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PAMI
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Using Straw as a Farm Heating Fuel

The use of straw as a heating fuel on the farm is growing in popularity because it helps to reduce the farm's dependency and related expenditures on fossil fuels and electricity, and it provides a practical and environmentally acceptable alternative to stubble burning. An inexpensive supply of fuel is usually close at hand. Most grain farms produce enough straw each year to supply a straw-burning system. However, even if straw for fuel must be purchased, it is usually a worthwhile venture. ***PAMI gratefully akcnowledges the funding assistance provided by the Canada - Manitoba Agreement on Agricultural Sustainability (CMAAS) for the research on this project.***

Start With the Burner

There are four basic types of straw burners:

- *those that accept shredded, loose straw*
- *burners that use densified straw products such as pellets, briquettes or cubes and straw logs*
- *small, square bale burners*
- *round bale burners*

A loose straw burner requires an automatic stoking system and the operator must have the capability of shredding bales into loose straw. The capital investment and increased operating cost for energy to chop and feed the straw is beyond the practical capabilities of most farms. Pellets, cubes and briquettes are very efficient forms of fuel but can be costly. They also require automatic stoking systems. Straw logs are generally too expensive at this time to be economical.

Whole bale burners are the most practical and most common straw burning systems on Manitoba farms. Most bale burners heat water which is in turn used to heat a home, workshop or similar building. Others are set up as hot air systems.

Square Bale Burners

The combustion chamber fuel capacity can range from a single, standard square bale size to one capable of holding as many as six bales at a time. Although the fuel-to-heat conversion efficiencies of square bale burners are generally the lowest of all straw burners - averaging 30% to 40% - output is still more than adequate to heat a home or workshop.

However, if you intend to heat more than one building, or a very large building such as a greenhouse or hog barn, a square bale burner will not likely be adequate, or at least be too inconvenient because of the frequent need for re-stoking. Consider using a round bale burner.

Advantages of square bale burners:

- *an existing wood-burning boiler can likely be used with little, if any modification*
- *least expensive to purchase—in the range of $3000 to $4000.*
- *stoked by hand—does not require special equipment*

Disadvantages

- *must be stoked several times a day and therefore could be inconvenient*
- *the building may require an auxiliary source of heat if the bale burner goes out*
- *the size of system it can effectively serve is somewhat limited*

PAMI monitored this square bale burner built by Glencross Heating Systems of Morden, Manitoba

- *requires frequent ash clean-out, perhaps as often as every second day. The interval will depend largely on the type of straw used.*

Round Bale Burners

Bales intended for use in a round bale burner are often made slightly smaller than normal so they can be fed into the combustion chamber more easily. Some burners can take two standard round bales at once. Burners may be top-loading or front-loading.

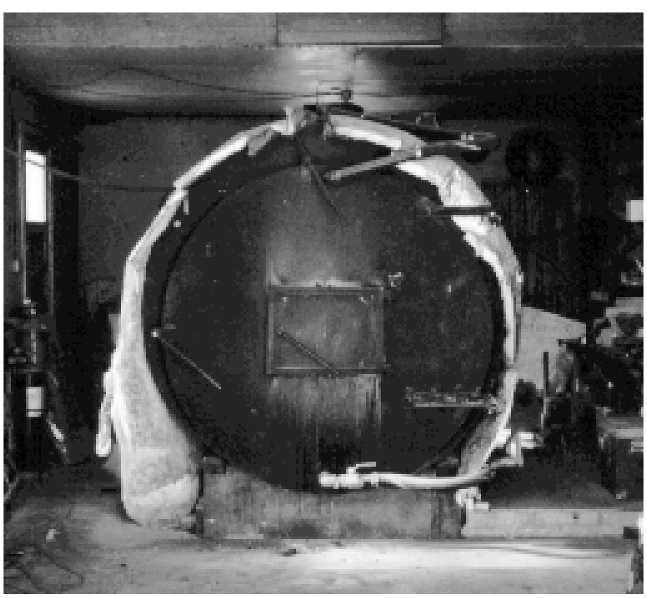
The combustion chamber should be at least 7 ft (2.13 m) in diameter to allow room for bales with flared ends and soft core bales that may have become deformed during storage and handling.

