LAKEHEAD UNIVERSITY
WOOD ENERGY PROJECT

I. WOOD RESIDUE HARVESTING IN COMBINATION WITH SITE PREPARATION.

II. WOOD GASIFICATION.

III. RESIDENTIAL HEATING AND CHIP STORAGE/DRYING.

PROJECT LEADER: E.J. DAVID

FEASIBILITY DEMONSTRATION

SPONSORED BY: ONTARIO MINISTRY OF NORTHERN AFFAIRS

LAKEHEAD UNIVERSITY
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I

WOOD RESIDUE HARVESTING
IN COMBINATION WITH SITE PREPARATION

FEASIBILITY DEMONSTRATION

E. J. DAVID

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1. Introduction:

The typical commercial cutover contains substantial quantities (50-95 cu m of solid wood /ha) of potentially usable slash which, as it lies, is a costly impediment to replanting. It is generally believed that the cost of utilizing the slash exceeds the value of the recovered product; and that likewise, clearing the site is more costly than working around the slash as it lies. An economical procedure that recovers the fuelchip and-or pulpchip values in the slash while preparing the site may, however, be viable. By sharing the costs of the work between chip production and site preparation, both operations may be made more cost-effective. Significant improvements in both harvest utilization and the silvicultural treatment to establish the next crop will result.

Figure 1. Site Preparation with No Residual Harvesting

Objectives and Scope

The development of such a dual-purpose procedure has been undertaken within a framework emphasizing the maintenance of site quality and the use of existing, proven mass-produced technologies where possible. In addition, of course, efficiency is always a consideration: The cost of site preparation and chip production should be as low as reliability and site quality permit.

Whole-tree logging removes far more nutrients from a site than shortwood or treelength logging (Malkonen, 1976, Kreutzeer, 1975; cf. Freedman et al, 1980, who indicate that natural weathering and fixation do not replace the lost nutrients over a rotation.)

Leaving slash where it falls for several months allows considerable nutrients to drop to the ground; and in addition permits natural sun-drying of the material, which increases its effective energy value and minimizes energy-robbing rot. Natural pre-drying also reduces the transportation cost per unit energy recovered. It is more economical than, and ecologically preferable to, premature concentration and forced drying with energy-consuming machinery.

The practice of delimbing at the roadside breaks vital nutrient cycles. If one considered the cost of replacing the nutrients found in bark and needles from roadside to their natural dispersal over the site, whole-tree harvesting of that kind would likely prove inefficient. Similar qualifications apply to proposals to employ branches, needles, etc. as animal fodder or feedstocks for energy or chemical production (though in this case the value of the proposed use may perhaps justify the costs of nutient replacement.) The maintenance of the nutrient quality of the site, which in some cases may require the provision of humus to hold the nutrients during the early years of regrowth, must be added to the cost of any technique involving removal of branches from the site.

The procedures tested thus began with dispersed, sun-dried slash. Processing took place from a few months to 1 year after cutting, preferably after one summer of drying time. When chipping along windrows and blowing chips into the carrier (wagon); fines, light chips, needle and bark fragments fell to the ground before reaching the wagon, thus remaining substantially dispersed on the site.

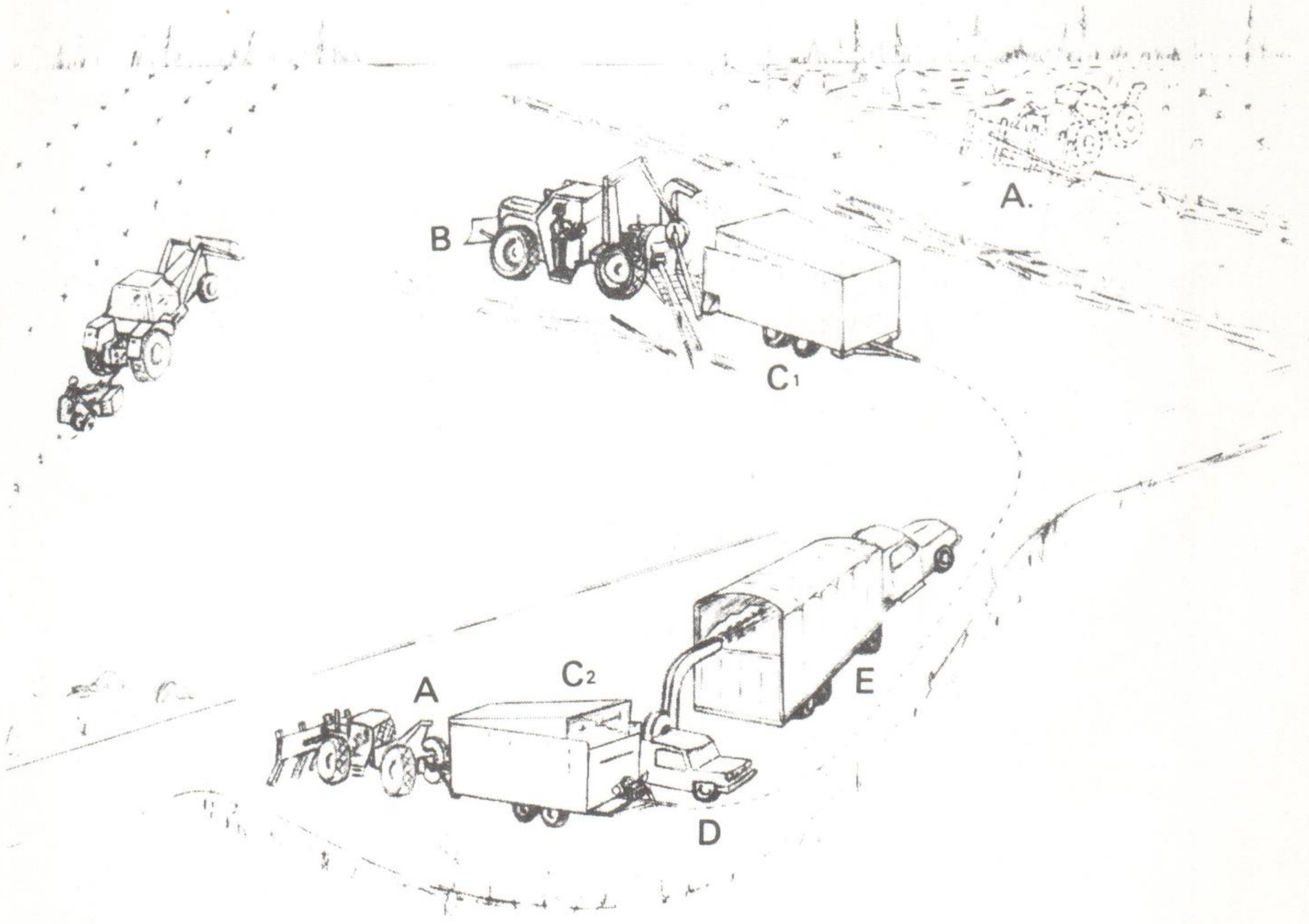
Table 2
Results of Initial Chipping Trials in old cutovers

Date	Plot size (sq m)	Volume of slash	Volume per Ha	Notes
1978	800	7.43	92.85	
1980a	625	3.4 cu m	54.4	Softwood**
1980b	625	5.1	81.6	Mixed wood*

**Pj10 *Po5, Sb2, Pj2, Bw1

Figure 5:

GENERAL CONCEPT OF WOOD RESIDUE HARVESTING IN COMBINATION WITH SITE PREPARATION



LEGEND: A. SLASH RAKE AND SKIDDER
(RAKING SLASH OR FORWARDING CHIP WAGONS
B. CHIP HARVESTER
C_1. CHIP WAGON
C_2. CHIP WAGON
D. TRANSFER BLOWER
E. HIGHWAY CHIP VAN
F. TREE PLANTER

FIGURE: "RAUMFIX" SLASH RAKE

Figure 2.2. Chipping From Low Windrows of Slash

RESULTS AND DISCUSSION:

Chip Quality:

The quality of chips produced in this "second pass harvest" depends on the original stand composition and the "first pass" harvesting techniques. In the Boreal Road trials, a large quantity of partly dried, small diameter, insect infested softwood was chipped. Visually, the quality appeared adequate; but the analyis report from the user of the chips (Domtar Ltd., Red Rock, Ontario--report is in Appendix II) indicated that it fell marginally below their acceptance standard.

Since slash was surface dry and the chips were blown into the chip wagon and from the chip wagon to the highway carrier; considerable cleaning took place incidental to chip handling. The quality chips proved heavy enough to blow reliably where they were directed, while the fines, bark dust, etc. fell short or drifted away in the wind.

The advantages of harvesting dry residues--advantages based on energy capture considerations--became disadvantageous when part or all of the chip production were to be sold for pulp. The pulp industry prefers fresh, moist chips. In spite of this difficulty, associated with chipping fresh slash, studies were made of upgrading methods, on the uncertain assumption that pulp chips would continue to command a premium over chips used for fuel.

A prototype cleaning device was built which blew a flat stream of air across the stream of chips being blown into the wagon or highway carrier. Trials of this device were still inconclusive when the field trials ended in August, 1982; and no worthwhile results are available.

Silvicultural Aspects and Benefits:

The concentration of slash by raking it into windrows prepared the site for intensive silvicultural treatment, such as mechanised planting of nursery-grown seedlings. In the present study, a simple, low-cost planting machine was given trial utilization on the cleared area; the results are indicated in Appendix I, Figures 30 and 31, and Table 8.

Not only did the treatment included in chip salvage lead to lower planting costs per hectare; but additionally, the capital cost of preparation plus planting equipment was lower than would be the case had the usual scarification plus hand planting technique to be followed. The slash rake both cleared the site and scarified it lightly, without uprooting stumps, creating excess soil compaction, or disturbance.

