PHYSICAL SURVEYS OF OVER 300 BUILDINGS IN HOT AND HUMID CLIMATES INDICATE MATERIAL/DESIGN PERFORMANCE FLAWS EXIST IN COMPARISON TO EXPECTED RESULTS USING NATIONALLY ACCEPTED STANDARDS

Alexander E. Othmer /CEA /CBA/ ASNT III NDE Manager
State of Florida Department of Community Affaires Energy Conservation Assistance Program
University of South Florida Small Business Development Centers

ABSTRACT

Surveys conducted by the State of Florida Energy Offices ***E**nergy **C**onservation **A**ssistance **P**rogram* (***ECAP***) at the University of South Florida and other participating centers, over a 10 year period, have consistently shown that construction materials including windows, skylighting, insulation, and major HVAC systems components do not perform as well as expected in installed / finished product state. The end result is buildings designed with calculations taken from standard ASTM and ASHRAE formulas **do not deliver the comfort levels expected by the design engineers or the facility occupants.**

INTRODUCTION

The Energy Conservation Assistance Program was created in 1989 as a joint effort between the United States Department of Energy, the Florida Energy Office and the Florida Small Business Development Center Network. Funded with Petroleum Violation Escrow Funds (PVE), the focus of the program is to assist small business owners in being more competitive through reduced energy consumption, therefore reducing operational overheads. This allows them to be on a closer parallel with their larger corporate brothers, who statistically have a lower energy consumption per square foot due to their ability to hire internal energy specialists.

10 years of field analysis as shown that even recently constructed buildings (1997 to 1999) have continued to experience comfort, energy and indoor air quality problems though using the most up to date codes, standards and materials. The facilities range from single story residential units to 450,000 square foot multi story office buildings and include schools, museums and retail outlet stores.

Every Facility surveyed needed **additional retrofits** such as ***interior storm windows, modifications to the return air systems, additional dehumidification or ways to lower internal heat loads*** to create economical comfort levels acceptable for a healthy indoor environment. **Over 25%** of the buildings surveyed were new construction that **had not reached full occupancy levels.**

It is the **economic burden** of the **additional retrofits** to the **end user** (owner / occupant) that we will attempt to address in this synopsis. We are not attempting to offer engineering or scientific arguments but rather document our actual experiences as to real time conditions that we encounter on a daily basis.

Our experience has been that no particular material performance failure or design flaw can be attributed to a single source. The existing codes and reference standards used by the engineering and architectural community in selecting building materials seem adequate but only if used with a common sense approach. This should include the realization that the laboratory testing procedures conducted to determine factors such as ***U and R values*** used temperature variants that ***do not represent the actual weather conditions and thermal loads in Southern regions.*** Add to this factor the anomalies encountered with typical construction practices and the lack of enforcement of existing building codes and you can anticipate the magnitude of the problem.

A good majority of our client base comes from referrals of legitimate vendors involved with energy conservation devices. In some cases this is due to direct referrals but more frequently it is due to a query of a building owner/occupant that in an honest effort to reduce energy cost, has become confused, by the proposals set before them from utility companies, shared savings schemes and equipment / retrofitting contractors.

As our affiliation with the United States Department of Energy and the State of Florida Energy Office does not allow us to endorse a specific product, we are looked at as a impartial third party by our client base. As the above affiliations do not represent a single energy source provider we are at liberty to suggest any number of energy conservation measures that may be beneficial to the end user. This may include the use of **renewable and sustainable technologies** in conjunction with conventional sources to reduce the clients energy consumption.

Our program is also responsible for disbursing funds through the **Florida Energy Loan Program** (***FELP***). This program allows the end user to finance the installation of energy conservation measures with low interest (5%) loans provided by the Florida Energy Office. This is one of the reasons our program is popular and promoted by legitimate vendors of energy conservation devices.

It also presents a problem with some vendors of new technology in that a small manufacturer of a conservation device, having knowledge of the Florida Energy Loan Program, will attempt to have their devices finance through the State program. The problems occur when our office asks for performance documentation on the new equipment and or device. In most instances we will be given either case history studies or independent laboratory test results that show performance curves, but the testing procedures do not correlate or comply to any ASTM/ ANSI / ASEAM testing procedures.

