SUSTAINABLE FUEL FOR SCHOOLS - PELLETISED WOOD REPLACES COAL

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INTRODUCTION

Pelletisation of wood waste has the potential to create a high-quality, marketable product from waste sawdust and shavings (van Loo and Koppejan 2002) and agricultural and municipal waste (Barnes, 2005). The Energy Group at Scion (formerly, Forest Research) has been involved in a number of projects to assist in the development of the wood pellet industry in New Zealand (Nielsen *et al.* 2004). The wood pellet industry in New Zealand has grown from one wood pellet manufacturer producing 5000 tonnes per year in 2000 to four wood-pellet manufacturers collectively producing 50000 tonnes per year in 2006. In this paper, a community project to convert school central-heating systems from burning fossil fuels, such as coal, to wood pellets is described. As wood pellets are produced from waste sawdust and shavings originating from sustainable forest products, they are a renewable fuel and considered to be carbon neutral, i.e., unlike coal, combustion does not lead to a net increase in CO_2 in the atmosphere. The additional benefits of wood pellets as compared to coal are:

- less particulate emissions (ash <0.5%, no sulphur) leading to cleaner air.
- cleaner handling
- less maintenance of boilers
- reduced ash and ease of disposal (can be used as compost on gardens).

The project to convert school heating systems to wood pellets was based in Rotorua due to the availability of low-cost wood pellets from Nature's Flame (Solid Energy) Rotorua manufacturing plant and proximity to Scion's Rotorua site. The project commenced three years ago, beginning with a survey of 11 local schools, and progressing to applications to local funding agencies, consultation with schools and Solid Energy, developing technical designs for the conversion of boilers, and culminating in the successful conversion for two schools. In this paper the important steps of this project in identifying the key areas leading to its success are described. The outline of this paper is as follows:

- a summary of the results of the school survey
- a description of the community project and the parties involved
- technical details of converting coal boilers to wood pellet fuels
- planned future projects.

Survey of School heating systems

In this section, the current state of New Zealand school heating systems, based on a survey of schools in Rotorua, is described.

The school survey included 5 high schools, 5 primary schools, and 1 intermediate school in the Rotorua area. The survey showed that approximately 50% of the schools were still using coal for central heating. For primary schools, in the majority of cases coal furnaces and boilers were around 200 kW and most likely to have been installed when the school was established, resulting in some very old systems. A trend that was evident in the schools was a move away from coal to electric heat pumps, due to their low capital cost and low maintenance costs. The survey did not determine the money spent on running the different systems due to the fact that, as with most New Zealand businesses, very little metering was done on energy consumption, especially sub-metering of individual equipment.

Some of the more modern heating systems included gas, and combinations of gas, electricity, and solar. The gas and coal boilers were of similar capacity and were used in much the same way. The operation of these boilers is far from optimal. The boilers are run at maximum capacity for a heating cycle of 4-5 hours in the morning and then left to idle for the remainder of the day and over the entire weekend. This type of operating procedure has forced us to look into heat storage systems to optimise the heating systems (discussed further in the conclusion).

Many of the schools operating on coal commented on the poor quality of the coal, i.e., low energy density and contamination. The contaminants in the coal are quite often rocks, which cause mechanical failures of the feed system and caused down time for the heating system. The lower energy density of the fuel causes poor performance of the boiler and increases the rate at which fuel is used. Another point made by the schools was the recent relocation of the coal distributor from Rotorua to Hamilton, which increased the cost per tonne to $180.

Community project

The community project to convert school heating systems to wood pellets required cooperation between a number of parties, including businesses, schools, a research organisation and the local funding body.

The information gained in the school survey pointed to a distinct possibility of conversion of coal boilers at the schools to a more sustainable fuel such as wood pellets. Unfortunately, at the time New Zealand had only one major pellet manufacturer in Christchurch, which meant wood pellets were four times more expensive than coal ($120/tonne at the time). From June 2005, however, Nature's Flame (Solid Energy) opened a wood-pellet production facility in Rotorua. This has immediately made wood pellets directly competitive with coal. Wood pellets have a heating value 19GJ/tonne as compared to ~20-23GJ/tonne for North Island coal, up to 33GJ/tonne for South Island coal, and cost approximately $300/tonne in bulk. There are also opportunities to convert gas systems to wood pellets to reduce running costs but this will probably require replacing the gas boilers with new wood-pellet boilers.

