

A REALISTIC APPROACH TO
HIGH EFFICIENCY GAS WATER- AND SPACE-HEATING

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There has been a gradual shift to more efficient residential water heaters due to increased consumer awareness and government regulation. The maximum overall efficiency of a gas water heater is now about 62%. Further increases are technically feasible but probably not cost effective. However, the integrated appliance, that is a combined water and space heater, offers an opportunity to raise the efficiencies of both units while keeping costs down. The integrated appliance uses the excess capacity of the gas water heater for space heating. A prototype integrated water-space heater is described, with 94% recovery efficiency and 1.21% standby loss. The initial cost will be less than that of a separate furnace and water heater.

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INTRODUCTION

For years, the usual method of providing gas water heating and space heating for the typical American household has remained relatively unchanged. The domestic water heater provided the hot water and a separate warm air furnace or boiler provided the space heating requirements for this house. Two separate appliances were performing two similar but separate functions.

The gas water heater proved to be a reliable product hidden away in a closet or a corner of a basement and was noticed only when it failed - once every seven to twelve years. And although this gas water heater may have used up to 30% of the overall home's gas consumption, when a high gas bill was received by the consumer, he attributed this high gas bill to the cost of operating his gas furnace or boiler. Gas consumption was highest in the winter months when the consumer could feel the cold outside and hear the gas furnace or boiler operating on the inside. Accordingly, when consumers became more conscious of increasing utility costs they looked at a furnace or boiler energy upgrade. The reliable gas water heater, which provided relatively quiet, consistent hot water year round, was taken for granted and often not even considered as part of this energy upgrade. So with an energy efficient gas furnace or boiler and an inefficient gas water heater, the percentage of the total gas bill attributed to the water heater rose to as high as 50%.

FTC Labels and Water Heater Efficiency

When the Federal Trade Commission began its water heater labeling program in May, 1980, a national average cost of water heating was determined and listed in dollars on the Energy Guide label on each water heater. However, most consumers did not "shop" for a water heater, they purchased a new water heater only after the old unit failed. The immediacy of their need outweighed any contemplation of which water heater provided the greatest efficiency. Furthermore, the "average" cost of water heating very likely did not relate to the individual consumer since his gas cost per therm, or daily hot water usage, may have varied greatly from the "average."

In time, better trained sales personnel learned to use the Energy Guide labels to educate the consumer on different grades of water heaters. Consumers gradually learned to compare initial cost with estimated energy costs to determine paybacks. As energy costs continued to rise, these payback periods became more realistic. Many state and

local codes began requiring the installation of more efficient units, which further helped establish a market for energy saving water heaters. With a growing awareness and need for improved products, water heater manufacturers began placing greater emphasis on developing increasingly more efficient units.

Two efficiency terms are used in referring to a gas water heater's "efficiency." The first is recovery efficiency which is the percentage of energy put into the water compared to the total energy used by the water heater. The second is the energy factor or overall efficiency which is a combination of a water heater's recovery efficiency, standby heat loss and energy input. Both efficiencies of all residential water heaters are listed in the Consumers' Directory of Certified Water Heater Efficiency Ratings, published bi-annually in January and July by GAMA (Gas Appliance Manufacturers Association). GAMA lists recovery efficiencies for forty-gallon natural gas water heaters of between 67% to 85% and overall efficiencies of between 41% and 61%. High hourly standby losses of 3.1% to 7.9% of stored heat loss compared to tank heat content, reduce the recovery efficiency percentages to the lower overall efficiency levels. In a gas water heater, flue losses comprise the majority of these standby losses during the long periods of inactivity experienced daily by a residential gas water heater.

The Energy Guide labels are based upon average hot water requirements equal to 47,743 Btu per day. With overall efficiencies of between 41% and 61%, a forty-gallon gas water heater requires between 78,267 Btu to 116,446 Btu to provide a day's worth of domestic hot water for the average residence. Since forty-gallon gas water heaters have a typical input of 33,000 to 52,5000 Btu per hour, a total of between 792,000 Btu to 1,260,000 Btu are available on a daily basis. This means, in an average household, a forty-gallon water heater will use only 6.2% to 14.7% of its potential capacity for domestic hot water purposes. This unused capacity translates into potential standby heat loss.

