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User Guide for Desiccant Dehumidification Technology

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Innovative Ideas for the Operation, Maintenance, & Repair of Army Facilities

Foreword

This study was done for the U.S. Army Center for public Works (USACPW) under the Facilities Engineering Application Program (FEAP); Work Unit F56, "FEAP Desiccant Demonstration at APG." The technical monitor was Dennis Vevang, CECPW-EM.

The work was performed by the Troop Installation Operation Division (UL-T) of the Utilities and Industrial Operations Laboratory (UL), U.S. Army Construction Engineering Research Laboratories (USACERL). The USACERL principal investigator was Thomas E. Durbin. Chang W. Sohn is Acting Chief, CECER-UL-U; Martin J. Savoie is Acting Operations Chief, CECER-UL; and Gary W. Schanche is the associated Technical Director, CECER-UL. The USACERL technical editor was William J. Wolfe, Technical Resources.

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1 Executive Summary

Manufacturing industries have used desiccants in various applications for over 50 years, but have only recently begun to apply desiccant dehumidification systems (DDSs) to Heating, Ventilation, and Air-Conditioning (HVAC) applications. Depending on climate and facility loading, a high percentage of a building's cooling load can be latent (moisture) load. Conventional cooling equipment operates at low temperatures to cool the air to its dew point temperature, where dehumidification via condensation on the coils begins. It may then be necessary to reheat the air to a comfortable temperature before it enters the occupied space. DDSs, by contrast, remove water from the air by using a desiccant, or chemical drying agent. DDSs offer several benefits when used in conjunction with air-conditioning systems. Removing moisture from the air by desiccation decreases the amount of vapor-compression energy needed to dehumidify the air being supplied to the user, and increases the comfort level in the conditioned space. Desiccant systems also decrease moisture accumulation in ducts and around coils, inhibiting the growth of mold and mildew.

While research in desiccant dehumidification technology development has been conducted for several years, commercial applications of desiccant dehumidification technology have been limited in the past by material and manufacturing considerations. Current desiccant dehumidification systems range in capacity to 30,000 cubic feet per minute (cfm) and are near the commercialization stage. Since these systems are heat driven (not electrically driven), conversion to a desiccant system can reduce site peak electrical demand and levelize utility loads, allowing for more efficient power plant operation. Energy cost savings result from reduced chiller loads, reduced electricity peak demand, and elimination of air reheating requirements. Desiccant dehumidification systems can also reduce or eliminate the use of harmful CFCs in the HVAC system by using natural gas or liquid propane gas (LPG) as the primary fuel for dehumidification.

AS yet, very few desiccant systems have been installed at military installations, and only then in specialized applications. Desiccant dehumidification systems may offer advantages for military applications over other energy supply options by increasing force readiness, providing greater system reliability, controlling humidity in areas with sensitive material and equipment, and by reducing environmental impact and energy costs.

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2 Pre-Acquisition:

Technology Description and Application

"Conventional" Air-Conditioning/Ventilation Process

Conventional air-conditioning systems are typically controlled by a thermostat (or similar type receiver/controller combination). They operate in a manner that keeps the space dry bulb temperature from exceeding the thermostat setpoint. To maintain that setpoint, conditioned air is typically introduced into the space approximately 20 °F* lower than the setpoint, so that the conditioned air can absorb the so-called "sensible" heat entering the space. Having absorbed this heat, air from the space is drawn back to the air-handling unit, where its temperature is again decreased before being returned to the space. The temperature decrease is accomplished by the returned air being drawn (or blown) through a cooling coil within the air handling unit. The coil is typically a specially designed finned-tube heat exchanger, containing a relatively cold circulating fluid (usually chilled water or a refiigerant) into which heat from the air is transferred. Invariably, the described situation is somewhat more complicated since some amount of outside air is mixed with the returned air from the space, and then the mixture is cooled by the coil. The most common reason for introducing outside (fresh) air is to provide ventilation for the occupants of the space. As the cooling coil reduces the dry bulb temperature of the air so that the air, in turn, will provide sensible cooling for the space, the dry bulb temperature of the air is reduced almost to its dew point temperature. In fact, a considerable portion of the air actually reaches saturation due to its contact with, or proximity to, the cooling coil, which has a temperature considerably lower than the air's dew point temperature. As a result, water condenses from the air onto the coil, where proper selection of airflow velocities (< 500 ft/minute) will allow the condensate to drip into a collection pan from which it will drain instead of being blown through the ductwork.

The process described above begins with the objective of keeping the dry bulb temperature of a space from exceeding a thermostatic setpoint, and produces a condition where the introduced air is not only cooler, but also drier. One device, the cooling coil, performs dual service by both lowering the dry bulb temperature of the air and reducing its moisture content. The moisture removal is neither incidental

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*1 °F = (°Cx1.8) + 32;1 ft = 0.305m.

nor accidental; the cooling coil is selected based on its capability to remove the space and outside air sensible and latent (moisture) loads estimated to occur on a “design day.”

Potential Problems With the “Conventional” Process

“Design day” conditions are generally defined as the dry bulb temperature and its mean coincident wet bulb temperature that are equaled or exceeded 2.5 percent of the time, on the average, during June, July, August, and September (months applicable for Department of Defense [DOD] installations in the contiguous United States). Generally, under design day conditions, the conventional process (previously described) can produce satisfactory conditions of dry bulb temperature and relative humidity within the space. For an appreciable amount of time, off-design conditions prevail, during which the proportion of the latent load to the total outside air cooling load is likely to increase compared to the ratio at the design day conditions. Table 1 lists typical outdoor conditions for a DOD site.

To illustrate the effect of non-design day conditions, consider unity flow (1 cfm) for the above conditions. Table 2 lists the sensible, latent, and total loads, and latent cooling ratio for the outside air conditions. Note that the much higher latent to total ratio at the off-design conditions requires the coil to perform primarily as a dehumidifier.

The data in Table 2 do not mean that the conventional process will necessarily provide poor indoor environmental conditions at off-design conditions. It may be that, for a given facility at a specific site, space loads predominate over outside air loads and the sensible heat ratio for the coil may stay relatively constant over the range of outdoor air conditions. The numbers do, however, suggest there could be a problem for facilities where the outdoor air load on the coil is a large part of the

Table 1. Outdoor conditions.

Dry Bulb Temp (Bin Average °F)	Wet Bulb Temp (°F)	Specific Humidity (grains/lb air)	Annual Hours
102	74	81.1	4
97	74	89.2	49
94	75	100.1	Design Day
92	74	97.3	250
87	72	93.8	479
82	71	96.3	659
77	69	93.5	921

Table 2. Sensible, latent, and total loads, and latent cooling ratio for outside air conditions.