Good air distribution within the combustion chamber is a necessity to ensure even, complete combustion, especially with cereal bales or damp straw. A forced combustion air system is required.

The flue pipes should pass the entire length of the water jacket before exiting the furnace. This helps to recover heat that would have otherwise been lost in exhaust gasses. The flue pipes must also be large enough and installed at a slope sufficient enough to avoid the buildup of creosote and tar which could lead to a chimney fire.

The main loading door should have a small inspection door to allow you light the fire, check on the fire, or to stir up a smoldering bale without opening the entire door. Also, an open inspection door makes the main door easier to close.

The main door must be "water-cooled" to avoid buckling. Water flow through the water jacket in the door must be sufficient to avoid boiling the water away. The system's return water should pass through the water jacket in the door before entering the main water jacket. Or, a separate pump may be used to circulate the water.



PAMI monitored this round bale burner built by Lawrence's Manufacturing of St. Anne, Manitoba

Did You Know?

Enough straw is produced each year in Manitoba alone to heat 400,000 homes for an entire heating season, even if the energy was recovered at a efficiency rate of only 40%.

Advantages of round bale burners

- *larger heat-producing capability than square bale burners*
- *requires stoking only once or twice a day*
- *less frequent ash clean-out—perhaps only once per month, depending on the type of straw.*

Disadvantages

- *more expensive to purchase—around $6000.*
- *requires front-end loader or skid-steer to load.*
- *Must start the tractor every day during the winter. However, for a livestock operator who has the tractor running each day anyway, this is not a problem.*

Natural draft versus forced air

Combustion air for the burner can be supplied as a natural draft or by forcing it in with a fan. Both systems are controlled by a thermostat in the boiler's water jacket.

Natural draft system

The amount of air entering the combustion chamber of a natural draft system is controlled by a damper operated by a solenoid or motor which is directed by the thermostat. The damper is closed when the water reaches the thermostat set temperature and when the water temperature falls below the set temperature, the damper is opened. A properly sealed damper will cut off air to the fire almost entirely, giving better control of heat production in warmer weather when little heat is being drawn from the system.

The chimney must be long enough to create a proper draft, but not so long as to promote creosote build-up. Cereal straw and wet straw do not burn well in natural draft furnaces.

Forced combustion air furnace

This system uses a fan controlled by the thermostat. When the water temperature drops below the set temperature, the fan comes on. The air is usually distributed evenly across the chamber through a manifold. Forced air greatly improves the rate of combustion and therefore the rate of heat production by the fuel. However, there are two problems with this system.

Problem one:

Significant air flow is present even when the fan is not running, promoting combustion. If the amount of heat being drawn from the system is very low—on a mild day, for example—the water temperature in the system could continue to rise above the rated temperature of the piping and even to the point of boiling water out of the system. However, this is not likely to be a problem if burning cereal straw.

Solution:

Install an automatic damper in line with the fan. When the fan stops, the damper would cut off the air flow into the combustion chamber.

Problem Two:

When the fuel has been consumed and the temperature of the water in the system drops below the set temperature, the fan continues to run, pushing cold air from the outdoors into the chamber, cooling the water in the water jacket faster than normal.

Solution:

Install a second thermostat designed to shut the fan off at a pre-set low temperature.

A word about efficiency...

Efficiency describes the amount of heat that is actually available for use compared to the total potential heat in the fuel. A large portion of the heat is lost up the chimney. Energy is also lost through inefficient combustion, unburned gasses escaping up the flue and by direct loss from the burner and heat distribution system. In the case of damp fuel, heat is consumed internally to evaporate the water before the straw can burn.

Fuel

All straw contains a similar amount of heat per unit weight—however, some straws release this energy more readily than others. Flax straw is the most convenient straw fuel. Dry flax straw produces more heat per unit weight than wood.

