Ketchikan Pulp's hog-fuel-boiler energy retrofits

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Redesigning two boilers firing a combination of waste wood, primary sludge, and No. 6 fuel oil yielded significant energy savings.

Ketchikan Pulp Co. (KPC) is a 600-b.d. ton/day sulfite mill located 679 Alaska Airlines miles north of Seattle on the island of Revillagigedo. Isolated from the world except for air and sea traffic, the KPC mill generates 100% of its power requirements from four sulfite boilers firing red liquor, a package boiler firing No. 6 fuel oil, and two power boilers firing a combination of hog fuel and No. 6 fuel oil. In addition to the red liquor and waste fuels, the mill consumed approximately 950 barrels/day of No. 6 fuel oil.

The two power boilers were manufactured by Babcock and Wilcox and erected at the mill in 1954. The boilers are vertical-set water wall boilers with two combustion zones per boiler separated by a water cooled wall.

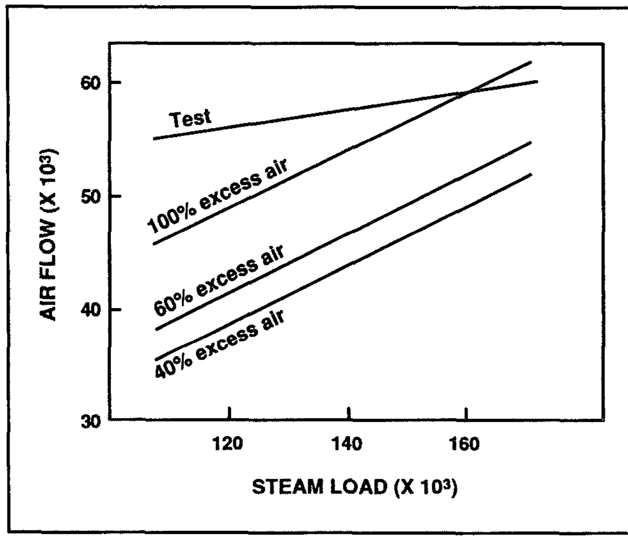
Designed to produce 860 psig steam at 825°F, each of the boilers is fired off a combination of No. 6 oil and waste wood. The boilers were designed to fire at a rate of 160,000 lb steam/h using oil only and at a rate of 120,000 lb steam/h using a combination of oil and bark.

The boiler grates contain approximately 105 ft^2 of effective area per cell. Each cell is capable of generating 20,000-30,000 lb/h of steam using 60%-moisture wood. Four oil burners are installed on the front of the boiler. Two burners are set in each cell and are designed to produce approximately 40,000 lb/h of steam per burner.

Combustion gases originally passed from the boiler superheater section into a set of 24-in. mechanical collectors prior to entering the air preheater. In 1974, these collectors were removed and a set of 9-in. high-efficiency collectors were installed between the air heater and induced draft (I.D.) fan on each boiler. In 1979, a primary set of high-efficiency mechanical collectors were installed ahead of the air preheater.

In 1984, a rotary bark dryer was installed in series between the existing boiler I.D. fans and the boiler stack. This system consists of a direct-contact rotary dryer unit followed by an additional I.D. fan and four cyclone separators. The combustion gases then return to the existing stack by way of the existing I.D. fan discharge ducting. This unit was designed to operate at a flue-gas inlet temperature of 550°F and maintained a discharge temperature of 300°F. The unit was designed to process approximately 360 units of hog fuel per day, drying it from 60% moisture to 40% moisture in a single-pass operation.

1. Total combustion air flow



Combustion air enters the system through a forced draft (F.D.) fan. The fans are designed to supply 60,000 std. ft^3/min (including test block) at a static pressure of 12 water column inches. The inlet temperature to the fans is approximately 70°F. The air preheater was designed to heat the combustion air to approximately 350°F. Temperature is controlled by a damper in the by-pass duct around the air preheater. In 1974, steam coils were installed ahead of the air preheater to heat the incoming air to prevent cold end corrosion on the heater tubes.

Following the air preheater the combustion air is diverted to both the oil fire and the wood fire by way of automatically controlled balancing dampers. The combustion air to the wood fire is further controlled by manual dampers to each cell. These dampers divide the air flow into four systems: undergrate air, overgrate air, mid air, and overfire air.