Sensible Load (Btu/hr)*	Latent Load (Btu/hr)	Total Load	Latent/Total
1.08 x(1 02-75) = 29.16	0.68 X (81.1 -65) = 10.95	40.11	0.273
1.08 x (97 - 75) = 23.76	0.68 X (89.2-65) = 16.46	40.22	0.409
1.08 x (94 - 75) = 20.52	0.68 X (100.1-65) = 23.87	44.39	0.538
1.08 x (92 - 75) = 18.36	0.68 X (97.3-65) = 21.96	40.32	0.545
1.08 x (87 - 75) = 12.96	0.68 X (93.8-65) = 19.58	32.54	0.602
1.08 x (82-75) = 7.56	0.68 X (96.3-65) = 21.28	28.84	0.738
1.08 x (77 - 75) = 2.16	0.68 X (93.5-65) = 19.38	21.54	0.900
1 Btu = 1.055 kJ			

total cooling load. The prospects for this happening have become more likely following the issuance of ASHRAE Standard 62-1989, which calls for more outdoor air (as much as 20 cfm/person)* for ventilation than previously required. Trying to improve indoor air quality retroactively through compliance with the ASHRAE standard can often be futile because the existing equipment lacks the capacity to handle the additional load imposed by the increased amount of (humid) outside air. Furthermore, the sensible heat ratio for the coil will likely differ, perhaps significantly, even for design day conditions, since the outdoor air load will be a larger proportion of the total cooling load. The Air Force (and ASHRAE) have recognized that, for numerous locations, operational problems at off-design conditions may likely occur using the design day concept as the basis for equipment selection. In an attempt to minimize these problems, the Air Force is restructuring the data contained in *Engineering Weather Data* (AFM 88-29, TM 5-785, NAVFAC P-89) to highlight for designers those locations where sustained high outdoor humidity levels need to be considered during the design process.

Note that the conventional process can be modified to provide improved indoor environmental conditions under off-design outdoor conditions. The modification involves overcooking the air in response to a signal for dehumidification from a humidistat (or by turning down a thermostat), then reheating the cold dry air as necessary to ensure that the thermostat dry bulb temperature setpoint is not exceeded.

This scheme will increase the controls' complexity and first cost. However, the primary increase in cost results from the need for the cooling system to run longer to dehumidify the air, and from the air subsequently requiring reheat. This type of modification is seldom employed due to the additional costs just cited. It is used

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* 1 cu ft / minute (cfm) = 0.028 m^3 / minute.

only for spaces where precise humidity control is essential, such as laboratories, clean rooms, and hospital operating rooms. It would be unusual for reheat to be used for an office building. For those types of facilities, off-design outdoor conditions may result in a humid indoor environment. Alternatively, to address occupant complaints of discomfort, the thermostat setpoint may be lowered, thereby reducing the indoor humidity level. However, without reheat control, this action can lead to complaints because the space is too cold. Poor indoor environmental conditions typically result in worker/occupant discomfort and decreased productivity.

Another problem with the conventional process is that of microbial and fungal growth that can occur in condensate drain pans. These growths can be carried into the ductwork and deposited where further growth can occur. Microbes and bacteria can be introduced into the space from breeding grounds in the pan or ductwork, causing occupant discomfort and possibly allergic reactions or illness. Reheat will not solve this potential problem. Biological fouling of ducts may pose a serious problem in sensitive spaces that require a sterile environment, such as operating rooms.

To summarize, potential problems with the conventional process are:

1. Difficulty in providing satisfactory indoor environmental conditions when off-design outdoor conditions are experienced
2. The increased first cost and, particularly, the increased operating expense when the conventional system is modified with reheat control to provide satisfactory environmental conditions when off-design outdoor conditions are experienced
3. Difficulty in modifying existing conventional systems to handle the additional outdoor air cooling load resulting from the increased ventilation rates called for by ASHRAE Standard 62-1989
4. Indoor air quality problems due to microbial or fungal growth in condensate drain pans and ductwork.

Possible Solutions Offered by Desiccant Dehumidification

Desiccant dehumidification equipment can, in many cases, address the problems created by the conventional air-conditioning process. Desiccants are materials that can directly remove moisture from the air, and are basically of two types: (1) a solid material such as silica gel that is deposited on the flutes of a rotating honeycomb wheel, and (2) a liquid that is sprayed into the air stream to remove moisture. The dehumidification process is similar for each type. For simplicity, the following discussion focuses on solid desiccant equipment.

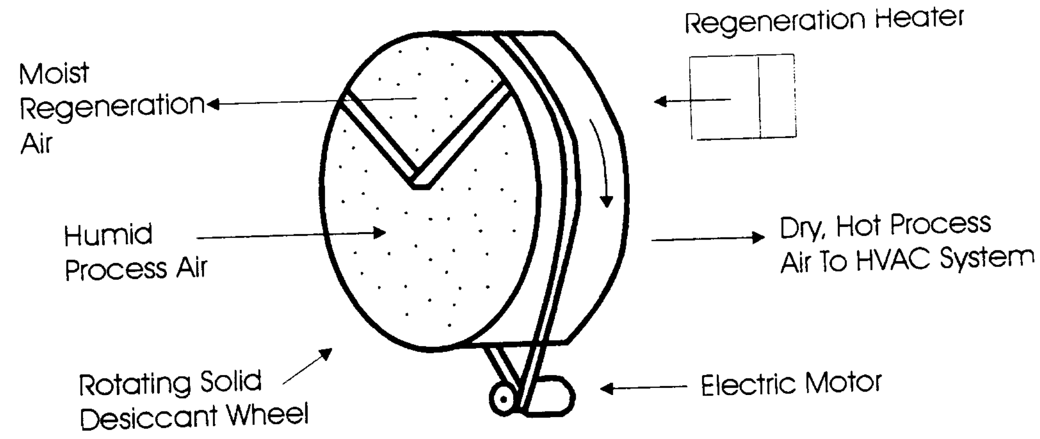

Figure 1. Desiccant wheel operation.

Figure 1 shows the desiccant wheel operation. Humid process air passes through the desiccating portion of the desiccant unit where the air is dehumidified. The humid air experiences a significant increase in its dry bulb temperature due to the latent heat of vaporization of the water that was removed and the temperature of the wheel due to the heat of the regeneration air. The desiccant wheel, belt- or chain-driven by an electric motor and laden with moisture from the process air, rotates slowly (-0.2 revolutions/minute) into a separate hot air stream, which removes that moisture, so the “regenerated” desiccant can again absorb moisture when it rotates back into the humid process air stream.

