GAS-HEAT-PUMP DEVELOPMENT

F. A. Creswick
Energy Division
Oak Ridge National Laboratory*
Oak Ridge, Tennessee 37830

For Presentation to the
1981 International Gas Research Conference
Los Angeles, California
to be held
September 28-October 1, 1981

*Research sponsored by the Office of Buildings and Community Systems, U.S. Department of Energy under contract W-7405-eng-26 with the Union Carbide Corporation.

GAS-HEAT-PUMP DEVELOPMENT[1]

Frederick A. Creswick
Heat Pump Project Manager
Oak Ridge National Laboratory

One way to view current gas heat pump developments is to consider them as extensions of the efforts of the 1950s and '60s to develop gas air conditioning systems for residential and commercial use. In those years, the gas industry and the HVAC industry conducted a variety of R&D projects involving absorption systems, gas-engine-driven systems, Rankine-cycle systems, desiccant systems, ejector systems, etc. Of these, three residential absorption systems made it into the marketplace and enjoyed moderate commercial success for a time. A few engine-driven systems were also sold in this period.

Today, we are looking at some of these same systems, and a few new technologies, for a somewhat different application -- gas-fired heat pumps for space heating and cooling. Although the fundamental concepts have not changed much in the past decades, the circumstances have changed substantially. For one thing, energy-conversion engineering technology has advanced steadily in this period -- development of aerospace power sources and improved automotive power plants have contributed substantially to this improvement, as has recent specific heat pump developments. Thus, potential performance has improved and technical risks have been reduced in many cases.

At least equally important is that the incentives for the development of this technology are increased greatly. For the consumer, the energy-cost savings accrue over both heating and cooling seasons, as compared to the cooling season only in the case of gas air conditioners. Also, recent increases in the real prices of energy augment these savings.

For this country as a whole and for the world, the gas heat pump represents an important option for significantly reducing the energy

---

[1] An overview address for presentation to the 1981 International Gas Research Conference, September 28-October 1, 1981, Los Angeles, California.

resources needed for the residential and commercial sectors. And for the gas industry, the availability of new gas-fired equipment having increased efficiency and cost effectiveness is needed if vigorous competition for new end-use markets is to be maintained in a bounded-supply and rising-cost situation.

As a result of these incentives, there is substantial activity underway at present to develop, demonstrate, and commercialize heat-actuated heat pumps, not only in the United States, but also in Europe and Japan.

One could say the gas-engine-driven heat pump is the leading candidate system in other countries, based on large numbers of development and demonstration projects alone. This is predictable because the gas-fired internal combustion engine is proven, available technology; it can produce high system efficiency; and the economics are particularly favorable for output ranges of 50 to 60 kW and higher. However, for commercial success, problems involving maintenance requirements, durability, noise, vibration, and exhaust emissions must be solved at reasonable cost. It is somewhat puzzling that there is little apparent interest in the United States in commercializing packaged heat pumps driven by conventional gas engines. This may be in part due to the negative experience with total-energy systems in this country, and possibly because the incentives of high energy costs are generally greater in other countries. There is, however, a gas-fueled free-piston engine-compressor under development in this country which shows promise for good durability and low maintenance requirements.

The second ranking system in terms of number of current world-wide development projects would appear to be the absorption heat pump. Single-stage systems based on technology used in current gas-fired absorption chillers can provide modest but worthwhile improvements in heating efficiency beyond the theoretical limits of advanced furnaces. Several ammonia-water systems are already commercially available in

Europe in limited quantities in heat-only versions. Other ammonia systems and organic-fluid systems are being developed in this country and abroad. Thus, the simple absorption cycle can be viewed as near-term technology -- available for wide use in only a few years. From experience with absorption chillers, we know that a carefully developed absorption heat pump can operate reliably over long periods of time with little maintenance within the present state of the art.

However, absorption systems are also part of the long-term picture for gas heat pumps. There are a number of cycle innovations, including the double-effect cycle, that promise substantial improvements in efficiency in both the heating and cooling modes over current single-cycle machines — potentially on par with engine-driven systems, in fact. Also, the development of improved fluid pairs still stands as an important research area, which could result both in modest efficiency gains and smaller, less-expensive hardware. Present and future R&D on advanced absorption systems could lead to some exciting new gas heat pump systems in five to ten years.

The Stirling engine is being examined as a heat pump driver in several projects around the world. There are at least three projects in the United States in which Stirling free-piston engine/compressors are being developed; also, there have been several efforts in the United States and abroad in which shaft-power Stirling engines have been coupled to conventional heat pump compressors. Stirling engines have almost all the desirable attributes of a heat pump driver -- they are efficient, clean and quiet and ideally require little maintenance. The projected system efficiencies of Stirling-engine-driven heat pumps are somewhat better than those attainable with conventional internal-combustion engines. However, Stirling-engine technology is immature at present. Durability is still the biggest problem; optimum thermal design is an important but less critical area. In the case of free-piston machines, dynamic performance prediction is in a developmental state, and the best design approach for separating the engine working fluid from the refrigerant has yet to be established. One design variation, the back-to-back,

free-piston Stirling/Stirling machine, avoids this latter complication. Accordingly, we view Stirling-engine-driven heat pumps as long-term high-development-cost, high-risk technology that offers the potential for superior performance.

Small Rankine-cycle engines have long been of interest as drivers for heat-actuated systems. There are a few current development projects receiving support in various parts of the world. Most of these are still in an experimental stage. There is at least one small Rankine engine that is commercially available at present, but, to my knowledge, it has not been used as a heat pump driver.

The gas-turbine-driven heat pump also deserves mention. Gas-turbines have established themselves as long-life, low-maintenance prime movers in many applications involving steady- or quasi-steady-state operation, and thus, they are attractive as heat pump drivers. Although attainable system efficiency is not as high as with some other systems, it is in an attractive range. In spite of these favorable attributes, we are aware of only one project to develop a packaged gas-turbine-driven heat pump. Very high development cost requirements are probably a contributing factor to this sparse interest in the system. It appears that at least one such system could be commercially available in a few years.

To summarize, there are strong incentives for the development of gas heat pumps, there are several promising technologies, good technical progress is being made, and there is potential initial commercialization in the next year or so. Nevertheless, it cannot be considered certain that gas heat pumps will be commercialized successfully in the near future. Some inhibiting factors are the following:

- The combination of a high-efficiency gas furnace and an electric air conditioner can be expected to give vigorous price competition to high-cost, high-efficiency gas heat pumps.

- The investment in manufacturing facilities for gas heat pumps will be high, and few organizations in the HVAC industry will have the financial resources required.
- There is no demonstrated market for gas heat pumps.
- The institutional structure of the building industry still favors low-cost equipment, irrespective of efficiency and life-cycle cost.

Accordingly, continued strong financial support with public funds for research and development and aggressive marketing support from gas utilities will be essential if the gas heat pump is to become a reality in the foreseeable future. Also, we will have to see some changes in consumer investment criteria for HVAC equipment in both the residential and commercial sectors. This change could be the natural consequence of escalating energy costs, or the result of consumer education efforts by both the federal government and the gas industry.