Cooling Climates Technologies
Hawaiian Investigations
2001 National Workshop on State Building Energy Codes

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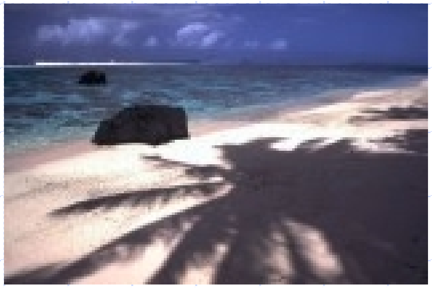
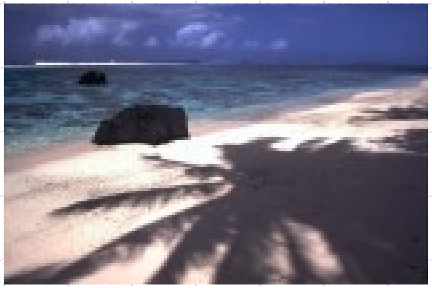
Cooling Climates Technologies



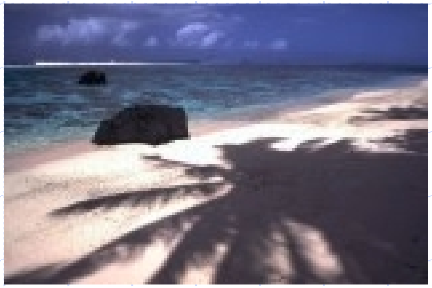
- High performance windows
- Heat pipes (and other dehumidification options)
- UV lamps
- Roof Color, Insulation, and Radiant Barriers
- Daylighting & controls

Goal of Work



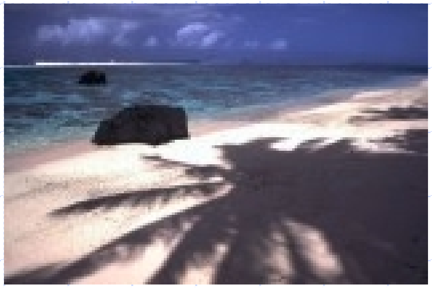
- Develop commercial building guidelines
- Identify potential energy code upgrades

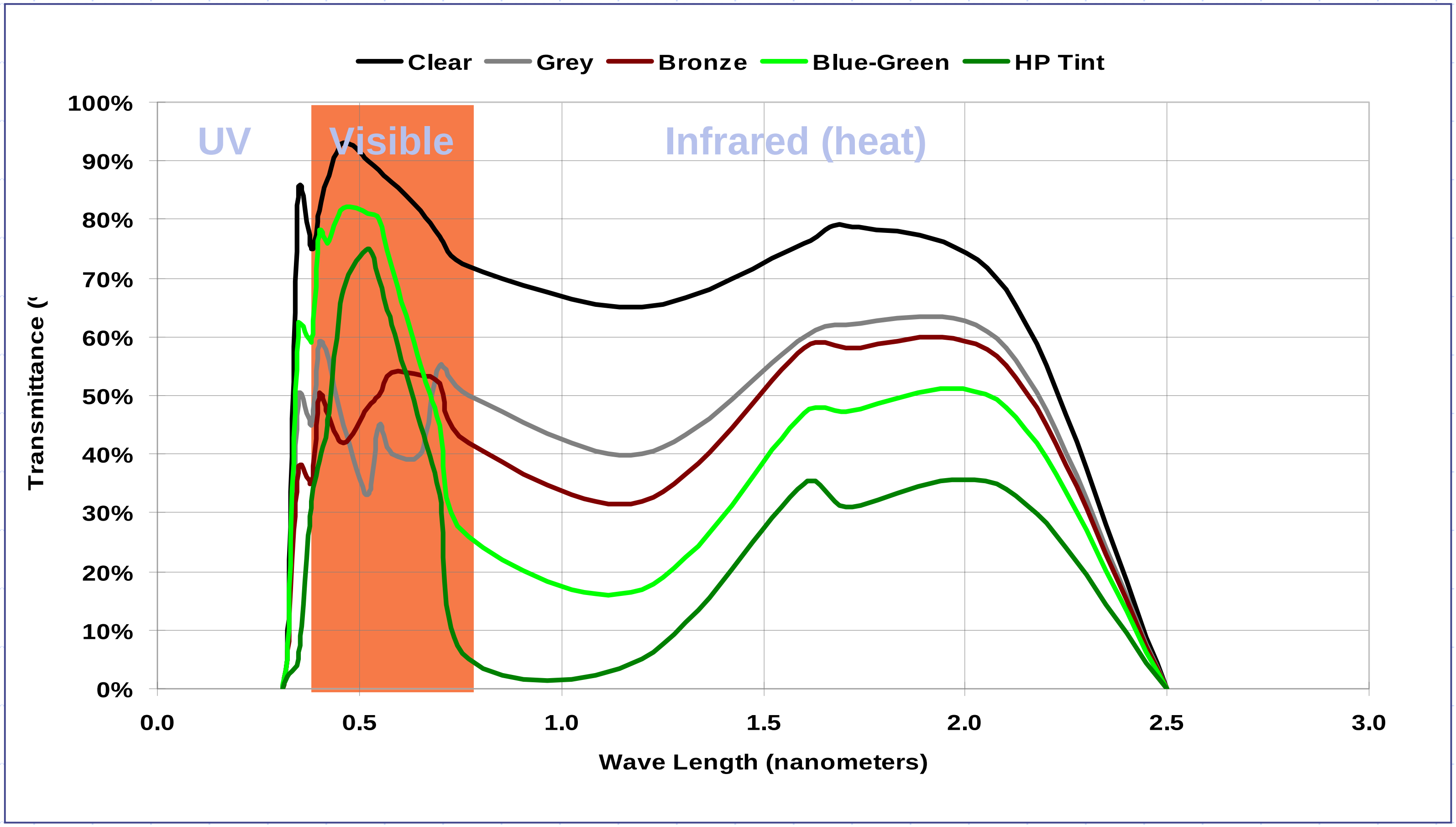
High Performance Windows



- Low solar heat gain coefficient (SHGC)
- High visible light transmittance (T_{vis})
- Technologies:
  - Coatings
  - Tints

Transmission Properties of Different Glass Types



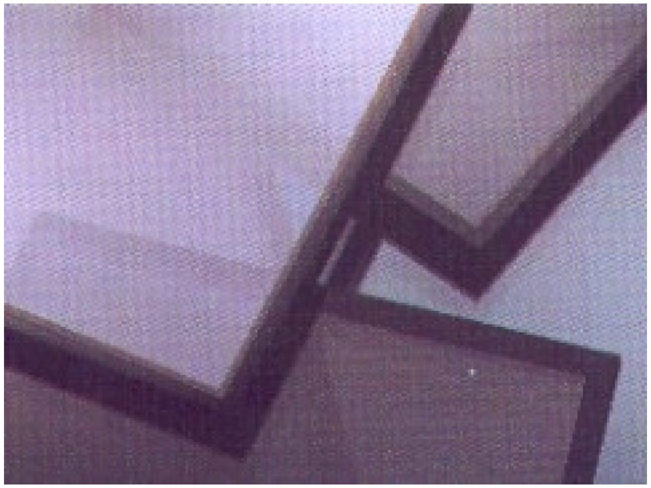


Specularly-Selective Glazings

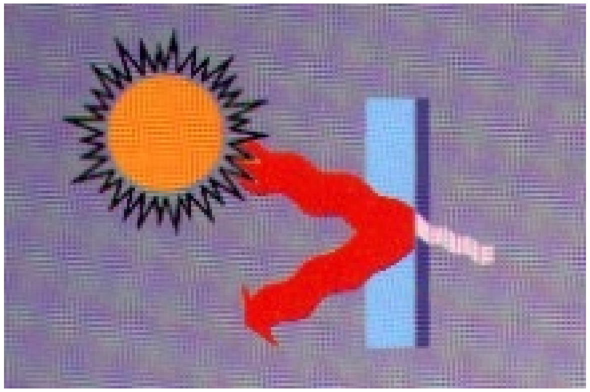
Blue or green tint

Heat Mirror

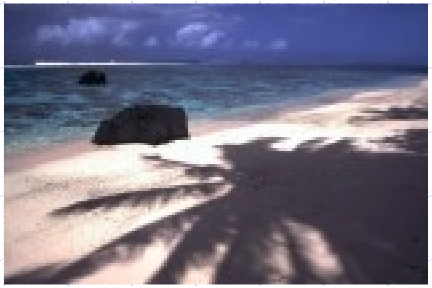
Low-e coatings



Some retrofit window films

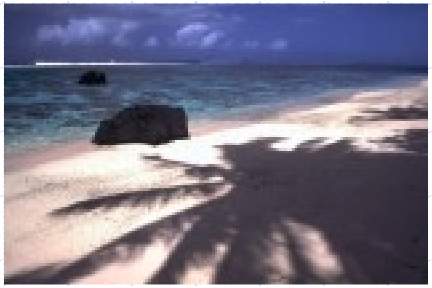


Life-Cycle Cost Methodology



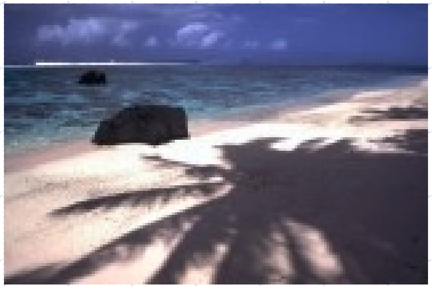
- Analysis accounting for:
  - Cooling energy (DOE2.1E)
  - Lighting energy including daylighting (DOE2.1E)
  - HVAC system size (DOE2.1E) and cost
  - Glazing cost (ASHRAE/T24 and CADMAC costs with additional 30% markup)
- Similar to LCC approach used for current Hawaii code
  - Also for Standard 90.1-1999 and CA standard

