RETROFITTING OF CONDITIONING SYSTEMS FOR EXISTING SMALL COMMERCIAL BUILDINGS - ANALYSIS AND DESIGN OF LIQUID DESICCANT - VAPOR COMPRESSION HYBRID

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ABSTRACT

The combination of several concepts of new energy technologies may make it possible to reduce the energy needs for thermal comfort, especially cooling and dehumidification, in small sized, single-story commercial buildings. The potentials and limitations of retrofit technology for these characteristic structures have been the focus of the experience gained through the design and installation of a system adapted to a building constructed in the early 1960's. The existing split package air conditioning system was combined with a desiccant air-conditioning unit with a waste heat and solar heat reclaim component. While this retrofit system is feasible, a number of questions remain to be considered regarding the design, installation and operation of the total system. This paper focuses on the practical applications of such a hybrid system - both architectural/construction issues and the mechanical components/system considerations.

INTRODUCTION

A significant source of thermal discomfort in the hot, humid climatological regions of the U.S. is the high humidities prevalent during much of the year. The use of dehumidification systems has been suggested as a means to remedy this condition. Desiccant dehumidification, incorporating either a liquid or solid desiccant, is considered a viable system to achieve acceptable thermal comfort (1). If used with conventional fuels, it is unlikely that these systems would produce any energy savings. A demonstration project, retrofitted to a characteristic small commercial building type, located on the Louisiana State University campus, involves the absorption properties of a salt solution to reduce the humidity of an outdoor air supplied to improve thermal comfort of the interior space. As the liquid desiccant becomes saturated with water, waste heat from an air conditioning condensing unit is combined with air heated passively in an attic to regenerate the desiccant. A prototype open-cycle, liquid desiccant dehumidification system has been adapted to the existing mechanical system of the building (Figure 1). Guidelines for retrofitting existing commercial buildings as well as design concepts for new construction incorporating the proposed hybrid system have been developed as a result of this experience. Test data indicate that the system can perform to achieve desired results. The work necessary to optimize the design and construction of a marketable system remains.

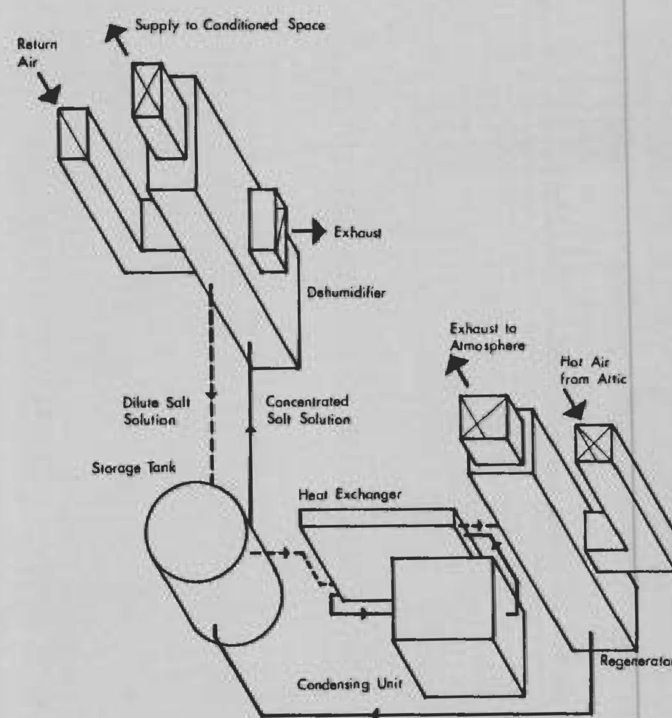

Figure 1. Overall Mechanical System

OVERALL SYSTEM

There are two major parts of the retrofitted air conditioning system: the regenerator and its supporting equipment and the dehumidifier. The regenerator side of the system (Figure 2), includes a storage tank, a packed tower (the actual regenerator) and a gas-to-liquid heat exchanger coupled to an existing air conditioning condensing unit (Figure 3). The dehumidifier (Figure 4), is connected with new ductwork to the existing air handling unit and air distribution system of the characteristic building.