Figure 28. Operation of Transfer Blower:
Chips Moving from Chip Wagon to Highway Van

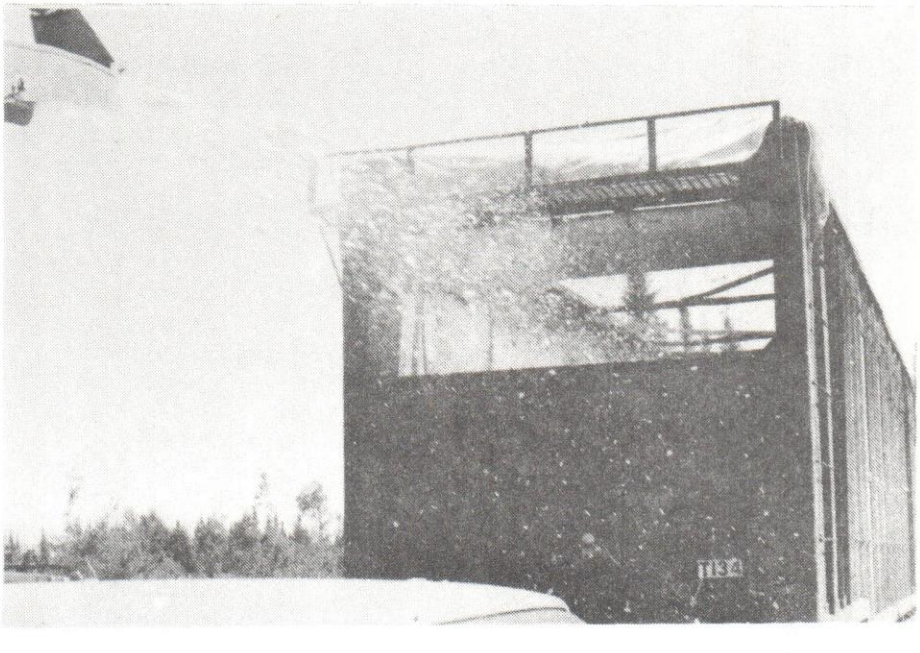


Figure 29. Chip 'Upgrading' by Flat Air Jet

Figure 30. Site Cleared by Crosswise Raking.
(Compare Figs. 1, 16, 22)

Figure 31. Project Culmination: Replanting the Site

TABLE 11. COSTS INVOLVED IN WOOD RESIDUE HARVESTING

Cost Factor	Cost $/AMH	Cost $/shift (78%)	Hours util./shift (71%)	Production Costs (in $/m³)		
				As tested at 50.43m³/shift	Probable production at 80m³/shift	Possible production at 100m³/shift
Equipment						
Slash-rake/Skidder	24.71	172.97	3.05-3.29	3.43	2.16	1.73
Chip Harvester	33.94 (35.22)*	237.58	6.4	4.71	3.08	2.47
Chip Transfer Blower	7.22	50.54	1.73	1.00	0.63	0.51
Two Chip Wagons	7.38	51.66	6.4	1.02	0.65	0.52
Total Equipment Cost	73.25	512.75	—	10.17	6.52	5.23
Wages (with 7.6% added for VP, UIC, CPP)	37.32	335.88	27 (9 x 3)	6.66	4.20	3.36
Transportation of Operators	4.44	40.00	—	0.79	0.50	0.40
TOTAL	115.01	888.63	—	17.62	11.22	8.99
Silvicultural Benefit Credit	—	75.00	—	1.50	1.50	1.50
TOTAL	**115.01**	**813.63**	—	**16.12**	**10.72**	**7.49**

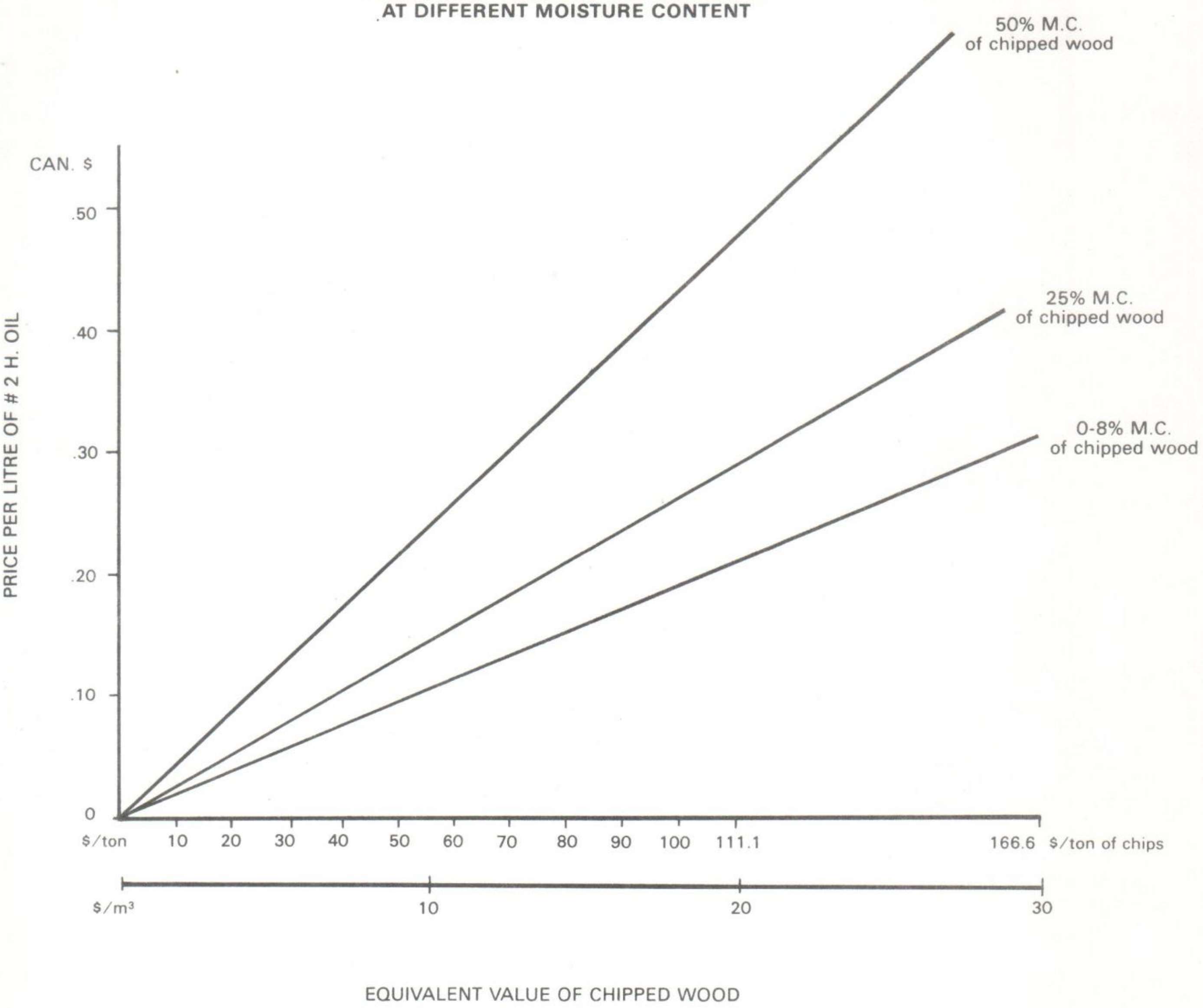
*Estimated cost for a chipper with greater production potential.

Alternatively, chips could be sold to private homes and farms, and to small public buildings, as a heating fuel. Figure 32 shows the relationship between the price of oil and the price of an equivalent amount of wood-chip energy (the latter expressed as dollars per cubic metre of chips.) The importance of the moisture content of the chips should be noted.

This graph indicates to the person contemplating chip heating, or supplying chips to the heating market, what chip price would be roughly appropriate for different heating oil prices. For example, if heating oil costs $.35 per litre, and the same price per joule of usable energy applies to both oil and woodchips, a cubic metre of chips is worth approximately $13. at 50% M.C. and approximately $22. at 25% M.C. It is unlikely that chips will command the same price per joule as refined oil; the bother of using wood will always be compensated by a somewhat lower price. With this qualification, potential producers and sellers of chips can readily work out the viability of a chipping operation. The implications of chipping sun dried slash rather than green slash for energy, and the potential for chipping as an energy technology, should be apparent.

Figure 32.

EQUIVALENT VALUE OF OIL AND WOOD AT DIFFERENT MOISTURE CONTENT



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II WOOD GASIFICATION

FEASIBILITY DEMONSTRATION

E.J. DAVID

MAY 1983

SUMMARY:

The utilization of wood as an alternate source of energy is an increasingly feasible idea, especially for forestry operations which have an abundance of wood. The rediscovery of wood gasification technology, which was used in the past but abandoned when cheap efficient fossil fuels became available, is an important part of this idea. Wood gasification is a more direct method of converting wood residue into usable energy, such as electricity, than direct combustion of wood which requires a boiler for generation of high pressure steam to run a turbine generator. For small scale electrical needs (50-500 KW) such as in forestry and sawmill operations, the wood gasifier-electrical generator system is more cost efficient because it has a much lower capital cost than the costly steam boiler, pressure vessels and turbines required with direct combustion.

The 'hands-on' valuable experience was gained through building and modifying the orginal prototype. The final version was a compact, self-contained, portable downdraft gasifier capable of producing electricity and heat.

The gasification of 'green' wood was abandoned in favor of a cleaner approach which predried the wood-fuel for gasification outside the reactor using the excess and otherwise escaping heat. The test runs showed that 10% to 15% of the total energy content of wood was recovered as electrical energy, while another 50% was recovered as heat energy.

Gasifier-generator units are recommended for use in locations or operations where the electrical energy as well as the heat energy may be used, such as smaller sawmills, logging camps, or wood operations.

INTRODUCTION AND OVERVIEW

In 1978, development of a prototype wood gasifier was initiated as a part of a forest mechanization course in the School of Forestry at Lakehead University, Thunder Bay, Ontario. It was initiated as a demonstration of the possibility of using wood residue, obtainable in a forest harvesting operation, as a source of mechanical or electrical energy. This would improve utilization of the forest resource, and it has the potential, with further development, for use in space heating and power generation in remote communities, logging camps, and sawmills. The design of the prototype was heavily influenced by information in A. Koroleff's (1952) book "Logging mechanization in the USSR". Koroleff claimed that a KT 12 skidder was being successfully fueled with a gasifier which processed freshly cut green wood (white birch).

In June of 1979, the first prototype gasifier was successfully tested at Lakehead University (see Figures 1 and 2). Good quality raw gas was produced from partially dried wood.

During the winter of 1979/80, the gasifier was installed on the back of a 1/2 ton truck, which served as a testbed for a number of experiments. Gas cleaning and cooling accessories were added and the first successful trials of the modified vehicle were conducted in March of 1980. Following further modifications, the final version of the gasifier was tested by driving the truck from Thunder Bay to Toronto.

The gasifier was then removed from the truck, and installed on a common diesel powered electric generator. The diesel engine was modified to accept the gasifier and then this unit was used to generate electricity from wood. The original intent was to use freshly cut green wood, but this was not possible. Instead, further modifications to the unit were made which allowed the wood to be predried using heat given off by the generator's cooling system (Figure 27).

Figure 1 L.U. gasifier-prototype first good quality gas produced on June 21, 1979.