Instantaneous Water Heaters

Instantaneous or point-of-use water heaters, those with little or no storage that heat water as it is needed, can greatly reduce standby losses. However, because of traditional water usage in American homes, instantaneous heaters would have to have much higher inputs than storage water heaters. Although the average household may use only 64.3 gallons of domestic hot water a day, peak usages may be much higher. During a shower, a 3 G.P.M. shower head may consume two gallons of hot water heated through a 100 °F temperature rise per minute. This means a water heater with an output of 1666 Btu per minute or 99,960 Btu per hour would be required. Even with a recovery efficiency as high as 80%, a water heater with an input of 124,950 Btu per hour would be necessary. And with an instantaneous water heater of this size, there would be no available Btu for other purposes such as shaving, washing or food preparation whenever the shower was being used.

Installation Problems of Gas Water Heaters

Gas water heaters present costly installation problems. Underfired heaters must meet minimum clearance standards and cannot be installed on combustible flooring. Vents, whether through the roof or through the wall, are time consuming and expensive to install. And although residential gas water heaters typically recover twice as quickly as their electric counterparts, these installation problems often cause builders to choose electric water heaters when initial cost is of prime concern.

The Move to High Efficiency

Manufacturers of gas furnaces and boilers have developed and successfully marketed high efficiency (+90%) equipment for years. Because the initial equipment cost of a standard furnace or boiler is many times that of a standard water heater, and because the consumer's perception of energy savings is more closely related to upgraded space heating equipment, as manufacturers of furnaces and boilers developed high efficiency (and more costly) gas equipment, consumers bought those products. In fact, GAMA reports that in 1985,¹ 12.3% of all gas furnaces sold had a D.O.E. A.F.U.E. of 86% and over and 31.3% had a DOE A.F.U.E. of 80% and over. This translates into sales of 568,955 gas furnaces sold in 1985 with a D.O.E. A.F.U.E. of 80% or better and 223,355 sold with a D.O.E. A.F.U.E. of 86% or better. Even though GAMA reported² 3,528,931 gas water heaters were shipped in 1985, the GAMA Consumers' Directory of Certified Water Heater Efficiency Ratings dated January, 1986, lists no gas water heaters with recovery efficiencies of 86% or better, and no gas water heaters with overall efficiencies of more than 62%.

Although water heater manufacturers could undoubtedly develop gas water heaters with efficiencies approaching those of high efficiency gas furnaces or boilers, the cost of these water heaters would be perceived by consumers as inordinately high.

And so the problem is to develop and market more efficient gas water heaters that solve the installation problems of gas water heaters, that last longer, and that do not have a prohibitively high initial cost.

The Integrated Appliance

This apparent paradox is solved by the integrated appliance. The integrated appliance is a single energy source used in a multipurpose application. The integrated appliance concept uses the excess capacity of a gas water heater to additionally and simultaneously provide heat for space heating purposes. This principal can be applied to combination water heating/warm air space heating, combination water heating/hydronic baseboard space heating, and combination water heating/warm air space heating and

¹APPLIANCE, May 1986.

²APPLIANCE, May 1986.

hydronic baseboard space heating.

Any properly sized gas water heater may be used in an integrated appliance application. But since essentially two energy sources (a water heater and furnace, or a water heater and boiler) are being combined into a single energy source, the necessary higher equipment cost of a high efficiency water heater can, in many circumstances, be justified because the payback is more reasonable. Potentially lower installation costs also improve those paybacks.

APPLICATIONS - COMBINATION WATER HEATING AND FORCED AIR SPACE HEATING

The most apparent and popular application for integrated appliances is that of combining water heating with forced air space heating. The components of this system are the gas-fired water heater, an air handler (air heater) and a pump and relay assembly which may be integral to or remote from the air heater.

In this and all other integrated appliance applications, the gas fired water heater operates as it would in a single purpose domestic hot water only situation. The water heater thermostat controls the burner and water is heated to the desired temperature normally. Cold water enters the water heater and hot water exits the water in the normal fashion. The difference between an integrated application and a single purpose applications that in an integrated application, the hot water can be additionally circulated by the pump assembly through a coil in the air heater. As in all integrated applications, the water heater burner is activated by the water temperature in the water heater, not by ambient air temperature.

