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Evaluation of Boiler Plant Energy Conservation Opportunities at Fort Hood, Texas

A Study for the Army Model Energy Installation Program

by
Thomas E. Durbin and Alan T. Chalifoux

Executive Order (EO) 12902 requires that by 2005 the Federal Government—including all U.S. Army installations—reduce energy consumption by 30 percent as measured against energy consumption in the baseline year of 1985. To help the Army meet the goals of EO 12902, the U.S. Army Construction Engineering Research Laboratories (USACERL) conceived of the Model Energy Installation Program (MEIP), a 5-year pilot project to investigate the feasibility of instituting energy efficiency on a basewide scale.

As part of MEIP, USACERL surveyed the large boiler plants at Fort Hood, TX, to identify energy conservation opportunities (ECOs). The study found numerous opportunities to save energy. Most opportunities consisted of minor repiping, installation of new ancillary equipment, and installation of new, modulating-type burners. The total estimated cost to install all ECOs and address all safety issues is approximately $968,050. The estimated overall natural gas savings is 25 percent per year, or 85,350 x 10^6 Btu per year. At a natural gas price of $3.93 per 1 x 10^6 Btu, the net savings are calculated to be $283,425, with an estimated simple payback period of 3.42 years.

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Executive Order (EO) 12902 requires that by 2005 the Federal Government including all U.S. Army installations reduce energy consumption by 30 percent as measured against energy consumption in the baseline year of 1985. To help the Army meet the goals of EO 12902, the U.S. Army Construction Engineering Research Laboratories (USACERL) conceived of the Model Energy Installation Program (MEIP), a 5-year pilot project to investigate the feasibility of instituting energy efficiency on a basewide scale.

As part of MEIP, USACERL surveyed the large boiler plants at Fort Hood, TX, to identify energy conservation opportunities (ECOs). The study found numerous opportunities to save energy. Most opportunities consisted of minor repiping, installation of new ancillary equipment, and installation of new, modulating-type burners. The total estimated cost to install all ECOs and address all safety issues is approximately $968,050. The estimated overall natural gas savings is 25 percent per year, or 85,350 x 106 Btu per year. At a natural gas price of $3.93 per 1 x 106 Btu, the net savings are calculated to be $283,425, with an estimated simple payback period of 3.42 years.

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Foreword

This work was conducted for Headquarters, U.S. Army III Corps and Fort Hood with funding by the Strategic Environmental Research and Development Program (SERDP) through a Funding Authorization Document (FAD) dated September 1992. Public Law 101-510 established SERDP as a multiagency program funded through the Department of Defense (DoD) to identify, develop, and demonstrate technologies in the areas of pollution prevention and cleanup, energy and resource conservation, and global environmental change. SERDP responds to the environmental requirements of the DoD and is undertaken in cooperation with other government agencies, including the Department of Energy, the National Institute of Standards and Technology, the National Oceanographic and Atmospheric Administration, the National Institutes of Health, the U.S. Geological Survey, and the National Aeronautics and Space Administration). The technical monitor for this project was Bobby Lynn, AFZF-DE-ENV.

The work was performed by Charles Schmidt and Sean Johnson of Schmidt Associates, Inc., Cleveland, OH, under the supervision of the Facilities Technology Laboratory (FL) and the Utilities and Industrial Operations Laboratory, UL), U.S. Army Construction Engineering Research Laboratories (USACERL). The Principal Investigators were Alan T. Chalifoux (CECER-FL-E) and Thomas E. Durbin (CECER-UL-U). Dr. Alan W. Moore is Acting Chief and Donald F. Fournier is Acting Operations Chief, CECER-FL; Gary W. Schanche is Chief and John T. Bandy is Operations Chief, CECER-UL. The USACERL technical editor was Gordon L. Cohen, Technical Information Team (TR-I).

COL James T. Scott is Commander and Acting Director of USACERL, and Dr. Michael J. O'Connor is Technical Director.

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1 Introduction

Background

Executive Order (EO) 12902 requires that by 2005 the Federal Government—including all U.S. Army installations—reduce energy consumption by 30 percent of consumption as measured in the baseline year of 1985. In the past, energy efficiency has been practiced on a building-by-building scale. While this approach has achieved many successes on a very small scale, it is clear that energy efficiency must be addressed on a systemic level to achieve on schedule the kind of savings required by EO 12902.

To help the Army meet the goals of EO 12902, the U.S. Army Construction Engineering Research Laboratories (USACERL) conceived of the Model Energy Installation Program (MEIP), a 5-year pilot project to investigate the feasibility of building energy efficiency into an installation on a basewide scale. MEIP is intended to address both a specific real-world goal and a broader research and development (R&D) goal:

- the real-world goal is to meet the mandate of EO 12902 within 5 years at a major Army installation
- the R&D goal is to investigate and solve problems unique to implementing energy efficiency on a basewide scale so the process and savings can be repeated at other installations.

Fort Hood, TX, was selected as USACERL's partner in the MEIP initiative. Fort Hood is located in central Texas, about 70 miles north of Austin. The installation has a daytime population of approximately 65,000, which shrinks to about 40,000 at night. Its building stock is diverse and covers approximately 25.5 million sq ft, 8.5 million of which consists of family housing. Fort Hood's utility bills in Fiscal Year (FY) 1993 were $16 million for electricity and $5 million for natural gas.

In 1991, the Fort Worth Army Engineer District commissioned Romine, Romine, and Burgess, Inc. (called "Romine" in this report) to produce an Energy Engineering Analysis Program (EEAP) study. As part of that work Romine studied energy conservation opportunities (ECOs) in 19 major boiler plants at Fort Hood. As part of MEIP, USACERL contracted Schmidt Associates, Inc. (called "Schmidt" in this report), to revisit the earlier EEAP findings, identify current ECOs, and produce an economic analysis for each. ECOs are exploited either through equipment retrofit or improved maintenance and management procedures.

Objective

The objective of this phase of MEIP was to evaluate the findings of the EEAP study for 19 major Fort Hood boiler plants, identify ECOs to help meet the goals set by EO 12902, and produce a timely, defensible economic analysis to project energy and cost savings.

Approach

No sophisticated computer simulations were required to meet the objective of this study because estimates were needed only for first cost and simple payback. It was possible to develop defensible projections by relying on field inspection data coupled with the contractor's expertise in engineering and economic analysis. Simple and easily documented calculations were used, and the contractor's assumptions were governed to ensure conservative projections for ECO-related savings.

A boiler inspection team comprising personnel from USACERL and Schmidt visually inspected each boiler and ran a performance test. The performance test included readings for oxygen (O_2), carbon monoxide (CO), and combustion efficiency. The boiler inspection team also examined boiler casings, gas trains, safety devices, and burner controls for signs of leakage or explosion hazards. Boiler feedwater systems, condensate return systems, and steam-distribution systems were also inspected. Samples of typical boiler data sheets, as shown in Appendix A, illustrate the type of field documentation produced.

Using these field data, the team recommended retrofits and produced an economic analysis of each. Schmidt also produced a complete flow diagram for each plant, based on drawings made during the site visits. Appendix B includes a sample.

The method used to estimate the current energy consumption of each boiler should be noted. Baseline energy consumption for each boiler was assumed to equal the firing of the boiler at 25 percent full rate for the entire heating season. Following on that assumption, savings were projected for each ECO based on the contractor's engineering experience. Metered data were available from only two of the boiler plants studied—Building 87018 and Building 36000. USACERL used these metered data to verify the contractor's energy-consumption assumption for those boilers. The verification calculation and results are shown in Appendix C. The contractor's energy-savings results were reviewed by USACERL and verified as reasonable for the types of boilers in place. A summary of the energy and cost-savings projected for all facilities may be found in Appendix D. Appendix E shows three representative retrofit detail diagrams.

Scope

The boiler inspection team provided safety recommendations wherever a potential hazard was found. While safety issues were beyond the explicit scope of this work, safety factors are critical matters for attention during any kind of boiler inspection. Consequently, the team's safety recommendations are documented along with its other findings.

It must be noted that resourcing the recommended improvements is beyond the scope of this work. Some recommendations imply that a number of boiler efficiency factors might best be addressed by routine visual inspection or adjustment, but it is understood that the Fort Hood Directorate of Public Works (DPW) operates under typical resource and staffing constraints. Therefore, the DPW will have to prioritize the recommendations to achieve safety and economy goals within the resourcing constraints.

Metric Conversion Factors

U.S. standard units of measure are used in this report. The table below provides conversion factors for standard international units.

1 in.	=	25.4 mm
1 ft	=	0.305 m
1 sq ft	=	0.093 m^2
1 cu ft	=	0.028 m^3
1 mi	=	1.61 km
1 lb	=	0.453 kg
1 gal	=	3.78 L
1 psi	=	6.89 kPa
°F	=	(°C × 1.8) +32

2 Boiler Plant Evaluations

Building 14020

Building 14020 needs water treatment. This water treatment should add cold zeolites to remove hardness from the makeup water, and it should add dealkalizers to the boiler feedwater to balance the pH. The cost to furnish and install the water treatment equipment is approximately $6,000. Fort Hood should hire an outside contractor to maintain and evaluate the equipment performance. This will incur an annual cost of approximately $3,000. By adding the water treatment equipment, boiler life should be extended approximately 10 years and heat transfer should be improved (due to decreased scale buildup on the tube), yielding approximately 10 percent natural gas savings per year.

There is one Burnham fire-box steam boiler (3.210 MMBtu/Hr) equipped with a Webster burner in this building. The boiler and burner are relatively new; however, the burner control is an ON/OFF only control, with a manually set firing rate. The burner controls should be retrofitted with new automatic controls modulating around a set steam pressure. This would allow the burner to remain on at lower firing rates, following the steam load demand instead of cycling off and on at 4-minute intervals. This would greatly decrease residual heat loss in the boiler during the purge and post-purge burner cycles. This heat loss is due to heat transfer from the boiler to the cool air that is forced through the furnace and out the stack during purge. The cost to retrofit the burner controls, linkage and drives is approximately $2,500. The estimated natural gas savings are 15 percent per year.

The air/fuel ratio on this burner must be adjusted. There are high CO readings at all firing rates, varying from 1688 ppm at low fire down to 292 ppm at high fire (150 ppm or less is an acceptable level for all firing rates). The cost of tuning the burner is approximately $1,000. The estimated natural gas savings are approximately 10 percent per year.

This boiler is not equipped with a continuous blowdown (CBD) distribution pipe, rate-set valve or separation tank. The CBD system removes suspended solids over the entire length of the drum. The collection pipe is positioned below the normal water line at the height of the maximum solids concentration. These solids, if not removed, will deposit onto heat transfer surfaces and form scale, which inhibits heat transfer. The cost to furnish and install the suspended solids distribution pipe, rate-set valve, and blowdown separator is approximately $7,000.

A blowdown separator is required to service the CBD and the bottom blowdown (BBD) system. The blowdown separator allows the high-temperature blowdown liquid to flash into steam at atmospheric conditions. The steam is vented to the atmosphere and the remaining liquid is cooled automatically via the addition of potable water to the effluent stream. The cooling of the effluent is required by plumbing codes to prevent deterioration of drain piping which occurs at 140 °F. The cost to furnish and install the blowdown separator is included in the previous CBD system.

The chemical feed system in this building is adequate; however, the amount of chemicals and the time they are added must be modified. Chemicals are being added based upon makeup water flow to the condensate tank. This is a good strategy; however, it must be augmented. If the boiler requires little makeup water, adding chemicals based solely on makeup water flow will not provide sufficient chemical treatment. Chemicals must also be added whenever the boiler feedwater pumps are running. The cost to install this complete system is $1,000. The chemical feed system should also: (1) add an oxygen scavenger chemical, such as sulfite, to prevent interior deterioration of the boiler, as well as (2) add amines to prevent rust and corrosion of the steam and condensate piping.

Several safety issues exist in this building. The first is that there are no reduced pressure principal backflow preventers (See Appendix E, Diagram 1). A backflow preventer is a device which prevents contaminated water (i.e., condensate, chemically treated water, boiler water, chilled water, etc.) from being drawn back into the potable water system. The cost to furnish and install these devices in this building is approximately $3,000.

The second safety issue is the lack of double block and bleed valves on the boiler fuel gas train (See Appendix E, Diagram 2). The fuel gas train should have a block valve, then a bleed valve (which is a vent to the atmosphere), and then another block valve. In the event of a gas leak the bleed valve vents the natural gas to the outside, preventing an explosion. The cost to furnish and install the double block and bleed system is $5,000.

The total cost to install all ECOs and correct safety issues is $25,500, with an estimated savings of 35 percent in natural gas per year. This equates to 2,500 x 10^6 Btu per year. Fort Hood should hire a qualified contractor to maintain the water treatment equipment. The estimated annual cost of this contract is $3,000. Proper water treatment will result in extended boiler and piping life; boiler maintenance should also decrease. The estimated simple payback of instituting all of the above ECOs and safety fixes is 3.74 years, based on Fort Hood's natural gas price of $3.93 per 1×10^6 Btu.

Building 21002

Building 21002 needs water treatment. This water treatment should add cold zeolites to remove hardness from the makeup water, and it should add dealkalizers to the boiler feedwater to balance the pH. The cost to furnish and install the water treatment equipment is approximately $6,000. Fort Hood should hire an outside contractor to maintain and evaluate the equipment performance. This will incur an annual cost of approximately $3,000. By adding the water treatment equipment, boiler life should be extended approximately 10 years and heat transfer should be improved (due to decreased scale buildup on the tube), yielding approximately 10 percent natural gas savings per year.

There are two boilers in this building. Boiler 1 is a Burnham miniature water-tube steam boiler (4.712 MMBtu/Hr) with a Power Flame burner, and Boiler 2 is a York-Shipley fire-tube steam boiler (4.184 MMBtu/Hr) with a York-Shipley burner. Both burners are relatively old and neither burner is capable of automatic modulation based upon a set steam pressure. Burner 1 is strictly an ON/OFF and Burner 2 appears to be HIGH/LOW/OFF. Both burners should be replaced with new burners equipped with automatic modulating controls. This would then allow the burners to follow the steam load demand instead of cycling off and on, eliminating residual heat loss in the boiler during the purge and post-purge burner cycles. This heat loss is due to heat transfer from the boiler to the cool air being forced through the boiler and out the stack. The cost to furnish and install two new burners is $25,000. The estimated natural gas savings are 20 percent per year due to the reduction in the number of start-ups and by not allowing the boilers to cool down during purge cycles.

Neither boiler is equipped with a CBD distribution pipe, rate-set valve, or separation tank. The CBD system removes suspended solids over the entire length of the drum. The collection pipe is positioned below the normal waterline at the height of the maximum solids concentration. These solids, if not removed, will deposit onto heat transfer surfaces and form scale, inhibiting heat transfer. The cost to furnish and install the suspended solids distribution pipe, rate-set valve, and blowdown separator is approximately $7,000.

A blowdown separator is required to service the CBD and the BBD system. The blowdown separator allows the high-temperature blowdown liquid to flash into steam at atmospheric conditions. The steam is vented to the atmosphere and the remaining liquid is cooled automatically via the addition of potable water to the effluent stream. The cooling of the effluent is required by plumbing codes to prevent deterioration of drain piping which occurs at 140 °F. The cost to furnish and install the blowdown separator is included in the previous CBD system.

There is a boiler feedwater problem relative to both storage and pump capacities. The feedwater storage tank, which is also the condensate return tank, is too small due to the fact that a large amount of condensate overflows down the drain during peak steam use periods. A new, larger (300 gallon) elevated tank should be installed at 5' above finished floor (5' AFF). The cost to furnish and install a new tank is $2,000.

The feedwater pumps are undersized. Consequently, the feedwater they deliver to the boiler is insufficient to maintain the water level when the boiler is at maximum firing rate. Eventually, the boiler turns off after reaching the low water safety limit. The feedwater pumps must be sized to overcome all piping and valve pressure drops. Two new feedwater pumps with high-efficiency motors are required to be installed. The cost to furnish and install new pumps and motors is $1,500. The savings is approximately 10 percent in natural gas per year.

Although not a necessity, the installation of a lead/lag panel could be implemented in this building as, most of the time, only one boiler is needed to carry the load. A lead/lag panel would allow one boiler to modulate from low to high fire along with the varying load. If the lead boiler was in high fire position and the steam pressure set point is not satisfied, the lag boiler would come on, increase the pressure, and then go off when the lag pressure requirement is satisfied. The cost to purchase and install the lead/lag panel is approximately $5,000, with an estimated gas savings of 5 percent per year.

The chemical feed system in this building is adequate; however, the amount of chemicals and the time they are added must be modified. Chemicals are being added based upon makeup water flow to the condensate tank. This is a good strategy; however, it must be augmented. If the boiler requires little makeup water, adding chemicals based solely on makeup water flow will not provide sufficient chemical treatment. Chemicals must also be added whenever the boiler feedwater pumps are running. The cost to install this complete system is $1,000. The chemical feed system should also: (1) add an oxygen scavenger chemical, such as sulfite, to prevent interior deterioration of the boiler, as well as (2) add amines to prevent rust and corrosion of the steam and condensate piping.

Several safety issues exist in this building. The first is that there are no reduced pressure principal backflow preventers (Appendix E, Diagram 1). A backflow preventer is a device which prevents contaminated water (i.e., condensate, chemically treated water, boiler water, chilled water, etc.) from being drawn back into the potable water system. The cost to furnish and install these devices in this building is approximately $3,000.

The second safety issue is the lack of a bleed valve on the boiler fuel gas train (Appendix E, Diagram 2). The fuel gas trains have two block valves and no bleed valve (which is a vent to the atmosphere). In the event of a gas leak, the bleed valve vents natural gas to the outside, preventing an explosion. The cost to install a bleed valve is $2,000.

Finally, two condensate legs with trap assemblies are required on the main steam header (Appendix E, Diagram E3). This drip and trap assembly will remove condensate (formed because of heat loss to the environment) from the steam header. This condensate, if not removed, will cause water hammer, eventually leading to pipe fractures and support failures. This condensate should be returned to the condensate return tank. The cost to furnish and install the drip and trap assembly and associated valves, fittings, insulation, and piping is $1,500. The condensate line from the steam header to each boiler should be removed.

The total cost to install all ECOs and correct safety issues is $54,000, with an estimated 45 percent savings in natural gas per year. This equates to 4,500 x 10^6 Btu per year. Fort Hood should hire a qualified contractor to maintain the water treatment equipment. The estimated annual cost of this contract is $3,000. Proper water treatment will result in extended boiler and piping life; boiler maintenance should also decrease. The estimated simple payback of instituting all of the above ECOs and safety fixes is 3.63 years, based on Fort Hood's natural gas price of $3.93 per 1 x 10^6 Btu.

Building 23001

Building 23001 needs water treatment. This water treatment should add cold zeolites to remove hardness from the makeup water, and it should add dealkalizers to the boiler feedwater to balance the pH. The cost to furnish and install the water treatment equipment is approximately $6,000. Fort Hood should hire an outside contractor to maintain and evaluate the equipment performance. This will incur an annual cost of approximately $3,000. By adding the water treatment equipment, boiler life should be extended approximately 10 years and heat transfer should be improved (due to decreased scale buildup on the tube), yielding approximately 10 percent natural gas savings per year.

