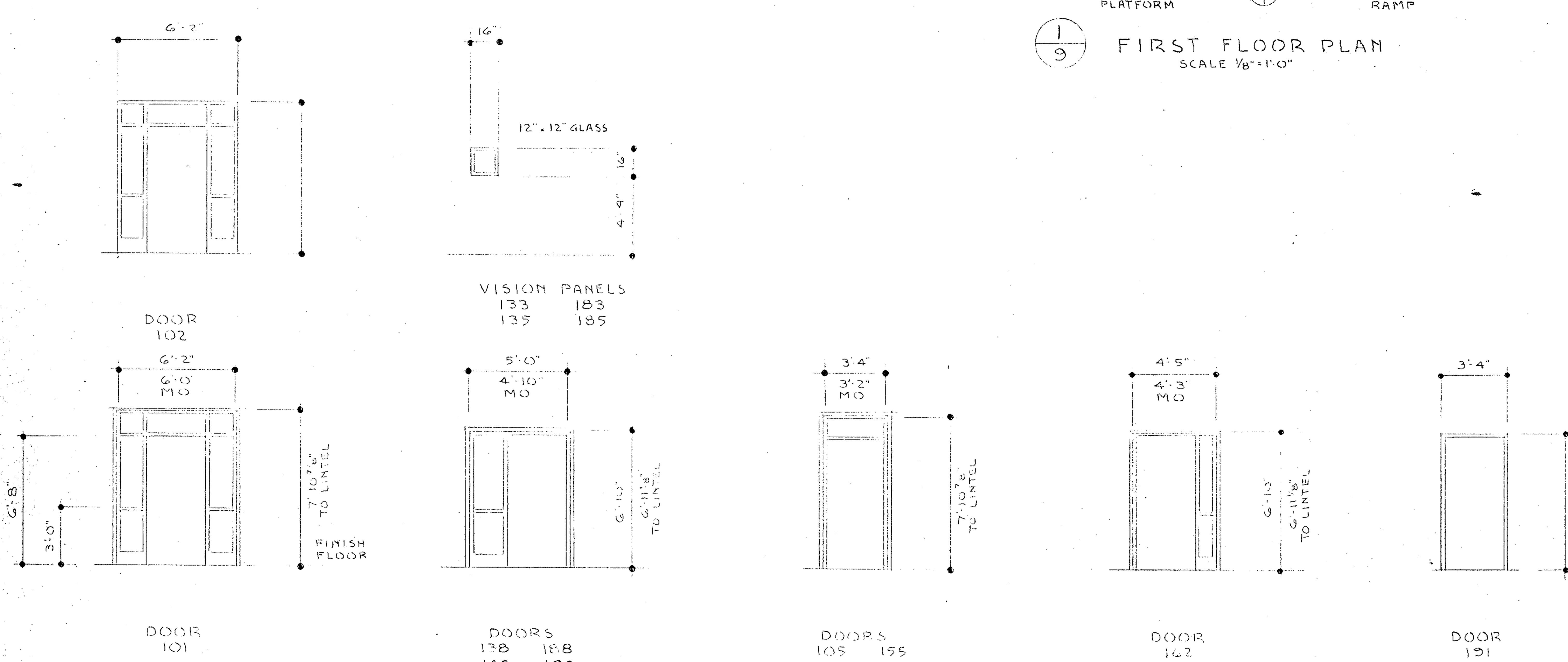
Typical Mechanical Room (Building 18)

Appendix

DRAWINGS

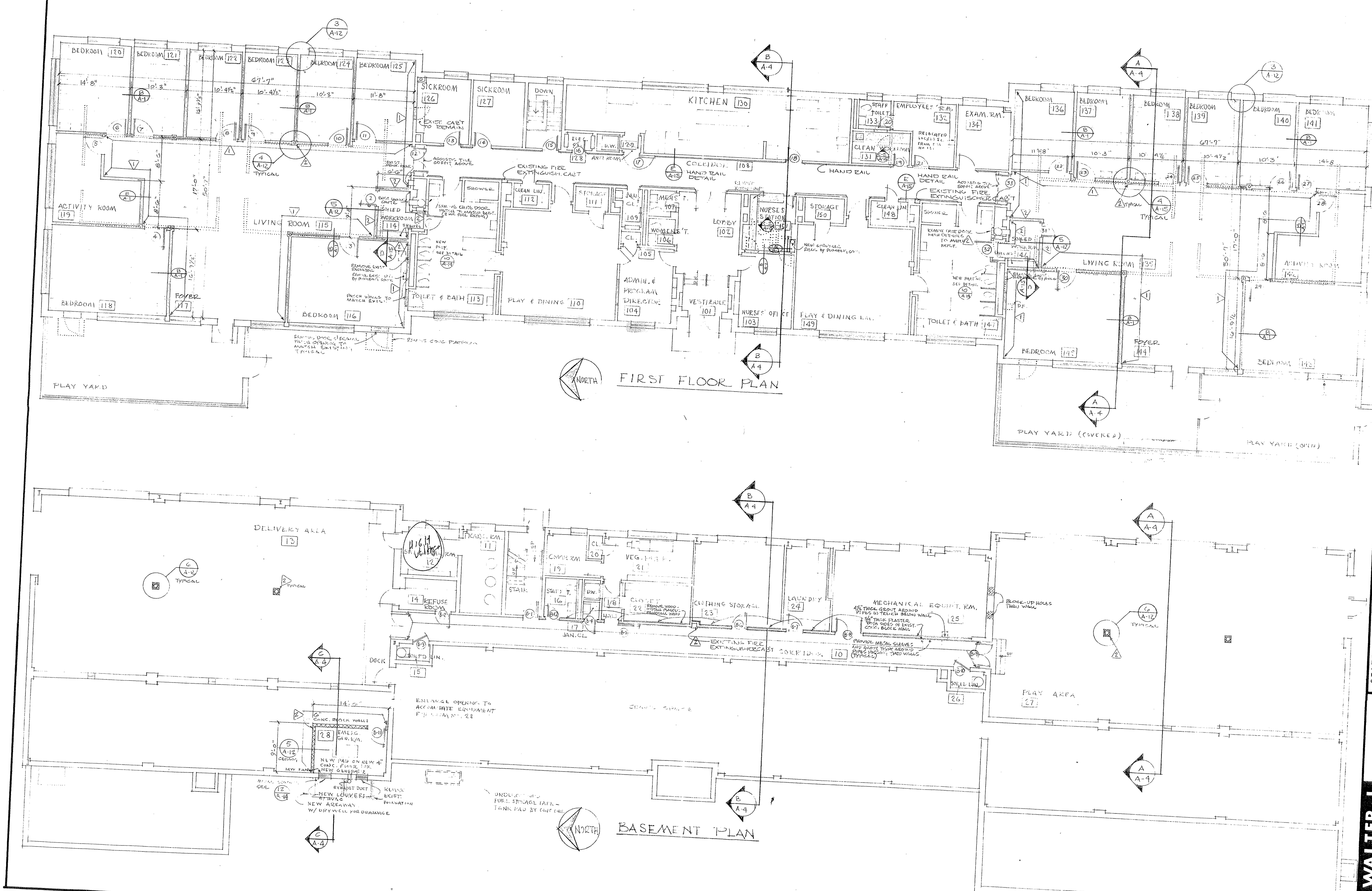


1/9 FIRST FLOOR PLAN
SCALE 1/8"=1'-0"



3 EXTERIOR & SPECIAL H.M. FRAMES

drawing title: COTTAGE No. 16 FIRST FLOOR PLAN	STATE OF CONNECTICUT DEPT. OF ADMINISTRATIVE SERVICES BUREAU OF PUBLIC WORKS C. THOMAS FOLEY, DEP. COMMISSIONER
REVISIONS mark / date / description	PLANS PREPARED BY RAYMOND BROWN, JR., ARCHITECT, A.I.A. WILDCAT HILL ROAD HARWINTON, CONNECTICUT 06790
	project: RENOVATION OF COTTAGES No. 16 AND FARM I SOUTHBURY TRAINING SCHOOL SOUTHBURY CONNECTICUT project no. BI-B-224
date / scale / drawn by / approved by	drawing no. 9



BUILDING 18
BASEMENT PLAN & FIRST FLOOR PLAN

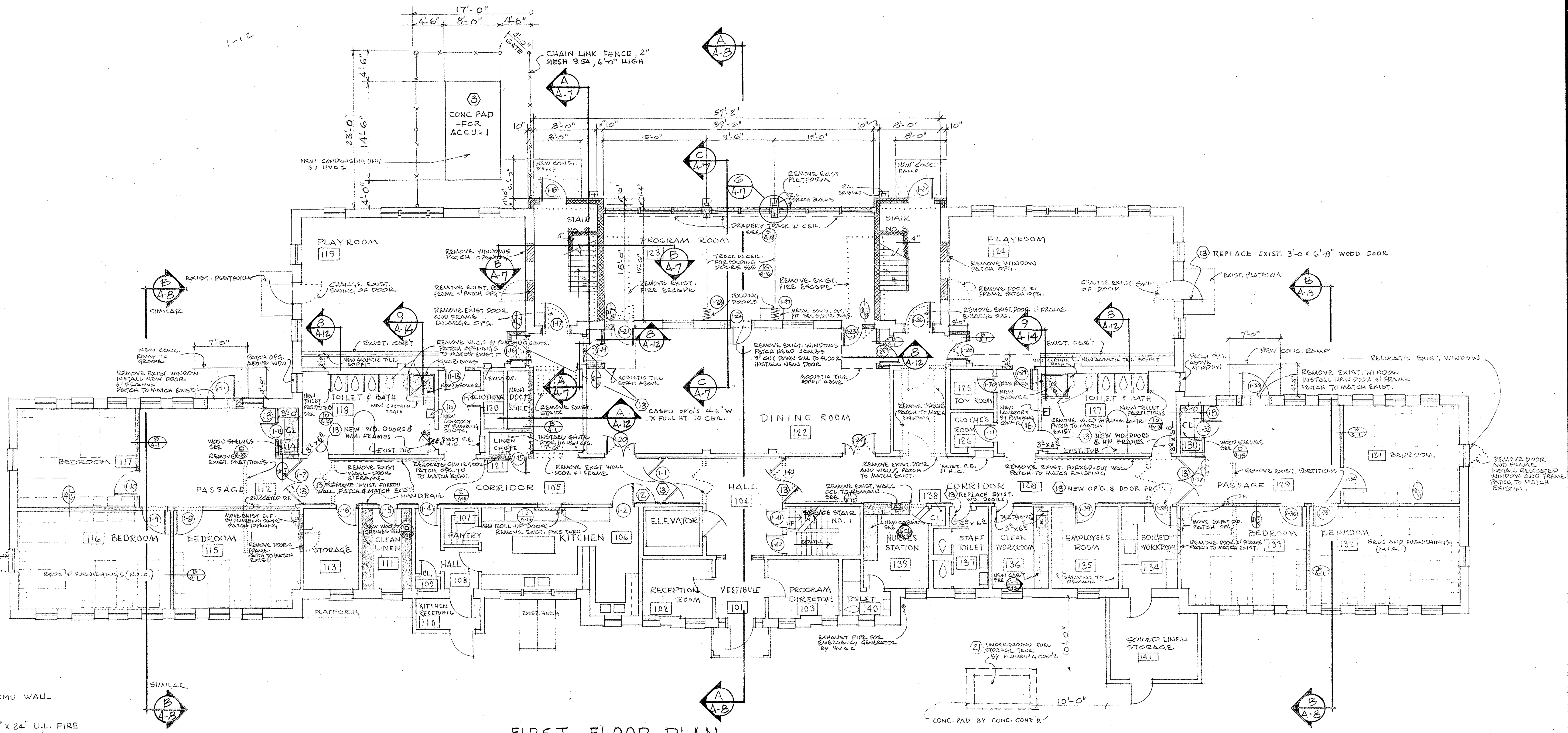
DRAWN	A.W.
CHECKED	P.A.G.
APPROVED	E.K.B.
SCALE	1/8"=1'-0"
PROJECT NO.	BI-B-209
DATE	3-7-74
DRAWING NO.	A-2

STATE OF CONNECTICUT
PUBLIC WORKS DEPARTMENT
PAUL J. MANAFORT COMMISSIONER

RENOVATIONS AND IMPROVEMENTS OF RESIDENTIAL FACILITIES
SOUTHBURY TRAINING SCHOOL
SOUTHBURY CONNECTICUT

WALTER J. DOUGLAS ASSOCIATES
CONSULTING ENGINEERS PLANNERS DESIGNERS
175 S. HIGHLAND ST. W. HARTFORD, CONN.