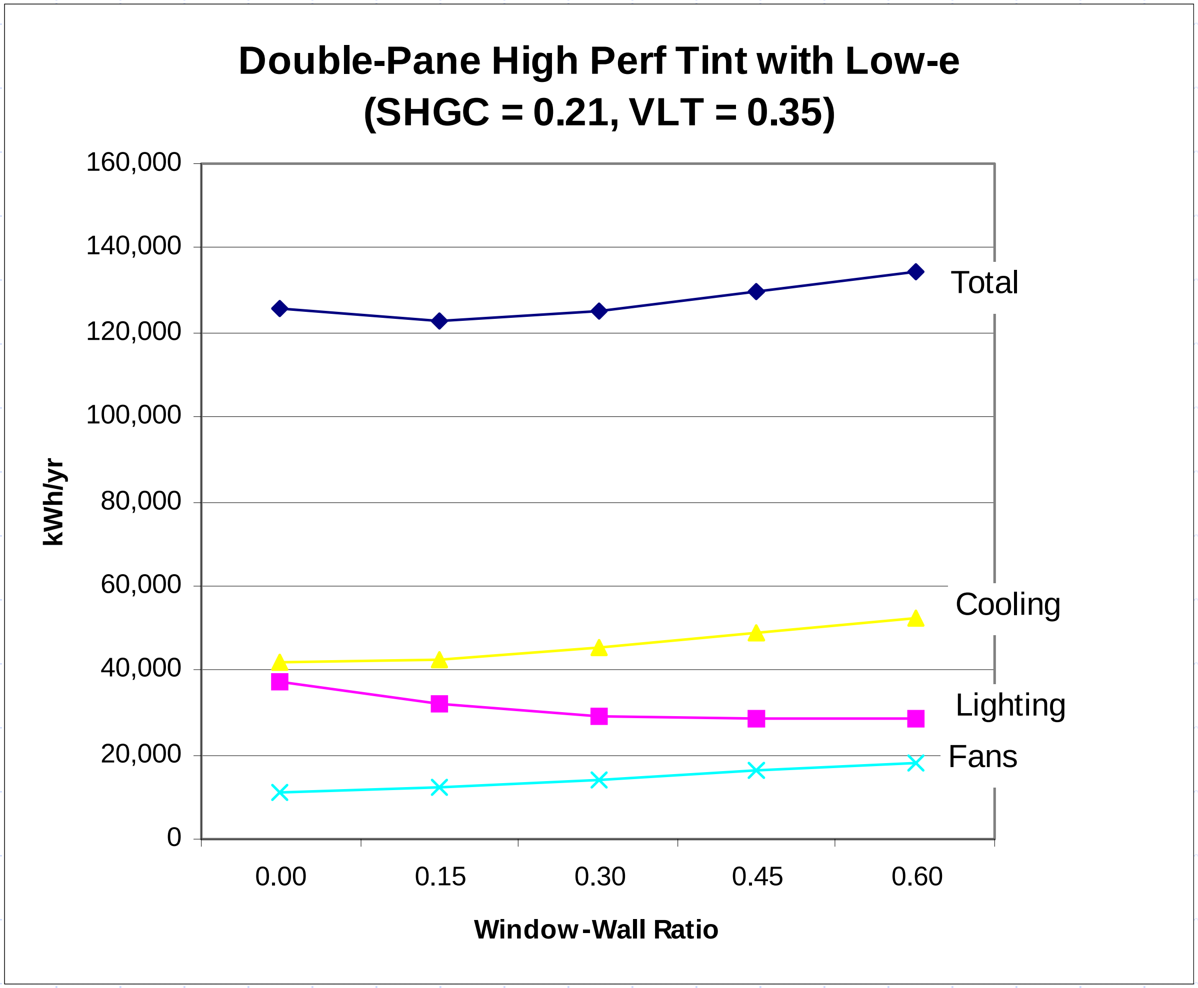
Glazing Types Considered



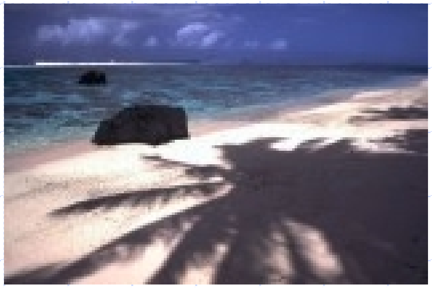
Glass Type	SC	SHGC	VLT	U-factor	Inc Cost
Single Clear	0.95	0.82	0.88	1.087	$ -
Single Tint	0.69	0.59	0.43	1.087	$ 0.68
Single High Perf Tint	0.60	0.50	0.66	1.088	$ 1.86
Single Reflective - Medium	0.64	0.55	0.39	1.088	$ 1.69
Single Reflective - High	0.36	0.25	0.13	0.912	$ 3.18
Double Clear	0.81	0.70	0.78	0.483	$ 5.10
Double Tint	0.54	0.46	0.38	0.483	$ 5.78
Double High Perf Tint	0.48	0.38	0.58	0.483	$ 6.96
Double Low-e	0.40	0.34	0.47	0.31	$ 8.28
Double High Perf Tint Low-e	0.25	0.21	0.35	0.31	$ 10.14