With some of the newer products the standard testing procedures could not be used to properly determine actual performance. In other cases products that had been properly tested and on the market for decades did not perform as well, when installed in a facility, as the laboratory tests and performance specifications stated they would. This not only creates a embarrassment factor for the architect and design engineers but more importantly creates **additional overhead burdens** for the buildings **end user,** or in some cases the tax payer when government buildings are involved, who are paying the utility and equipment maintenance costs.

EVALUATING A BUILDINGS PERFORMANCE.

In our programs infancy, stage the latest codes and standards catalogs of all lighting products engineering specifications for heating, air conditioning, and violation equipment, literatures on window treatments, insulation materials and roofing systems, and along with our notebook computers with management software, were used to make a client's facilities more energy efficient.

With clipboard and tape recorder ready, every lighting fixture wattage, thermostat location, return air duct system, window size, with type and orientation, along with every millimeter of missing caulking and door sealant are recorded for evaluation.

Using standard procedures, the data was process. The results would normally concur with reports issued to the end user by the utility company or product/ retrofit vendor. Adding some alternatives, such as solar dehumidification, hot water and day lighting techniques would enhance the overall savings.

IMPLEMENTATION OF ENERGY CONSERVATION MEASURES

Our success rate pertaining to actual implementation of suggested conservation measures far exceeds the private sector norm. Approximately 93 % of our client base implements at least one suggested conservation measure within 120 days of receiving their final report from our office. This success rate is due to our approach on making recommendations. Unlike the utility companies, that normally focus on specific conservation methods that employ their rebate program materials/ devices and private vendors. Our program has the ability to suggest different conservation measures, that can be categorized as no or low cost to the end user.

END RESULTS (ACTUAL SAVINGS)

Using the standard formulas and procedures to calculate facilities load and process the data was relatively successful. Low and medium cost conservation measures that calculated out as having a potential to produce a 25% savings would perform close to that projection, half of the time. We considered this as not acceptable especially considering that every effort was made by our office to use the latest data, computer programs and manufacturers reference materials to estimate savings.

Another concern was that in some cases where high cost conservation measures, such as new chiller equipment, automated computer control systems and expensive window treatments the track record pertaining to the projected savings was not better. On these higher cost recommends the projected energy savings were compiled by large private sector corporations who were either the manufacturer of the devices being installed or professional energy management companies with world wide repetitions. The end results were significantly flawed in comparison to the actual savings being realized.

Another problem that occurred concerned our repeat client base. As stated before our reports normally containing low cost conservation measures. Normally, our clients are given advises pertaining to energy savings. This is the reason the clients elect to implement some of our free counseling recommendations as a first step.

The majority of the time these counseling measures show results on the only equation they are familiar with, their utility bills. After seeing reductions in utility cost using these methods, they normally contact us again and are willing to take the next step which normally involves a low cost conservation measure such as a window treatment. Our dilemma was that as the complexity and cost of the conservation measures increased the anticipated savings, regardless of who generated the figures, were not as reliable as expected.

CAUSE AND EFFECT

In some cases, normally larger facilities such as office buildings, government facilities and hotels, it was apparent that the client had contracted their facilities maintenance to every available energy management and equipment manufacturer available. In reviewing the documentation provided to us by the client it was apparent that during these contract periods virtually every modification that could be made was made. Company "A" would secure the contract and install $ 50,000.00 worth of retrofits, the projected savings would not be accomplished and comfort levels did not increase, results, the dismissal of company "A". Company "B" would secure the contract and install another $ 50,000.00 worth of retrofits, the projected savings would not be accomplished and comfort levels did not increase, results, the dismissal of company "B". Company "C" would secure the contract, install $ 50,000.00 worth of additional retrofits, the projected savings would not be accomplished and comfort levels did not increase resulting in the dismissal of company "C".

To add to the confusion our review of all the retrofits installed using standard software and reference materials indicated that the projected savings were accurate and should have worked.