There are two boilers in this building. Both of these boilers are Burnham fire-box steam boilers (4.712 MMBtu/Hr). Boiler 1 is equipped with a Webster Burner; Boiler 2 is equipped with a Gordon-Piatt burner. The Webster burner appears to be an old burner and not the type which can be automatically modulated around a set steam pressure; therefore, this burner should be replaced with a new burner equipped with automatic modulation controls. This would then allow the burner to follow the steam load demand instead of cycling off and on. This would eliminate a negative efficiency during purge and post-purge cycle because of cold air being shoved through the boiler, cooling the boiler, and losing the warm air up the stack. The cost to purchase and install a new burner is $10,000. The estimated natural gas savings of 10 percent is due to the reduction in the number of start-ups and by not allowing the boilers to cool down during purge cycles.

The Gordon-Piatt burner appears to be relatively new and is an automatic modulating burner with manual potentiometer control; however, the air/fuel ratio on the burner must be adjusted. There are high CO readings at all firing rates, varying from 240 ppm at low fire up to 1514 ppm at high fire (150 ppm or less is an acceptable level at all firing rates.) The cost of tuning the burner is $1,000 and the natural gas savings will be 10 percent per year.

Neither boiler is equipped with a CBD distribution pipe, rate-set valve, or separation tank. The CBD system removes suspended solids over the entire length of the casing. The collection pipe is positioned below the normal waterline at the height of the maximum solids concentration. These solids, if not removed, will deposit onto heat transfer surfaces and form scale, inhibiting heat transfer. The cost to furnish and install the suspended solids distribution pipe, rate-set valve, and blowdown separator is approximately $7,000.

A blowdown separator is required to service the CBD and the BBD system. The blowdown separator allows the high-temperature blowdown liquid to flash into steam at atmospheric conditions. The steam is vented to the atmosphere and the remaining liquid is cooled automatically via the addition of potable water to the effluent stream. The cooling of the effluent is required by plumbing codes to prevent deterioration of drain piping which occurs at 140 °F. The cost to furnish and install the blowdown separator is included in the previous CBD system.

The feedwater storage tank (which is also the condensate return tank) is badly rusted. The vent off the tank has been disconnected, allowing the tank to vent directly into the room. *This is a code violation and must be corrected as, when there is hot condensate, vapor will be vented directly into the room.* A new (300 gallon), elevated (5' AFF) tank should be installed at a cost of $2,000.

The feedwater pumps are in good condition. The pumps are base mounted, independent from the motor (i.e., not close-coupled), which is the proper type of pump for feedwater service.

Although not a necessity, installation of a lead/lag panel could be implemented in this building because, most of the time, only one boiler is needed to carry the load. A lead/lag panel would allow one boiler to modulate from low to high fire along with the varying load. If the lead boiler was in high fire position and the steam pressure kept dropping, the lag boiler would come on, increase the pressure, and then shut off when the pressure requirement is satisfied. The cost to purchase and install the lead/lag panel is approximately $5,000, with an estimated gas savings of 5 percent per year.

The chemical feed system in this building is adequate; however, the amount of chemicals and the time they are added must be modified. Chemicals are being added based upon makeup water flow to the condensate tank. This is a good strategy; however, it must be augmented. If the boiler requires little makeup water, adding chemicals based solely on makeup water flow will not provide sufficient chemical treatment. Chemicals must also be added whenever the boiler feedwater pumps are running. The cost to install this complete system is $1,000. The chemical feed system should also: (1) add an oxygen scavenger chemical, such as sulfite, to prevent interior deterioration of the boiler, as well as (2) add amines to prevent rust and corrosion of the steam and condensate piping.

Several safety issues exist in this building. The first is that there are no reduced pressure principal backflow preventers (Appendix E, Diagram 1). A backflow preventer is a device which prevents contaminated water (i.e., condensate, chemically treated water, boiler water, chilled water, etc.) from being drawn back into the potable water system. The cost to furnish and install these devices in this building is approximately $3,000.

The second safety issue is the lack of a bleed valve on the boiler fuel gas trains (Appendix E, Diagram 2). The fuel gas trains have two block valves but no bleed valve (which is a vent to the atmosphere). In the event of a gas leak, the bleed valve vents natural gas to the outside, preventing an explosion. The cost to install the bleed valve is $2,000.

The third safety issue is that the gas vent from the gas pressure regulator, low gas pressure, and high gas pressure switches on the Boiler 2 fuel train is vented directly into the combustion air intake of Burner 2. This vent should be vented to the atmosphere. The cost to vent to the atmosphere is $1,000.

The fourth safety issue is that neither boiler has its safety-relief valve vented to the atmosphere. The safety-relief valves are vented into the building. Should a safety-relief valve pop, the boiler plant would become filled with steam at a temperature greater than 212 °F. An accumulation of steam at such a temperature would render it almost impossible for a person to see or breathe, due to the displacement of the air by the steam, and has a high probability of causing a fatality.

All safety-relief valves on steam boilers should be vented to the atmosphere. These could be vented out through the wall or through the roof; however, if vented through the roof, drip pan elbows should be used to ensure that no water accumulates on the safety-relief valves, causing failure. The cost to vent the safety-relief valves is $1,500.

Finally, two condensate legs with trap assemblies are required on the main steam header (See Appendix E, Diagram 3). This drip and trap assembly will remove condensate (formed because of heat loss to the environment) from the steam header. This condensate, if not removed, will cause water hammer, eventually leading to pipe fractures and support failures. This condensate should be returned to the condensate return tank. The cost to furnish and install the drip and trap assembly and associated valves, fittings, insulation, and piping is $1,500. The condensate line from the steam header to each boiler should be removed.

The total cost to install all ECOs and correct safety issues is $41,000, with an estimated 35 percent savings in natural gas per year, equating to 3,500 x 10^6 Btu per year. Fort Hood should hire a qualified contractor to maintain the water treatment equipment. The estimated annual cost of this contract is $3000. Proper water treatment will result in extended boiler and piping life; boiler maintenance should also decrease. The estimated simple payback of instituting all of the above ECOs and safety fixes is 3.74 years, based on Fort Hood's natural gas price of $3.93 per 1 x 10^6 Btu.

Building 27004

Building 27004 needs water treatment. This water treatment should add cold zeolites to remove hardness from the makeup water, and it should add dealkalizers to the boiler feedwater to balance the pH. The cost to furnish and install the water treatment equipment is approximately $6,000. Fort Hood should hire an outside contractor to maintain and evaluate the equipment performance. This will incur an annual cost of approximately $3,000. By adding the water treatment equipment, boiler life should be extended approximately 10 years and heat transfer should be improved (due to decreased scale buildup on the tube), yielding approximately 10 percent natural gas savings per year.

This building has two boilers. Both boilers are Kewanee fire-box steam boilers (9.688 MMBtu/Hr) and are equipped with Kewanee burners which are capable of automatic modulation around a set steam pressure with manual potentiometer control.

Boiler 1 is a new boiler with a new burner; however, the air/fuel ratio on this burner must be adjusted. There are high CO readings at lower firing rates varying from 774 ppm at low fire down to 20 ppm at high fire (150 ppm or less is an acceptable level for all firing rates). The cost of tuning the burner is $1,000 and the savings will be 10 percent in natural gas per year.

It should be noted that this boiler shows signs of internal explosions in that both sidewalls are puffed out 1 to 3 in. This again indicates a poor air/fuel ratio.

Boiler 2 is an old boiler and burner. The casing on the boiler has completely rusted through on the lower portion. Both sidewalls are puffed out, indicating internal explosions.

Lying on the floor next to the bottom blowdown is a large pile of scale, up to a quarter of an inch thick. The CO level at minimum firing rate is 400 ppm (150 ppm or less is an acceptable level for all firing rates). Because of the existing condition, the boiler and burner should be removed and a new boiler and burner with automatic modulating controls should be installed. The cost to furnish and install a new boiler and burner is $150,000. The savings in natural gas should be 10 percent per year.

Boiler 2 is not equipped with a CBD distribution pipe or rate-set valve. The CBD system removes suspended solids over the entire length of the casing. The collection pipe is positioned below the normal waterline at the height of the maximum solids concentration. These solids, if not removed, will deposit onto heat transfer surfaces and form scale, inhibiting heat transfer. The cost to furnish and install the suspended solids distribution pipe and rate-set valve and connect them to the existing blowdown separator is included in the cost of the new boiler.

The feedwater storage tank, which is also the condensate return tank, is of adequate size; however, the tank should be elevated an additional 2 ft to increase the available pump suction head. The vent off the tank is vented directly into the room. When there is hot condensate, vapor will be vented into the room. If this occurs, anyone standing near the tank could be scalded by the hot vapor. The vent must be extended to the atmosphere, either through the wall or out through the roof. The cost to elevate the tank and extend the vent is $1,000.

The feedwater pumps are an inexpensive type, with the pump and motor being close-coupled. These pumps must be replaced as the packing on a pump of this type cannot be repaired, the whole pump must be replaced. Two new feedwater pumps, with high-efficiency motors, are required to be installed. Pumps and motors should be independent, not close-coupled. The cost to purchase and install new pumps and motors is $1,500.

The installation of a lead/lag panel is required in this building as both boilers are on at minimum firing rates. Most of the time, however, only one boiler is needed to carry the load. A lead/lag panel would allow one boiler to modulate from low to high fire along with the varying load. If the lead boiler was in high fire position and the steam pressure kept dropping, the lag boiler would come on, increase the pressure, and then go off when the pressure requirement is satisfied. The cost to furnish and install the lead/lag panel is approximately $5,000, with an estimated gas savings of 10 percent per year.

The chemical feed system in this building is adequate; however, the amount of chemicals and the time they are added must be modified. Chemicals are being added based upon makeup water flow to the condensate tank. This is a good strategy; however, it must be augmented. If the boiler requires little makeup water, adding chemicals based solely on makeup water flow will not provide sufficient chemical treatment. Chemicals must also be added whenever the boiler feedwater pumps are running. The cost to install this complete system is $1,000. The chemical feed system should also: (1) add an oxygen scavenger chemical, such as sulfite, to prevent interior deterioration of the boiler, as well as (2) add amines to prevent rust and corrosion of the steam and condensate piping.

Several safety issues exist in this building. The first is that there is no reduced pressure principal backflow preventer (Appendix E, Diagram 1). A backflow preventer is a device which prevents contaminated water (i.e., condensate, chemically treated water, boiler water, chilled water, etc.) from being drawn back into the potable water system. The cost to furnish and install this device in this building is approximately $1,500.

The second safety issue is the blowdown separator. The vent pipe, which passes through the roof, has been reduced in size from that of the separator. This size reduction may cause excessive back pressure buildup in the separator. The separator is not an American Society of Mechanical Engineers (ASME) coded pressure vessel and it may not be able to withstand the pressure. The cost of increase the size of the vent is $500.

Finally, two condensate legs with trap assemblies are required on the main steam header (Appendix E, Diagram 3). This drip and trap assembly will remove condensate (formed because of heat loss to the environment) from the steam header. This condensate, if not removed, will cause water hammer, eventually leading to possible pipe fractures and support failures. This condensate should be returned to the condensate return tank. The cost to furnish and install the drip and trap assembly and associated valves, fittings, insulation, and piping is $1,500. The condensate line from the steam header to each boiler should be removed.

The total cost to install all ECOs and correct safety issues is $169,000, with an estimated 40 percent savings in natural gas per year, which equates to 8,600 x 10^6 Btu per year. Fort Hood should hire a qualified contractor to maintain the water treatment equipment. The estimated annual cost of this contract is $3,000. Proper water treatment will result in extended boiler and piping life; boiler maintenance should also decrease. The estimated simple payback of instituting all of the above ECOs and safety fixes is 5.45 years, based on Fort Hood's natural gas price of $3.93 per 1 x 10^6 Btu.

Building 29005

Building 29005 needs water treatment. This water treatment should add cold zeolites to remove hardness from the makeup water, and it should add dealkalizers to the boiler feedwater to balance the pH. The cost to furnish and install the water treatment equipment is approximately $6,000. Fort Hood should hire an outside contractor to maintain and evaluate the equipment performance. This will incur an annual cost of approximately $3,000. By adding the water treatment equipment, boiler life should be extended approximately 10 years and heat transfer should be improved (due to decreased scale buildup on the tube), yielding approximately 10 percent natural gas savings per year.

There are two boilers in this building. Boiler 1 is a new Cleaver-Brooks fire-tube steam boiler (16.738 MMBtu/Hr) with a Cleaver-Brooks burner and Boiler 2 is a Burnham fire-tube steam boiler (16.738 MMBtu/Hr) with a Webster burner.

Both burners are capable of automatic modulation around a set pressure with manual potentiometer control; however, the air/fuel ratio must be adjusted on both. Boiler 1 begins to vibrate at firing rates above 60 percent. This vibration indicates unstable combustion within the boiler and can cause the boiler to explode. Boiler 2 has a high CO reading, 400 ppm (150 ppm or less is acceptable at all firing rates), at lower firing rates. The cost of tuning both burners is $2,000. The estimated savings is 10 percent natural gas.

The installation of a lead/lag panel is required in this building as, most of the time, only one boiler is needed to carry the load. However, both boilers are usually left on and both boilers are usually close to minimum fire.

A lead/lag panel would allow one boiler to modulate from low to high fire along with the varying load. If the lead boiler was in high fire position and the steam pressure kept dropping, the lag boiler would come on and increase the pressure and then go off when the pressure requirement is satisfied. The cost to purchase and install the lead/lag panel is approximately $5,000 with an estimated natural gas savings of 10 percent per year.

The chemical feed system in this building is adequate; however, the amount of chemicals and the time they are added must be modified. Chemicals are being added based upon makeup water flow to the condensate tank. This is a good strategy; however, it must be augmented. If the boiler requires little makeup water, adding chemicals based solely on makeup water flow will not provide sufficient chemical treatment. Chemicals must also be added whenever the boiler feedwater pumps are running. The cost to install this complete system is $1,000. The chemical feed system should also: (1) add an oxygen scavenger chemical, such as sulfite, to prevent interior deterioration of the boiler, as well as (2) add amines to prevent rust and corrosion of the steam and condensate piping.

This building has a blowdown separator which allows the boiler water to be cooled to the proper temperature before going down the drain; however, the CBD for neither boiler is piped to the blowdown separator. The cost to repipe the CBD is $1,000.

Several safety issues exist in this building. The first is that there are no reduced pressure principal backflow preventers (Appendix E, Diagram 1). A backflow preventer is a device which prevents contaminated water (i.e., condensate, chemically treated water, boiler water, chilled water, etc.) from being drawn back into the potable water system. The cost to furnish and install these devices in this building is approximately $3,000.

The second safety issue is that the fuel gas train vent pipe through the roof is too small. That is, the fuel gas train contains a double block and bleed system (Appendix E, Diagram 2) that is vented through the roof and this vent has been downsized. Other gas train devices (i.e., high gas pressure switch, low gas pressure switch, gas pressure regulator) should be vented to the atmosphere separately. The vent size should increase as the sum of the cross-sectional areas of each vent entering the system. For example, a 2 in. vent which joins a 2 in. vent should increase to a 3 in. vent out through the roof. The estimated cost to change the venting is $1,500.

The final safety issue is that the blowdown separator is connected to the safety-relief valve vent. This can cause vapor to condense and water to accumulate on the safety-relief valve, causing excessive back pressure on the safety-relief valve. This could result in insufficient safety-relief valve capacity thus causing a boiler explosion. The cost to change the blowdown separator vent is $1,000.

The total cost to install all ECOs and correct safety issues is $20,500, with an estimated 30 percent in natural gas per year, which equates to 11,100 x 10^6 Btu per year. Fort Hood should hire a qualified contractor to maintain the water treatment equipment. The estimated annual cost of this contract is $3,000. Proper water treatment will result in extended boiler and piping life; boiler maintenance should also decrease. The estimated simple payback of instituting all of the above ECOs and safety fixes is 0.5 years, based on Fort Hood's natural gas price of $3.93 per 1 x 10^6 Btu.

Building 31008

Building 31008 needs water treatment. This water treatment should add cold zeolites to remove hardness from the makeup water, and it should add dealkalizers to the boiler feedwater to balance the pH. The cost to furnish and install the water treatment equipment is approximately $6,000. Fort Hood should hire an outside contractor to maintain and evaluate the equipment performance. This will incur an annual cost of approximately $3,000. By adding the water treatment equipment, boiler life should be extended approximately 10 years and heat transfer should be improved (due to decreased scale buildup on the tube), yielding approximately 10 percent natural gas savings per year.

There are two boilers in this building both of which are Kewanee fire-tube steam boilers (8.561 MMBtu/Hr) equipped with Kewanee burners. These burners are ON/OFF with no automatic modulation. The left side of Boiler 1 is rusted through due to a leak in the safety-relief valve. Boiler 2 has high CO readings, 554 ppm (150 ppm or less is an acceptable level at all firing rates), at low fire. Boiler 2 also has difficulty catching up to the load. This indicates scale buildup on the outside of the tubes which is prohibiting heat transfer. It is therefore recommended that both boilers and burners be replaced with new boilers and burners capable of automatic modulation around a set steam pressure. The new gas trains for the boilers should contain double block and bleed system as shown in Appendix E, Diagram 2. Both boilers should have CBD to remove total dissolved solids from the boiler water. The cost to furnish and install two new boilers and burners is $300,000. This should save 30 percent in natural gas per year.

The feedwater storage tank, which is also the condensate return tank, is adequately sized; however, the feedwater pumps must be replaced. These pumps are an inexpensive type with the pump and motor being close-coupled. There is a problem with this close-coupled setup in that the packing cannot be repaired on the pump and the pump itself must be completely replaced.

Two new feedwater pumps, with high-efficiency motors, are required to be installed. Pumps and motors should be independent, close-coupled units. The cost to furnish and install new pumps and motors is $1,500.

The installation of a lead/lag panel is required in this building as, most of the time, only one boiler is needed to carry the load. A lead/lag panel would allow one boiler to modulate from low to high fire along with the varying load. If the lead boiler was in high fire position and the steam pressure kept dropping, the lag boiler would come on, increase the pressure, and then go off when the pressure requirement is satisfied. The cost to furnish and install the lead/lag panel is approximately $5,000, with an estimated natural gas savings of 5 percent per year.

The chemical feed system in this building is adequate; however, the amount of chemicals and the time they are added must be modified. Chemicals are being added based upon makeup water flow to the condensate tank. This is a good strategy; however, it must be augmented. If the boiler requires little makeup water, adding chemicals based solely on makeup water flow will not provide sufficient chemical treatment. Chemicals must also be added whenever the boiler feedwater pumps are running. The cost to install this complete system is $1,000. The chemical feed system should also: (1) add an oxygen scavenger chemical, such as sulfite, to prevent interior deterioration of the boiler, as well as (2) add amines to prevent rust and corrosion of the steam and condensate piping.