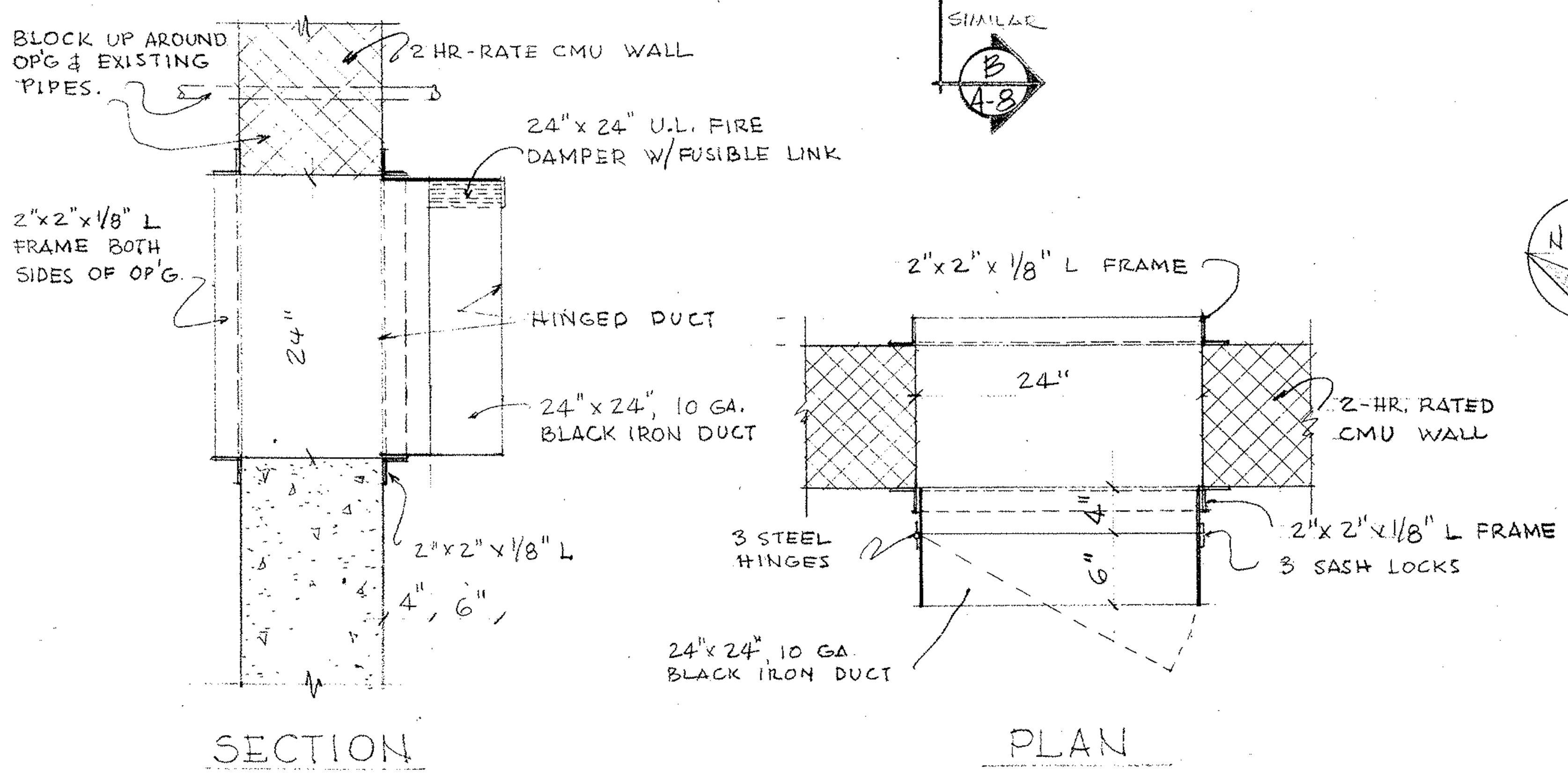
A-2



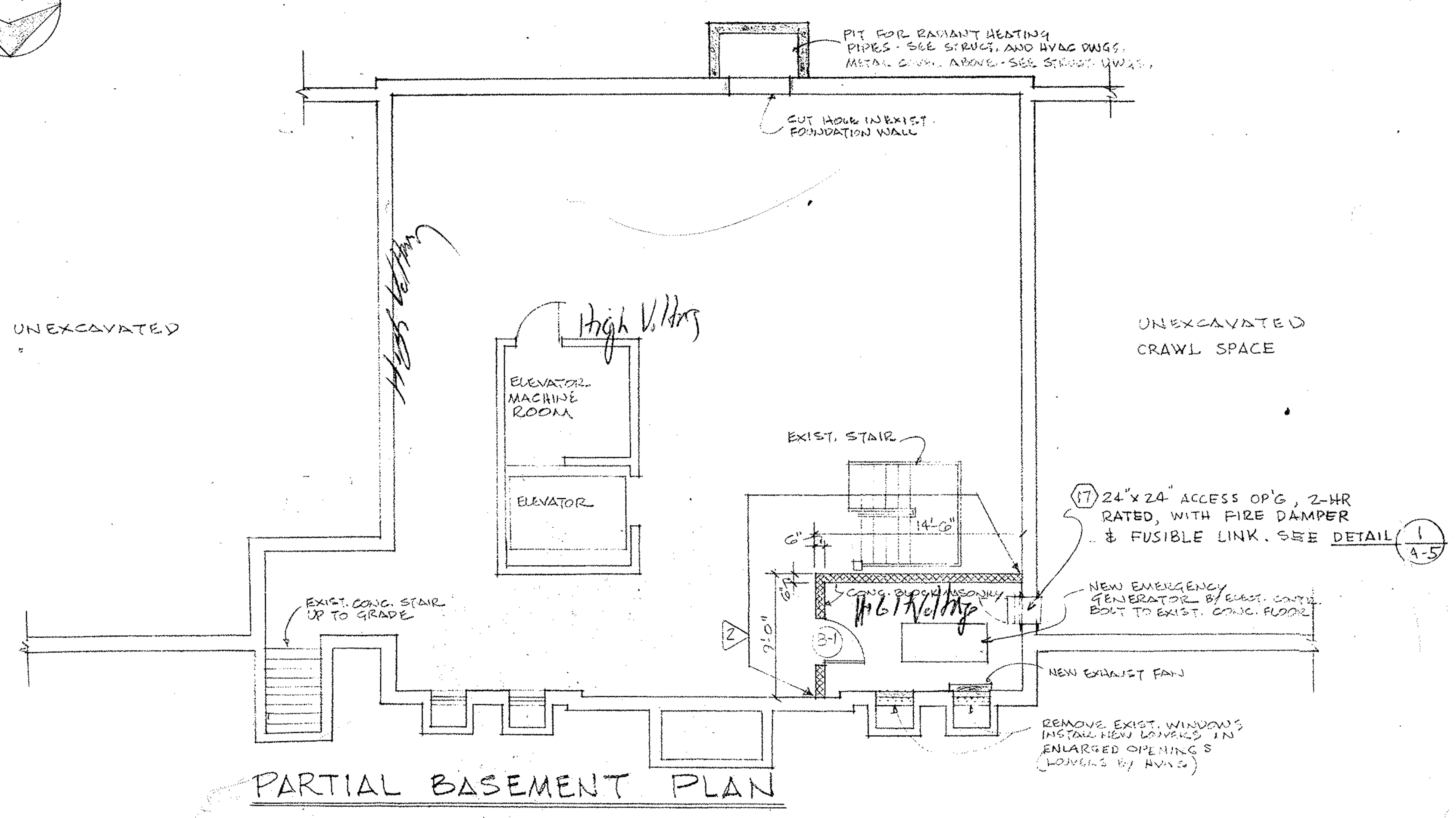
FIRST FLOOR PLAN

NORTH

(12) CORRIDORS 105 & 128 :
AT WALLS OF TOILET & BATH RMS 118 & 127 WHERE EXISTING FURRED-OUT WALLS ARE TO BE REMOVED, DELETE PATCH TO MATCH EXISTING. THESE WALL AREAS COMPLETELY PLASTERED OVER NEW MTL. LATH.



(1/A-5) (17) FIRE RATED ACCESS OPENING & DOOR
SCALE : 1" = 1'-0"



PARTIAL BASEMENT PLAN

REVISIONS

ITEM NO.	DESCRIPTION	DATE
(22)	NEW MTL. LATH & PLASTER WHERE NOTED, CORR. 105 & 128	

REVISIONS JUNE 23, 1977

ITEM NO.	DESCRIPTION	DATE
(8)	REVISED LOCATION ACCU-1	
(12)	DOOR 1-2 · CHANGE TO SWING INTO CORRIDOR 180°	
(13)	MISC. DOOR & OPG. CHANGES. SEE ALSO DOOR SCHED. DWG A-16	
(16)	DELETE ONE LAV. EA. RMS. 118 & 127. RELOCATE REMAINING LAV.	
(17)	FIRE-RATED ACCESS OP'G, GENERATOR RM. TO CRAWL SPACE	
(18)	DECREASE DEPTH CLOSETS 114 & 130	
(21)	INCREASE SIZE & RELOCATE PROPANE TANK	

DRAWN A.W.	CHECKED P.A.E.	APPROVED E.K.B.	SCALE 1/8"=1'-0"
PROJECT NO. BI-8-209	DATE 3-7-74	DRAWING NO. A-5	

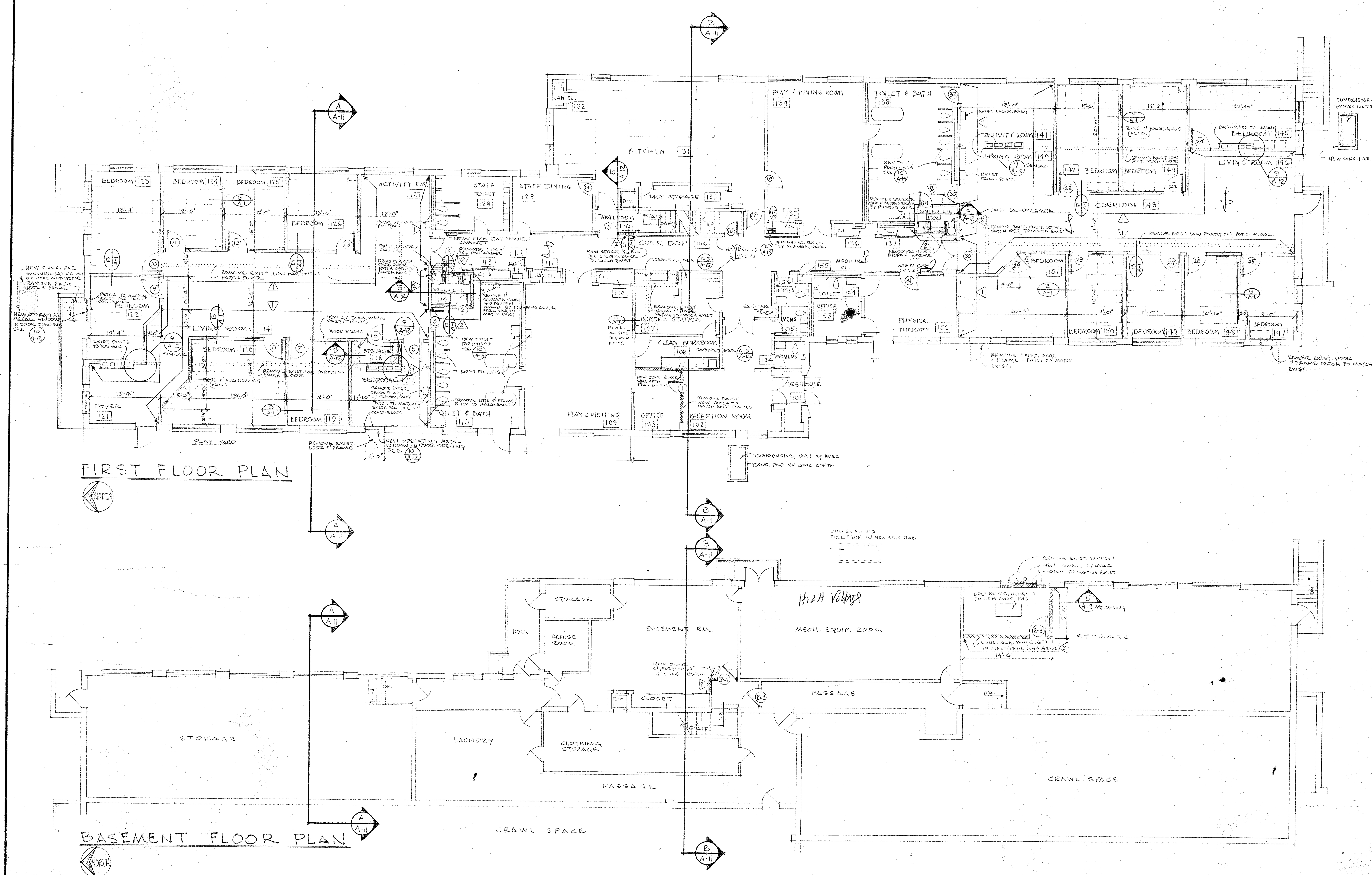
BUILDING 33
BASEMENT & FIRST FLOOR PLAN

STATE OF CONNECTICUT
PUBLIC WORKS DEPARTMENT
PAUL J. MANAFORT COMMISSIONER

RENOVATIONS AND IMPROVEMENTS OF RESIDENTIAL FACILITIES
SOUTHBURY TRAINING SCHOOL
SOUTHBURY CONNECTICUT

WALTER J. DOUGLAS ASSOCIATES
CONSULTING ENGINEERS
PLANNERS DESIGNERS
17 S. HIGHLAND ST.
W. HARTFORD, CONN.