The dilemma became quite involved, no apparent anomalies could be found with the newly installed equipment, all the specifications for the equipment met the existing codes and were calculated using prescribed test methods and yet the published performance curves used by the engineers to calculate the end result were not accurate. Our office struggled with this, what was causing these inadequate projections. Not every chiller came from the same manufacturer, no common thread their, not every duct system was installed by the same contractor, no common thread their, not every window treatment came from the same source, no common thread their and absolutely no reason for the lighting retrofits to not work, after all we all know a watt is a watt!

Then one day while seeking knowledge from our trustee GRANGER catalog it occurred to us that maybe the problem is that we are all using the same book. Was it possible that the accepted published standards used in the industry were not accurate enough for our local conditions. We began to research this possibility further, looking into some of the laboratory procedures used to determine the thermal performance of building assemblies such as ASTM C 976. It became obvious early on in this endeavor that some of the procedures were not representative of conditions encountered by building materials in southern regions.

This set the course for our next project, which was to as accurately as possible, with the equipment available, gather as much ***actual thermal load data*** on as many facilities and construction materials as possible.

BASIC PROCEDURES USED

This procedure outlines the field test methods used to determine the overall thermal conductance or overall thermal resistance of fully assembled building materials / components in our Florida enviroment.

The objective of this procedure was to determine the impact of such building materials / components on the heating and air conditioning loads in residential and commercial buildings built using standard construction methods.

Discussion- Though standard tests methods presently exist, such as *ASTM C 976-90, ASTM E 547-93, ASTM C 518-91, ASTM E 1105-93 and NFRC 100-91,* for testing the thermal performance of building assemblies and windows, it became apparent in the early development stages of new products such as passive Daylighting systems, that under the above standard test methods, the ***minimum precision conclusions*** needed could not produce repeatable results in comparison to ***actual performance curves of installed / operational systems***. This was causing serious problems in determining the economic impact of Daylighting systems and other conventional energy conservation retrofits to the end user.

Note -1 Testing some individual systems components to standard methods produced results that were 4***0 to 60 % less*** than the assembled, properly installed systems actual performance curves.

The focus of this procedure was to provide us with ***a comparison*** to known standards for all parties interested in using alternative energy devices, to displaced conventional lighting loads during daytime hours, until a uniform testing procedure, that is accurate and can economically provide similar information to the consumer can be developed and agreed upon by the engineering community. This procedure addresses the thermal properties of the materials / products tested and has no relationship to structural building code requirements.

TYPICAL DATA POINTS RECORDED

1 Inside room temperature at ceiling level & work levels.
2 Air Conditioning discharge duct temperatures Discharge Duct Air Velocity
3 Percent of Relative Humidity Dew Point
4 Abs Humidity (gm/cu.m)
5 Uncompomised Percent Relative Humidity
6 Light intensity (lumens per square foot)
7 Window Heat Flux in BTU's per square foot per hour
8 Lighting fixture Heat Flux in BTU's per square foot per hour
9 Outside ambient temperature
10 Wind speed
11 Wind direction
12 Outside wind chill temperature

Some of the equipment and instrumentation employed in this phase of the project was as follows;

1 Pete Brothers model 200 portable weather station with RS232 interface.

2 Extech Instruments CMM-15 Process Calibrator Multimeter with RS232 interface.

3 Omega Engineering Corp. HFS-1 Heat Flux Sensor Sn. 970898567, NBS traceable calibration.

4 Texas Instruments Extensa 600 CD computer for RS232 interfaces.

5 AGEMA 210 Infrared Imaging system with a –22 Deg. F to 1500 Deg. F range and a thermal resolution of 2.25 X 2.25 mrad (V&H), field calibrated to a black body standard that is NBS traceable.

6 ALNOR type 3002 Velometer with a range of 0 to 3000 feet per minute.

7 Extech Instruments Model 4077026 Light Meter / NBS traceable calibration.

8 Omega Engineering Corp. Model OS71 Infrared Thermometer.

9 ONSET Computer Corp. Model HO-006-04 Data Loggers.

Summary of Test Methods

The heat source was natural sunlight and outside ambient temperatures producing a thermal transfer to and on all outside surfaces.