A blowdown separator is required to service the CBD and the BBD system. The blowdown separator allows the high-temperature blowdown liquid to flash into steam at atmospheric conditions. The steam is vented to the atmosphere and the remaining liquid is cooled automatically via the addition of potable water to the effluent stream. The cooling of the effluent is required by plumbing codes to prevent deterioration of drain piping which occurs at 140 °F. The cost to furnish and install the blowdown separator is included in the previous CBD system.

A couple of safety issues exist in this building. The first is that there are no reduced pressure principal backflow preventers (Appendix E, Diagram 1). A backflow preventer is a device which prevents contaminated water (i.e., condensate, chemically treated water, boiler water, chilled water, etc.) from being drawn back into the potable water system. The cost to furnish and install these devices in this building is approximately $3,000.

Finally, two condensate legs with trap assemblies are required on the main steam header (Appendix E, Diagram 3). This drip and trap assembly will remove condensate (formed because of heat loss to the environment) from the steam header. This condensate, if not removed, will cause water hammer, eventually leading to pipe fractures and support failures. This condensate should be returned to the condensate return tank. The cost to furnish and install the drip and trap assembly and associated valves, fittings, insulation, and piping is $1,500. The condensate line from the steam header to each boiler should be removed.

The total cost to install all ECOs and correct safety issues is $323,000, with an estimated 45 percent in natural gas per year, which equates to 8,600 x 10^6 Btu per year. Fort Hood should hire a qualified contractor to maintain the water treatment equipment. The estimated annual cost of this contract is $3,000. Proper water treatment will result in extended boiler and piping life; boiler maintenance should also decrease. The estimated simple payback of instituting all of the above ECOs and safety fixes is 10.42 years, based on Fort Hood's natural gas price of $3.93 per 1 x 10^6 Btu.

Building 34008

Building 34008 needs water treatment. This water treatment should add cold zeolites to remove hardness from the makeup water, and it should add dealkalizers to the boiler feedwater to balance the pH. The cost to furnish and install the water treatment equipment is approximately $6,000. Fort Hood should hire an outside contractor to maintain and evaluate the equipment performance. This will incur an annual cost of approximately $3,000. By adding the water treatment equipment, boiler life should be extended approximately 10 years and heat transfer should be improved (due to decreased scale buildup on the tube), yielding approximately 10 percent natural gas savings per year.

This building has two boilers, both of which are new Kewanee fire-box steam boilers (9.688 MMBtu/Hr) equipped with Kewanee burners capable of automatic modulation around a set steam pressure with manual potentiometer control.

The feedwater storage tank, which is also the condensate tank, is adequately sized; however, the tank needs to be elevated an additional 2 ft to increase available pump suction head. The cost to raise this tank is $500.

The feedwater pumps are an inexpensive type, with the pump and motor being close-coupled. These pumps must be replaced as the packing on a pump of this close-coupled type cannot be repaired and the entire pump must be replaced. Two new feedwater pumps, with high-efficiency motors, are required to be installed. Pumps and motors should be independent, close-coupled units. The cost to furnish and install new pumps and motors is $1,500.

The installation of a lead/lag panel is required in this building. Both boilers are on at minimum firing rates. With the exception of peak steam load requirements during the morning, most of the time only one boiler is needed to carry the load. A lead/lag panel would allow one boiler to modulate from low to high fire along with the varying load. If the lead boiler was in high fire position and the steam pressure kept dropping, the lag boiler would come on, increase the pressure, and then go off when the pressure requirement is satisfied. The cost to furnish and install the lead/lag panel is approximately $5,000, with an estimated natural gas savings of 10 percent per year.

The chemical feed system in this building is adequate; however, the amount of chemicals and the time they are added must be modified. Chemicals are being added based upon makeup water flow to the condensate tank. This is a good strategy; however, it must be augmented. If the boiler requires little makeup water, adding chemicals based solely on makeup water flow will not provide sufficient chemical treatment. Chemicals must also be added whenever the boiler feedwater pumps are running. The cost to install this complete system is $1,000. The chemical feed system should also: (1) add an oxygen scavenger chemical, such as sulfite, to prevent interior deterioration of the boiler, as well as (2) add amines to prevent rust and corrosion of the steam and condensate piping.

This building has a blowdown separator which allows the boiler water to be cooled to the proper temperature before going down the drain. However, there are several A.S.M.E. code violations which are also safety issues.

The first issue is that the blowdown separator vent is connected to the safety-relief valve vent. This can cause vapor to condense and water to accumulate on the safety-relief valve, causing excessive back pressure on the safety-relief valve. This could result in insufficient safety-relief valve capacity, causing a boiler explosion. The cost to change the flash tank vent is $1,000.

The second issue is that the vent pipe on the blowdown separator has been reduced in size from that of the separator. This size reduction may cause excessive back pressure buildup in the separator. The separator is not an A.S.M.E. coded pressure vessel and it may not be able to withstand the pressure. The cost to change the vent size is $500.

Third issue is that the CBD and safety-relief valve drains have been piped into the vent pipe, not the tank. The cost to reroute the piping to the tank is $500.

Another code violation is that the overflow pipe from the boiler feedwater/condensate return tank is piped into the blowdown separator. The overflow should be piped to the floor drain. The cost to repipe the overflow is $100.

Several other safety issues exist in this building. The first is that cast iron fittings were used on the blowdown lines instead of malleable iron. Cast iron, subjected to shock, may fail and become projectiles. The cost to change the cast iron fittings is $500.

The second safety issue is that there are no reduced pressure principal backflow preventers (Appendix E, Diagram 1). A backflow preventer is a device which prevents contaminated water (i.e., condensate, chemically treated water, boiler water, chilled water, etc.) from being drawn back into the potable water system. The cost to furnish and install these devices in this building is approximately $2,000.

The third safety issue is the lack of a bleed valve on the boiler fuel gas train (Appendix E, Diagram 2). The fuel gas train has two block valves but no bleed valve (which is a vent to the atmosphere). In the event of a gas leak, the bleed valve vents natural gas to the outside, thus preventing an explosion. The cost to install a bleed valve is $2,000.

The fourth safety issue is the feedwater storage tank (which is also the condensate return tank) in that it is vented directly into the room. *This is a code violation and must be corrected as, when there is hot condensate, vapor will be vented directly into the room.* The vent should either be extended outside through the roof or wall. The cost to extend the vent is $1,000.

Finally, another drip and trap assembly needs to be installed in the steam header (Appendix E, Diagram 3). Two drip and trap assemblies are required in case one should fail. The condensate should go back to the condensate return tank. The cost to furnish and install a drip and trap assembly is $1,000.

The total cost to install all ECOs and correct safety issues is $22,600, with an estimated 20 percent savings in natural gas per year, which equates to 4,400 x 10^6 Btu per year. Fort Hood should hire a qualified contractor to maintain the water treatment equipment. The estimated annual cost of this contract is $3,000. Proper water treatment will result in extended boiler and piping life; boiler maintenance should also decrease. The estimated simple payback of instituting all of the above ECOs and safety fixes is 1.56 years, based on Fort Hood's natural gas price of $3.93 per 1 x 10^6 Btu.

Building 36000

Building 36000 has cold zeolite water treatment. Dealkalizers need to be added to the boiler feedwater to balance the pH. The cost to furnish and install the water treatment equipment is approximately $3,000. An outside contractor should be contracted to maintain and evaluate the equipment performance at an annual cost of approximately $3,000. By adding the water treatment equipment, boiler life should be extended approximately 5 years and heat transfer should be improved, due to decreased scale buildup on the tubes, yielding an approximate 5 percent natural gas savings per year.

The existing deaerator has been disconnected and no longer in use. Sulfite chemicals are being added through one-shot feeders to scavenge out the oxygen. A new deaerator should be installed, eliminating the use of chemicals and saving $3,000 per year. The cost to furnish and install a new deaerator is $30,000.

There are three boilers in this building. All three of these boilers are Superior firetube steam boilers (8.870 MMBtu/Hr) with relatively new Webster burners. The burners are automatic modulation type (around a set steam pressure) for both natural gas and oil with manual potentiometer control. However, when the boilers were retrofitted with the new Webster burners, the refractory throats were not changed to match the burner flame patterns of the new burners. The cost to furnish and install three refractory throats is $15,000. With the proper heat distribution, this should save 10 percent of the natural gas used per year.

The total cost to install all ECOs is $48,000, with an estimated natural gas savings of 15 percent per year, which equates to 2,000 x 10^6 Btu per year. Fort Hood should hire a qualified contractor to maintain the water treatment equipment. The estimated annual cost of this contract is $3,000. Proper water treatment will result in extended boiler and piping life; boiler maintenance should also decrease. The estimated simple payback of instituting all of the above ECOs and safety fixes is 6.11 years, based on Fort Hood's natural gas price of $3.93 per 1 x 10^6 Btu.

Building 36006

Building 36006 needs water treatment. This water treatment should add cold zeolites to remove hardness from the makeup water, and it should add dealkalizers to the boiler feedwater to balance the pH. The cost to furnish and install the water treatment equipment is approximately $6,000. Fort Hood should hire an outside contractor to maintain and evaluate the equipment performance. This will incur an annual cost of approximately $3,000. By adding the water treatment equipment, boiler life should be extended approximately 10 years and heat transfer should be improved (due to decreased scale buildup on the tube), yielding approximately 10 percent natural gas savings per year.

There are two boilers in this building, both of which are Burnham fire-tube steam boilers (7.381 MMBtu/Hr and 5.314 MMBtu/Hr) with Webster burners. The Webster burners are ON/OFF with a manual set firing rate. Both burners should be replaced with new burners equipped with automatic modulating controls. This would then allow the burners to follow the steam load demand instead of cycling off and on, eliminating residual heat loss in the boiler during the purge and post-purge cycles. This heat loss is due to heat transfer from the boiler to the cool air being forced through the boiler and out the stack. The cost to furnish and install two new burners is $20,000. The estimated natural gas savings is 10 percent per year due to the reduction in the number of start-ups and by not allowing the boilers to cool down during purge cycles.

Neither boiler is equipped with a CBD distribution pipe, rate-set valve, or separation tank. The CBD system removes suspended solids over the entire length of the casing. The collection pipe is positioned below the normal waterline at the height of the maximum solids concentration. These solids, if not removed, will deposit onto heat transfer surfaces and form scale thus inhibiting heat transfer. The cost to furnish and install the suspended solids distribution pipe, rate-set valve, and blowdown separator is approximately $7,000.

A blowdown separator is required to service the CBD and the BBD system. The blowdown separator allows the high-temperature blowdown liquid to flash into steam at atmospheric conditions. The steam is vented to the atmosphere and the remaining liquid is cooled automatically via the addition of potable water to the effluent stream. The cooling of the effluent is required by plumbing codes to prevent deterioration of drain piping which occurs at 140 °F. The cost to furnish and install the blowdown separator is included in the previous CBD system.

The boiler feedwater tank, which is also the condensate return tank, is an old converted air compressor tank. Because air compressor tanks are not designed to be feedwater tanks, a new larger (300 gallon) elevated (5' AFF) tank should be installed. The cost to furnish and install a new tank is $2,000.

There appears to be a condensate return problem in this building because they are in the process of installing a duplex condensate station (which is a small tank with two in-line pumps) on the floor beside the feedwater/condensate return tank. It seems that the condensate is unable to enter the feedwater/condensate return tank due to lack of pressure and because of the elevation of the condensate return line. That is, the condensate return line enters the tank in the middle instead of the top or near the top above the water level. The condensate return lines must be raised, the cost of which is $2,000.

The feedwater pumps are in good condition. The pumps are base mounted, independent from the motor, which is the proper type of pump for feedwater service.

Although it is not necessary, the installation of a lead/lag panel could be implemented in this building if the kitchen is placed back into service as, most of the time, only one boiler is needed to carry the load. A lead/lag panel would allow one boiler to modulate from low to high fire along with the varying load. If the lead boiler was in high fire position and the steam pressure kept dropping, the lag boiler would come on, increase the pressure, and then go off when the pressure requirement is satisfied. The cost to furnish and install the lead/lag panel is approximately $5,000.

There is no automatic chemical feed in this building, only one-shot feeders. A chemical feed system should be added to the feedwater/condensate return tank. Chemicals should be added based on the amount of makeup water entering the tank as well as when the boiler feedwater pumps come on. A meter should be installed within the makeup water pipe to control the chemical feed pump based upon gallons of makeup water. The cost to install a chemical feed system is $1,500. The chemical feed system should be used to add an oxygen scavenger chemical, such as sulfite, to prevent deterioration of the boiler from the inside out, and amines to prevent rust and corrosion of the steam and condensate piping. This should extend boiler life by approximately 5 years.

Several safety issues exist in this building. The first is that there are no reduced pressure principal backflow preventers (Appendix E, Diagram 1). A backflow preventer is a device which prevents contaminated water (i.e., condensate, chemically treated water, boiler water, chilled water, etc.) from being drawn back into the potable water system. The cost to furnish and install these devices in this building is approximately $3,000.

The second safety issue is the lack of a bleed valve on the boiler fuel gas trains. The fuel gas train has two block valves, but no bleed valve (which is a vent to the atmosphere). In the event of a gas leak, the bleed valve vents the natural gas to the outside, preventing an explosion. The new burner gas trains should be specified to contain a double block and bleed system.

The third safety issue is that the safety-relief valves for Boiler 1 are not vented to the atmosphere, but are vented into the building. Should a safety-relief valve pop, the boiler plant would become filled with steam at a temperature greater than 212 °F. This accumulation of steam at such a temperature would render it almost impossible for a person to see or breathe, due to the displacement of the air by the steam, and has a high probability of causing a fatality.

All safety-relief valves on steam boilers should be vented to the atmosphere. These could be vented out through the wall or through the roof; however, if vented through the roof, drip pan elbows should be used to ensure that no water accumulates on the safety-relief valves, causing failure. The cost to change the safety-relief valves with drip pan elbows is $2,000.

The fourth safety issue is that the feedwater storage tank (which is also the condensate return tank) is vented directly into the room. This is a code violation and must be corrected as, when there is hot condensate, ultimately hot vapor is then vented directly into the room. The vent must be extended outside, either through the roof or wall. The cost to extend this vent is $500.

The fifth and final safety issue is that the stack on Boiler 1 is open on the bottom. When the boiler goes through purge, if the stack is not hot enough to pull the flue gas up the stack, this flue gas may be pushed back into the building. There was a high CO reading on Boiler 1 (1900 ppm: 150 ppm or less is acceptable at all firing rates.) The high CO would be pushed into the building and would asphyxiate anyone standing by the stack. The bottom of the stack should be capped like Boiler 2, or an atmospheric damper should be installed. The cost to cap the stack or install an atmospheric damper is $500.

The total cost to install all ECOs and correct safety issues is $49,500, with an estimated 20 percent savings in natural gas per year, which equates to 2,400 x 10^6 Btu per year. Fort Hood should hire a qualified contractor to maintain the water treatment equipment. The estimated annual cost of this contract is $3,000. Proper water treatment will result in extended boiler and piping life; boiler maintenance should also decrease. The estimated simple payback of instituting all of the above ECOs and safety fixes is 7.7 years, based on Fort Hood's natural gas price of $3.93 per 1 x 10^6 Btu.

Building 36009

Water treatment is not an absolute necessity in Building 36009 because there is a hot water boiler system in this building. Hot water systems are closed systems. That is, hot water supply approximately equals hot water return with little or no makeup. However, to ensure the quality of water, a water treatment system should be added. This water treatment system should include cold zeolites for removing hardness. The cost to furnish and install the water treatment equipment is approximately $3,000. An outside contractor should be contracted to maintain and evaluate the equipment performance at an annual cost of approximately $3,000.

This building has one Burnham fire-box hot water boiler (6.312 MMBtu/Hr) with a Gordon-Piatt burner. Both the boiler and burner appear to be relatively new and in good condition; however, the burner control is an ON/OFF only control, with a manually set firing rate. The burner should be retrofitted with new automatic controls modulating around a set temperature. This would then allow the burner to remain on at a lower firing rate thus following the hot water load demand instead of cycling off and on at 4-minute intervals. This would eliminate residual heat loss in the boiler during the purge and post-purge burner cycles. This heat loss is due to heat transfer from the boiler to the cool air being forced through the boiler and out the stack. The cost to retrofit the burner is $5,000. The estimated natural gas savings is 10 percent per year due to the reduction in the number of start-ups and by not allowing the boiler to cool down during purge cycles.

The air/fuel ratio must be adjusted on the burner. There are high CO readings at 50 percent firing rate, 287 ppm (150 ppm or less is acceptable for all firing rates). The cost of tuning the burner is $1,000. The estimated savings is 10 percent in natural gas per year.

Several safety issues exist in this building. The first is that there is no reduced pressure principal backflow preventer (Appendix E, Diagram 1). A backflow preventer is a device which prevents contaminated water (i.e., chemically treated water, boiler water, chilled water, etc.) from being drawn back into the potable water system. The cost to furnish and install this device in this building is approximately $1,000.

The second safety issue is the lack of double block and bleed valves on the boiler fuel gas train (Appendix E, Diagram 2). The fuel gas train should have a block valve, then a bleed valve (which is a vent to the atmosphere), and then another block valve. In the event of a gas leak, the bleed valve vents the natural gas to the outside, preventing an explosion. The cost to install the double block and bleed system is $5,000.

The third safety issue is that the vent from the natural gas regulator, natural gas low-pressure switch, and the natural gas high-pressure switch runs into the stack. This should be a separate vent which is vented to the atmosphere through the roof or a wall. The cost to reroute this vent is $500.

The fourth and final safety issue is that the safety-relief valve from the boiler should go into a flash tank instead of directly down the drain. This would prevent an accident such as burning or scalding someone should the safety-relief valve pop. The cost to furnish and install a flash tank is $3,000.

The total cost to install all ECOs and correct safety issues is $18,500, with an estimated 20 percent savings in natural gas per year, which equates to 2,800 x 10^6 Btu per year. Fort Hood should hire a qualified contractor to maintain the water treatment equipment. The estimated annual cost of this contract is $3,000. Proper water treatment will result in extended boiler and piping life; boiler maintenance should also decrease. The estimated simple payback of instituting all of the above ECOs and safety fixes is 2.31 years, based on Fort Hood's natural gas price of $3.93 per 1 x 10^6 Btu.

Building 37005

Building 37005 needs water treatment. This water treatment should add cold zeolites to remove hardness from the makeup water, and it should add dealkalizers to the boiler feedwater to balance the pH. The cost to furnish and install the water treatment equipment is approximately $6,000. Fort Hood should hire an outside contractor to maintain and evaluate the equipment performance. This will incur an annual cost of approximately $3,000. By adding the water treatment equipment, boiler life should be extended approximately 10 years and heat transfer should be improved (due to decreased scale buildup on the tube), yielding approximately 10 percent natural gas savings per year.

There are two boilers in this building. Boiler 1 is a Kewanee fire-box steam boiler (3.312 MMBtu/Hr) equipped with a Kewanee burner; Boiler 2 is a Cleaver-Brooks fire-tube steam boiler (4.184 MMBtu/Hr) equipped with a Cleaver-Brooks burner. Both burners are capable of automatic modulation around a set pressure with manual potentiometer control.