Figure 2 shows the desiccant wheel relative to the other components typically provided to make the system work. Note that two modes of operation are shown: *Recirculation* and *Ventilation.* The choice between modes depends on first cost differences, the specific building application, utility rates, and climate. Regardless of the mode of operation, two separate fans are used, one to move the process air, and the other to move the regeneration air. On the process air side, the humid process air typically enters the desiccant at state 1 and emerges at state 2, dryer and hotter. The hot, dry process air at state 2 then passes through a heat exchanger where it is sensibly cooled to state 3. Usually, the process air at state 3 is still too warm to deliver to the space to effect sensible cooling. Consequently, some final element such as a direct evaporative cooler or cooling coil is used to condition the air to state 4 before its entry into the space.

On the regeneration air side, exhaust or outside air at state 5 passes through a direct or indirect evaporative cooler to reach the condition at state 6. This air is cooled so that it can, in turn, cool the heat exchanger, after which the air is at state 7. The air at state 7 is then heated by the regenerator to the much higher temperature at state 8. Then. from state 8 to state 9. the hot air regenerates the

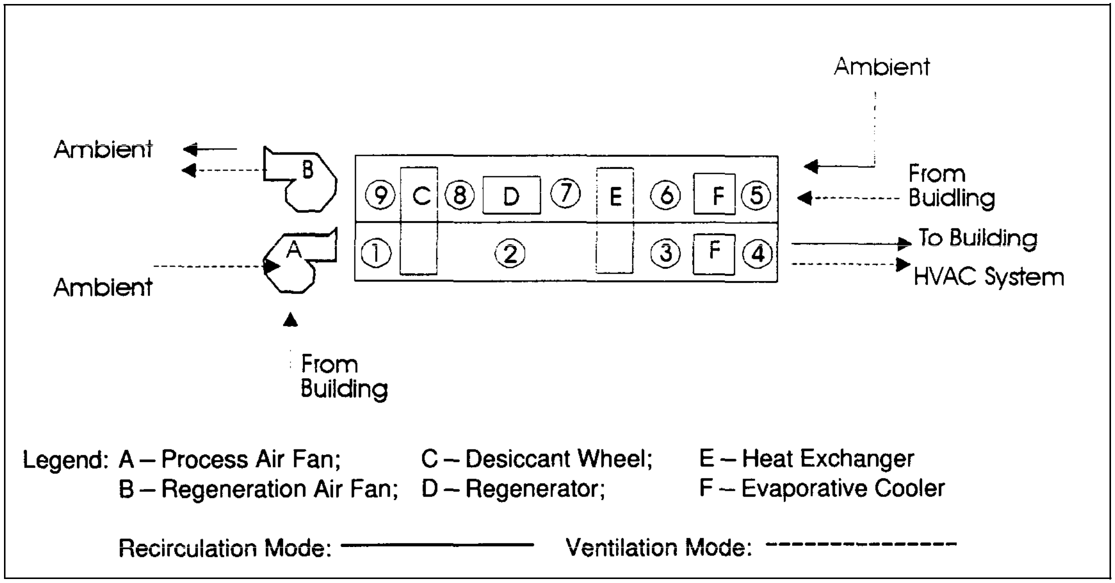

Figure 2. Desiccant wheel relative to other components.

desiccant. It is not readily apparent why air, the basic purpose of which is to regenerate the desiccant, should be initially cooled from states 5 to 6. In fact, if relatively inexpensive evaporative cooling is used, the lower temperature at state 6 allows the heat exchanger to cool the process air more effectively. Also, the heat recovered and transferred to the regeneration air increases its temperature and reduces the amount of energy that must be supplied by the regenerating heater. The heat exchanger may be a plate-type heat exchanger, thermal wheel, or heat pipe, depending on the desiccant unit manufacturer. (The latter two types are the most common.) For all types, the energy transferred is principally sensible heat. The thermal wheel is driven in a manner similar to the desiccant wheel, but considerably faster (10 to 20 revolutions/minute).

There are several possible mixes of air to be desiccated: (1) 100 percent outside air, all desiccated; (2) only outside air desiccated, then mixed with return air; or (3) outside air and return air mixed, with the mixture desiccated. In most cases, some final dry bulb temperature reduction will be required, usually requiring a cooling coil. However, this coil should have to do little, if any, further dehumidification. Using the desiccant for dehumidification has enabled the decoupling of the dry bulb cooling and dehumidification processes, allowing the cooling coil to do sensible cooling with minimal latent cooling. This decoupling enables the desiccant system to address humidity control problems with the conventional system:

1. The desiccant will provide almost all the dehumidification required for the air to be supplied to the space to meet the space latent load, under all outdoor air conditions. The cooling coil will provide the sensible cooling required and remove residual moisture (if any) so that the air introduced into the space will be able to meet the space sensible and latent cooling loads.

2. The desiccant unit is generally large and heavy and will result in increased first cost compared to adding reheat to a conventional system. However, installing a desiccant will result in reduced operating cost compared to a conventional system with reheat where the cost of electricity is high compared to natural gas (fuel typically used as the energy source for desiccant regeneration). The user needs to bear in mind that electrical billing for DOD facilities typically has two components, an energy charge and a demand (power) charge. The demand charge can be a significant portion of the total cost for electricity. When electrically powered equipment would otherwise be used to provide latent cooling, desiccant dehumidification will reduce both electrical demand and electrical energy consumption. Energy consumption for reheat would be eliminated. Subcooling to ensure adequate moisture removal would not be necessary. A dry cooling coil to enhance heat transfer may actually permit an increase in evaporator temperature without sacrificing sensible cooling capability.

   With the air in the space drier due to the desiccant's deep dehumidification capacity, it may also be possible to increase the dry bulb temperature setpoint for the space without sacrificing occupant comfort. Latent cooling using desiccation may be almost free in circumstances where waste heat is available, (such as from a natural gas engine-driven chiller). Latent cooling through desiccation, instead of by subcooling the air stream using electrically-powered equipment, can also provide environmental benefits. This occurs when the primary energy source for desiccation is clean-burning natural gas, which displaces electrical energy generated by a coal- or fuel oil-fired power plant.