The test specimen / product is installed in a ***standard constructed building envelope with a known R-Value traceable to accepted industry standards.***

Inside chamber (controlled zones) thermal and heat flux transducer placement vary depending on product design ***but always include inside BTU per Square Foot per hour heat flux, inside ambient temperature and inside humidity (non-contact)*** with inside specimen surface transducers isolated from circulating air within the chamber by means of an insulated jacket when applicable.

Thermal and heat flux transducer placement on **outside surfaces** vary depending on product design but ***always include BTU per Square Foot per hour heat flow, outside ambient temperatures (non-contact) and wind chill factors.***

The Placement of Thermal and Heat Flux transducers on the outside surface of the building envelope uses a insulated blanket to protect the transducers from wind chill and direct sunlight absorption. Thermal and Heat Flux transducers on surface of the building envelope are protected, in the same manor, from direct exposure to heating and air conditioning air flows.

A consecutive logging of data is accomplished with computer interfaces.

The minimum test period was 48 hours at various locations and the average test period was 168 hours. The maximum test period was 35,040 hours at one facility.

The minimum data recording time period between temperature readings at each test point is 5 minutes. All readings were taken in conjunction with each other from each test point in the same time frame.

Calculating the results

The actual inside and outside surface temperatures ***of both*** the test specimen and the known *R-Value* of the **Modified Climatic Chamber** (the buildings actual envelope) are processed to obtain maximum and minimum temperature Delta-T and actual Heat Flux at the interface. The variables due to a natural heat source, wind chill and outside ambient conditions were considered. The area of the test surfaces, the physical size of the test specimen and other variables such as air gap between test surfaces are calculated.

The data can be expressed in ***actual or average*** readings and then used in our modified calculation equations to express the ***performance equivalents*** of transmittance ***U*** and resistance ***R.***

This method was used to determine the thermal resistance **(R-Value)** of two **Passive Solar Daylighting Devices** a Tubular Skylight model **TSL-13** manufactured by Tubular Skylight Inc. of Sarasota, Florida and the **Winsulator Interior Storm Window System** manufactured by South Sun Energy Conservations of Sarasota, Florida.

The results clearly indicated that the thermal resistance of both systems used as Passive Solar Daylighting Devices is not a unique value. A range values found to be consistent with the tenets of Thermal Design theory. Which can be expressed in a performance equivalent value similar to that used to express the characteristics of other materials such as radiant barriers. Using this method and actual utility billing records we have proven that both of these systems do not negatively impact heating or air conditioning loads in our area.

The standard ASTM test methods use a controllable heat source. When the specimen / component is exposed to ***real life heat dynamics,*** as installed to perform its job, the behavior is different. In case of both the these Daylighting systems, every installation was a unique case with the R-value varying within the specified, building / energy code, acceptable range. Our test on **Tsl-13 Tubular Skylight system** showed that the system we tested actually added less heat load to the building then a standard T8 fluorescent fixture.

The same held true for the test conducted on the **Interior Storm Window System.** If you simply add up the accepted **published data** for a,

MATERIAL	*VALUE* ***R***	***U***
1. WINDOW, SINGLE GLASS	0.88	1.136
2. 3/4" AIR SPACE	0.91	1.098
3. 0.120" thick HMW Acrylic sheet	4.00	0.250
Total	5.79	2.484

you can see that even using this simple method, the R and U Values of the interior storm window system we tested exceeds that of most high cost window retrofits. When you actually install this type of retrofit over an existing system you normally end up with an air space between the glass and acrylic of at least 2 inches thus increasing the performance to even more desirable levels. Once again these assertions have been collaborated by the end users in actual energy dollar savings. When using our method and recording the performance of ***all components in a controlled zone*** a relatively accurate profile of internally generated heat loads can be establish. The following data was collected in a portable school building and is a typical example of the type of profiles we have accumulated.