Boiler 1 was off because only one boiler is needed to carry the load. Boiler 2 needs to be repaired and the air/fuel ratio must be adjusted. A modulating set screw and spring are missing on Burner 2 and the modulating controls are not working correctly. The CO readings are high (531 ppm at minimum fire down to 363 ppm at 50 percent firing rate: 150 ppm or less is an acceptable level at all firing rates). The cost to tune and repair the boiler is $1,200. The estimated natural gas savings is 10 percent per year.

Neither boiler is equipped with a CBD distribution. A blowdown separator is required to service the CBD and the BBD system. The blowdown separator allows the high-temperature blowdown liquid to flash into steam and liquid at atmospheric conditions. The steam is vented to the atmosphere and the liquid is cooled automatically with the addition of potable water to the effluent stream. The cooling of the effluent is required by plumbing codes to prevent deterioration of drain piping which occurs at 140 °F. The cost to furnish and install the blowdown separator is included in the previous CBD system.

The feedwater storage tank, which is also the condensate return tank, is rusted through and leaking. A new (300 gallon) elevated (5' AFF) tank should be installed. The cost to purchase and install a new tank is $2,000.

The feedwater pumps are base mounted, independent from the motor, which is the proper type of pump for feedwater service. However, the water leaking from the feed-water storage tank has rusted the pumps and motors. As a result of this, two new feedwater pumps, with high-efficiency motors, are required to be installed. These new feedwater pumps and motors should also be independent type, not close-coupled. The cost to furnish and install new pumps and motors if $1,500.

The chemical feed system in this building is adequate; however, the amount of chemicals and the time they are added must be modified. Chemicals are being added based upon makeup water flow to the condensate tank. This is a good strategy; however, it must be augmented. If the boiler requires little makeup water, adding chemicals based solely on makeup water flow will not provide sufficient chemical treatment. Chemicals must also be added whenever the boiler feedwater pumps are running. The cost to install this complete system is $1,000. The chemical feed system should also: (1) add an oxygen scavenger chemical, such as sulfite, to prevent interior deterioration of the boiler, as well as (2) add amines to prevent rust and corrosion of the steam and condensate piping.

Two safety issues exist in this building. The first is the lack of double block and bleed valves on the boiler fuel gas trains (Appendix E, Diagram 2). The fuel gas trains should have a block valve, then a bleed valve (which is a vent to the atmosphere), and then another block valve. By venting the gas outside in this manner, there will be no buildup of gas within the boiler in the event of valve leaks, preventing an explosion. The cost to install the double block and bleed system is $5,000.

The second safety issue is that two condensate legs with trap assemblies are required on the main steam header (Appendix E, Diagram 3). This drip and trap assembly will remove condensate (formed because of heat loss to the environment) from the steam header. This condensate, if not removed, will cause water hammer, eventually leading to pipe fractures and support failures. This condensate should be returned to the condensate return tank. The cost to furnish and install the drip and trap assembly and associated valves, fittings, insulation, and piping is $1,500. The condensate line from the steam header to each boiler should be removed.

The total cost to install all ECOs and correct safety issues is $25,200, with an estimated 20 percent savings in natural gas per year, which equates to 1,400 x 10^6 Btu per year. Fort Hood should hire a qualified contractor to maintain the water treatment equipment. The estimated annual cost of this contract is $3,000. Proper water treatment will result in extended boiler and piping life; boiler maintenance should also decrease. The estimated simple payback of instituting all of the above ECOs and safety fixes is 9.33 years, based on Fort Hood's natural gas price of $3.93 per 1 x 10^6 Btu.

Building 37007

Building 37007 needs water treatment. This water treatment should add cold zeolites to remove hardness from the makeup water, and it should add dealkalizers to the boiler feedwater to balance the pH. The cost to furnish and install the water treatment equipment is approximately $6,000. Fort Hood should hire an outside contractor to maintain and evaluate the equipment performance. This will incur an annual cost of approximately $3,000. By adding the water treatment equipment, boiler life should be extended approximately 10 years and heat transfer should be improved (due to decreased scale buildup on the tube), yielding approximately 10 percent natural gas savings per year.

There are two boilers in this building both of which are Cleaver-Brooks water-tube steam boilers (4.5 MMBtu/Hr) with built-in burners. Burner control is automatic HIGH/LOW/OFF firing rate.

Boiler 1 is off because only one boiler is needed to carry the steam load since the kitchen is not in operation at this time. Boiler 2 must have the air/fuel ratio adjusted. There are high CO readings as the burner modulates from low fire to high fire. The CO goes from 120 ppm to 524 ppm to 115 ppm, respectively. An acceptable CO level is 150 pm or less at all firing rates. The cost of tuning the burner is $1,000. The estimated natural gas savings are 10 percent per year.

Neither boiler is equipped with a CBD distribution pipe, rate-set valve, or separation tank. The CBD system removes suspended solids over the entire length of the casing. The collection pipe is positioned below the normal waterline at the height of the maximum solids concentration. These solids, if not removed, will deposit onto heat transfer surfaces and form scale, inhibiting heat transfer. The cost to furnish and install the suspended solids distribution pipe, rate-set valve, and blowdown separator is approximately $7,000.

A blowdown separator is required to service the CBD and the BBD system. The blowdown separator allows the high-temperature blowdown liquid to flash into steam at atmospheric conditions. The steam is vented to the atmosphere and the remaining liquid is cooled automatically via the addition of potable water to the effluent stream. The cooling of the effluent is required by plumbing codes to prevent deterioration of drain piping which occurs at 140 °F. The cost to furnish and install the blowdown separator is included in the previous CBD system.

The feedwater storage tank, which is also the condensate return tank, is rusted through and leaking. A new (300 gallon) elevated (5' AFF) tank should be installed. The cost to furnish and install a new tank is $2,000.

The feedwater pumps are base-mounted, independent from the motor, which is the proper type of pump for feedwater service; however, the water leaking from the feedwater storage tank has rusted the motor and Pump #1. One new feedwater pump, with a high-efficiency motor, is required to be installed. Pump and motor should be independent base-mounted, not close-coupled. The cost to furnish and install a new pump and motor is $750.

The chemical feed system in this building is adequate; however, the amount of chemicals and the time they are added must be modified. Chemicals are being added based upon makeup water flow to the condensate tank. This is a good strategy; however, it must be augmented. If the boiler requires little makeup water, adding chemicals based solely on makeup water flow will not provide sufficient chemical treatment. Chemicals must also be added whenever the boiler feedwater pumps are running. The cost to install this complete system is $1,000. The chemical feed system should also: (1) add an oxygen scavenger chemical, such as sulfite, to prevent interior deterioration of the boiler, as well as (2) add amines to prevent rust and corrosion of the steam and condensate piping.

One safety issue exists in this building. Two condensate legs with trap assemblies are required on the main steam header (Appendix E, Diagram 3). This drip and trap assembly will remove condensate (formed because of heat loss to the environment) from the steam header. This condensate, if not removed, will cause water hammer, eventually leading to pipe fractures and support failures. This condensate should be returned to the condensate return tank. The cost to furnish and install the drip and trap assembly and associated valves, fittings, insulation, and piping is $1,500. The condensate line from the steam header to each boiler should be removed.

The total cost to install all ECOs and correct safety issues is $19,250, with an estimated 20 percent savings in natural gas per year, which equates to 2,000 x 10^6 Btu per year. Fort Hood should hire a qualified contractor to maintain the water treatment equipment. The estimated annual cost of this contract is $3,000. Proper water treatment will result in extended boiler and piping life; boiler maintenance should also decrease. The estimated simple payback of instituting all of the above ECOs and safety fixes is 3.8 years, based on Fort Hood's natural gas price of $3.93 per 1 x 10^6 BTU.

Building 39015

Building 39015 needs water treatment. This water treatment should add cold zeolites to remove hardness from the makeup water, and it should add dealkalizer's to the boiler feedwater to balance the pH. The cost to furnish and install the water treatment equipment is approximately $6,000. Fort Hood should hire an outside contractor to maintain and evaluate the equipment performance. This will incur an annual cost of approximately $3,000. By adding the water treatment equipment, boiler life should be extended approximately 10 years and heat transfer should be improved (due to decreased scale buildup on the tube), yielding approximately 10 percent natural gas savings per year.

There are two boilers in this building both of which are Holman fire-tube steam boilers (16.8 MMBtu/Hr) equipped with Gordon-Piatt Burners with automatic modulating controls around a set steam pressure with manual potentiometer control. The air/fuel ratio must be adjusted on both of these burners. Although Boiler 1 was not on-line, it should have the air/fuel ratio checked and, if necessary, adjusted.

Boiler 2 begins to vibrate at firing rates above 60 percent. This vibration indicates unstable combustion within the boiler and can cause the boiler to explode. Boiler 2 also has a high CO reading, 400 ppm (150 ppm or less is an acceptable level at all firing rates) at lower firing rates. The cost of tuning both burners is $2,000 and the savings will be 10 percent of the natural gas used per year.

A blowdown separator is required to service the CBD and the BBD system. The blowdown separator allows the high-temperature blowdown liquid to flash into steam at atmospheric conditions. The steam is vented to the atmosphere and the remaining liquid is cooled automatically via the addition of potable water to the effluent stream. The cooling of the effluent is required by plumbing codes to prevent deterioration of drain piping which occurs at 140 °F. The cost to furnish and install the blowdown separator is included in the previous CBD system.

The installation of a lead/lag panel is needed in this building since, most of the time, only one boiler is needed to carry the load. However, at times both boilers are left on because this is a central plant and supplies so many buildings, and both boilers are usually close to minimum fire. The cost to furnish and install the lead/lag is approximately $5,000 with an estimated natural gas savings of 5 percent per year.

The chemical feed system in this building is adequate; however, the amount of chemicals and the time they are added must be modified. Chemicals are being added based upon makeup water flow to the condensate tank. This is a good strategy; however, it must be augmented. If the boiler requires little makeup water, adding chemicals based solely on makeup water flow will not provide sufficient chemical treatment. Chemicals must also be added whenever the boiler feedwater pumps are running. The cost to install this complete system is $1,000. The chemical feed system should also: (1) add an oxygen scavenger chemical, such as sulfite, to prevent interior deterioration of the boiler, as well as (2) add amines to prevent rust and corrosion of the steam and condensate piping.

Several safety issues exist in this building. The first is that there is no reduced pressure principal backflow preventer (Appendix E, Diagram 1). A backflow preventer is a device which prevents contaminated water (i.e., condensate, chemically treated water, boiler water, chilled water, etc.) from being drawn back into the potable water system. The cost to furnish and install this device in this building is approximately $1,000.

The second safety issue is that the gas pressure regulator, high gas pressure switch, and low gas pressure switch all vent into the building. These vents should all be vented to the atmosphere or capped. The estimated cost to change the venting is $1,000.

Finally, another drip and trap assembly needs to be installed in the steam header (Appendix E, Diagram 3). Two drip and trap assemblies are required in the event that one fails. The condensate should be piped back to the condensate return tank. The cost to furnish and install a drip and trap assembly is $1,500.

The total cost to install all ECOs and correct safety issues is $22,500, with an estimated 25 percent natural gas savings per year. This equates to 9,250 x 10^6 Btu per year. Fort Hood should hire a qualified contractor to maintain the water treatment equipment. The estimated annual cost of this contract is $3,000. Proper water treatment will result in extended boiler and piping life; boiler maintenance should also decrease. The estimated simple payback of instituting all of the above ECOs and safety fixes is 0.67 years, based on Fort Hood's natural gas price of $3.93 per 1 x 10^6 BTU.

Building 39043

Building 39043 has water treatment. The existing cold zeolite system in place, but it has been disconnected and bypassed. The cold zeolite system should be reconnected and repaired. The cost to repair the water treatment is approximately $3,000. An outside contractor should be contracted to maintain and evaluate the equipment performance at an annual cost of approximately $3,000. By adding the water treatment equipment, boiler life should be extended approximately 10 years and heat transfer should be improved, due to decreased scale buildup on the tubes, yielding approximately 10 percent natural gas savings per year.

The two boilers in this building are Trane fire-tube hot water boilers (16.8 MMBtu/Hr) equipped with Gordon-Piatt burners. Burner controls are automatic modulation around a set temperature or manual potentiometer control. Both boilers were on-line at approximately 30 percent fire rates. Air/fuel ratio must be adjusted on the burners due to high CO readings at low and medium firing rates. Readings were 141 ppm and 190 ppm CO for Boiler 1, and 301 ppm and 469 ppm CO for Boiler 2 (150 ppm or less is an acceptable level at all firing rates). However, according to Mr. John Easterwood, Mechanical Engineer for the Directorate of Public Works, both boilers and burners are going to be replaced because of deterioration of the upper plates on both of the units. This deterioration is due to oxygen corrosion caused by lack of proper chemical feed. An oxygen scavenger and amines should be added through the existing chemical feed system. At the time of the site visit it was empty. These boilers have been temporarily repaired until new boilers can be purchased and installed.

The installation of a lead/lag panel is required in this building as, most of the time, only one boiler is needed to carry the load, but both boilers are on at 30 percent firing rates. A lead/lag panel would allow one boiler to modulate from low to high fire along with the varying load. If the lead boiler was in high fire position and the hot water temperature kept dropping, the lag boiler comes on, increases temperature, then shuts off when the temperature requirement is satisfied. The cost to furnish and install the lead/lag is approximately $5,000, with an estimated natural gas savings of 10 percent per year.

There is only one safety issue. The airflow switch on Boiler 2 has been removed and the switch is bypassed in the burner control loop. Should the blower become disconnected while the motor was running, there would be no combustion airflow and the airflow switch would shut down the boiler. However, with the airflow switch bypassed, the boiler will not shut down, gas will continue to fill the boiler and the boiler will explode. Maintenance personnel must reconnect the airflow switch until this boiler is replaced.

The total cost to install all ECOs and correct the safety issue is $8,000, with an estimated 20 percent savings in natural gas per year, which equates to 7,400 x 10^6 Btu per year. Fort Hood should hire a qualified contractor to maintain the water treatment equipment. The estimated annual cost of this contract is $3,000. Proper water treatment will result in extended boiler and piping life; boiler maintenance should also decrease. The estimated simple payback of instituting all of the above ECOs and safety fixes is 0.31 years, based on Fort Hood's natural gas price of $3.93 per 1 x 10^6 BTU.

Building 41003

Building 41003 needs water treatment. This water treatment should add cold zeolites to remove hardness from the makeup water, and it should add dealkalizers to the boiler feedwater to balance the pH. The cost to furnish and install the water treatment equipment is approximately $6,000. Fort Hood should hire an outside contractor to maintain and evaluate the equipment performance. This will incur an annual cost of approximately $3,000. By adding the water treatment equipment, boiler life should be extended approximately 10 years and heat transfer should be improved (due to decreased scale buildup on the tube), yielding approximately 10 percent natural gas savings per year.

There are two boilers in this building both of which are Kewanee fire-box steam boilers (4.807 MMBtu/Hr) equipped with Kewanee burners. The burner controls are automatic modulation around a set steam pressure with manual potentiometer control. Boiler 1 is not on-line. Only one boiler is required to carry the steam load since the kitchen is not in operation at this time. Should the kitchen be placed back into operation, a lead/lag panel could be installed. A lead/lag panel would allow one boiler to modulate from low to high fire along with the varying load. If the lead boiler was in high fire position and the steam pressure kept dropping, the lag boiler would come on, increase the pressure, and then go off when the pressure requirement is satisfied. The cost to furnish and install the lead/lag panel is approximately $5,000.

Both of these boilers require the installation of several blowdown legs. Two blowdown legs should be installed in the back of both boilers; one in each side. One blowdown leg should be installed in the front left side of both boilers. These blowdowns should run to a blowdown separator. The cost to install the blowdowns is $1,000. The savings will be realized in extended boiler life and better heat transfer due to less scale buildup. This will save 5 percent in natural gas use per year.

Neither boiler is equipped with a CBD distribution pipe, rate-set valve or separation tank. The CBD system removes suspended solids over the entire length of the casing. The collection pipe is positioned below the normal waterline at the height of the maximum solids concentration. These solids, if not removed, will deposit onto heat transfer surfaces and form scale, inhibiting heat transfer. The cost to furnish and install the suspended solids distribution pipe, rate-set valve, and blowdown separator is approximately $7,000.

A blowdown separator is required to service the CBD and the BBD system. The blowdown separator allows the high-temperature blowdown liquid to flash into steam at atmospheric conditions. The steam is vented to the atmosphere and the remaining liquid is cooled automatically via the addition of potable water to the effluent stream. The cooling of the effluent is required by plumbing codes to prevent deterioration of drain piping which occurs at 140 °F. The cost to furnish and install the blowdown separator is included in the previous CBD system.

There is a boiler feedwater problem relative to both storage and pump capacities. The feedwater storage tank, which is also the condensate return tank, is too small. This undersizing causes a large amount of condensate to overflow down the drain during peak steam use periods. A new, larger (300 gallon) elevated (5' AFF) should be installed. The cost to furnish and install a new tank is $2,000.

The feedwater pumps are undersized because the feedwater delivered to the boiler is insufficient to maintain water level when the boiler is at maximum firing rate. Eventually the boiler turns off after reaching the low water safety limit. The feedwater pumps must be sized to overcome all piping and valve pressure drops. Two new feedwater pumps, with high-efficiency motors, are required to be installed. The cost to furnish and install new pumps and motors is $1,500.

The chemical feed system in this building is adequate; however, the amount of chemicals and the time they are added must be modified. Chemicals are being added based upon makeup water flow to the condensate tank. This is a good strategy; however, it must be augmented. If the boiler requires little makeup water, adding chemicals based solely on makeup water flow will not provide sufficient chemical treatment. Chemicals must also be added whenever the boiler feedwater pumps are running. The cost to install this complete system is $1,000. The chemical feed system should also: (1) add an oxygen scavenger chemical, such as sulfite, to prevent interior deterioration of the boiler, as well as (2) add amines to prevent rust and corrosion of the steam and condensate piping.

Several safety issues exist in this building. The first is that there are no reduced pressure principal backflow preventers (Appendix E, Diagram 1). A backflow preventer is a device which prevents contaminated water (i.e., condensate, chemically treated water, boiler water, chilled water, etc.) from being drawn back into the potable water system. The cost to furnish and install these devices in this building is approximately $3,000.

The second safety issue is the lack of double block and bleed valves on the boiler fuel gas trains (Appendix E, Diagram 2). The fuel gas trains have two block valves and no bleed valve (which is a vent to the atmosphere). In the event of a gas leak, a bleed valve vents natural gas to the outside, preventing an explosion. The cost to furnish and install an additional block and bleed valve is $1,500.

The third safety issue is that the vents for both gas regulators vent directly into the room. Should the diaphragm rupture, the room would fill with gas, causing an explosion. These vents should be vented to the atmosphere at a cost of $1,000.