Many different varieties of water heaters may be used in forced air and all other integrated appliance applications. The proper water heater will have adequate storage and input, overcome any existing installation obstacles, and provide an efficiency to allow the fastest payback. Even standard water heaters, with recovery efficiencies of approximately 70% and overall efficiencies of approximately 45%, can provide heat for a combination system. Energy savings water heaters with their 76% recovery and 55% overall efficiencies and higher efficiency water heaters with their 85% recovery and 60-62% overall efficiencies, are more common in integrated applications.

Other sources may be used to provide the energy for an integrated application. Boilers have been used for both indirect and direct applications. Because of the additional heat exchangers required in indirect applications, system efficiency suffers with each additional heat exchanger. Direct applications mean that the 180 °F water necessary for the typical design of hydronic heating, may also be delivered for domestic hot water purposes, even though tempering valves may be used. Hot water at 180 °F can instantly scald.

Another method for providing heat for integrated applications is to use a warm air furnace as the energy source (see Figure 1). Some type of heat transfer fluid is heated by the furnace and transfers heat to the water through a heat exchanger in a tank. This can mean firing the furnace during the air conditioning season which reduces air conditioning efficiency. Also, piping losses from the transfer fluid between the furnace and

the water tank reduces the water heating efficiency. These piping losses in a system fired by a water heater are lost to the atmosphere in the space heating process and therefore do not reduce heating efficiency.

The Very High Efficiency Water Heater

Because two energy sources are being replaced by a single energy source, the door has been opened for the development of very high efficiency water heaters that include features previously too costly to practically be included on single purpose residential water heaters. The Polaristm, developed by Mor-Flo Industries, includes many of these features. The combustion chamber, flue and tank are stainless steel to prolong tank life (see Figure 2). Operation begins with the thermostat calling for heat and after hot surface ignition, the power blower induces combustion in a submerged combustion chamber. Excess combustion heat is pushed up a flue toward the top of the tank. But instead of exiting the top of a tank as in a standard water heater, the flue coils its way down and around the combustion chamber and exits at the bottom of the tank. Since the coldest water stratifies at the bottom of the tank, heat is continually extracted from the gasses in the flueway until when, they leave the tank, they are condensing. Because of the induced flow through the flueway and these low flue temperatures, 2 inch ABS or CPVC plastic pipe may be used for venting either through the roof or through the wall. Correspondingly, outside combustion air is drawn through 2 inch plastic pipe. This efficient design gives the Polaristm a recovery efficiency of 94%. And since the normal convection losses from the flueway are eliminated, standby heat losses are less than 1.21%. In order to provide heat from homes with heat losses up to 75,000 Btu per hour, the Polaristm has 100,000 Btu per hour input.

Polaristm units are currently in field tests at various locations across the country in a variety of applications, such as electric conversions, gas energy upgrades and new homes. Systems include combination water heating and forced air space heating, combination water heating and hydronic baseboard space heating, combination water heating, forced air space heating and hydronic baseboard space heating, and combination water heating and forced air space heating with multiple air heaters. The product will be marketed in a limited geographic area during the third quarter of 1986 and nationally in the first quarter of 1987.

The Air Heater

The air heater is a simple device consisting of a hot water coil, a blower and, most often, a direct expansion coil for air conditioning. The blower circulates air across the hot water coil, producing warmed air which is circulated through the home's ductwork. A wall thermostat activates the blower and the pump assembly so that, although Btu's are available for domestic water and space heating in the storage of the water heater at all times, this heat is used for space heating only when the wall thermostat for heat.

The air heaters are available in a wide variety of configurations. Different air heaters may be mounted vertically, horizontally, above a drop ceiling, in a closet, in an attic, on a wall and with or without a return air duct (see Figure 3). Multiple air

handlers may be installed in remote areas of a home to provide zoned warm air heating. Since air heaters have no flame or heat exchanger for that flame, they may be installed in many areas prohibited to gas furnaces and are more compact than gas furnaces. Air heaters are available in a wide range of units with variously sized heating and air conditioning coils that allow virtually any home to be comfortably sized.