3. Installing a desiccant unit may well be the least-expensive way to retrofit a facility to ensure compliance with ASHRAE Standard 62-1989. Increasing the amount of ventilation air will increase the sensible and latent cooling loads imposed on the cooling coil. (The exception, of course, would be when outside air conditions and a facility cooling load warrant air-side economizer operation.) The latent cooling capacity of the desiccant can make an equivalent amount of capacity available in the chiller or direct-expansion equipment, allowing that equipment to meet the additional sensible cooling loads due to increased ventilation air flow. Similarly, the cooling coil may well experience no increase in total load, with the increase in sensible load from the outside air negated by the desiccant removing most of the outside air latent load that the cooling coil formerly had to remove, plus the additional latent load due to the increased amount of ventilation air. Further, the cooling coil should perform more effectively since sensible heat ratios will be higher.

4. All the foregoing discussion leads to the conclusion that microbial or fungal growth in the condensate drain pan and ductwork should be eliminated or

greatly reduced since the cooling coil will be dry most of the time. Types of facilities where desiccant technology may be applied for performance and economic advantage include: refrigerated warehouses, ice rinks, supermarkets, laboratories (requiring close tolerance on relative humidity and/or with significant makeup air requirements), educational facilities, humidity-controlled warehouses, lodging facilities, commissaries, and medical facilities (particularly operating rooms).

Costs and Benefits

The main factors that will determine the amount of energy and energy cost savings realized by installing a desiccant system have been covered already. The desiccant unit will require electrical energy for the process and regeneration fan motors, the fractional horsepower motors required to drive the desiccant wheel and (if used) thermal wheel heat exchanger, the hot water circulating pump motor when hot water is used for desiccant regeneration, and for any evaporative cooler water pump motors. The largest energy use by the desiccant unit is for the heat required to regenerate the desiccant material. Generally, this heat is produced by natural gas combustion. To undertake an accurate analysis, the user will have to make a preliminary selection of a desiccant unit suitable for the application and obtain manufacturer's data regarding motor horsepower and regeneration energy requirements for the anticipated modes of operation.

Another cost consideration is the cost to provide the final sensible cooling to decrease the dry bulb temperature of the process air stream before its introduction into the space. The user must be sure to include the cost for electrical demand. The demand charge is a cost for electrical power (kW), not electrical energy (kWh). Weighed against the desiccant unit's energy and electrical demand costs would be the energy and demand costs for the conventional system to deliver the same amount of air to the space at the same conditions. To ensure a fair comparison, costs should be included for any dry-bulb subcooling and reheating that would be required for a modified conventional system to provide the same indoor conditions as the desiccant system for all outdoor conditions occurring when dehumidification and/or sensible cooling would be required.

Sample Cost Summary

This example is for a desiccant unit placed on an Avionics facility in Jacksonville, FL. The local natural gas cost is $0.35/therm and the local electricity cost is $0.068/kWh. The electrical demand charge is part of the base rate ($0.068/kWh), so the cost summary does not include a separate cost for demand. The desiccant unit capacity is 5670 cfm and that amount of desiccated air is mixed with 15,130 cfm of return air. This system operates approximately 7050 hours per year. The desired conditions in the conditioned space are 75 “F and 42 percent relative humidity (RH). The return air is typically 78 “F and 62 percent RH. The energy use and cost comparison is between a conventional cool/reheat system with steam for reheat (at a cost of $14.75/MBtu) and a cooling system retrofitted with a desiccant dehumidification unit to dehumidify the outside air. The desiccant unit energy consumption is based on data from ICC/Engelhard. The desiccant unit is expected to last 20 years, with a major overhaul scheduled for the tenth year for life-cycle cost calculations. The cost of the 5670 cfm unit is approximately $61,000. Installation costs are estimated to be $75,000 for a roof-mounted unit of this size. The maintenance requirements are estimated to be 100 hours per year for this unit. The maintenance labor costs, using a cost of $35.00/hour, would be $3500/year.

Table 3 was developed using a preliminary energy and economics analysis spreadsheet created for use in screening candidate sites for desiccant technology application. USACERL developed this screening tool to evaluate potential projects. The primary inputs necessary for this screening include building function, size of area, local utility rates, local weather data, description of current system, and conditioned space requirements. The payback period on the investment is then:

[Initial Cost, Installed] /[Annual Energy Savings-Annual Labor Cost]

or:

[$61,000+ $75,000] /[$25,589 - $3500] = 6.16 years.

Life Cycle Cost/Benefit Prediction

Table 4 includes a sample life cycle cost analysis for retrofit of a system with a 5670 cfm desiccant unit. The LCC estimate is based on a comparison of an existing

Table 3. Cost comparison of conventional vs. desiccant systems.

	Conventional System	With 5670 cfm Desiccant
Electricity Rate ($/kWh)	0.068	0.068
Natural Gas Rate ($/therm)	0.35	0.35
Annual Electricity (kWh)	674,327	544,911
Annual Natural Gas (mcf)	0	2,000
Annual Electricity Cost ($)	45,517	36,781
Annual Natural Gas Cost ($)	0	7,080
Annual Reheat Cost ($)	23,933	0
Total Annual Cost ($)	69,450	43,861
Annual Savings ($)		25,589

conventional system using reheat against the existing system retrofitted with a desiccant unit, which essentially eliminates the need for reheat. The conventional system is considered to be the baseline case, and the costs associated with the desiccant unit for Annual Maintenance, Total Maintenance, and Major Repair/Replace are incremental costs associated with the desiccant system in a retrofit situation. To be conservative, no credit was taken for the extended life and reduced maintenance anticipated for the portion of the existing system that will continue in use with the desiccant unit. The system with the desiccant unit was modeled with annual costs and capital costs as described previously for a unit at an Avionics facility near Jacksonville, FL, using the weather data and utility costs applicable for that site.

Utility and Space Requirements

In planning possible use of desiccant dehumidification equipment, the user must consider whether electricity, water (for evaporative cooling), and an energy source for desiccant regeneration (usually natural gas) will be available at the site in sufficient quantity. Natural gas supply pressure also needs to be considered. If these items are not already available, the cost of utility improvements will need to be added.

Other siting considerations include unit size and weight, and clearances required for safety, maintenance, and adequate air flow. This latter information is usually available from vendors. Before considering these siting issues, the user should examine performance data supplied by various desiccant vendors and tentatively select models that will provide the degree of dehumidification required for the application under consideration. Desiccant units can be roof-mounted (with appropriate curbs supplied by the vendor) or ground-mounted. If roof-mounted,

Table 4. Life-cycle cost analysis for system retrofit.

