HIGH-EFFICIENCY RESIDENTIAL GAS HEATING SYSTEMS

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INTRODUCTION

There is potential for significant reductions in energy consumption by improving in the efficiency of residential heating systems. This potential is scarcely realized to date in Canada. The following discussion is based on detailed experiments carried out by CCRL, both in the laboratory and in lived-in instrumented homes, so that the effects on the whole house as a system could be examined, considered and understood. The discussion applies equally well to poorly insulated older houses and also to new, well-insulated houses such as the R2000 housing.

Factors affecting furnace performance

There is a close relationship between the house and the heating system, as seen in Table I (ref 1). On the LHS are the demand factors - the reasons why heat is required; on the RHS are the supply factors - the ability of the heating system to supply the heat.

Demand is controlled by the inside temperature requirement (the thermostat) and the outside temperature.

At the same time, the house is constantly losing heat, in two basic areas, transmission losses and ventilation losses. Transmission losses are losses through the fabric of the structure. Ventilation losses are due to the passage of air through holes in the structure. The common ventilation loss is the infiltration/exfiltration through cracks (around doors, windows, etc.). A second component is directly attributable to the fossil fuel furnace. When the furnace is off, there is a large direct opening to the outside via the chimney, through which warm air from the house and the furnace heat exchanger can escape.

The supply, or performance, factors measure how well the heating system can supply the heat required. Three aspects must be considered:

(i) steady state efficiency is the measurement with which industry is most familiar. However, it takes furnaces 4 to 14 minutes to get to steady state from the time that the thermostat calls for heat and the burners begins firing. Until then the furnace is in the ...

(ii) transient state. In general, most physical systems work much more efficiently in steady state. Just imagine your car. You use much more gasoline per kilometer accelerating and delerating around town than you do cruising on the highway. Similarly, a furnace is much more efficient at steady state than in the transient condition.

(iii) dilution air through the draft dilution device (draft hood/draft diverter or double acting barometric damper on gas) accounts for a much larger air requirement and heat loss than does the air actually required for combustion - anywhere from 2 to 10 times the latter. The main purpose of this device is to isolate the burner from outside pressure fluctuations. New technologies such as induced draft fans, pulse combustion or high pressure drop burners eliminate the need for air dilution and the losses and problems entailed therein.

It was shown in Reference 2 that two similar-sized houses with different effective insulation levels both have consumption rates which follow outside temperature variations linearly. Expressed in another way, energy consumption rises in a straight line to the right when plotted against increasing degree days (decreasing outside temperature).

CONSERVATION STRATEGIES

Thermostat Cutback

Thermostat cutback, an effective way of lowering heat demand, moves the consumption curve (i.e. the straight line) parallel to right, giving less consumption for any specific outside temperature (or inside-outside temperature differential). A similar result would occur if insulation was added to the house.

Improved Furnace Performance

Just as for reduced demand, improving furnace efficiency moves consumption curve parallel to right, giving less consumption for any specific temperature differential.

Reduced Firing Rate

For conventional furnace technology, installing a lower firing rate unit to make the furnace more in tune with the reduced home heat demands of today has little effect to consumption at mild temperatures but has an increasing effect on fuel efficiency as the temperature gets colder, so that the consumption profiles diverge with decreasing outside temperature and savings can increase.

GAS FURNACE TECHNOLOGY

Conventional Gas Furnaces

Most conventional gas furnaces have a continuously running pilot light, that accounts for at least 2-4% increase in fuel consumption if left running all year. For R2000 housing this % loss could be even greater. Intermittent ignition devices (IID) (eg. spark plug) eliminate this energy loss.

Such furnaces also have naturally aspirating atmospheric burners, with no fan/blower to assist either in the fuel-air mixing, nor in the generation or maintenance of draft. There is a very low pressure drop through the unit and under certain conditions they may be subject to flow reversals, particularly if other equipment with large air demands, such as the fireplace, are also operating.

These furnaces also have a continuously open draft hood with a large dilution air requirement. This is obviously a major loss of heated house air up the chimney, both when the furnace is running and when it is not.

Generally, conventional gas furnaces operate with a seasonal efficiency of about 60%.

Vent Damper-Equipped Furnace

This type of furnace has a damper in the flue exhaust, downstream of the furnace heat exchanger and draft dilution device, which is driven by a signal from the thermostat. It is located downstream of the final heat exchanger and draft dilution device, closing of the flue when the burner is not working and opening before gas valve opens and the burner ignites. The appliance still has a draft hood, which always remains open. Contrary to the effect of reduced firing rate, savings with a vent damper are higher when climate is mild and decrease as it gets colder, where the consumption profiles converge. Fuel savings are generally fairly low: from 3% to 10%. This furnace type loses most of its effect if a conventional gas-fired water heater is also connected to the same chimney, as the water heater keeps the chimney open.

GAS FURNACE ADVANCES

New developments are yielding more efficient gas furnaces, with positive venting of combustion products and no dilution air requirement. Typically, they offer safer venting of the combustion products and from 12% to 40% fuel savings, as shown in Table II.