Finally, two condensate legs with trap assemblies are required on the main steam header (Appendix E, Diagram 3). This drip and trap assembly will remove condensate (formed because of heat loss to the environment) from the steam header. This condensate, if not removed, will cause water hammer, eventually leading to pipe fractures and support failures. This condensate should be returned to the condensate return tank. The cost to furnish and install the drip and trap assembly and associated valves, fittings, insulation, and piping is $1,500. The condensate line from the steam header to each boiler should be removed.

The total cost to install all ECOs and correct safety issues is $30,500, with an estimated 15 percent savings in natural gas per year, which equates to 1,500 x 10^6 Btu per year. Fort Hood should hire a qualified contractor to maintain the water treatment equipment. The estimated annual cost of this contract is $3,000. Proper water treatment will result in extended boiler and piping life; boiler maintenance should also decrease. The estimated simple payback of instituting all of the above ECOs and safety fixes is 9.85 years, based on Fort Hood's natural gas price of $3.93 per 1 x 10^6 BTU.

Building 41007

Building 41007 is currently closed for asbestos abatement; however, this building is similar to Building 37005 and it will therefore be assumed that it is also in need of water treatment. This water treatment should add cold zeolites to remove hardness from the makeup water, and it should add dealkalizers to the boiler feedwater to balance the pH. The cost to furnish and install the water treatment equipment is approximately $6,000. Fort Hood should hire an outside contractor to maintain and evaluate the equipment performance. This will incur an annual cost of approximately $3,000. By adding the water treatment equipment, boiler life should be extended approximately 10 years and heat transfer should be improved (due to decreased scale buildup on the tube), yielding approximately 10 percent natural gas savings per year.

There are two boilers in this building, both of which are Cleaver-Brooks fire-tube steam boilers (4.184 MMBtu/Hr) equipped with Cleaver-Brooks burners. Burner controls provide automatic modulation around a set steam pressure or manual potentiometer control.

Neither boiler is equipped with a CBD distribution pipe, rate-set valve, or separation tank. The CBD system removes suspended solids over the entire length of the casing. The collection pipe is positioned below the normal waterline at the height of the maximum solids concentration. These solids, if not removed, will deposit onto heat transfer surfaces and form scale, inhibiting heat transfer. The cost to furnish and install the suspended solids distribution pipe, rate-set valve, and blowdown separator is approximately $7,000.

A blowdown separator is required to service the CBD and the BBD system. The blowdown separator allows the high-temperature blowdown liquid to flash into steam at atmospheric conditions. The steam is vented to the atmosphere and the remaining liquid is cooled automatically via the addition of potable water to the effluent stream. The cooling of the effluent is required by plumbing codes to prevent deterioration of drain piping which occurs at 140 °F. The cost to furnish and install the blowdown separator is included in the previous CBD system.

The chemical feed system in this building is adequate; however, the amount of chemicals and the time they are added must be modified. Chemicals are being added based upon makeup water flow to the condensate tank. This is a good strategy; however, it must be augmented. If the boiler requires little makeup water, adding chemicals based solely on makeup water flow will not provide sufficient chemical treatment. Chemicals must also be added whenever the boiler feedwater pumps are running. The cost to install this complete system is $1,000. The chemical feed system should also: (1) add an oxygen scavenger chemical, such as sulfite, to prevent interior deterioration of the boiler, as well as (2) add amines to prevent rust and corrosion of the steam and condensate piping.

One safety issue exists in this building. Two condensate legs with trap assemblies are required on the main steam header (Appendix E, Diagram 3). This drip and trap assembly will remove condensate (formed because of heat loss to the environment) from the steam header. This condensate, if not removed, will cause water hammer, eventually leading to pipe fractures and support failures. This condensate should be returned to the condensate return tank. The cost to furnish and install the drip and trap assembly and associated valves, fittings, insulation, and piping is $1,500. The condensate line from the steam header to each boiler should be removed.

The total cost to install all ECOs and correct safety issues is $15,500, with an estimated 10 percent savings in natural gas per year, which equates to 900 x 10^6 Btu per year. Fort Hood should hire a qualified contractor to maintain the water treatment equipment. The estimated annual cost of this contract is $3,000. Proper water treatment will result in extended boiler and piping life; boiler maintenance should also decrease. The estimated simple payback of instituting all of the above ECOs and safety fixes is 21.03 years, based on Fort Hood's natural gas price of $3.93 per 1 x 10^6 BTU.

Building 87018

Building 87018 needs water treatment. This water treatment should add cold zeolites to remove hardness from the makeup water, and it should add dealkalizers to the boiler feedwater to balance the pH. The cost to furnish and install the water treatment equipment is approximately $6,000. Fort Hood should hire an outside contractor to maintain and evaluate the equipment performance. This will incur an annual cost of approximately $3,000. By adding the water treatment equipment, boiler life should be extended approximately 10 years and heat transfer should be improved (due to decreased scale buildup on the tube), yielding approximately 10 percent natural gas savings per year.

There are two boilers in this building, both of which are Burnham fire-tube steam boilers (16.738 MMBtu/Hr) equipped with Webster burners. The burner controls provide automatic modulation around a set pressure with a manual potentiometer. Boiler 2 is off-line due to a tube leak which is being repaired. The air/fuel ratio should be adjusted on both burners. Boiler 1 has a high CO reading, 400 ppm (150 ppm or less is an acceptable level at all firing rates) at lower firing rates. The cost of tuning both burners is $2,000 and the estimated savings is 5 percent in natural gas per year.

The installation of a lead/lag panel is required in this building because, most of the time, only one boiler is needed to carry the load. However, both boilers are usually on-line and both boilers are usually close to minimum fire, according to plant personnel.

A lead/lag panel would allow one boiler to modulate from low to high fire along with the varying load. If the lead boiler was in high fire position and the steam pressure kept dropping, the lag boiler would come on and increase the pressure and then go off when the pressure requirement is satisfied. The cost to furnish and install the lead/lag panel is approximately $5,000, with an estimated natural gas savings of 5 percent per year.

The chemical feed system in this building is adequate; however, the amount of chemicals and the time they are added must be modified. Chemicals are being added based upon makeup water flow to the condensate tank. This is a good strategy; however, it must be augmented. If the boiler requires little makeup water, adding chemicals based solely on makeup water flow will not provide sufficient chemical treatment. Chemicals must also be added whenever the boiler feedwater pumps are running. The cost to install this complete system is $1,000. The chemical feed system should also: (1) add an oxygen scavenger chemical, such as sulfite, to prevent interior deterioration of the boiler, as well as (2) add amines to prevent rust and corrosion of the steam and condensate piping.

A blowdown separator is required to service the CBD and the BBD system. The blowdown separator allows the high-temperature blowdown liquid to flash into steam at atmospheric conditions. The steam is vented to the atmosphere and the remaining liquid is cooled automatically via the addition of potable water to the effluent stream. The cooling of the effluent is required by plumbing codes to prevent deterioration of drain piping which occurs at 140 °F. The cost to furnish and install the blowdown separator is included in the previous CBD system.

The air intake for the burners requires cleaning. A dirt buildup on the fan blade can cause a reduction in airflow thus reducing boiler efficiency and causing a potential for explosion due to insufficient combustion air.

Several safety issues exist in this building. The first is that there is no reduced pressure principal backflow preventer (Appendix E, Diagram 1). A backflow preventer is a device which prevents contaminated water (i.e., condensate, chemically treated water, boiler water, chilled water, etc.) from being drawn back into the potable water system. The cost to furnish and install this device in this building is approximately $1,000.

The second safety issue is that the gas pressure regulator, high gas pressure switch, and low gas pressure switch all vent into the building. These vents should be vented to the atmosphere. The cost to change the vent is $1,000.

The third safety issue is that the gas train vent pipe through the roof is too small. The gas train contains a double block and bleed system (Appendix E, Diagram 2) that is vented through the roof. The pilot bleed valve device is vented into the block and bleed vent without an increase in the vent size. The vent size should increase as the sum of the cross-sectional area of each vent entering the system. That is, a 2 in. vent which joins a 2 in. vent should increase to a 3 in. vent out through the roof. The other gas train devices (i.e., high gas pressure switch, low gas pressure switch, gas pressure regulator) should be vented to the atmosphere separately. The estimated cost to change the venting is $2,000.

Finally, another drip and trap assembly needs to be installed in the steam header (Appendix E, Diagram 3). Two drip and trap assemblies are required in the event one fails. The condensate should go back to the condensate return tank. The cost to furnish and install a drip and trap assembly is $1,000.

The total cost to install all ECOs and correct safety issues is $24,000, with an estimated 20 percent savings in natural gas per year, which equates to 7,300 x 10^6 Btu per year. Fort Hood should hire a qualified contractor to maintain the water treatment equipment. The estimated annual cost of this contract is $3,000. Proper water treatment will result in extended boiler and piping life; boiler maintenance should also decrease. The estimated simple payback of instituting all of the above ECOs and safety fixes is 0.93 years, based on Fort Hood's natural gas price of $3.93 per 1 x 10^6 BTU.

Building 90038

Building 90038 needs water treatment. This water treatment should add cold zeolites to remove hardness from the makeup water, and it should add dealkalizers to the boiler feedwater to balance the pH. The cost to furnish and install the water treatment equipment is approximately $6,000. Fort Hood should hire an outside contractor to maintain and evaluate the equipment performance. This will incur an annual cost of approximately $3,000. By adding the water treatment equipment, boiler life should be extended approximately 10 years and heat transfer should be improved (due to decreased scale buildup on the tube), yielding approximately 10 percent natural gas savings per year.

There is one Cleaver-Brooks fire-tube steam boiler (8.8995 MMBtu/Hr) in this building equipped with a Cleaver-Brooks burner. The burner controls provide automatic modulation around a set pressure and manual potentiometer control. The automatic modulating controls and the boiler ON/OFF switch are not working properly. The burner is in manual mode and is set at about 50 percent firing rate. The boiler cycles on for about 1 minute and then off for 5 to 10 minutes. The burner controls should be repaired to allow automatic modulation which will then reduce the ON/OFF cycling. The cost to repair the burner is $2,000. The estimated natural gas savings is 10 percent per year.

Lying underneath the boiler by the bottom blowdown are several large pieces of scale, up to an eighth of an inch thick. This again indicates the dire need for effective water treatment.

Neither boiler is equipped with a CBD distribution pipe, rate-set valve, or separation tank. The CBD system removes suspended solids over the entire length of the casing. The collection pipe is positioned below the normal waterline at the height of the maximum solids concentration. These solids, if not removed, will deposit onto heat transfer surfaces and form scale, inhibiting heat transfer. The cost to furnish and install the suspended solids distribution pipe, rate-set valve, and blowdown separator is approximately $7,000.

A blowdown separator is required to service the CBD and the BBD system. The blowdown separator allows the high-temperature blowdown liquid to flash into steam at atmospheric conditions. The steam is vented to the atmosphere and the remaining liquid is cooled automatically via the addition of potable water to the effluent stream. The cooling of the effluent is required by plumbing codes to prevent deterioration of drain piping which occurs at 140 °F. The cost to furnish and install the blowdown separator is included in the previous CBD system.

There is a boiler feedwater problem relative to both storage and pump capacities and boiler entry point. The feedwater storage tank, which is also the condensate return tank, is too small as there is a large amount of condensate overflowing down the drain during peak steam use periods. The feedwater tank sits directly on the floor, which is also a problem. A new larger 300 gallon elevated (5' AFF) tank should be installed. The cost to furnish and install a new tank is $2,000.

The feedwater pumps are an inexpensive type, with the pump and motor being close-coupled. These pumps must be replaced since the packing of this close-coupled type cannot be repaired and the pump must be completely replaced. Two new feedwater pumps, with high-efficiency motors, are required to be installed. Pumps and motors should be independent, not close-coupled. The cost to purchase and install two new pumps and motors is $1,500.

The boiler feedwater enters the boiler through the center bottom blowdown point. Sludge is trying to settle in this area of the boiler. Boiler feedwater should enter about halfway up the boiler, not in the bottom. Maintenance personnel should be able to relocate the boiler feedwater inlet.

The chemical feed system in this building is adequate; however, the amount of chemicals and the time they are added must be modified. Chemicals are being added based upon makeup water flow to the condensate tank. This is a good strategy; however, it must be augmented. If the boiler requires little makeup water, adding chemicals based solely on makeup water flow will not provide sufficient chemical treatment. Chemicals must also be added whenever the boiler feedwater pumps are running. The cost to install this complete system is $1,000. The chemical feed system should also: (1) add an oxygen scavenger chemical, such as sulfite, to prevent interior deterioration of the boiler, as well as (2) add amines to prevent rust and corrosion of the steam and condensate piping.

Several safety issues exist in this building. The first is that there are no reduced pressure principal backflow preventers (Appendix E, Diagram 1). A backflow preventer is a device which prevents contaminated water (i.e., condensate, chemically treated water, boiler water, chilled water, etc.) from being drawn back into the potable water system. The cost to furnish and install these devices in this building is approximately $3,000.

The second safety issue is that the gas train vent pipe through the wall is too small. The gas train contains a double block and bleed system (Appendix E, Diagram 2) which is vented through the wall. Other gas train devices (i.e., high gas pressure switch, low gas pressure switch, gas pressure regulator) should not be connected to the block and bleed vent system, but should be vented to the atmosphere separately. The vent size should increase as the sum of the cross-sectional area of each vent entering the system (i.e., a 2 in. vent which joins a 2 in. vent should increase to a 3 in. vent out through the roof. The estimated cost to change the venting is $1,000.

Finally, two condensate legs with trap assemblies are required on the main steam header (Appendix E, Diagram 3). This drip and trap assembly will remove condensate (formed because of heat loss to the environment) from the steam header. This condensate, if not removed, will cause water hammer, eventually leading to pipe fractures and support failures. This condensate should be returned to the condensate return tank. The cost to furnish and install the drip and trap assembly and associated valves, fittings, insulation, and piping is $1,500. The condensate line from the steam header to each boiler should be removed.

The total cost to install all ECOs and correct safety issues is $25,000, with an estimated 20 percent savings in natural gas per year, which equates to 3,800 x 10^6 Btu per year. Fort Hood should hire a qualified contractor to maintain the water treatment equipment. The estimated annual cost of this contract is $3,000. Proper water treatment will result in extended boiler and piping life; boiler maintenance should also decrease. The estimated simple payback of instituting all of the above ECOs and safety fixes is 2.09 years, based on Fort Hood's natural gas price of $3.93 per 1 x 10^6 BTU.

Building 91001

Building 91001 needs water treatment. This water treatment should add cold zeolites to remove hardness from the makeup water, and it should add dealkalizers to the boiler feedwater to balance the pH. The cost to furnish and install the water treatment equipment is approximately $6,000. Fort Hood should hire an outside contractor to maintain and evaluate the equipment performance. This will incur an annual cost of approximately $3,000. By adding the water treatment equipment, boiler life should be extended approximately 10 years and heat transfer should be improved (due to decreased scale buildup on the tube), yielding approximately 10 percent natural gas savings per year.

There are two Cleaver-Brooks fire-tube steam boilers (3.347 MMBtu/Hr) equipped with Cleaver-Brooks burners in this building. The burner controls provide manual or automatic modulation around a set pressure. Boiler 2 was off at the time of the site visit. Only one boiler is needed to carry the steam load. Both boilers are in need of repair and the air/fuel ratios must be adjusted. The gas control valve for Boiler 1 is open 100 percent at 50 percent firing rate. There should be a better turndown ratio, allowing the boiler to remain on at minimum fire instead of cycling on and off at the existing minimum fire position. This would eliminate residual heat loss in the boiler during the purge and post-purge burner cycles. This heat loss is due to heat transfer from the boiler to the cool air that is forced through the boiler and out the stack during purge.

Boiler 2 is missing a screw and a spring on the control cam. This allows more gas to enter the burner without an increase in combustion air, causing an improper air/fuel ratio. Also, the gas valve could stick in the open position and cause a boiler explosion. The cost to repair and tune both boilers is $3,000. The estimated natural gas savings is 10 percent per year due to the reduction in the number of start-ups and by not allowing the boiler to cool down.

Neither boiler is equipped with a CBD distribution pipe, rate-set valve, or separation tank. The CBD system removes suspended solids over the entire length of the casing. The collection pipe is positioned below the normal waterline at the height of the maximum solids concentration. These solids, if not removed, will deposit onto heat transfer surfaces and form scale, inhibiting heat transfer. The cost to furnish and install the suspended solids distribution pipe, rate-set valve, and blowdown separator is approximately $7,000.

A blowdown separator is required to service the CBD and the BBD system. The blowdown separator allows the high-temperature blowdown liquid to flash into steam at atmospheric conditions. The steam is vented to the atmosphere and the remaining liquid is cooled automatically via the addition of potable water to the effluent stream. The cooling of the effluent is required by plumbing codes to prevent deterioration of drain piping which occurs at 140 °F. The cost to furnish and install the blowdown separator is included in the previous CBD system.

The feedwater storage tank, which is also the condensate return tank, is too small. This is evidenced by the large amount of condensate overflowing down the drain during peak steam use periods. A new, larger (300 gallon) elevated (5' AFF) tank should be installed. The cost to furnish and install a new tank is $2,000.

The feedwater pumps are in good condition. These pumps are base mounted, which is the proper type of pump for feedwater service.

Several safety issues exist in this building. The first is that there are no reduced pressure principal backflow preventers (Appendix E, Diagram 1). A backflow preventer is a device which prevents contaminated water (i.e., condensate, chemically treated water, boiler water, chilled water, etc.) from being drawn back into the potable water system. The cost to furnish and install these devices in this building is approximately $3,000.

The second safety issue is the lack of double block and bleed valves on the boiler fuel gas trains (Appendix E, Diagram 2). The fuel gas trains have two block valves and no bleed valve (which is a vent to the atmosphere). In the event of a gas leak, a bleed valve vents natural gas to the outside, preventing an explosion. The cost to furnish and install a block and bleed valve is $3,500.

The third safety issue is that the vents off of the gas regulators are vented out through the intake louver for the boiler plant. This improper venting causes the gas to get drawn right back into the boiler plant. The regulators should be vented outside at a different location. The cost to move the vent is $500.

Finally, two condensate legs with trap assemblies are required on the main steam header (Appendix E, Diagram 3). This drip and trap assembly will remove condensate (formed because of heat loss to the environment) from the steam header. This condensate, if not removed, will cause water hammer, eventually leading to pipe fractures and support failures. This condensate should be returned to the condensate return tank. The cost to furnish and install the drip and trap assembly and associated valves, fittings, insulation, and piping is $1,500. The condensate line from the steam header to each boiler should be removed.

The total cost to install all ECOs and correct safety issues is $26,500, with an estimated 20 percent savings in natural gas per year, which equates to 1,400 x 10^6 Btu per year. Fort Hood should hire a qualified contractor to maintain the water treatment equipment. The estimated annual cost of this contract is $3,000. Proper water treatment will result in extended boiler and piping life; boiler maintenance should also decrease. The estimated simple payback of instituting all of the above ECOs and safety fixes is 10.59 years, based on Fort Hood's natural gas price of $3.93 per 1 x 10^6 BTU.

