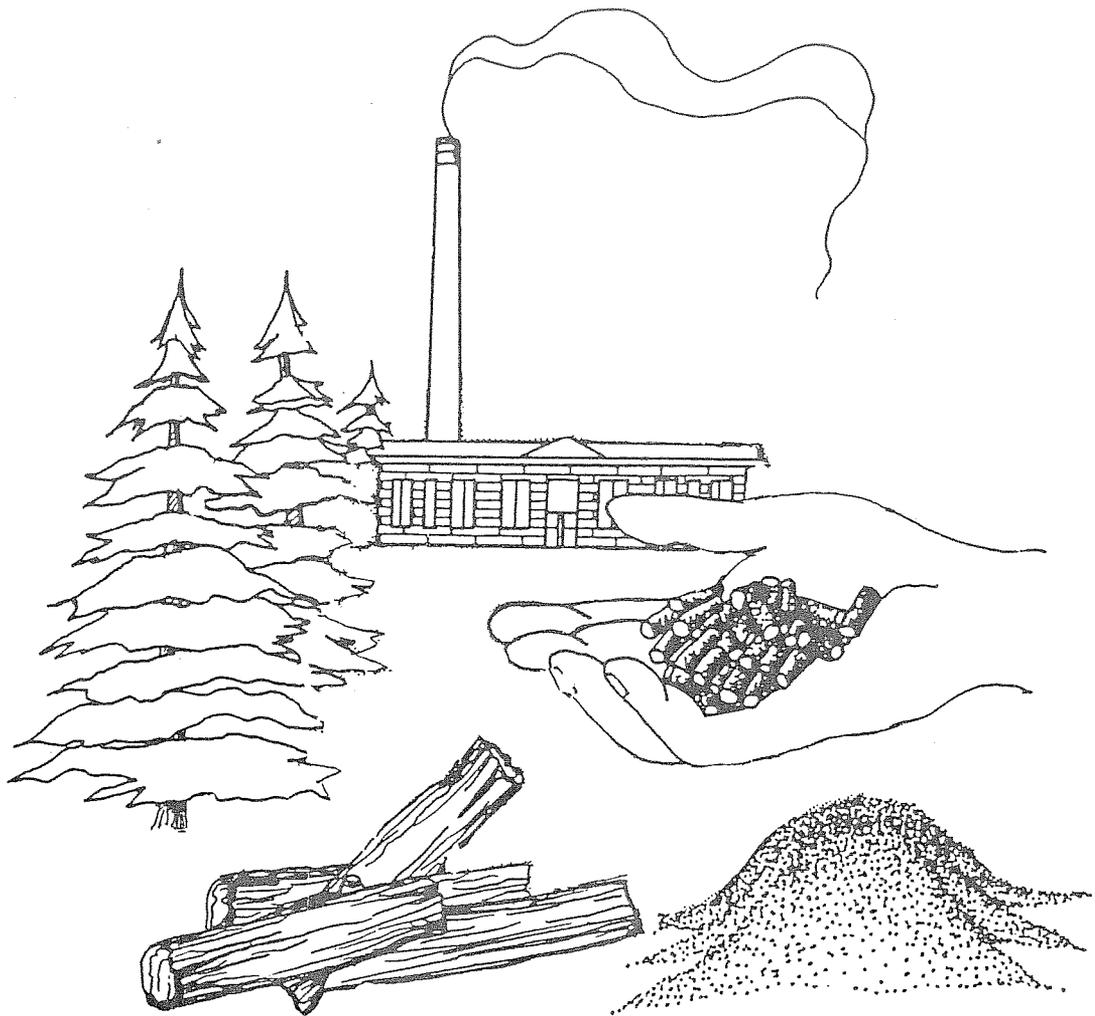


Use of Biomass Energy by Non-Forest Product Facilities

- CASE STUDY -



Idaho Department of Water Resources

 **Energy Division**

March 1991



**USE OF BIOMASS ENERGY BY
NON-FOREST PRODUCT FACILITIES**

- Case Studies -

Prepared by
Gerald Fleischman, P.E.
Idaho Department of Water Resources
Energy Division
Boise, Idaho

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INTRODUCTION

Examples of bioenergy are wood-fired boilers at sawmills, wood stoves in homes, biogas-fired electric generation units at wastewater treatment plants, black liquor boilers at paper mills, the production of ethanol from grains or corn for use in automobiles, the production of wood pellets and their use in pellet stoves and the use of biomass fuel (wood and municipal solid waste) for space heating and cooling and as industrial process heat. Bioenergy has tremendous potential to be an energy resource. If all the biomass waste in the Pacific Northwest were used to produce energy, it could supply a substantial percentage of the region's energy needs.

The forest-products industry has a long history of biomass fuel use, so when needs for energy arise, forest product facility managers have no aversion to considering biomass as an energy source. The same cannot be said for non-forest products facilities. Because of non-forest product facility managers' unfamiliarity with bioenergy¹, they often do not consider it as a possible energy source. However, bioenergy could be the best energy option. The following case studies were written to help people in the non-forest products sector become more familiar with the use of bioenergy so they will consider it as an energy option in the future.

There are several reasons for promoting the use of bioenergy. Most of the time, the biomass fuel used in bioenergy projects is locally produced. This prevents energy dollars from leaving the local economy. The use of locally produced bioenergy products can help keep rural economies strong and counteract migration of population from rural to urban areas. When bioenergy displaces the use of oil or natural gas, a percentage of energy dollars is prevented from leaving the country. Biomass wastes are the most common form of bioenergy resource used. If these wastes are not utilized in the production of energy, they would be landfilled or become a disposal problem. So, besides being a viable renewable energy resource, bioenergy helps to dispose of biomass waste products in an environmentally sound manner.

This publication is funded by the Pacific Northwest and Alaska Regional Bioenergy Program. The program is funded by the U. S. Department of Energy and administered by the Bonneville Power Administration. The program's purpose is to promote the use of biomass energy resources in economically and environmentally sound ways. The publication of these case studies is in furtherance of this purpose, and it is hoped some of the constraints to bioenergy use will be removed as a result.

A map of the Pacific Northwest on page headings indicates the location of the case study facility discussed on that page.

¹ Bioenergy: The conversion of the complex carbohydrates in organic material into energy, either by using it directly as a fuel or by processing it into a more usable or transportable fuel.

WESTERN STATE HOSPITAL

FORT STEILACOOM, WASHINGTON

SYNOPSIS

Western State Hospital switched from coal to wood pellets 13 years ago and used them as the main heating fuel for 11 years before switching to natural gas. The hospital found pellets to be superior to coal. However, because of the unreliability of pellet fuel supplies, when the price of natural gas became lower than wood pellets in 1987, the hospital switched to natural gas as the main heating fuel. Pellets have proven to be an excellent backup fuel and allow the hospital to take advantage of the lower natural gas prices available with non-exclusive service.

BACKGROUND/PROJECT DESCRIPTION

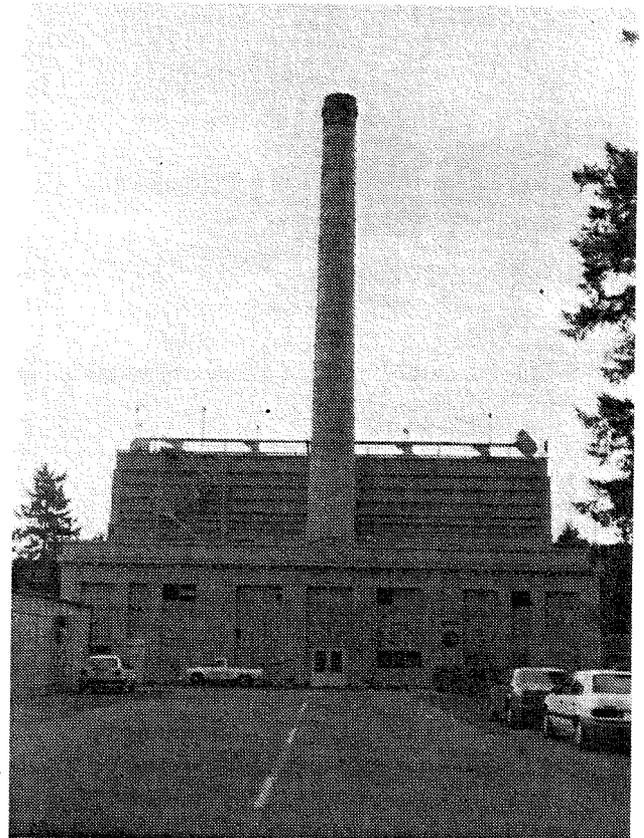
Western State Hospital is a mental institution operated by the State of Washington, Department of Social and Health Services. It is located in Fort Steilacoom, Washington, about 10 miles southwest of Tacoma near Puget Sound. The facility is the major mental institution in Washington with about 1,500 residents and 1,500 staff.

The central heating plant provides steam to heat 1.25 million square feet of building area on the campus. To switch from coal to wood pellets, the covered storage elevator was expanded and a new fuel elevator installed.

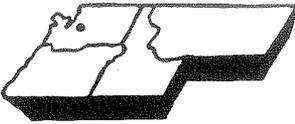
Until 1956 when the hospital added boiler No. 1, a natural gas boiler, to handle summer demand for steam, the only fuel used was coal. In 1965, because the price of natural gas was becoming competitive with coal, the hospital modified boiler No. 2 so it could burn natural gas as well as coal.

In the early 1970s, air pollution became a concern, and the hospital was fined for not meeting air pollution regulations while burning coal. Also, natural gas was becoming more expensive. It would have been very expensive for the hospital to add the air emissions control equipment necessary to allow it to continue to burn coal.

Instead, the hospital looked for alternative fuels which could meet air emissions requirements without adding costly air pollution control equipment. At about the same time, Bio-Solar of Brownsville, Oregon, started producing wood pellets making them available to Western State Hospital. The hospital initially purchased five tons of pellets for experimentation. They worked well so the hospital ordered more. From the fall of 1976 to the spring of 1987 (except during the construction of the new fuel elevator and the addition to pellet storage capacity in 1979), the heating plant used pellets as the main-winter fuel using approximately 12,000 tons a year. In 1987, the price of natural gas became low enough to make it a lower cost fuel than wood pellets. The hospital was glad to switch to natural gas because of the problems it had experienced maintaining a reliable supply of wood pellets. However, pellets worked well in the solid fuel boilers, making an excellent backup fuel and allowing the hospital to take advantage of low non-exclusive rates for natural gas service. Non-exclusive gas service requires that the customer have a reliable backup fuel.



Heating plant building.



There are three types of gas service offered by gas companies:

1. Firm Service - The gas company makes continuous supply of gas to the customer. The cost for gas supplied under this type of service is the highest of the various service options.

2. Interruptible Service - The gas company maintains service unless a shortage in supply requires cutting the load on its system. The interruptible customer will then be cut off after being given prior notice by the gas company. The customer must switch to its secondary fuel source within a time period specified in its gas service contract with the gas company. Generally, gas is sold at a lower rate with interruptible than with firm service.

3. Non-Exclusive Service - Gas service can be cut off for any reason as long as the customer is given a pre-agreed length of time to make the transition to its secondary fuel. Non-exclusive customers can buy transportation gas directly from a gas producing company and pay a pipeline rental charge to gas pipeline companies for transporting it through their pipelines. Non-exclusive service generally has the lowest rates.

TECHNOLOGY/EQUIPMENT

The hospital operates a central heating plant equipped with three boilers. The size, type, and auxiliary equipment are presented in Table 1.

Table 1
HEATING PLANT EQUIPMENT
Western State Hospital

| Boiler No. | 1 | 2 | 3 |
|---------------------------------|--------------------------------------|-----------------------------------|----------------------------|
| Make | Garret and Shaffer Engineering Works | Whyatt and Kipper | Puget Sound Machinery Dept |
| Boiler Type | water tube | water tube | water tube |
| Year Installed | 1956 | 1965 | 1947 |
| Boiler Ratings (lbs steam/hour) | 18,000 | 62,000 | 47,000 |
| Boiler Hp. | 422 | 827 | 650 |
| Stoker | none | Hoffman spreader | Hoffman spreader |
| Grate Type | none | shaker | shaker |
| Fuel | natural gas | wood pellets, coal or natural gas | wood pellets or coal |

In 1976, when the hospital switched to wood pellets, the heating plant had a pellet storage capacity of 200 tons. This is a three-day supply during the winter. Heating plant management soon discovered that wood pellets, unlike coal, could not be stored outside if necessary to increase storage because they fall apart when they get wet.

Bio-Solar and Lignetics in Sandpoint, Idaho, were the only major pellet suppliers in the Northwest in 1976. Because of the hospital's small fuel storage capacity, pellet suppliers delivered pellets twice a day compared to the previous three times a week delivery schedule of coal. Bad weather and the distance from the suppliers (260 miles to Brownsville and over 300 miles to Sandpoint) caused delays in delivery of pellets.