Induced Draft (ID) Fan Furnace

The ID fan furnace has a fan, downstream of the furnace proper, which pulls the gases from the furnace and propels them up the stack. There is spark ignition and no draft hood. Downstream of the ID fan there need be only a small opening, so the unit also functions as if it had a vent damper on the off cycle, but with no draft hood loss. Fuel savings of the induced draft fan furnace, relative to a conventional furnace, would be from 10% to 25%, depending on the furnace design. Manufacturers should be cautioned not to attempt to make this type of furnace too efficient from a heat exchange point-of-view; this could result in condensation of the flue gas and subsequent corrosion, either within the furnace proper, during short cycling, or through the venting system. This type of appliance design should yield seasonal efficiencies on the order of 78%, with safe steady state efficiencies up to 82%.

Hydrogen Content of Gas

Natural gas has a high hydrogen content which, on combustion, goes to water vapour, tying up a large amount of energy in the form of latent heat; hence, the requirement for a chimney liner to avoid condensation, damage and even ice bridging in masonary chimneys. In comparison to oil, natural gas has twice the hydrogen content, resulting in a "hydrogen loss" of about 12%. This accounts for the fact that conventional gas-fired furnaces and boilers typically have a lower steady state efficiency when fired with gas than with oil.

Condensing Gas Furnaces

The highest efficiency furnaces, now accepted in the market place, have an extra stainless steel heat exchanger, wherein the combustion products are partially condensed and the latent energy is recovered. Flue gas temperature is reduced dramatically. At the same time, there is spark ignition and no draft hood. Designs with conventional combustion use an induced draft fan, downstream of the condensing section, to exhaust the combustion products. Other designs use a pulsating combustion principle, where no ID fan is needed - the pulse exhausts the products. Depending on the particular design, fuel savings are from 26% to 38%, relative to a conventional gas furnace.

Because the flue gas temperature is so low with any condensing furnace, no chimney is required. The flue gas is merely carried in a plastic pipe to a exhaust vent on the outside wall of the house.

Contrary to conventional furnaces, the shorter the cycle length of a condensing furnace, the more water is condensed, due to cold furnace walls, and the higher is the efficiency. This type of furnace generally has a seasonal efficiency very similar to its steady state efficiency, with transient and off-cycle losses negligible.

CCRL Retrofit Condensing Furnace

CCRL has developed a retrofit condensing furnace, designed to be fitted on to an existing conventional gas furnace. The unit consists of a stainless steel condensing section, over which flows the return air, an induced draft fan to exhaust the combustion products, and pressure and spillage switches to shut off the appliance in the event of a venting failure. The unit is shown schematically in Figure 1. The seasonal efficiency of the conventional furnace is raised from 60% to 90%, for a fuel saving of 33%. Additional benefits are the powered exhaust, much lower air requirements and the safety shutoffs in the event of flue blockage or reversal. This appliance is now being produced and marketed across North America by a Canadian manufacturer.

Advanced Plastic Condensing Furnace

CCRL has been carrying out R&D to develop a new condensing heat exchange system using alternative materials, which could be cheaper and more resistant to corrosion than the high cost stainless steels presently being used in condensing appliances.

The result is a unit based on a unique flue gas recirculation process, which enables the use of a low temperature plastic heat exchanger to condense the combustion products. The choice of plastics and assembly techniques have been optimized to make the concept suitable to manufacturers. Prototype furnaces using this plastic condensing section have been produced and are presently undergoing cycling tests to determine if problems can be anticipated under long term operation.

The heat exchanger is a cross-flow heat exchanger, as shown in Figure 2. Flue gas passes through the ribbed sheets, which are cooled directly by the return air. The design consists of a core constructed of polypropylene-polyethylene co-polymer, with inlet and outlet manifolds injection molded from the same co-polymer.

The flue gas recirculation system, which controls the temperature of the gases entering the plastic heat exchanger, is shown in Figure 3.

Performance testing has given steady state efficiencies of over 92%, with cyclic temperatures as shown in Figure 4.

The design offers an alternative material, which is significantly more resistant to acidic corrosion, particularly where chlorides are present, is cheaper, and is easy to fabricate and assemble. It is anticipated that more and more plastics and plastic coated materials will find their way into condensing applications in the future, for the same reasons.

Condensing Boilers

Condensing gas-fired heating systems are now also available for homes heated with hot water. One type uses the pulsating combustion principle, operating at low excess air with high rates of heat transfer. There is no continuous combustion nor ID fan, but rather a regular series of combustion pulses, ignited by a spark and yielding high rates of heat transfer at low excess air. Significant efficency gains have been realized, but not as mauch as for the condensing furnaces. This is because the warmer the return water temperature, the less water is condensed and the lower the efficiency, as shown in Table III (ref 3). In most hot water heating systems, water is returned above the dewpoint ($50^{\circ}C$), so there is little condensation of the combustion products.