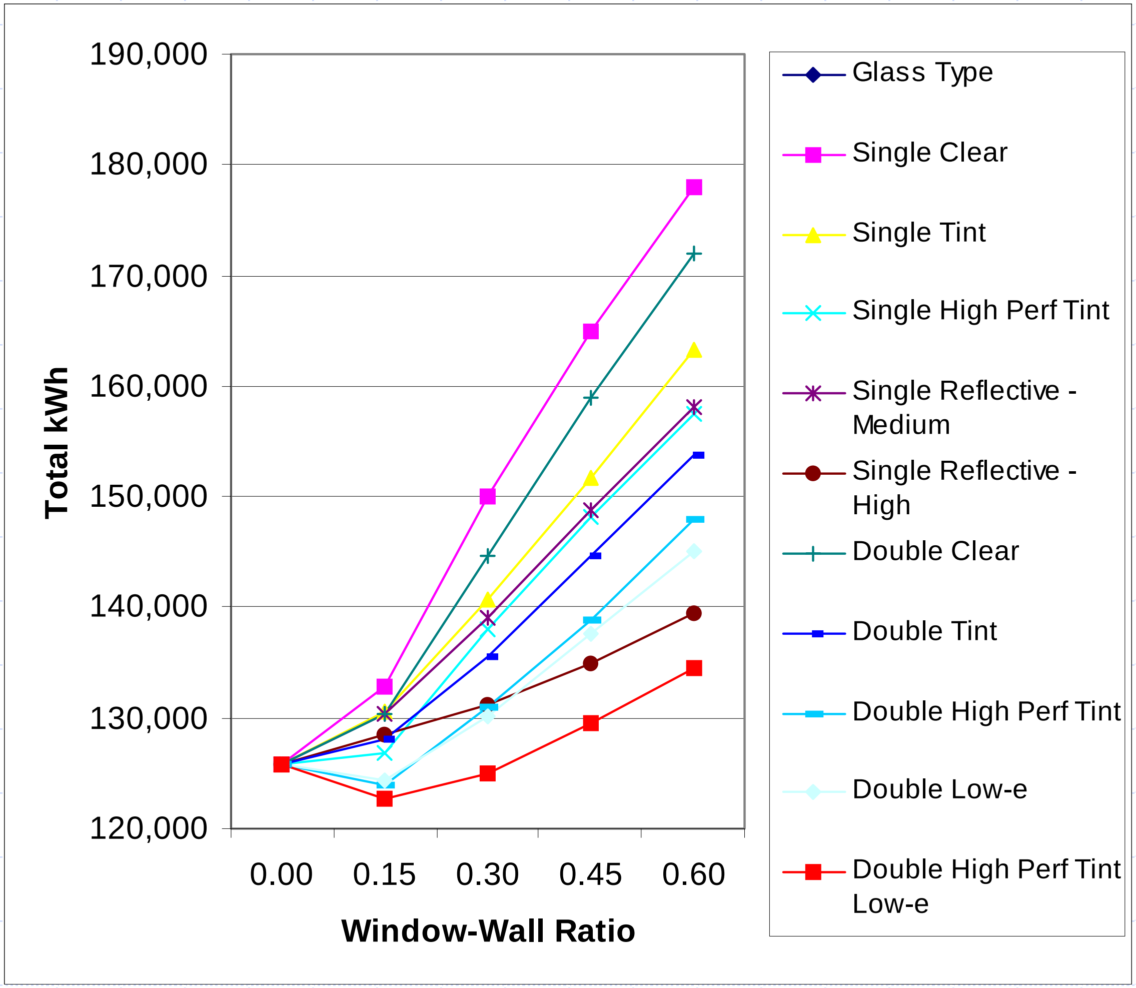
Example Fenestration Electricity Impact



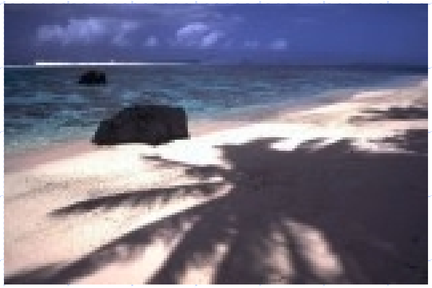


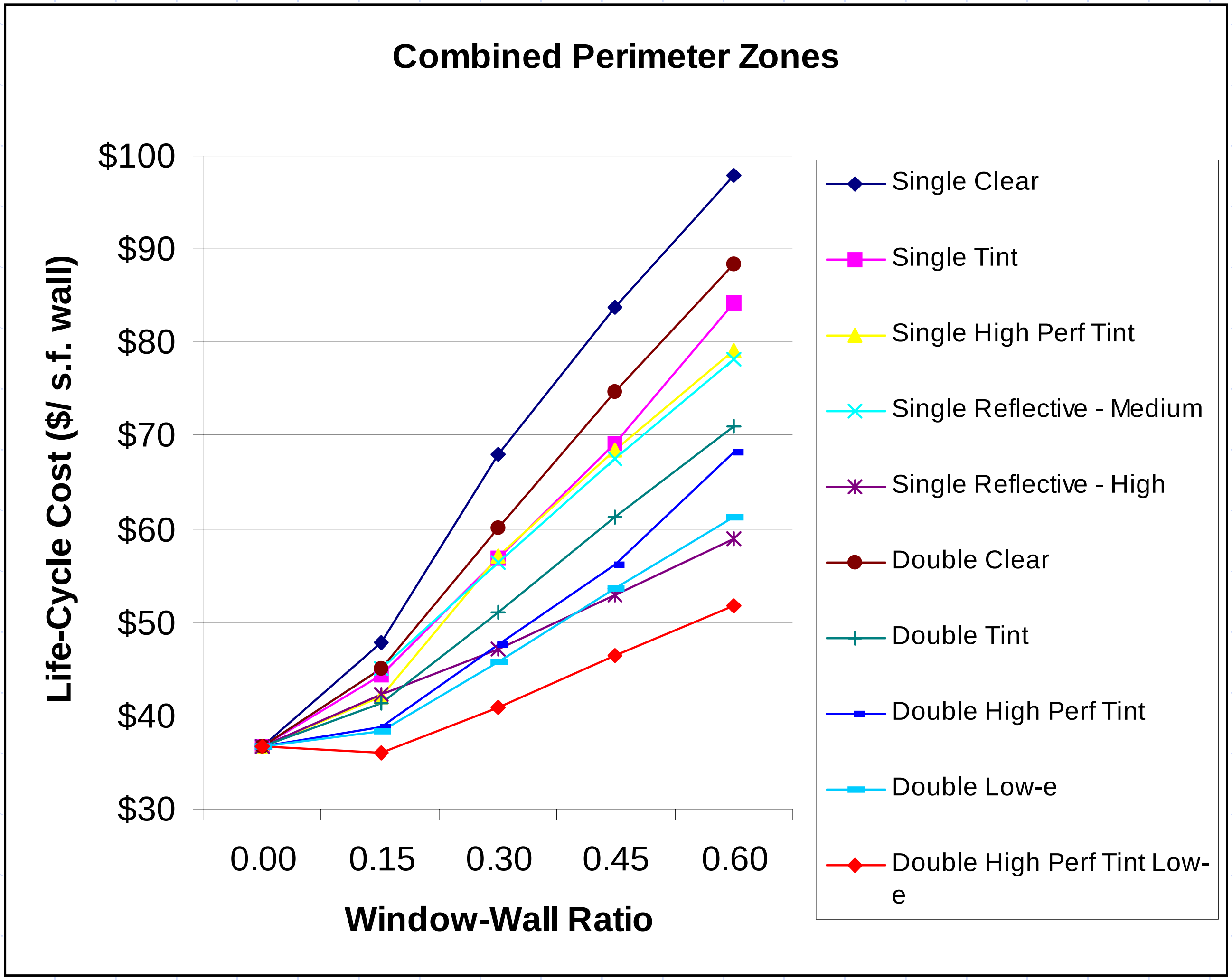
Electricity Impact



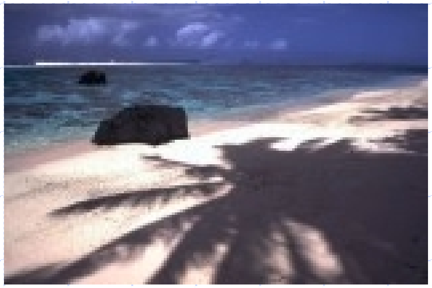


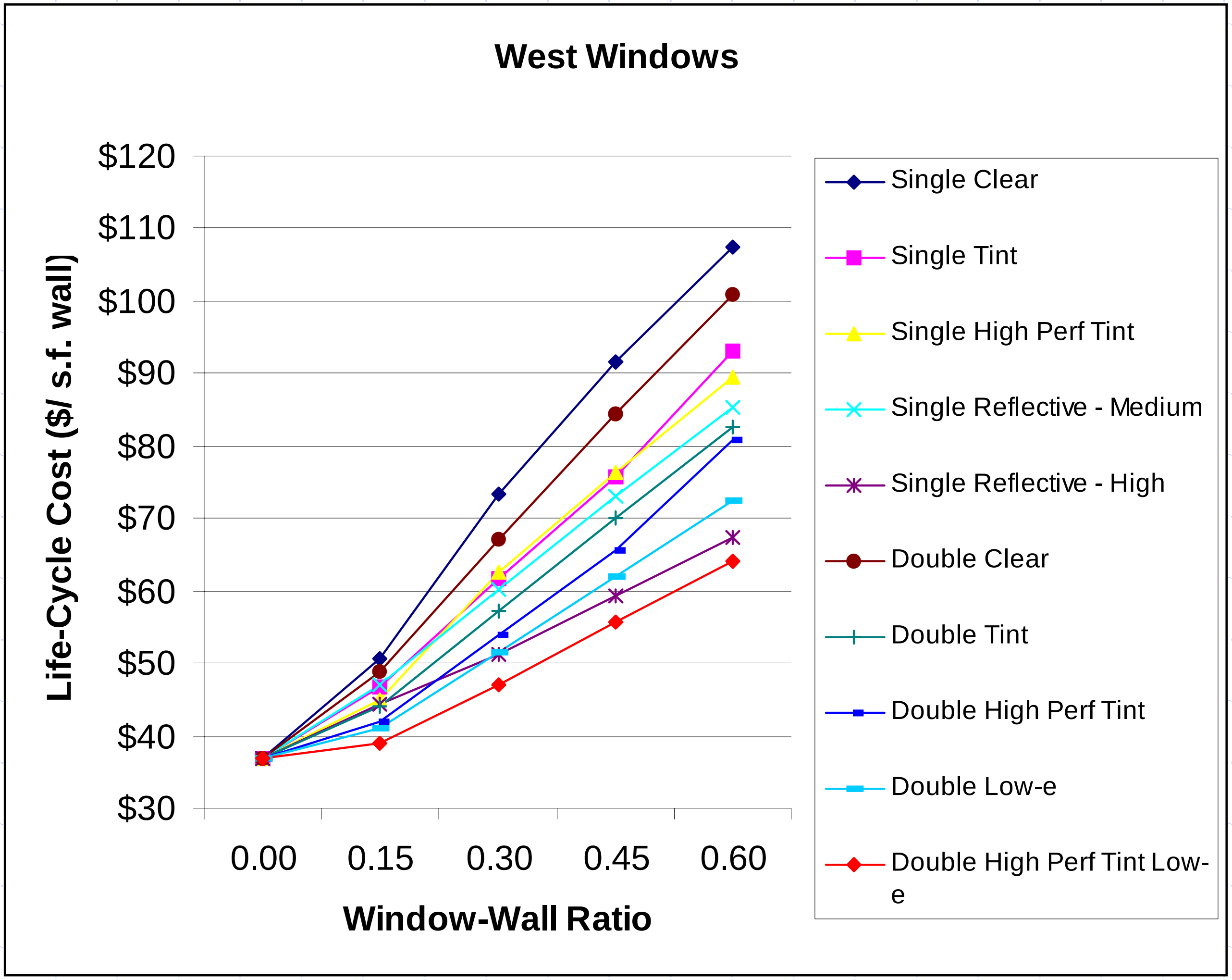
Life-Cycle Cost Comparison



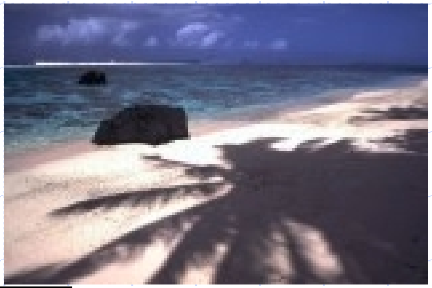


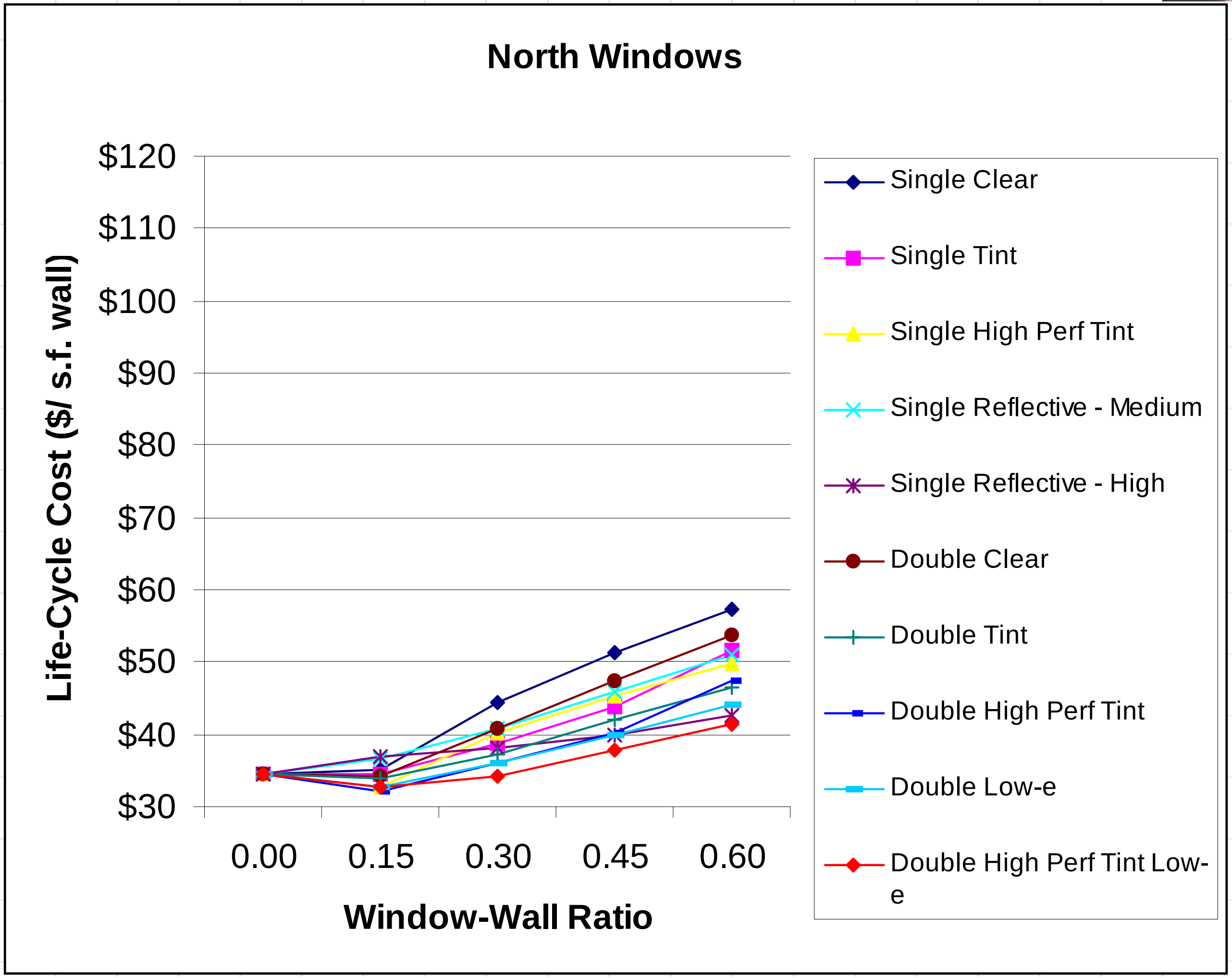
Life-Cycle Cost Comparison – West Orientation



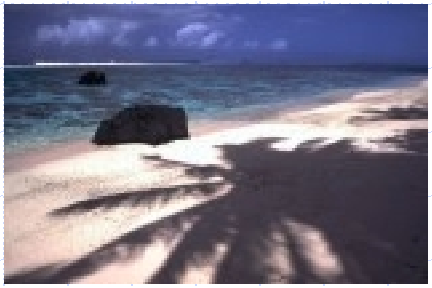


Life-Cycle Cost Comparison – North Orientation



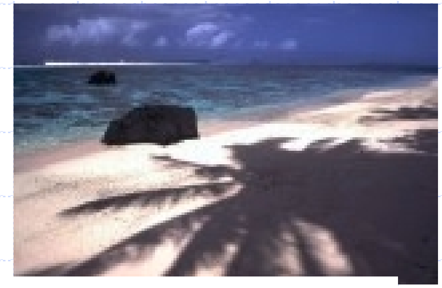


Optimal Glazing Results



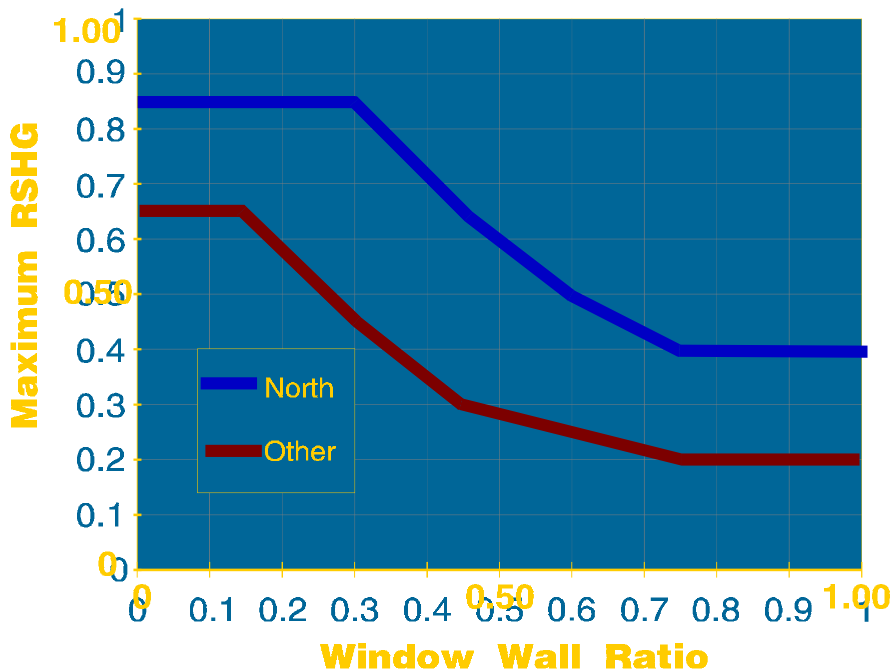