The water heating sequence of operation for a combination water heating and warm air space heating system is the water heater provides domestic hot water just like any single purpose water heater. Water in the water heater tank is heated up to the setting on the thermostat just like any other water heater. When the wall thermostat in the home calls for space heat, the pump assembly pumps water through the coil in the air heater, the blower in the air heater circulates air across the hot water coil and the warm air is distributed throughout the ductwork in the home. The hot water, which has incurred a 15-30 °F temperature drop across the coil, is returned to the water heater tank through the cold water inlet to be heated again and used for additional space heating or for domestic hot water.

Electric Warm Air Conversions

Combination hot water and forced air space heating systems can particularly be attractive in electric conversion appliances. With a direct-vented water heater and a hot water coil in the plenum of an electric furnace, an inexpensive conversion can be made. The existing electric furnace can be used in the blower mode only. Equipment cost and installation time are kept to a bare minimum.

Water Temperature Parameters

The proper thermostat setting on the water heater is 140 °F which, in a properly sized system, will provide adequate heat for space heating without providing dangerously hot water for domestic purposes. A water heater thermostat setting of 120 °F will provide approximately 30% less Btu heating output than 140 °F and may result in inadequately warm air for space heating purposes. A water heater thermostat setting of 180 °F will provide approximately 50% more Btu heating output than 140 °F, but may provide dangerously hot water for domestic purposes unless a tempering valve is installed. Water heated to 180 °F will also diminish the tank life and increase liming in the tank.

Air Conditioning

Because the air heaters normally are installed with an integral DX coil, the combination water heating/forced air space heating systems most often include central air conditioning. A condensing unit may easily be connected to the air heater - either upon original installation or retrofitted at a later time.

Applications - Combination Water Heating/Hydronic Space Heating

Integrated appliances may be used in combination water heating and hydronic baseboard space heating systems and are particularly popular in areas that do not require central air conditioning. However, since potable water is being supplied for both domestic hot water and baseboard purposes, certain standards must be adhered to:

1. These systems should never, under any circumstances, be used to retrofit on existing baseboard or to replace an existing boiler.
2. Materials used in boiler-type hydronic systems, such as leak detectors or sealants, should under *no* circumstances be introduced into combination water heating and space heating systems.
3. Water heater thermostat temperature settings should never be set at more than 140 °F. This means design criteria and type and amount of baseboard should be adjusted accordingly from 180 °F to 140 °F. If water temperatures are set at 180 °F, water heater tank life will be diminished, liming will greatly increase, and most importantly, dangerously hot water may be delivered for domestic usage.

When a water heater is used in a combination hot water and hydronic space heating application, after the piping and baseboard is initially filled, no more potable water is used than in single purpose systems. The potable water is expelled from the system only at domestic hot water taps.

Application - Combination Water Heating/Forced Air Space Heating/Hydronic Space Heating

Certain homes can present special heating problems. The lower level in split level homes and homes with finished basements can be particularly difficult to heat with forced air, because the warmer air tends to rise to the upper levels of the home. In these applications, a combination system can include domestic water heating, forced air space heating for the upper levels of the home and hydronic baseboard for the hard to heat lower level. The zoning of the hydronic baseboard can insure constant heat on the homes lower level.

Homes with a room or rooms added on, particularly on a slab, also can be ideal candidates for combination domestic hot water, forced air space heating, and hydronic baseboard for the added area.

Keys to Successful Marketing on the Integrated Appliance

The major components of a successful integrated-appliance marketing campaign include a need for the product, economic feasibility, reliability and an awareness of the product.

The need for an integrated gas appliance is quite apparent to many groups including consumers, builders, gas utilities, dealers and distributors. Certain areas of the South, Mid-South, Midwest and West have demonstrated that this is a real, rather than perceived need. From 1980 - 1985, it is estimated that over 50,000 various combination

systems were installed in these areas for residential use, primarily in new construction.