A proposal was put forward to Rotorua Trust (previously Rotorua Energy Charitable Trust (RECT)) to seek funds for the conversion of coal or gas boilers to wood pellets for several schools over a two-year period. This proposal was supported by Solid Energy as the wood-pellet and equipment supplier. This proposal was accepted by the Rotorua Trust and funding allocated to a two year programme.

On receiving the funding, Nature's Flame contacted schools in the Rotorua district to give them the option of accepting the challenge of using sustainable energy. Selwyn and Sunset Primary Schools were the first to accept. Prior to the offer to schools, Rotorua Girls High School had already made the change to wood pellets. In this case the change was made very easily due to a modern coal boiler being installed in the school approximately 6 years earlier.

Converting coal boilers to use wood pellets

The technical details of converting legacy coal boilers so they can run on wood pellets are described in this section.

The coal boilers

The schools run a variety of boilers but, conveniently, the Selwyn and Sunset school systems are essentially identical. Figure 1 shows a picture of the coal boiler and hopper at Selwyn Primary School. Note, the system requires the operator to shovel coal from the main bunker into the day hopper shown here. This is a dirty and very time-consuming job for the caretaker.

Fig.1: Test setup at Selwyn Primary School, with day hopper filled with wood pellets.

The boiler furnace itself is an underfeed stoker. The fuel is pushed along a steel tube by an auger until it reaches the grate, where it is forced upward into the combustion zone. The air for combustion is supplied by an electric fan. This air is delivered to the grate where it travels upwards through the bed of fuel supplying enough oxygen for relatively clean combustion (see Fig. 3).

With the quality of the coal the schools were using, the furnace required high man hours for maintenance and tending. A lot of clinker and ash was evident around the grate and needed removed twice daily.

The furnaces were kept running over the weekend by shutting down the air and fuel feed for long periods of time. An automatic timer system brings the air and fuel back on line at timed intervals over the weekend to maintain the combustion temp and then ramps up towards Sunday evening to be fully operational by Monday morning.

Considerations when converting coal boiler to wood pellets

Originally it was thought that converting the coal furnace to wood pellets would be reasonably straightforward. For the more modern, larger coal furnaces this is true. Wood pellets like most woody material, require excess air for full combustion. Older coal furnaces only supply air at one point and this is up through the fuel bed. Coal can combust reasonably effectively with just the one supply of air. As shown in Figures 2 and 3, the air flows through the bed of fuel from slots in the walls of the grate. Additional air is forced along the stoker screw and up through the combustion zone in order to reduce air back feeding up through the day hopper.

Fig.2: Standard coal grate. Air vents visible on sides. No secondary air.