Combined Space and Tap Water Heating

Most gas-fired water heaters utilize similar technology to conventional gas furnaces, with even lower seasonal efficiencies, on the order of 50%. At the same time heating demand for neew, high efficiency housing is dropping rapidly, so that in many instances, yearly consumption for space and tap water heating are becoming fairly equal. Combined space/water heating appliances offer major energy and equipment savings.

CCRL has developed a prototype condensing system, based on a standard gas-fired water heater (DHW), coupled to a condensing water preheat tank and an air blower/fin coil unit, as shown in Figure 4. Hot flue gas leaving the water heater is passed through tubes in the preheat tank, where it is cooled by water flowing around the tubes. This condenses most of the water vapour in the flue gases, which are subsequently exhausted via an ID fan. The preheated water is fed to the DHW tank. There, the water is heated further in order to meet domestic hot water and/or space heating demands. When necessary for space heating, water from the DHW tank is pumped through a finned coil heat exchanger/air blower unit, and then returned to the preheat tank.

In performance trials at CCRL, the water heater was capable of providing adequate space heating and up to 7.5 litres per minute of domestic hot water. Thermal efficiencies for space and water heating were 92% and 98%, respectively, with a combined efficiency between the two, depending on the relative usage.

Combustion Appliances and Indoor Air Quality

Increased interest in energy conservation, changes in airtightness, appliance design and building materials, along with fuel switching have all combined to potentially raise the level of pollutants in the indoor environment, resulting in increased concern for indoor air quality in homes.

At the same time, with homes being made tighter, combustion appliances are having an increasingly difficult time receiving adequate air to operate safely and properly. Spillage of incomplete combustion products or even chimney flow reversals can result in significant amounts of carbon monoxide and other toxic combustion products being exhausted into the house.

Table IV presents the air requirements for most common residential combustion appliances (ref 6).

As mentioned, the draft hood on the conventional gas furnace does represent the major air requirement of the heating system, typically at least 3 times the air required for combustion. On the other hand, the new gas combustion systems reaching the market place, eliminate the dilution device and forcibly exhaust the combustion products either with a fan or a series of powerful combustion pulses. At the same time, they have flow proving devices which can shut off the appliance in the case of chimney reversal or blockage. Such appliances, with their high efficiency and low air demand, are well suited to the low energy consuming homes of today.

The combustion appliance requiring the most air is the conventional wood-burning fireplace. While new housing may have an air change rate of one-half air changes per hour or less, fireplaces can require nearly three times this amount. The fireplace under high fire, with its high draft and air demand, can force reversal of the stack flow of the central furnace. Small airtight woodstoves, on the other hand, have little need for air. On low fire, at the tail end of the burning cycle of a fireplace, the reverse can occur, with the central furnace pulling the incomplete combustion products from the fireplace into the living space.

In addition to the air required for combustion appliances, air is exhausted from the house, as required, for other specific applications, like cooking, showers or clothes drying. One type of electric cooking appliance, the BBQ range, has massive air requirments, which can only be met by its own specific air supply, in tight housing. The intermittent use, high flow and high moisture content of a clothes dryer exhaust also precludes its use with an air-to-air heat exchanger. One solution is to duct outside air directly to the dryer. For cold winter temperatures, the moisture content of the incoming air will be very low and may actually aid the drying process. Central vacuum systems also exhaust large quantities of air and may pose problems for tight housing.

It is now considered that approximately 0.5 air changes per hour is required to keep the pollutant and odour levels in a house at a satisfactory level. Conventional gas furnaces are seen to have air demands on the same order as the half air change rate of many houses, due primarily to dilution air. As such, they offer potential problem sources for spillage of combustion products, or even flow reversals in adverse circumstances, unless steps are taken to alleviate the problem.

Even worse, with the fireplace having a potential air demand nearly three times that of a moderately tight house, how can this inefficient appliance not be expected to interfere with the operation of other air-breathing equipment?

The higher efficiency gas furnaces/boilers and small "airtight" wood stoves have no significant air demand and thus mate well with the lower energy consuming, tighter houses of today and tomorrow.

The new medium and high efficiency gas furnaces have eliminated the dilution device by having a high pressure forced exhaust system. The air demands of these units are consequently much lower. At the same time, they have flow proving devices which shut off the appliance in the event of chimney reversal or blockage.

SUMMATION

Condensing (high efficiency) and induced draft fan (mid-efficiency) furnaces now offer major energy efficiency gains to the consumer, as well as being more suited to the tighter houses of today, due to their low air demands and powered exhausts.

Care should be taken not to attempt to gain too much efficiency from the mid-efficiency appliance. Otherwise, it is almost certain that condensation regimes will be almost continually encountered in either the heat exchanger or the flue system, with attendant potential for corrosion.

The plastic furnace developed by CCRL offers an effective alternative to stainless steel for condensing furnace design. The material is cheap, easy to work with and offers superior resistance to corrosion, Particularly if chlorides are present.

With decreasing home heat demands, it becomes more and more likely that future systems will serve a multi-purpose role. The combined space and water heating condensing system yields high efficiencies for all mmodes of operation and mates well with low energy housing.