REGENERATOR SIDE

Storage Tank

The brine solution is stored in a 360 gallon

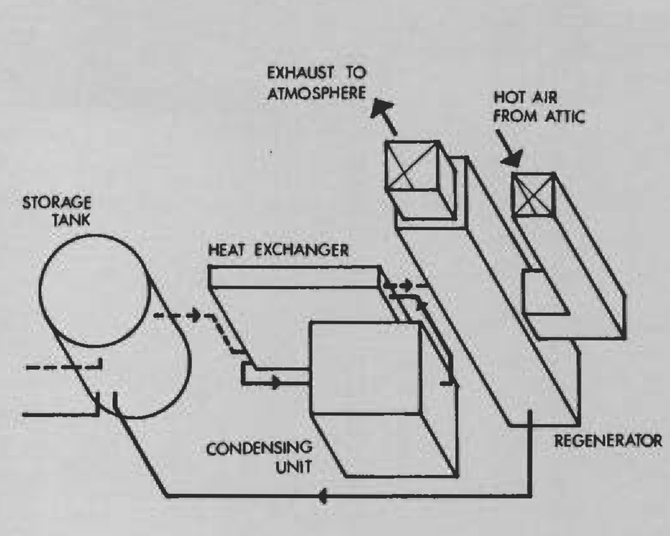

Figure 2. Regenerator Side

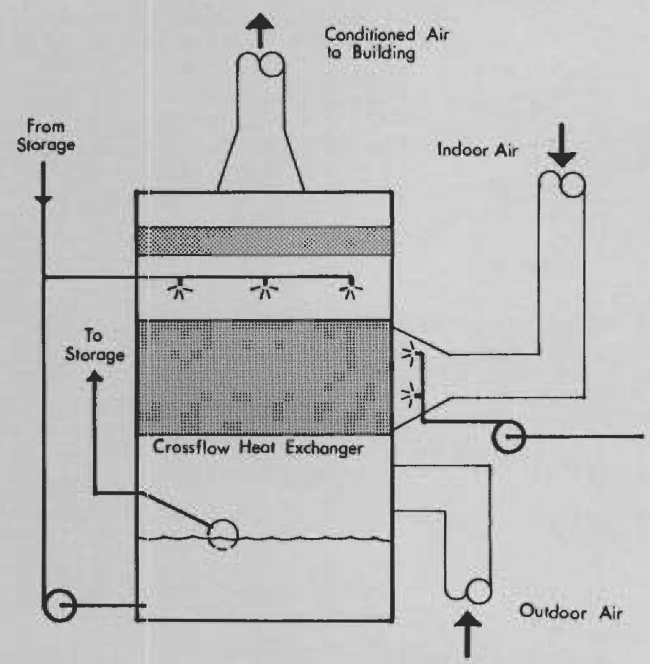

Figure 4. Dehumidifier Side

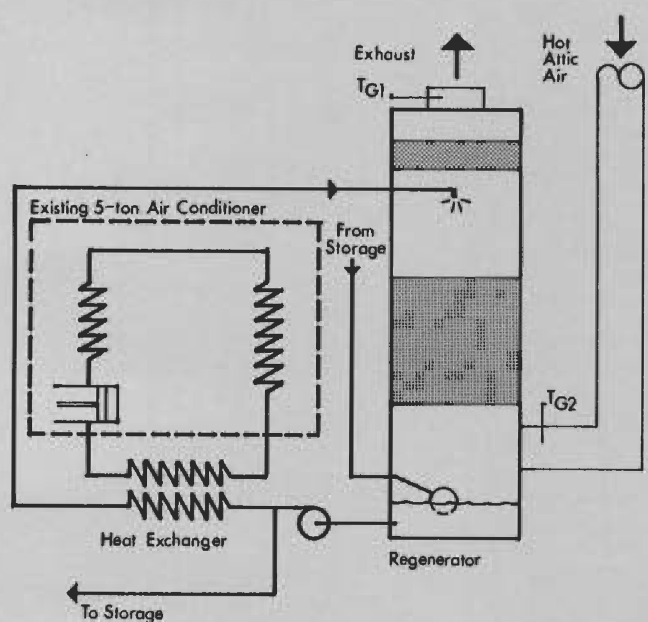

Figure 3. Hybrid System

(1363 liter) uninsulated plastic tank. Thermal storage is not required of this part of the system. This provides sufficient storage for those times when regeneration is not possible. The solution stratifies with the more dilute brine at the top and the concentrated solution at the bottom of the tank. A 42 percent, by weight, solution is produced by mixing 1500 lbm (681 kilograms) of calcium chloride with 200 gallons (756.7 liters) of water. The regenerator is supplied from the top of the tank.

Heat Exchanger

As a preliminary step in the drying process, the dilute solution is heated using the waste heat of condensation of the existing air conditioning equipment. This component consists of six heat exchanger tubes, each 8 feet (2.438 meters) in length. Freon is contained in the inner tube, which has a finned inner surface and a knurled outer surface to enhance heat transfer. These units were arranged as a pair of heat exchangers of three tubes each to minimize pressure loss.

Regenerator

From the heat exchanger the hot salt solution enters at a flow rate of 18 to 20 gallons per minute (1.13 to 1.26 liters per second) . The solution is sprayed into the regenerator, essentially a fiber-glass box 2 feet (0.609 meters) on a side by 8 feet (2.438 meters) high, through a nozzle to distribute it evenly across the top of the packing material. A vapor barrier located above the spray nozzle prevents the solution from being blown out of the top.

Ducted from the attic, hot air in the temperature range of 130-148°F (55.8 to 64.8°C) is blown into the regenerator at 900 cubic feet per minute (427.3 liters per second) . The salt solution cascades down the packing material, meeting this counterflowing hot air that carries away some of the water in the solution. This air becomes saturated and carries away moisture and is exhausted to the outdoors. The salt solution that remains is collected at the base of the regenerator for recirculation. On each pass through a small quantity, one-half to one gallon (1.893 to 3.785 liters) per minute, is bled off and returned to the storage tank to be used later in the dehumidifier.

DEHUMIDIFIER SIDE

The dehumidifier consists of two major parts: a cross-flow, flat plate heat exchanger and a vapor barrier. A demister is used to prevent solution from being carried into the supply air stream.