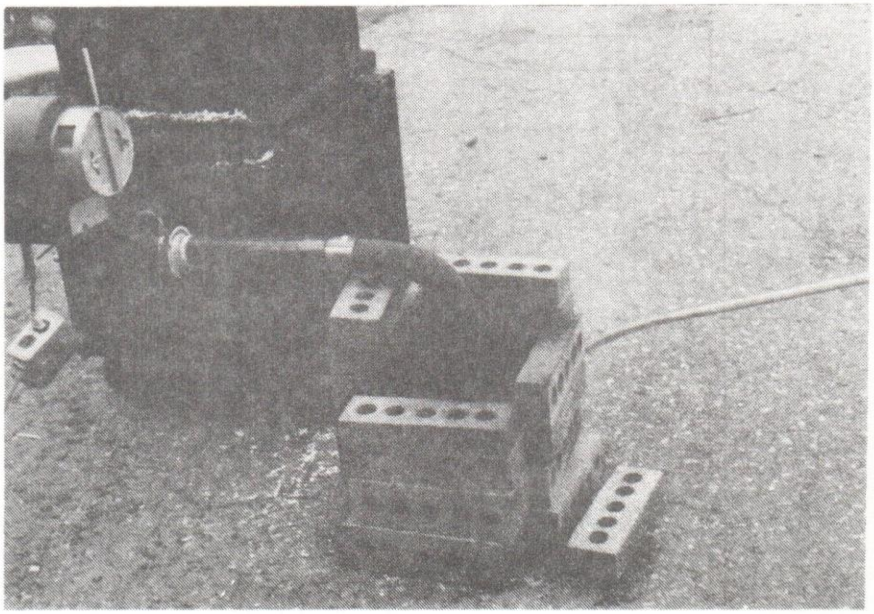


Figure 2 Raw wood gas produced, suitable for space heating

EQUIPMENT TESTING

Test of Gasifier on a 1/2 ton Truck driven from Thunder Bay to Toronto:

To demonstrate the function, reliability and amount of maintenance and fuel required to run the final version of the improved gasifier, an invitation was acccepted to display the wood powered truck at the "Alternate Energy show in Toronto on November 6-8, 1981.

The last improvements and changes were finished just before the trip. A short test run was conducted to confirm the correct function of the unit. Forty "potato bags" were filled with kiln dried lumber trimings from Kakabeka Timber and loaded on a support truck which also went to Toronto.

Table 1 summarizes the most important data recorded during the test run between Thunder Bay and Toronto. There were no mechanical problems during the entire trip. The engine ran very well and the driver soon gained the necessary skills such as refuelling before the charcoal bed was burnt, (approximately after every 45-50 minutes of driving) and draining the condensate and shaking the grate when refilling the fuel hopper.

Maintenance during stops decreased from approximately 15 minutes per stop to 5 minutes per stop during the second day of the trip. The engine was left running, especially during the short stops, so that the engine suction would reduce the reverse flow of the gas (figure 16).

Table 1: Gasifier Test on 1/2-Ton Truck Test Bed Equipped with GMC 250 Cid 6 cylinder Engine during trip from Thunder Bay to Toronto, Ontario.

Date: 1981	Fuel* Kg	Distance Km	Driving Time Min.	Maintenance Minutes	Notes
4 Nov	37.0	46.7	45	15	*Fuel Used: Kiln dried wood blocks (trimmings of 4" wide, 1/2" thick interior panelling boards, warring length from 6"-12"). Comp. by Species. 40% black ash, 40% which birch and 20% pine and cedar Vehicle speed on level ground or gentle slopes. 65-80 km/hr., with top speed recorded at 90 km/hr. average speed for the trip = 62 km/hr.
4	30.0	111.1	100	20	
4	34.5	62.8	70	20	
5 Nov	26.5	49.9	50	15	
5	20.0	49.9	45	10	
5	21.0	49.6	45	5	
5	16.0	20.3	20	5	
5	12.0	46.2	45	5	
5	18.0	49.7	45	5	
5	21.0	46.2	50	5	
5	21.0	41.2	35	10	
5	11.5	40.9	40	5	
5	23.0	56.5	55	10	
5	15.0	42.2	50	5	
5	14.5	72.4	65	5	
5	30.0	24.3	25	15	
5	21.5	56.3	50	5	
5	17.0	42.7	35	5	
5	15.0	33.6	35	5	
6 Nov	33.0	99.9	105	15	
6	36.0	61.6	50	5	
6	17.5	70.5	60	5	
6	28.5	65.0	60	5	
6	17.0	48.1	45	5	
6	28.0	39.8	35	5	
6	12.0	37.8	45	10	
6	19.0	30.4	45	5	
Totals	595.5 (35 bags)	1395.6	1350 (22.5 hrs)	225 (3.75 hrs)	

Test Results: 1. Fuel consumption:

Distance travelled on one 17 Kg Bag of wood = 39.9 Km.
Distance travelled on 1 Kg of Wood = 2.3 Km

Fuel consumption per 100 Km = 43.5 Kg

Comparison with the same vehicle using gasoline as fuel:

Distance travelled on 1 l of gasoline = 5.308 Km or 18.84 l per 100 Km.

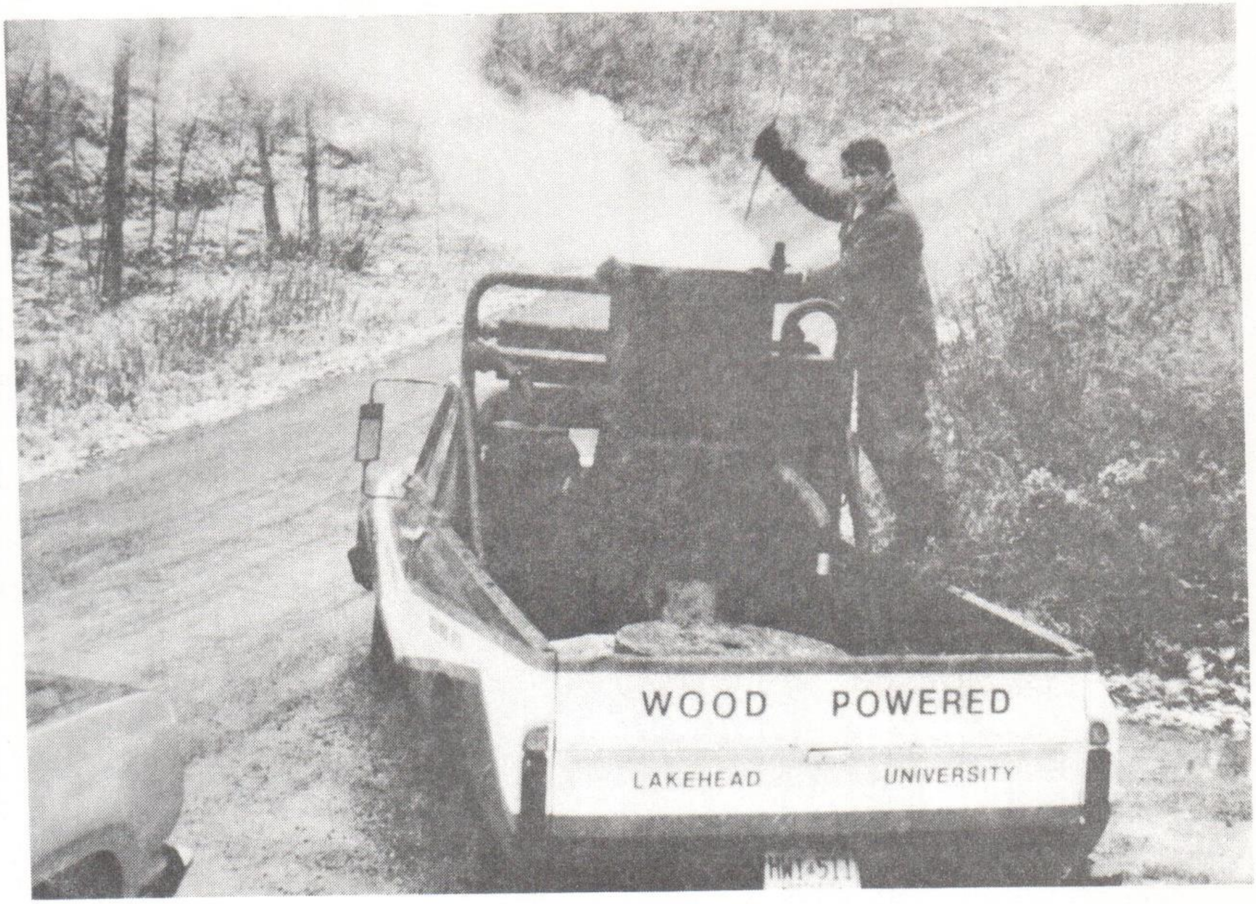


Figure 16. Typical fuel refilling stop during Toronto trip.

During the 3-day Energy Show in Toronto, the public showed considerable interest in wood gasification. Many citizens expressed amazement that the truck was driven on straight wood fuel and an unmodified engine (Figure 17).

During the return trip from Toronto to Thunder Bay, the crew ran out of fuelwood in the middle of the trip (around Sault Ste. Marie) so the second half of the trip had to be finished on gasoline. A thorough inspection of the gasifier was performed after returning to Thunder Bay. No major problems were found except that air leaking through the clean-

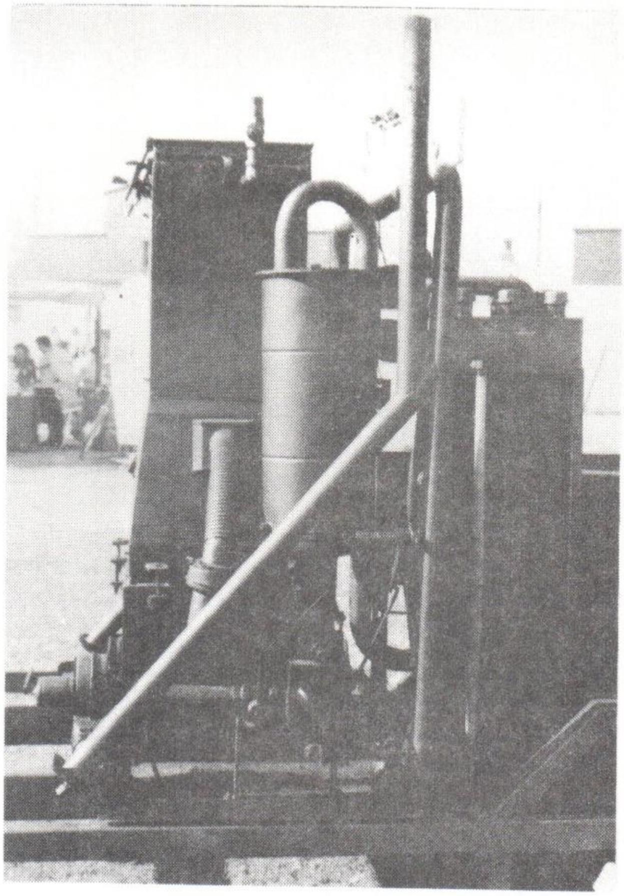


Figure 14

Side view of L.U. gasifier showing vertical cooler, both blowers, fine filter, gas flare (the longest vertical pipe) and two interconnected valves directing the gas to the flare or to the engine.