The Facts on Flax

• Flax burns easily. Flax straw stems do not seem to collapse when baled, allowing oxygen easier access into the straw, encouraging better burning.

• Ash from flax is very fine and powdery and falls off or is blown off of the bale by the combustion air fan as it is formed, continually exposing fresh straw to the flames.

• Flax produces less ash, therefore less combustion chamber clean-out—as little as once a month for very large burners

• Flax straw is readily available in parts of the Prairies. Producers are often looking for ways to dispose of it because it does not decompose easily in the field.

About Lower Heat Value (LHV)...

The energy content of a material is expressed in British Thermal Units per pound (BTU/lb) or megajoules per kilogram (MJ/kg). One MJ/kg is approximately equivalent to 430 BTU/lb. The maximum amount of energy available for use in a fuel is called the Lower Heat Value (LHV). The amount of moisture in the fuel affects the LHV because approximately 1170 BTU of energy is consumed by heating and evaporating each pound of water (2.72 MJ/kg). This energy would otherwise be used to create heat.

For example, the LHV of flax straw with a moisture content of 20% is 6635 BTU/lb (15.43 MJ/kg) while dry flax straw has a LHV of 8586 BTU/lb (19.97 MJ/kg). More than 22% of the potential heat production is consumed in drying the straw.

Straw bales with a density of 6.24 lb/ft³ (100 kg/m³)—soft-core round bales, for example—contain about 40,260 BTU's per cubic foot (1500 MJ/m³). Compacted, 40 lb (18 kg) square bales contain anywhere from 80,500 to 107,000 BTU/ft³ (3000-4000 MJ/m³) of energy.

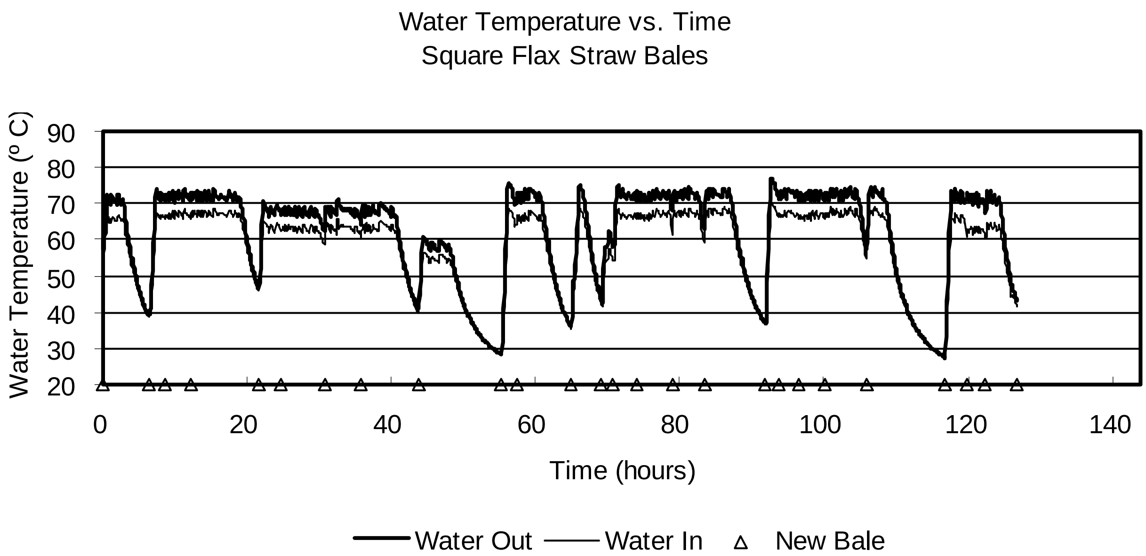
Table 1 below gives a comparison of Lower Heat Values for some fuels.