Tighter housing creates significant competition for air among all the air breathing appliances in the house. The fireplace is the main culprit, with massive air demands, yet potential for serious indoor pollutant emissions. It must be isolated, with tight fitting glass doors and its own air supply to its firebox, if it is not removed entirely. As mentioned, the high efficiency furnaces are far more suited to this environment than conventional appliances.

The potential for major reductions in fuel consumption and increased safety through research and development in residential heating system technology is high, with continuing efforts required to achieve the required goals.

V1 P9

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6. Hayden, A.C.S.; "Air Demands of Residential Combustion Appliances"; Paper 84-32.1; Proceedings of Air Pollution Control Association Annual Meeting; San Francisco; June 1984.

Table I. Factors affecting furnace performance.

Demand Factors (House)		Performance Factors (Heating System)
Heat Requirements	Heat Losses	
- Thermostat	- Transmission	- Steady State Efficiency
	- Infiltration	- Transient Operation
	- Downtime Losses	- Dilution Air

Table II. Comparison of Gas Furnace Technologies.

Furnace Type	Fuel Savings re Conventional Furnace	Seasonal Efficiency
conventional with pilot	base	60%
conventional with spark ignition	2-4%	62%
vent damper & spark ignition	3-10%	63-67%
induced draft (ID) fan & spark ignition	10-25%	67-82%
condensing furnace	25-38%	80-97%

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Table III. Effect of inlet water temperature on the performance of a condensing boiler.

Tin °C	dT C°	Excess Air,%	Flue Gas Temp, °C	% H20 Cond.	DFG Loss,%	Hydrogen Loss,%	SS Effic %
25	40	20	38	51	.48	4.93	94.5
40	25	21	52	30	.93	7.03	91.9
55	10	13	58	21	1.04	7.57	90.0
60	5	13	60	14	1.14	8.73	90.0
65	15	13	58	4	1.10	9.72	89.2

Table IV. Typical air demands for different heating appliances.

Appliance	Air Requirement (Air changes/hour)
airtight wood stove	.03
high efficiency gas furnace	.06
conventional gas furnace	.39
conventional oil furnace	.52
fireplace	1.40