System evaluation

To develop viable design solutions to improve the

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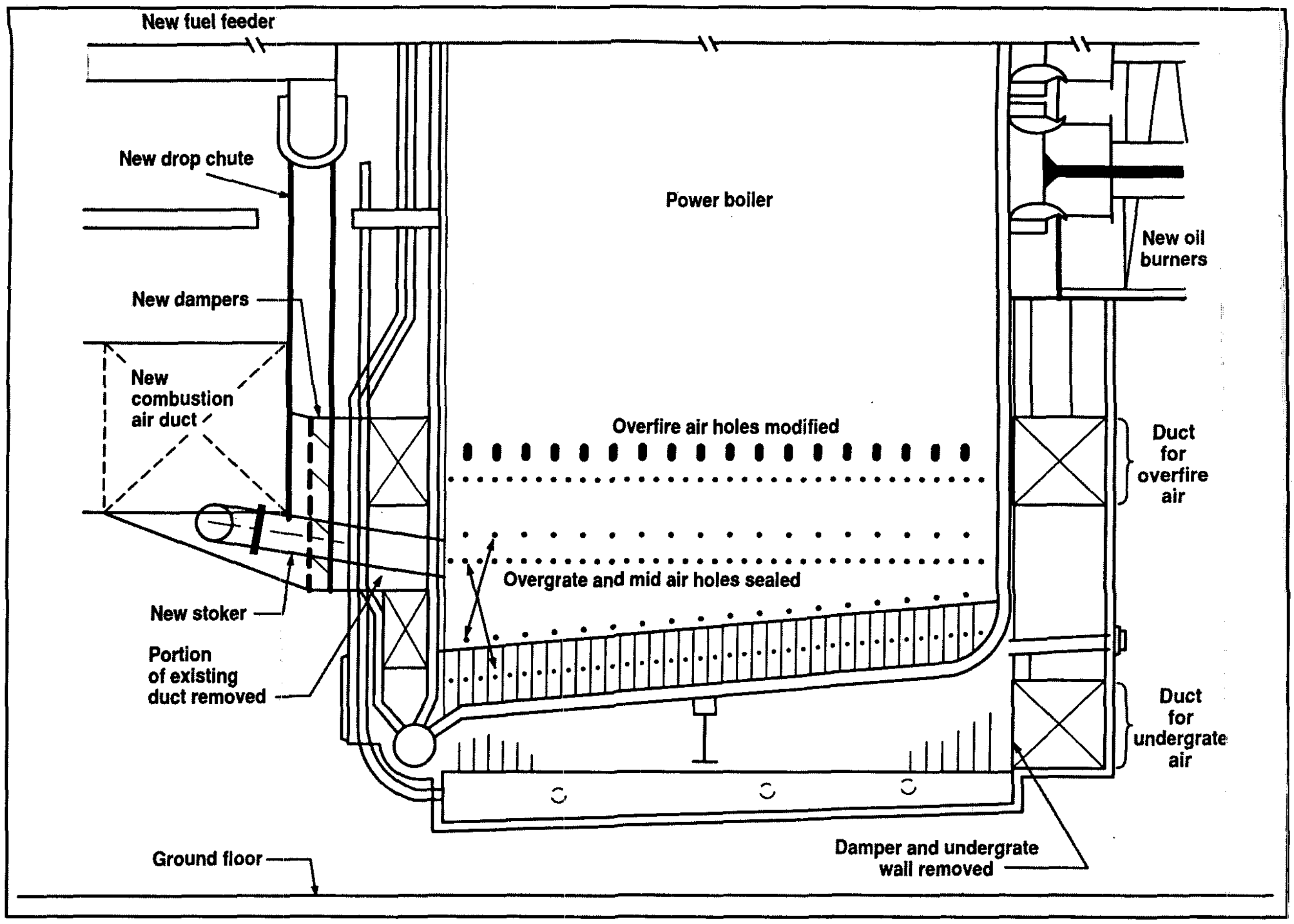
2. Sectional view of new cell section



combustion efficiency of the power boilers, a series of tests were needed to determine the operating conditions of the boilers and the system deficiencies. During a two-week period, a series of 10 combustion tests were conducted on the power boilers to determine the operating conditions. Simultaneous stack emission tests, orsat analysis of the combustion gases, and air flow to the oil burners and wood fires were measured to determine combustion efficiencies and the amount of excess air to the fires and the capacities of the existing fans.