- Same result for all orientations and glass areas
  - High performance tint outer pane with low-e coating
  - Clear inner pane
  - SHGC = 0.21
  - VLT = 0.35
- (without overhangs or other shades)

Window Criteria for Hawaii



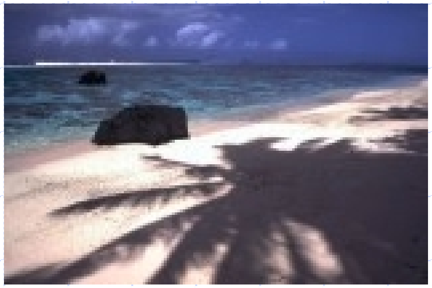
$$RSHG = SC_{glz} \times \frac{IS_{prop,i}}{IS_{def,i}} \times SC_{ext,i} \times M_i$$

Non-Residential and High-Rise Residential



Manual Figure 3E

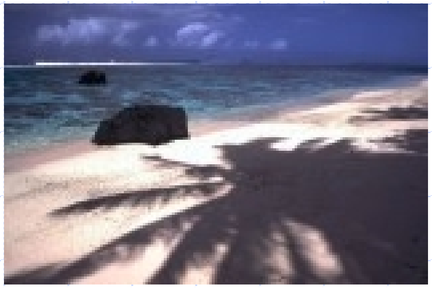
California 2001 Nonresidential Window Requirements



Maximum SHGC

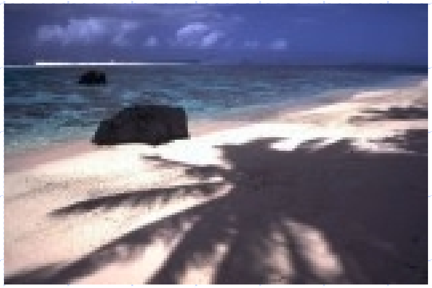
WWR	All Orientation	North Orientation
0% - 10%	0.46	0.61
11% - 20%	0.36	0.51
21% - 30%	0.36	0.47
31% - 40%	0.31	0.40