A-5



STATE OF CONNECTICUT
PUBLIC WORKS DEPARTMENT
PAUL J. MANAFORT COMMISSIONER

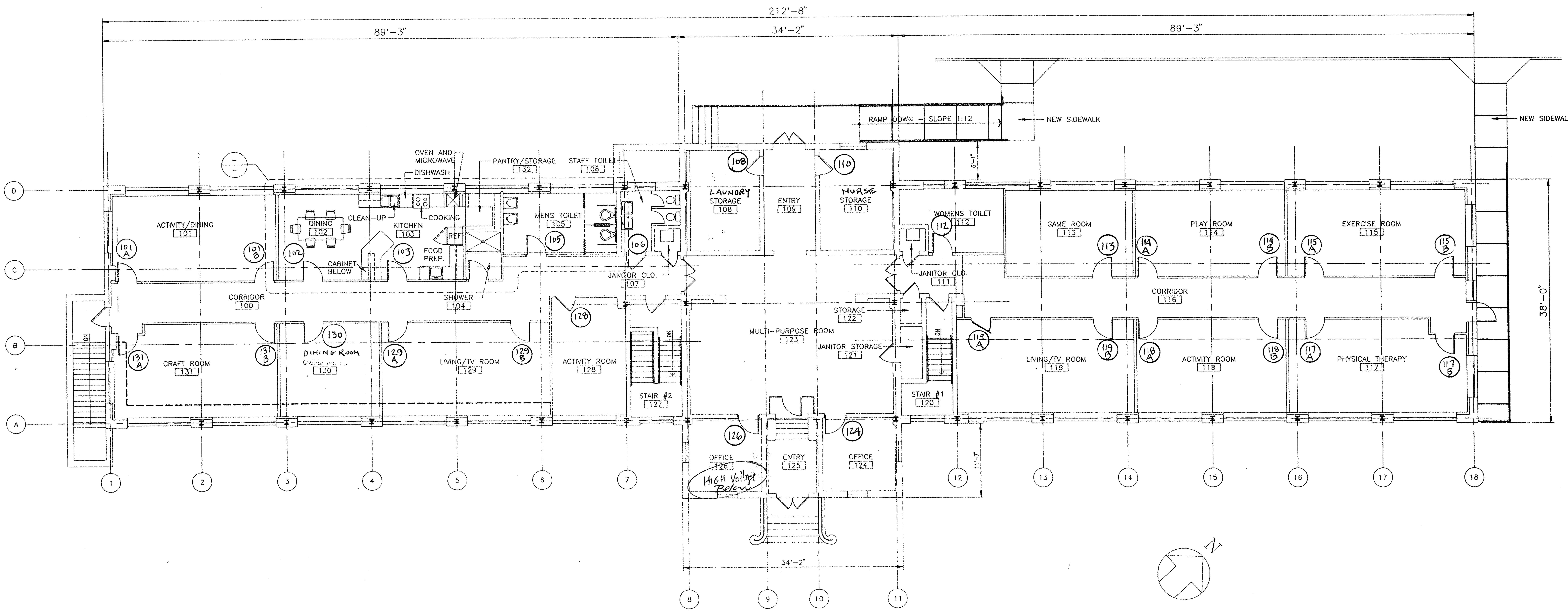
RENOVATIONS AND IMPROVEMENTS OF RESIDENTIAL FACILITIES
SOUTHBURY TRAINING SCHOOL
SOUTHBURY CONNECTICUT

BUILDING 34
BASEMENT PLAN &
FIRST FLOOR PLAN

DRAWN A.W.	PROJECT NO. BI-B-209
CHECKED P.A.E.	DATE
APPROVED	DRAWING NO. A-9
SCALE	

WALTER J. DOUGLAS ASSOCIATES
CONSULTING ENGINEERS
PLANNERS DESIGNERS
17 S. HIGHLAND ST.
W. HARTFORD, CONN.

A-9



PROPOSED FIRST FLOOR PLAN
SCALE: 1/8" = 1'-0"

Cottage 36
N.I.P. BUILDING

FIRST REVIEW
PROGRESS PRINT OCT. 11, 1993

CONSTRUCTION NOTES

drawing title	
PROPOSED FIRST FLOOR PLAN	STATE OF CONNECTICUT DEPARTMENT OF PUBLIC WORKS

REVISIONS

mark	date	description
X.X.X	X.X.X	X.X.X

DRAWING PREPARED BY
STRAUS-EDWARDS ASSOCIATES ARCHITECTS
WOODBURY, CONNECTICUT

project
SOUTHBURY TRAINING SCHOOL
N.I.P. BUILDING
SOUTHBURY, CT

project no. BI-RS-286B

date –
scale 1/8"=1'-0"
drawn by JMP
approved by –
drawing no. A-29

Appendix

CUTSHEETS

HEROS™

Water-tube Boilers

steam generation systems
for process and power

B&W

ENERGY | ENVIRONMENTAL

With more than **5,000** *units and* **150** *years of experience,*

Babcock & Wilcox (B&W) is a global leader in supplying a wide range of industrial water-tube boiler designs to meet targeted, challenging, long-lasting operational and performance goals. Our Heros™ industrial boilers are custom-engineered to each project's unique specifications for varying inputs and desired outputs. All of our designs feature the highest levels of quality, reliability and efficiency for which B&W is known.

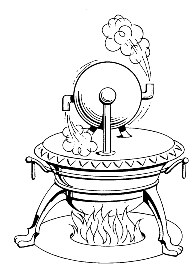
Evolution of B&W's Heros boilers

More than 2,000 years ago, a Greek mathematician and scientist named Hero designed a device that used steam as a power source. His invention, the aeolipile, is credited as being the first steam engine. In 1856, Stephen Wilcox built upon Hero's science to engineer and patent the water-tube boiler for use in industry. His success led him to team up with childhood friend George Babcock and establish The Babcock & Wilcox Company and begin a legacy of innovation in steam generation that continues today.

Over the years, B&W's industrial boiler configurations have been known by various model names, including FM, HCFM, PFM, PFI, PFT, TSSG and others — D-type or O-type, single-drum or multi-drum. While the unique designs offered by these various models will continue to be offered, they are now all known under the Heros industrial boiler name.

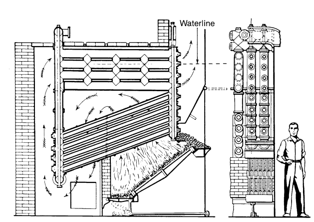
Today, B&W's line of Heros industrial boilers represents more than 150 years of ingenuity and experience, all providing dependable performance for a wide range of industries and applications.

1st century A.D.



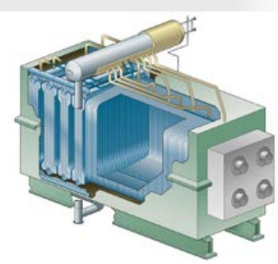
Hero's aeolipile

1867



B&W's first water-tube boiler

Today



One of B&W's high-pressure, high-capacity, single-drum, all-welded design boilers

Heros industrial boilers offer:

- Reliable steam generation
- Low auxiliary power requirements
- Low emissions
- Simple operation and low maintenance
- Operational flexibility – high turndown and fast load ramping

Custom configurations
meet targets for:

Capacity	10,000 to 1,200,000 lb/hr (4.5 to 544.2 t/hr)
Size/Space	Various designs for shop and/or modular field assembly to fit most any space limitations
Temperature	Saturated to 1005F (540C)
Design Pressure	250 to 2400 psig (1.7 to 16.5 MPa)
Fuel	Liquid or gaseous fuels such as oil, natural gas, CO, blast furnace gas (BFG), coke oven gas (COG), and various other byproduct liquid and gaseous fuels
Air/Water Treatment	Emissions and water-side deposition control systems
Timeline/Budget	Ability to optimize and expedite to meet cost and scheduling expectations

More than 5,000 Heros industrial boilers have been installed in a variety of facilities, including:

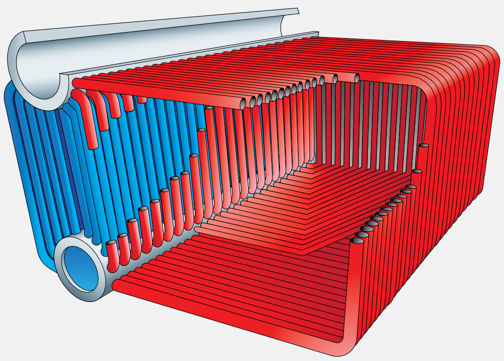
- Refining and petrochemical
- Utility power
- Pulp and paper
- Chemical and pharmaceutical
- Universities and institutions
- Food processing
- Metals and mining
- Composite and carbon fiber
- Carbon black
- Wood products
- and many more

For firing solid fuels such as pulverized or stoker coal, wood, bark, and bagasse or other biomass products, we offer Stirling™ and/or Towerpak™ model boilers.

B&W Innovation

Developing firsts that last is a cornerstone of our company. Having earned more than 17,000 patents, we are committed to technological innovation that provides measurable benefits.

A few innovations that our Heros industrial boilers can include are multi-circulation systems, connection-ready installations and elevated-drum designs.



MultiCirc *(patent-pending)*

Our multi-circulation systems accommodate lower-quality feedwater and maximize thermal efficiency while maintaining reliability by minimizing boiler tube internal scaling.

Connection Ready

The boiler and auxiliary equipment modules, depending on size, can be shop mounted to skids where they are pre-wired and piped to accelerate transporation and reduce field installation times.

Elevated Drum

Our elevated-drum design is used for drum retention times of 5 minutes or more from normal water level to low water fuel cutout. Additionally, this design is utilized where shipping limitations exist as it allows for a more symmetrical load with the upper steam drum shipped separately from the boiler and installed onsite.

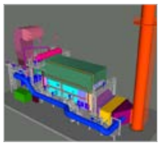
Proven Experience


Elevated three-drum unit for IRPC Clean Power Co., Ltd. in Rayong, Thailand

To meet the project's steam drum retention requirements, we engineered and delivered an elevated three-drum unit for the combined heat and power plant's use in supplying steam to a neighboring factory.


High-capacity unit for U.S. refinery

We engineered and supplied a 300,000 lb/hr (136,100 kg/hr) shop-assembled unit, which was shipped by barge and field-installed. The project scope also included all boiler auxiliaries, fans, economizer, valves, instrumentation and installation of all equipment on the boiler island.

Single-drum modular units for oil sands project in Alberta, Canada

Challenged to provide a solution for highly reliable steam generation at high pressure with ultra-low NO_x emissions, minimized blowdown for zero liquid discharge requirements, multi-fuel usage, and low field erection and maintenance costs, we supplied eight high-performing modularized single-drum units.


Custom-branded units for U.S. universities

In addition to predefined specifications for operating conditions, our Heros industrial boilers can be delivered featuring designated colors and logos. We recently supplied two U.S. universities with multiple custom-branded units, each capable of providing approximately 80,000 lb/hr (36,300 kg/hr) of saturated steam with a design pressure of 250 psig (1.7 MPa).

More than 5,000 installations in more than 60 countries

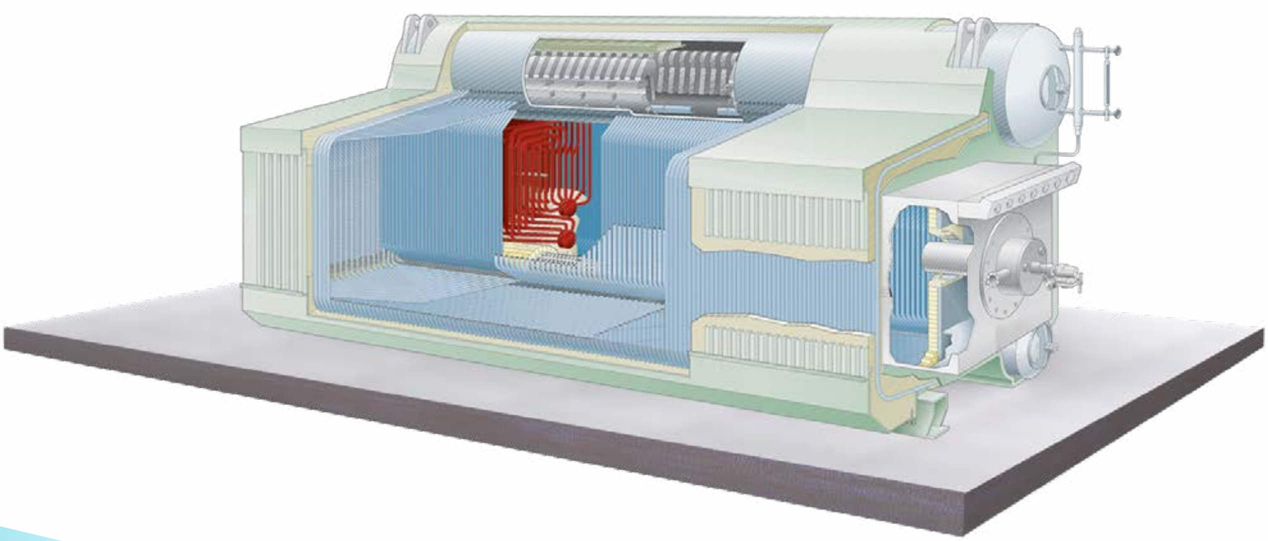




Design Features

Our Heros water-tube boilers offer numerous features that benefit your operations, including:

- Furnace wall water cooling – eliminates refractory and related maintenance
- Gas-tight setting membrane – inhibits dew-point sulfur corrosion and outages caused by gas leaks
- Rugged steel-based frame – supports boiler and allows jacking and skidding
- Outer lagging – galvanized, weather-tight for outdoor installations
- Drum internals – ensure positive circulation, low-moisture, high steam purity
- Water wash troughs and drains
- Grooved tube seats – protect against leaks during transportation and throughout operation
- Solid membraned division wall – prohibits furnace gases from bypassing generating tubes
- Larger tube diameter – helps to prevent membrane thermal cracking and contributes to a faster load response
- Inverted loop, fully drainable superheaters