HEAT FLUX TEST

Location of Sample	BTU per Square foot per hour
Inside Walls	12
Inside Ceiling	7
Inside Floor	6
Standard Windows	33
Light Fixtures (heat)	93
Computer (heat)	22
Computer Monitor (heat)	45
VCR/TV (heat)	43

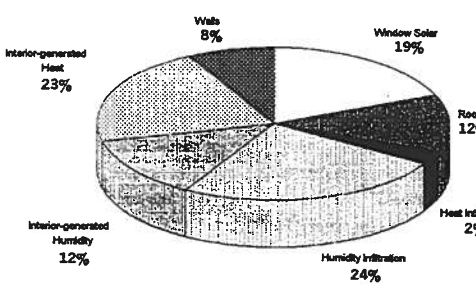
Unfortunately using the same test methods on other materials and building component produce results that we do not fully understand. As an example windows treated with different types of film rejected heat and solar gain on work level surfaces such as desks and carpeting. Our field test indicated however, that the interior surface of the filmed glass had in most cases a significant heat gain. Once again reflecting back to actual load conditions in the south. The question posed is, what percent of the typical 18% of window loads to an air conditioning system that the window solar has gain. Calculated to produce in our area is being transfer into interior generated heat, if the surface of the filmed glass is directly exposed to the conditioned space is generating a higher load then anticipated?

This scenario may explain the disappointment of some of our clients that have invested in these types of window treatments. It has been our experience that though comfort levels seem to increase after such installations, actual savings in comparison to projected savings fall short of the clients expectation. Having investigative several retrofits that the end user was not satisfied with, we have concluded that more than one factor normally comes into play. The first factor though not obvious is the increased surface temperature of the inside glass, the second factor that is obvious especially with heavy tint systems is the sudden appearance of additional task lighting being used by employees. Normally these task lights are of the Halogen type so popular these days. This type of task lighting adds significant heat loads and increased kWh usage to the system.

Another area identified was the increase humidity infiltration caused by improperly installed return air duct systems. In some cases do to construction anomalies and the seemingly endless practice of not isolating the return from the utility room it is located in. Our field surveys have revealed that the air in the condition space all the way back to the return register can have acceptable moisture levels but once the air enters the utility room, that is not properly sealed, the moisture content can increase as much as 10% before it enters the exchanger. Not only does this practice create additional energy loads, in some cases it has been the source of Indoor Air Quality problems. This is do to the normal habit of using the utility rooms as storage areas for cleaning chemicals, copy machine toner and other seemingly harmless consumables.

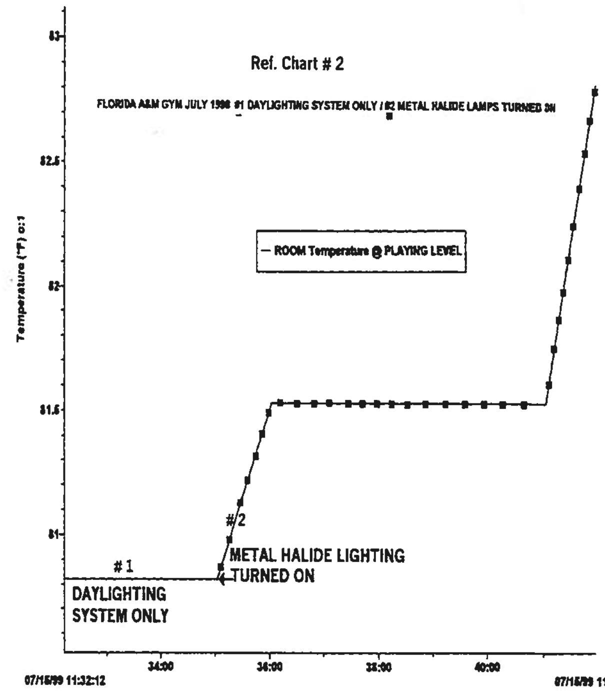
Reference # 1 shows the results of our field study to date. Interestingly the results parallel findings from the Florida Solar Energy Center in a study completed almost 20 years ago. This raises the question, that with all of our advances in building materials, window systems and construction techniques, why is their so little change in air conditioning load sources in Southern Climates?