	Conventional System	With 5670 cfm Desiccant
Capital Cost ($)	0	136,000
Annual Energy Cost ($)	69,450	43,861
Total Energy Cost ($)	1,736,250	1,096,525
Annual Maintenance Cost ($)	0 (no change)	3,500
Total Maintenance Cost	0 (no change)	87,500
Major Repair/Replace Cost ($)	0 (no change)	37,500
Total Life-Cycle Cost ($)	1,736,250	1,357,525
Savings ($)		**378.725**

provisions should be made for safe access to the roof. The structural strength of the existing roof and supporting framing needs to be checked for adequacy. Aesthetics are a consideration for either roof- or ground-mounting. Roof-mounted units may have to be located away from the edges of the roof, or behind a parapet wall, to minimize visibility of the unit. Ground mounting may require the use of a screen wall. A partial list of vendors can be found in Appendix A. Additional information is available in the *Natural Gas Cooling Guide* published by the American Gas Cooling Center.

3 Acquisition/Procurement

Acquisition/Procurement Strategy

In general, the initial step in the acquisition process is design accomplished under a design contract. However, because this is a fairly complex technology to apply, a preliminary analysis/concept design should be performed before a full scale "design." Construction then follows based on the design plans and specifications incorporated into a construction contract. Within the DOD, project specifications are usually an assembly of generic guide specifications edited to address the specific requirements of a particular project. Guide specifications for particular items of equipment generally result from considerable research and experience with different types of equipment intended to perform a given task or function. They are usually based on technical criteria and guidance developed within the Government and refer to standards that industry has developed for the equipment and/or its components. Over time, the guide specification writer eliminates parts of the guide specifications that allowed equipment that performed inadequately or failed prematurely to be procured and installed. Portions of guide specifications dealing with equipment that has performed well are retained.

The Huntsville Division of the Corps of Engineers is currently developing guide specifications and technical guidance for desiccants for DOD facilities. However, designers of DOD commissaries have been specifying desiccants for their facilities for about 10 years and have developed guide specifications for the desiccants appropriate for their facilities. Alternative approaches to the typical design and construction scenario outlined above are available. An integrated design/build approach does not usually include guide specifications. Rather, a Request for Proposals (RFP) is issued that indicates the functional and performance requirements for a project to prospective offerors. The Government then reviews the proposals and selects the one that offers the best value in satisfying the requirements indicated in the RFP. This approach is one possible way to get a satisfactory desiccant system installed in the absence of Government guide specifications or technical criteria or guidance. Appendix B to this report includes an example of a contract scope of work, and Appendix C includes sample equipment specifications.

Potential Funding Sources

In retrofit applications, a desiccant unit might be installed to reduce utility costs where the existing method for dehumidification is more expensive, or to provide dehumidification where the existing method is inadequate. In the former case, funding through either the Federal Energy Management Program (FEMP) or (for larger projects) the Energy Conservation Investment Program (ECIP) maybe viable options. In the latter case, regular O&M finding would seem appropriate to effect repair of an inadequate system. Additionally, special technology demonstration programs may have funding available that can be used to renovate or replace existing systems. Bear in mind that some utilities provide incentives through rebates for installing desiccant equipment; they may be able to assist their customers with advice on design strategies and installation work.

Procurement Documents

As for DOD construction projects in general, a project to install a desiccant unit will typically require completion and approval of a DD Form 1391 programming document. For FEMP- and ECIP-funded projects, an analysis is also required to demonstrate that certain economic criteria will be satisfied, which justifies use of those categories of funding. It is recommended that base-level planners and programmers have the required documentation complete and ready for submittal in response to call letters for energy-funded projects. Regular O&M funding for desiccant projects will typically depend on their priority versus other projects, as determined by an installation facility board.

Procurement Scheduling

The equipment normally required with installation of a desiccant system, such as controls, ductwork, and utility connections, is generally standard and readily available. For roof-mounted units, the facility should ensure the availability of a crane (or helicopter) for lifting the desiccant system to the required location. Also, any structural support work needed to stabilize a roof for roof-mounted systems should be planned well ahead of time.

Except for particularly large units, or units with special optional features, the customer can typically expect to have a unit delivered within 12 weeks of the actual order. Remember to allow time for the procurement staff to process the request to purchase the desiccant unit. Two weeks is usually adequate for paperwork to be processed, but be aware that year-end deadlines may apply to orders during September.

Design Considerations

The design needs to revisit the potential problems mentioned above (p 6). Decisions must be made regarding the source of the air for desiccation (100 percent outside air supplied to the space, outside air subsequently mixed with return air or outside air and return air mixed, then desiccated), the source of air for regeneration (outside air, exhaust air, or a mixture of the two), medium for regeneration (steam, hot water, or products of (direct or indirect) combustion, and method(s) for process air post-cooling.

The designer should thoroughly examine the existing HVAC systems already serving the spaces to determine how the unit should interface with the existing equipment, from a control as well as physical standpoint. The sequence of operation and a control diagram for all fans, pumps, and operators for dampers and valves should be provided on the design drawings. Internal controls to be provided as an integral part of the desiccant unit should be specified as such. Ladder diagrams showing safety interlocks and all on/off controls should be provided. Proper control design, installation, and documentation are paramount if the desiccant unit and the entire HVAC system are to meet the requirements of the spaces to be served.

The designer should indicate in the specifications that complete O&M manuals are to be provided for the desiccant unit. Manuals will clearly explain the function of each major component of the desiccant unit (desiccant wheel, regenerator, etc.) and indicate maintenance intervals and procedures for all unit components for which maintenance will be required. Manuals will contain control drawings and schematics as outlined in the preceding paragraph. Specifications should also indicate that the contractor and desiccant unit manufacturer will provide training (clearly specifying the duration and number of trainees) regarding operation of the desiccant unit and the HVAC system of which it is to be a part. Such training may be omitted if maintenance will be performed under a service contract. Strong consideration should be given to entering into an extended warranty agreement. The designer must design for maintainability, and ensure that clearances around the unit are in accordance with the manufacturer's recommendations and do not compromise safety, access, or performance.

Construction Considerations

It is highly recommended that the project specifications require detailed contractor submittals for the desiccant unit itself and the HVAC/desiccant controls. These submittals and all contractor substitution proposals should require "E [Engineer]-level" review and approval or disapproval. It is further recommended that the Government contract with the designer to provide these services as an extension of the design. It is also recommended that the designer develop the as-built drawings for the project.