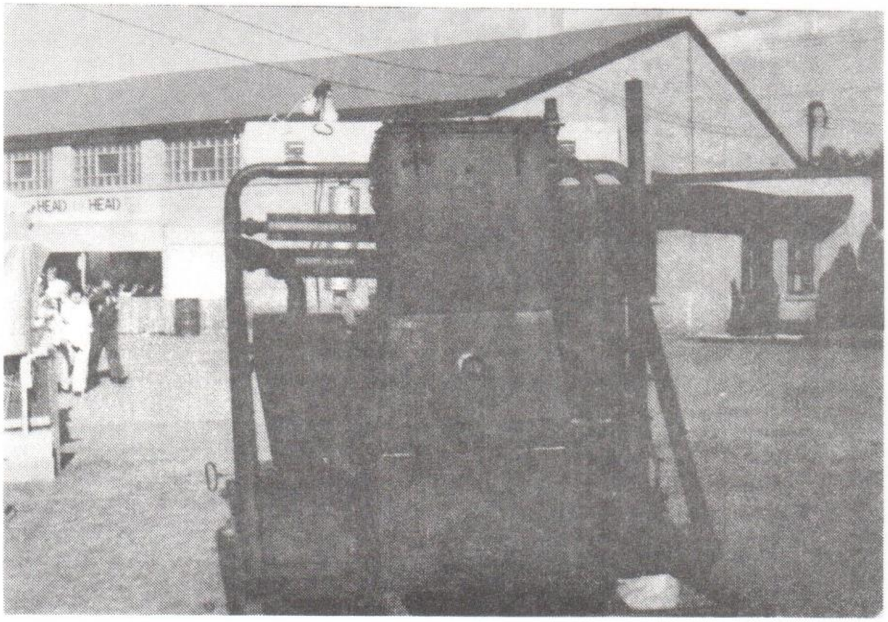


Figure 15 End view of L.U. gasifier. The final version.

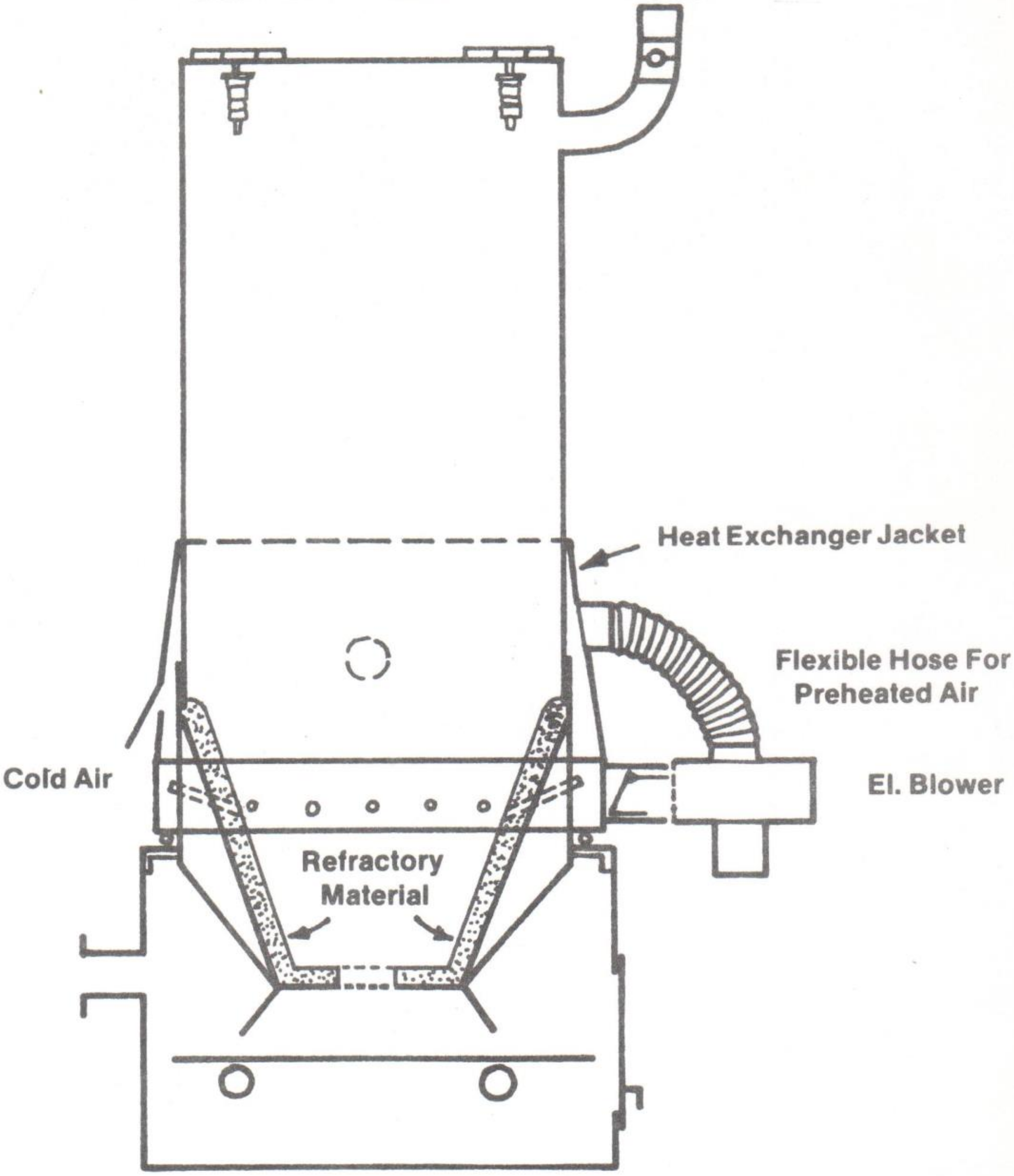


Figure 11 L.U. gasifier, second modification

Table 2a) Summary of gasifier-el. generator test run on aspen bark briquetes:

Date: 1982	Test Run Hrs	Fuel Consumption	Fuel Consumption Kg/hr	Output Kw	Specific Fuel Consumption	Notes
April 22	3.92	109 Kg	27.81 Kg	3.96	7.03 Kg/Kw/Hr	80 mm dia. Approx. 100 mm long briquettes
April 26	3.50	95.34 Kg	27.24 Kg	7.36	3.71 Kg/Kw/Hr	Briquettes produced on Hausman's press
Avg $\bar{x}$	3.71	102.17 Kg	27.54 Kg			

Cost per 1 KWH (Fuel only) = $0.18, if gasifier consumes 3.71 Kg/KW of Briquetes at $50.00 per ton.

b) Summary of gasifier-el. generator test run on kiln dried wood blocks (trimmings):

Date: 1982	Test Run Hrs	Fuel Consumption Kg.	Fuel Consumption Kg/hr	Output Kw	Specific Fuel Consumption Kg/Kw/Hr	Notes
April 27	4.0	68.1	17.03 Kg	7.590	2.24	Fuel: Kiln Dried woodblocks 7 - 11% MC, composed:70% of black ash and 30% of white pine. Fuel cost is about 60% - 70% of total cost of energy produced by vehicle type gasifier (Koroleff, 1952).
April 28	5.83	72.64	12.46	6.90	1.81	
June 29	2.00	34.0	17	8.97	1.90	
June 30	2.75	44.01	16.0	8.570	1.88	
July 1	1.75	28.0	16.0	8.625	1.85	
Avg. $\bar{x}$	3.26	49.35	15.70	8.13	1.93	

Cost per KWH (Fuel only) = $0.10, if dry wood block cost = $50.00 per ton.

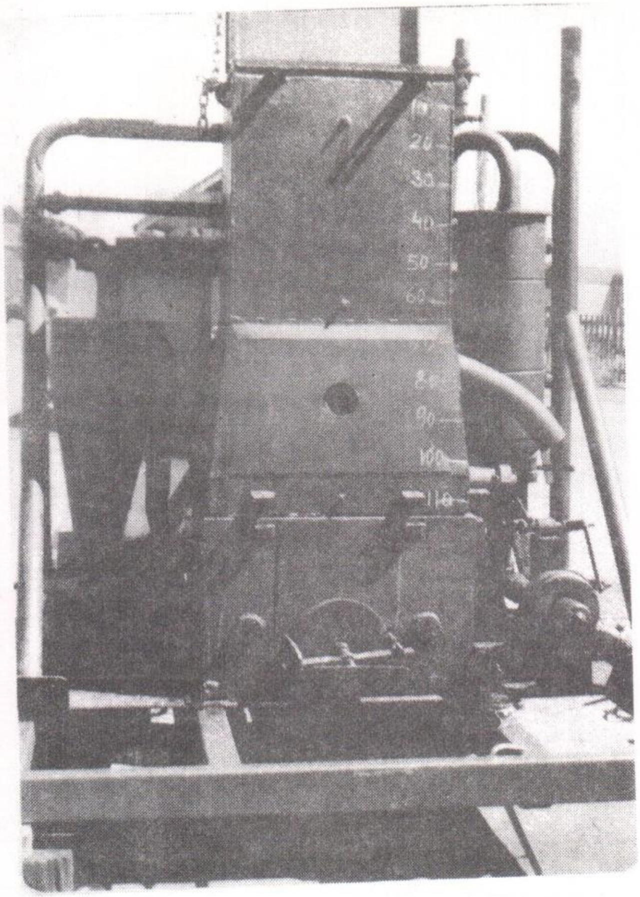


Figure 24:

Aspen briquette test. Chalk Marks on gasifier correspond to the layers of briquettes removed after sudden stop of gasification process.

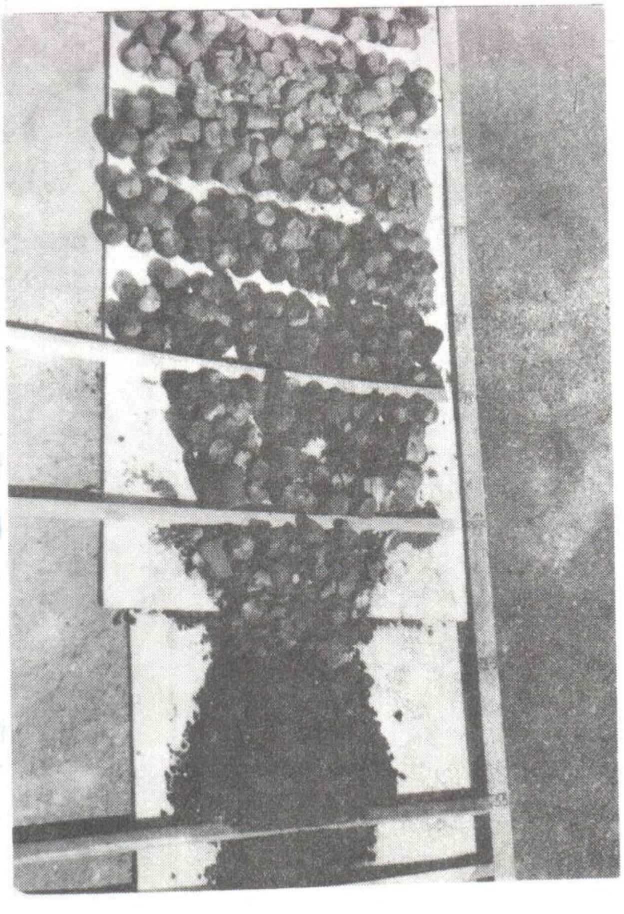


Figure 25:

Displayed briquettes in the same sequence on the ground to show the progress of the gasification proven in the downdraft gasifier.