For these reasons, in 1979, after three years of wood-pellet use, hospital management decided to expand the covered fuel storage to ensure an adequate supply of clean, dry pellets through the winter. The hospital expanded the storage area by extending the walls upward 30 feet and installing a new roof. This increased the storage capacity from 200 to 1,129 tons of pellets. Because of the modifications to the storage area, the old coal elevator was too short. It also allowed dust to escape when pellets were moved from the unloading hoppers to storage. As a result, the hospital replaced it with a new enclosed grain elevator. The only modifications made to the boilers were adjustments to fuel-feed and air-feed rates.

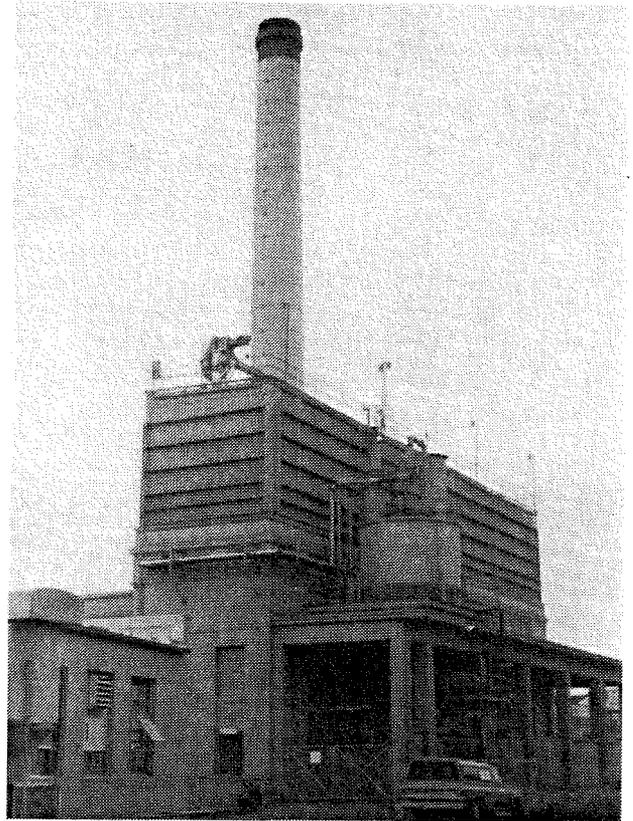
Heating plant operators have made several other improvements to make the use of pellets more efficient and safe. They added grates over the hoppers in the bottom-dump truck unloading area to prevent trucks or people from falling into them. Wooden decks and grates were also added over the grain elevator under the main building for the same reason. They also installed an emergency pellet-elevator shutoff cable near the bottom-dump hopper unloading gates, similar to the type used on busses to signal the driver to stop and to shut the elevator off in case of an emergency.

OPERATING EXPERIENCE

Bottom-dump semi-tractor trailers deliver pellets to an unloading area at the back of the plant building. The hoppers under the unloading area can hold approximately 120 tons of pellets. (See flow chart on page 6)

Plant operators move pellets from these hoppers to a storage bin above the plant building by opening gates which let pellets flow from the hoppers to a grain elevator. The elevator carries pellets to the top of the storage bin. By opening the appropriate gates, plant operators can place pellets into the storage areas above any one of the three boilers.

The No. 2 and No. 3 solid-fuel boilers have Hoffman spreader stokers and vibrating grates. Pellets come down from the storage bin through chutes to the stoker which throws them to the back of a shaker grate in the boiler. The shaker grate is a large flat platform (about 12 feet square) covered with fire brick with many small holes. Air comes through these holes from under the grate to burn pellets on the grate. The entire grate structure moves in a circular motion that shakes pellets toward the front of the grate. An adjustable timer controls the percentage of time the grate vibrates. By the time pellets reach the front of the grate, they are completely burned to ash. The ash then drops over the front of the grate into an ash pit.



Pellet unloading area at rear of building on right and pellet storage on top of boiler plant building.



Western State Hospital Heating System Flow Diagram

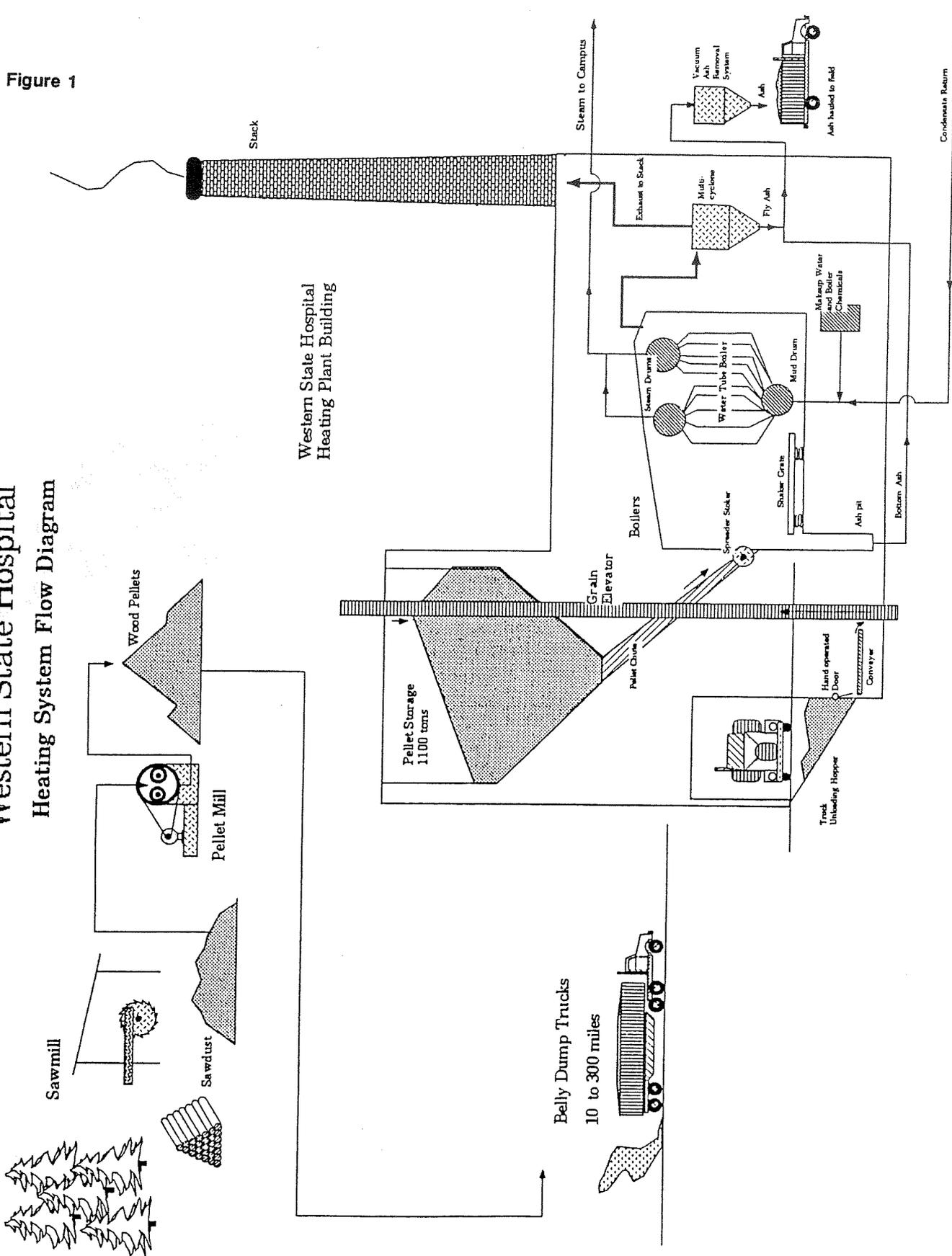
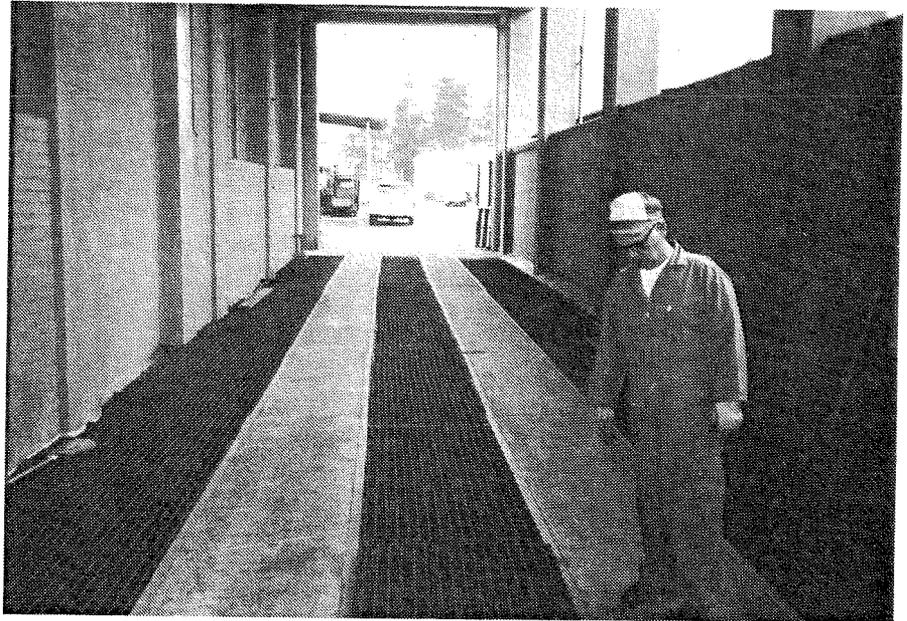


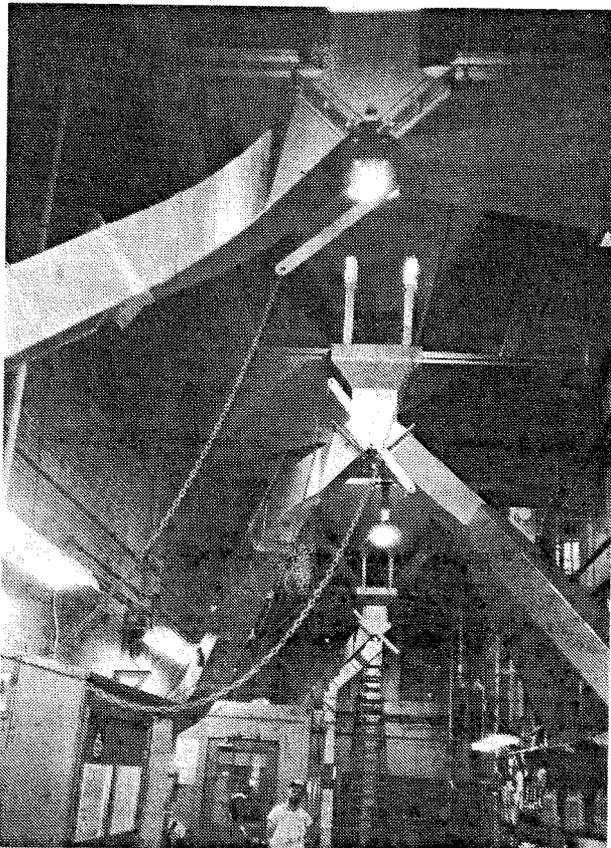
Figure 1

When the boilers are operating on pellets, plant operators use a vacuum system to remove ash from the ash pits in front of No. 2 or No. 3 boilers. The vacuum system delivers ash to a cone-bottom tank at the rear of the heating plant building. Operators use the same vacuum system to collect fly ash from the multicyclones on the exhaust side of the boiler. When the cone bottom tank is full, operators empty the ash into a truck and haul it to fields on the campus where it is spread.

When using pellets, plant operators blow soot off the boiler tubes by manually operating soot blowers once during the swing shift and once during the night



Ernie Truijuillo, boiler plant foreman, inspects pellet unloading area.



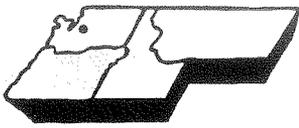
Interior of boiler plant building showing chutes from pellet storage bins to boilers at lower right.

shift. Soot blowers are rotatable steam pipes inside the boiler that have steam spray nozzles. Steam from the nozzles blows soot from boiler tubes. When the hospital burned coal, boiler tubes were cleaned by hand every 600 hours of operation. Since using pellets, operators have only cleaned boiler tubes with soot blowers, and the tubes have remained clean enough to maintain good boiler efficiency.

The maintenance cost associated with the use of wood pellets are lower than those associated with coal. Pellets slide on conveyors and chutes whereas coal digs in and causes wear. Coal contains rocks and other hard materials which damage conveying equipment and boiler grates. Also, wood pellet dust is less abrasive than coal dust and causes fewer problems. The hospital has experienced no bearings failures or fuel-related downtime since using pellets.