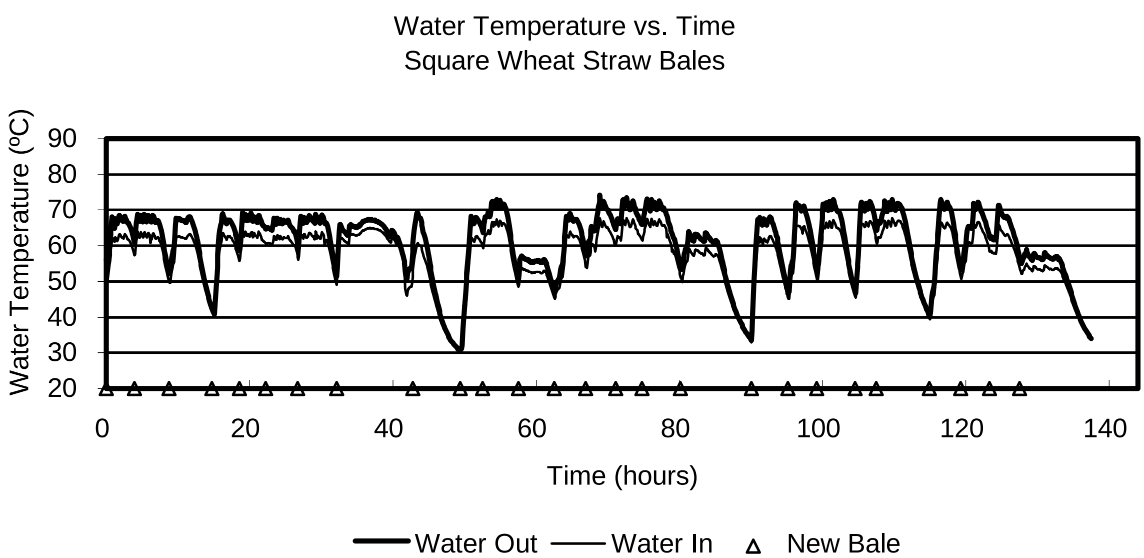
Table 1. A comparison of lower heat values (LHV)

Fuel	LHV	
	BTU/lb	MJ/kg
Propane	19,940	46.37
#1 Fuel Oil	15,910	37.00
Flax straw (dry)	8,587	19.97
Wheat straw (dry)	7,680	17.86
Flax straw (20% m.c.)	6,635	15.43
Coal (lignite)	6,583	15.31
Wood (15% m.c.)	6,450	15.00
Wheat straw (20% m.c.)	5,908	13.74

Environmental Note:

If straw is destined to be burned in the field, it should be considered for use in a straw-burning furnace. Regardless of the type of straw, enough heat can be created to do the job.





The graphs show water temperature versus time for square flax straw bales and square wheat straw bales. Triangles on the X-axis show when the stove was re-fueled with fresh bales.

Cereal Straw

• Produces more ash—cleanout may be required as often as once every two days.

• The straw seems to collapse and become compressed when baled, inhibiting oxygen movement within the straw.

• Cereal straw must have a lower moisture content— 20% or less—than flax straw to burn properly.

• Canola straw is also an excellent fuel because it burns clean and hot, like flax. However, it cannot be easily baled into round bales.