To test each of the boilers independently, a sample port was installed at the inlet to the hog-fuel dryer, and the combustion gases for one boiler were directed through the hog-fuel dryer while the gases from the second boiler bypassed the dryer and were sent directly up the boiler stack.

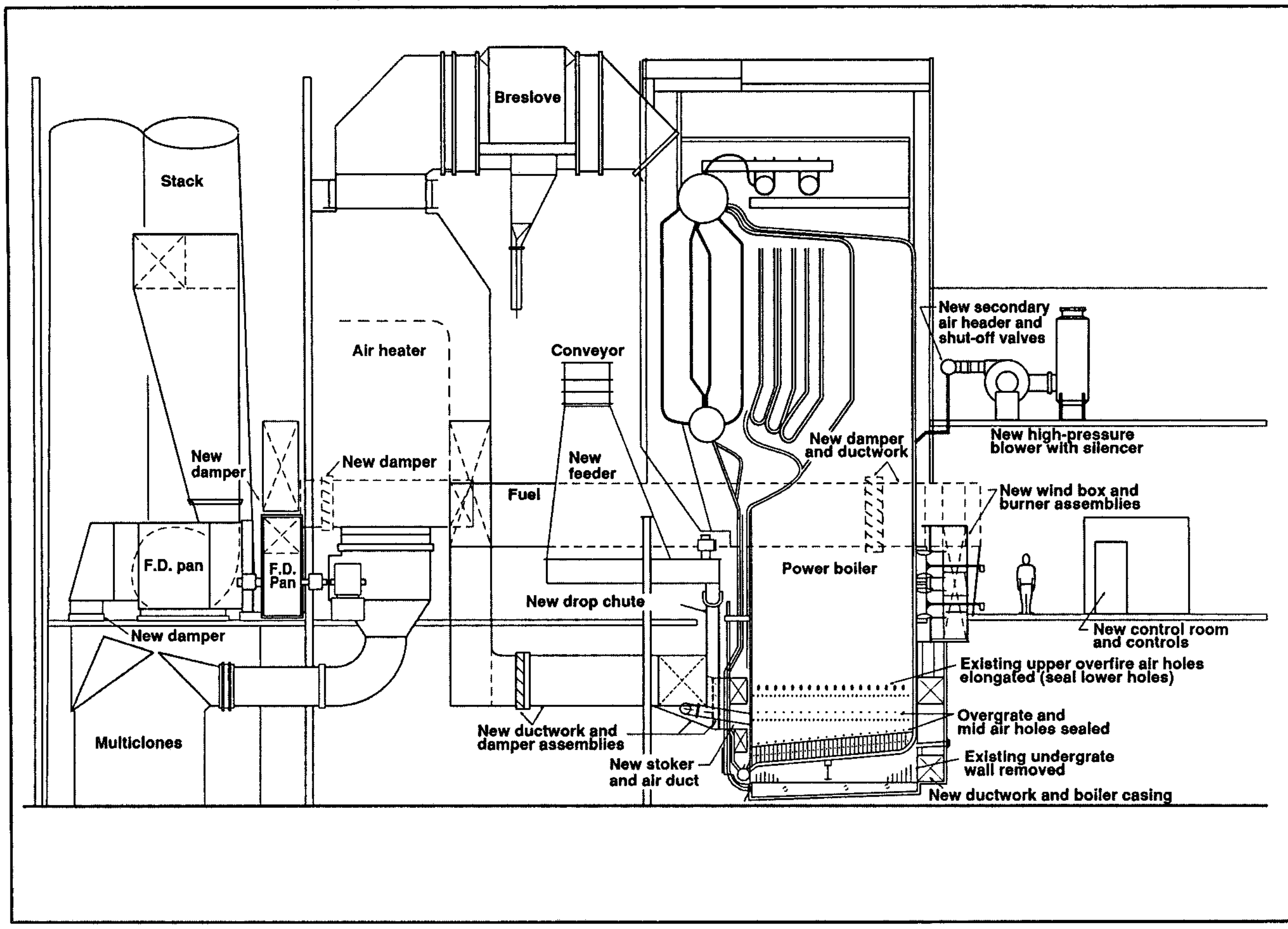
The steam production conditions for each boiler were set at the original combined fuel steaming rate of 120,000 lb/h and at the current maximum steaming rate of 160,000 lb/h. An Environmental Protection Agency Method 5 particulate sampling train was utilized to collect the particulate samples. The particulate emissions from the main stack were sampled simultaneously with the inlet to the fuel dryer to assess the effect upon particulate emissions of passing the boiler exhaust gases through the fuel dryer. Emissions were sampled at the main stack from a single sampling port on the roof. The main stack was sampled with both boilers operating at normal operating conditions of approximately 270,000 lb steam/h.