The heating plant has five operators. No additional staff are needed to run on pellets than on natural gas. However, when the plant is running on natural gas, the operators are available for other work, which they could not do when the plant runs on pellets.

Since 1987, the heating plant has operated on natural gas except for a 10-day period in February 1989 when a record cold spell forced the gas utility to cut off its interruptible and non-exclusive service customers and the hospital converted to pellets in less than four hours. During this period, the hospital used 575 tons of pellets.



FINANCING/ECONOMICS

Converting to the use of wood pellets in 1976 cost very little. However it became apparent that a larger fuel storage capacity and a new elevator would greatly improve operations using wood pellets. So, in 1979, the hospital increased its pellet storage capacity and installed a new elevator. The total cost of these improvements was approximately \$500,000.

The plant manager said the project was financed from the state's general fund. No payback period was calculated because the improvements did not lower the cost of fuel. However, the improvements allowed the hospital to continue using pellets and avoid the cost of expensive emission control equipment, which burning coal would have required.

There are many variables involved in calculating which fuel, natural gas or pellets, costs less to use. In the fall of 1989 the hospital was paying about 35 cents a therm for natural gas. At the same time, the hospital purchased 300 tons of pellets to replenish its backup fuel supply from a Tacoma wood pellet manufacturer for approximately \$48 a ton. At this price, the energy value of pellets is equivalent to natural gas at 29 cents a therm. Considering fuel costs only, wood pellets would cost the hospital \$120,000 a year less than natural gas.

However, several factors enter into the decision to switch fuels. As a result of using natural gas, plant staff are available for other work an extra 22 hours a day. Also, there is some extra wear on equipment and a little more electric power usage when operating on pellets.



By manually operating dump doors on grain elevator (upper left of photo) pellets can be dropped into any part of the pellet storage area.

PERMITTING AND ENVIRONMENTAL CONSIDERATIONS

The hospital has not been cited for an air emission regulation violation while using wood pellets. Air emissions standards for uncontrolled boilers, those boilers without major air pollution control equipment like Western State Hospital's, are more stringent for coal than for wood. An uncontrolled wood boiler can discharge a maximum of 0.2 grains of particulate per standard cubic foot of stack exhaust gas. An uncontrolled coal boiler can discharge only half that amount.

CONCLUSION

Hospital staff would not recommend wood pellets as a main fuel because the supply has been too unreliable. However, the hospital's experience has shown pellets to be a good main and backup fuel. The residential pellet fuel market has grown tremendously during the past few years and is helping make the supply of wood pellet fuel more dependable. When Western State Hospital first converted to pellets, the residential market was almost non-existent. Decisions of large institutions to use pellets had a big influence on the pellet market. Now, because of the number of residential pellet stoves in use, the demand for residential fuel pellets is helping to increase the number of pellet manufacturers thus making a more dependable supply of pellets available. A reliable supply of wood pellet fuel will remove one of the major drawbacks to the use of wood pellet fuel by large commercial or institutional fuel users.

ALCOTECH

RINGLING, MONTANA

SYNOPSIS

Gordon and Jay Doig run Alcotech, a privately owned company that manufactures ethanol in Ringling, Montana. Local barley and wheat and out of state corn are the raw materials used. Waste wood from local sawmills supplies plant energy needs. Originally, the plant used propane to produce process heat. In 1987 the Doigs switched to a hog-fuel² boiler which saves from \$350 to \$900 a day and helps to make Alcotech an economically sound enterprise.

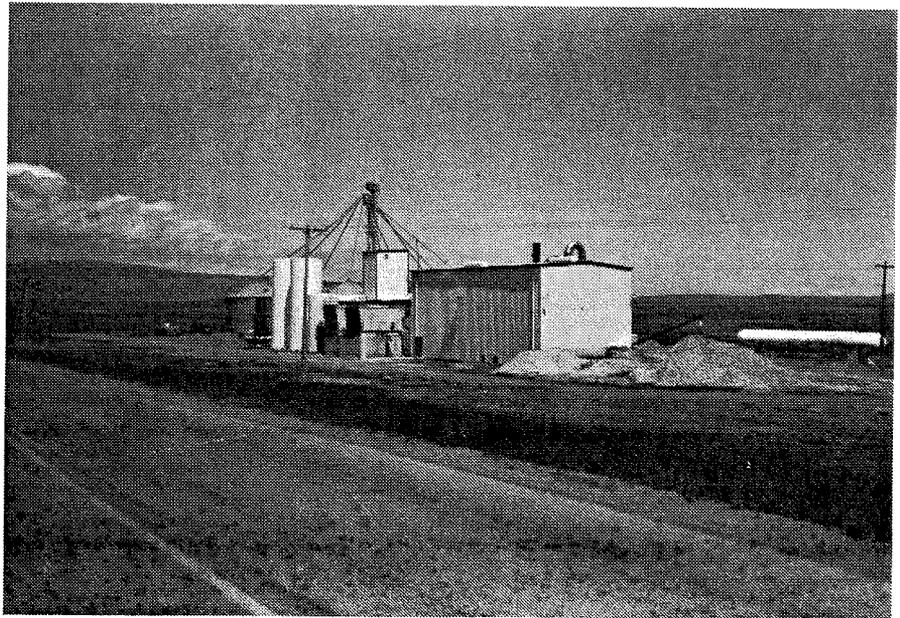
BACKGROUND/PROJECT DESCRIPTION

The land around Ringling is excellent for dry land wheat and barley farming and cattle ranching. A main line of the Milwaukee Railroad, connecting the Upper Great Plains to Seattle, passed through Ringling. This made ranching and farming more profitable with low freight costs.

The Doigs owned ranches in the area and a grain elevator at Ringling. Due to financial difficulties, the Milwaukee Railroad decided in the late 1970s to abandon its lines. The Doigs knew it would be very difficult to be competitive in barley and wheat with the additional cost of truck transportation to the Burlington Northern Railroad at Livingston 52 miles away. They decided to find a way to add value to their crop to reduce the significance of freight costs. In the fall of 1989 barley sold for about \$3 a bushel or 7 cents a pound while ethanol sold for about \$1.50 a gallon or 22 cents a pound. With the same freight rate per pound, freight would represent a significantly smaller percentage of the cost of ethanol. Because of ethanol's bright future in the late 1970s the Doigs decided it was a good way to get around the transportation problem created by the abandonment of the railroad line through Ringling.

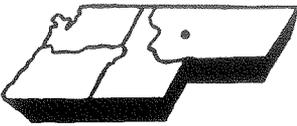
Although a consultant who specialized in the design and construction of ethanol plants built the plant in the early 1980s, the Doigs found that it did not work as well as promised. Early in the plant's operation, fire caused considerable damage and the plant had to be rebuilt. This was a blessing in disguise because it allowed the Doigs to rebuild the plant incorporating modifications they knew from experience would improve its operation.

After rebuilding the plant, rising costs of propane fuel prompted the Doigs to look for alternative energy sources. Hog fuel from local sawmills promised much lower energy costs. So in 1987, they removed the propane boiler and replaced it with a wood-fired boiler and added a new boiler building.



Alcotech plant with wood-fired boiler and hog fuel pile in foreground.

²Hog-fuel is sawmill wood residue that has been run through a chipper commonly called a hog, hence the name hog fuel.



TECHNOLOGY/EQUIPMENT

The main plant building occupies an area of 140 feet by 8 feet. There are several grain storage silos with a total capacity of 400,000 bushels which were part of the Doigs' original grain elevator business to the north of the main plant building. Also north of the main plant building are grain bins and milling equipment. East of the main building, in an attached uninsulated structure, are three 18,000 gallon vertical cone-bottom tanks for cold water storage, hot water preheating and cooking. Inside the main building are six 35,000-gallon horizontal fermentation tanks, distillation towers, and a dehydration unit. West of the main building are a cooling tower, denatured ethanol storage tanks and offices. East of the grain storage silos is the distillers' dried grain storage building, which is 80 feet by 120 feet and can store 191,000 bushels. South of the main building is the new boiler building. It is 40 feet by 60 feet in area.

OPERATING EXPERIENCE

Ethanol Plant Operation

Alcotech uses wheat, barley or corn as raw materials. Its final products are distillers' dried grains and denatured ethanol. The plant uses 21 tons or \$105 of hog fuel a day, with a usable energy content of 179 million Btus. Therefore the process uses 43 percent as much energy to produce the ethanol as the ethanol has in it. If process energy was expensive, energy conservation would be an important consideration. Low cost biomass fuel, however, allows much flexibility in plant operation. (Figure 2)

To produce ethanol, grain from the grain storage silos is first weighed before being run through a hammermill that grinds the grain into flour. The flour is lifted by grain elevator to the top of the cooking tank where it mixes with hot water and a liquefaction enzyme. This enzyme helps prepare the mixture, called mash, for fermentation by preventing it from turning into an oatmeal consistency and by helping to convert the starch in the grain to sugar. Grinding grain into flour is necessary to expose as much surface area as possible to the action of enzymes. Cooking mash takes one to two hours at 200°F. Heat from cooking ruptures starch cells allowing enzymes to attack and convert complex carbohydrates of starch to simple sugars.

The wood-fired boiler supplies steam for cooking through a steam line. One hundred twenty-five psig, 350°F steam is blown directly into the mixture. Operators manually control cooking temperature and almost every other process in the plant by observing gauges and adjusting valves. For example, if the temperature in the cooking tank gets too high the operator turns down a valve on the cooking steam line, reducing the amount of steam going to the cooking tank. The plant is manually operated so that if something is wrong, there is somebody there to take care of the problem.



Wes Stidham, plant foreman, checks level of enzymes in enzyme dispensing tank.

ETHANOL PROCESS AND STEAM FLOW CHART
ALCOTECH

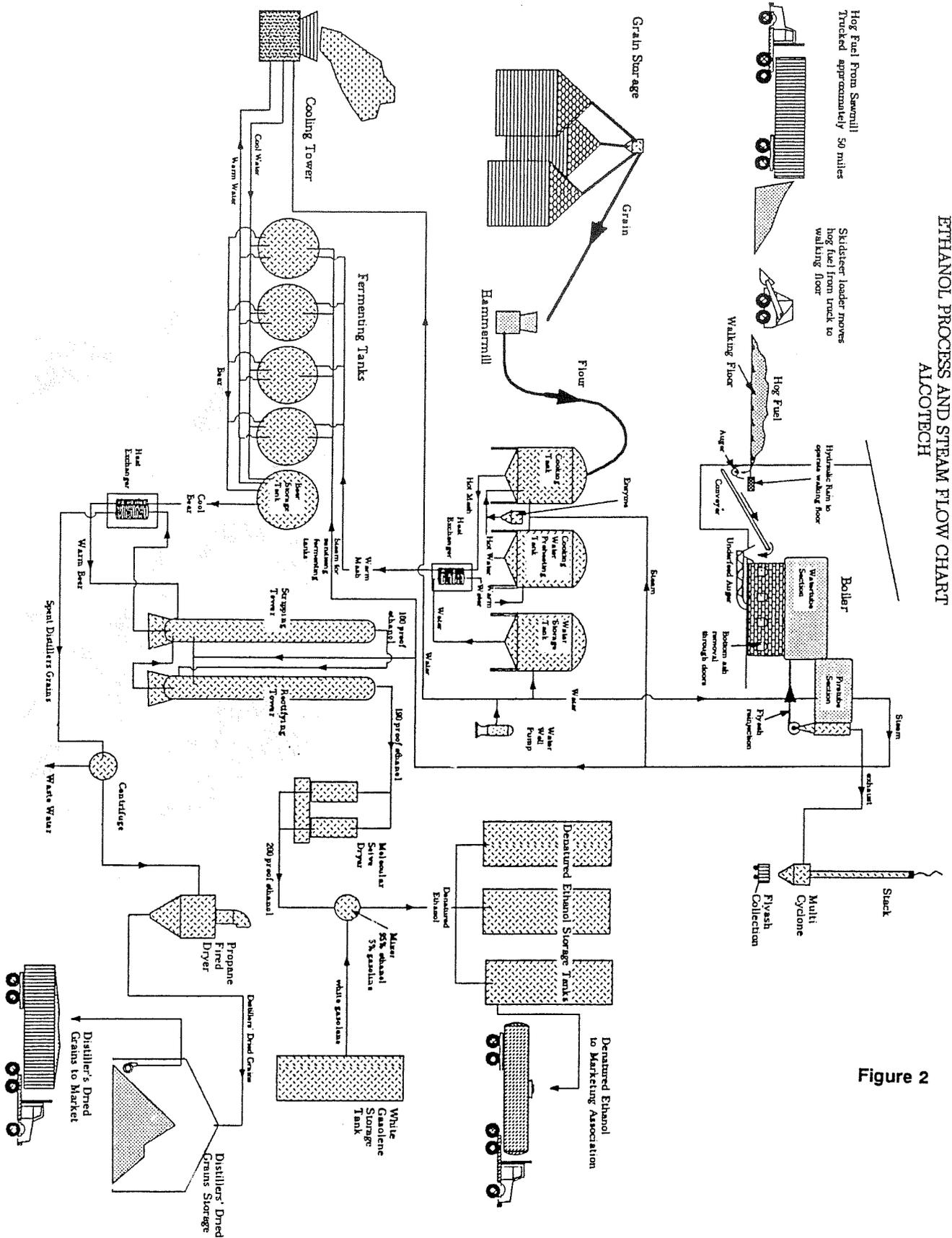
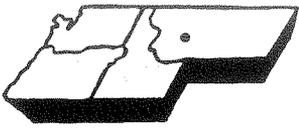


Figure 2



After mash is cooked, a plant operator sends it to one of five fermenting tanks. The ideal temperature for fermentation is around 100°F, but mash leaves the cooking tank at 200°F. A heat exchanger cools the mash while preheating the cooking water, transferring over 8 million Btus of heat per batch. This saves .38 cents per gallon of ethanol produced or almost \$5.50 on each 14,250 gallon cooking batch.