Services

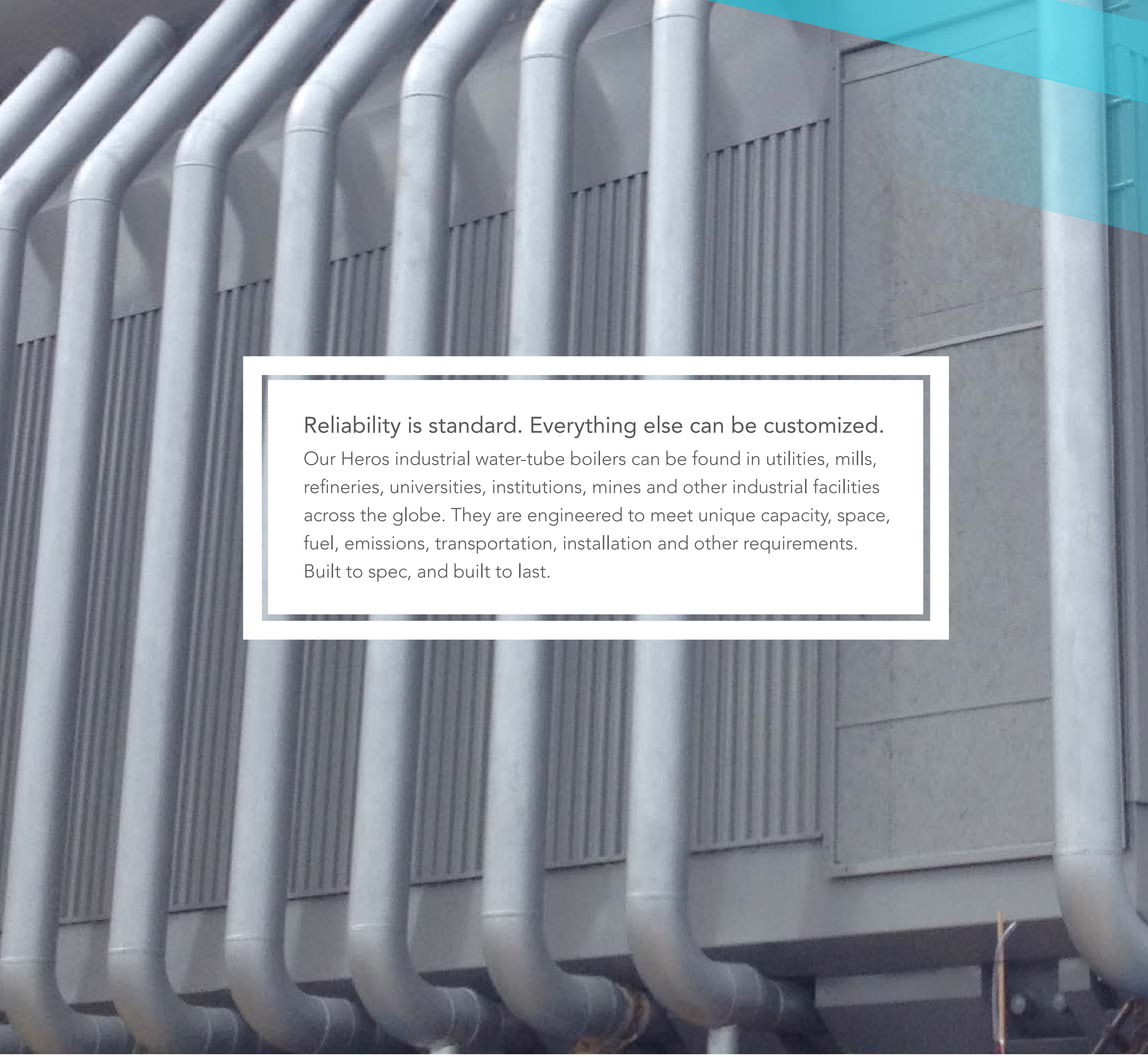
- Engineering studies
- Proprietary computational fluid dynamics (CFD) modeling and circulation analysis
- Equipment design, tuning and testing
- Stress analysis and graphics
- Transportation and logistics
- Turnkey installation and construction services
- Field advisory services for start-up, commissioning, equipment installation and operator training
- Retrofits and replacement parts
- Responsive global network of sales and field engineers to provide expert service and support

Codes and standards

Each project is reviewed to meet customer requirements and all applicable ASME and industry codes. Additional design standards typically provided are ANSI, API, PIP, SIL, UL, CSA and NFPA. B&W will meet or exceed most any requirement requested.

Auxiliary equipment

- Economizers
- Burners
- Controls
- Forced draft fan and drives
- Flues and ducts
- Stacks
- Deaerators, feedwater pump sets
- Oil pumps
- Heater sets
- Post-combustion emissions control systems
- Code piping
- Balance of plant



Reliability is standard. Everything else can be customized.

Our Heros industrial water-tube boilers can be found in utilities, mills, refineries, universities, institutions, mines and other industrial facilities across the globe. They are engineered to meet unique capacity, space, fuel, emissions, transportation, installation and other requirements. Built to spec, and built to last.

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Phone: +1 330.753.4511

www.babcock.com

ENERGY | ENVIRONMENTAL

Established in 1867, Babcock & Wilcox is a global leader in advanced energy and environmental technologies and services for the power, industrial and renewable markets, with operations, subsidiaries and joint ventures worldwide.

For more information or to contact us, visit our website at www.babcock.com.

E101-3240 100U7L

INDUSTRIAL WATERTUBE BOILERS

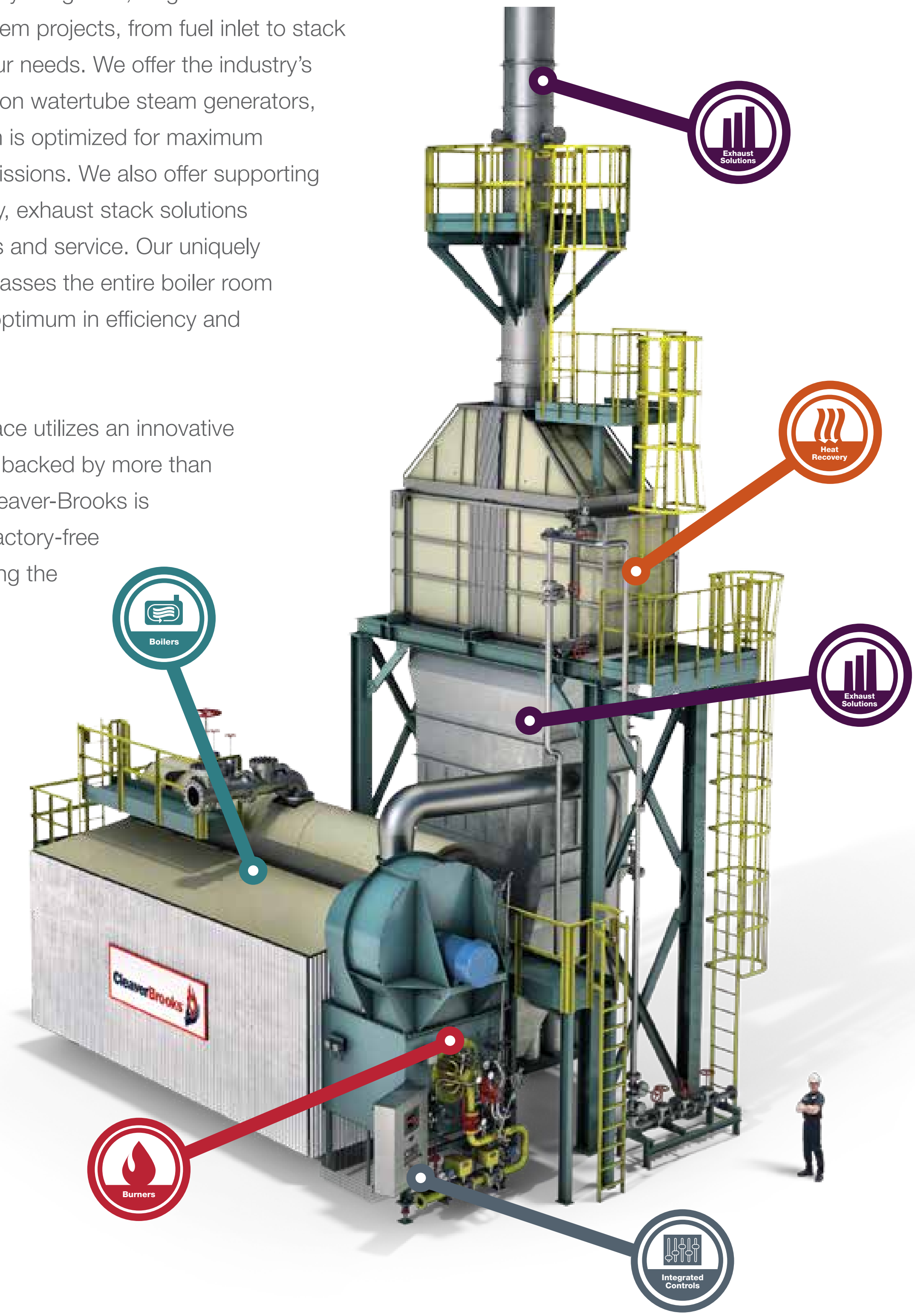
Innovative solutions for maximum efficiency

Cleaver-Brooks Engineered Boiler Systems
Manufacturers of Nebraska Boilers, NATCOM Burners and ERI HRSG Systems

Industrial Watertube Boilers
Total Integration from the Company that Pioneered It

Only Cleaver-Brooks offers totally integrated, single-source solutions for every aspect of your boiler system projects, from fuel inlet to stack outlet, custom built to meet your needs. We offer the industry's widest range of natural circulation watertube steam generators, and every aspect of our system is optimized for maximum efficiency, reliability and low emissions. We also offer supporting controls systems, heat recovery, exhaust stack solutions and complete aftermarket parts and service. Our uniquely engineered integration encompasses the entire boiler room and is designed to deliver the optimum in efficiency and environmental sustainability.

Every industrial watertube furnace utilizes an innovative welded-membrane wall design backed by more than 80 years of experience. And Cleaver-Brooks is the only manufacturer with refractory-free boiler wall construction, including the burner throat.



Engineered Boiler Systems Product Overview

	Capacity	Fuel Type	Design Pressure	Application	Emissions
D-Style	10,000 to 500,000 lb/hr Steam	Natural gas, #2 and #6 oil, alternative fuels, combination	Up to 1,500 psig	Steam, temperatures to 1,050°F	Available to <7ppm NOx* Ultra-Low CO
A-Style	10,000 to 500,000 lb/hr Steam	Natural gas, #2 and #6 oil, alternative fuels, combination	Up to 1,500 psig	Steam, temperatures to 1,050°F	Available to <7ppm NOx* Ultra-Low CO
O-Style	10,000 to 500,000 lb/hr Steam	Natural gas, #2 and #6 oil, alternative fuels, combination	Up to 1,500 psig	Steam, temperatures to 1,050°F	Available to <7ppm NOx* Ultra-Low CO
CBND	10,000 to 225,000 lb/hr Steam	Natural gas, #2 oil	Up to 375 psig	Saturated Steam	Available to <7ppm NOx* Ultra-Low CO
Elevated Drum & Modular	200,000 to 1,000,000 lb/hr Steam	Natural gas, #2 and #6 oil, alternative fuels, combination	Up to 1,500 psig	Steam, temperatures to 1,050°F	Available to <7ppm NOx* Ultra-Low CO
FC-OSSG	150,000 to 500,000 lb/hr Steam	Natural gas, #2 and #6 oil, propane, digester, combination	Up to 2,500 psig	Saturated steam	Available to <7ppm NOx* Ultra-Low CO
HRSGs	10,000 to 500,000 lb/hr Steam	Natural gas, #2 oil, propane, digester, landfill	Up to 2,300 psig	Steam, temperatures to 1,050°F	Available to <2ppm NOx* Ultra-Low CO
High Temperature Hot Water & Thermal Fluid Heater	20 to 200 MMBTU/hr Water	Natural gas, #2 oil, propane, digester, landfill	Up to 2,300 psig	Hot Water Fluid Heater	Available to <7ppm NOx* Ultra-Low CO

*available to <2ppm NOx with SCR

Custom Watertube Boilers

10,000 to 500,000 lb/hr

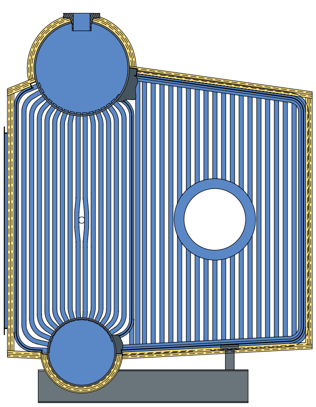
Cleaver-Brooks uses our experience and expertise to ensure every watertube boiler we manufacture is the highest quality in the industry and offers the lowest operational costs possible for that style of boiler. We leverage our specialized engineering expertise to deliver fully customized steam solutions that meet your specific needs. Our extensive range of watertube products, delivering from 10,000 to 500,000 lb/hr of steam, are available in D-, A- and O-style configurations.

Both single- and dual-stage integral convective superheaters are available, and can accommodate Selective Catalytic Reduction (SCR) and CO catalyst. And you have your choice of firing natural gas, #2 and #6 oil, alternative fuels or a combination, available to <7ppm NOx.

FEATURES

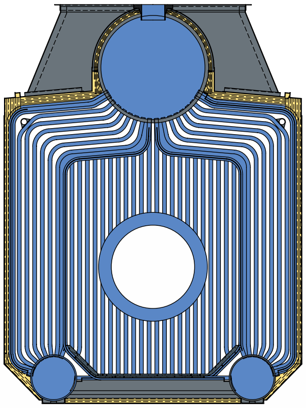
- Membrane wall constructions are 100% water-cooled and refractory-free
- Grooved tube seats for improved tube-to-drum attachment
- Large, water-cooled furnace areas feature refractory-free burner throat to optimize emissions performance and longevity and reduce maintenance
- Fully welded gas seals are used throughout to ensure gas-tight operation

Capacities
10,000 to 500,000 lb/hr
Design Pressure
Up to 1,500 psig
Steam Temperature
Up to 1,050˚F



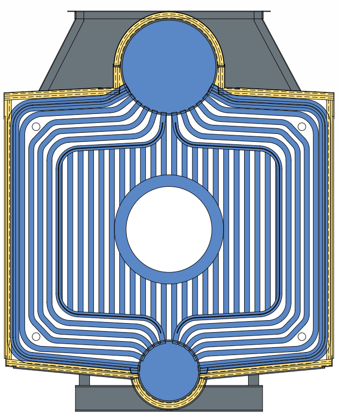
D-STYLE

The D-style is a 100% membrane water-cooled furnace, reducing costly, time-consuming, annual maintenance. The burner throat and the front and rear walls are welded and refractory-free, utilizing our NATCOM burner design. D-style boilers can be customized to provide superheated steam. We offer both single- and dual-stage integral superheater systems with optional temperature control over turndown.



A-STYLE

The A-style design features a large, water-cooled furnace and an evaporator section with a low gas-side pressure drop that reduces fan power consumption. The vertical gas outlet minimizes the width of the overall package and allows for large steam capacities in restrictive footprints.



O-STYLE

This rugged design has become the true workhorse of the rental boiler industry. The vertical gas outlet on the O-style puts the economizer above the boiler, minimizing the width of the overall package. Its symmetrical design is ideally suited for mounting on a trailer for over-the-road transport. Cleaver-Brooks line of boilers for the rental industry continues to provide efficient and reliable service year after year, while withstanding rapid emergency startups.