4 Post Acquisition

Acquisition Scheduling

In many cases, it is best to install the system in fall or winter so that normal air conditioning system operation is not disrupted during construction. Spring would also be an acceptable time, but if delays are encountered, the facility could be forced to incur downtime for construction/installation during the summer. If a facility does not have critical AC needs, the desiccant system could be installed during summer months. Standard installation should not require more than a few days of interruption to operation of the system being modified.

Commissioning

The entire system should be tested under normal and extreme operating conditions. Simulation of design-day performance and off-design performance should be performed immediately after installation and before final acceptance is issued. The commissioning process can be performed by the customer or by a third party. Written schedules and logs for recording maintenance should be provided and kept near the unit for convenience. Laminated schematics and preventive maintenance guides should be provided and kept near the desiccant unit as well.

It is also recommended that the operators attend a detailed training session on the equipment before the customer issues final acceptance of the system. The training should include on-site instruction and written materials, an explanation of the concept of desiccant dehumidification and its role in modern HVAC systems, description of the system components, analysis of the internal operation, recommended preventive maintenance to be scheduled and performed, troubleshooting tips, and a manufacturer's point of contact for warranty issues.

Operation and Maintenance Issues

Routine maintenance procedures are required to achieve optimal system performance:

1. Inspect and replace filters at intervals recommended by equipment manufacturers.
2. Lubricate desiccant and heat exchanger wheel bearings twice per year.
3. Lubricate fan motor bearings twice per year.
4. Check/clean evaporator pads at the beginning and end of the cooling/heating seasons.
5. Check controls and settings twice per year.
6. Clean unit, fans, and coils as required by conditions (at least annually).
7. Repair any broken or defective part whenever reported or found (immediately).
8. Report to Post Engineer any problem when found (immediately).
9. Balance system and optimize performance of units based on loads twice per year.
10. Tune burners at least once per year (when applicable).

Performance Evaluation

The performance of a desiccant unit and the HVAC system it operates within can be evaluated through use of Energy Management System (EMS) equipment or a separate data logging computer and sensors. Feedback from occupants, measurements of temperature and humidity in the occupied space, and inspection of materials in the occupied space also serve as important indicators in the evaluation of the performance of the desiccant equipment.

Data should be collected from each desiccant dehumidification system for a period of 90 calendar days during the summer and 90 calendar days during the winter. The monitoring should be consistent with the Data Acquisition and Database Management (DADM) standard system monitoring protocol with 15 minute (or less) scan intervals. The system should record, at a minimum, the following measurement points or equivalent points such that system performance, thermal efficiency, and electrical efficiency, can be determined:

1. Outdoor ambient temperature
2. Outdoor ambient relative humidity
3. Building supply air temperature
4. Building supply air relative humidity
5. Heating coil leaving temperature
6. Supply air stream pressure drop through system
7. Electrical energy consumed by desiccant unit
8. Regeneration energy consumption of desiccant unit
9. Runtime for each air-conditioning (A/C) units serving the site
10. Air temperature in the occupied space(s)
11. Relative humidity in the occupied space(s).

Note that sensors that need to be placed inside the desiccant unit can be installed by most manufacturers before the unit is shipped. This protects the customer from potentially voiding the warranty due to damage to the equipment that could occur during installation of internal data collection devices. Meters should be included in the design documents for the energy supply lines and installed along with the utility lines.

Appendix A: Vendors

Company	Phone/Fax
Airflow Company DRYOMATIC General Products Group	301/695-6500 301/631-0396
Engelhard/ICC	21 5/625-0700 21 5/592-8299
Kathabar Systems Division, Somerset Technologies Inc.	908/356-6000 9081356-0643
Munters Corporation DryCool Division	210/651-5018 21 0/651-9085
Seasons 4 Inc.	404/489-071 6 404/489-2938
SEMCO Incorporated	314/443-1481 314/443-6921

Appendix B: Example Scope of Work for Two-Wheel Desiccant Dehumidification Systems

1.0 General

1.1 Delivery Order Title: Install two-wheel desiccant dehumidification systems for Buildings 247,249, and 251 and connect them to the existing makeup air ducts.

2.0 Description

2.1 Existing Conditions: The current condition of the HVAC system warrants the implementation of a desiccant dehumidification to assist in the control of air quality in the facility.

2,2 Project Description: The objective of this project is for the contractor to provide all labor, materials, and equipment necessary to complete the following requirements in accordance with all installation, State, and Federal codes and laws. To accomplish this objective, under Section C of the basic contract and the following sections, the Contractor shall:

a. Coordinate all remediation activities with facility personnel, prior to installation, to minimize interruption to normal operations. The facility shall not be deprived of critical cooling during the remediation period.

b. Identify all existing asbestos in the work area that would be disturbed as a result of this delivery order. If no asbestos is found, the Contractor shall certify its absence. If asbestos is present, the Contractor shall identify all existing asbestos insulation, indicating which areas would be disturbed as a result of this delivery order. The Contractor shall certify that all asbestos has been removed in accordance with the removal plan which has been approved as part of the work plan.

c. Prepare the existing equipment for connection to the new two-wheel desiccant dehumidification system. Repair/modify existing building intake duct and/or mixing box to accommodate installation of the two-wheel desiccant system.

d. Provide new two-wheel desiccant dehumidification systems sized to provide the appropriate amount of dehumidified air for each of the basement makeup air units on Buildings 247, 249, and 251. The desiccant system shall be covered by a five (5) year warranty on all parts and labor. Requirements for desiccant systems are defined in Attachment A (Reference: Appendix B).

e. Install the new two-wheel desiccant system with concrete pad, proper intake and exhaust dampers, ducts, vibration isolation, valves, piping, insulation, electrical safety disconnect, gas safety disconnect (double block valves and bleed line), controls, control panel interconnected with the existing system and controls, and accessories as required (Reference Appendix B).

f. Provide and install all data collection equipment as described.

g. Dispose of scrapped parts and materials in accordance with installation, local, State, and Federal regulations.

h. Restore the project site to its original configuration including replacement or repair of items damaged, modified or removed during the project.

2.3 Technical Criteria: Technical criteria for the above described work shall be as defined in Section C of the primary contract and by the following:

2.3.1 Air-Conditioning & Refrigeration Institute (ARI)

2.3.2 American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)

2.3.3 American Society of Mechanical Engineers (ASME)

2.3.4 American Society for Testing and Materials (ASTM)

2.3.5 American Welding Society (AWS)

2.3.6 Military Specifications (MS)

2.3.7 National Fire Protection Association (NFPA)

2.3.8 National Electrical Manufacturers Association (NEMA)

2.4 Technical POC:

3.0 Services to Be Performed: Services listed shall be in accordance with Section C of the primary contract except as amended herein.