It takes two cooking batches to make one 28,500-gallon fermentation batch. A plant operator sterilizes the fermenting tank with steam before each fermentation cycle. The mash is cooled when it enters the fermentation tank, and during the fermentation process, by cool water flowing through copper tubes in the tank. The operator adds yeast, and the first batch gets a head start on fermentation before the second cooking batch is added. The fermentation process takes 60 hours to complete and converts sugar in the mash into ethyl alcohol, carbon dioxide and heat.

When fermentation is complete, the liquid is a "beer" and contains about 10 percent alcohol. It is then pumped to a holding tank. From the holding tank, the beer is pumped through distillation columns. Operators introduce steam from the boiler to the bottom and beer to the top of the first column. The first column is called the stripping tower because it separates alcohol and some of the water from the beer. This water-alcohol vapor mixture goes to the bottom of the second column, called the rectifying column, which raises the concentration of ethanol to 190 proof or 95 percent alcohol and 5 percent water. The hot beer with the alcohol removed, called wet distillers' grains, flows through a heat exchanger, which cools it and preheats cool beer from the beer storage tank on its way to the stripping tower, transferring 14 million Btus of heat per batch in the process. Wet spent distillers' grain flows from the heat exchanger to a centrifugal water extractor and through a propane-fired drier to make distillers' dried grains.

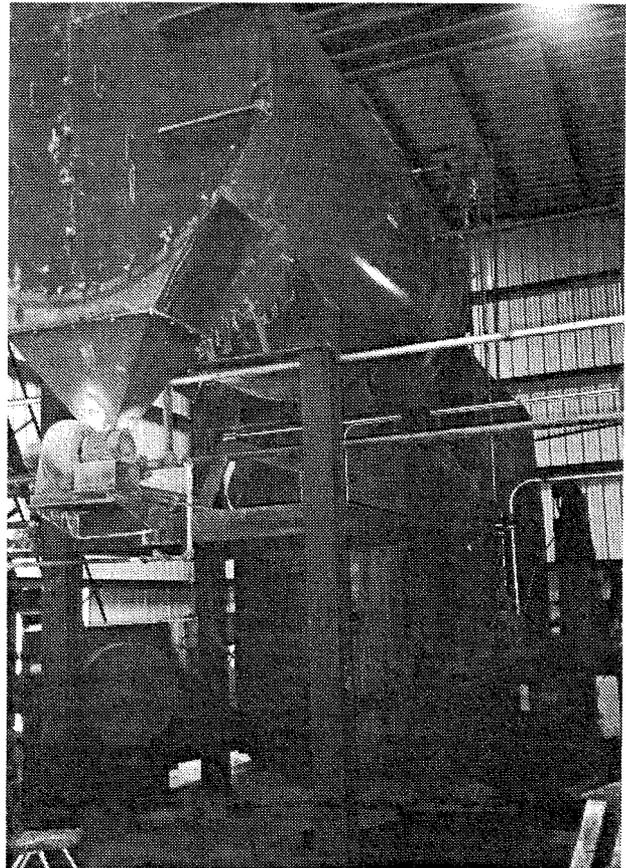
From the top of the rectifying tower, the 190 proof water-alcohol vapor mixture goes to a molecular sieve dehydration unit. After the ethanol vapor is condensed, it is mixed with gasoline in a 19 to 1 ratio to denature it and make it ready for sale (5% gasohol).

HOG-FUEL BOILER OPERATION

Hurst Boiler and Welding Co. Inc, of Coolidge, Georgia, installed the new 650 hp, 20,000 pounds of saturated 125 PSI steam per hour, hybrid boiler and all associated equipment in 1987. Rooney Construction, of White Sulfer Springs, Montana, constructed the boiler building.

There have been few problems associated with the hog-fuel boiler. One problem, which has been corrected, was in the fuel feed system. A paddle wheel sensor, called a bindicator, was failing to detect that a hopper was full, causing the auger upstream of the hopper to keep running. This would fill the entire area around the hopper with hog fuel. The plant manager changed the bindicator to a simple lever switch, which has worked well since.

A walking floor system moves fuel from the fuel storage pile outside the boiler building to a hopper inside. This system uses wedge shaped bars about 4 feet long by 1 foot wide by 3 inches high at the big end of the wedge. These wedges are attached perpendicularly to rods which can move in slots in the walking floor. An electric motor driven hydraulic pump supplies power to hydraulic cylinders which move the rods back and forth parallel to the direction of wood movement. Plant operators using a bobcat loader pile hog fuel on top of the walking floor outside the boiler building. The sharp edges of the wedge shaped bars point away from the direction of motion of the wood



Hog fuel boiler showing firetube section on upper left and water tube section on lower right.

and are flush with the floor. As the rods and attached wedges move away from the building, opposite to the direction of wood movement, the wedges' sharp edges move underneath the pile of wood. When the rod moves back, the thick edges of the wedges drag fuel with them. The motion of the walking floor pushes hog fuel from one wedge to the next until the wedges nearest the building push the fuel into a hopper inside the building. Adjacent rods and rows of wedges on the floor move in opposite direction, hence the name "walking floor."

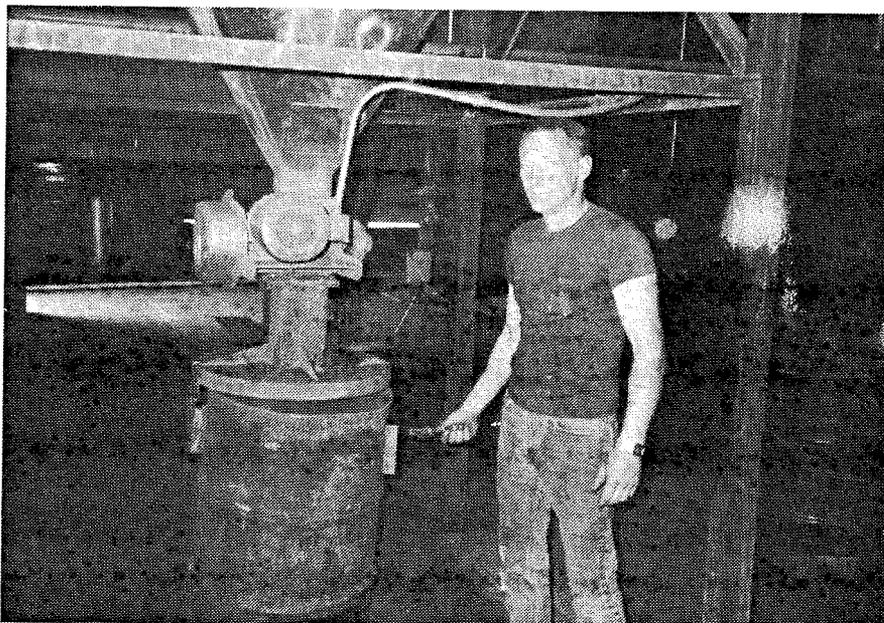
Another auger moves fuel to the underfeed fuel-screw auger. The underfeed screw auger pushes fuel into a retort or burning pot in the middle of the boiler. The fuel then falls over the edge of the retort onto surrounding cast iron grates. The fuel burns on the grates. Because the grates slope to the outside, ash ends up in a V-shaped area between the grates and refractory walls of the boiler. Plant operators remove ash manually with a rake and shovel about once a day.

A hybrid boiler is one that has both firetube and water tube sections. The boiler at Alcotech has a water tube section above the retort. This section connects to a firetube section, which is above and behind the retort-watertube section (See Figure 3). Exhaust gas from the retort-watertube section makes three passes through tubes in the firetube section before being discharged to a multicyclone, which removes fly ash.

A centrifugal induction draft fan on the rear of the firetube section of the boiler flings heavy incompletely burned ash to the outside of the fan housing where a small



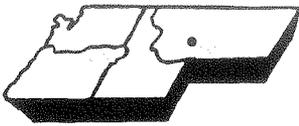
One of the walking floor wedges. Fuel moves to the left in this photograph.



Wes Stidham, plant foreman, demonstrates fly ash collection system.

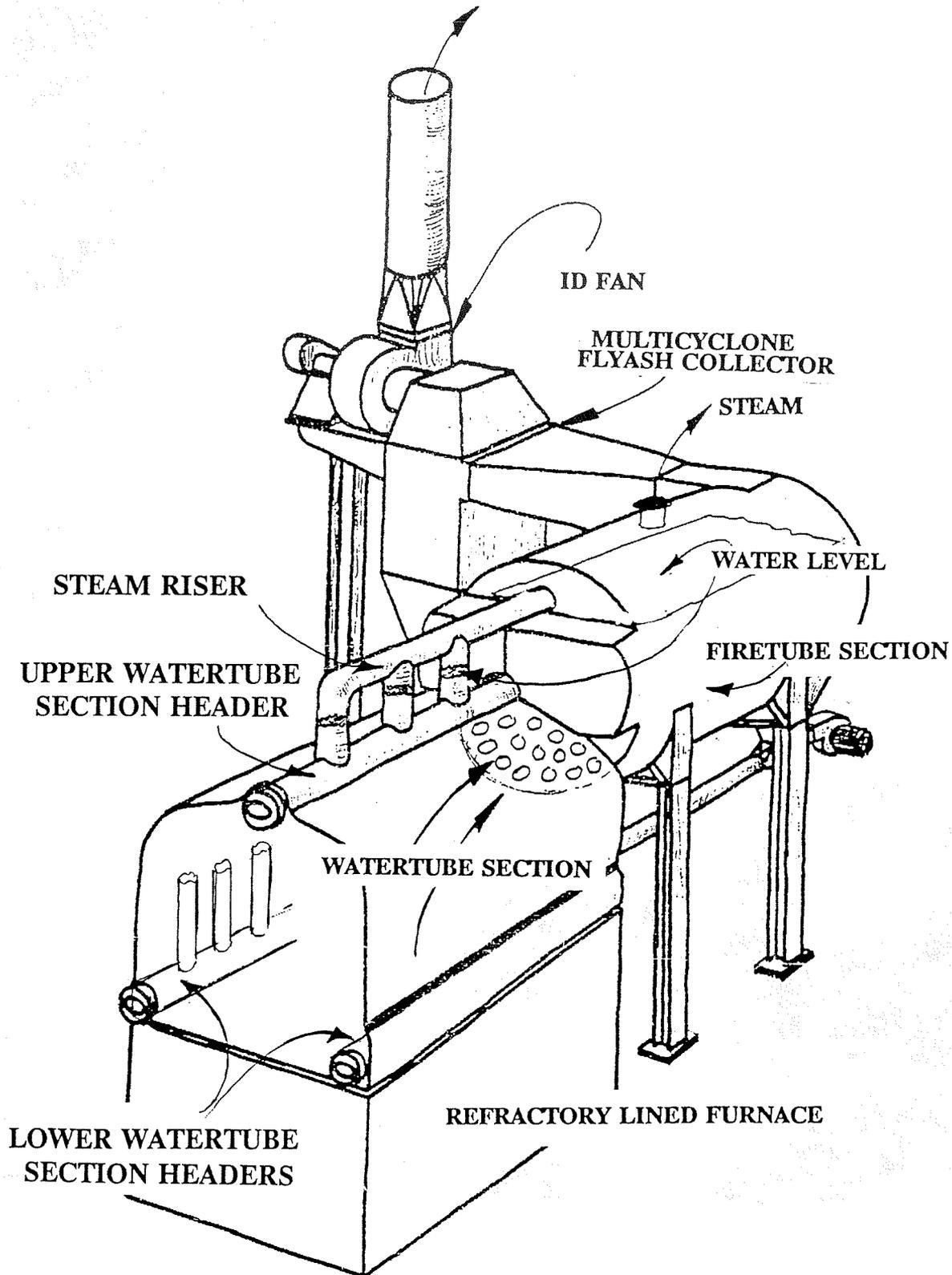
blower collects it and returns it to the firebox to be reburned.