Return air from the conditioned space acts as a cooling medium after it has been saturated with water, lowering its temperature to 67°F (19.7°C) . A fine spray of water both cools the air and coats the surface of the heat exchanger, which enhances its heat transfer characteristics. After passing through the heat exchanger, this air is exhausted to the outdoors.

Outside air enters the dehumidifier at 97°F DB (36.4°C) and 80°F WB (27.0°C) at a flow rate of 1500 cubic feet per minute (712.1 liters per second). This air is blown into the heat exchanger where it is cooled and dehumidified through contact with the concentrated salt solution before being introduced into the building. The liquid desiccant, a 42 percent calcium chloride solution, is sprayed into the fresh outdoor air stream at a rate of 20 gallons per minute (1.26 liters per second) . The solution absorbs 66 lbm/hr (30 kg/hr) of water from the air stream, assuming an approach factor of 80 percent, i.e., the desiccant absorbs 80 percent of the theoretical maximum possible. The cooled outside air enters the conditioned space at 78°F DB (25.9°C) and 62°F WB (17.0°C) which produces the desired thermal comfort level. The level of desiccant in the dehumidifier is controlled by a float value as the solution is fed to the unit by gravity from the storage tank. A portion of the diluted solution is returned to the regenerator. The air distribution system prior to and after retrofit are shown in Figures 5 and 6, respectively.

Many existing small commercial buildings, especially single-story structures, possess the physical features that are necessary for retrofitting a dehumidification system. Generally speaking, it is the character and construction of the roof that is a deciding factor. If the roof is not supported by prefabricated trusses, buildings with either light wood or metal framing may be good candidates for retrofit. When the roof support is a braced-rafter framing system work in the attic space is more easily accomplished. A large attic volume is desirable and this should be associated with high roof slopes, in the order of 5 in 12 or greater. The roofing material should be of a dark color. Insulation must be provided between the attic heat source and the conditioned space. If the insulation has deteriorated, it should be replaced and consideration should be given to the installation of additional insulation in most cases. Typically, the structure should be a single-story in height, but some two-story structures may be included, if the roof construction characteristics are similar to those indicated.