Ref. chart #1

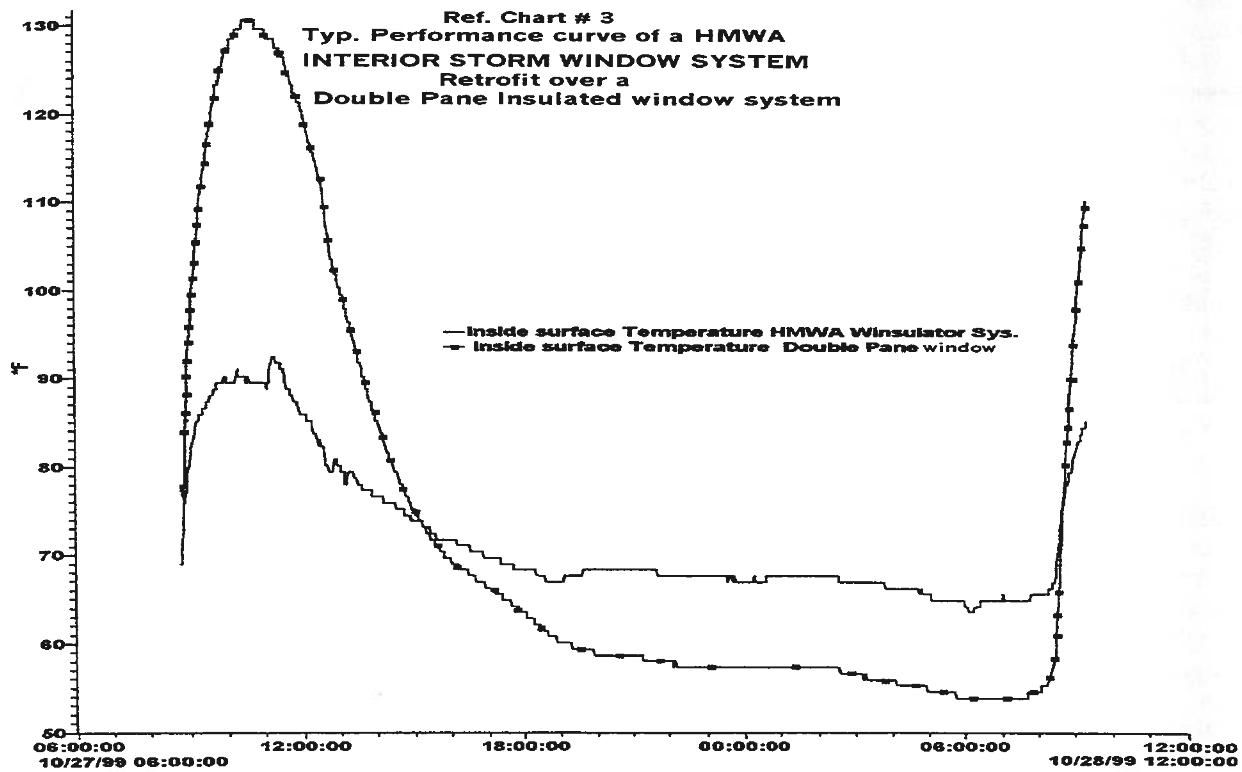


Typ. central Florida annual air-conditioning load sources in buildings surveyed to date.

While pursuing additional information on Passive Daylighting systems some of the result were astonishing. Reference #2 shows the heat gain in a Gymnasium when the standard Metal Halide lighting system is turned on, you will note that at playing level (5 feet from the floor) the temperature increases better than 2.6 deg. F in 6 minutes. Though not represented on this chart, the increase in foot candles was 12%, hardly a good trade off considering their are no watts per lumens cost when using the Passive Daylighting system.



When investigating window systems the result are perplexing, though we have tested hundreds of systems, even identical systems, manufactured by the same company, never perform the same way, at different locations. Even when the facilities are of exactly the same construction type and less than one mile apart, with identical window orientation and all the data is being gathered consecutively (same time period, on the same day) the performance curves are always different. Reference # 3 shows the inside glass surface temperatures of a double pane insulated system that has tinted glass and a known winter U-value of .48 and a summer value of .57 with a South East exposure. The window as been retrofitted with a high molecular weight clear acrylic interior storm window system.