Operation of the boiler is almost totally automatic. Although plant operators do not need to watch it continuously, they are all licensed boiler operators and capable of handling problems which may arise. Plant operators spend about an hour a day in boiler maintenance and operation. They also keep fuel on the walking floor and rake ash from grates daily and empty a barrel which collects fly ash from under the multicyclone when it is full. They dump the ash on a dirt road near the boiler building as a road topping. Reportedly, the ash makes an excellent road surface. After it has been wet and packed down, it is very similar to asphalt. In the



THREE PASS HURST HYBRID BOILER

Figure 3



two years the boiler has been in operation, there have been no problems other than the fuel feed problem which was fixed.

FINANCING/ECONOMICS

The original alcohol plant cost about \$3.5 million in 1981. It was privately financed by the Doigs with no government or other help.

Ethanol Plant Economics

Each bushel of barley yields approximately 2.5 gallons of ethanol, 14 pounds of dried distillers' grains and 14 pounds of carbon dioxide. At Alcotech,

carbon dioxide now has no market. However, there are markets for carbon dioxide in other parts of the country and one ethanol plant in the midwest sends it to an adjacent greenhouse where it promotes plant growth.

Dried distillers' grain makes a good cattle feed. In the fall of 1989, it sold for about \$156 a ton.

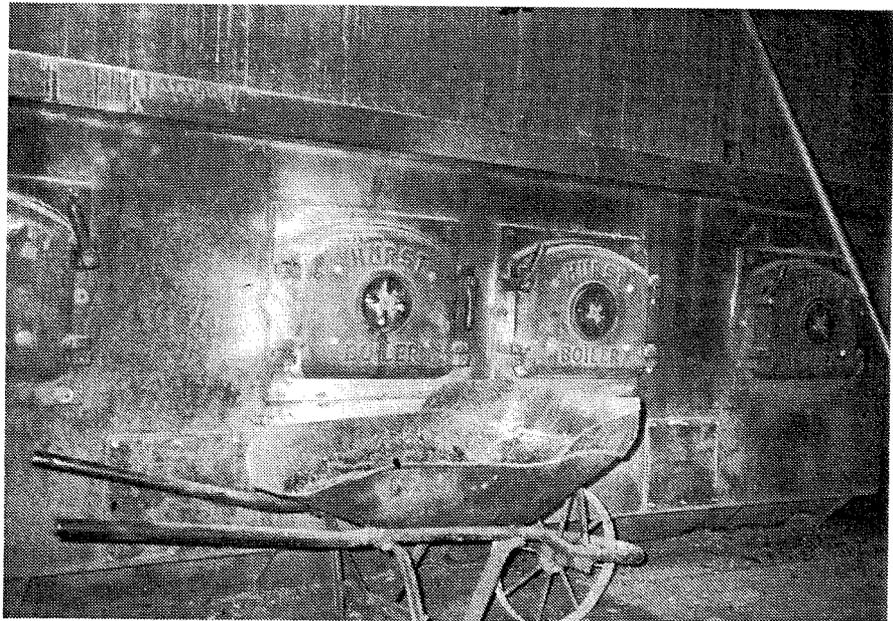
Alcotech produces about 5,000 gallons of ethanol a day. If the plant receives \$1.50 per gallon of ethanol and 43 cents for the 5.6 pounds of distillers' dried grains produced for each gallon of ethanol produced, the total income per gallon of ethanol produced would be \$1.93. Barley now costs about \$3 a bushel or about \$1.20 per gallon of ethanol produced. This makes an initial margin of 73 cents per gallon of ethanol. All the other costs of running the plant come out of this. If labor costs about 10 cents per gallon and amortization on the \$3.5 million initial cost of the plant about 49 cents a gallon, the remaining profit margin would be about 12 cents a gallon.

Process heat is one of the major costs of operating an alcohol plant. At Alcotech, it takes about 30,000 Btus of process heat to produce a gallon of ethanol. Producing this heat with 60 cents a gallon propane would contribute 20 cents to the cost of producing a gallon of ethanol. Heat produced by the hog-fuel boiler costs 9 cents per gallon of ethanol produced (2 cents for hog fuel and 7 cents for the additional capitalization cost of the wood-fired boiler), as compared to the propane-fired boiler.

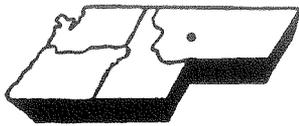
Using the above estimates, the plant would have a net loss of 8 cents per gallon of ethanol using propane and a profit of 3 cents per gallon using hog fuel. It is apparent that the use of hog fuel can make a significant difference in the profitability of a business where heat is a significant portion of the costs.

Hog-Fuel Boiler Economics

In 1987, the total cost of conversion from the propane-fired boiler to the wood-fired boiler was about \$500,000 (\$400,000 for the boiler and \$100,000 for the building). At that time, the plant was using 2,000 gallons of propane a day at a cost of 56 cents a gallon. Hog fuel was available from local sawmills for the cost of hauling, which was \$5 a green ton. An additional cost with the wood-fired boiler is an hour more operation and maintenance time than what is required for the propane fired boiler. Twenty-one tons of hog fuel at a cost of \$105 is equivalent to 2000 gallons of propane at a cost of \$1,120. Including the difference in operation and maintenance costs, the Doigs projected the wood-fired boiler would save about \$1,000 a day. Assuming 250 operating days a year, the boiler would have a simple payback of two years.



Bottom ash is removed through these side boiler doors by hand and hauled away with the wheelbarrow.



PERMITTING AND ENVIRONMENTAL CONSIDERATIONS

Alcotech has only a few inspections and regulations it must follow. The boiler is inspected once a year. The grain scale and ethanol meter are inspected periodically. Selling distillers' grain requires a feed license.

The Doigs own the land on which the Alcotech plant sits, and there is no zoning required in Meagher County.

Operators became familiar with the characteristics of ethanol and ethanol production and learned how to handle potential problems associated with it. For example, an ethanol fire can be controlled with water where as a petroleum fire cannot. Water mixes with alcohol eventually lowering the proof to a point that the mixture will not burn. Petroleum products will float on top of water and keep burning. The fermentation process produces carbon dioxide, so while fire is not a problem, there is a danger of suffocation.

CONCLUSION

The hog-fueled boiler has had a positive effect on the economics of producing ethanol at Alcotech. If it was necessary, a propane burner could be attached to the hog-fuel boiler to give it dual fuel capability. This has not been necessary. The hog-fuel boiler and hog-fuel supply have both been dependable enough to supply reliable process energy needs. In an industry in which energy is a significant percentage of the cost of the final product, low cost and reliability of the energy supply are important. At Alcotech, hog-fuel is proving to have these attributes.

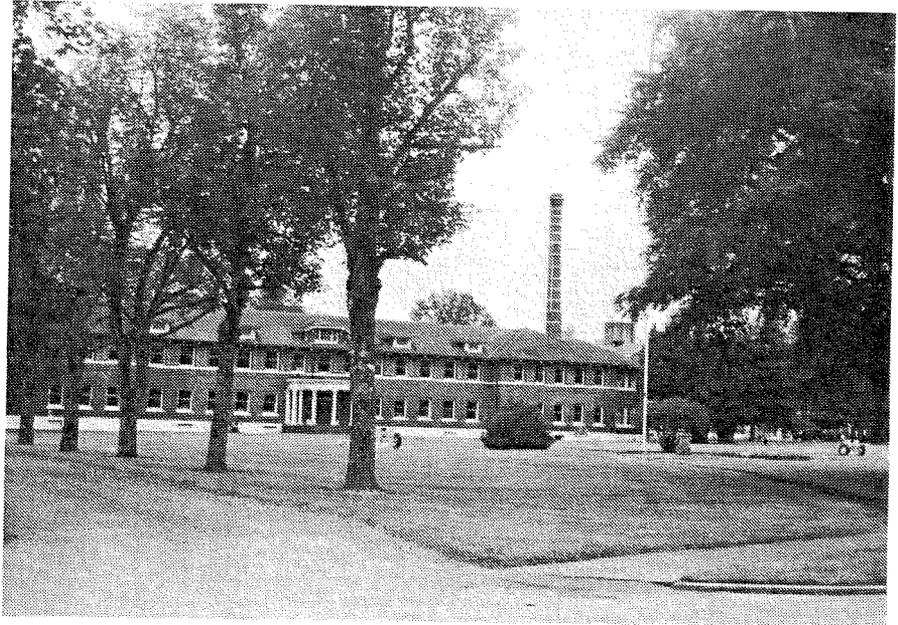
WASHINGTON SOLDIERS' HOME AND COLONY

ORTING, WASHINGTON

SYNOPSIS

For several years in the late 1970's and early 1980's, Washington Soldiers' Home and Colony (Home) used wood pellets. A couple of years ago the Home switched to natural gas when the management determined that switching would result in a considerable savings. The biggest part of the savings was due to the reduction by one in the heating plant operating staff which the use of natural gas and a new alarm system made possible.

Wood pellets now serve the role of a backup fuel which allows the Home to get low interruptible natural gas rates. A cold snap in February 1989 tested wood pellets use as a backup fuel. The gas company asked its interruptible service customers to switch to their secondary fuel sources. However, when Home personnel tried to switch to pellets, they found the pellets frozen in the fuel feed chute from the pellet storage silo. After attempting for several hours to run on pellets, John Buffington, manager of the Home's physical plant, informed the gas company that the Home would have to stay on natural gas. Home management has made arrangements to prevent a similar problem in the future and feel that pellets will work well as a backup fuel.



Garfield Building near entrance to Washington Soldiers' Home and Colony. Smoke stack on heating plant can be seen in background.

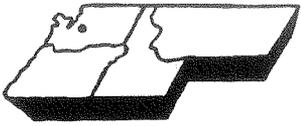
However, when Home personnel tried to switch to pellets, they found the pellets frozen in the fuel feed chute from the pellet storage silo. After attempting for several hours to run on pellets, John Buffington, manager of the Home's physical plant, informed the gas company that the Home would have to stay on natural gas. Home management has made arrangements to prevent a similar problem in the future and feel that pellets will work well as a backup fuel.

BACKGROUND/PROJECT DESCRIPTION

Established in 1891, Washington Soldiers' Home and Colony is a state run soldiers' home and full-care facility in Orting, Washington, about 25 miles southeast of Tacoma. There are now about 190 members (residents) at the 188-acre facility. Approximately 90 members take care of themselves while the remainder require full-time nursing care. (See Figure 4, Campus Map)