Consumer Advantages

Consumers can see an immediate need for combination systems, because of the increased energy efficiency of the systems. Properly sized combination systems will use the excess water heater capacity to provide space heating at an efficiency level approaching the recovery efficiency level of the water heater. So space heating can be provided within a percentage point or two of the 70% efficiency of a standard water heater, 76% efficiency of energy saving water heaters, the 85% efficiency of higher efficiency water heaters, and the 94% recovery efficiency of the PolarisTM. Furthermore, since the standby loss is greatly reduced, at least during the heating season, the overall efficiency of the water heater in the water heating mode is also greatly improved.

The initial equipment cost of a combination system can also be less than that of replacing two appliances, because an air heater can cost much less than a gas furnace. Installation costs can be similar - combination systems will have more water lines, but single purpose systems will have more gas lines and can take up more space.

The flexibility and versatility of combination systems provide the consumer with options not found in single purpose furnace or hydronic systems. Add-on or hard to heat areas may be heated without eliminating central air conditioning as an option. The relatively low cost of the air heater means multiple air heater installations can be made and zoning with forced air becomes possible.

The availability of a gas combination system means the consumer can choose the least expensive, most desirable energy source in all cases - whether it be gas or electric - without sacrificing peripheral advantages of that fuel. Lower energy costs can positively affect the consumer's ability to qualify for mortgage loans. The proper energy selection can make homes more marketable.

Once a combination system has been installed, energy upgrades become easier to do because only the water heater, a relatively inexpensive appliance, needs to be replaced. This, coupled with the expected increased life-cycle of the water heater used in a combination system, could mean lower consumer equipment costs over the life of the home. The increased circulation within the water heater, due to the heating cycle, should reduce residue build-up inside the tank and could prolong the tank life.

Builder Advantages

Builders face many of the same advantages that consumers do as far as freedom to exercise energy options. The low initial equipment cost of combination systems compare favorably with the least expensive equipment currently on the market. Since combination systems can couple these low installation costs with low ongoing energy costs, the builder has an additional selling feature - overall home affordability. The versatility and flexibility of the systems can save precious floor space. These economics mean more features can be built into the home without affecting the overall affordability of the home.

Utility Advantages

Gas utilities have much at stake with combination systems. Since the growth of these systems has greatly influenced the development of more innovative gas water heaters, venting problems inherent with gas water heaters have been overcome. Gas utility companies are now able to run gas lines to multi-family structures in markets that they have been shut out of for years. This developing gas technology is also spurring electric product research and development.

Dealer and Distributor Advantages

Dealers and distributors who have seen a significant erosion in their water heater business to Home Centers and Do-It-Yourself Centers now have an opportunity to recover some of that business. When consumers call for an energy upgrade or replacement of their space heating system, the dealer now has a real opportunity to include the water heater in that upgrade. Electric conversions become inexpensive and more realistic when a direct-vent water heater may be installed with a hot water coil inserted in the plenum of an existing electric furnace. Because of reduced time periods for paybacks, energy upgrades become more practical and more plentiful and additional unit sales of water heaters are created. The increased competition between gas and electric utilities for load should increase the cooperative advertising opportunities for dealers and distributors.

The Bottom Line

The bottom line regarding combination systems is they are simple systems whose time has come. This common sense approach to home comfort affords the opportunity for innovative and more efficient product development, more practical building design, reduced equipment costs and significant consumer energy savings.