Steam-Ready CBND

10,000 to 225,000 lb/hr

You choose the size and options you need on the Cleaver-Brooks Nebraska D boiler, and we'll have a solution that's ready faster than ever. We do not interface with any other brand's parts. Just like every Cleaver-Brooks system, steam-ready systems are integrated only with Cleaver-Brooks components. Available with emissions as low as 9 ppm NOx with combustion, 5 ppm NOx with Selective Catalytic Reduction (SCR) and 50 ppm CO, it's a flexible and cost-effective way to get your boiler room online fast, firing natural gas or #2 oil.

FEATURES

- Completely integrated and engineered from a single source
- Engineered integrations include watertube boiler, burner, heat recovery economizer and controls
- Engineering up front for shortened lead times
- Competitively priced
- Vast network of trained startup/service technicians

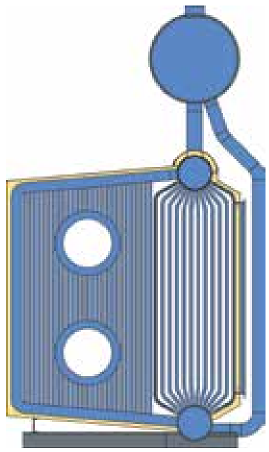
Capacities
10,000 to 225,000 lb/hr
Design Pressure
Up to 375 psig
Steam Temperature
Saturated Steam

Modular-Style Watertube Boilers

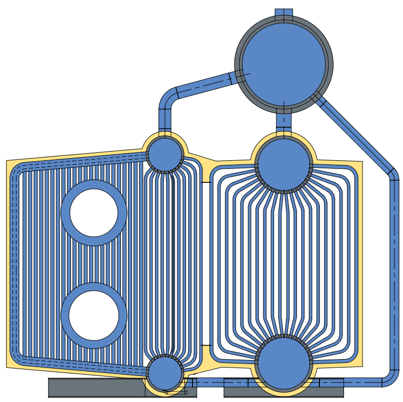
200,000 to 1,000,000 lb/hr

The Cleaver-Brooks elevated drum design maximizes shop assembly time while minimizing the cost of field labor often associated with boilers of such high capacity. The elevated drum design is a 100% membrane water-cooled furnace, reducing costly, time-consuming, annual maintenance. The front and rear walls are welded and refractory-free, as well as the burner throat, when integrated with our NATCOM burner. Elevated drum boilers can be customized to provide superheated steam. We offer both single- and dual-stage integral superheater systems with optional temperature control over turndown. Our design allows for reduced gas-side pressure drop and smaller forced-draft fans and can accommodate Selective Catalytic Reduction (SCR) and CO catalyst.

Elevated Drum and Modular-Style



Elevated Drum



Modular-Style

FEATURES

- Minimal field assembly
- Faster, more cost-effective delivery time versus field erect boilers
- Reduced gas-side pressure drop and smaller forced-draft fans
- Superheated steam options available
- Dual burners available to meet specific applications
- Can accommodate Selective Catalytic Reduction (SCR) and CO catalyst

Capacities
200,000 to 1,000,000 lb/hr
Design Pressure
Up to 1,500 psig
Steam Temperature
Up to 1,050°F

Forced-Circulation Steam Generator (FC-OSSG)

150,000 to 500,000 lb/hr

The Cleaver-Brooks FC-OSSG combines the benefits of a traditional D-style watertube boiler, with high saturated steam purity and very low blowdown, and the ease of cleaning once-through steam generators (OTSG). This large-capacity steam generator is uniquely suited for the needs of the heavy industrial, refinery and petrochemical markets and is ideal for use in steam-assisted gravity drainage (SAGD) applications utilizing produced water. Available to <7 ppm NOx or higher and will fire natural gas, #2 and #6 oil, propane, digester or a combination.

FEATURES

- Highly efficient steam solutions capable of meeting strict emissions requirements
- Increased efficiency with minimal blowdown
- 10:1 turndown
- Single-source integrated boiler/burner/control package engineered to work together
- Smaller footprint for reduced material cost and space savings
- Shipped modular packages for ease of installation
- 100% mechanically cleanable by pigging

Capacities
150,000 to 500,000 lb/hr
Design Pressure
Up to 2,500 psig
Steam Temperature
Saturated Steam

(Patent Pending)

Heat-Recovery Steam Generators and Waste Heat Boilers

10,000 to 500,000 lb/hr

With state-of-the-art, customized, packaged heat-recovery steam generators for gas-fired turbines from 1 to 95 MW, Cleaver-Brooks is a leading global provider of natural circulation-packaged and modular HRSG products for gas turbine, process exhaust, incinerator exhaust and hot water generation. We also manufacture Thermal Fluid Heaters (TFH) and High Temperature Hot Water (HTHW) generators, which incorporate a fluid-cooled membrane wall construction for the furnace and heating coil enclosure, creating a highly efficient, shop-assembled package. These units are available for most applications ranging from 20-200 MMBTU/hr. We have extensive experience customizing systems for your specific application. Our systems can increase efficiency for large-scale industrial applications such as thermal oxidizers, incinerators, FCCUs, thermal oil heaters, economizers and air heaters.

FEATURES

- Multiple pressure units available
- External superheaters, economizers and feedwater heaters
- Compact design results in low installation costs
- Can accommodate Selective Catalytic Reduction (SCR) and CO catalyst

Capacities
10,000 to 500,000 lb/hr
Design Pressure
Up to 2,300 psig
Steam Temperature
Up to 1,050°F

Integrated Controls

Custom Controls Systems
The brains behind the system

Cleaver-Brooks utilizes an in-house instrumentation and controls department to develop next-generation boiler control and burner management systems. Our approach delivers seamless, single-source engineered boiler/burner package systems. Our controls range from a cost-efficient, standard boiler-control logic and flame safeguard system to a custom-engineered package to meet specific customer requirements. Regardless of the level of complexity, we will provide state-of-the art hardware and programming for safe, reliable and efficient operation with a user-friendly interface. Cleaver-Brooks industrial watertube boilers are controlled by the Hawk 6000. Our control systems meet the latest NFPA, CSA, CE, TUV and GOST international codes and standards.

FEATURES

- Burner Management System (BMS)
- Combustion Control System (CCS)
- Plant Master Panel
- Balance of Plant Controls
- Supervisory Control and Data Acquisition (SCADA)
- Auxiliaries
- Factory Accepted Test (FAT) and Site Acceptance Test (SAT)
- Fuel transfer, simultaneous firing, preferred fuel strategies
- Solid state, loop controller, PLC and DCS platforms

Hawk 6000

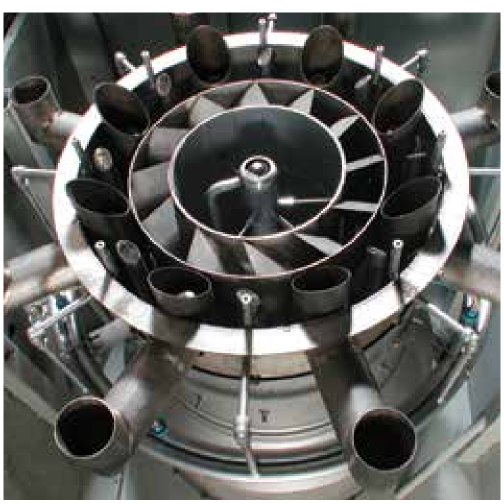
NATCOM Burners
Unsurpassed engineering and testing

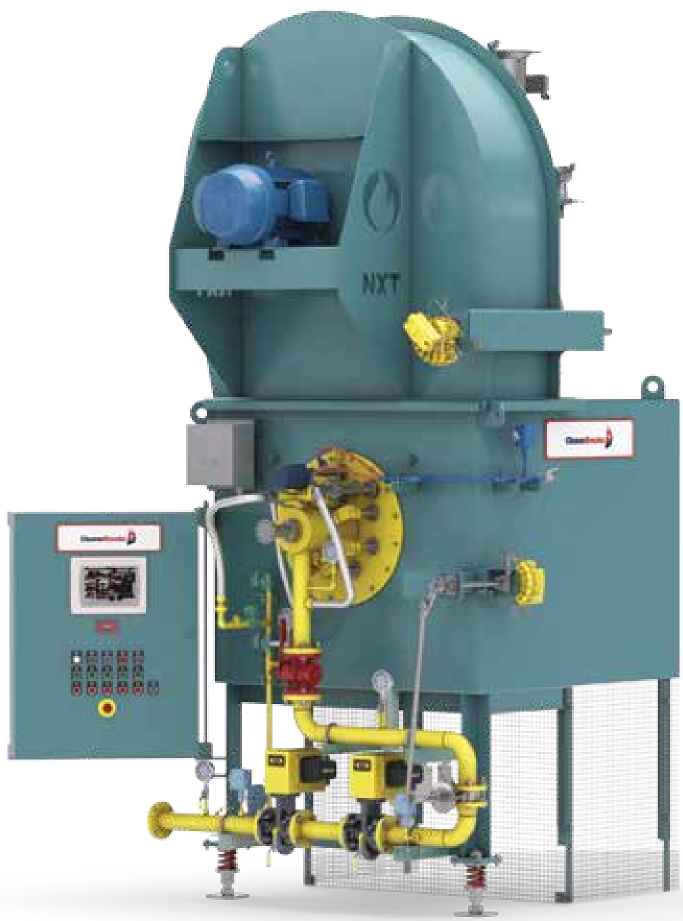
Every Cleaver-Brooks industrial watertube boiler is integrated with our NATCOM burners, which are custom-built to exacting specifications to meet each application and furnace configuration, ensuring seamless integration and unmatched fit and finish.

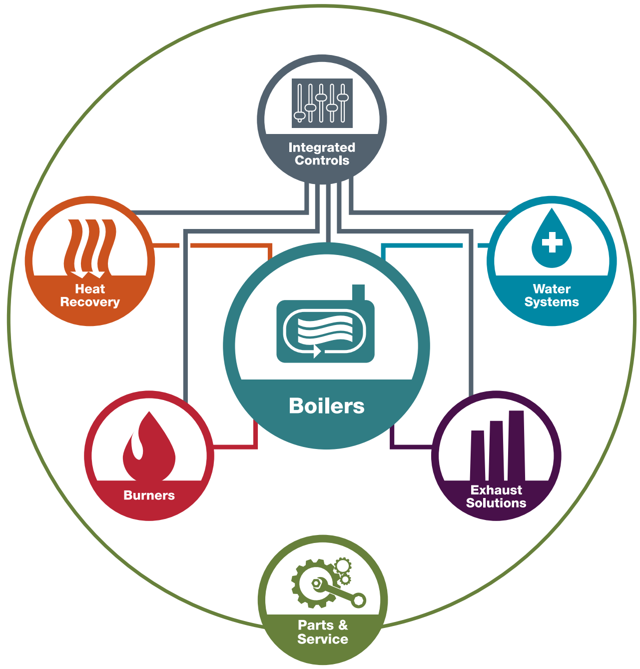
Our advanced, in-house Computational Fluid Dynamics (CFD) modeling is the key to our revolutionary NATCOM burner technology. Matching burner flame and furnace aerodynamics optimizes efficiency and lowers emissions without costly field tests. Simulations in a virtual environment provide calculations for fuel and air distribution in any furnace configuration. Our design provides ultra-low NOx, ultra-low CO and minimal particulate matter (PM).

FEATURES

- Multi-fuels applications including natural gas, refinery gas, landfill gas (LFG) and other processed waste gases, light to heavy fuel oils, and liquid waste streams
- On-line adjustability and possible removal of individual gas injectors
- No refractory burner throat
- Unmatched flame stability with Center-Core technology
- NOx levels available to <7ppm with FGR and <30ppm without FGR
- Ultra-low excess air for high efficiency
- High turndown ratio of 40:1 on gas and 10:1 on oil







Total Integration goes far beyond boilers.

For more than 80 years, Cleaver-Brooks has built a reputation for innovation in the boiler solutions industry. We remain committed to introducing technology and products that enable a more energy-efficient and environmentally friendly generation of steam and hot water.

When you come to us for a fully integrated solution, you can know that each element is created to the highest standards and all will work seamlessly together to give you a highly efficient and reliable solution for protecting your boiler system. To learn more, please call or visit us online at cleaverbrooks.com.