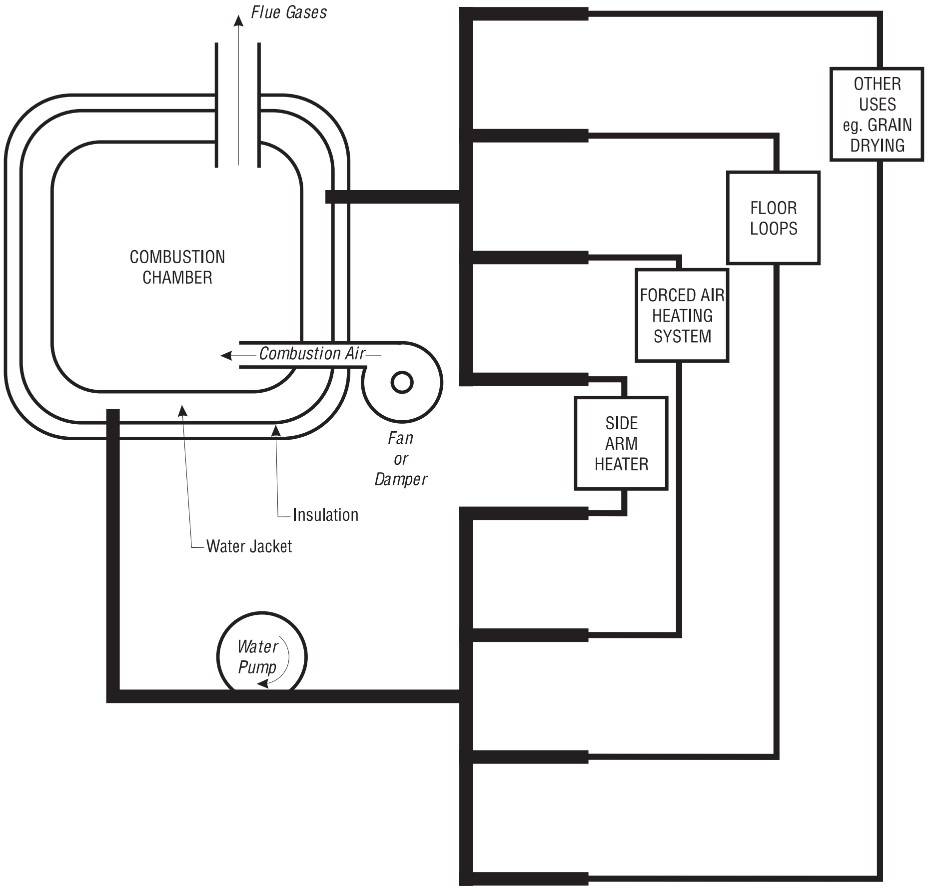
Hot water heating systems

Burning straw heats water in a boiler, which is then distributed through the heating system. Water in the boiler actually stays well below boiling.

System types

Hot water floor heat is a very comfortable heat. The heat radiates upwards from the floor, all but eliminating cold floors. It is installed primarily in new buildings during construction. Several loops of pipes are embedded in a concrete floor or fastened beneath the floor between floor joists.

The pipes can be installed as concentric loops as one,



A hot water heating system might look like this.

large continuous system or in separate zones for greater heat control. The temperature in each zone can be managed thermostatically using solenoids to open and close valves.

A radiator or heat exchange coil can be installed in an existing furnace, making this system the most common method of retrofitting existing heating systems. Hot water from the straw burner is circulated through the coil, releasing heat which is distributed by the existing furnace ductwork.

Heat can also be provided by a space heater made of a radiator with a mounted fan.

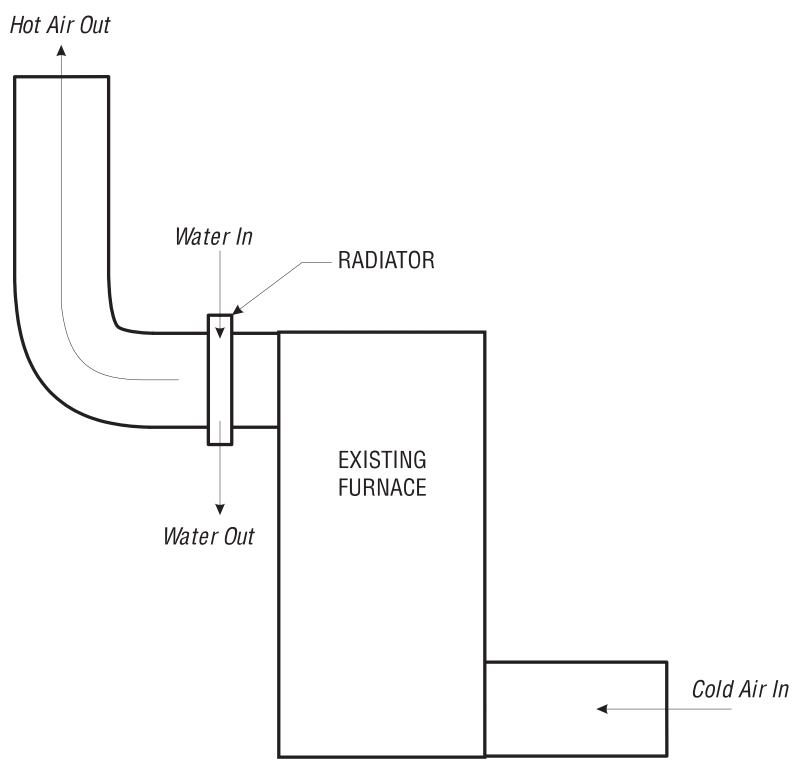
Baseboard radiators may also be used but are less common.