Windows
Conclusions and Next Steps



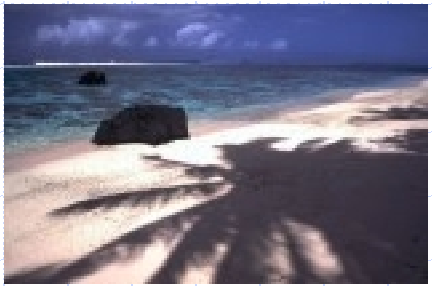
- High performance spectrally selective windows appear cost effective in Hawaii
- Potential for more stringent window requirements in Hawaii
- Continuing analysis should include:
  - Impact of shading – exterior and interior
  - Impact of other orientations – NE, SE, SW, NW
  - Additional window types

Pop Quiz (multiple choice)



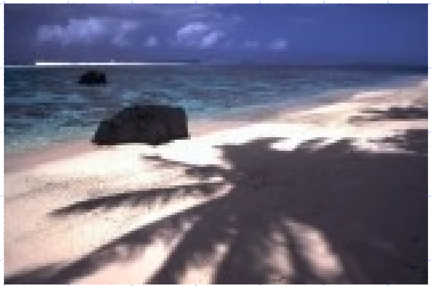
- A "heat pipe" is defined as...
  a. a heat recovery device
  b. a conduit for heat generated by a heat pump
  c. a police crowd-control weapon
  d. the opposite of "peace pipe"
  e. a & c
  f. b & d
  g. c & a
  h. a, b, c, & d
  i. x, y & z

Dehumidification



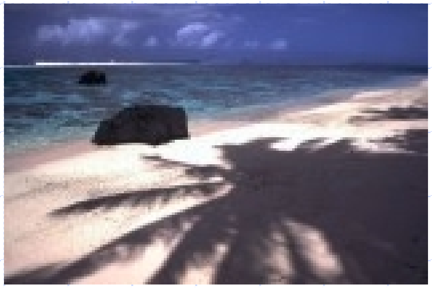
- Humidity control important in Hawaii
  - Required all year
  - IAQ
    - 40% to 60% RH desired for comfort
    - < 60% RH to prevent mold growth
  - Material degradation and maintenance
  - Energy consumption

Current Status In Hawaii



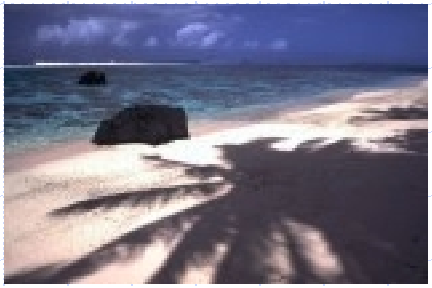
- Most cooling systems designed to meet humidity requirements at full load
- Usually don't dehumidify adequately at partial load
- Many systems are oversized
- Mildew problems are common
- Some critical applications use electric reheat, at high energy cost
- Some use more efficient systems

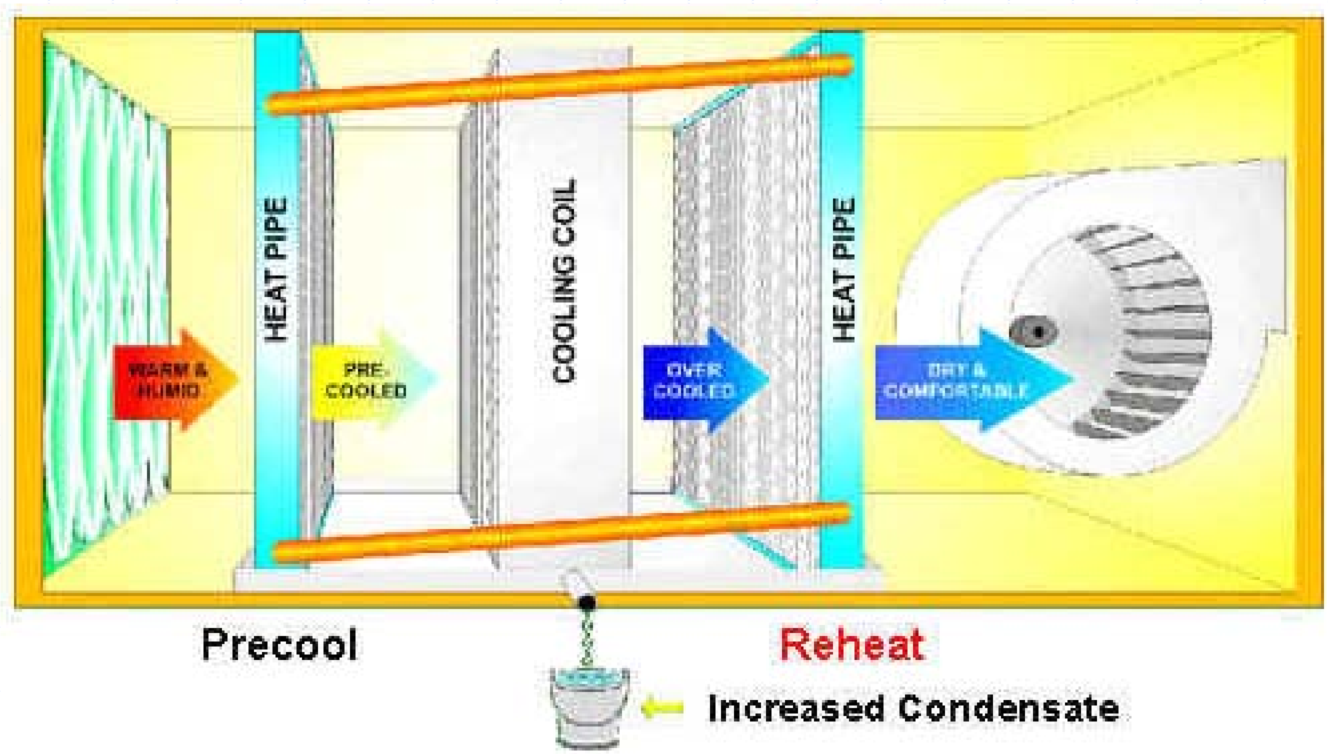
Dehumidification Alternatives



- Standard cooling system
  - Does not provide enough dehumidification at low load
- Standard cooling with reheat
  - Good humidity control, but high energy consumption
- Heat pipe or run-around coil
  - Precools and reheats supply air
- Dual-path system design
  - Separate cooling coil for outside air
- Refrigerant subcooling
  - Improves dehumidification of packaged DX systems
- Desiccant systems

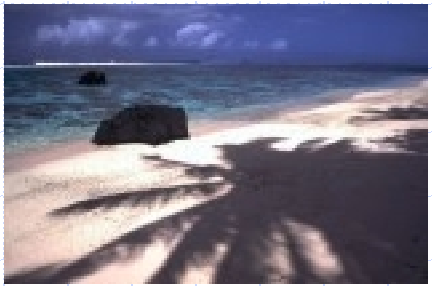
Heat Pipe

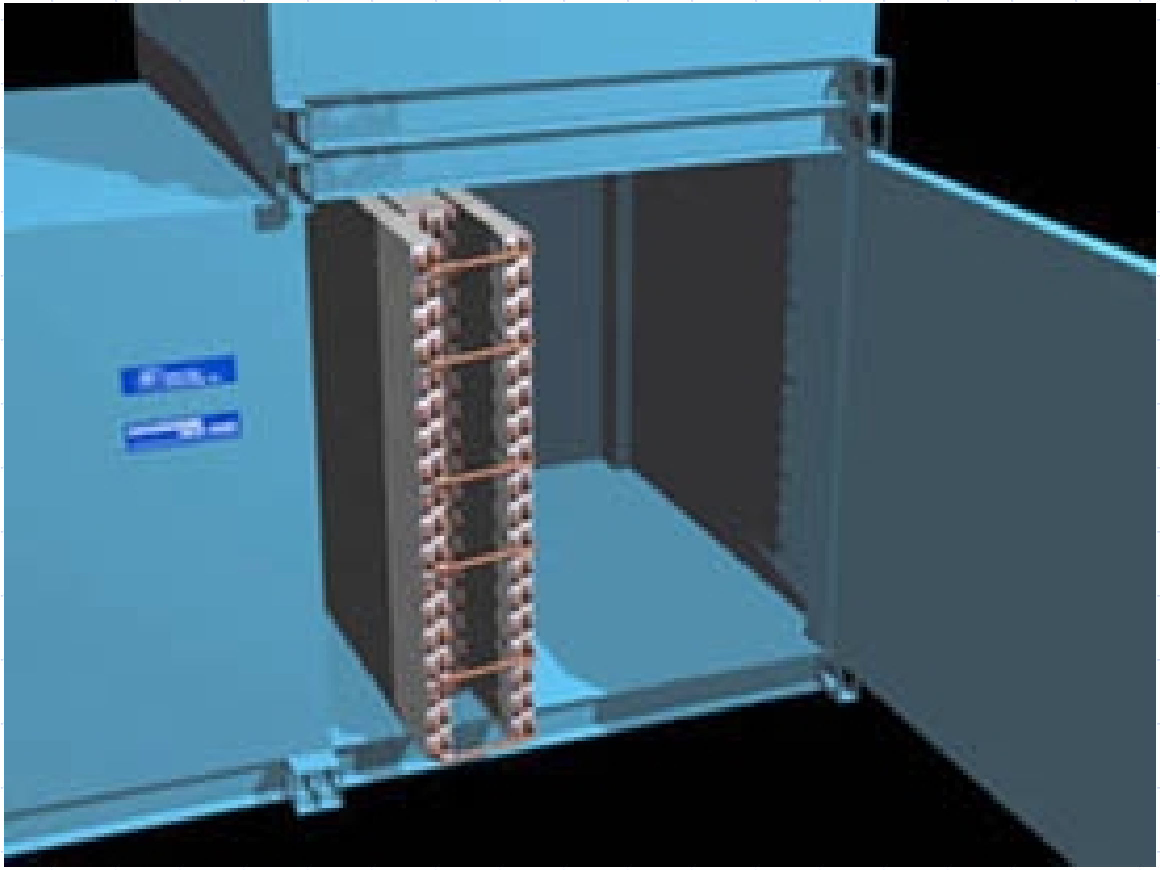




Source: Heat Pipe Technology, Inc.