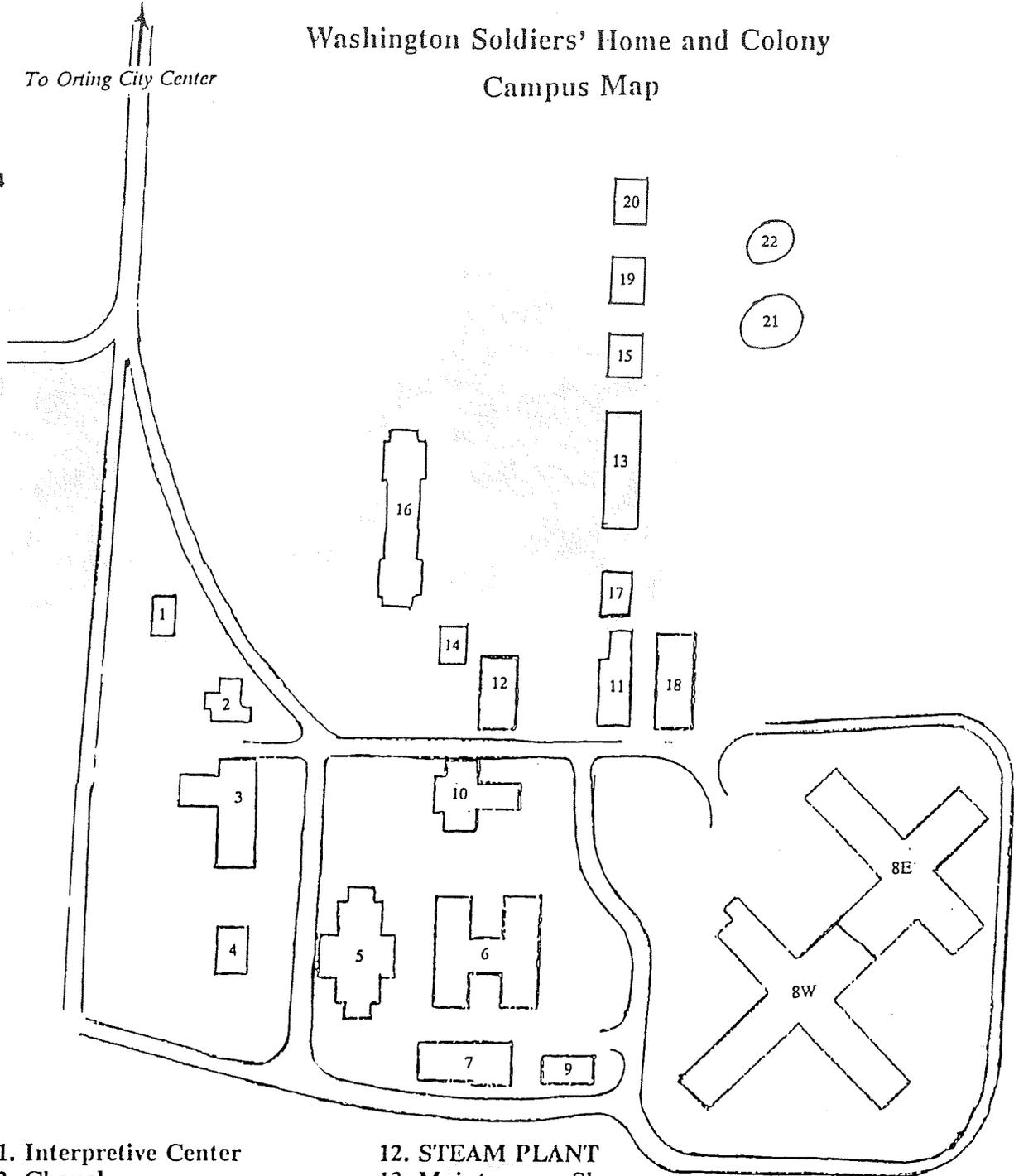
In 1976, the plant manager at Western State Hospital, about 20 miles away, suggested that the Home try wood pellets because of his facility's success with them. Soon afterwards, the Home tried wood pellets on an experimental basis. Until 1987, the Home used pellets as the main heating fuel. Lower gas prices at that time prompted the Home's management to switch to natural gas as the main fuel.

A central steam plant heats 18 of the 22 buildings on the campus. Built in about 1935, it has a smoke stack 125 feet high. The plant contains two solid fuel boilers and one natural gas boiler. The fuel silo was originally used to store coal, now it stores pellets. No major changes were made to burn pellets.



Washington Soldiers' Home and Colony Campus Map

Figure 4



- | | |
|----------------------------|---|
| 1. Interpretive Center | 12. STEAM PLANT |
| 2. Chapel | 13. Maintenance Shops |
| 3. Administration Building | 14. Emergency Generator |
| 4. Betsy Ross | 15. Fire Pump Building |
| 5. Chilson Hall | 16. Garfield |
| 6. Roosevelt | 17. Paint Shop |
| 7. Member Storage | 18. Vehicle Maintenance |
| 8. Nursing Care East/West | 19. Water Treatment Plant |
| 9. Member Hobby Shop | 20. Well House |
| 10. Dining Hall | 21. Fire Storage Tank (100,000 Gallons) |
| 11. Commissary | 22. Domestic Water Storage Tank (48,000 Gallons) |

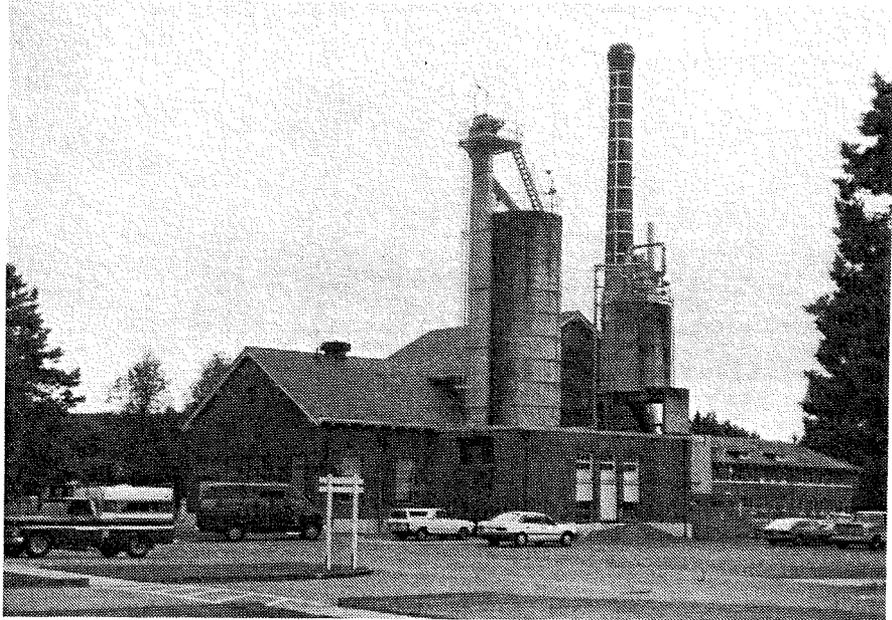
TECHNOLOGY/EQUIPMENT

The fuel storage silo is located next to the heating plant building. A chute transfers pellets to the heating plant.

The three boilers provide steam to the campus through a closed steam system going to the various buildings through tunnels. (See Table 2) The system uses about 35,000 gallons of makeup water a month. (See Figure 5, Flow Chart)

The Home runs 100 PSIG pressure in the boilers. Steam is used on the campus at various pressures from 40 PSIG in the kitchen to 5 or 6 PSIG for space heating.

The Home has converted two of the buildings to hot water heating systems. These systems use a heat exchanger in the buildings in which steam from the heating plant heats water which a pump circulates through the buildings.

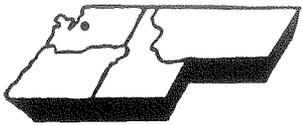


Steam plant building. The fuel storage silo is in the center.

Table 2 gives specifications of the steam generating equipment in the steam plant building.

Table 2
HEATING PLANT EQUIPMENT
Washington Soldiers Home and Colony

| Boiler No. | 1 | 2 | 3 |
|---------------------------------|-------------------|------------------|------------------|
| Manufacturer | Whyatt and Kipper | C & B | Cleaver Brooks |
| Type | water tube | firetube | 3 pass firetube |
| Fuel | solid fuel only | natural gas only | natural gas only |
| Fuel Feed | spreader stoker | underfeed | N/A |
| Grate system | shaker | fixed | N/A |
| Capacity (lbs steam/hr) | 5,000 | 8,550 | 3,450 |
| Boiler rating (lbs steam/hr) | 14,500 | 14,500 | Not Available |
| Operating pressure (psi) | 100 | 100 | 100 |