The **size of the hot water reservoir** can be important to the efficiency of the system. A large reservoir helps to reduce fluctuations in temperature as the straw burns down and flares up with new fuel. A very large reservoir allows a fast, hot, more efficient burn to heat stored water for later use.

Piping and Pumps

The piping in hot water systems must be rated to withstand the water temperatures in the system, at least 180°F (80°C). Most manufacturers recommend using a polybutylene pipe with a built-in oxygen barrier of aluminum or higher density plastic. The passage of oxygen into the system slowly deteriorates the pipe.

A space heater built from a radiator and fan.



A forced air heating system.

Environmental Note:

A hotter fire burns more completely, or efficiently. If the straw in the burner is burning efficiently, very little smoke is produced. Wet straw produces more smoke than dry.

Regular PVC pipe is definitely not recommended because it cannot withstand the temperatures.

Piping transferring the hot water from the outdoor boiler to the building is buried one to three feet (up to one metre) underground. Insulate all underground pipes with a box of rigid foam insulation formed around the pipe to reduce heat loss.

Pipes generally range in size from ½ in (13 mm) to 1¼ in (32 mm). The smaller pipes are used for in-floor heat loops or for other small loads. The larger pipes are used to carry the hot water from the boiler to a distribution manifold in the building.

A variety of circulating pumps is available for hot water furnaces. The proper sized pump can be matched to the size of your system.

Water treatment

Treat the heating water with antifreeze and a rust inhibitor. Antifreeze can save the system if a pump failure or power outage occurs. Some operators do not use antifreeze, but keep a generator on hand to power the system if necessary.

Polypropylene glycol is a food-grade antifreeze recommended for heating systems in a mixture of 20 to 50 per cent. The cost to treat a 150 gal (700 L) system would be $500 to $1400. A rust inhibitor would cost about $30 for the same system.

Hot air systems

Heating

Heat produced by bale burners can be collected from the furnace and fed into a forced hot air system, either by transferring the heat via its own ductwork, or by feeding into an existing forced hot air system.

A small straw burner can also be used as a space heater to heat a smaller, confined area. However, fire safety is a concern in this situation.

Grain drying

The hot air produced by a bale burner can be used to dry grain. For example, one Manitoba farmer uses a single round bale burner with a plenum surrounding the combustion chamber to collect the hot air produced. The air is drawn from the plenum and forced through an aeration bin with a 7 hp (5.2 kW) fan.

It takes about ten days to dry 4000 bu (109 tonne) from 21% to 14% moisture, using one bale every twelve hours. The total cost of drying was $155, including the bales and electricity to run the fan. This is approximately equivalent to $0.04/bu ($1.44/tonne) and compares to an estimated cost of $0.39/bu ($14/tonne) using propane at a cost of 0.50/lb.

The unit is easily moved from bin to bin.

The cost

Three factors determine whether a straw burning system is economical.

• The rate of utilization is the most important determining factor, especially with a round bale burner. The capital cost is such that very high savings must be made each year to make it pay. A yard site with more than one building or a very large building is required.