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Printed in the USA

CB-8500
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CleaverBrooks

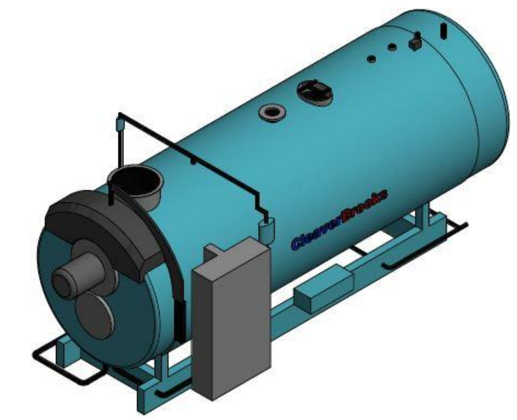
Dimensions & Ratings

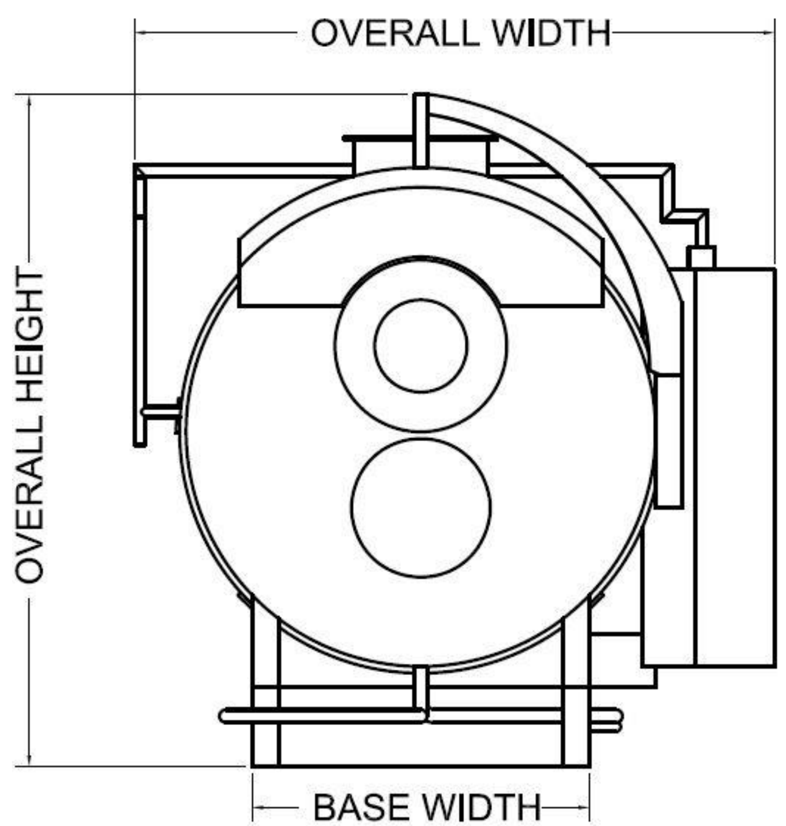
Models: CBEX Dryback Elite-200-(250 to 800)-150ST

Date Revised: September 21, 2017

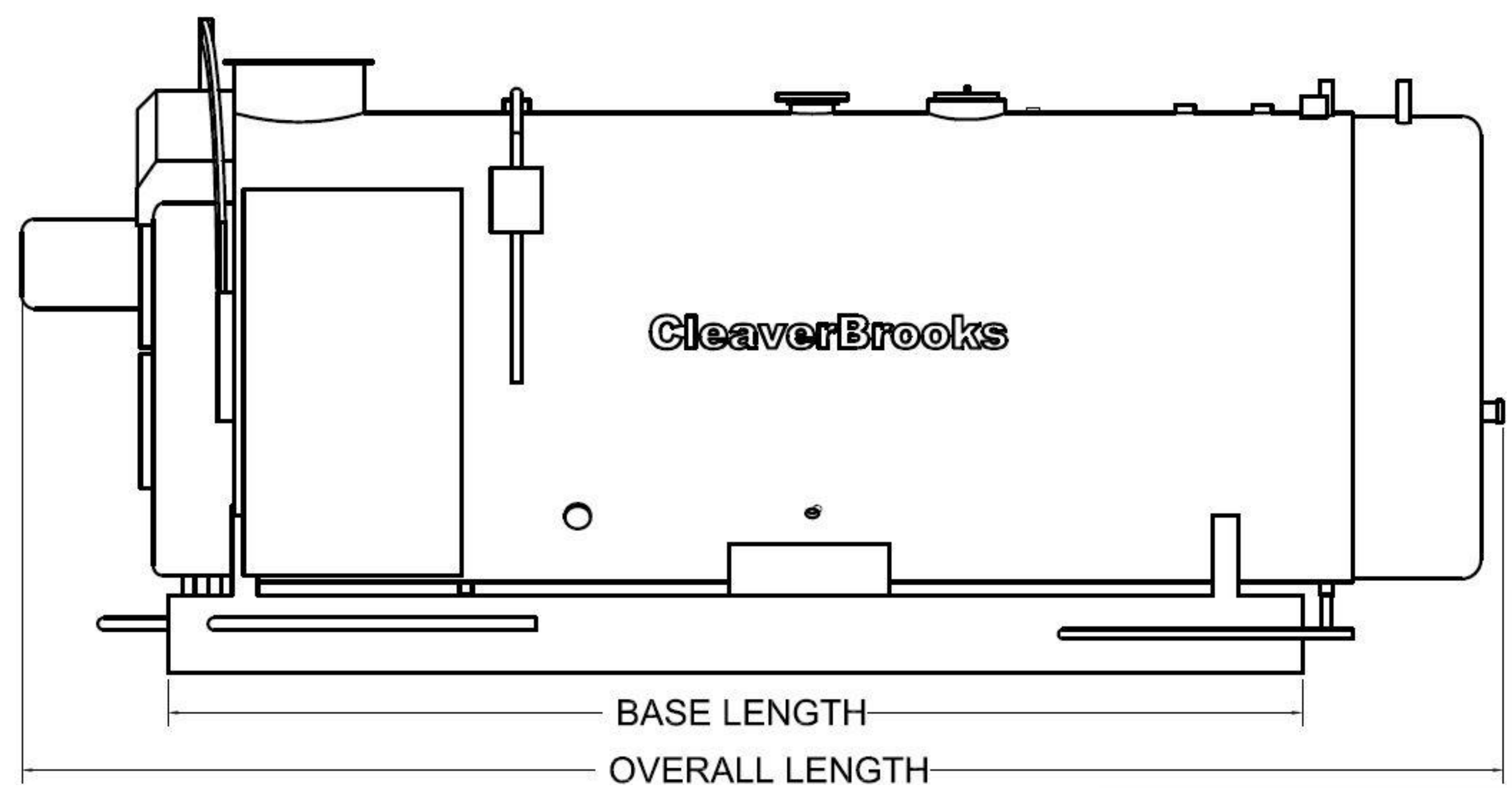
APPLICATION DATA – Model: CBEX Dryback Elite **| Fuel Series:** 200 **| Design Pressure:** 150 psi Steam **| Operating Pressure:** 125 psi **| System Voltage:** 460/3/60 **| NOx Emissions Level:** 30ppm **| Feedwater Temperature:** 212°F **| Elevation:** 700 ft ASL

Boiler Horsepower:	250	300	350	400	500	600	700	800
Dimensions [in.]								
Overall Height:	103	103	103	115	118	118	118	118
Overall Width:	93.5	93.5	93.5	104	110	110	110.5	110.5
Overall Length:	230.5	241.5	253.5	259	261	288.5	290.5	300
Base Width:	51	51	51	64	60	60	60	60
Base Length:	176.5	185.5	195.5	200.5	196.5	221.5	223.5	232.5
Power Ratings								
Output Capacity [MBtu/hr]:	8,369	10,043	11,716	13,390	16,738	20,085	23,433	26,780
Blower Motor [HP]:	15	20	30	25	30	50	50	75
Oil Pump Motor (No. 2 Oil) [HP]:	1/2	3/4	3/4	3/4	3/4	3/4	1	1
Air Compressor Motor (Oil Firing) [HP]:	5	5	5	5	7.5	7.5	7.5	7.5
Fuel Consumption Ratings (Approx.)								
Light Oil (140 MBtu/gal.) [gph]:	73	87.5	102	116.5	146	175	204	233
Natural Gas (1 MBtu) [cfh]:	10,206	12,247	14,288	16,329	20,412	24,494	28,576	32,659
Weights [lb]								
Shipping Weight (Approx.):	17,960	18,540	23,970	24,710	29,300	30,900	38,500	39,450
Flooded Total Weight:	32,260	33,510	46,920	48,110	55,250	58,780	71,500	73,450
Operating Weight:	17,200	18,070	20,530	22,960	29,580	30,730	43,310	44,360





FRONT VIEW



RIGHT SIDE VIEW

NOTE: All dimensions are approximate. Product data may vary based on application. Contact your local Cleaver-Brooks representative for additional information.

HIGH EFFICIENCY COMMERCIAL CONDENSING BOILERS

KNIGHT® COMMERCIAL BOILER XL

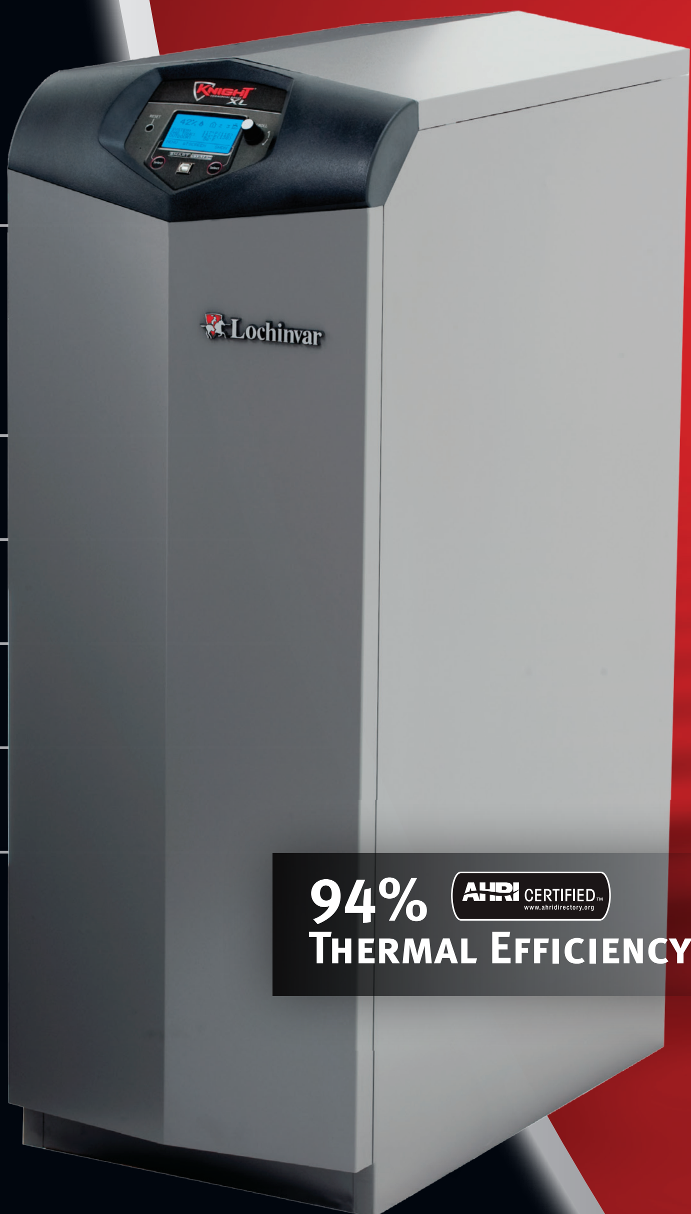
SMART SYSTEM
OPERATING CONTROL FEATURING
A BUILT-IN CASCADING SEQUENCER

5 MODELS: 399,000 – 800,000 BTU/HR

5:1 TURNDOWN RATIO

LESS THAN 20 ppm NOx

DIRECT VENT FLEXIBILITY TO 100 FEET



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THERMAL EFFICIENCY

Lochinvar®
HIGH EFFICIENCY BOILERS & WATER HEATERS

DESIGNED ★ ENGINEERED ★ ASSEMBLED
USA

Lochinvar.com

KNIGHT® COMMERCIAL BOILER XL

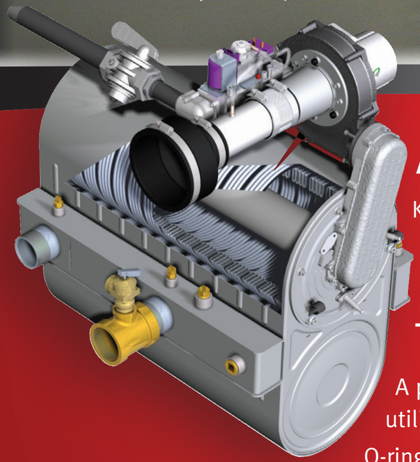
The Smartest Choice for Condensing Boiler Performance

The KNIGHT® XL, engineered with Lochinvar's exclusive SMART SYSTEM™ control and an array of other innovative features, places it far ahead of any commercial heating boiler in its class. It promises and delivers ultimate ease of installation and maintenance. With up to 94.6% thermal efficiency, low-NOx emissions and a fully modulating burner, it is the best "green choice" for today's environmentally focused market.

Five modulating/condensing stainless steel KNIGHT XL boilers are available with 399,000–800,000 Btu/hr inputs and remarkably small space-saving footprints. All are equipped for direct-vent installation with air intake and exhaust runs up to 100 feet using PVC, CPVC, Polypropylene or AL29-4C vent materials. This range of choices is ideal for light-duty applications such as small hotels, schools and office buildings. For higher-demand applications, up to eight KNIGHT XL units can be installed utilizing the built-in cascading sequencer to deliver up to 6.4 million Btu/hr heating capacity.

THE KNIGHT XL BOILER reflects Lochinvar's constant commitment to providing all the options you need to serve every application.

KNIGHT XLs installed and commissioned by Black & McDonald



Advanced Negative Regulation Technology

KNIGHT XL safely and reliably operates with supply gas pressure as low as 4 inches water column. Negative Regulation (Neg/Reg) technology automatically adjusts fan speed that ensures the correct volume and mix of fuel and air throughout the firing range.

Two-in-One Stainless Steel Heat Exchanger

A primary heat exchanger combined with a secondary heat exchanger captures flue gas heat and condenses to utilize available latent energy. The stainless steel, pH-tolerant design features a weld-sealed assembly with no O-rings or gaskets and does not require special glycol. ASME Section IV approved and stamped.

Fully Modulating Burner

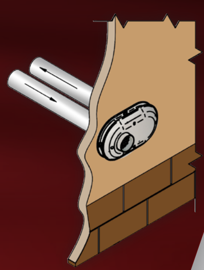
The SMART SYSTEM allows fully modulating combustion with 5:1 turndown. The burner can fire as low as 20% of maximum input and modulates the firing rate up to 100% as demand increases. The burner is a single stainless steel assembly covered with woven steel mesh and fires in a 360° pattern along the entire length of the primary heat exchanger. This allows the compact KNIGHT XL to exceed the capacity of units with larger multiple burners.

Direct Venting up to 100 Feet

Sidewall Vent Termination

KNIGHT XL offers 7 venting options and tremendous flexibility for placement of units within the building, because it permits direct-vent air intake and exhaust runs up to 100 equivalent feet using either PVC, CPVC, Polypropylene or AL29-4C stainless steel vent pipe. A sidewall vent termination kit is shipped standard with every KNIGHT boiler.