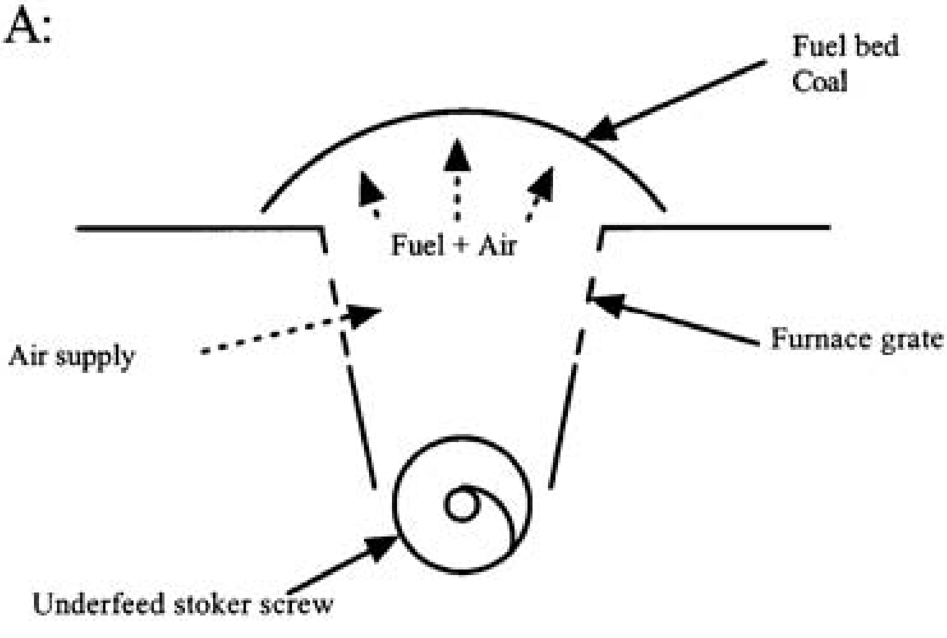

Fig 3: Schematic of original coal grate

After running a trial of feeding wood pellets into the standard coal furnace, it quickly became apparent that the coal grate was not at all appropriate. There were two issues: firstly, the amount of air required to produce enough heat was twice that required for coal (this caused a volcano effect as hot spots occurred and wood pellets were physically blasted out of the combustion zone, see Figure 4); secondly, it was necessary to increase the speed of the fuel feed. Within a week the school had used three times the amount of wood pellets as it previously used coal. Due to the running conditions it was also believed that combustion was poor and carbon monoxide levels may have been very high.

Fig.4: Poor combustion with standard coal grate.
Volcano effect with high-temperature, small combustion zones, and airborne pellets.

For good combustion, characteristics of the furnace needed to be improved in a non-intrusive way. An important factor was that this was taking place during winter while the school needed heating. There was, however, a small window of opportunity over a school holiday period to build, install, and satisfactorily test a new system. If the new system didn’t work then it would need to be removed and the old system reinstalled.

An additional issue of changing to a more volatile fuel with lower energy density is the reduction in storage capacity and increase in fuel usage. To overcome this, an automation system was planned to supply wood pellets to the day hopper.

Technical modifications

Once the decision was made to create a better combustion zone we needed to produce a grate that suited wood pellet combustion. Allan Estcourt Ltd was employed to design a new grate that could be installed on top of the existing grate and possibly removed without any disturbance to the original coal grate. The other requirement for better combustion was to introduce secondary, or over-fire air, to complete the combustion process and reduce CO emissions.

The grate was designed to capture all the original primary air and then redistribute it to smaller primary air and then to secondary air vents, as shown in Figures 5 and 6. The new grate was also manufactured in several pieces to fit inside the small furnace door and assembled once in place. The grate was built and installed by Kawerau Engineering.

Once the grate was in place it was tack-welded together and sealed along the outer circumference using refractory grout. The secondary air vents were screwed into sockets on the face of the grate. This setup allowed for easy removal and modification of vents if needed.

Fig.5: New stainless steel grate.
Air slots visible on flat plate for both primary and secondary air via upright tubes.