Fuel-wood Predryer Development:

A large quantity of heat was generated and wasted during wood conversion into electric energy by the gasifier-generator unit. The average specific fuelwood consumption per 1 kWh produced by L.U. gasifier-generator unit is 1.93 kg or 0.518 kWh per 1 kg of approximately 8-10% M.C. kiln dried wood (from Table 2).

The average content of energy in

1 kg of Oven Dry, solid wood = 19.45 mJ

1 kWh = 3.6 MJ; $\frac{19.45}{3.6} = 5.4$ kWh

If this energy content could be converted without losses into power then 5.4 kWh could be recovered. The efficiency of the L.U. gasifier =

$$\frac{\text{Recorded output}}{\text{Theoretical output}} = \frac{0.518}{5.4} = 9.6\%$$

If the wood to energy conversion losses represent 30-40% and electric energy output = 10%, then 50-60% of the heat escaping from reactor piping, coolers and engine cooling is wasted. To utilize part of the wasted heat a fuelwood predryer was proposed and facricated. The resulting prototype predryer using waste heat from the gasifier's own consumption, is shown on the figure 27.

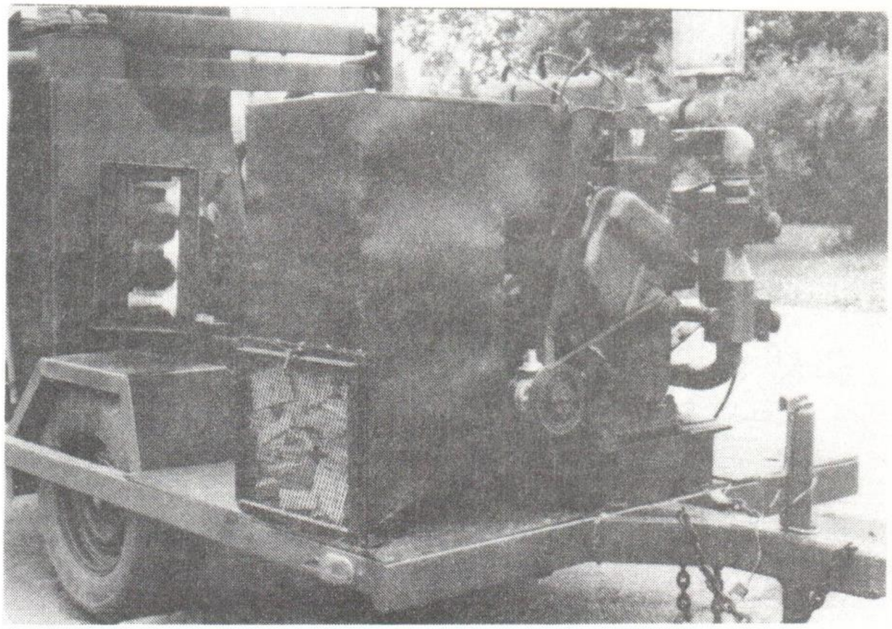
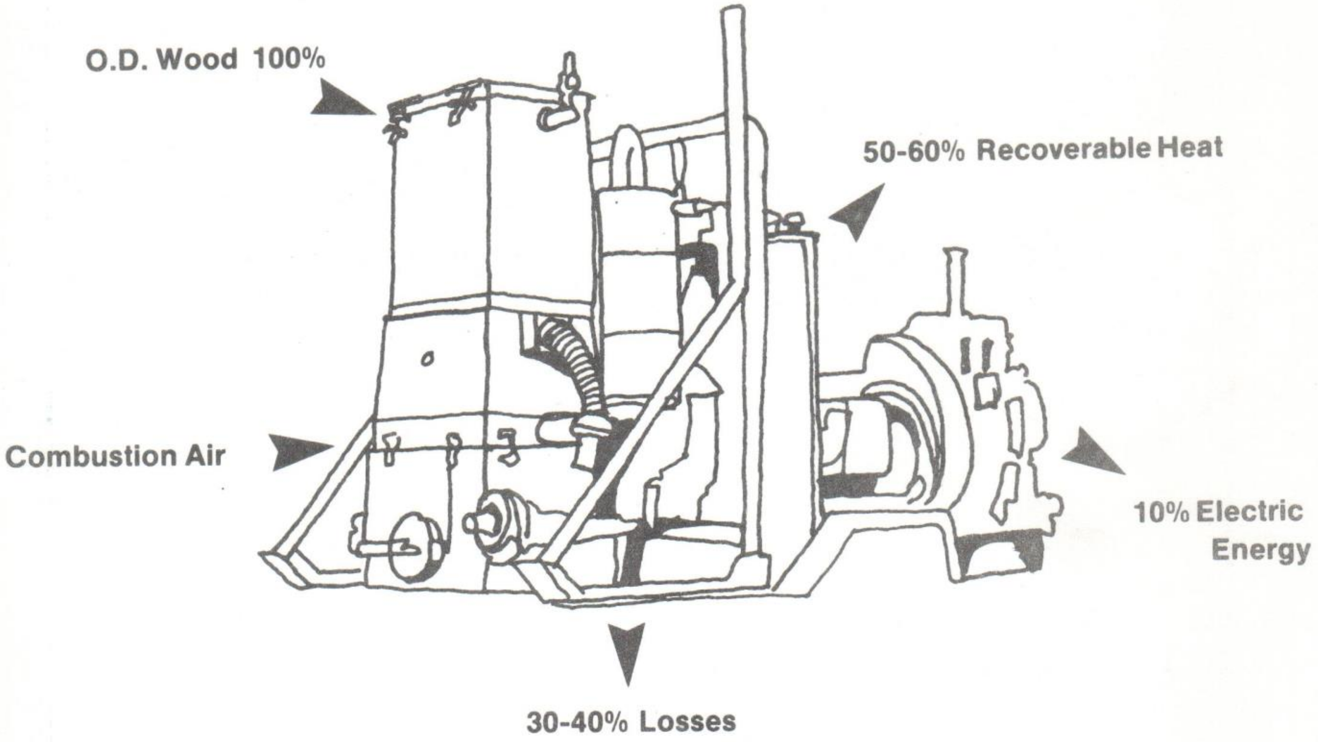


Figure 27 Wood predrying outside the gasifier by hot air from engine cooling system.



Efficiency of Small (10KW) Gasifier-Generator Unit:

Figure 28. Gasifier-wood predryer.

D. Conclusions and Recommendations

Conclusions:

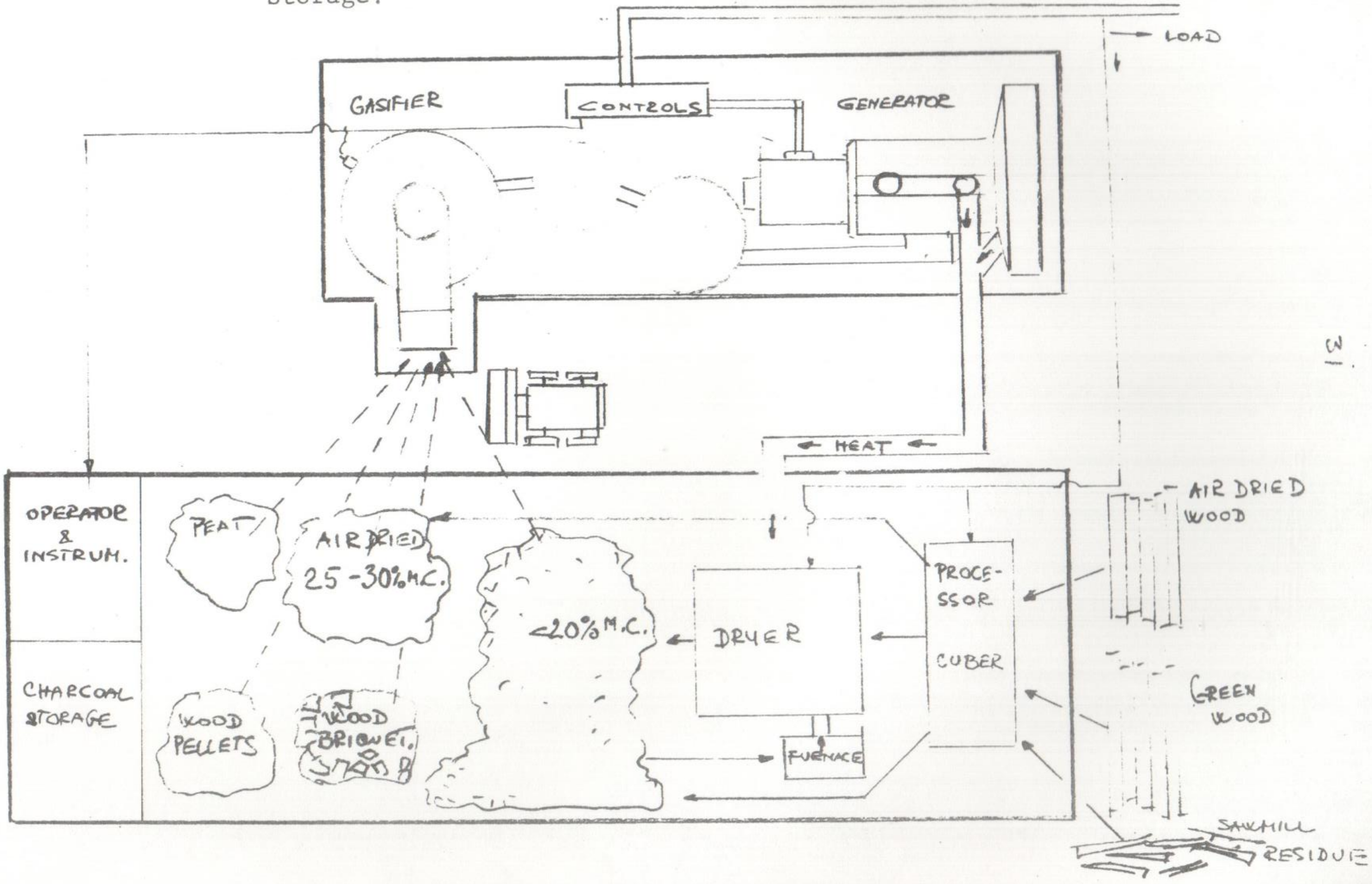
1. This research and development demonstration project proved to be useful in obtaining the necessary skills, "hands-on" experience, and confidence in our ability to obtain (through gasification technology) heat, mechanical and electrical energy from locally abundant wood residue.
2. The gasification technology can be considerably improved and made more practical and convenient. The continuation of gradual improvements and development work is necessary.
3. Wood residue gasification is presently a high maintenance and inconvenient process in comparison with fossil fuels use. It may be even hazardous to untrained operators at the present time.
4. Gasification of greenwood in a downdraft, fixed bed gasifier is a complex problem. It appears that fuelwood predrying outside of gasifier reactor by use of the heat escaping or being disposed from the gasification process is necessary.
5. Under certain conditions small and medium gasifiers (10-150 kW) may be used immediately, if a supply of low cost, dry wood in the right form is available (for example sawmill operations).
6. Solid predried wood for the gasifier is preferable, especially for cost reasons.