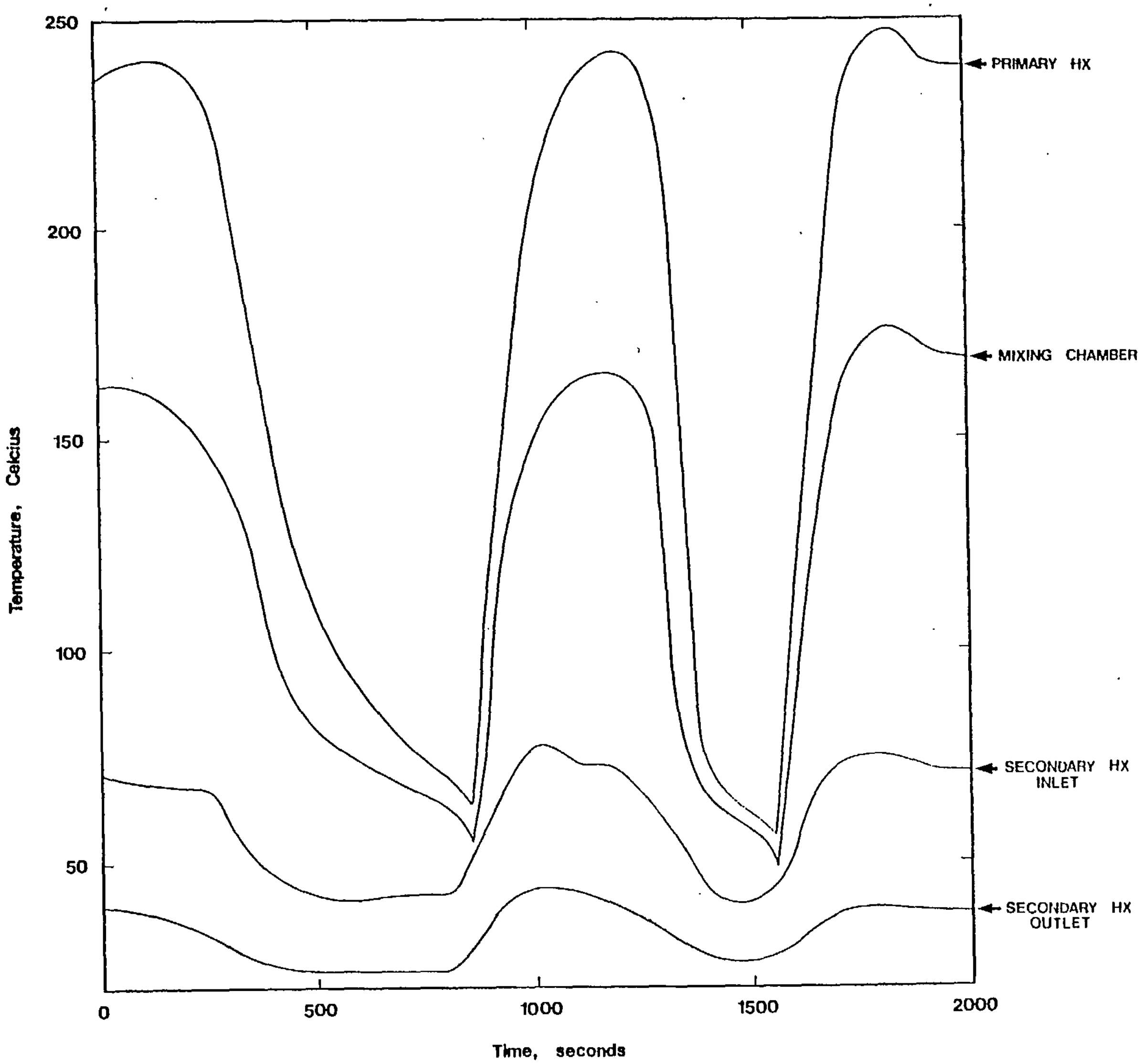

Figure Cyclic furnace operation (10 mins on, 10 mins off).

VI P13

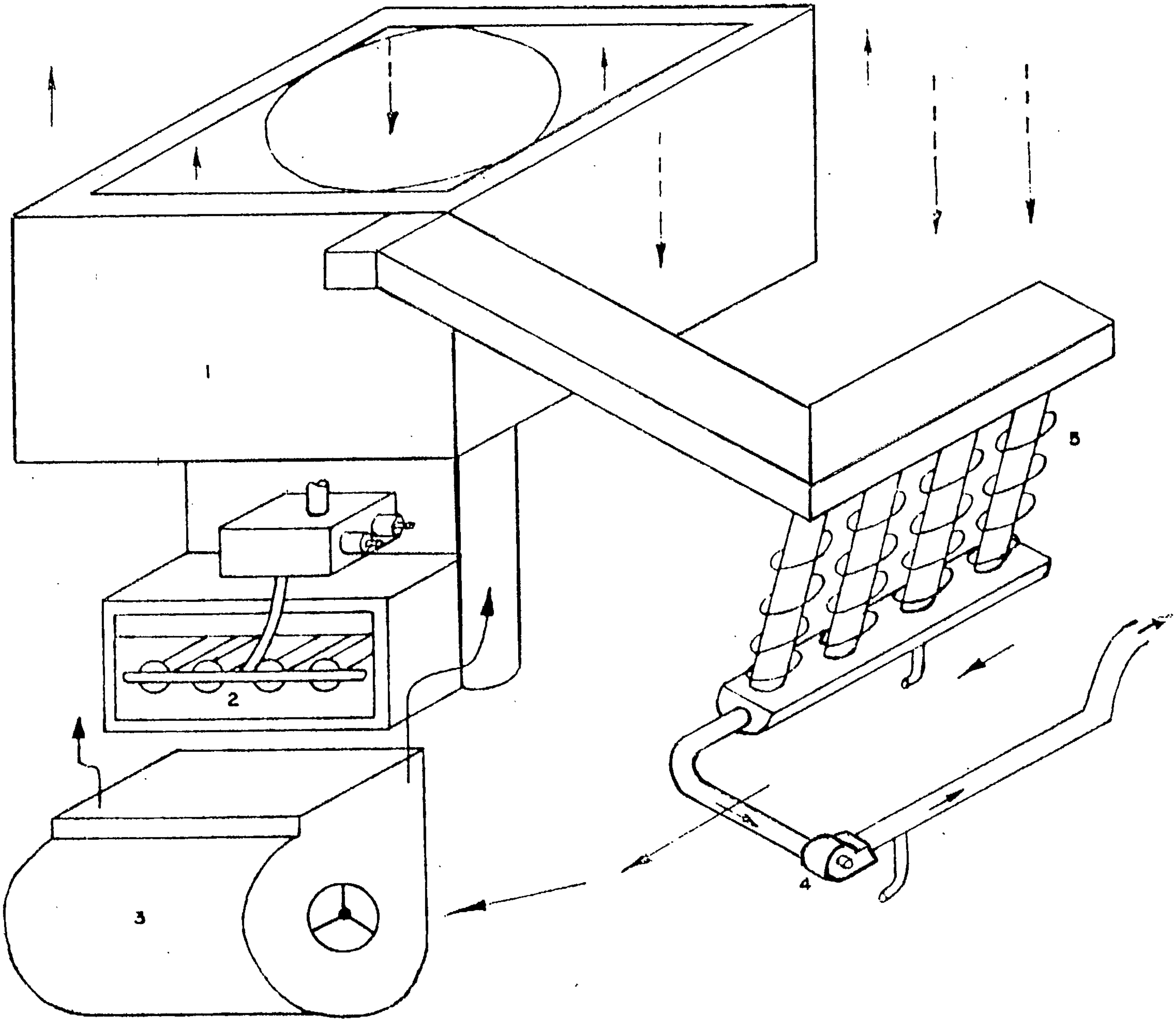

Figure 1. Fournaise à condensation modifiée, à haut rendement.