CONCLUSIONS

Further study of this system is necessary and a number of areas for further development exist. First, the major concern is the optimization of the components and the total system. A life cycle cost analysis is necessary to determine reductions in both equipment first costs and system operating costs. It is desirable to have all retrofit components in one package or modules that can be adapted to various site conditions. In a climatic zone with mild winters equipment can be located outdoors and exposed to the weather, yet consideration should be given to the reduction of area and space requirements for the system. All of the connections to the existing system, plumbing, electrical, and mechanical need to be simplified. Costs of retrofit installations will depend greatly on the complexity of the control system and electrical service requirements.

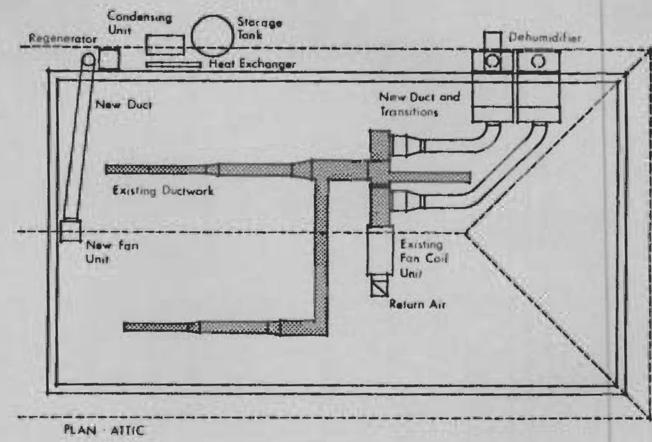

Figure 5. Air Distribution System - Before Retrofit

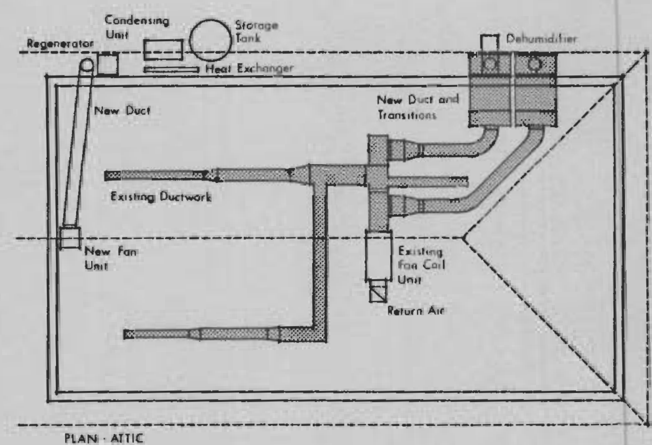

Figure 6. Air Distribution System - After Retrofit

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BIBLIOGRAPHIC REFERENCES

(1) Barlow, R., "Analysis of Solar Desiccant Systems and Concepts", Solar Energy Research Institute, Golden, CO, (DE-AC02-77CH-00178; EG-77-col-4042), May 1981.

(2) Arnas, O. A., "Integration of Retrofitted Vapor Compression, Desiccant Air-Conditioning, Waste Heat Reclaim System and Roof Solar Heat Reclaim", Final Report Louisiana State Department of Natural Resources, DNR-IA-No. 21400-82-21, April 13, 1984.

(3) McQueen, T. M. and O. A. Arnas, "Retrofitted Conditioning Systems for Commercial Buildings", Proceedings of ASES 84, Anaheim, CA, June 5-9, 1984.

(4) McQueen, T. M. and O. A. Arnas and D. M. Nugent, "Retrofitted Solar Assisted Air Conditioning Systems for Small Commercial Buildings - Experimental Results", Proceedings of the Ninth IASTED International Conference on "Energy, Power and Environmental Systems", San Francisco, CA, June 4-6, 1984.