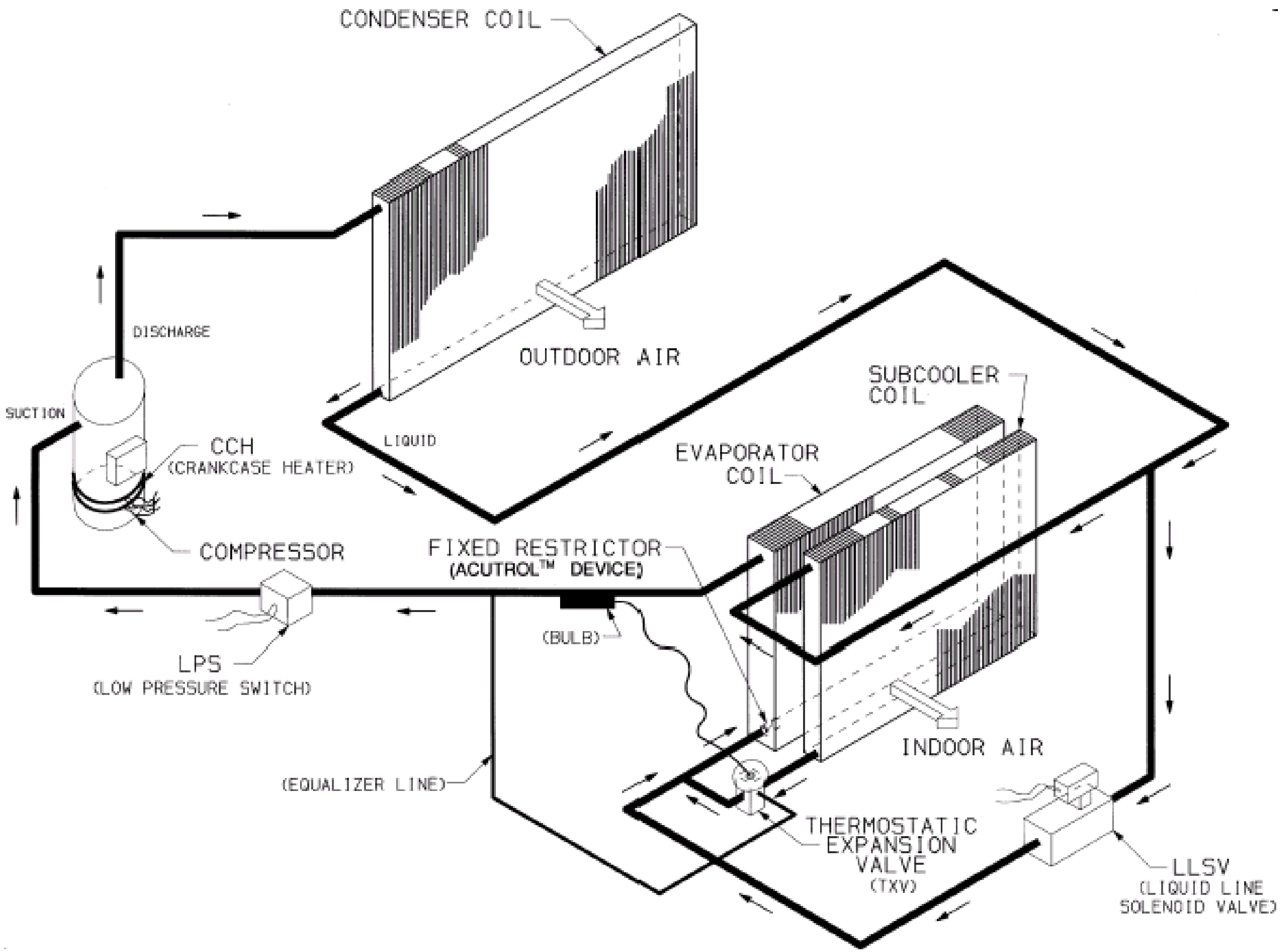
Heat Pipe





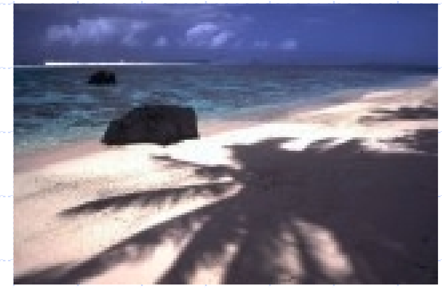
Source: Heat Pipe Technology, Inc.