The average grain loading of the boilers as tested was 0.393 grains/std. dry ft^3 (SDCF). The average grain loading at the original design condition of 120,000 lb steam/h was 0.471 grains/SDCF; at the current maximum firing rate of 160,000 lb steam/h, it was 0.316 grains/SDCF. The grain loading decreases as the boiler load condition increases. This is explained by the fact that the incremental load increase is from the oil fire. Therefore, the combined combustion gases are diluted by the cleaner oil-fire combustion gases. Chlorides accounted for approximately 23.8–37.1% of the particulate carry-over in the tests performed.

Air flow tests were conducted on the oil burner combustion air ducts and on the ducts supplying combustion air to each of the cells to the wood fires. The tests showed that total air flow to each of the boilers was approaching the maximum design conditions of the F.D. fan and that there was little variance in air flow as it relates to boiler steam production. The combustion air temperatures were found to range from a low of 430°F to a high of 533°F. The design temperature for the boiler is only 350°F. The design conditions resulted in an increase of approximately 25% in air volume, which increased velocities and caused static pressure losses. These three items were the keys to correcting the majority of boiler combustion air problems.

An orsat analysis was conducted during each test to determine the efficiency of combustion at each load

3. Boiler room elevation with new equipment



condition. Based on the results of these tests, boiler combustion efficiency calculations were performed in accordance with the American Society of Mechanical Engineers short form. Two sets of efficiency calculations were performed on the test results. The first set of boiler efficiency calculations involved only the boiler system proper without the hog-fuel dryer in the system. Combustion gas data was collected prior to the dryer unit, and fuel samples were taken following the dryer at the feed to the boilers.

Based on this envelope, the average boiler efficiencies were 79.5% at a steam load of 120,000 lb/h and 81.8% at a steam load of 160,000 lb/h.

A second set of combustion efficiency calculations were performed which included the hog-fuel dryer in the system. In this case, the moisture of the fuel was assumed to be a constant 60% in the incoming fuel to the dryer, and the exit temperature of the combustion gases out of the dryer was maintained at a constant 300°F. Under these conditions, the boiler combustion efficiency increased to 81.5% at a boiler load of 120,000 lb/h and 84.0% at a boiler load of 160,000 lb/h. Based on these calculations, the hog-fuel dryer presently contributes approximately 2% to the overall improvement of the boiler combustion efficiency.

Existing system deficiencies and solutions

Three major components control the overall combustion efficiency of a boiler and the resultant level of boiler emissions: the quality of fuel being fired (fuel preparation), the control of the combustion process (combustion control), and the recovery of usable waste heat (heat recovery). To maximize the combustion efficiency of the boilers at Ketchikan, all three components were examined. However, only combustion control will be discussed here.