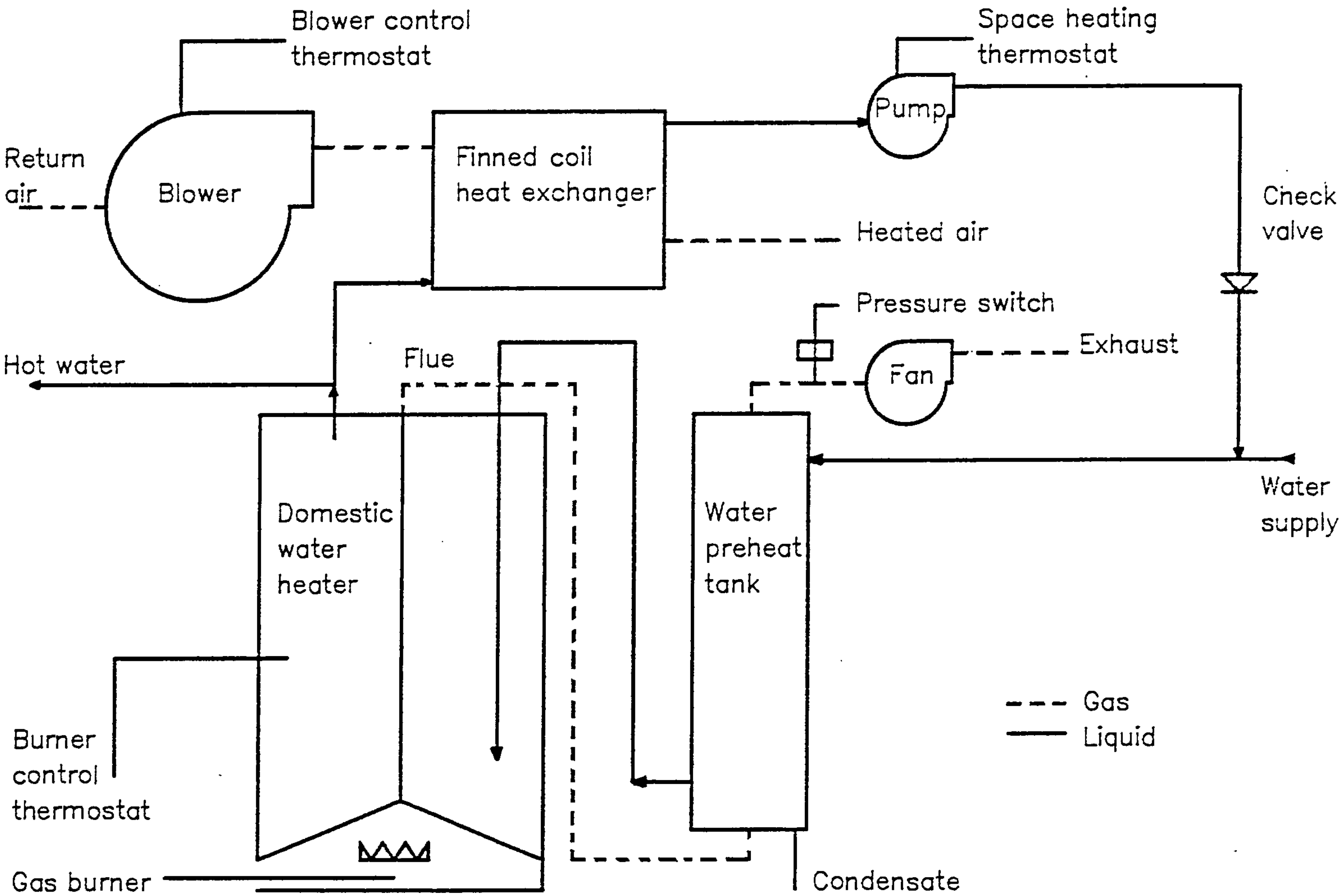

Figure Combined space heating/hot water system schematic

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industry is most familiar. However, it takes furnaces 4 to 14 minutes to get to steady state from the time that the thermostat calls for heat and the burners begins firing. Until then the furnace is in the ...

(ii) transient state. In general, most physical systems work much more efficiently in steady state. Just imagine your car. You use much more gasoline per kilometer accelerating and delerating around town than you do cruising on the highway. Similarly, a furnace is much more efficient at steady state than in the transient condition.

(iii) dilution air through the draft dilution device (draft hood/draft diverter or double acting barometric damper on gas) accounts for a much larger air requirement and heat loss than does the air actually required for combustion - anywhere from 3 to 10 times the latter. The main purpose of thiis device is to isolate the burner from outside pressure fluctuations. New technologies such as induced draft fans, pulse combustion or high pressure drop burners eliminate the need for air dilution and the losses and problems entailed therein.

Figure 1 shows the effects of both the transient heat exchange and dilution for a furnace in a real house. The top two curves are for temperature and CO2 (excess air) before dilution and the bottom two are after dilution. 8% CO2 represents 100% excess air and 1.7% CO2 represents about 800% excess air, a dramatic difference.