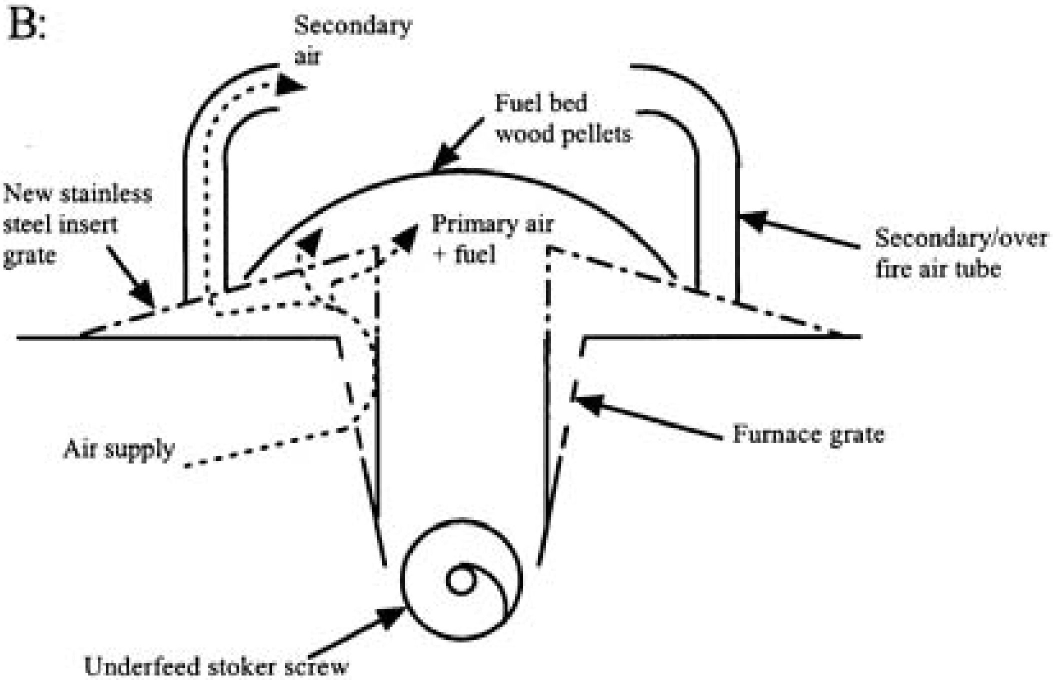

Fig. 6: Schematic of new stainless steel grate inserted inside the original coal grate.

The automation of the fuel feed required the introduction of an auger from the main bunker into the day hopper with a paddle switch that controls the rate and time of supply. The system chosen was a fuel-feed system commonly used to convey feed pellets to dairy cows during milking. This is a coreless auger with paddle switch built into the top section. A plywood bunker was initially planned but required a large proportion of structural reinforcing, which made it unfeasible for this project. A steel bunker was built with a 40-degree slope to maintain good flow of the pellets towards the auger feed. This is shown in Figure 7.

Fig. 7: Constant flow of wood pellets by coreless auger fed by steel bunker

Selwyn and Sunset schools have both been operating on wood pellets with the new grate configuration for one month. The secondary air supply and ratio of primary to secondary air are at a level that is necessary for effective clean burning of wood pellets. Currently, Nature's Flame is delivering wood pellets in bags, which are man handled and emptied into the steel bunker. A bulk delivery system is currently being designed for deliveries of up to 5m^3 (3 tonne) of wood pellets.

The total cost of conversion was $9,990, which included:

- grate design ($500)
- grate construction and installation ($1500)
- bunker ($3,500), new auger ($1,574)
- electrical work ($1506)
- general engineering work ($1410).

Results and Conclusion

The same conversion procedure has been carried out at both Selwyn and Sunset Primary schools and both systems have been running successfully for one month. The schools are satisfied with the process. We believe the success of the conversion process was a result of being able to capture multiple benefits:

▪ Improved sustainability	The project gave schools an opportunity to improve their sustainability by moving to a renewable fuel and thereby act as positive role models for their students.
▪ Reduced caretaker time	Installing additional automation during the conversion process resulted by substantially reducing the caretaker workload in the boiler house.
▪ Reduced ash disposal	Unlike ash from coal, wood ash can be used as compost (effectively reducing ash disposal costs to zero).
▪ Reduced boiler maintenance	By using high quality wood pellets the school was able to avoid maintenance costs from stones in coal, also reducing ash resulted in less maintenance of boilers.
▪ Low emissions	Sulphur is eliminated and CO is reduced with good secondary air supply

Three more school conversions are presently being planned. At the next stage we would like to convert a school running on gas to wood pellets. It is not as simple to modify a gas system to operate on wood pellets. For this reason, and because the school we are considering has gas boilers that have reached their replacement date, we are considering replacing the present gas boiler with a wood-pellet boiler with the addition of a heat-storage system to improve the operating characteristics of the wood-pellet boiler. This type of heat storage system would allow the school to use a much smaller capacity boiler and run it for a longer period of time, which would promote cleaner emissions and better heating efficiencies.

References

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