Heatin' with Hydrogen

Walt Pyle, Jim Healy, Reynaldo Cortez, & David Booth

We want to share our experiments running a catalytic space-heater on hydrogen fuel. Three space-heaters are now installed in various rooms of one of the author's Richmond, California home. They are currently fueled with natural gas. These heaters present an almost ideal opportunity for conversion to hydrogen combustion. We plan to operate these space heaters routinely in the near future on hydrogen produced at home.

Gas Appliance Conversion

In the last issue of Home Power (#33), we examined an approach for modifying conventional kitchen stove burners (intended for natural gas or propane use) to allow cooking on hydrogen fuel. This method involved using stainless steel wool as a catalyst, and delivering hydrogen to the burner head without pre-mixing the fuel with air. The originators of this technique refer to this approach as "flame assisted catalytic combustion of hydrogen."

In this article we'd like to focus on pure catalytic combustion of hydrogen and air. Catalytic combustion of hydrogen and air can occur in the presence of certain noble metal catalysts (such as platinum or palladium), without any flame whatsoever. Water vapor and heat are byproducts of the reaction.

The Platinum CAT™

Catalytic space-heaters are available as mass-produced, low-cost consumer appliances. Some are intended for propane and some are for natural gas fuel. We chose to work with a Platinum CAT™ catalytic space-heater since it was the only model with forced external venting and an American Gas Association approval. Our intended application was for a home, not a recreational vehicle.

The manufacturer of the Platinum CAT™ flameless, catalytic, radiant space-heater is Thermal Systems, Inc. of Tumwater, Washington. The propane versions were conceived with the recreational vehicle market in mind, so they rely on 12 VDC power. The natural gas models are very similar in overall design, but they require 120 vac for operation of the solenoid gas valve and blower fan. Both types require a vent to the outdoors for the exhaust gases.

Our Platinum CAT™ was a Model 1500 120 vac 60 Hz version with a gas orifice sized for pipeline natural gas. (Model 1500 can also run on propane with the correct orifice installed.) The first CAT was installed in the living room during 1991 and operated for one year on natural gas to gain service experience. We were so pleased with its performance that we ordered and installed two more CATs during 1992.

Multiple Benefits

The radiant heat available from the Platinum CAT™ is long wavelength infra-red radiation similar to the sun's own rays. Radiant heat, unlike convection or conduction heat, is transmitted through space, and only releases its energy when the rays strike objects and/or people. Warmth from this space-heater is felt immediately, unlike forced air convection systems which first must heat the surrounding air.

The efficiency of catalytic hydrogen-air combustion with platinum catalysis is extremely high. The range of efficiencies commonly reported in technical literature is 85–100%. Efficiency is high because the combustion takes place at a substantially lower temperature than under ordinary conditions. This means in the presence of the platinum catalyst, no pilot light, spark, or glow plug is needed to initiate flameless combustion. This important

safety feature helps prevent the accidental buildup of unburned gas and air mixtures. Also, catalytic combustion occurs far below the threshold temperature at which oxygen and nitrogen can react to form polluting nitrogen oxides (NOx). As a result, these emissions are 0.1 parts per million (ppm) or less compared to conventional burners at 200 to 300 ppm.

In the future, we will take full advantage of the higher heating value of hydrogen. This can be accomplished if the byproduct — water in the vapor state — changes back to a liquid and gives up its heat before it leaves the heated space. This is called the latent heat of condensation.

Conversion of The Platinum CAT™ to Hydrogen

These space heaters can be modified for the direct use of pure hydrogen by controlling the feed flow rate of hydrogen gas (and thus the heat release rate). The hydrogen flow rate to the Platinum CAT™ can be adjusted by raising or lowering the delivery pressure, or by resizing the gas inlet orifice. It may not be necessary to adjust anything if you are content with less output from the space heater.