• Straw cost is the second most important factor. However, if utilization is high enough, even purchasing straw can be justified.

• The overall efficiency of the system is a relatively small factor. In tests conducted, the buildings being heated did not

Domestic hot water heating

An existing domestic hot water tank can be fitted with a device called a side arm heater. The side arm is a double pipe heat exchanger, with the domestic water passing through the inside pipe surrounded by the heating water in the outer pipe. The domestic water enters the device from the drain tap at the bottom of the tank and re-enters the tank hot water outlet. A restriction valve prevents too much cold water from mixing with the hot as it leaves the tank.

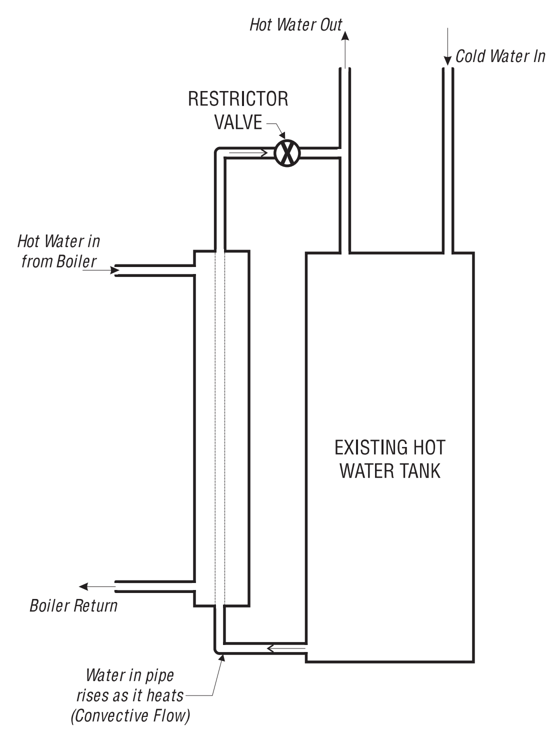


Table 2. Calculation of annual savings for five straw burning systems

Cost/bale	Efficiency	Buildings heated	Annual straw cost	Equivalent electrical cost	Annual savings	Simple payback period
$0.15	30%	1	$151	$1197	$1046	2.9 years
$0.75	30%	1	$756	$1197	$441	6.8 years
$7.00	40%	1	$353	$1197	$844	7.1 years
$13.00	40%	3	$1966	$3591	$1625	3.7 years
$13.00	60%	3	$1310	$3591	$2281	2.6 years

Cost/bale: Assumptions include that a square bale costs $0.15 to produce on-farm and $0.75 to buy. Round bales cost $7.00 to produce on-farm and $13.00 to buy.

Efficiency: Heat producing efficiency varies according to the individual burner and the type of straw and its moisture content.

use nearly all of the heat produced by the systems being examined.

Tests conducted by the Prairie Agricultural Machinery Institute (PAMI) have shown that even if straw bales must be purchased for fuel, installation of a straw burning furnace is probably a good investment. Table 2 describes a few scenarios examined by the study.

The information in the table at is based on:

- square bale burner costs of around $3000
- round bale burner costs of around $6000
- the average power usage for each building is 24,000 BTU/h (7 kW/h)
- the cost of electric heat is 4.75 cents/kWh

How big should your system be?

The following variables will affect the size of the system you require:

- *size of combustion chamber*
- *capacity of boiler*
- *size of building to be heated*
- *construction type*
- *insulation of buildings*
- *length of water lines (distance from boiler to buildings)*

In general, PAMI found that the heat production of most burners is sufficient for most applications. For example, a 1000 sq. ft. house needed only 25% of the output from a square bale burner to keep it warm. However, if you plan to use a square bale burner, look for one that will hold two or three bales at a time for convenience sake.

Note: Bale burning heating systems are relatively new in the marketplace. More work is needed to accurately size a system for specific needs.

Safety Note:

For safety and insurance reasons, most straw burners are located outdoors with insulated ductwork or piping used to convey the heated air or water to its intended use. For efficiency and safety, all burners must be well insulated.