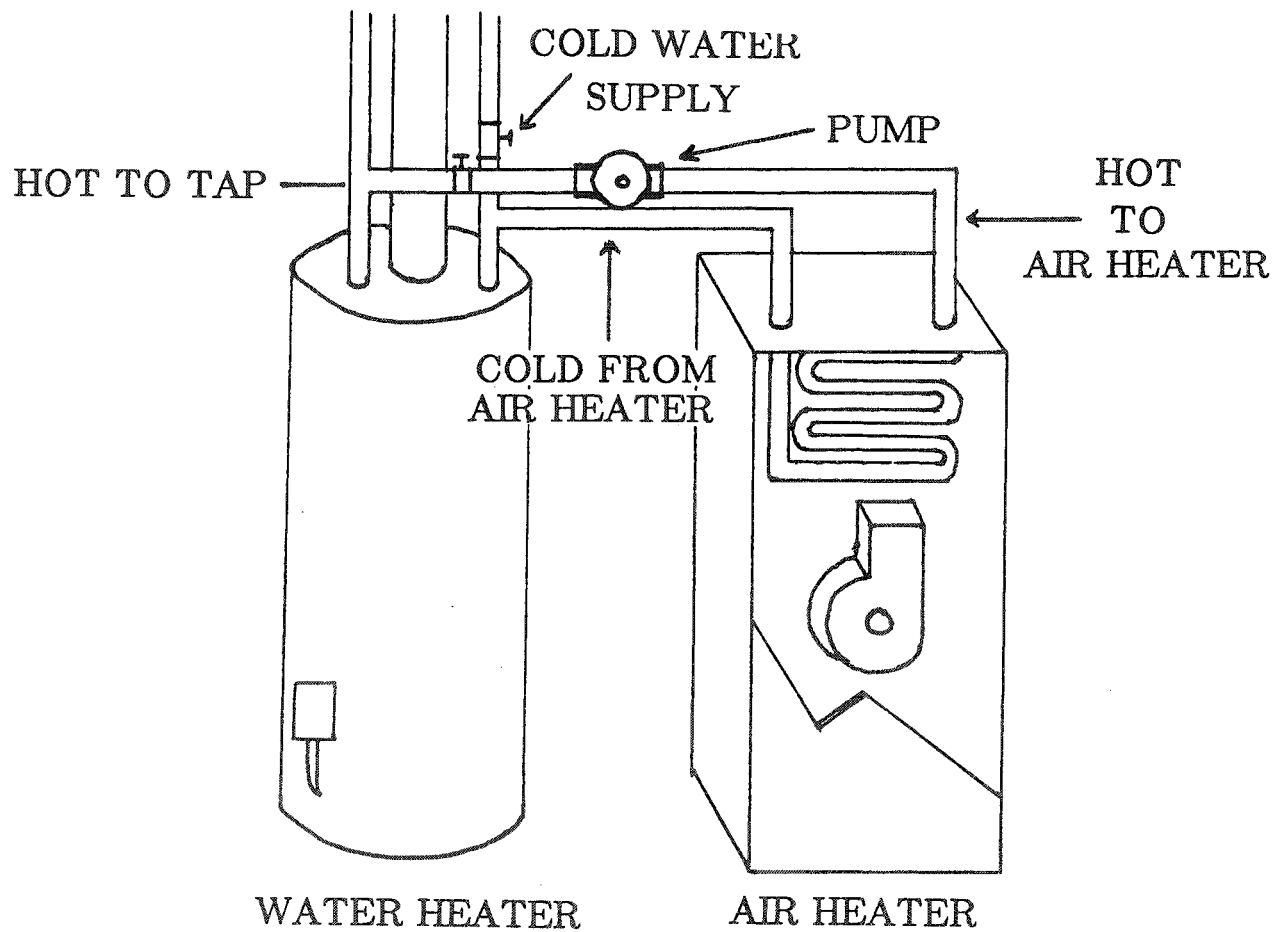


Figure 1. Typical integrated appliance application using water heater and air heater.