Piping and Wiring the CAT

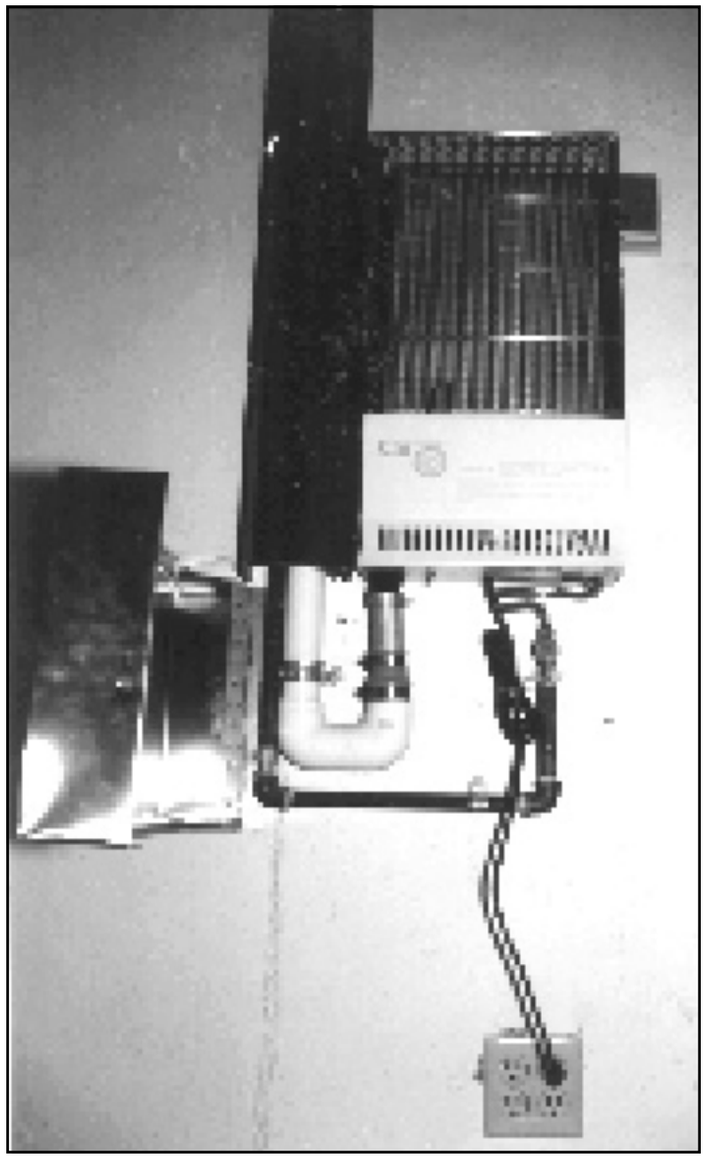
An excellent instruction and installation manual comes with the Platinum CAT™. The installation must conform to local codes. In the absence of local codes, the installation must conform with American National Standard (National Fuel Gas Code) known as NFPA 54 and ANSI Z223.1 1984.

We used threaded 3/4 inch black iron pipe for the fuel delivery line with a high quality thread sealer (Permatex Industrial Hydraulic Sealer). A fuel gas shut-off valve was installed at the appliance entrance flex hose.

A 2 inch plastic flue pipe was used since the flue gases are low temperature with the fan running. The heater will not open the fuel gas solenoid valve unless the fan is running. No provision was made for condensed water removal, since we are operating the unit in a mild climate where this is not a problem.

A soap solution was used for leak testing the piping after installation. A product useful for this purpose is called Rectorseek Leak Detector (Rectorseal Corporation).

A thermostat is supplied with the unit to control the temperature in the room. It works by turning the space heater “on” or “off” as required. We mounted our thermostat at the upper right of each unit so the wires could be hidden behind the heater frame. With this configuration we found that one must set the thermostat to a higher temperature than that desired for the room. The thermostat is heated by local conduction somewhat and tends to shut off prematurely. Placing the thermostat further away from the space-heater would benefit some installations.



Above: Platinum CAT™Space Heater in Basement bedroom showing vent piping and fuel supply line.
Photo by Reynaldo Cortez

The control unit for our natural gas approved Platinum CAT™ had a 120 vac power card, so we just plugged it in and we were “on the air”!

Is Venting Needed?

Platinum CAT™ heaters produce radiant heat as the result of flameless catalytic combustion, whether or not hydrogen gas is the fuel of choice. With propane and natural gas, the space-heater exhaust gases will contain water vapor, carbon dioxide, and minimal quantities of carbon monoxide, NOx, and hydrocarbon pollutants. Common sense, AGA safe practices, and local building code regulations require that space-heater exhaust gases be vented away from the living space.

Only with hydrogen fuel is water vapor the primary combustion end product. So, why must the space-heater on hydrogen be vented? Well, you might argue, homes heated in the winter are in need of further humidification to raise the "comfort factor", and much valuable heat is lost (your energy dollars) up those exhaust flues. It is tempting then, to think about venting the space-heater into the room. We advise against this practice.