Sidewall Vent Termination



SMART SYSTEM™ — Lochinvar

Refined Design Puts More Control and Information at your Fingertips

Advanced features include:

- Multi-Color Graphic LCD Display
- Navigation Dial
- USB Port
- Ability to control up to three different setpoint temperatures
- Compatibility with Copper-Fin II Non-Condensing Boiler to Create a Front-End Loading System
- Boilers with Different Inputs can be Cascaded Together to Maximize Boiler Plant Turndown
- Modbus Capability (Optional)
- DHW Modulation Limiting
- DHW Night Setback*
- 0-10 VDC Boiler Rate Output
- 0-10 VDC Signal to control variable speed boiler pump*
- 0-10 VDC System Pump Signal Input*
- Heat Demand from 0-10V Input
- Installer Can Program Name and Number into the Boiler
- Installer Adjustable Freeze Protection Parameters
- Separately adjustable SH/DHW Switching times*
- Installer access to BMS and ramp delay settings

**Exclusive to Lochinvar Smart System*

At-a-Glance Color Coding

Blue Screen
Normal system operation.

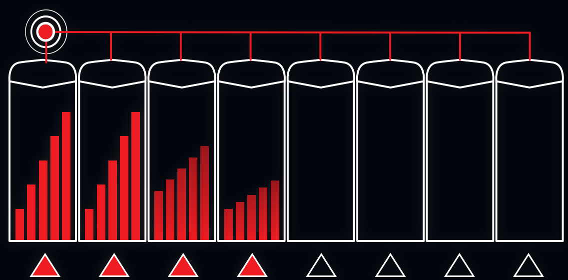
Yellow Screen
Maintenance due - shows the installer's name and number on the display.

Red Screen
Lockout mode.

New Selectable Cascade Options

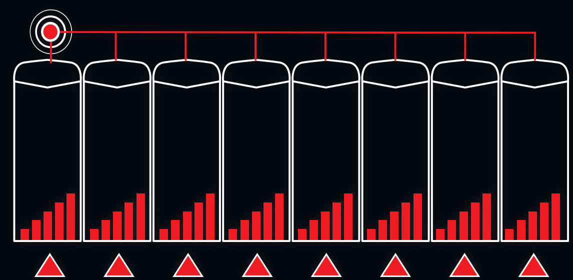
When multiple KNIGHT boilers are installed together, the SMART SYSTEM built-in sequencer can be set for "Lead-Lag" cascade or "Efficiency Optimized" cascade operation.

Lead-Lag Cascade



The "lead" boiler modulates with demand to capacity. As demand increases, additional boilers fire and modulate to capacity. This continues, with additional boilers firing and modulating to capacity until all units are operating. Every 24 hours, the SMART SYSTEM automatically shifts the lead boiler role to the next in the sequence, distributing lead-lag runtimes equally.

Efficiency Optimized Cascade

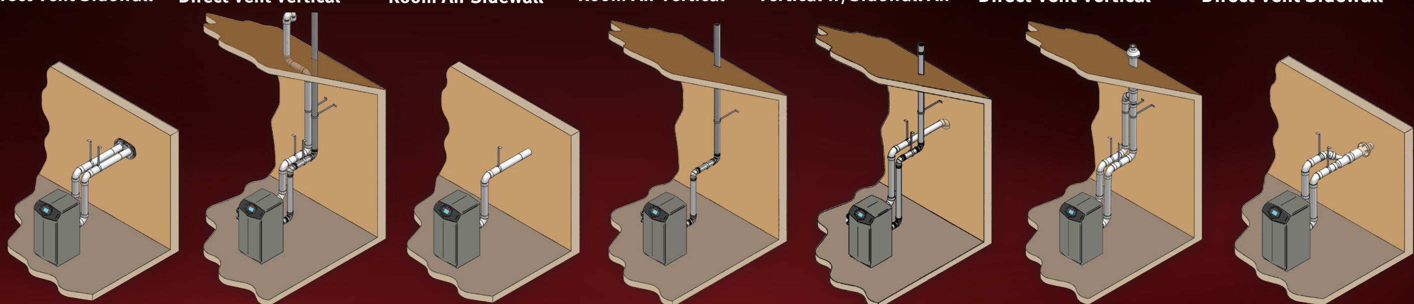


This feature optimizes the modulation capabilities of the Boiler Plant while evenly distributing run time across all cascaded boilers. Every 24 hours the SMART SYSTEM automatically shifts the 1st boiler on role to the next in the sequence, distributing run time equally.

SMART SYSTEM Cascade option allows 2 - 8 boilers to be sequenced.

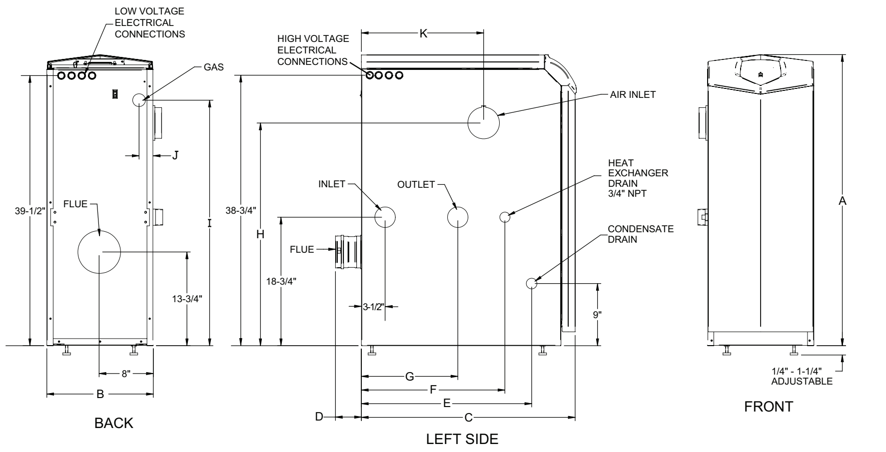
7 Flexible Venting Options

Direct Vent Sidewall | **Direct Vent Vertical** | **Room Air Sidewall** | **Room Air Vertical** | **Vertical w/Sidewall Air** | **Direct Vent Vertical*** | **Direct Vent Sidewall***



**Optional Concentric Vent Kit Sold Separately (for 400-601 Models)*

Knight® XL Boiler Dimensions and Specifications



Model Number Guide

KB — Model
N — Natural Gas
701 — Btu/hr Input
M13 — Firing Controls

Knight XL ***B****oiler,*
N*atural Gas,*
700*,000 Btu/hr input,*
M13 *firing controls*

Knight XL Heating Boiler						Dimensions and Specifications															
Model Number	Input Min MBH	Input Max MBH	Thermal Efficiency	Output MBH	Net AHRI Rating MBH	A	B	C	D	E	F	G	H	I	J	K	Gas Conn.	Water Conn.	Air Inlet	Vent Size	Shipping Wt. (lbs.)
KBN400	80	399	94.0%	376	327	42-1/2"	15-1/2"	27-3/4"	3-3/4"	20-3/4"	21"	14"	34"	34"	2"	18-3/4"	1"	1-1/2"	4"	4"	280
KBN501	100	500	94.0%	470	409	42-1/2"	15-1/2"	31-1/2"	3-3/4"	25-1/2"	21"	14"	32-1/2"	36"	2"	18"	1"	1-1/2"	4"	4"	310
KBN601	120	600	94.0%	564	490	42-1/2"	15-1/2"	36-1/4"	3-3/4"	25"	21"	14"	36"	32-3/4"	5-1/2"	19-1/2"	1"	2"	4"	4"	340
KBN701	140	700	94.0%	658	572	42-1/2"	15-1/2"	40-1/4"	3-3/4"	29"	23"	17"	36"	32-3/4"	3-1/4"	23-1/2"	1"	2"	4"	6"	370
KBN801	160	800	94.0%	752	654	42-1/2"	15-1/2"	45-1/4"	3-3/4"	33-1/4"	23"	17"	36"	32-3/4"	3-1/4"	27-3/4"	1"	2"	4"	6"	405

Notes: Indoor installation only. All information subject to change. Change "N" to "L" for LP gas models.

Standard Features

- **94% Thermal Efficiency**
- **Modulating Burner with 5:1 Turndown**
  - Direct-Spark Ignition
  - Low NOx Operation
  - Sealed Combustion
  - Low Gas Pressure Operation
- **ASME Stainless Steel Heat Exchanger**
  - ASME Certified, "H" Stamped
  - Gasketless Heat Exchanger
  - 160 psi Working Pressure
  - 50 psi ASME Relief Valve
  - Highly efficient, condensing design
- **Vertical & Horizontal Direct-Vent**
  - Category IV venting up to 100 feet
  - PVC, CPVC, Polypropylene or AL29-4C Venting up to 100 Feet
  - Factory Supplied Sidewall Vent Termination
- **Smart System Control**
- **Other Features**
  - On/Off Switch
  - Adjustable High Limit w/ Manual Reset
  - Automatic Reset High Limit
  - Flow Switch
  - Flue Temperature Sensor
  - Low Air Pressure Switch
  - Temperature & Pressure Gauge
  - Adjustable Leveling Legs
  - Condensate Trap
  - Zero Clearances to Combustible Material
  - 10 Year Limited Warranty (See Warranty)

Firing Codes

M9	Standard Construction
M7	California Code
M13	CSD1 / FM / GE Gap (KB501-KB801)

Smart System Features

- **SMART SYSTEM Digital Operating Control**
  - Multi-Color Graphic LCD Display w/ Navigation Dial
- **Three Reset Temperature Inputs with curves for three set point temperature inputs**
- **Built in Cascading Sequencer for up to 8 Boilers**
  - Multiple Size Boiler Cascade
  - Front end loading capability with Copper Fin II
  - Lead Lag
  - Efficiency Optimization
- **Outdoor Reset Control with Outdoor Air Sensor**
- **Programmable System Efficiency Optimizers**
  - Night Setback
  - DHW Night Setback
  - Anti-Cycling
  - Outdoor Air Reset Curve
  - Ramp Delay
  - Boost Temperature & Time
- **Three Pump Control**
  - System Pump With Parameter for Continuous Operation
  - Boiler Pump With Variable Speed Pump Control*
  - Domestic Hot Water Pump
- **Domestic Hot Water Prioritization**
  - DHW tank piped with priority in the boiler loop
  - DHW tank piped as a zone in the system with the pumps controlled by the Smart System
  - DHW Modulation Limiting
  - Separately Adjustable SH/DHW Switching Times*
- **Building Management System Integration**
  - 0-10 VDC Input to Control Modulation or Set Point
  - 0-10 VDC Input Signal from Variable Speed System Pump*
  - 0-10 VDC Modulation Rate Output
  - 0-10 VDC Input to Enable/Disable call for heat
  - Access to BMS Settings through Display
- **High Voltage Terminal Strip**
  - 120 VAC / 60 Hertz / 1 Phase Power Supply
  - Three sets of Pump Contacts with Pump Relays
- **Low Voltage Terminal Strip**
  - 24 VAC Device Relay
  - Proving Switch Contacts
  - Flow Switch Contacts
  - Alarm on Any Failure Contacts
  - Runtime Contacts
  - DHW Thermostat Contacts
  - 3 Space Heat Thermostat Contacts
  - System Sensor Contacts
  - DHW Tank Sensor Contacts
  - Outdoor Air Sensor Contacts
  - Cascade Contacts
  - 0-10 VDC BMS External Control Contact
  - 0-10 VDC Boiler Rate Output Contacts
  - 0-10 VDC Variable Speed System Pump Signal Input
  - 0-10 VDC Signal to Control Variable Speed Boiler Pump
  - Modbus Contacts
- **Time Clock**
- **Data Logging**
  - Hours Running, Space Heating
  - Hours Running, Domestic Hot Water
  - Ignition Attempts
  - Last 10 Lockouts
- **Other Features**
  - Low Water Flow Safety Control & Indication
  - Password Security
  - Inlet & Outlet Temperature Readout
  - Customizable Freeze Protection Parameters
  - Custom Maintenance Reminder with Contractor Info

**Exclusive feature, available only from Lochinvar*

Optional Equipment

- Alarm Bell
- Condensate Neutralization Kit
- Concentric Vent Kit (KB400-KB601)
- BMS Gateway to LON or BacNet
- High & Low Gas Pressure Switches w/ Manual Reset (KB501-KB801)
- Variable Speed Boiler Circulation Pump
- MODBUS Communication
- Multi Temperature Loop Control
- Low Water Cutoff w/Manual Reset & Test
- Constant Speed Boiler Circulation Pump
- Stainless Steel Vent Kits (KB701-KB801)
- Stack Frame