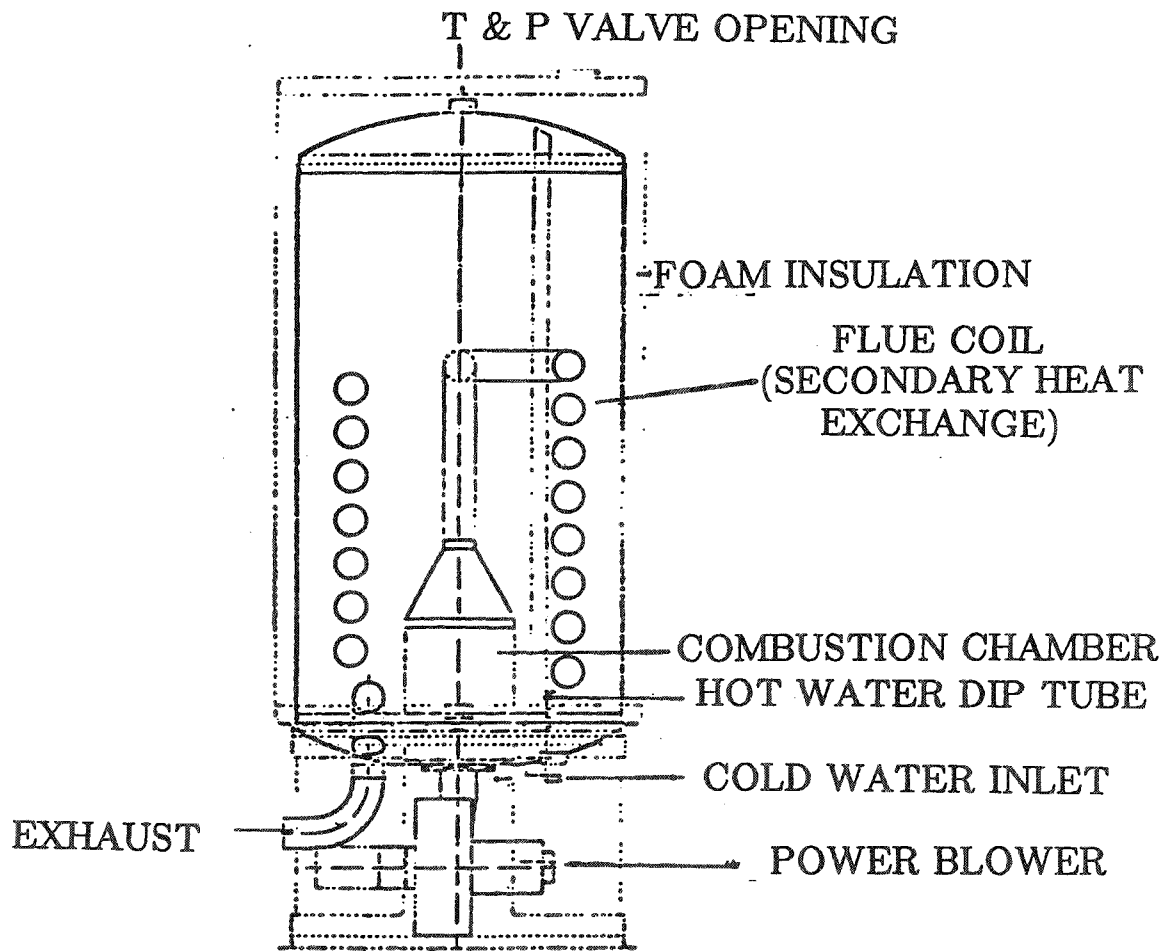
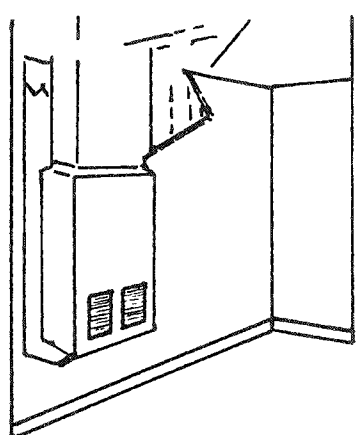
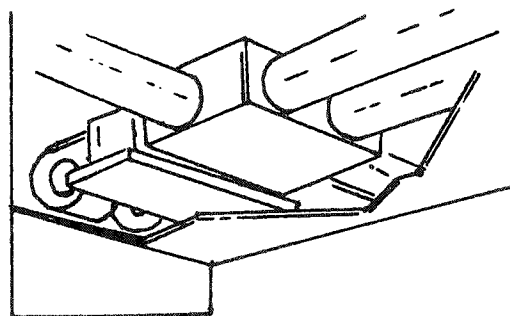


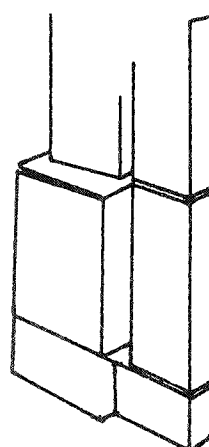
Figure 2. Polaris' very high efficiency water heater.



WALL-MOUNTED
AIR HEATER



AIR HEATER
INSTALLED ABOVE
DROP CEILING



CLOSET-TYPE
AIR HEATER
MAY BE INSTALLED
VERTICALLY
OR HORIZONTALLY

Figure 3. Types of air heaters.