3.1 Site Survey Proposal: The site survey proposal shall be as defined in Section C of the primary contract.

3.2 Site Survey: The Contractor shall survey the proposed desiccant system site and gather all information necessary for sizing, planning, and completion of the installation of the prescribed two-wheel desiccant system and its ancillary equipment. The Contractor shall also verify in the field the location and size of existing equipment and verify that the recommended desiccant system is correctly sized to provide the dehumidification required for this application. The Contractor shall also determine the feasibility of installing a steam to hot water heat exchanger to supply the necessary thermal energy to the desiccant system instead of using a boiler (normally included with the desiccant system) housed within the desiccant unit to supply thermal energy.

3.3 Site Survev Report: The Contractor shall provide a written report of the results of the site survey within 2 weeks of completion of the site survey. The report shall include all information gathered and verification of the site data and proper equipment selection for the application.

3.4 Work Plan: The work plan shall be as defined in Section C of the primary contract except as amended herein.

a. Deletions: None

b. Additions:

1) To facilitate the preparation of the work plan, the Contractor will be allowed to visit the site to become familiar with existing field conditions. Each site visit shall be coordinated with the Contracting officer and installation personnel. As part of a site visit, the Contractor shall investigate the site and facility as necessary to prepare the work plan. The Contractor shall evaluate and document in the work plan the accessibility of all areas where field efforts will occur. The Contractor shall investigate and document the presence of asbestos in the work place. Location, type, and amount of asbestos shall be documented. A plan and a cost proposal for locating, labeling, handling, removing, storing, and disposing of any asbestos present in accordance with installation, state, and Federal laws and codes shall be submitted. Minimal disruption to the remediation action schedule shall be of primary importance in asbestos removal. All investigations taken shall be in accordance with JCAHO standards. The Contractor will be allowed to review existing as-built drawings, maintenance records, and other pertinent documentation as approved by the Contracting Officer. The Contractor may interview on-site maintenance personnel and staff to determine the existing conditions of the site or facility as approved by the Contracting Officer. Information necessary to adapt the generic Site

Safety and Health Plan (see DID MFRP005, Paragraphs 10.2.1, 10.2.2, and 10.2.3 for details) and Site Quality Control Plan shall be gathered and documented to prepare project adaptation documents. The Contractor shall only investigate areas that are pertinent to the work items defined by this delivery order. The contractor shall identify the areas where cost reductions may be accomplished in lieu of performing any of the proposed project items. A report of findings from the site visit shall be included as part of the work plan submittal.

2) The work plan shall specifically detail the techniques for removing and disposing of the existing equipment as necessary and installing the two-wheel desiccant system(s) and ancillary equipment required by this delivery order with a minimum of interference with facility operation.

3) The work plan shall specifically detail phasing of remediation so that the facilities HVAC requirements shall always be maintained during remediation activities.

3.5 Negotiations: The negotiations shall be as defined in Section C of the primary contract.

3.6 Remedial Action: The remedial action shall be as defined in Section C of the primary contract except as amended herein. A pre-remediation conference will be scheduled at _ on a date to be determined by the Contracting Officer.

a. Deletions:

b. Additions:

4.0 Site Security and Safety Site security and safety shall be in accordance with the primary contract and/or in accordance with the Contracting Officer.

5.0 Document Schedule

5.1 The preliminary work plan, adapted site safety and health plan, and adapted quality control plan shall be completed no later than_. The final submittal, if required, shall be made no later than 3 weeks after receipt of the preliminary comments. Monthly progress reports and telephone log shall be submitted as defined on DD Form 1423 in Section C of the basic contract. The site specific remediation report, operating and maintenance manual, list of standard and equipment and service organizations, and as-built drawings shall be submitted within 2 weeks after completion of remediation. All activities required by this delivery order shall be completed no later than _ calendar days after award.

5.2 Presentations and Meetings (Reviews): One formal review of the deliverable is anticipated at the facility site to review final plans, details, and arrangements pursuant to beginning on-site work.

5.3 Submittal List:

Agencies Number of copies

a. Project Manager

b. Facility Point of Contact

c. Installation Representative

d. Corps of Engineers Office (USACERL)

e. MACOM Representative.

6.0 Enclosure: Attachment A, Two-Wheel Desiccant Dehumidification/Cooling System Specifications (Reference Appendix C).

Appendix C: Sample Specifications for Two-Wheel Desiccant Dehumidification/Cooling System

Note: the following specification is presented for standard product construction and performance. Certain applications may call for options or specials. This specification must be edited accordingly.

Standard Suggested Specification

Desiccant Air Handling Units

I. General:

1. Unit shall be a complete, factory assembled and tested air-conditioning system. Design shall use two-wheel, hybrid type desiccant cooling, using regeneration heat supplied by a gas-fired boiler. Manufacturer must have similar two-wheel systems installed and operating for a minimum of — years. Unit must be per the specifications herein without exception unless approved by the specifying authority in advance of bid.

2. Unit construction shall include supply fan, regeneration fan, hot water or steam boiler or gas burner, desiccant wheel for dehumidification, thermal wheel for sensible cooling, heat transfer coils, controls, and housing as specified herein to form a complete packaged system.

3. Performance shall be as shown on the Schedule and as specified herein.

II. Unit Construction:

1. General - Housing shall be suitable for outdoor installation. It shall be designed for either structural or curb mounting without field modification. The

enclosure system shall be air-tight (2 percent maximum leakage at 150 percent design static pressure) from section to section.

2. Base - The unit base shall be constructed of formed steel coated with appropriate primer and paint. Cross members will be located to support each major component. The longitudinal members will be fitted with lifting lugs.

3. Housing - The unit housing and internal partitions shall be constructed of minimum 18 GA galvanized steel with the exterior panels treated to allow for painting. All external walls shall be insulated with foil-faced fiber glass insulation at least 1 in. thick and secured by permanent mechanical fasteners welded to the panels. Adjoining panels shall be sealed to one another with a silicone or equivalent compound.

4. Removable service access panels shall be provided for all components. The openings shall be of sufficient size to allow service to all maintenance items. All service panels shall be provided with resilient gaskets and hardware to assure compression. Hinged access doors shall be provided for boiler and control sections.