7. Efficiency of conversion of wood energy into electricity is relatively low, (about 10%), but a large quantity of heat is available for space heating or drying, (about 50% of original heat energy value of wood).
8. The effect of disposal of process wastes (such as condensate) was not studied and is an unknown factor at present.
9. The general public doesn't understand the gasification process and probably doesn't realize the full potential and the high value of energy from wood residue.

Recommendations:

1. Effort should be concentrated on development of small (10 kW - 150 kW) gasifer-electric generator heat generator type units instead of vehicle type gasifiers.
2. Gasifier-generator units should be built in Canada for sawmill and secondary lumber processing operations as well as for remotely located logging camps. The remote communities should not be included at present in gasifier technology.
3. Effort should be aimed at gasifier feedstock (woodblocks) processing and predrying. Equipment for wood cube production and dryers using waste heat should be developed. See the attached sketch, Figure 29.
4. Charcoal production for use in gasifiers should be studied. Large quantities of low quality hardwood are available.
5. Public education about gasifier technology advantages and shortcomings should be pursued.

Figure 29: Proposed Small Scale (50-250 kw) Wood Gasification System for Electrical Power Generation - Including Feedstock Processing and Storage.



Feedstock Processing & Storage Area

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III RESIDENTIAL HEATING AND CHIP STORAGE/DRYING

E.J. DAVID

MAY 1983

SUMMARY

Low quality and unutilized waste wood, especially wood that is left after forest harvesting operations, may be converted into valuable woodchip fuel, which can then be used in space heating systems. Solid wood fired, coal fired, and some oil fired furnaces can be converted to accept wood chip stokers or gasifiers. The stoker-furnace which has already been tested (Hermelin et al, 1982; David, 1982) and has shown to be reliable, was used in this experiment. The chip conveyer system and the chip storage-dryer bin were the components of the woodchip heating system that were being tested in this experiment.

The prototype chip storage bin and conveyer system was unreliable, so the total automation of the residential woodchip heating system was not acheived during this experiment. The chips frequently bridged above the storage bin unloading ports, cutting off the 'flow' of chips, and occasionally jammed or overloaded the auger conveyer system, stopping the movement of chips. Further improvements in design of both the storage bin and the conveyer system should alleviate these problems. The drying techniques incorporated into the design of the chip storage-dryer bin proved effective, but their potential was not realized in this experiment due to the above mentioned problems.

The moisture content of the woodchips was a major factor affecting the efficiency of the stoker-furnace. Green or wet chips (45-50% M.C. wet) caused poor combustion and frequent fire outages. Kiln dried birch chips (7-11% M.C.) burned the best, but all chips below 35% moisture content (M.C.) performed well.

The woodchip heating system, as compared to a solid wood fired furnace, is safer, more efficient, more convenient, and can be totally automated. It is generally a more intelligent way of utilizing wood for fuel and may prove economically feasible if the prices of other, more conventional fuels continue to rise. A cost nomogram has been produced to show the comparisons between oil and woodchip fuel consumption and costs.

INTRODUCTION AND OBJECTIVES

During cutover clean-up and site preparation for the next forest crop, large quantities of low quality wood residue (slash) may be salvaged. The energy content of this wood residue and its cost in comparison with fossil fuels is becoming more and more attractive as prices of fossil fuels rise. Part I of this report showed how logging residue could be converted through chipping to a marketable product.

A study was carried out from 1978 to 1982 to explore the feasibility of wood residue derived chip supply, storage, drying, combustion, and consumption, for residential heating installations. Equipment maintenance and reliability analyses were performed as well. The design of the woodchip space heating system attempted to duplicate the user convenience of a conventional oil fired furnace. Experience was obtained in conversion of an oil fired hot air heating system to a wood chip fired hot air heating system.

Substantial experience and knowledge was obtained in the use of this technology. This should be of value in the design of space heating systems for facilities having access to abundant stocks of inexpensive waste wood, such as logging camps, sawmills, and woodlot owners. Remote areas having poor access to grid electricity or fossil fuels might also be able to use this technology for space heating.

AUTOMATED RESIDENTIAL WOODCHIP HEATING

There are two basic approaches to obtaining the heat energy from woodchips. One is direct combustion (burning) of the woodchips and the other is gasification of woodchips with the resulting combustible wood gases being burned. Direct combustion is accomplished in a woodchip stoker(feeder) -furnace unit and gasification in a woodchip gasifier (precombustor)-furnace unit. Technological advances in furnace design have allowed both methods to be suitable for residential use. Each has its advantages and disadvantages as shown in Table 1.

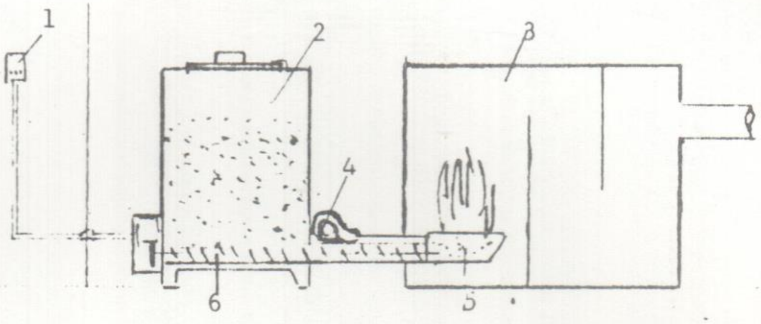
Table 1: Advantages and Disadvantages of Woodchip Stokers and Woodchip Gasifiers

	Advantages	Disadvantages
Woodchip Stokers	- Low or zero creosote deposits - Simpler and more reliable - Lower fuel consumption - Thermostatically controlled	- Dry woodchips required (< 35% M.C.) - Ash cleaning approximately every two weeks - Hot ash and sparks from chimney; cyclone ash removerr required on some instalations
Woodchip Gasifiers	- Wetter woodchips can be used (<50% M.C.) - Clean exhaust - no creosote (except during start-up) - Higher fuel heat-energy extraction efficiency - Less frequent ash removal - Thermostatically controlled	- High minimum operating temperature - Must be operated hot to stay efficient - Difficulty controlling heat output during low heat demand period - Higher fuel consumption - More attention required - smoke may escape into bin if fuel runs out

Source: David, 1982; and Hermelin et al, 1982

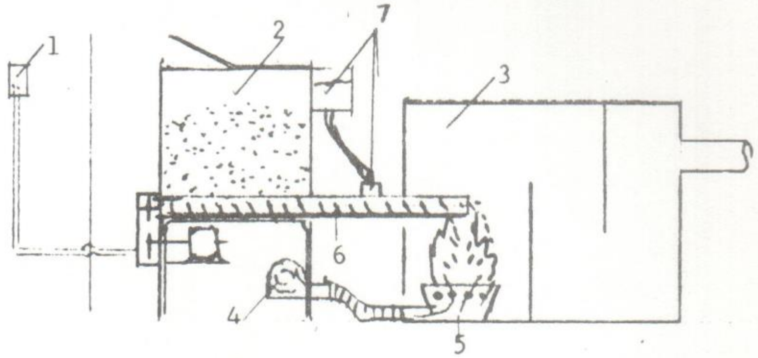
A. STOKER

!. Thermostat and controls
2. Chip container
3. Furnace
4. Forced draft
5. Fire box
6. Metering auger



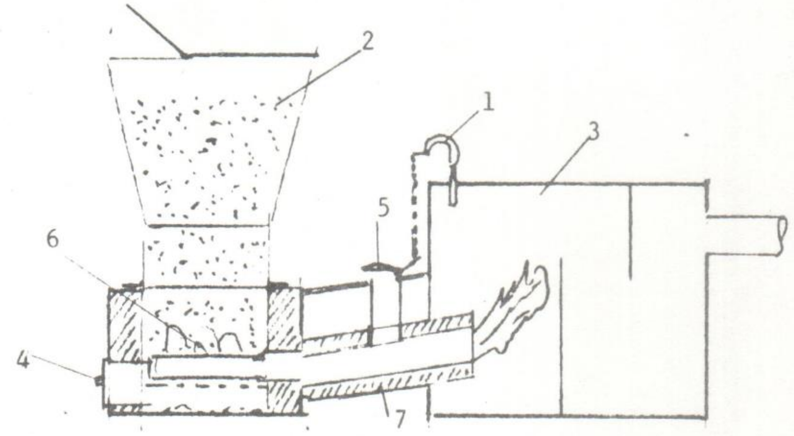
B. STOKER - OVERHEAD FEED

1. Thermostat and controls
2. Chip container
3. Furnace
4. Forced draft
5. Fire box
6. Metering auger
7. Backfire sprinkler



C. GASIFIER

1. Thermostat
2. Chip container
3. Furnace
4. Primary air-draft
5. Secondary air-draft
6. Gasification chamber
7. Insulated pipe



D. AUTOMATICALLY FED GASIFIER

1. Thermostat and control
2. Chip container
3. Furnace
4. Forced draft
5. Gasifiaction chamber
6. Metering auger
7. Insulated pipe

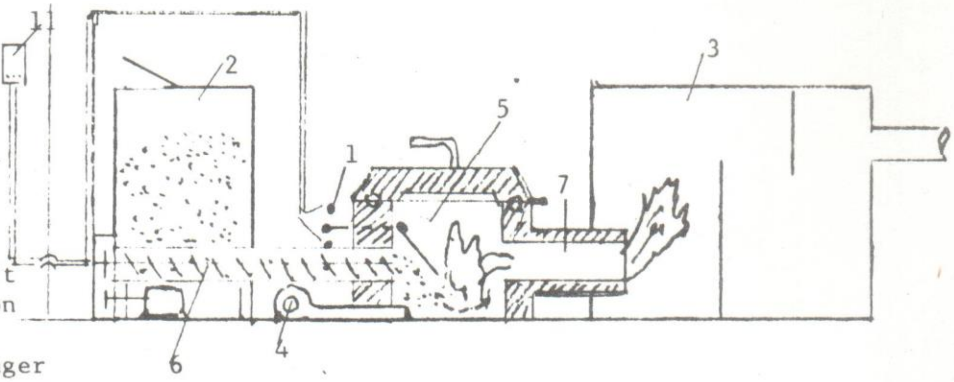


Figure 1. Residential woodchip systems

FIGURE 7: EXPERIMENTAL RESIDENTIAL WOODCHIP HEATING SYSTEM

1. Insulated ducts for cold and hot air
2. Experimental furnace house
3. Cyclone to collect the fly ash
4. Converted hot air furnace - oil to chips
5. Chip stoker
6. Vertical conveyor with two way valve
7. Stoker fill~~ing~~er
8. Bin fill~~ing~~er
9. Loading hopper
10. Spout with gate
11. Cold air
12. Solar box generating hot air
13. Hot air duct
14. Perforated hot air pipe
15. Bin filling conveyor
16. Chips
17. Bin unloading conveyor
18. Experimental chip drying bin
19. Bin unloading conveyor