Figure 2 presents consumptions over time for two similar-sized houses with nominally-comparable insulation levels, but with house A built with superior workmanship by the owner, having almost half the other's consumption. Both consumption rates follow outside temperature variations closely, effectively linearly. Expressed in another way, rises in a straight line to the right when plotted against increasing degree days (decreasing outside temperature).

CONSERVATION STRATEGIES

Thermostat Cutback

Thermostat cutback, an effective way of lowering heat demand, moves the consumption curve (straight line) parallel to right, giving less consumption for any specific outside temperature (or inside temperature differential). A similar result would have occured if insulation was added to the house.

Improved Furnace Performance

Just as for reduced demand, improving furnace efficiency moves consumption curve parallel to right, giving less consumption for any specific temperature differential. In a sample case, changing to a flame retention head burner increased steady state efficiency from 68% to 82%, with a fuel saving of about 20%. Condensing furnaces give even higher results.

Reduced Firing Rate

For a conventional furnace, lowering firing rate to make the furnace more in tune with home heat demands makes little effect at mild temperatures but has an increasing effect on fuel efficiency as the temperature gets colder, so that the consumption profiles diverge with decreasing outside temperature.

Chimney (Vent) Damper

A chimney (vent) damper closes off the flue when the furnace is not operating, and is located downstream of the final heat exchanger and draft dilution device. Contrary to effect of reduced firing rate, savings with vent damper are greatest when climate is mild and decrease as it gets colder, where the consumption profiles converge. However, the effect of the damper is almost negated if a fossil-fuel water heater also uses the same chimney.

GAS FURNACE TECHNOLOGY

Conventional Gas Furnaces

Most conventional gas furnaces have a continuously running pilot light, that accounts for at least 5% increase in fuel consumption if left running all year. For R2000 housing this % loss could be even greater. Intermittent ignition devices (IID) (eg. spark plug) eliminate this energy loss.

Such furnaces also have naturally aspirating atmospheric burners, with no fan/blower to assist either in the fuel-air mixing, nor in the generation or maintenance of draft. There is a very low pressure drop through the unit and under certain conditions they may be subject to flow reversals, particularly if other equipment with large air demands such as the fireplace, are also operating.

Gas furnaces also have a continuously open draft hood with a large dilution air requirement. This is obviously a major loss of heated house air up the chimney, both when the furnace is running and when it is not.

Generally, conventional gas furnaces operate with a seasonal efficiency of 60% or less.

V2 P4

Vent Damper-Equipped Furnace

This type of furnace has a damper in the flue exhaust, downstream of the furnace heat exchanger and draft dilution device, which is driven by a signal from the thermostat. It closes the flue when the burner is not operating and opens before the burner ignites. The unit must have an intermittent ignition device (IID). The unit still has a draft hood and a naturally aspirating burner. Fuel savings are generally from 7% to 15%. This furnace loses most of its effect if a conventional gas-fired water heater is also connected to the same chimney, as the water heater keeps the chimney open.

GAS FURNACE ADVANCES

New developments are yielding more efficient gas furnaces with positive venting of combustion products and no dilution requirement, which will be safer and from 15% to 40% more efficient.

Induced Draft (ID) Fan Furnace

The induced draft fan furnace has a fan downstream of the furnace proper which pulls the gases from the furnace and propels them up the stack. There is a spark ignition and no draft hood. Downstream of the ID fan there is only a small opening (2 cm) so the unit also operates as if it had a vent damper on the off cycle. Fuel savings of the induced draft fan furnace relative to a conventional furnace would be from 10% to 25%, depending on the furnace design. Most of this type of appliance design should yield savings closer to the high end, and seasonal efficiencies on the order of 80%.

Hydrogen Content of Gas

Natural gas has a high hydrogen content which, on combustion, goes to water vapour, tying up a large amount of energy in the form of latent heat and making the flue gases much more moisture-laden than oil; hence the requirement for a chimney liner to avoid condensation, damage and even ice bridging in masonary chimneys. In comparison to oil, natural gas has twice the hydrogen content, resulting in a "hydrogen loss" of about 12%. This accounts for the fact that conventional furnaces and boilers have a lower efficiency when fired with gas than with oil.

Condensing Gas Furnace

The highest efficiency furnaces, now reaching the market place, have an extra stainless steel heat exchanger wherein the combustion products are partially condensed and the latent energy is recovered. Flue gas temperature is reduced dramatically. At the same time, there is spark ignition and no draft hood. Designs with conventional combustion use an induced draft fan, downstream of the condensing section, to exhaust the combustion products. Other designs use a pulsating combustion principle, where no ID fan is needed - the pulse exhausts the products. Depending on the particular design, fuel savings are from 20% to 40%, relative to a conventional gas furnace.

CCRL Retrofit Condensing Furnace

CCRL has developed a retrofit condensing furnace, designed to be fitted on to an existing conventional gas furnace, using similar techniques to those described in the previous paragraph. The seasonal efficiency of the conventional furnace is thus raised from 60% to 90%, for a fuel saving of 33%. There are fifteen manufactured prototypes on field test in actual homes in central Ontario, with good operational results. If the regulation authorities can be convinced, it could be on the market for the next heating season. Additional benefits are powered exhaust, much lower air requirements and a safety shutoff in the event of flue blockage or reversal.