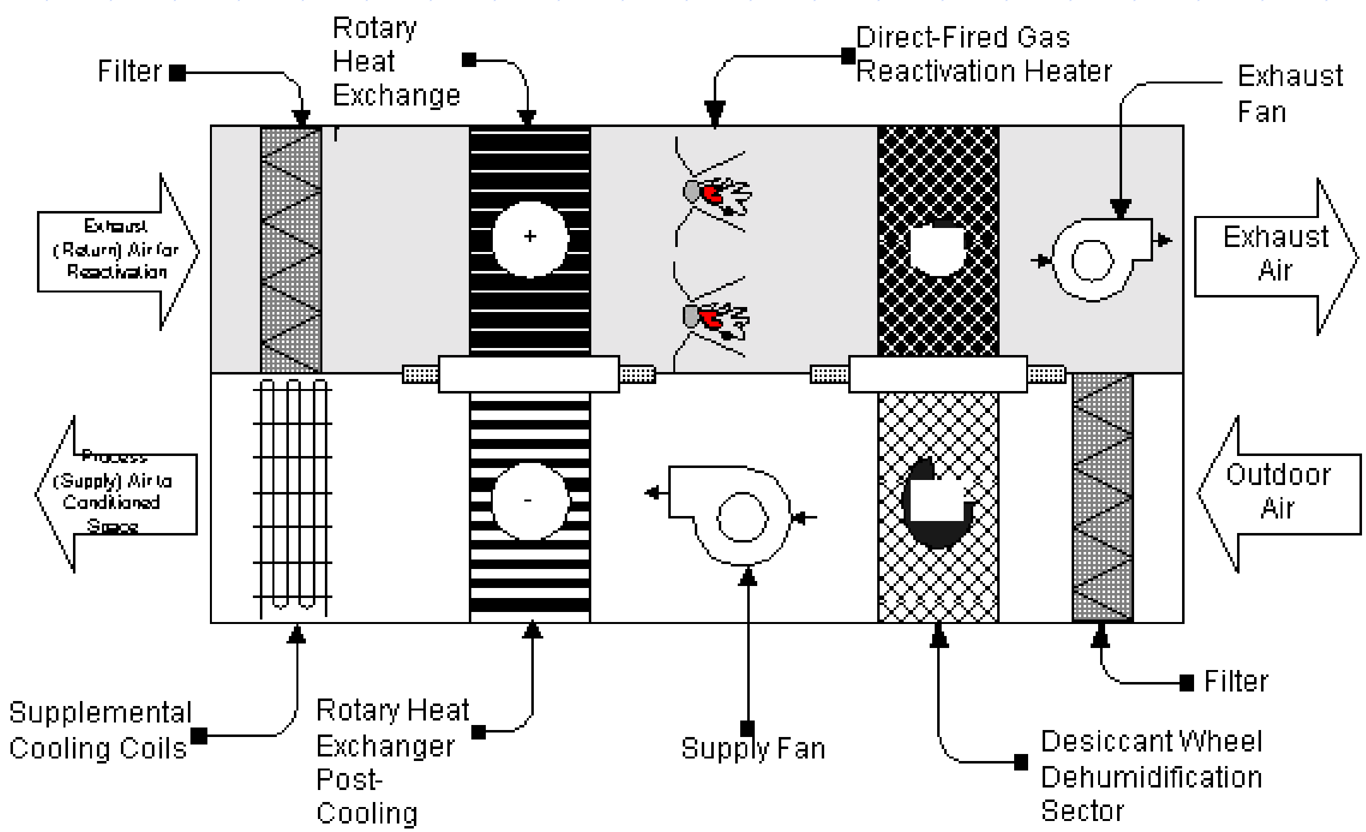
MOISTUREMISER DEHUMIDIFICATION OPTION



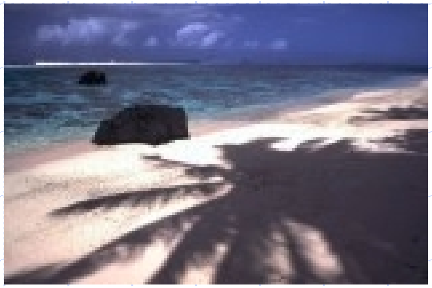
Source: Carrier

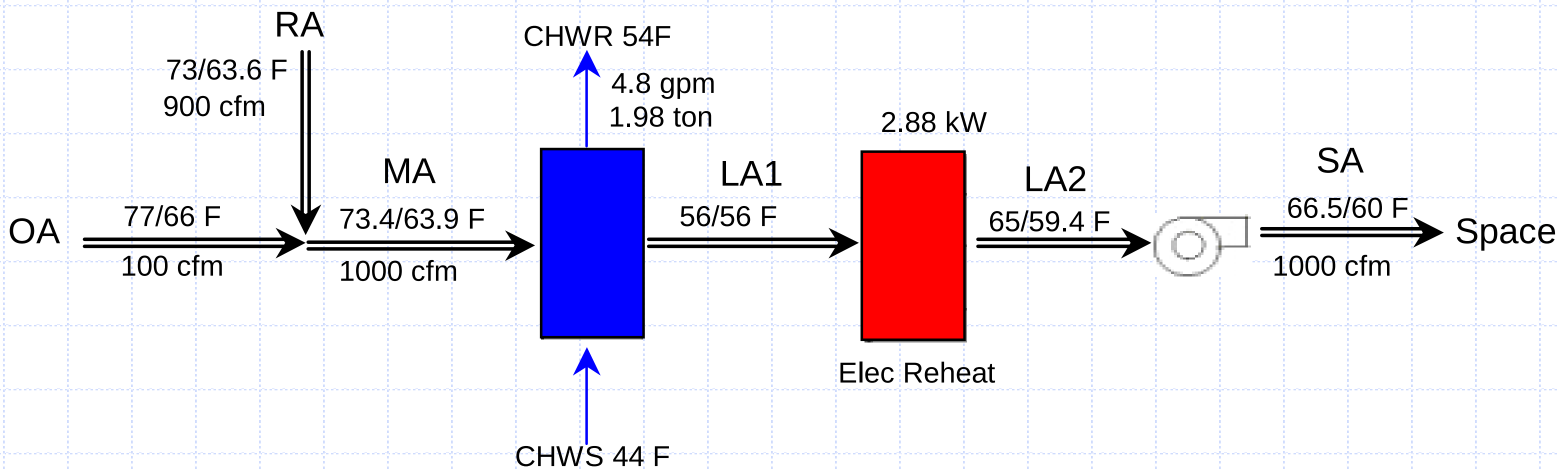
Desiccant Dehumidification





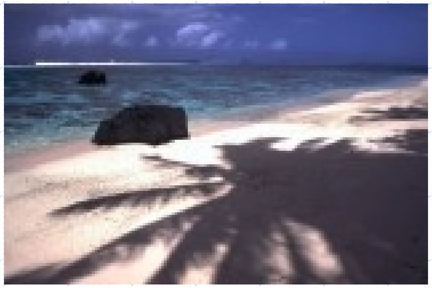
Standard Cooling With Reheat

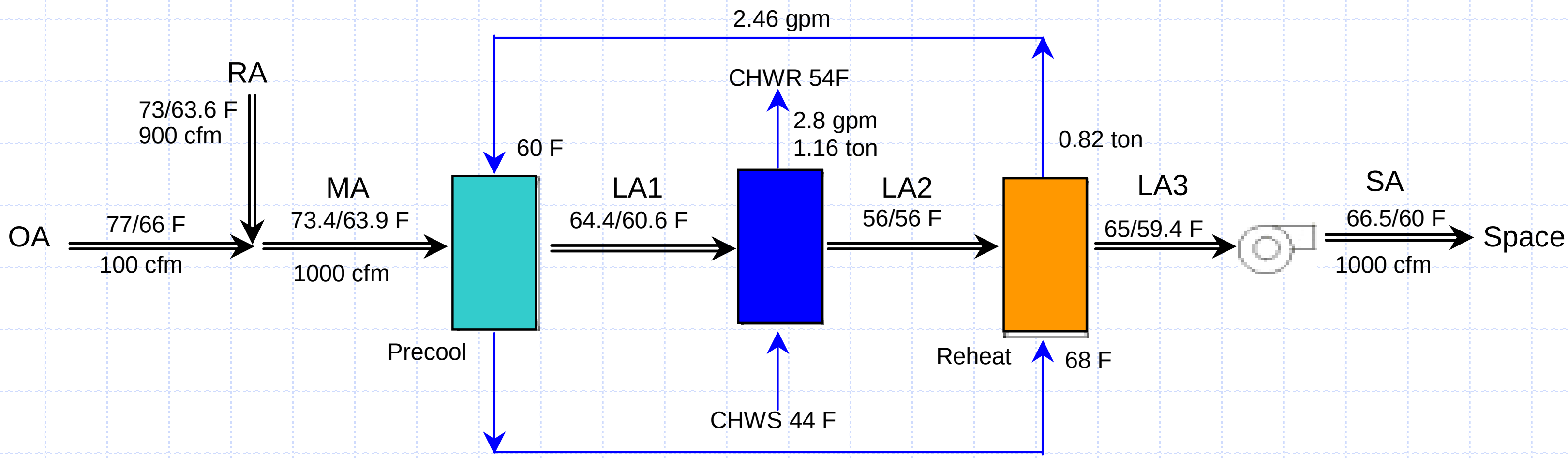




50% cooling load conditions

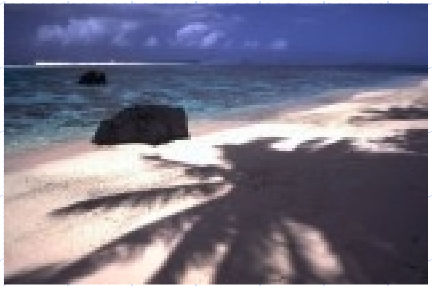
Run-Around Loop or Heat Pipe

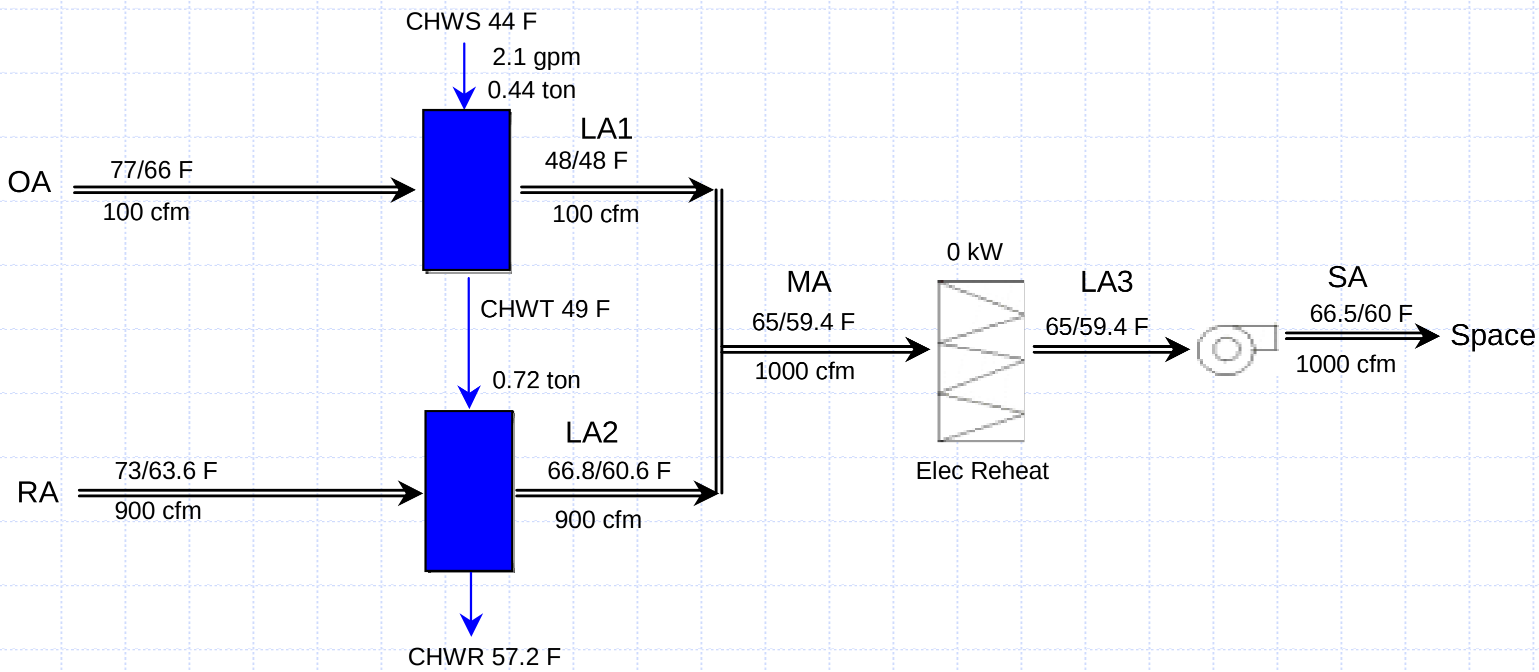




50% cooling load conditions

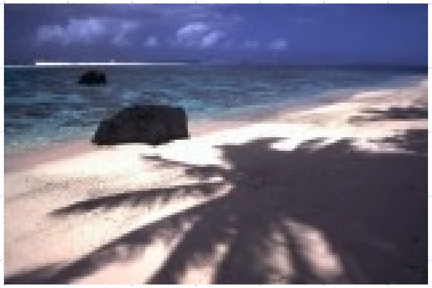
Dual Path System





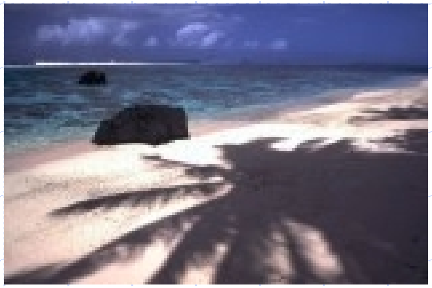
50% cooling load conditions

Dehumidification Energy Comparison



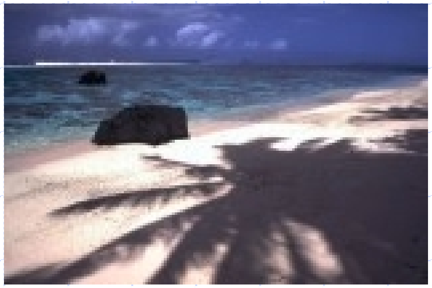
	Cooling and Ventilation Demand		
System Type	**100% Load**	**75% Load**	**50% Load**
Standard Cooling with Reheat	2.6 kW	3.3 kW	5.0 kW
Run-around Coil/ Heat Pipe	2.6 kW	2.1 kW	1.6 kW
Dual Path System	2.6 kW	2.0 kW	1.6 kW

Dehumidification Code Questions



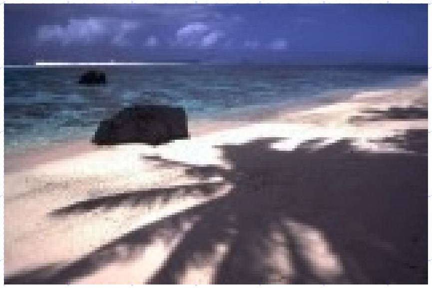
- What can and should be codified?
  - What should be limited to guidelines?
- Reheat limitations?
  - More important as IAQ becomes a bigger issue
- More stringent load calculation and system sizing requirements?
  - Avoid oversizing cooling capacity
- Part-load system efficiency/performance requirements?
  - Problem: still need cold air for dehumidification, but too cold for space conditions

Preliminary Observations and Conclusions



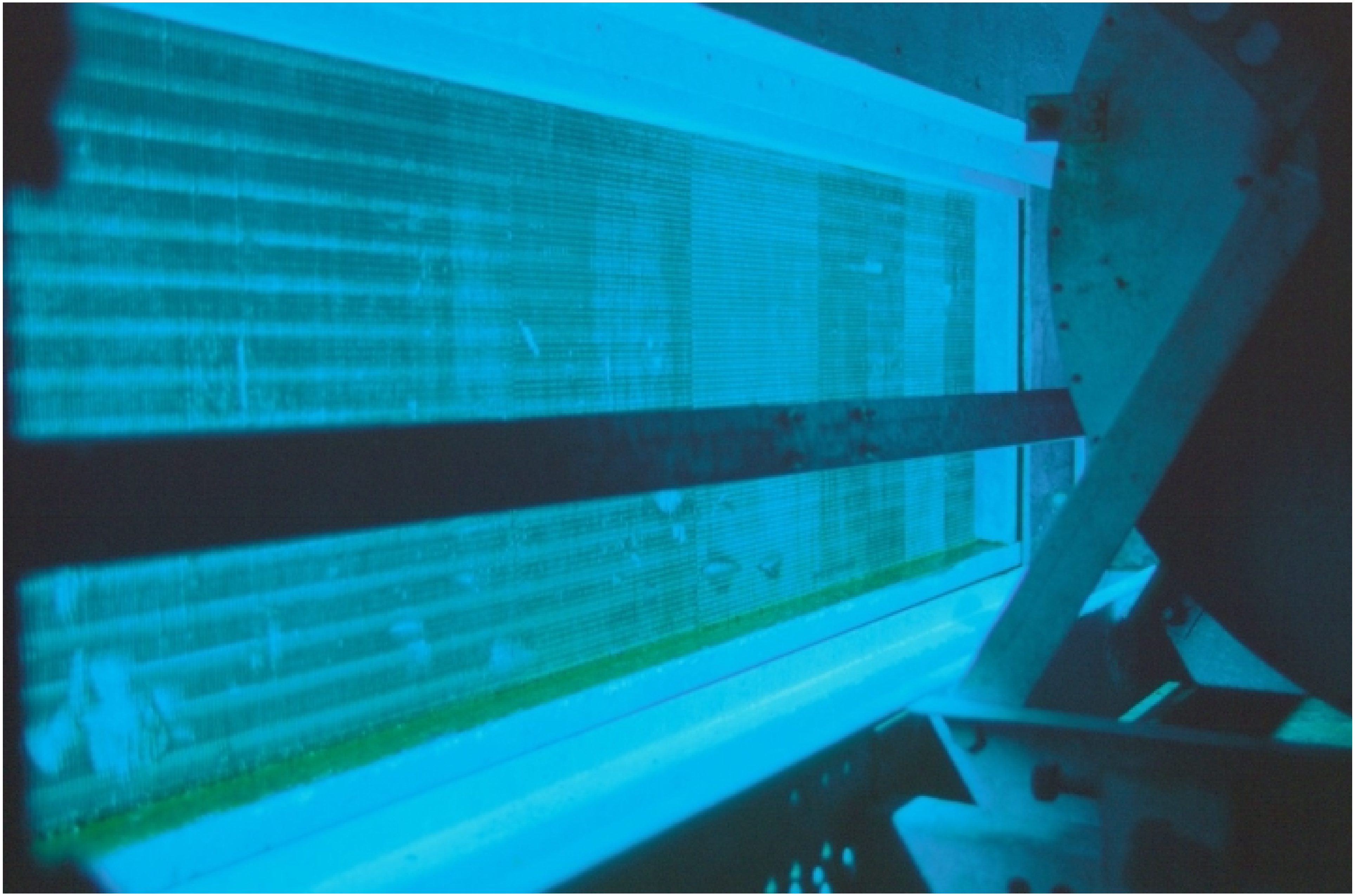
- If further study shows that alternatives are more cost effective, then stricter reheat limitations will be recommended.