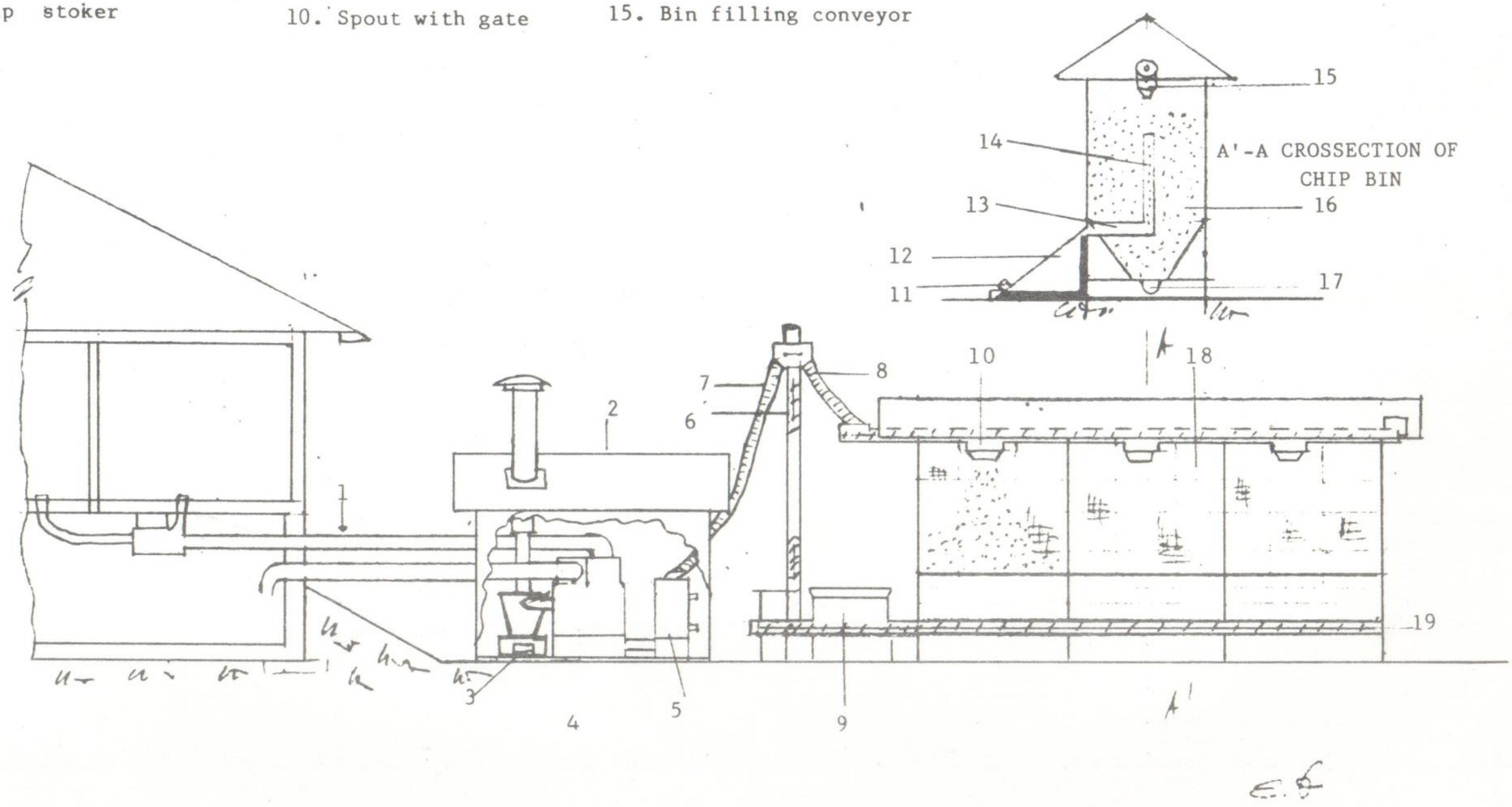


Figure 9 Alder brush - suitable fuel when chipped.

Figure 10 Hardwood tops and branches being chipped with a Bruks 720 Chipper

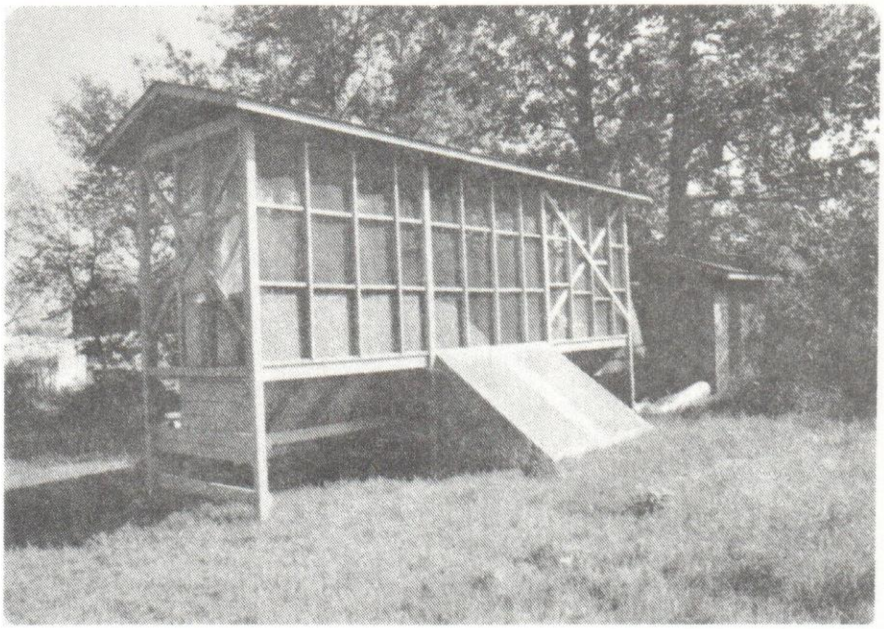


Figure 13 Overall view of experimental woodchip heating system, showing storage bin in foreground and stoker and furnace building in back.

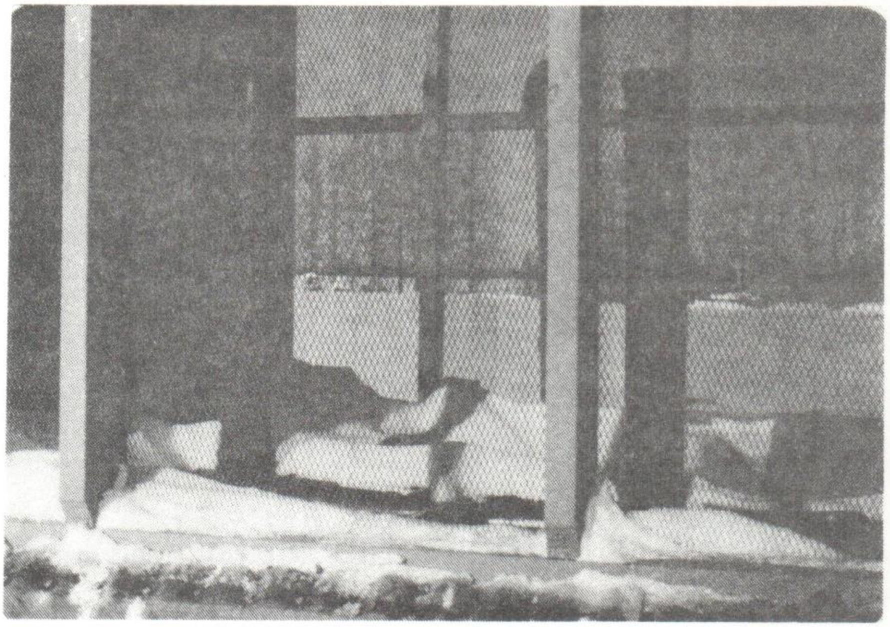


Figure 14 Vertical ducts which distribute heated air from the solar box to the chips in the 2nd section of storage bin.

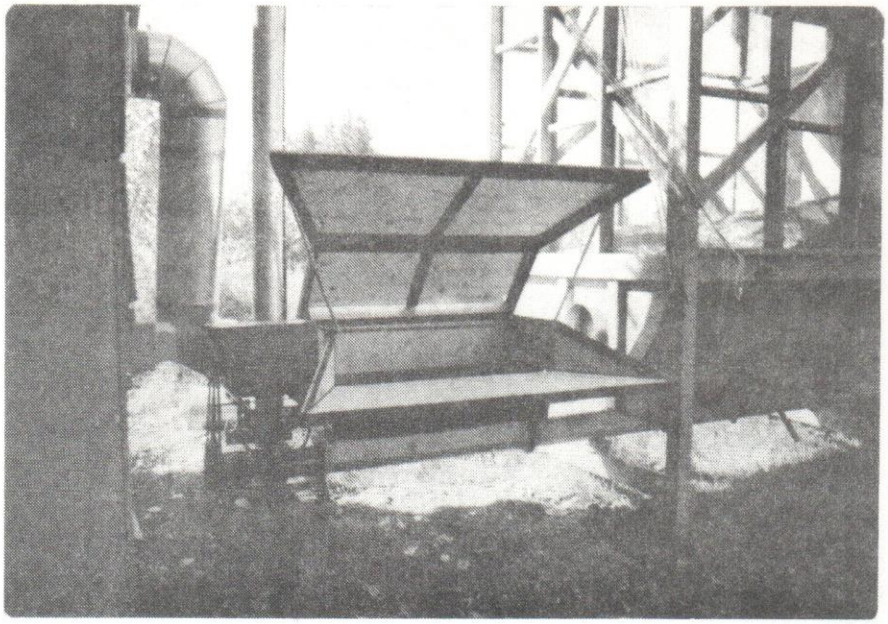


Figure 16 Storage bin filling hopper

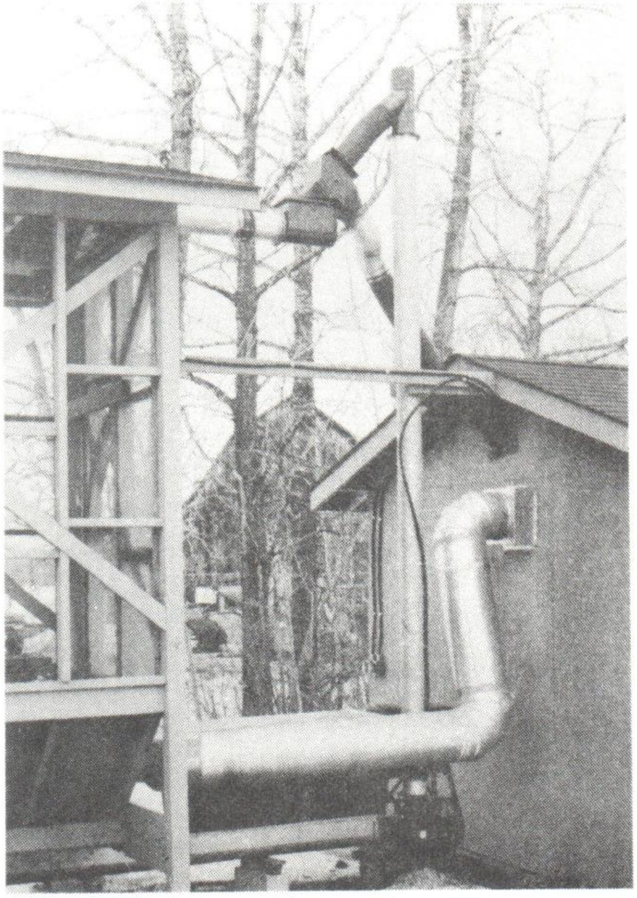


Figure 17

Vertical 'auger', conveying chips from hopper into stoker bin or storage bin via diversion valve, and 30cm hot air duct which blows hot air from furnace to the chips in section 1 of storage bin

Table 2A. Monthly Woodchip Consumption Summaries for January, February and March 1982.