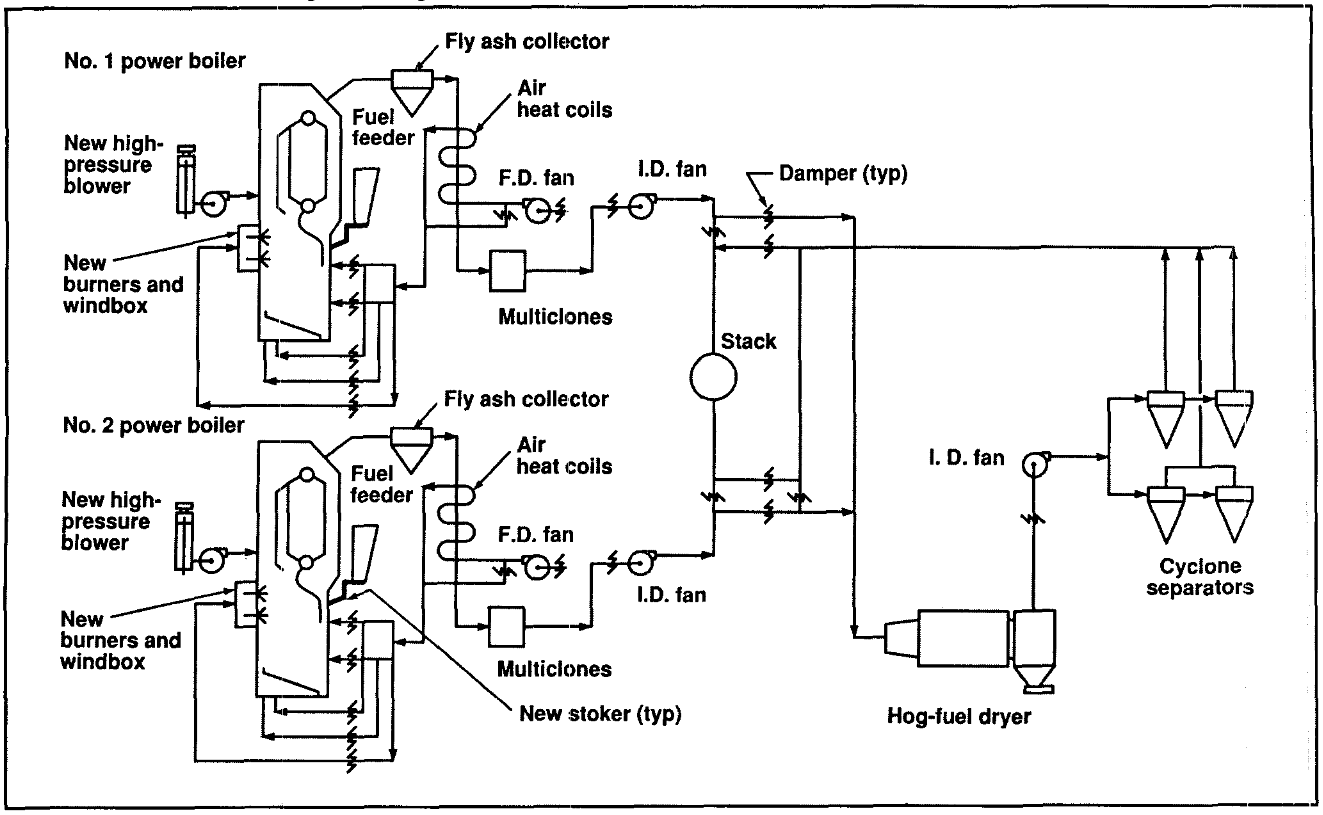
Combustion control

The existing boiler combustion controls were outdated and in poor condition. Many of the original controls were comprised of manual positioners. These controls were not used over the years due to equipment failures and to the level of difficulty involved in controlling boiler load swings.

To properly understand the combustion air problems associated with both boilers, we must compare the test air flow to the required combustion air flows relative to design conditions. **Figure 1** demonstrates the operating conditions of the boiler combustion air flows relative to the original design conditions. Obviously, there was very little, if any, control of air flow over the boiler load range. The boilers were being operated at the maximum air flow conditions. By replacing dampers, modifying air ducts, and installing new controls, the boilers are now capable of being fired at the original design conditions of between 40% and 60% excess air.

Breaking the combustion air flows down further, we

4. New combustion air and flue-gas flow diagram



found that there was no control of the combustion air flow to the wood fire, and there was very little control of combustion air flow to the oil fire. Although new dampers, positioners, and combustion controls would correct the deficiencies of the oil-fire combustion air flows, it would not totally correct the wood-fire combustion problems. Because there were too many air nozzles in the wood-fire ducts into the combustion zone, inadequate static pressure was developed to obtain proper air penetration through the boiler grates and over the fire. Duct modifications were required to correct this problem. **Figure 2** shows the system with the modifications.