5. Roof- Roof panels shall be sealed to provide a weather-tight enclosure.

6. Finish - The exterior shall be painted with a beige (or other agreed upon color) low gloss enamel.

III. Supply and Regeneration Fan Assemblies:

1. The unit shall be equipped with belt driven blowers and employ backward curved impellers for regeneration air and supply air. Blowers shall be AMCA rated.

2. V-belts rated for 150 percent of motor horsepower shall be used on each fan. The motor sheave on the supply air blower shall be adjustable to allow for air balancing at installation.

3. The motors shall be NEMA design B with open drip-proof housings and a service factor of 1.15 or more, sized as shown on the Schedule.

IV. Desiccant Dehumidification Wheel:

1. Supply and regeneration air streams shall be counterflow. The dehumidifier shall be a rotary type designed for continuous operation. The wheel structure shall be of the extended surface type in the axial flow direction and the geometry

shall provide for laminar flow over the operating range for minimum air pressure differentials.

2. The dehumidifier shall be complete with a drive system utilizing a fractional-horsepower electric motor and speed reducer assembly driving the rotor. A slack-side tensioner shall be included for automatic take-up for belt-driven wheels.

3. The desiccant material shall be adsorption or absorption type material such as silica gel, titanium silicate, or equivalent desiccant material.

4. The wheel shall be fitted with full-face, low-friction contact seals on both sides to prevent cross leakage.

V. Thermal (Sensible Heat Exchanger) Wheel:

1. Ambient cooling shall be provided by an air-to-air heat exchanger. The exchanger shall be of the rotary regenerative type. Supply and cooling air streams shall be counterflow and the component fitted with full-face, low friction contact seals on both sides to prevent leakage.

2. The rotor structure shall be non-hydroscopic to minimize the transfer of water vapor and shall be coated for corrosion resistance. The structure shall be of the extended surface axial flow type and the air flow shall be laminar to minimize air pressure differentials.

3. The drive system will be complete with a fractional-horsepower electric motor. close-coupled speed reducer.

VI. Heat Transfer Coils:

1. Regeneration and supply heating coils shall be of the finned tube type mounted in each air stream to provide for desiccant regeneration and space heat. They shall be constructed of seamless copper tube mechanically bonded to aluminum fins. The coils shall include a flanged, heavy-gauge, galvanized steel housing by which they are mounted in the unit. Circuiting shall be counterflow.

2. Each coil shall be suitable for use at pressure up to 150 psig, and tested to 400 psig.

3. Coils shall be sized for performance as shown on the Schedule.

VII. Boiler or Thermal Supply:

We may be able to specify a steam to hot water heat exchanger to be installed in mechanical room and supply hot water/glycol mixture to the desiccant unit when gas is not readily available.

1. The boiler shall be gas fired water heater suitable for delivering fluid temperatures of 210-220 °F. It shall include a stainless steel combustion chamber and copper tube exchanger. It shall be AGA certified and complete with all controls, including a combination gas valve, automatic pilot spark ignition system, auto reset high limit control, and supply water control temperature sensor.

2. Hydronic system shall include properly sized diaphragm, which shall be flexible butyl securely attached to inner tank wall with steel retaining ring. Maximum allowed working pressure shall be at least 100 psig, and 240 °F temperature.

3. Circulating pump shall be close coupled and single stage design. Pump volute and impeller shall be of appropriate metals, enclosed type, dynamically balanced, keyed and secured to the shaft by lock cap screw or nut. Pump shall have heavy-duty grease lubricated ball bearings adequate for maximum motor rating load. Motor shall meet NEMA specifications and shall be ODP type, sized for required performance.

4. Hydronic piping shall include appropriate copper tubing.

VIII. Air Filters:

1. Air filters shall be provided for the process and regeneration airflows.

2. Air filters shall be 2-in. deep pleated disposable type, minimum 30 percent efficiency (ASHRAE 52-76).

3. A supply of replacement filters for the first year of operation shall be included.

IX. Evaporative Cooler:

1. Evaporative cooler assemblies shall be provided to allow evaporative cooling of the supply air when appropriate.

2. Cooling media shall be made from cellulose paper or equivalent material which is impregnated to resist degradation.

3. Evaporative cooling pump shall include protective coating, thermal overload protection, and proper seal.

4. Piping shall be of appropriate material and include balancing valve to set proper water flow.

X. Electrical:

1. The factory wired unit shall be equipped with a central electrical control panel mounted inside the service compartment. A single power supply shall be required. All internal wiring shall be in accordance with the National Electrical Code. All electric components required for automatic operation, based on signals from space mounted humidity and temperature controls, will be included. Connections to remote devices will be made at the marked terminals.

2. Each three phase motor shall be wired to a separate three leg contactor with motor thermal overload protection. Fuses shall be provided for each motor larger than one hp. Transformers shall be provided as required for thermostat and humidistat operation.

XI. Services:

1. Start-up shall be provided by a factory employed or certified service technician.

2. Operator training shall be provided to installation personnel by a factory employed or certified service technician.

XII. Performance:

1. Dehumidification shall be accomplished by adsorption or absorption of water vapor by a desiccant. The unit will be capable of dehumidification, heating and cooling without the use of refrigerants or a compressor. Changeover from one mode to another will be accomplished automatically, as determined by the set points of space mounted sensors (by others). Operation modes shall be:

a. heat only
b. dehumidification with heat
c. dehumidification with ambient cooling
d. dehumidification with indirect evaporative cooling
e. indirect evaporative cooling.

2. Consumption of energy shall decontrolled to meet dehumidification load by maintenance of fluid temperature.

3. The heat transfer fluid for regeneration shall be a mixture of ethylene glycol and water with a freezing point of -20°F and inhibitors to minimize oxidation.

4. Regeneration air temperature shall not exceed 190°F.

5. Desiccant and thermal wheels shall have, respectively, a minimum moisture removal and heat transfer effectiveness for performance as shown on the Schedule.

XIII. Warranty: The apparatus manufactured by the Seller shall be free from defects in material and workmanship for a period of one (1) year under normal use and service and when properly installed. Obligation under this agreement is limited solely to repair or replace at manufacturer's option, at its factory or in the field, any part or parts thereof which shall, within twelve (12) months from the date of original start-up or eighteen (18) months from the date of shipment from factory to the original purchaser, whichever first occurs, be returned to manufacturer with transportation charges prepaid. The desiccant and thermal wheels shall be warranted (parts only) for five (5) years from date of shipment. Liability does include any labor charges for the replacement of parts, adjustments, repairs, or any other work done outside factory, and does not include labor to troubleshoot. Additional limitations and disclaimers may apply.