			Deg. Days		Stoker		Stoker Chip Consumption				
		# of	Monthly	Daily	'On' hours		By Weight		By Volume		
Month		Days	Total	Avg.*	Total	Avg/day*	Kg	Kg/hr*	Liters	L/hr*	L/day*
January	A	31	1212.6	39.1	114.7*	3.7*	1204*	10.5*	6859.1*	59.8*	--
	B	25	1002.1	40.1	92.2	3.7	968*	10.5*	5509.0*	59.8*	--
	C	22	871.0	39.6	86.8	3.9	912	10.5	5186.3	59.8	235.7
February	A	27	900.5	33.4	110.7*	4.1*	1085*	9.8*	6088.5*	55.0*	--
	B	21	737.8	35.1	85.3	4.1	834*	9.8*	4691.5*	55.0*	--
	C	18	612.0	34.0	75.2	4.2	736	9.8	4133.0	55.0	229.6
March	A	31	755.2	24.4	136.4*	4.4*	1569*	11.5*	8306.8*	60.9*	--
	B	29	702.0	24.2	128.3	4.4	1479*	11.5*	7813.5*	60.9*	--
	C	27	669.0	24.8	118.3	4.4	1364	11.5	7207.1	60.9	266.9
Total	A	89	2868.3	32.2	361.8*	4.1*	3858*	10.7*	21254.4*	59.0*	--
	B	75	2441.9	32.6	306.8	4.1	3298*	10.7*	18042.2*	59.0*	--
	C	67	2152.0	32.1	280.3	4.2	3012	10.7	16526.4	59.0	246.7

* Calculated or extrapolated from other recorded data in this table

Note: A - Monthly data that was available for each day of the month.
B - Monthly data for each day that the woodchip stoker was operational.
C - Monthly data for each day that the stoker was operational and there was no missing data.

Dry chips were primarily used in January. Kiln dryed birch chips and green poplar chips were used in February and in March green poplar chips, mixed dry chips, and kiln dryed cedar chips were used.

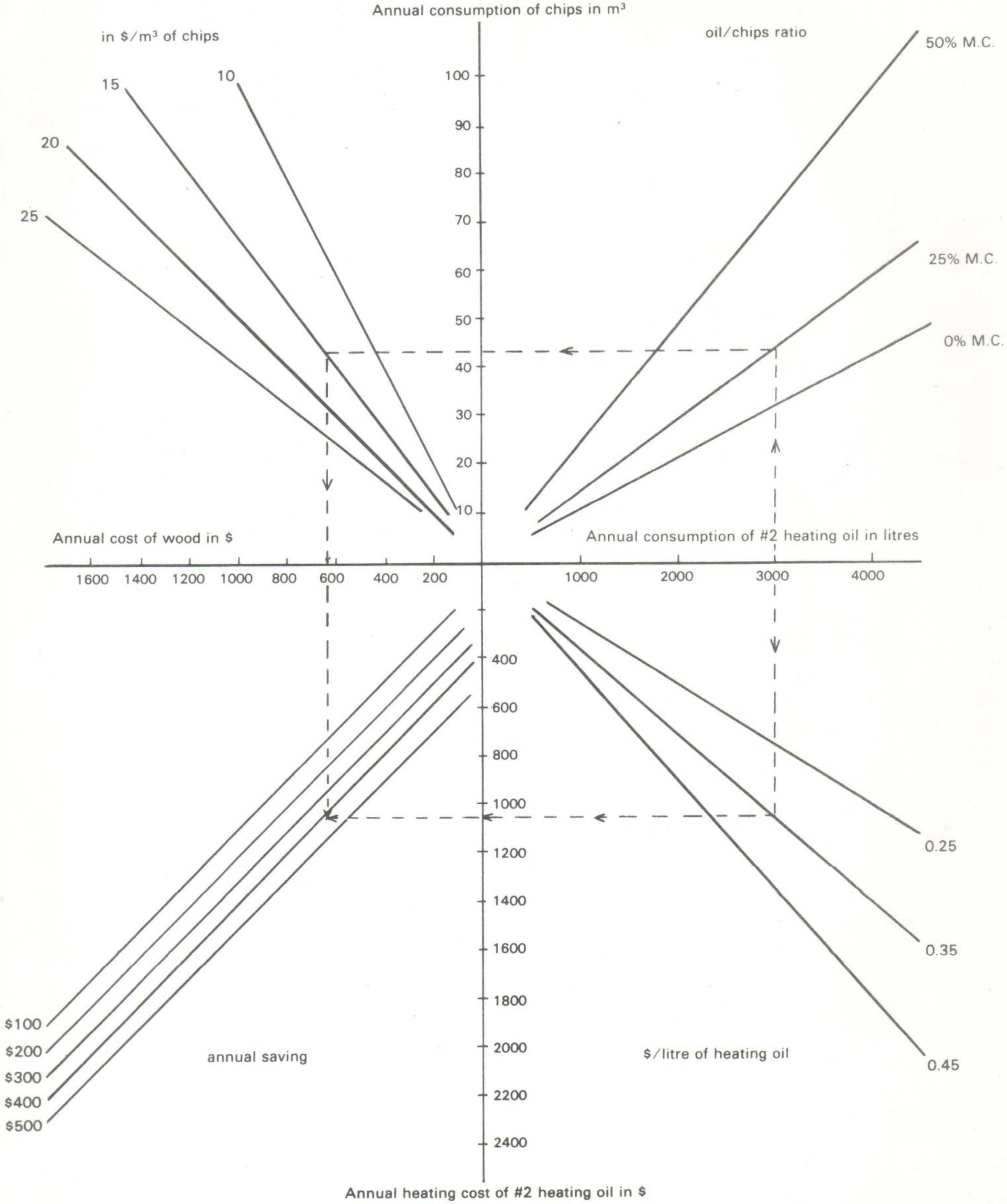
Table 2B. Daily Stoker Woodchip Consumption
Results for 20 days in January 1982

Date		Deg. Days (18°C Base)	Stoker 'On' Hours	Stoker Chip Consumption			
				Liters	L/hr	Kg	Kg/hr
1	Jan. 12	40.6	4.6	266.6	58.0	46	10.0
2	13	41.3	5.2	310	60.0	60	11.5
3	14	32.0	4.7	291.4	62.0	50	10.6
4	15	35.2	1.5*	68.2	45.5	12	8.0
5	16	49.1	5.2	310	60.0	60	11.5
6	17	51.0	4.3	257.3	60.0	44	10.2
7	18	46.6	3.5	223.2	63.8	38	10.9
8	19	36.3	4.8	260.4	54.3	45	9.4
9	20	45.1	0 *	0	–	0	–
10	21	42.5	6.1	359.6	59.0	62	10.2
11	22	38.0	4.8	263.5	54.9	45	9.4
12	23	34.8	4.5	272.8	60.6	47	10.4
13	24	42.3	1.6*	99.2	62.0	17	10.6
14	25	39.2	5.5	310	56.4	60	10.9
15	26	37.9	4.3	263.5	61.3	45	10.5
16	27	23.2	1.6*	93	58.1	16	10.0
17	28	28.9	2.0*	127.1	63.6	22	11.0
18	29	34.4	4.4	263.5	59.9	45	10.2
19	30	35.8	4.3	257.3	59.8	45	10.5
20	31	43.0	4.2	251.1	59.8	43	10.2
Total		777.1	77.1	4547.7	59.0	802	10.4

* Stoker went out; thrice due to bridging of woodchips and twice due to the need for cleaning.

Note: Dry, mixed woodchips with 25-35% Moisture Content used during these twenty days.

Figure 28 **COST COMPARISON OF HEATING OIL VERSUS WOODCHIPS**



CONCLUSION

The chipping of low quality, unutilized waste wood or wood residue for use in a home heating system is feasible. The major chip quality that affected stoker-furnace performance was moisture content. All chips that had low moisture contents burned better and more efficiently (except cedar) than 'green' or wet chips. The denser woodchip species (i.e. birch) had lower consumption rates, but all species (except cedar) which were used in this experiment burned effectively.

The woodchip stoker-furnace is safer in this application, than conventional solid wood fired furnaces, because of better combustion control and the elimination of chimney fires. The hot temperatures involved with combustion of woodchips effectively reduces smoke, and eliminates carbon monoxide and creosote formation. The installation of a cyclone flyash separator between the furnace and the chimney eliminated any sparks or flyash from escaping through the chimney and made ash clean-up easy. Also the standard and widely used regulatory controls found on oil furnaces could be reliably used with woodchip fired furnaces.

The agricultural auger conveyers did not work very well with woodchips. An overloaded vertical power corner or a jammed auger would frequently stop the conveyer system. Chip bridging in the storage bin also reduced the usefulness of the automatic conveyer system.

The storage-dryer chip bin, though not fully tested, did provide useful experience about chip drying. The various drying techniques all showed potential for residential application in spite of difficulties with the chip conveyer system and chip bridging. Solid wood is easier to transport and store and is less affected by rain or snow than woodchips, so more studies should be done comparing wood chip storage to solid wood storage.

There is room for considerable improvements in the woodchip home heating system. The stoker-furnace and the chip drying methods were relatively problem free but their potentials were not realized in this experiment due to the problems with other components of the heating system. Once these problems are solved the woodchip heating system could prove to be a feasible space heating system for logging camps, sawmills, farmers, and woodlot owners.