As a result of equipment and control failures, the existing temperature control system, which controls the combustion air temperature to 350°F, was not functioning. This resulted in excessive temperatures of the combustion air which ultimately resulted in damage to the existing control dampers and the existing oil burners. New temperature controls were installed to correct this problem. In addition, a new windbox and low-excess-air oil burners were also installed.

To maximize boiler combustion efficiency, new controls were installed incorporating air-flow measurement as well as fuel-flow measurement. This allows the air-fuel ratio to be properly maintained for both the oil fire and the wood fire. To aid in the measurement of the wood-fire flow, four new screw feeders were installed to replace the aging fuel bins, which are hard to maintain and difficult to control. Incorporating air flow into the controls rather than just static pressure control allows the operator to maintain a proper air-fuel ratio on wood even as the ash bed increases during the firing period.

Incorporated into the boiler control scheme is oxygen control and carbon monoxide monitoring. This addition permits the operator to maximize the boiler combustion efficiency. A new opacity monitor was also installed in the new system.

To incorporate the new boiler controls, a new boiler control room was installed adjacent to the existing control room. The new control room houses the new distributed control system with four operator stations: one station for each of the two power boilers, one for the package boiler, and one for the hog-fuel dryer. The recorders and standalone controllers are located on the back panel of the control room. The new control room looks down the firing line and incorporates an air conditioning system to protect the electronic controls.

To correct the problem of burning in suspension, the existing wood-fire feed system, which injected the fuel above the overfire air system directly across from the oil burners, was replaced with a new feed system located under the overfire air system. This modification permits the fuel to drop from the new stoker onto the bed for proper burning. Although returning the wood fire to the grate did not reduce the boiler emissions to the goal of 0.15 grains/SDCF, the emissions were reduced to approximately 0.18 grains/SDCF, and without the salt portion would have met our goals.

To assure that there is total combustion of the hydrocarbons within the boiler even with the new higher velocities, a high-pressure air system (30 in. w.c.) was installed above the combustion zone. This new system injects high-pressure, low-volume air into the boiler across the combustion zone toward the bull nose. This system acts as a final polishing system to complete combustion.

Figures 3 and 4 show a cross section of the boiler with the modifications and the revised combustion-gas flow diagram. We found that the overall boiler efficiency with the dryer in operation, assuming the same oil-to-wood firing ratio and oil burner combustion efficiency, increased from 81.5% to 83.5% at a firing rate of 120,000 lb/h and from 84.0% to 84.9% at a firing rate of 160,000 lb/h. This increased combustion efficiency by only 0.9–2.0%.

Due to the low exit temperature of the combustion gases from the air preheater prior to the rebuild, there was very little potential to recover waste heat. However, even with these low temperatures, the hog fuel was being dried from a moisture content of approximately 60% to levels in the low- to mid-50% range.

By correcting the temperature control system for the combustion air at the air preheater, the combustion gas temperatures increased from the original 350°F to the design temperature of 550°F. This higher combustion-gas temperature entering the dryer greatly increases the drying capacity of the hog-fuel dryer. The moisture content of the hog fuel is now approximately 40–47%, permitting wood-firing rates as high as 120,000 lb/h. Because of the drier hog fuel, the ratio of oil fire to wood fire decreases. This has resulted in a decrease in oil consumption from an average of 950 barrels per day to a new low of approximately 650 barrels per day. At those high hog-fuel firing rates, the existing hog-fuel delivery system cannot maintain adequate hog-fuel flow. Phase 2 of the project will correct this problem.

Summary

An evaluation of the two existing power boilers at the Ketchikan mill has been completed with the purpose being to increase the overall combustion efficiency of the boilers and thereby reducing the mill's dependence on oil. By updating the boiler combustion systems and modifying the boiler's method of firing hog fuel, we have demonstrated that substantial energy savings can result. In the next few months, the new hog-fuel delivery system and back-end clean-up system will be completed. Following the completion of these projects, the mill's dependency on oil will be reduced even more.□

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