Washington Soldiers Home & Colony Flow Chart

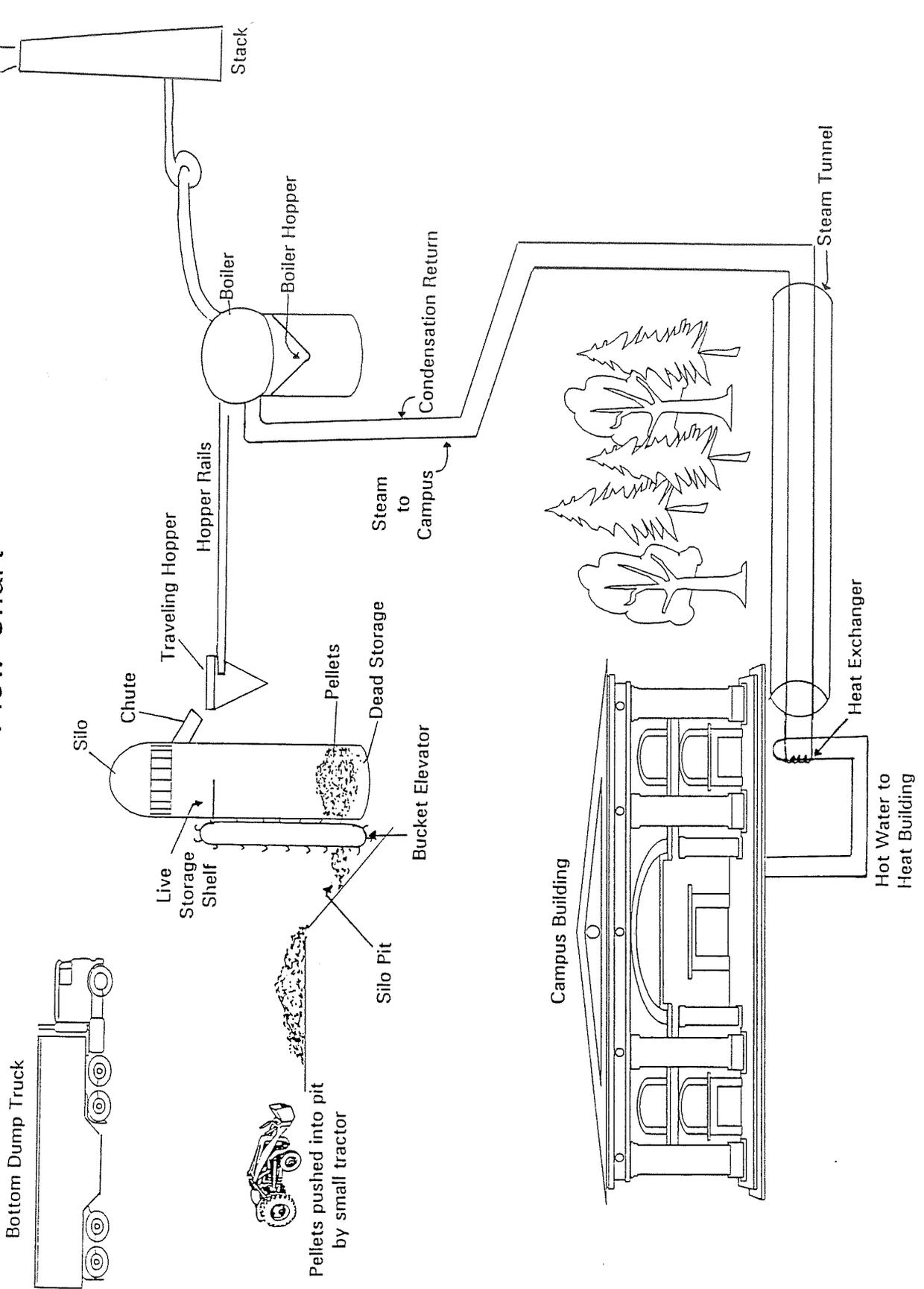


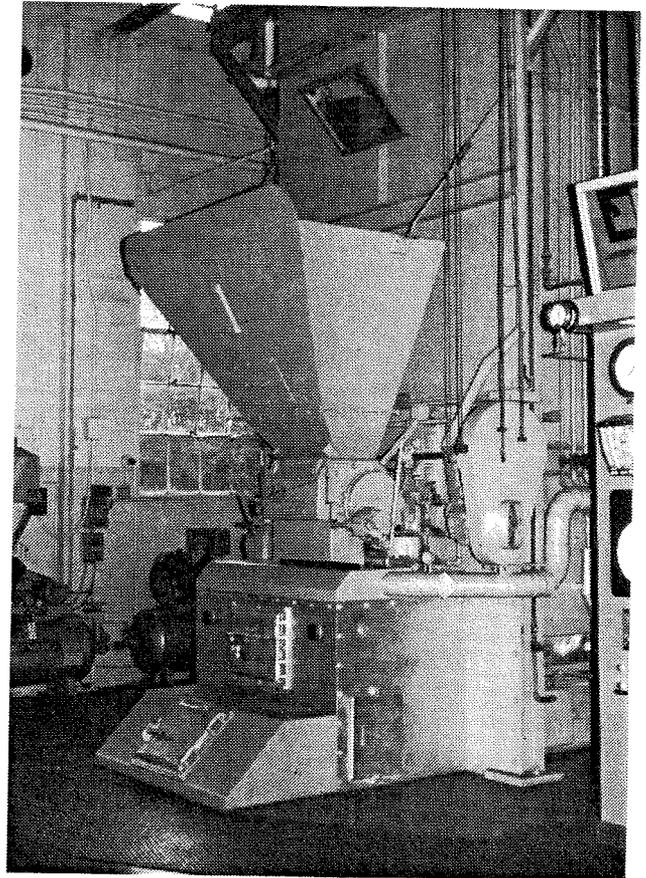
Figure 5

OPERATING EXPERIENCE

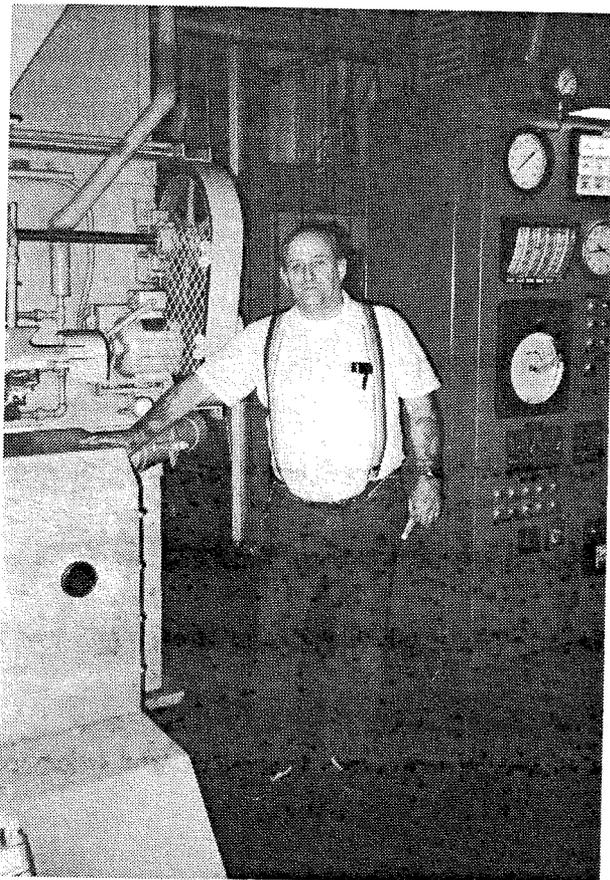
In 1976 when the Home first used pellets, the heating plant had a different setup than it does today. Number 1 boiler, which can burn only solid fuel, is the same today as it was then. It has a spreader stoker and vibrating grate system and works well on wood pellets. Boilers No. 2 and No. 3 were also solid-fuel boilers built in 1935. Pellets did not work well in them because they were underfire feed and slag would build up on the burning pot air holes. When an operator cleaned the slag from the air holes, the fire would backfire, creating a dangerous situation. In 1961 the Home replaced Boiler No. 2 with a boiler which can burn natural gas, solid fuel or oil. The present No. 2 boiler also uses underfeed for solid fuel so the problem of backfire is still a problem when it burns pellets. The Home replaced Boiler No. 3 in 1980 with a boiler which burns natural gas only.

An alarm system, installed in November 1987, allows the natural gas fired boilers (No. 2 and No.3) to operate unattended at night. However, when pellets are burned, an operator must be on duty.

During a cold snap in February 1989, the pellets froze in the chute which prevented the Home from switching to pellets. The problem was caused by mixing of coal and pellets. When the Home switched to pellets, it was not able to stick with them on a continuous basis. At times bad weather and road



Boiler #1 showing mirror that operators use to tell when to add more fuel to the boiler fuel hopper.

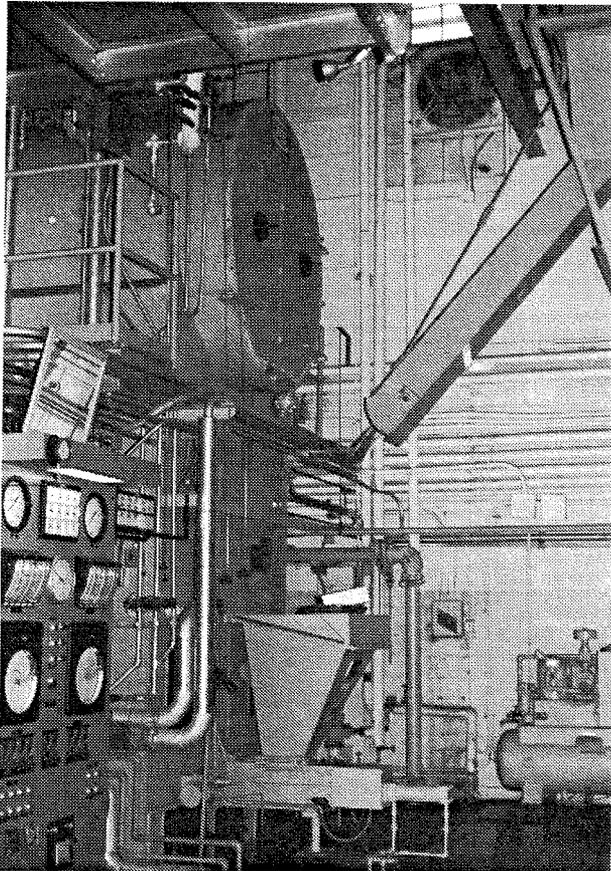


John Buffington, steam plant manager, poses next to boiler #1.

conditions prevented delivery of pellets, so the Home had to buy coal. Coal has a much higher moisture content than wood pellets and when the two are mixed, the pellets absorb moisture from the coal, swell, and can freeze together. Plant operators learned not to store the two fuels together.

Physical plant manager Buffington, prefers natural gas to wood pellets. He says natural gas is cleaner and requires less maintenance work. With practice, however, the heating plant crew has devised ways of keeping the plant clean while using pellets. Two of the ways they have accomplished this involve the unique solid-fuel delivery system (Photo 14). The pellet storage silo stands near the east side of the boiler building. A chute leads from the silo to the building. Operators use a travelling transfer hopper, which moves on rails suspended from the ceiling of the building, to move pellets from the live storage outlet chute to the boiler hoppers.

When the plant is using pellets, the operator can determine the level of pellets in the boiler fuel hoppers by looking in a mirror above the hoppers. When the level in the boiler hopper gets low enough, the operator brings the travelling hopper over and dumps a load into it. He then returns the traveling transfer hopper to the end of the building near the silo and refills it. Operators have found that leaving 100 pounds of pellets in the bottom of the traveling transfer hopper keeps pellet dust from falling out the bottom when loading it. Plant personnel also



Boiler #2 with travelling transfer hopper in upper right. Fan near the travelling transfer hopper is used to remove dust during the transfer hopper filling operation.

hotter and thus cleaner. When the Home switched to pellets, air pollution was not as much of a problem and the pellets burned too hot, warping the boiler's cast iron grate plates. The extra refractory that was added for coal also reduced the boiler's capacity. For these reasons, the Home removed the extra refractory after switching to wood pellets.

The Home installed an alarm system, which allows the boiler plant to be operated unattended on natural gas. When operating on pellets, the plant still needs an operator on duty at all times. In 1987, Home management estimated a savings of \$60,000 a year by switching to natural gas. This included the saving from one fewer plant operator which the use of natural gas allowed.

The Home now pays 41.3 cents a therm for interruptible gas service. In August 1989, the Home received a load of pellets from Manke Lumber in Tacoma for approximately \$59 a ton including tax. This is equivalent to 35 cents a therm. The Home uses about 300,000 therms of natural gas a year. Using these prices and assuming the efficiency of the gas boiler is about the same as the pellet boiler, the Home could save \$18,900 a year in fuel costs using pellets. With natural gas, the boiler operator is available for 3.5 hours of maintenance work around the campus each day, which he could not do if the plant used pellets. At \$14 an hour, this is equivalent to \$12,740 a year. Including the savings of needing one fewer \$35,000 a year plant operator, the Home is saving \$28,840 a year by using natural gas instead of wood pellets. If the price of pellets were to remain at \$59.13 a ton including tax, natural gas would have to cost more than 51 cents a therm for the full-time use of pellets to save money.

CONCLUSION

While natural gas remains a better choice economically, having a dependable backup fuel supply in the form of pellets has and will help Washington Soldiers' Home and Colony by allowing it to get low interruptible natural gas rates.

installed an exhaust fan near the live storage discharge chute which they turn on during the traveling hopper loading operation. These two measures eliminate most of the dust from the use of pellets.

The Home does not have as much energy storage capacity with pellets as it had with coal. The reason is because wood pellets' energy content per unit volume is about 65 percent of coal's. Thus the Home's energy storage capacity is 35 percent less than it was with coal. Because the Home still uses as much energy with pellets as with coal, this lack of storage capacity gives the Home less flexibility in the scheduling of fuel delivery.

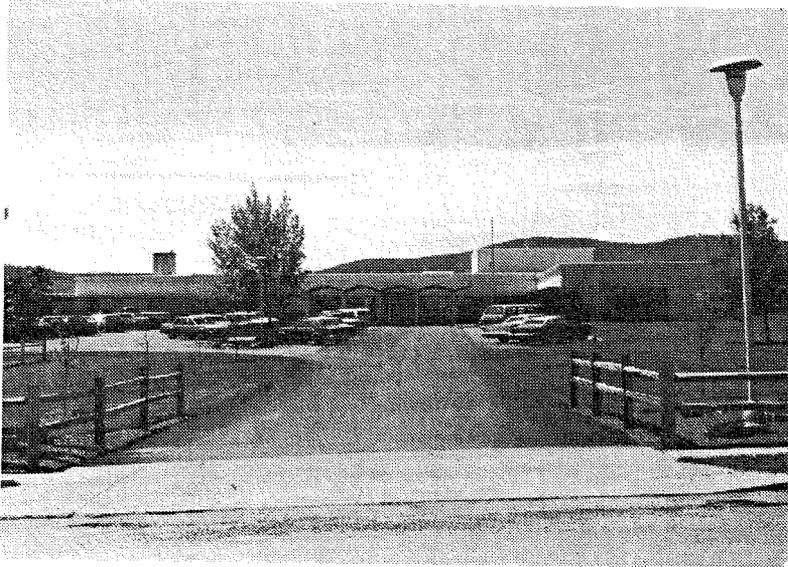
The type of trucks used to deliver pellets has also caused problems. Beet bed trucks with bottom unloading conveyers were used in the past. These trucks backed up to the unloading pit near the silo and unloaded the entire load of pellets. Belly-dump trucks are now used. These trucks dump a layer of pellets on the ground in front of the silo's loading pit. Using a small tractor, a plant operator pushes it into the pit. The system works well unless it is raining or snowing. Then the pellets can get wet or get mixed with snow and will swell and freeze in the storage or outlet chute.

FINANCING/ECONOMICS

Washington Soldiers' Home and Colony is run by the State of Washington Veterans' Affairs Administration. The Department of Veteran's Affairs and the state of Washington provide funding. The conversion to use of wood pellets required no major modifications to existing equipment other than the removal of refractory from the No. 1 boiler to allow efficient burning of pellets. The removal was required because refractory had been added to the walls of the boiler (covering the lower ends of the watertubes) in an attempt to make coal burn

ST. MARY'S HOSPITAL

COTTONWOOD, IDAHO



St. Mary's Hospital. Boiler smoke stack is on left. Although boiler is operating, no smoke is visible.

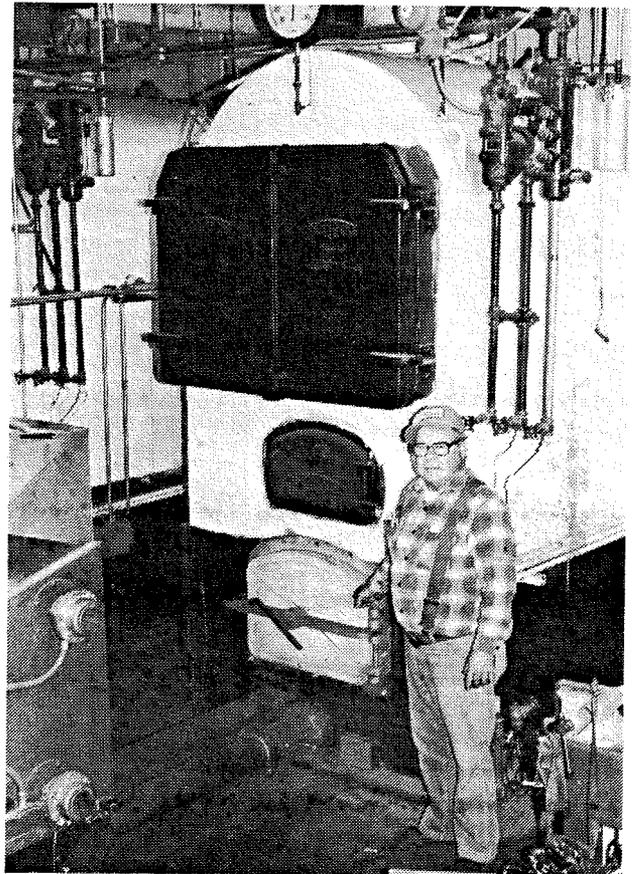
BACKGROUND/PROJECT DESCRIPTION

Initially two 72-hp oil-fired horizontal-return firetube boilers heated the 28 bed hospital built in 1964. When oil prices became high during the energy crunch of the 1970's, hospital management looked for alternative fuels. In 1980 one of the lower cost fuel choices was electricity, so the hospital installed a 90-hp electric boiler and kept the oil-fired boilers for backup.