List of Manufacturers

Cal Shoemaker
Grandview, Manitoba
(204) 546-2771

Can-Wood Fire Tube Hot Water Boilers
Canwood, SK. and Pilot Butte. SK.
(306) 468-2283 and (306) 781-4835

Central Boiler Inc.
Greenbush, Minnesota 56726
(218) 782-2575

Cozyburn Fabricating
Box 888, Arborg, Manitoba R0C 0A0
(204) 364-2318

D. Welding (Arden) Ltd.
Box 155 Arden, Manitoba R0J 0B0
(204) 368-2305

Friesen Built
Niverville, Manitoba
(204) 388-4004

Glencross Heating Systems
Morden, Manitoba
(204) 822-3648

Homestead Plumbing Warehouse
Box 160, Winkler, Manitoba R6W 4A4
(204) 325-4253

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Straw Burning at a Glance

Burning straw for recovery of heat energy is a viable alternative use using excess straw produced on Prairie farms. This project included a review of existing straw burning technology, a survey of those currently heating with straw, monitoring of two on-farm straw burning installations, and a quick look at the economic feasibility of changing to a straw burning heating system.

Whole bale burners are in general use on both British and Danish farms. A growing number of Prairie farmers are also burning straw to heat their houses and workshops. Most farmers who heat with straw burners, burn flax straw. Flax straw is advantageous due to its low ash content, and improved burnability. Most straw is burned as whole bales in hot water furnaces. These furnaces produce heat with overall efficiencies of 30 - 60%.

The square bale burner monitored operated at approximately 30% efficiency, recovering about 4.5 MJ/kg (1,935 BTU/lb) of straw. This burner had a maximum output of 18 kW (61,400 BTU/h) when burning wheat straw, and 24 kW (81,900 BTU/h) when burning flax straw. The house being heated used only 22 - 24% of the maximum output.

The round bale burner monitored operated at approximately 40% efficiency, recovering 5 - 6 MJ/kg (2150 - 2580 BTU/lb) of straw. This burner had a maximum output of 49 kW (167,200 BTU/h) when burning oat straw and 61 kW (208,140 BTU/h) when burning flax straw. The buildings being heated used 53 - 57% of the maximum output.

Economic feasibility of burning straw increases as system output increases. Using a large volume of water to store heat may significantly increase the efficiency of the system by causing it to operate at maximum capacity while straw is being burned.

Conclusions and Recommendations

- Burning straw as a heating fuel can be an economical heating method for on farm use.
- The most common system for burning straw is an outdoor boiler used to heat water which is then piped to buildings.
- A straw burning system is most economical if a large heat load, usually for multiple buildings or grain drying, needs to be met. Overall efficiency of the furnace is important if straw cost is high (straw is purchased) as well as for the convenience of long loading intervals.
- Flax straw is the most convenient straw to use for fuel. However, if other types of straw are to be burned in the field, consideration should be given to using them for heating fuel.
- Further research should pursue using a large volume of water as heat storage for increased efficiency and convenience of straw burning systems.

A sixty page engineering report on this topic is available. Call 1-800-567-PAMI (7264) and ask for Report RP0594, ***Use of Straw as a Farm Heating Fuel****. A small charge may apply.*

Imperial Metal Industries
Box 160, Steinbach, Manitoba R0A 2A0
(204) 326-6683

Ivey's Manufacturing
Virden, Manitoba
(204) 748-6200

Lawrence's Manufacturing
Box 1073, St. Anne, Manitoba R0A 1R0
(204) 422-5491 or (204) 422-5249

Northern Specialties Ltd.
Box 1360, Swan River, Manitoba R0L 1Z0
(204) 734-3404 or 1-800-268-3648

Partnership Welding
Carman, Manitoba
(204) 745-2897

Portage & Main Woodfire Systems
Box 26, South Junction, Manitoba R0A 1Y0
(204) 437-2394

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