3 Conclusions and Recommendations

The total estimated cost to install all ECOs and correct all safety issues in the 19 major boiler plants studied is approximately $968,050. The estimated overall natural gas savings is 25 percent per year, which equates to 85,350 x 10^6 Btu per year. At a natural gas price of $3.93 per 1 x 10^6 Btu, the estimated dollar savings would be $335,425 per year. The estimated chemical savings amount to $5,000 per year. The estimated annual cost to maintain the water treatment equipment in all 19 major boiler plants is $57,000. Factoring all costs and annual savings renders a net savings of $283,425 per year and results in an estimated simple payback of 3.42 years.

To the greatest extent permitted by installation DPW resources, maintenance personnel should be used for periodic routine maintenance. Such tasks would include blowing down the boilers once a day, and visual checking of boilers, burner flames, pumps, condensate systems, and other ancillary equipment. This would extend boiler life and eliminate extended downtimes.

Acronyms and Abbreviations

ASME	American Society of Mechanical Engineers
BBD	bottom blowdown
Btu	British Thermal Unit
CBD	continuous blowdown
CO	carbon monoxide
DoD	Department of Defense
DoE	Department of Energy
ECOs	Energy Conservation Opportunities
EO	Executive Order
EEAP	Energy Engineering Analysis Program
FAD	Funding Authorization Document
FY	fiscal year
MEIP	Model Energy Installation Program
MMBtu/HR	million Btu per hour
NASA	National Aeronautics and Space Administration
NIH	National Institute of Health
NIST	National Institutes of Science and Technology
NOAA	National Oceanographic and Atmospheric Administration
O_2	Oxygen
ppm	parts per million
R&D	research and development
SERDP	Strategic Environmental Research and Development Program
U.S.	United States

USACERL	U.S. Army Construction Engineering Research Laboratories
USGS	U.S. Geological Survey
5' AFF	5 feet above finished floor

Appendix A: Sample Data Sheets Used in Field Work

INFORMATION SHEET

BASE: FT. HOOD — PAGE 1 of 6

LOCATION: FT. HOOD, TEXAS — DATE 12/15/92

BLDG. #: 14020 (K) — BY TD

BOILER NO. 1	2	3	
BURNHAM 4FL-346-46LB	N/A	N/A	MANUFACTURER
STEAM			STEAM/HOT WATER
N.G.			FUEL (COAL, NATURAL GAS, OIL)
10			OPERATING PRESSURE (PSIG)(STEAM ONLY)
(SAT)			OPERATING TEMPERATURE °F
120			FEEDWATER TEMPERATURE °F (STEAM ONLY)
NO			CONTINUOUS BLOWDOWN (YES/NO)
3.210			MMBtu/Hr INPUT
2.568			MMBtu/Hr OUTPUT 86.2 Hp
2975			#/Hr STEAM (STEAM ONLY)
15120			SERIAL NO.
no -	low		NATIONAL BOARD
No			YEAR MFG.
—			°F INLET/RETURN (HW ONLY)
—			°F OUTLET/SUPPLY (HW ONLY)
—			GPM (HW ONLY)
Burnham FIRE BOX			TYPE (FIRETUBE/WATERTUBE/FIRE BOX)
15			DESIGN PRESSURE
(SAT)			DESIGN TEMP.
			USE (HEATING, HOT WATER, KITCHEN)

COMMENTS: Order# 205930LB on boiler

Serial# 19516 Model# 4FL-345-40-G-WEB

INFORMATION SHEET

BLDG. # 14020 PAGE 2 of 6

DATE 12/15/92

BURNER			
~~WEBSTER~~-WINFIELD, KS			BURNER MANUFACTURER
3609			MMBtu/Hr INPUT Max. – Min. = 0.721 MBtu/hr.
?			NAT. GAS CF/Hr
			#____ OIL Gal/Hr
4021362-2			SERIAL NO.
High fire/off			COMBUSTION CONTROL (On-Off, Modulating, High or Low)
?			YEAR MFG.
F.D.			TYPE (POSTIVE PRESSURE/ATMOSPHERE)
JB26-10-R7795C-M.20			MODEL

COMMENTS:

$$\frac{212 + 11}{223} = T_{sat}$$ (too hot for sewer drain)

INFORMATION SHEET

BLDG. # 14020 PAGE 3 of 6

DATE: ____

NO			STOKER (YES/NO)
			MANUFACTURER
			TYPE (UNDERFEED TRAVELING GRATE, SS)
			NO. OF FEEDERS
x	x	x	GRATE SIZE
NO			ECONOMIZER (YES/NO)
			MANUFACTURER
			SERIAL NO.
			TYPE (PLATE OR TUBULAR)
			HEATING SURFACE, FT^2

COMMENTS: ____

OPERATING DATA

BOILER NO. 1

	90%	60%	30%
FLUE GAS TEMP. BOILER OUTLET ECONOMIZER/AIR HEATER	478 °F	468 °F	383 °F
O_2 AT BOILER OUTLET	11.6 %	11.1 %	14.7 %
CO AT BOILER OUTLET	292 PPM	104 PPM	1688 PPM
EFFICIENCY	72.9 %	74 %	64.9 %
% BLOWDOWN	0 %	0 %	0 %
NOX	22 PPM	26 PPM	5 PPM

NIGHT & WEEKEND SET BACK NO (YES/NO)

INFORMATION SHEET

BLDG. # 14020 PAGE 4 of 6

DATE ______

BOILER NO. 2 NO

	90%	60%	30%
FLUE GAS TEMP. BOILER OUTLET ECONOMIZER/AIR HEATER	____ °F	____ °F	____ °F
O_2 AT BOILER OUTLET	____ °F	____ °F	____ °F
CO AT BOILER OUTLET	____ PPM	____ PPM	____ PPM
EFFICIENCY	____ %	____ %	____ %
% BLOWDOWN	____ %	____ %	____ %
NOX	____ PPM	____ PPM	____ PPM
NIGHT & WEEKEND SET BACK	____ (YES/NO)		

BOILER NO. 3 NO

	90%	60%	30%
FLUE GAS TEMP. BOILER OUTLET ECONOMIZER/AIR HEATER	____ °F	____ °F	____ °F
O_2 AT BOILER OUTLET	____ °F	____ °F	____ °F
CO AT BOILER OUTLET	____ PPM	____ PPM	____ PPM
EFFICIENCY	____ %	____ %	____ %
% BLOWDOWN	____ %	____ %	____ %
NOX	____ PPM	____ PPM	____ PPM
NIGHT & WEEKEND SET BACK	____ (YES/NO)		

INFORMATION SHEET

BLDG. # 14020 PAGE 5 of 6

DATE ______

NO MAKEUP WATER TREATMENT EQUIPMENT (YES/NO)

______ COLD ZEOLITES (YES/NO) ______ HOT ZEOLITES (YES/NO)

COLD ZEOLITES		HOT ZEOLITES
______	NO. OF UNITS	______
______'	DIAMETER OF UNIT	______
______'	STRAIGHT SIDE HEIGHT OF UNIT	______
______	TYPE OF RESIN	______
______	AGE OF RESIN	______
______	GPM AT MAXIMUM FLOW	______
______	GPM AT MINIMUM FLOW	______
______	MANUFACTURER	______
______	SERIAL NO.	______
______	MODEL NO.	______
______	YEAR MANUFACTURED	______
______	PRESSURE DROP AT MAXIMUM FLOW	______

BRINE TANK

______ NO. OF TANKS

______' DIAMETER OF UNIT

______ HEIGHT OF UNIT

COMMENTS: ______

INFORMATION SHEET

BLDG. # 14020 PAGE 6 of 6

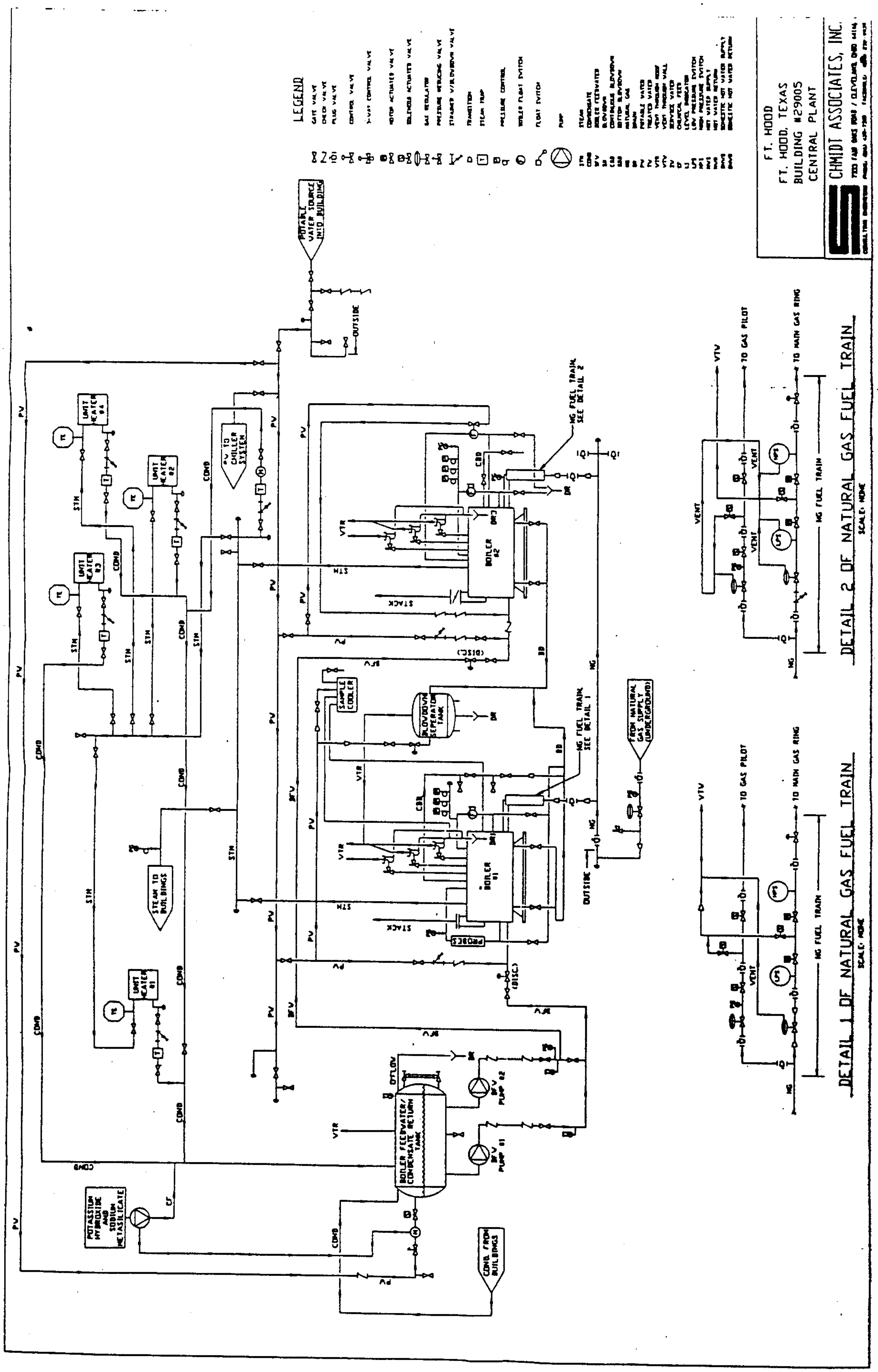
DATE

YES CHEMICAL FEED (YES/NO)
(Sulfate, Phosphate, Amine, Chelate, Caustic, Other)

Potassium Hydroxide & Sodium Metasilicate	CHEMICAL
Cond. tank	ADDITION POINT INTO SYSTEM
yes	AUTOMATIC (YES/NO)
as needed 0.57 gph max. output	RATE
0.57 gph	PUMP SIZE

COMMENTS: 145 psig max. oper. press.
Calgon Vestal model/Series ID# 1354-0 291349

Appendix B: Sample Plant Flow Diagram


LEGEND
FT. HOOD
FT. HOOD, TEXAS
BUILDING #29005
CENTRAL PLANT
CHMIDT ASSOCIATES, INC.
DETAIL 1 OF NATURAL GAS FUEL TRAIN
DETAIL 2 OF NATURAL GAS FUEL TRAIN
BOILER #1
BOILER #2
BLOWDOWN SEPERATOR TANK
SAMPLE COOLER
BOILER FEEDWATER/ CONDENSATE RETURN TANK
POTASSIUM HYDROXIDE AND SODIUM METASILICATE
STEAM TO BUILDINGS
COND. FROM BUILDINGS
FROM NATURAL GAS SUPPLY (UNDERGROUND)
POTABLE WATER SOURCE INTO BUILDING
PV TO CHILLER SYSTEM
UNIT HEATER #1
UNIT HEATER #2
UNIT HEATER #3
UNIT HEATER #4
NG FUEL TRAIN, SEE DETAIL 1
NG FUEL TRAIN, SEE DETAIL 2
STACK
OUTSIDE
TO GAS PILOT
TO MAIN GAS RING
NG FUEL TRAIN

Appendix C: Sample Energy Savings Calculations

Formulas for Calculating Annual Energy Use (Btu) and Savings

Btu used in 1 year	=	100% Load 25% of Year
X	=	Boiler Input in Btu/Hr
Y	=	Total Btu Saved Per Year
Z	=	% Savings

1. Btu/Year Used

   (X Btu/Hr)(24 Hrs/Day)(7 Days/1 Week)(13 Weeks/1 Year) = Btu/Yr.

   2184(X) = Btu/Yr.

2. Btu Savings/Year (for each ECO)

   2184(X)(Z) = Btu Saved/Yr.

3. Total Btu Saved/Year

   Sum of [2184(X)(Z)] (for each ECO) = Y

4. Dollars Saved/Year

   Y($3.93/1x$10^6$Btu) = $/Yr

5. Net Savings/Year (In Dollars)

   Y($3.93/1x$10^6$Btu) -(Cost of Annual Contracts) + (Dollar Savings/Year) = Net Savings/Year (In Dollars)

6. Simple Pay Back (In Years)

$$\frac{\text{Total Cost of ECO \& SI}}{\text{Net Savings/Year}} = \text{Simple Pay Back}$$

7. Savings To Investment Ratio

$$\frac{\text{Savings}}{\text{Investment}} = \frac{Y(25\ \text{Years})(3.93/1\text{x}10^6\text{Btu})}{\text{Sum of Life Cycle Cost}}$$

$$= \frac{98.25\text{x}10^6 Y}{\text{Sum of Life Cycle Cost}^*}$$

Sample Calculation - Building No. 23001

X = 4.712 Btu/Hr

1. Btu/Year Used at Present Time

($4.712\text{x}10^6$Btu/Hr)(24 Hrs/Day)(7 Days/Week)(13 Weeks/Year) = $10{,}291\text{x}10^6$Btu/Yr

2. Btu Saved in a Year

ECO1	10% Savings ($10{,}291\text{x}10^6$Btu/Yr)(.1)	=	$1000\text{x}10^6$Btu/Yr
ECO3	10% Savings ($10{,}291\text{x}10^6$Btu/Yr)(.1)	=	$1000\text{x}10^6$Btu/Yr
ECO5	10% Savings ($10{,}291\text{x}10^6$Btu/Yr)(.1)	=	$1000\text{x}10^6$Btu/Yr
ECO8	5% Savings ($10{,}291\text{x}10^6$Btu/Yr)(.05)	=	$500\text{x}10^6$Btu/Yr

3. Total Btu Saved/Year = $3500\text{x}10^6$Btu/Yr

4. Dollars Saved Per Year

ECO1	($1000\text{x}10^6$Btu/Yr)($3.93/$1\text{x}10^6$Btu)	=	$ 3,930.00
ECO3	($1000\text{x}10^6$Btu/Yr)($3.93/$1\text{x}10^6$Btu)	=	$ 3,930.00
ECO5	($1000\text{x}10^6$Btu/Yr)($3.93/$1\text{x}10^6$Btu)	=	$ 3,930.00
ECO8	($500\text{x}10^6$Btu/Yr)($3.93/$1\text{x}10^6$Btu)	=	$ 1,965.00

* Note: Life Cycle Cost includes initial installation, equipment replacement, equipment maintenance and annual contract costs.

5. Net Savings Per Year

ECO1	$(1000x10^6$Btu/Yr)($3.93/1x$10^6$Btu) -$3,000.00 Annual Contract	=	$ 930.00
ECO3	$(1000x10^6$Btu/Yr)($3.93/1x$10^6$Btu)	=	$ 3,930.00
ECO5	$(1000x10^6$Btu/Yr)($3.93/1x$10^6$Btu)	=	$ 3,930.00
ECO8	($500x10^6$Btu/Yr)($3.93/1x$10^6$Btu)	=	$ 1,965.00
ECO9	$200.00 Savings in Chemicals/Yr	=	$ 200.00
Total:		=	$10,955.00

6. Simple Payback (In Years)

ECO1	$ 6,000.00/$ 930.00	=	6.45
ECO3	$ 1,000.00/$ 3,930.00	=	0.25
ECO5	$10,000.00/$ 3,930.00	=	2.54
ECO8	$ 5,000.00/$ 1,965.00	=	2.54
ECO9	$ 1,000.00/$ 200.00	=	5.0
Total =	$41,000.00/$10,955.00	=	3.74

7. Savings to Investment Ratio

ECO1	($ 3,930.00)(25) / $92,000.00	=	1.07
ECO3	($ 3,930.00)(25) / $ 5,000.00	=	19.65
ECO5	($ 3,930.00)(25) / $10,000.00	=	9.83
ECO8	($ 1,965.00)(25) / $10,000.00	=	4.92
ECO9	($ 200.00)(25) / $ 2,000.00	=	2.5
Total:	($13,955.00)(25) / $141,500.00	=	2.47

Verification of Schmidt's Assumption Regarding Boiler Annual Fuel Use

Building 87018 Natural Gas Meter Readings (primary boiler):

Sept. 1992:	1,130,391
Sept. 1991:	880,482
difference:	249,909

Multiply the meter reading difference by 100, the meter multiplier to get the cubic feet of natural gas consumed in the year:

$$249{,}909 \times 100 = 24{,}990{,}900 \text{ cf}$$

$$\frac{(24{,}990{,}900 \text{ cf}) \times (1000 \text{ BTU/cf})}{(1{,}000{,}000 \text{ BTU/MBTU})} = 24{,}990.9 \text{ MBTU/yr}$$

Manipulating the meter data for the other (secondary) boiler yields an annual energy consumption of 11,311.3 MBTU.