Because the flue gas temperature is so low with any condensing furnace, no chimney is required. The flue gas is merely carried in a plastic pipe to a exhaust vent on the outside wall of the house.

Contrary to conventional furnaces, the shorter the cycle length of a condensing furnace, the more water is condensed, due to cold furnace walls, and the higher the efficiency. This type of furnace generally has a seasonal efficiency very similar to its steady state efficiency, with transient effects negligible.

Condensing Boiler

Condensing gas-fired heating systems are now also available for homes heated with hot water. CCRL is carrying out field trials in houses where conventional and high efficiency boilers/furnaces are flip-flopped on a weekly basis. Major efficency gains have been realized with the condensing boiler. This boiler uses the pulsating combustion principle, operating at low excess air with high rates of heat transfer. There is no continuous combustion nor ID fan, but rather a regular series of combustion pulses, ignited by a spark and yielding high rates of heat transfer at low excess air.

The cooler the return water temperature, the more water is condensed and the higher the efficiency. In most hot water heating systems, water is returned above 50^{o}C, so there is little condensation.

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COMPARISON OF GAS FURNACE TECHNOLOGIES

Furnace Type	Fuel Savings re Conventional Furnace	Seasonal Efficiency
conventional with pilot	base	60%
conventional with spark ignition	5%	63%
power gas burner	5-10%	63-67%
vent damper & spark ignition	7-15%	65-71%
induced draft (ID) fan & spark ignition	10-25%	67-82%
condensing furnace	25-38%	80-97%

Advanced Plastic Condensing Furnace

CCRL has been carrying out R&D to develop new and retrofit condensing systems which will be cheaper and even more efficient, using new concepts and materials, such as plastics, as opposed to the high cost stainless steels presently being used in condensing appliances.

The result is a plastic condensing furnace, with recirculated flue gas to control the temperature of the incoming flue gas. Three prototype furnaces using this plastic condensing section have been produced and are undergoing cycling tests to determine if problems can be anticipated under long term operation. Another study is looking at optimized materials and assembly techniques to make the concept suitable to manufacture.

AIR REQUIREMENTS FOR DOMESTIC COMBUSTION SYSTEMS

Tightening houses, changing fuels, reduced firing rates, lowered air requirements, hybrid systems, etc. are all acting to increase the potential for increased venting problems with combustion systems. Outside chimneys, the common construction for Canada, are more prone to problems.

There are dramatic differences among the air demands of different combustion appliances, due primarily to dilution air. If one considers a fairly "tight" house to have an air change (AC) of about 0.5/hour, it can be seen from the following table that a fireplace can create extreme problems, with its typical very high air requirement of 1.4 AC/hour. Conventional gas and oil furnaces also have air demands on the same order as the house, so that if other devices, such as fans, clothes drier or a fireplace are also operating, there can be major problems getting enough air to allow the heating appliance to function properly.

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Typical air demands for different heating appliances:

Appliance	Air Requirement (Air changes/hour)
airtight wood stove	.03
high efficiency gas furnace	.06
conventional gas furnace	.39
conventional oil furnace	.52
fireplace	1.40

Recommendations to ensure that combustion appliances have adequate air:

- * close up fireplace.
- supply outside air to fireplace and use good glass doors.
- don't use unvented heaters in tight houses.
- don't use isolated furnace rooms in cold climates.
- don't connect dilution device directly to outside.
- release outside air near burner.
- connect from outside to cold air return, then have opening in warm air plenum to supply furnace. The connection to the cold air return could have a damper, actuated by the thermostat, so that it was only open when the furnace was actually running.
- * seriously consider the purchase of a high efficiency (ID fan or condensing) gas furnace, that has no dilution air requirement.
- consider use of carbon monoxide detectors in homes, for safety.
- for conventional gas furnaces, installation of a spillage switch at the draft hood opening could shut off the furnace in the event of flue blockage or reversal.
- BE CAREFUL

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NEW FUELS - METHANOL AND OILS FROM BIOMASS

Research is also being carried out at CCRL on alternate storable heating fuels for the future, with vegetable and fish oils being examined for limited applications.

More importantly, alcohols appear extremely promising as fuels in condensing furnaces, where their efficiency is even higher than for gas. The retrofit condensing furnace, described previously, can be added to a conventional oil furnace. Using a flame retention head burner, methanol can be burned to give a seasonal efficiency of about 95%, compared to 60% for oil. This is one of the only applications of alcohol fuels where the end use shows a major efficiency advantage, as well as premium fuel displacement.

SUMMATION

As has been seen in this presentation, the potential for major reductions in fuel consumption through research and development in residential heating system technology is high, with continuing efforts required to achieve the required goals.

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Table I. Factors affecting furnace performance.

Demand Factors (House)		Performance Factors (Heating System)
Heat Requirements	Heat Losses	
- Thermostat	- Transmission	- Steady State Efficiency
	- Infiltration	- Transient Operation
	- Downtime Losses	- Dilution Air