Dangerous and harmful situations could arise if a space-heater on hydrogen (or conventional fuels) is not vented to the outdoors:

- Excessive moisture could condense in the home causing damage to building materials and the growth of unwanted bioorganisms.
- Loss of oxygen in the breathing atmosphere of a tightly sealed or "superinsulated" home could lead to asphyxiation or loss of consciousness for occupants.
- Confinement of a potentially explosive mixture of hydrogen and air is possible.

A simple well designed vent can prevent these problems from occurring with any hydrogen appliance. The vent system (shown in photo on page 27) was made for our second Platinum CAT™ space-heater, which we installed in 1992 in a basement bedroom.

Our Experience to Date

During the summer of 1991 we made the first test of the Platinum CAT™ using hydrogen fuel. The hydrogen came from a high pressure compressed gas cylinder followed by a two stage pressure regulator. This allowed us to drop the pressure from as high as 2300 psig (pounds per square inch gauge) down to a pressure of about 4 inches of water column (w.c.), suitable for a gas appliance. We found that the hot wire starter for natural gas operation was unnecessary for initiation of hydrogen-air catalytic combustion. The hydrogen gas reacted with air on contact with the platinum coated silica quatz pad, giving off about as much heat as when running on natural gas.

A few weeks later, we contacted Thermal Systems, the manufacturer of the Platinum CAT™, and discussed operation on hydrogen with Arnie Lind, their resident R&D Lab Engineer. Arnie was interested in our approach. A few weeks later when we talked again, Arnie told us about some experiments he had run in the lab using hydrogen in a Platinum CAT™. Arnie became even more interested in the hydrogen fuel space heater after talking to Sandy Stuart from Electrolyser Corporation in Canada (to whom we had provided a copy of the Platinum CAT™ literature). Arnie confirmed that he had reliably obtained catalytic combustion of hydrogen and air without the ignitor, within 45 seconds or less after he turned the Platinum CAT™ on.

Using a 5 inch w.c. hydrogen supply pressure to the Platinum CAT™, Arnie measured fuel consumption of about 16 cubic feet per hour. On natural gas the fuel consumption was about 5 cubic feet per hour using 4 inches w.c. pressure at rated output of 5200 BTU/hour. An even combustion pattern was seen on the silica quartz pad face, glowing a dull orange when viewed in a dark room. Arnie found that he could get the same heat release as natural gas if he enlarged the natural gas orifice (normally 0.043 inches) to 0.052 inches (drill size #55).

One of Arnie Lind's primary concerns was in testing to assure that the surface of the catalyst silica quartz pad was not damaged by overheating (temperatures greater than 1100°F were known to cause problems). By using a non-contact infrared thermometer he found that the surface temperature of the rock wool was only 600° to 800°F when operating on hydrogen at the rated heat input, and not a problem. Another of Arnie's concerns was about the flue gas composition. He planned to obtain samples of the gas for analysis. Maybe there will be an AGA approved hydrogen Platinum CAT™ in our future! We hope so.

Demonstrating Flameless Combustion

We shared the news of this novel appliance with David Katz of Alternative Energy Engineering. He proceeded to order one for his home, but initially it became our handy demonstrator unit for a recent alternative energy fair and a one day hydrogen workshop. Even without plumbing or wiring this device, we amazed more than a few curious souls and skeptics with a simple demonstration of flameless combustion. After removing the protective grill on the heater, a silica quartz pad with minute amounts of platinum is left exposed. All that was needed to instantaneously produce heat and a reddish-orange glow was the direction of a slow, steady stream of hydrogen from our compressed gas cylinder across the surface of this material. Of course, this was only done to visually confirm the novel quality of flameless combustion. We don't suggest that this approach is in any way a substitute for a properly piped and wired installation. In one of our demonstrations, the hot silica quartz pad surface started a flame in the stream of hydrogen, which jumped out to the end of our delivery line! The catalytic combustion temperature was above the ignition temperature, and a hydrogen flame was kindled.

Flameless combustion or oxidation is really not that unique a phenomenon. The body's oxidation of carbohydrates, the yellowing of newspapers, and the rusting of iron are well known examples.

Safety Warning

Please be forewarned that although our experience may indicate that such a conversion is relatively simple, the use

of this appliance with hydrogen fuel is not yet approved by the manufacturer. Approval from the American Gas Association must be obtained before the Platinum CAT™ on hydrogen will be ready for commerce. The use of any gaseous fuel in a space heater, other than the one recommended specifically by the manufacturer will void the warranty, and may not comply with American Gas Association (AGA) safe practices.