Adding the annual consumption of both boilers yields the total energy consumption for the entire boiler plant:

$$24{,}990.0 + 11{,}311.3 = 36{,}221.2 \text{ MBTU/yr.} \qquad \text{Equation (1)}$$

For Building 87018, Schmidt's calculation of boiler annual energy consumption yields a figure very close to the energy use calculated in Equation (1):

$$(16.738 \text{ MBTU/yr}) \times (24 \text{ hr/ day}) \times (365 \text{ days/yr}) \times (0.25) = 36{,}656.2 \text{ MBTU/yr}$$

Appendix D: Spreadsheet Summary of Calculated Energy and Cost Savings

Energy Conservation Opportunities (ECO)

ECO1	Water Treatment
ECO2	Retrofit Existing Burner Controls
ECO3	Repair and Adjust Air/Fuel Ratio
ECO4	Continuous Blowdown System
ECO5	Furnish and Install New Burner
ECO6	Furnish and Install New Elevated Condensate/Feedwater Storage Tank
ECO7	Furnish and Install New Feedwater Pumps
ECO8	Furnish and Install New Lead/Lag Panel
ECO9	Change Existing Chemical Feed System
ECO10	Furnish and Install New Boiler and Burner
ECO11	Elevate Existing Condensate Tank
ECO12	Repipe Continuous Blowdown System
ECO13	Furnish and Install New Deaerator
ECO14	Furnish and Install New Refractory Throats
ECO15	Repipe Condensate Piping
ECO16	Furnish and Install New Chemical Feed System
ECO17	Install New Blowdown Legs
ECO18	Clean Combustion Air Intake Fan and Dampers

Safety Issues (SI)

SI1	Backflow Preventer
SI2	No Double Block and Bleed System on Fuel Train
SI3	No Drip and Trap Assemblies in Steam Header
SI4	Fuel Train Devices Vent Into Building
SI5	Safety Relief Valves Not Vented to Atmosphere
SI6	Incorrect Fuel Train Vent Piping
SI7	Blowdown Separator Vents Into Safety Relief Valve Vent
SI8	Incorrect Piping
SI9	Cast Iron Fittings Used on Boiler

SI10	Condensate Vents Into Room
SI11	Existing Boiler Stack Open on Bottom
SI12	Safety Relief Valves Vents Improperly Piped
SI13	Disconnect Airflow Switch

ECO/ SAFETY ISSUES	COST TO INSTALL ($)	LIFE OF EQUIPMENT (YEARS)	ANNUAL COST ($)	ENERGY SAVINGS PER YEAR (10^6 BTU)	DOLLARS PER YEAR	MONEY SAVED PER YEAR	NET SAVINGS PER YEAR	SIMPLE PAYBACK (YEARS)	SAVINGS TO INVESTMENT RATIO (25 YEARS)	LIFE CYCLE COST (25 YEARS)	ESTIMATED EXISTING BOILER PLANT LIFE CYCLE COST (25 YEARS)
BUILDING No. 14020											
ECO1	$6,000.00	15	$3,000.00	700	$2,751.00	***	($249.00)	***	0.75	$92,000.00	
ECO2	$2,500.00	25	***	1,100	$4,323.00	***	$4,323.00	0.58	43.23	$2,500.00	
ECO3	$1,000.00	5	***	700	$2,751.00	***	$2,751.00	0.36	13.76	$5,000.00	
ECO4	$7,000.00	25	***	***	***	***	***	***	***	$7,000.00	
ECO9	$1,000.00	15	***	***	***	***	***	***	***	$2,000.00	
SI1	$3,000.00	15	***	***	***	***	***	***	***	$6,000.00	
SI2	$5,000.00	25	***	***	***	***	***	***	***	$5,000.00	
TOTALS -	$25,500.00		$3,000.00	2,500	$9,825.00	$0.00	$6,825.00	3.74	2.06	$119,500.00	$886,700.00
BUILDING No. 21002											
ECO1	$6,000.00	15	$3,000.00	1,000	$3,930.00	***	$930.00	6.45	1.07	$92,000.00	
ECO4	$7,000.00	25	***	***	***	***	***	***	***	$7,000.00	
ECO5	$25,000.00	25	***	2,000	$7,860.00	***	$7,860.00	3.18	6.55	$30,000.00	
ECO6	$2,000.00	25	***	***	***	***	***	***	***	$2,000.00	
ECO7	$1,500.00	15	***	1,000	$3,930.00	***	$3,930.00	0.38	32.75	$3,000.00	
ECO8	$5,000.00	15	***	500	$1,965.00	***	$1,965.00	2.54	4.91	$10,000.00	
ECO9	$1,000.00	15	***	***	***	$200.00	$200.00	5.00	2.50	$2,000.00	
SI1	$3,000.00	15	***	***	***	***	***	***	***	$6,000.00	
SI2	$2,000.00	25	***	***	***	***	***	***	***	$2,000.00	
SI3	$1,500.00	15	***	***	***	***	***	***	***	$3,000.00	
TOTALS -	$54,000.00		$3,000.00	4,500	$17,685.00	$200.00	$14,885.00	3.63	2.85	$157,000.00	$1,648,000.00

ECO/ SAFETY ISSUES	COST TO INSTALL ($)	LIFE OF EQUIPMENT (YEARS)	ANNUAL COST ($)	ENERGY SAVINGS PER YEAR (10^6 BTU)	DOLLARS PER YEAR	MONEY SAVED PER YEAR	NET SAVINGS PER YEAR	SIMPLE PAYBACK (YEARS)	SAVINGS TO INVESTMENT RATIO (25 YEARS)	LIFE CYCLE COST (25 YEARS)	ESTIMATED EXISTING BOILER PLANT LIFE CYCLE COST (25 YEARS)
BUILDING No. 23001											
ECO1	$6,000.00	15	$3,000.00	1,000	$3,930.00	***	$930.00	6.45	1.07	$92,000.00	
ECO3	$1,000.00	5	***	1,000	$3,930.00	***	$3,930.00	0.25	19.65	$5,000.00	
ECO4	$7,000.00	25	***	***	***	***	***	***	***	$7,000.00	
ECO5	$10,000.00	25	***	1,000	$3,930.00	***	$3,930.00	2.54	9.83	$10,000.00	
ECO6	$2,000.00	25	***	***	***	***	***	***	***	$2,000.00	
ECO8	$5,000.00	15	***	500	$1,965.00	***	$1,965.00	2.54	4.91	$10,000.00	
ECO9	$1,000.00	15	***	***	***	$200.00	$200.00	5.00	2.50	$2,000.00	
S11	$3,000.00	15	***	***	***	***	***	***	***	$6,000.00	
S12	$2,000.00	25	***	***	***	***	***	***	***	$2,000.00	
S13	$1,500.00	15	***	***	***	***	***	***	***	$3,000.00	
S14	$1,000.00	25	***	***	***	***	***	***	***	$1,000.00	
S15	$1,500.00	25	***	***	***	***	***	***	***	$1,500.00	
TOTALS -	$41,000.00		$3,000.00	3,500	$13,755.00	$200.00	$10,955.00	3.74	2.47	$141,500.00	$1,649,000.00
BUILDING No. 27004											
ECO1	$6,000.00	15	$3,000.00	2,200	$8,646.00	***	$5,646.00	1.06	2.35	$92,000.00	
ECO3	$1,000.00	5	***	2,000	$7,860.00	***	$7,860.00	0.13	39.30	$5,000.00	
ECO7	$1,500.00	15	***	***	***	***	***	***	***	$3,000.00	
ECO8	$5,000.00	15	***	2,200	$8,646.00	***	$8,646.00	0.58	21.62	$10,000.00	
ECO9	$1,000.00	15	***	***	***	$200.00	$200.00	5.00	2.50	$2,000.00	
ECO10	$150,000.00	25	***	2,200	$8,646.00	***	$8,646.00	17.35	1.44	$150,000.00	
ECO11	$1,000.00	25	***	***	***	***	***	***	***	$1,000.00	
S11	$1,500.00	15	***	***	***	***	***	***	***	$3,000.00	
S13	$1,500.00	15	***	***	***	***	***	***	***	$3,000.00	
S16	$500.00	25	***	***	***	***	***	***	***	$500.00	
TOTALS -	$169,000.00		$3,000.00	8,600	$33,798.00	$200.00	$30,998.00	5.45	3.15	$269,500.00	$3,171,500.00

ECO/ SAFETY ISSUES	COST TO INSTALL ($)	LIFE OF EQUIPMENT (YEARS)	ANNUAL COST ($)	ENERGY SAVINGS PER YEAR (10^6 BTU)	DOLLARS PER YEAR	MONEY SAVED PER YEAR	NET SAVINGS PER YEAR	SIMPLE PAYBACK (YEARS)	SAVINGS TO INVESTMENT RATIO (25 YEARS)	LIFE CYCLE COST (25 YEARS)	ESTIMATED EXISTING BOILER PLANT LIFE CYCLE COST (25 YEARS)
BUILDING No. 29005											
ECO1	$6,000.00	15	$3,000.00	3,700	$14,541.00	***	$11,541.00	0.52	3.95	$92,000.00	
ECO3	$2,000.00	5	***	3,700	$14,541.00	***	$14,541.00	0.14	36.35	$10,000.00	
ECO8	$5,000.00	15	***	3,700	$14,541.00	***	$14,541.00	0.34	36.35	$10,000.00	
ECO9	$1,000.00	15	***	***	***	***	***	***	***	$2,000.00	
ECO12	$1,000.00	25	***	***	***	***	***	***	***	$1,000.00	
SI1	$3,000.00	15	***	***	***	***	***	***	***	$6,000.00	
SI6	$1,500.00	25	***	***	***	***	***	***	***	$1,500.00	
SI7	$1,000.00	25	***	***	***	***	***	***	***	$1,000.00	
TOTALS -	$20,500.00		$3,000.00	11,100	$43,623.00	$0.00	$40,623.00	0.50	8.83	$123,500.00	$5,388,400.00
BUILDING No. 31008											
ECO1	$6,000.00	15	$3,000.00	1,900	$7,467.00	***	$4,467.00	1.34	2.03	$92,000.00	
ECO4	$5,000.00	25	***	***	***	***	***	***	***	$5,000.00	
ECO7	$1,500.00	15	***	***	***	***	***	***	***	$3,000.00	
ECO8	$5,000.00	15	***	1,000	$3,930.00	***	$3,930.00	1.27	9.83	$10,000.00	
ECO9	$1,000.00	15	***	***	***	$200.00	$200.00	5.00	2.50	$2,000.00	
ECO10	$300,000.00	25	***	5,700	$22,401.00	***	$22,401.00	13.39	1.87	$300,000.00	
SI2	$3,000.00	15	***	***	***	***	***	***	***	$6,000.00	
SI3	$1,500.00	15	***	***	***	***	***	***	***	$3,000.00	
TOTALS -	$323,000.00		$3,000.00	8,600	$33,798.00	$200.00	$30,998.00	10.42	2.02	$421,000.00	$2,849,100.00

ECO/ SAFETY ISSUES	COST TO INSTALL ($)	LIFE OF EQUIPMENT (YEARS)	ANNUAL COST ($)	ENERGY SAVINGS PER YEAR (10^6 BTU)	DOLLARS PER YEAR	MONEY SAVED PER YEAR	NET SAVINGS PER YEAR	SIMPLE PAYBACK (YEARS)	SAVINGS TO INVESTMENT RATIO (25 YEARS)	LIFE CYCLE COST (25 YEARS)	ESTIMATED EXISTING BOILER PLANT LIFE CYCLE COST (25 YEARS)
BUILDING No. 34008											
ECO1	$6,000.00	15	$3,000.00	2,200	$8,646.00	***	$5,646.00	1.06	2.35	$92,000.00	
ECO7	$1,500.00	15	***	***	***	***	***	***	***	$3,000.00	
ECO8	$5,000.00	15	***	2,200	$8,646.00	***	$8,646.00	0.58	21.62	$10,000.00	
ECO9	$1,000.00	15	***	***	***	$200.00	$200.00	5.00	2.50	$2,000.00	
ECO11	$500.00	25	***	***	***	***	***	***	***	$500.00	
SI1	$2,000.00	15	***	***	***	***	***	***	***	$4,000.00	
SI2	$2,000.00	25	***	***	***	***	***	***	***	$2,000.00	
SI3	$1,000.00	15	***	***	***	***	***	***	***	$2,000.00	
SI6	$500.00	25	***	***	***	***	***	***	***	$500.00	
SI7	$1,000.00	25	***	***	***	***	***	***	***	$1,000.00	
SI8	$600.00	25	***	***	***	***	***	***	***	$600.00	
SI9	$500.00	25	***	***	***	***	***	***	***	$500.00	
SI10	$1,000.00	25	***	***	***	***	***	***	***	$1,000.00	
TOTALS -	$22,600.00		$3,000.00	4,400	$17,292.00	$200.00	$14,492.00	1.56	3.67	$119,100.00	$3,171,500.00
BUILDING No. 36000											
ECO1	$3,000.00	15	$3,000.00	1,000	$3,930.00	***	$930.00	3.23	1.07	$92,000.00	
ECO13	$30,000.00	15	***	***	***	$3,000.00	$3,000.00	10.00	1.25	$60,000.00	
ECO14	$15,000.00	15	***	1,000	$3,930.00	***	$3,930.00	3.82	3.28	$30,000.00	
TOTALS -	$48,000.00		$3,000.00	2,000	$7,860.00	$3,000.00	$7,860.00	6.11	1.49	$182,000.00	$1,903,300.00

ECO/ SAFETY ISSUES	COST TO INSTALL ($)	LIFE OF EQUIPMENT (YEARS)	ANNUAL COST ($)	ENERGY SAVINGS PER YEAR (10^6 BTU)	DOLLARS PER YEAR	MONEY SAVED PER YEAR	NET SAVINGS PER YEAR	SIMPLE PAYBACK (YEARS)	SAVINGS TO INVESTMENT RATIO (25 YEARS)	LIFE CYCLE COST (25 YEARS)	ESTIMATED EXISTING BOILER PLANT LIFE CYCLE COST (25 YEARS)
BUILDING No. 36006											
ECO1	$6,000.00	15	$3,000.00	1,200	$4,716.00	***	$1,716.00	3.50	1.28	$92,000.00	
ECO4	$7,000.00	15	***	***	***	***	***	***	***	$7,000.00	
ECO5	$20,000.00	15	***	1,200	$4,716.00	***	$4,716.00	4.24	5.90	$20,000.00	
ECO6	$2,000.00	15	***	***	***	***	***	***	***	$2,000.00	
ECO3	$5,000.00	25	***	***	***	***	***	***	***	$10,000.00	
ECO15	$2,000.00	15	***	***	***	***	***	***	***	$2,000.00	
ECO16	$1,500.00	25	***	***	***	***	***	***	***	$3,000.00	
SI1	$3,000.00	15	***	***	***	***	***	***	***	$6,000.00	
SI2	***	25	***	***	***	***	***	***	***	***	
SI5	$2,000.00	25	***	***	***	***	***	***	***	$2,000.00	
SI10	$500.00	25	***	***	***	***	***	***	***	$500.00	
SI11	$500.00	25	***	***	***	***	***	***	***	$500.00	
TOTALS -	$49,500.00		$3,000.00	2,400	$9,432.00	$0.00	$6,432.00	7.70	1.63	$145,000.00	$1,820,200.00
BUILDING No. 36009											
ECO1	$3,000.00	15	$3,000.00	***	***	***	($3,000.00)	***	***	$85,000.00	
ECO2	$5,000.00	25	***	1,400	$5,502.00	***	$5,502.00	0.91	27.51	$5,000.00	
ECO3	$1,000.00	5	***	1,400	$5,502.00	***	$5,502.00	0.18	27.51	$5,000.00	
SI1	$1,000.00	15	***	***	***	***	***	***	***	$2,000.00	
SI2	$5,000.00	25	***	***	***	***	***	***	***	$5,000.00	
SI4	$500.00	25	***	***	***	***	***	***	***	$500.00	
SI12	$3,000.00	25	***	***	***	***	***	***	***	$3,000.00	
TOTALS -	$18,500.00		$3,000.00	2,800	$11,004.00	$0.00	$8,004.00	2.31	2.61	$105,500.00	$2,155,700.00

ECO/ SAFETY ISSUES	COST TO INSTALL ($)	LIFE OF EQUIPMENT (YEARS)	ANNUAL COST ($)	ENERGY SAVINGS PER YEAR (10^6 BTU)	DOLLARS PER YEAR	MONEY SAVED PER YEAR	NET SAVINGS PER YEAR	SIMPLE PAYBACK (YEARS)	SAVINGS TO INVESTMENT RATIO (25 YEARS)	LIFE CYCLE COST (25 YEARS)	ESTIMATED EXISTING BOILER PLANT LIFE CYCLE COST (25 YEARS)
BUILDING No. 37005											
ECO1	$6,000.00	15	$3,000.00	700	$2,751.00	***	($249.00)	***	0.75	$92,000.00	
ECO3	$1,200.00	5	***	700	$2,751.00	***	$2,751.00	0.44	11.46	$6,000.00	
ECO4	$7,000.00	25	***	***	***	***	***	***	***	$7,000.00	
ECO6	$2,000.00	25	***	***	***	***	***	***	***	$2,000.00	
ECO7	$1,500.00	15	***	***	***	***	***	***	***	$3,000.00	
ECO9	$1,000.00	15	***	***	***	$200.00	$200.00	5.00	2.50	$2,000.00	
S12	$5,000.00	25	***	***	***	***	***	***	***	$5,000.00	
S13	$1,500.00	15	***	***	***	***	***	***	***	$3,000.00	
TOTALS -	$25,200.00		$3,000.00	1,400	$5,502.00	$200.00	$2,702.00	9.33	1.19	$120,000.00	$1,247,500.00
BUILDING No. 37007											
ECO1	$6,000.00	15	$3,000.00	1,000	$3,930.00	***	$930.00	6.45	1.07	$92,000.00	
ECO3	$1,000.00	5	***	1,000	$3,930.00	***	$3,930.00	0.25	19.65	$5,000.00	
ECO4	$7,000.00	25	***	***	***	***	***	***	***	$7,000.00	
ECO6	$2,000.00	25	***	***	***	***	***	***	***	$2,000.00	
ECO7	$750.00	15	***	***	***	***	***	***	***	$1,500.00	
ECO9	$1,000.00	15	***	***	***	$200.00	$200.00	5.00	2.50	$2,000.00	
S13	$1,500.00	15	***	***	***	***	***	***	***	$3,000.00	
TOTALS -	$19,250.00		$3,000.00	2,000	$7,860.00	$200.00	$5,060.00	3.80	1.79	$112,500.00	$1,587,400.00

ECO/ SAFETY ISSUES	COST TO INSTALL ($)	LIFE OF EQUIPMENT (YEARS)	ANNUAL COST ($)	ENERGY SAVINGS PER YEAR (10^6 BTU)	DOLLARS PER YEAR	MONEY SAVED PER YEAR	NET SAVINGS PER YEAR	SIMPLE PAYBACK (YEARS)	SAVINGS TO INVESTMENT RATIO (25 YEARS)	LIFE CYCLE COST (25 YEARS)	ESTIMATED EXISTING BOILER PLANT LIFE CYCLE COST (25 YEARS)
BUILDING No. 39015											
ECO1	$6,000.00	15	$3,000.00	3,700	$14,541.00	***	$11,541.00	0.52	3.95	$92,000.00	
ECO3	$2,000.00	5	***	3,700	$14,541.00	***	$14,541.00	0.14	36.35	$10,000.00	
ECO4	$5,000.00	25	***	***	***	***	***	***	***	$5,000.00	
ECO8	$5,000.00	15	***	1,850	$7,270.50	***	$7,270.50	0.69	18.18	$10,000.00	
ECO9	$1,000.00	15	***	***	***	$200.00	$200.00	5.00	2.50	$2,000.00	
SI1	$1,000.00	15	***	***	***	***	***	***	***	$2,000.00	
SI3	$1,500.00	15	***	***	***	***	***	***	***	$3,000.00	
SI4	$1,000.00	25	***	***	***	***	***	***	***	$1,000.00	
TOTALS -	$22,500.00		$3,000.00	9,250	$36,352.50	$200.00	$33,552.50	0.67	7.31	$125,000.00	$5,406,100.00
BUILDING No. 39043											
ECO1	$3,000.00	15	$3,000.00	3,700	$14,541.00	***	$11,541.00	0.26	3.95	$92,000.00	
ECO8	$5,000.00	15	***	3,700	$14,541.00	***	$14,541.00	0.34	36.35	$10,000.00	
SI13	***	***	***	***	***	***	***	***	***	***	
TOTALS -	$8,000.00		$3,000.00	7,400	$29,082.00	$0.00	$26,082.00	0.31	7.13	$102,000.00	$5,406,100.00