- Difficult balance between limiting energy consumption and encouraging IAQ

Ultraviolet Germicidal Irradiation (UVGI)

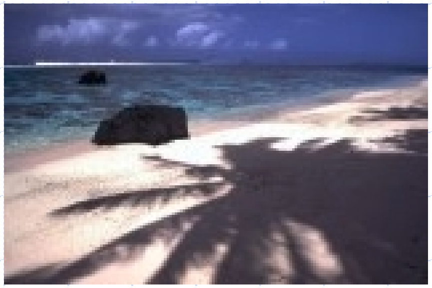


- Look like linear fluorescent lamps
  - UV-C, wavelength of 0.2537 microns
  - Penetrates germ cells, destroys DNA info
- Two primary applications
  - Prevent mold growth on cooling coils
    - Coverage of about 4 ft^2 coil per 24 inch lamp
  - Kill organisms in air stream
    - Requires much higher light intensity
    - Tuberculosis control


CAUTI

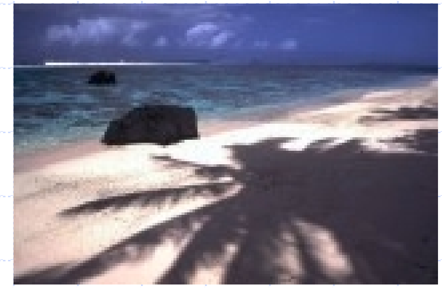


Iolani School, Honolulu



- 35,000 ft^2 office and classroom building
- Six AHUs, total of 45,000 cfm
- 20 UV lamps total
- Lamps last 1.5 years
- Replacement cost approx. $1,300/year
- Eliminated mold growth and odor
- Maintenance savings $8,000 per year
- Report fewer complaints of respiratory problems
- Facility manager very satisfied

Preliminary Observations and Conclusions



- All Hawaiian cooling coils grow mold!
  - Cleaning required 1 to 2 times per year
  - UV lamps effectively inhibit mold growth on cooling coils
- Primary benefits are:
  - Improved IAQ
  - Lower maintenance cost (less cleaning required)
  - Less frequent use of potentially toxic cleaning chemicals
- Energy benefits are small
  - (But mold probably reduces system cooling capacity)
- Most important applications
  - Areas with dirty/dusty air
  - Spaces with health concerns
- Code Issues
  - More appropriate for IAQ standards
  - Probably not appropriate as mandatory requirement