Lochinvar®
HIGH EFFICIENCY BOILERS & WATER HEATERS

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MIURA

MIURA'S LX SERIES
ON DEMAND STEAM BOILERS

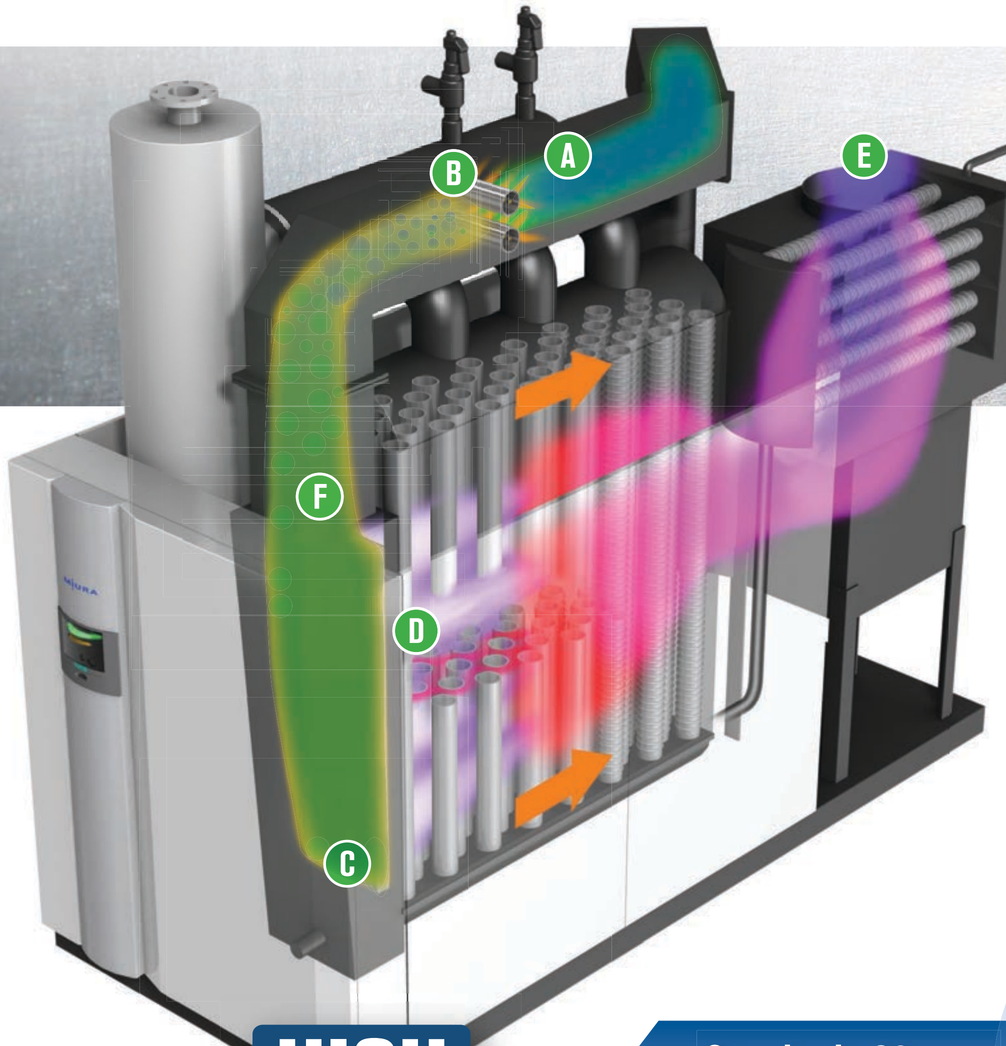
LOW NOx & HIGH EFFICIENCY

LX SERIES

Newly Redesigned

UNIQUE COMBUSTION

Although conventional wisdom state that a pressure vessel with the largest surface area will be the most efficient, this does not hold true for MIURA's unique boiler design. MIURA's proprietary burner is specifically designed for each pressure vessel resulting in optimal performance. Natural gas and propane burn very cleanly and as a result we can forgo conventional wisdom shying away from flame impingement. By spreading the flame **directly onto the water tubes**, this greatly reduces the flame temperature resulting in **higher efficiency** and **lower NOx** (without the need for gas re-circulation). In addition, each pressure vessel includes fin tubes that increases the surface area and turbulent flow to the maximum heat transfer. Most importantly, each tube has been designed to provide optimum protection against thermal shock.



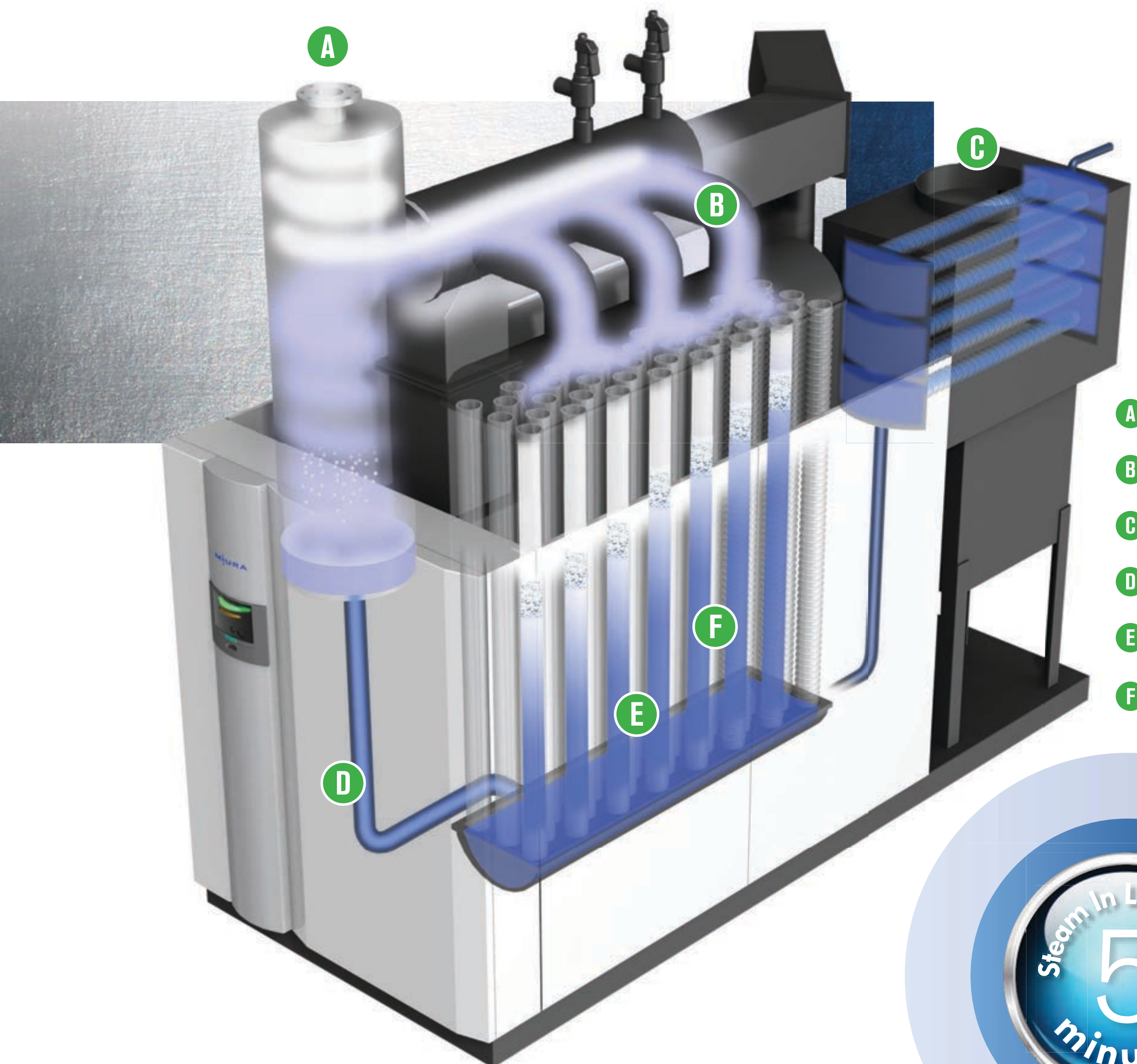
- **A** Combustion Air
- **B** Natural Gas
- **C** Metal Burner
- **D** Burner Flame
- **E** Exhaust Gas
- **F** PRE-MIX GAS and AIR

HIGH EFFICIENCY

Standard 20ppm
Optional 9ppm!

INHERENT SAFETY

The **low water content** in the LX boiler design also contributes to a much safer boiler design. Because the interior is multiple tubes sandwiched together instead of one large vessel, failure is substantially less catastrophic. With well over 140,000 boilers in service, there has never been a fatality associated with a MIURA boiler failure.



- **A** Dry Steam
- **B** Wet Steam
- **C** Economizer
- **D** Return Water
- **E** Smooth Water Tubes
- **F** Finned Water Tubes

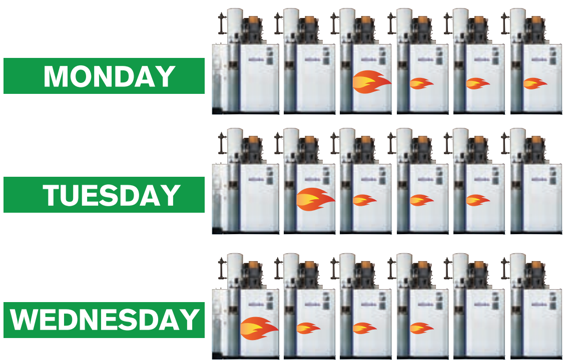
PREMIER DESIGN

Because of their low water content and exclusive "floating header" design, MIURA LX Boilers produce steam in less than 5 minutes. This quick cycle not only helps you get to work faster, but also use substantially less gas. The small footprint occupies 50% less floor space than typical firetubes, with no need for tube space. Double your capacity in the same space, or reduce space requirements by half for new construction. And best of all, MIURA's premier design results in fuel-to-steam efficiencies of up to 87%.

M.I. CONTROL STEAM OPS

The secret behind our industry-leading energy management system is the Multiple Installation controller (M.I.). This controller constantly monitors all the boilers in the system for performance and changes in demand.

Combustion Rotation Function



The controller automatically brings boilers on line, regulates outputs of other units, or switches off boilers as needed.

ADDITIONAL FEATURES

Central Monitoring:
Boilers, MW Water Softeners, Colormetry, Steam Header Pressure, Feed Water System, and Chemical Pump monitoring

Five Programmable Control Patterns:
Applications: Summer load vs winter load, night setback, batch load vs heating load, high/low pressure applications.

Pattern Selection Method: Touch screen, remote input, or weekly schedule

Response Optimization: Efficiency vs quick response.

Remote Inputs: External contact input signals for pattern switching, system-wide halt, manual control, and system-wide standby.

SIDE-BY-SIDE CAPABILITY

With our innovative M.I. system, you can build an on-demand steam plant customized to meet your specific demand needs. The M.I. system provides the flexibility to build to current steam loads within very tight tolerances while allowing easier future expansion of system capacity. The multiple modular units also enhance a facility's energy management capability by providing higher efficiency during part-load/standby conditions via the M.I. system's ability to stage multiple units on or off in response to demand fluctuations.

SPACE SAVINGS
SOLUTIONS

MIURA'S unique, compact, modular design utilizes a low water content pressure vessel. The resulting smaller boiler footprint provides design flexibility, reduced construction costs, and more options with existing spaces. In fact, LX models up to 200 horsepower can fit through a standard door-way.

ON-DEMAND
STEAM SOLUTIONS

Would you buy a car that needs to idle all night long or warm up for 90 minutes before you can drive it? Of course not. So why put up with that for your boiler? Because of its low water content design, MIURA boilers produce full steam in less than 5 minutes from a cold startup. This allows it to create steam when you need it and only when you need it, with the highest in-service efficiencies available for industrial boilers.

SAFETY
SOLUTIONS

MIURA has produced boilers since 1959. With over 140,000 units in operation, there has never been a fatal accident. Ever. MIURA boilers inherently safer by design. With low water content combined with the unique boiler geometry, catastrophic vessel failure is practically impossible. MIURA boilers also have numerous safeguards beyond primary vessel safety to ensure not only safe operations, but also high efficiency and reliable operation.

EMISSION
SOLUTIONS

MIURA is the leader in high efficient, low NOx technology. In addition to the N+1 solution, the LX model does not rely on flue gas recirculation, maintaining efficiencies even down to 9 ppm of NOx at 3% corrected O2.

MIURA's burner technology results in an average flame temperature of less than 2,200 F without fear of any backfire, common with other technologies.

TURN-KEY STEAM
SOLUTIONS

MIURA can provide the total turn-key solution for your operations — from the boiler, to chemicals, water softeners, hotwell/deaerators, steam headers, chimneys — everything you need for a one source system. MIURA is the only steam manufacturer that can partner with you for a comprehensive online maintenance system and total pressure vessel warranties against workmanship and water treatment issues.

FLEXIBLE INSTALLATION
SOLUTIONS

By the nature of the modular approach, a MIURA system is inherently much more flexible than a comparably sized traditional boiler room solution. Because of their compact size and compatibility, it's easy to add or subtract boilers as needs increase or decrease.

N+1
SOLUTIONS

As compared to the "two boiler system," where one large boiler carries the load and the second large boiler acts as a backup, MIURA uses small units in a modular design to function as one large steam system. Therefore, one smaller unit provides N + 1 backup, allowing the reduction of total system horsepower. As an added bonus, MIURA can reduce construction space by half or double the output in the same space.

LX SERIES SPECIFICATIONS

		Boiler Horsepower	Equivalent Output (lbs/hr)[ii]	Heat Input (BTU/hr)	Heat Output (BTU/hr)	Fuel-to-Steam Efficiency [iii]	NOx Ratings (ppm)[iv]
15 PSI	LXL- 50 SG	50	1,725	1,970,000	1,674,000	85%	20
15 PSI	LXL- 100 SG	100	3,450	3,939,000	3,348,000	85%	9
15 PSI	LXL- 150 SG	150	5,175	5,908,000	5,022,000	85%	9
15 PSI	LXL- 200 SG	200	6,900	7,877,000	6,695,000	85%	9
170 PSI	LX- 50 SG	50[i]	1,725	1,970,000	1,674,000	85%	20
170 PSI	LX- 100 SG	100	3,450	3,939,000	3,348,000	85%	9
170 PSI	LX- 150 SG	150	5,175	5,908,000	5,022,000	85%	9
170 PSI	LX- 200 SG	200	6,900	7,877,000	6,695,000	85%	9
170 PSI	LX- 250 SG	250	8,625	9,620,000	8,369,000	87%	9
170 PSI	LX- 300 SG	300	10,350	11,544,000	10,043,000	87%	9
300 PSI	LXH- 200 SG	200	6,900	7,971,000	6,695,000	84%	12
300 PSI	LXH- 250 SG	250	8,625	9,732,000	8,369,000	86%	12
300 PSI	LXH- 300 SG	300	10,350	11,678,000	10,043,000	86%	12

Notes: i) 50 HP model falls below 2,000,000 BTU/HR Requirements for certain jurisdictions.
ii) Equivalent Output calculated from 212°F feed water at 212°F steam
iii) Fuel-to-Steam Efficiencies based on 68°F feed water
iv) 20 ppm standard, lower is optional. Based on natural gas combustion

Additional Notes: 1) All boiler assemblies are UL and c-UL approved for natural gas or propane
2) All boilers are built to meet or exceed UL and ASME standards in the U.S.A.; c-UL & B-51 standards in Canada
3) Please see www.miuraboiler.com for complete boiler specifications and size information

MIURA

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