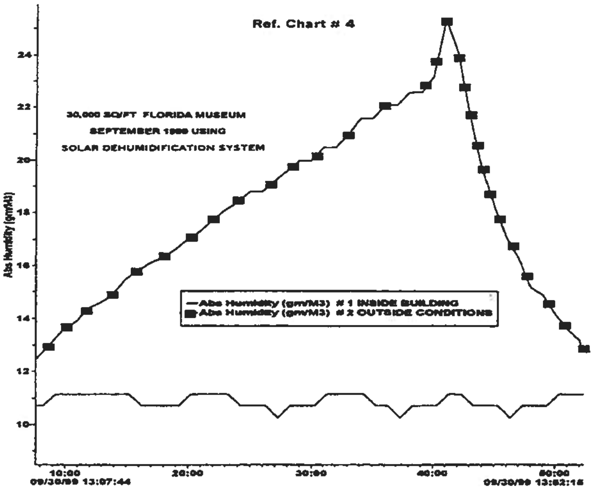


In this case the end user is a fortune 500 company located near Norfolk Virginia, the facility is less than 3 years old and is experiencing horrendous comfort levels in the main entrance reception area that is 100% glass. The lighting system in this area is recessed Metal Halide in a 24 foot high ceiling.

This installation was done as a **DAYLIGHTING RETROFIT**, with the intent being too reduce the thermal loads on the window system thus allowing us to open the vertical blinds and turn off the conventional lighting system during day light hours. Though not shown on this chart the end result was that the retrofitted window was creating less heat load than the standard Metal Halide fixtures.

Reference at # 4 shows some results of a Solar Desiccant Dehumidification system we have installed in a Florida museum. This facility houses both a hands on science museum and a standard art museum located on the top floor. Though meeting code the chill water system has no isolation capabilities so the facility must run 100% circulation to accomplish that humidity control the facility was having to run a boiler in conjunction with the chillers under certain weather conditions.

To eliminate these additional energy costs we installed a Solar System, the day represented on the reference chart was overcast with broken clouds, even with that factoring in, you can clearly see the solar system reducing the loads as the air conditioning system cycles. Every time the cloud cover clears and the solar collector reaches maximum absorption you can see the humidity reduction in the controlled zone.



CONCLUSIONS

All to often it seems we rely on data and specifications that though correct do not relate well to hot and humid climates. This couple with a lack of information pertaining to a specific energy or indoor air quality problem often leads to suggesting solutions that do not completely solve the original concern.

Being called to a facility that is suffering from a mold and mildew problem that the owners spent thousands of dollars to try and eliminate, only to find that no one ever checked the construction schedule and compared it to the weather conditions during the buildings erection is disheartening. One cannot expect a concrete block building where the block was exposed to over 2 1/4 inches of rain, 4 days prior to the installation of the dry wall and interior vapor barriers, along with a really slick Elastomeric paint application to the outside fascia within 90 days, to have anything but mold and mildew problems in our Florida environment. Unfortunately the standard, by the book, solutions will not help this client much. Eventually the building might dry out and after replacing all the wall paper for the fifth time the mildew might disappear but the financial burden will still be on the end user, not the architect or the mechanical engineer and who knows where the building inspector or construction site manager is by this time.

Similarly when a vendor suggests a typical window treatment and expounds on the anticipated savings without noticing that lizards and small cats freely come and go as they please through the window frame, that has pulled 6 inches away from the building fascia, can you really expect the "by the book" savings to result.

Walking into a new facility and looking up at the lighting only to see a four foot fluorescent lighting fixture less than six inches from a six foot window immediately tells you that the room meet the local building codes for Lumens per square foot but unfortunately it also tells you that once again the calculations were done" by the book".

The codes and standards are necessary and a valuable tool. However they should not be our only tool. Common sense and an occasional **SITE VISIT** along with consideration to the **costs incurred by the end user** should also have a place in design criteria. A source for evaluating new products such as the Solar Systems reflected on in this paper, and other new building materials that are not driven by corporate sponsors is desperately needed for small business inventor. Our use of the **SOLAR** retrofits outlined in this paper has been extremely successful. Unfortunately the technical data in the existing standards do not support the end results. The ***Photobiological effects of the DAYLIGHTING*** systems alone normally go far beyond the energy savings. We have systems such as these installed in Schools, Manufacturing Facilities, Retail Stores, Hotels and Government buildings of all types. Hopefully the results we have shared will inspire the Energy Conservation Professionals to **THINK OUT OF THE BOX and REVISE THE BOOK.**