ECO/ SAFETY ISSUES	COST TO INSTALL ($)	LIFE OF EQUIPMENT (YEARS)	ANNUAL COST ($)	ENERGY SAVINGS PER YEAR (10^6 BTU)	DOLLARS PER YEAR	MONEY SAVED PER YEAR	NET SAVINGS PER YEAR	SIMPLE PAYBACK (YEARS)	SAVINGS TO INVESTMENT RATIO (25 YEARS)	LIFE CYCLE COST (25 YEARS)	ESTIMATED EXISTING BOILER PLANT LIFE CYCLE COST (25 YEARS)
BUILDING No. 41003											
ECO1	$6,000.00	15	$3,000.00	1,000	$3,930.00	***	$930.00	6.45	1.07	$92,000.00	
ECO4	$7,000.00	25	***	***	***	***	***	***	***	$7,000.00	
ECO6	$2,000.00	25	***	***	***	***	***	***	***	$2,000.00	
ECO7	$1,500.00	15	***	***	***	***	***	***	***	$3,000.00	
ECO8	$5,000.00	15	***	***	***	***	***	***	***	$10,000.00	
ECO9	$1,000.00	15	***	***	***	$200.00	$200.00	5.00	2.50	$2,000.00	
ECO17	$1,000.00	25	***	500	$1,965.00	***	$1,965.00	0.51	49.13	$1,000.00	
SI1	$3,000.00	15	***	***	***	***	***	***	***	$6,000.00	
SI2	$1,500.00	25	***	***	***	***	***	***	***	$1,500.00	
SI3	$1,500.00	15	***	***	***	***	***	***	***	$3,000.00	
SI4	$1,000.00	25	***	***	***	***	***	***	***	$1,000.00	
TOTALS -	$30,500.00		$3,000.00	1,500	$5,895.00	$200.00	$3,095.00	9.85	1.19	$128,500.00	$1,675,200.00
BUILDING No. 41007											
ECO1	$6,000.00	15	$3,000.00	900	$3,537.00	***	$537.00	11.17	0.96	$92,000.00	
ECO4	$7,000.00	25	***	***	***	***	***	***	***	$7,000.00	
ECO9	$1,000.00	15	***	***	***	$200.00	$200.00	5.00	2.50	$2,000.00	
SI3	$1,500.00	15	***	***	***	***	***	***	***	$3,000.00	
TOTALS -	$15,500.00		$3,000.00	900	$3,537.00	$200.00	$737.00	21.03	0.90	$104,000.00	$1,497,000.00

ECO/. SAFETY ISSUES	COST TO INSTALL ($)	LIFE OF EQUIPMENT (YEARS)	ANNUAL COST ($)	ENERGY SAVINGS PER YEAR (10^6 BTU)	DOLLARS PER YEAR	MONEY SAVED PER YEAR	NET SAVINGS PER YEAR	SIMPLE PAYBACK (YEARS)	SAVINGS TO INVESTMENT RATIO (25 YEARS)	LIFE CYCLE COST (25 YEARS)	ESTIMATED EXISTING BOILER PLANT LIFE CYCLE COST (25 YEARS)
BUILDING No. 87018											
ECO1	$6,000.00	15	$3,000.00	3,700	$14,541.00	***	$11,541.00	0.52	3.95	$92,000.00	
ECO3	$2,000.00	5	***	1,800	$7,074.00	***	$7,074.00	0.28	17.69	$10,000.00	
ECO4	$5,000.00	25	***	***	***	***	***	***	***	$5,000.00	
ECO8	$5,000.00	15	***	1,800	$7,074.00	***	$7,074.00	0.71	17.69	$10,000.00	
ECO9	$1,000.00	15	***	***	***	***	***	***	***	$2,000.00	
ECO13	***	1	***	***	***	***	***	***	***	***	
SI1	$1,000.00	15	***	***	***	***	***	***	***	$2,000.00	
SI3	$1,000.00	15	***	***	***	***	***	***	***	$2,000.00	
SI4	$1,000.00	25	***	***	***	***	***	***	***	$1,000.00	
SI6	$2,000.00	25	***	***	***	***	***	***	***	$2,000.00	
TOTALS -	$24,000.00		$3,000.00	7,300	$28,689.00	$0.00	$25,689.00	0.93	5.69	$126,000.00	$5,388,400.00
BUILDING No. 90038											
ECO1	$6,000.00	15	$3,000.00	1,900	$7,467.00	***	$4,467.00	1.34	2.03	$92,000.00	
ECO3	$2,000.00	5	***	1,900	$7,467.00	***	$7,467.00	0.27	18.67	$10,000.00	
ECO4	$7,000.00	25	***	***	***	***	***	***	***	$7,000.00	
ECO6	$2,000.00	25	***	***	***	***	***	***	***	$2,000.00	
ECO7	$1,500.00	15	***	***	***	***	***	***	***	$3,000.00	
ECO9	$1,000.00	15	***	***	***	***	***	***	***	$2,000.00	
SI1	$3,000.00	15	***	***	***	***	***	***	***	$6,000.00	
SI3	$1,500.00	15	***	***	***	***	***	***	***	$3,000.00	
SI6	$1,000.00	25	***	***	***	***	***	***	***	$1,000.00	
TOTALS -	$25,000.00		$3,000.00	3,800	$14,934.00	$0.00	$11,934.00	2.09	2.96	$126,000.00	$2,109,600.00

ECO/ SAFETY ISSUES	COST TO INSTALL ($)	LIFE OF EQUIPMENT (YEARS)	ANNUAL COST ($)	ENERGY SAVINGS PER YEAR (10^6 BTU)	DOLLARS PER YEAR	MONEY SAVED PER YEAR	NET SAVINGS PER YEAR	SIMPLE PAYBACK (YEARS)	SAVINGS TO INVESTMENT RATIO (25 YEARS)	LIFE CYCLE COST (25 YEARS)	ESTIMATED EXISTING BOILER PLANT LIFE CYCLE COST (25 YEARS)
BUILDING No. 91001											
ECO1	$6,000.00	15	$3,000.00	700	$2,751.00	***	($249.00)	***	0.75	$92,000.00	
ECO3	$3,000.00	5	***	700	$2,751.00	***	$2,751.00	1.09	4.59	$15,000.00	
ECO4	$7,000.00	25	***	***	***	***	***	***	***	$7,000.00	
ECO6	$2,000.00	25	***	***	***	***	***	***	***	$2,000.00	
S11	$3,000.00	15	***	***	***	***	***	***	***	$6,000.00	
S12	$3,500.00	25	***	***	***	***	***	***	***	$3,500.00	
S13	$1,500.00	15	***	***	***	***	***	***	***	$3,000.00	
S14	$500.00	25	***	***	***	***	***	***	***	$500.00	
TOTALS -	$26,500.00		$3,000.00	1,400	$5,502.00	$0.00	$2,502.00	10.59	1.07	$129,000.00	$1,257,500.00
GRAND TOTALS -	$968,050.00		$57,000.00	85,350.00	$335,425.50	$5,000.00	$283,425.50	3.42	2.98	$2,856,600.00	$50,218,200.00

Appendix E: Selected Retrofit Detail Diagrams

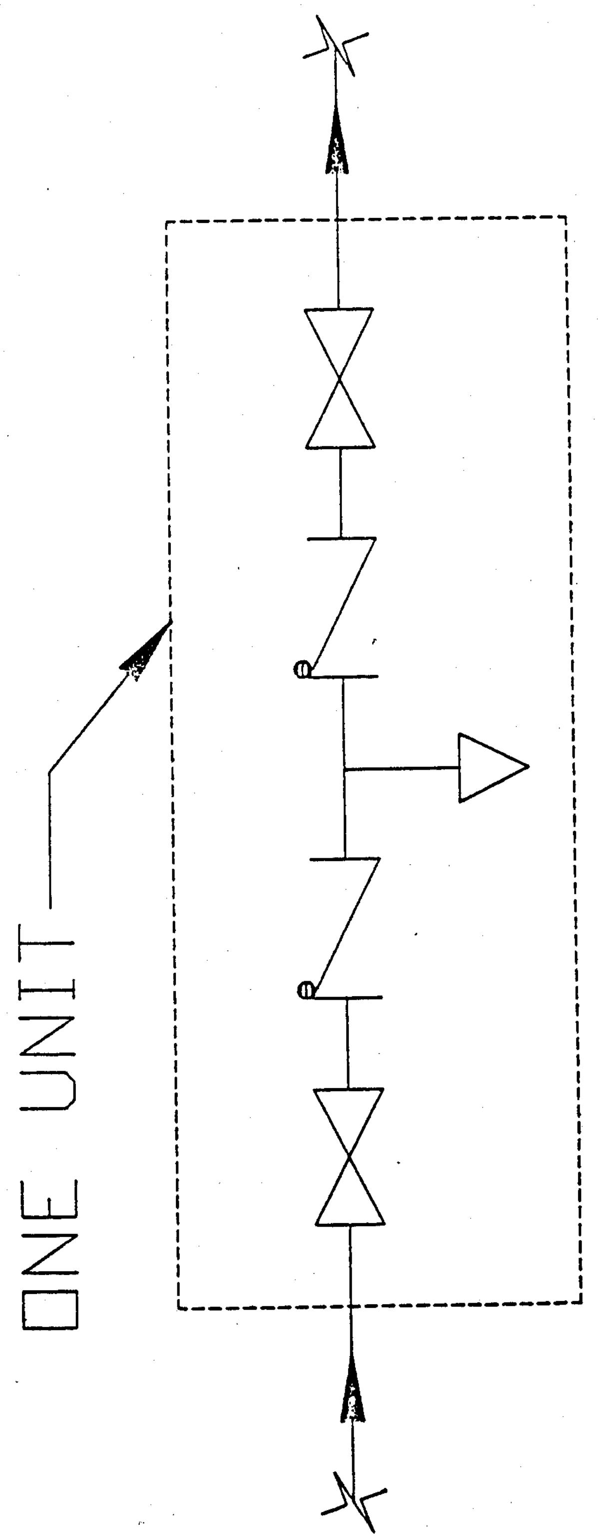


DIAGRAM 1
REDUCED PRESSURE PRINCIPAL
BACKFLOW PREVENTER

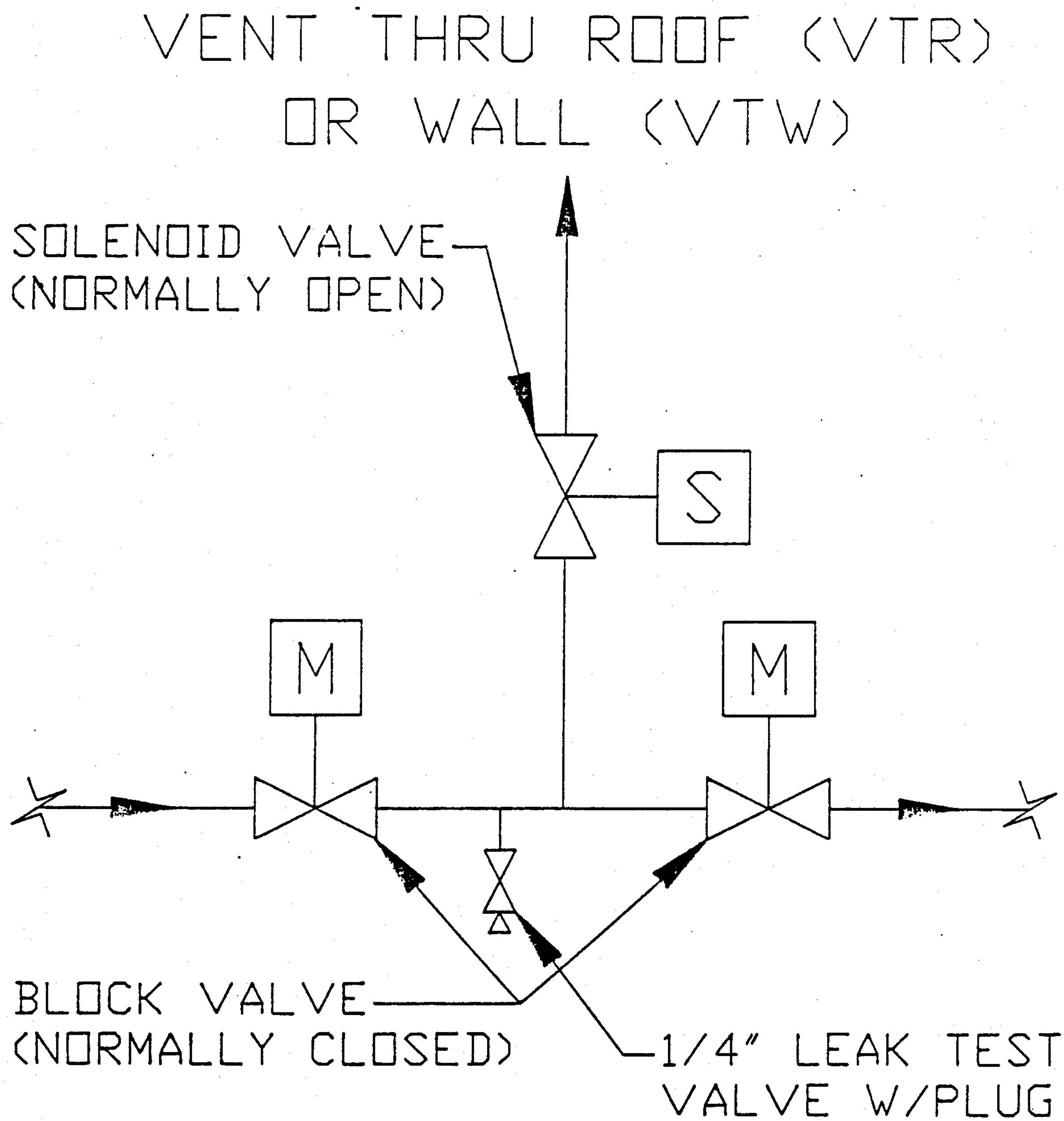


DIAGRAM 2

DOUBLE BLOCK AND BLEED

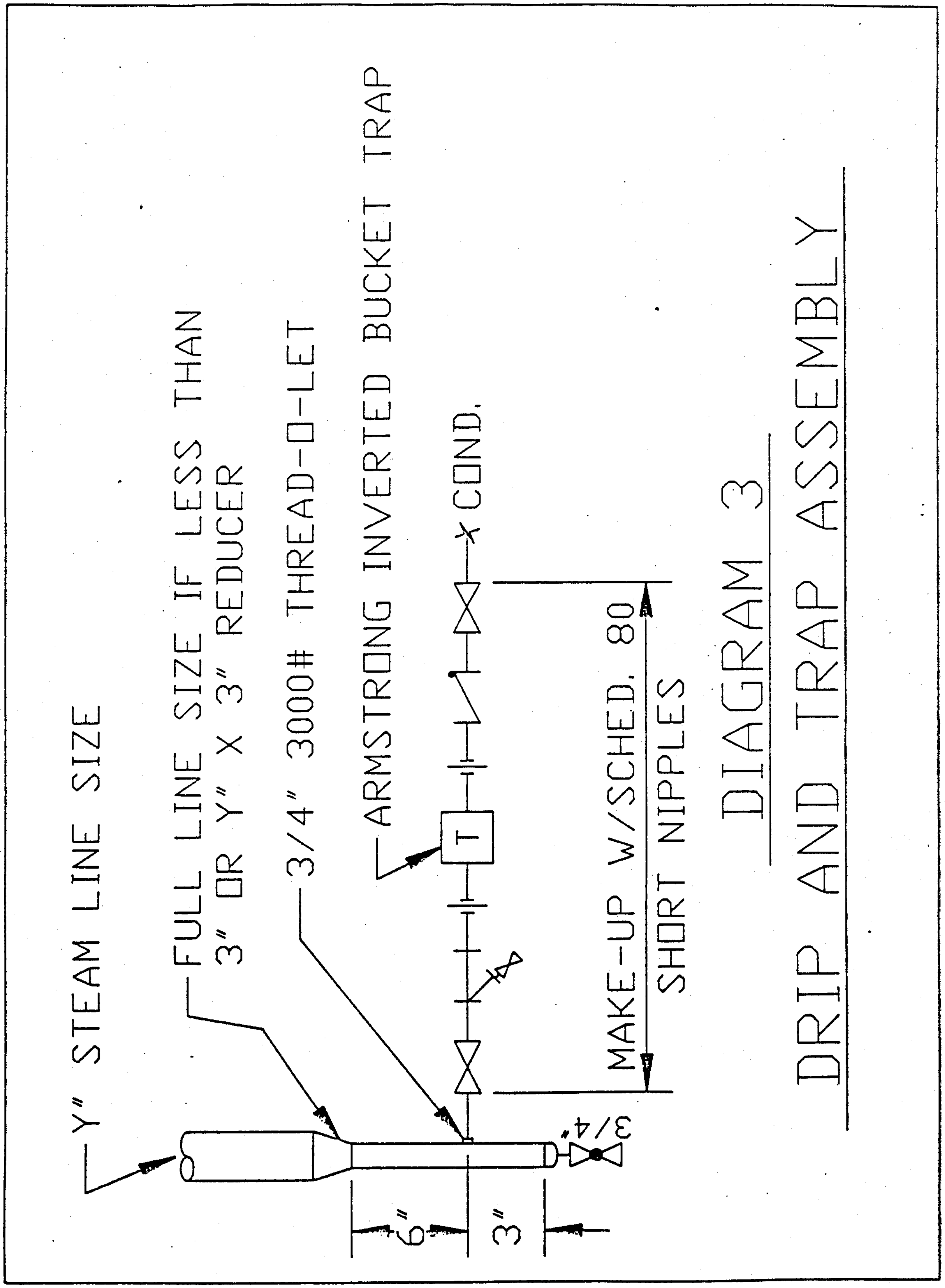


DIAGRAM 3

DRIP AND TRAP ASSEMBLY

USACERL DISTRIBUTION

Chief of Engineers
ATTN: CEHEC-IM-LH (2)
ATTN: CEHEC-IM-LP (2)
ATTN: CECC-R
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