If you want to try any hydrogen space-heater experiments on your own, be aware:

- Installation should only be done by a qualified service person.
- Any changes to the heater or its controls, or attempts to clean the catalytic pad can result in damage, defective operation, and may be dangerous.
- Any experiments with hydrogen fuel should be done outside.
- Hydrogen gas is odorless; you cannot smell a leak.
- Remember that hydrogen gas and air mixtures are potentially combustible and explosive over wide mixture ratios (4 to 75% hydrogen in air). Only pure gases should be stored, never mixtures of hydrogen and air.

Access

Authors: David Booth, Alternative Energy Engineering, PO Box 391, Miranda, CA 95553 • 707-923-4336

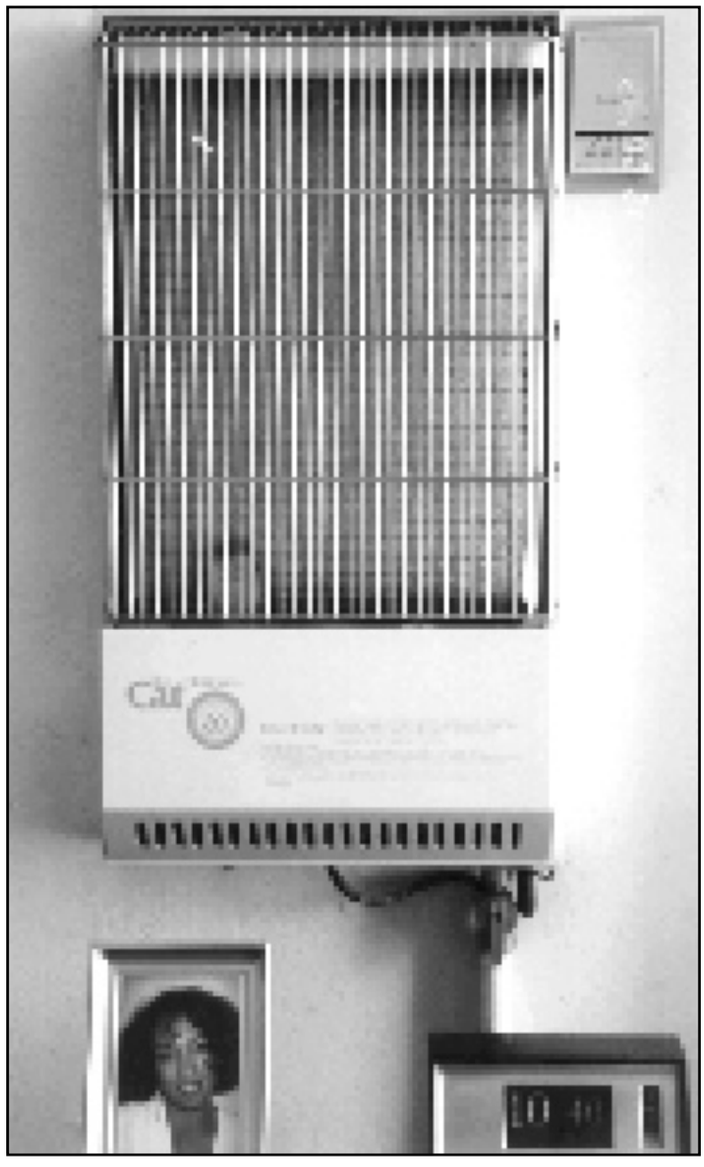
Walt Pyle, WA6DUR, Richmond, CA • 510-237-7877

Jim Healy, KD6LYV, Richmond, CA • 510-236-6745

Reynaldo Cortez, Richmond, CA • 510-237-9748

Platinum CAT™ Heater: Thermal Systems Inc., Mottman Industrial Park, 2757 29th St. SW, Tumwater, WA 98502 • 206-352-0539

Safety Regulations: NFPA 54 and ANSI Z223.1 1984 from: American National Standards Institute Inc., 1430 Broadway, New York, NY 10018 or National Fire Protection Assoc., Batterymarch Park, Quincy, MA 02269



Above: Multi fuel space heater at work warming the living room. The heater normally runs on natural gas, but runs equally well using hydrogen.
Photo by Reynaldo Cortez

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