In 1983 the price of electricity was becoming high causing hospital management to again look for alternative fuels. The cost of oil was also high, so the option of using the oil-fired boilers as the main heat supply would not save any money. Because wood pellets were available and offered a good energy value, the hospital made an in-house study to examine the technical and economic feasibility of converting the oil-fired boilers to wood pellets. Hospital management looked at the reliability of pellet supply, the cost of equipment modifications required to burn pellets, potential savings from using pellets and the availability of financial assistance. Because of the potential fuel-cost savings and financing available through the Energy Division, they decided to go ahead with the conversion to wood pellet fuel.

SYNOPSIS

Because of its location in Cottonwood, Idaho, the choices of fuel for St. Mary's Hospital management did not include natural gas when rising electric heating costs caused them to look for other fuels in 1985. Natural gas would be the lowest cost energy option if it were available. The hospital was using an electric boiler as its main source of heat with two 72-hp oil-fired boilers as a backup. At the same time, Lignetics of Idaho, in Sandpoint, was manufacturing and promoting the use of wood pellets and making them available at good prices. A loan from the Idaho Department of Water Resources' Energy Division helped the hospital retrofit its oil-fired boilers to burn pellets. The hospital now saves almost \$19,000 a year in fuel costs.



Bill Long, former maintenance supervisor, points out where fuel auger and combustion air tube from the stoker on the left enters the boiler near the floor.

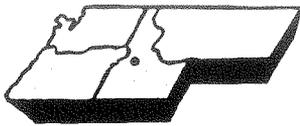
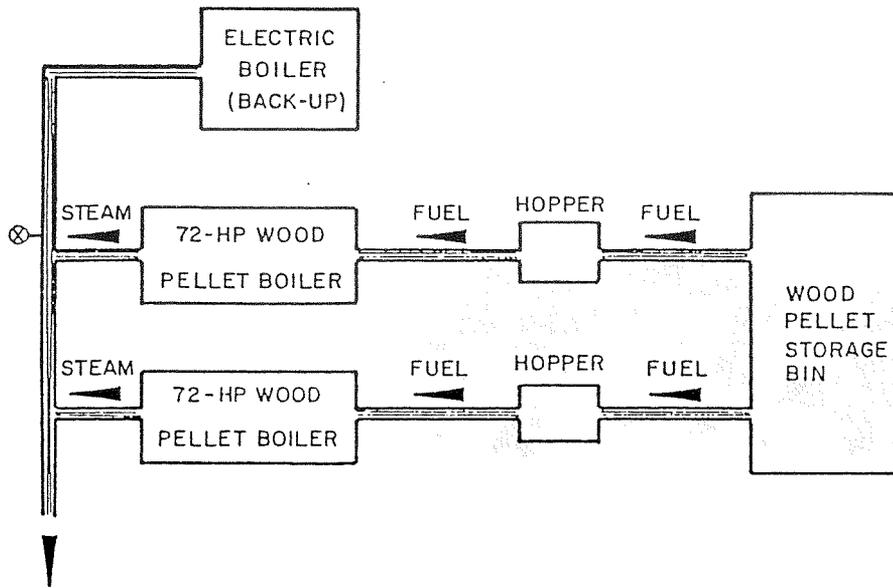
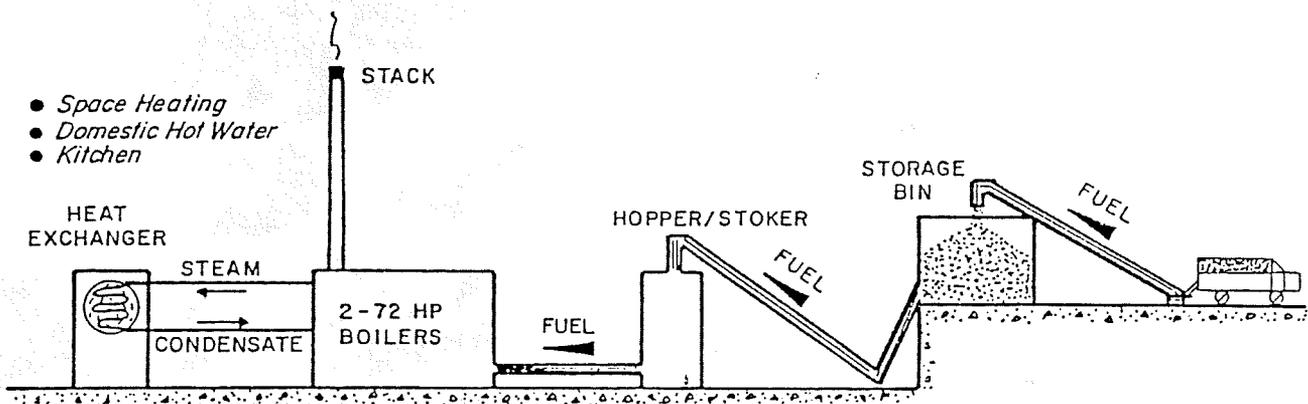


Figure 6



GENERAL LAYOUT OF ST. MARY'S HOSPITAL
BOILER SYSTEM



- Space Heating
- Domestic Hot Water
- Kitchen

ST. MARY'S HOSPITAL WOOD - PELLET BOILER PROJECT

TECHNOLOGY/EQUIPMENT

The only changes required to convert the oil-fired boilers to wood pellet fuel were changes in the fuel feed and burning systems. A contractor from Spokane installed wood pellet hoppers and Will-Burt stoker burners. A local contractor from Cottonwood built the pellet-storage bin and the conveyor system to deliver pellets from the main storage to the stoker hoppers. The hospital made no other modifications to the boiler. (See Figure 6)

OPERATING EXPERIENCE

According to John Hull, administrator of the hospital at the time, the availability of the low interest loan money and fuel cost savings were the main reasons for converting to pellets. Hospital management was concerned with pellet supply dependability and potential fuel handling and storage problems. In spite of these concerns, they decided to go ahead with the project.

The hospital completed the project in December 1985 and started operation in January of 1986. The boilers now run, usually one at a time, 24 hours a day throughout the year providing space heat and hot water. There has been no major breakdown of the system since the switchover. Because it is fully automated, the system is very easy to operate and requires little maintenance. According to hospital management, maintenance requirements are less with the wood-fired system than with the electric-fired system which had problems with electrical contact breakdown.

The boilers at St. Mary's hospital use underfeed stokers, which normally are prone to slag buildup. However, while there is some buildup, it has not proven to be a problem.

On firetube boilers, the fire goes through the inside and boiler water is on the outside of the boiler tubes. Before the retrofit, these tubes could be cleaned with a long brush rod. Now, the stokers and stoker hoppers are in the way, so the hospital purchased a tube cleaner which uses a coil of flat tape and a vacuum to clean the tubes. It works well.

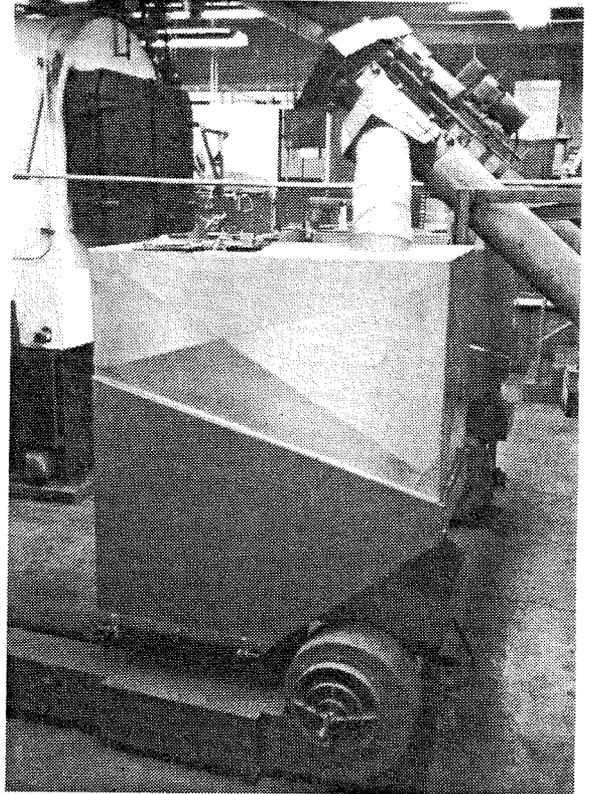
None of the hospital administration's concerns with switching to wood pellets has proven to be a problem. The price has not increased substantially, pellet supply has been dependable and adequate and pellet storage has worked well.

When the hospital first started using pellets in January of 1986, the price was \$70 a ton. Now (September 1990) it is about \$76 a ton. This is an average increase of approximately 2.1% a year which is below the rate of inflation.

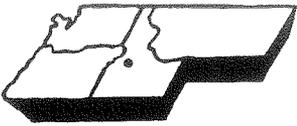
Supply and delivery of pellets have been very dependable over the last 4½ years. Lignetics delivers 36 tons to the hospital with each delivery. In the winter, the hospital uses about one ton a day, so the deliveries can be about a month apart.

A belly dump truck is generally used to deliver pellets. The truck dumps the pellets on the ground where a small grain elevator moves them to the intake hopper of a larger grain elevator owned by the hospital. This elevator delivers them to the pellet storage bin.

Pat Watkins, maintenance supervisor at the hospital, is happy with how well pellets have worked. Although he did not work with the boilers when they were fired with oil, from what he heard from previous maintenance personnel he said, "They were nothing but a nightmare for us, the maintenance men, and a lot more work. There was a lot more daily cleaning. You had to clean these burners, and clean these jets, and do a lot of maintenance back and forth on them." Since switching to pellets, most of the problems have been minor.



Will-Burt stokers which were added to convert oil-fired boilers to the use of wood pellets. Fuel is delivered to stoker from fuel bin by auger in upper right of photo. Combustion air feed is at lower right.



FINANCING/ECONOMICS

Potential fuel-cost savings was the main reason for the hospital's decision to convert to wood pellet fuel. Space and water heating account for about 38,000 therms a year or 75 percent of the total energy use of the hospital. The total annual heating cost before the conversion was about \$46,000. The hospital now uses about 380 tons at a little over \$70 a ton, or \$27,000 worth of pellets a year. The savings attributed directly to the use of wood pellets has been almost \$19,000 a year.

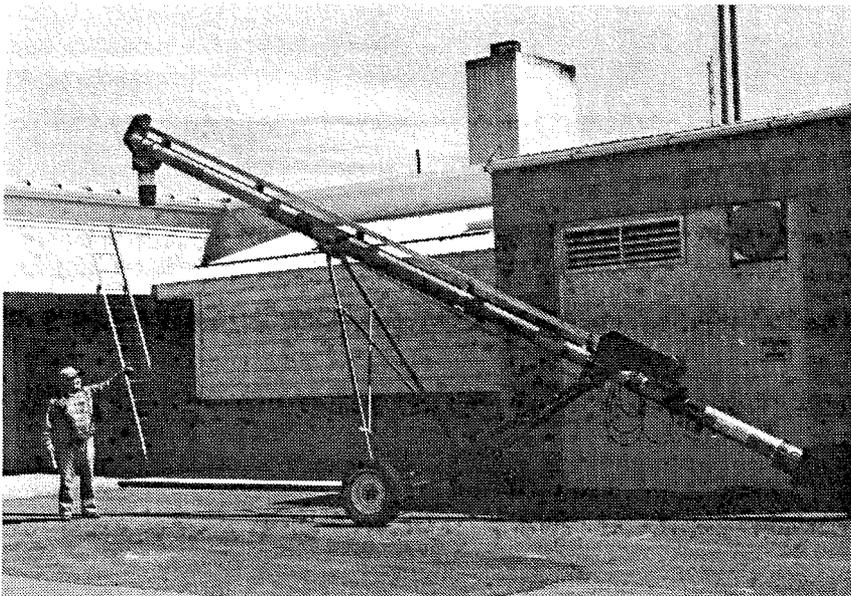
The original cost of the retrofit project was \$40,000 which included \$22,200 for two stokers, \$10,000 for a storage bin, \$4,800 for labor and \$3,000 for an electrical control panel and miscellaneous items. The hospital later expanded the storage bin to hold 50 tons of pellets at an additional cost of \$1,000. With the annual fuel cost savings of \$19,000 the project had a simple payback of just over years. The Energy Division financed the project with a loan of \$40,000 from the Low-Interest Energy Conservation and Renewable Resource Loan Program.



A clean burning flame shows through the inspection hole of a boiler door.

CONCLUSION

St. Mary's Hospital has had very good results using wood pellets. It is not only saving over \$19,000 a year with pellets, but the operation and maintenance staff is happy with them. In areas like Cottonwood, Idaho, where natural gas is not available, wood pellets are proving to be dependable low cost fuel.



Bill Long points out auger used to load pellets from the fuel delivery truck into the fuel storage bin (metal shed behind auger).