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Economic Analysis Process Applied To The Worlds' Largest Wind Tunnel

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ISPA-SCEA 2007 Joint Conference

June 12 – 15, 2007

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Arnold Engineering Development Center (AEDC)

AEDC is the World's Largest Complex of Wind Tunnels and Simulation Facilities

- Located in Tullahoma, Tennessee
- Established in 1950
- 56 Interrelated Plant Systems and Test Facilities

AEDC is a Major Range & Test Facility Base (MRTFB)

- Arnold
- Eglin
- Edwards

AEDC is Undr USAF Management with Contractor Workforce

- 8% Government, 92% Contractor
- 2,978 Total Personnel

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AEDC – Aerial View

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AEDC Detail View 1

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AEDC Detail View 2

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RC-1 Cooler

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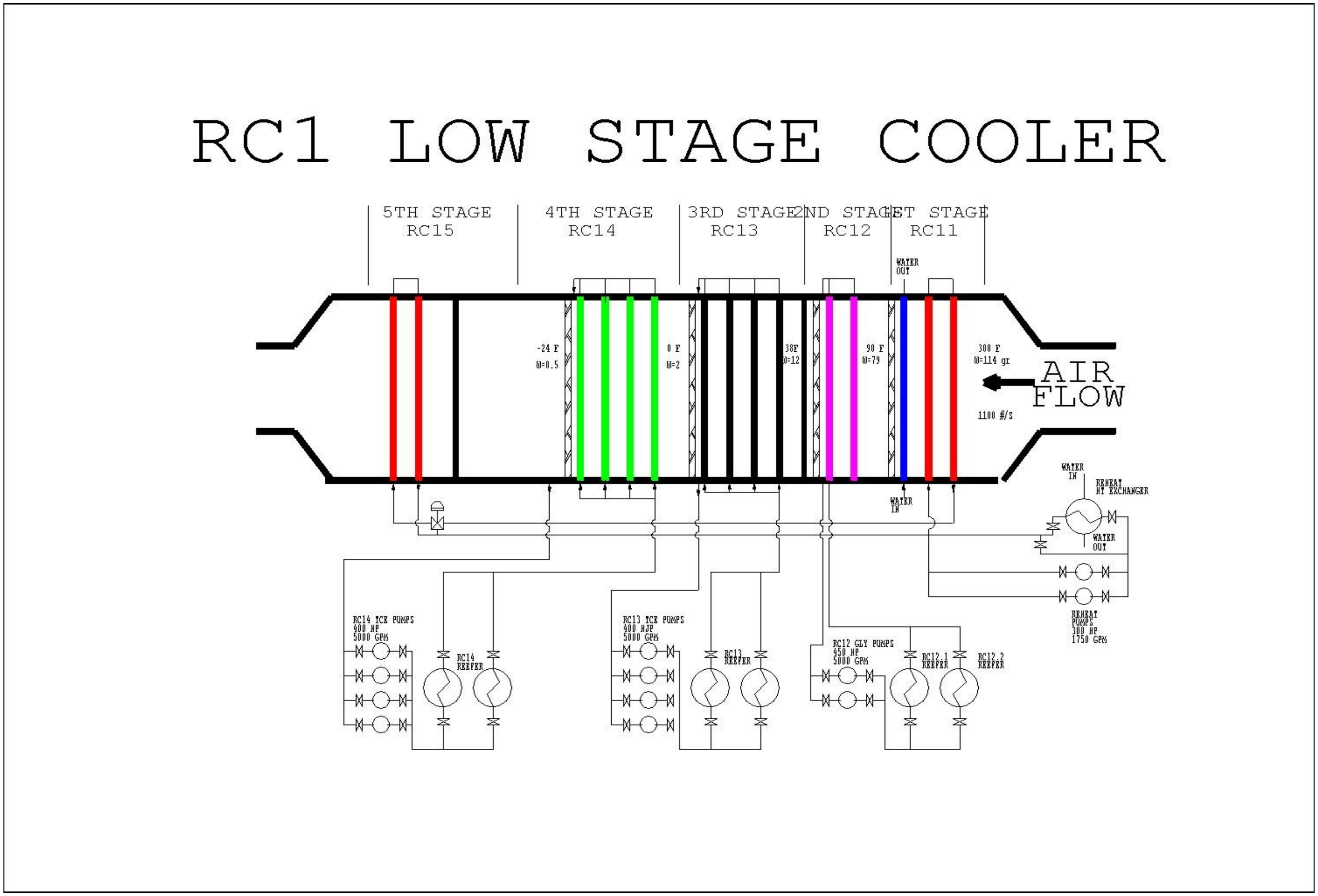
RC-1 Diagram



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Some RC-1 Cooler Information

1,200 lb/second of ambient air brought in by compressors

- About the volume of a 2,100 sq ft house
- Exits at 300ºF.

RC-1 cools and dries the air to simulate conditions at high altitude and prevent ice from forming

- Cools to -25ºF
- Humidity reduced up to 99.6% (over 3 gal/sec.)

Downstream compressors “suck out” the air creating low pressure & low humidity high altitude conditions.

Cold Dry Low Pressure Air Moving Really Fast

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RC-1 Cooler Concern

- 1970s design
  - Mechanical refrigeration
  - Pressurized dehumidification cooler
  - Time - worn out
  - Could be a single-point-of-failure
  - Environmental issues
    - 24,000 lbs of Freon (R12)
      - Ozone depletion
    - 50,000 gallons of trichloroethylene (TCE)
      - Affects the central nervous system
      - Damage nerves, liver, kidneys, cause cancer

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RC-1 Cooler Task

Identify an approach to restore the RC-1 Cooler that:

- Meets current operational performance capabilities
- Eliminates single-point-of-failure
- Removes TCE as the brining agent
- Removes R12 as the refrigerant.

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Economic Analysis – Point 1

Those who are accomplishing the EA need and understanding of the technical attributes and features of the system for which the EA is being accomplished.

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Options Considered

- Mechanical Drying
  - Refrigerant System Upgrade with R12 & Dynalene HC40, new refrigeration system, new RC1 coils
  - Refrigerant System Upgrade with Ammonia & Dynalene HC40, new refrigeration system, new RC1 coils)
  - Four New Coolers (one cooler for each compressor)
  - One New Cooler ("RC-1B" parallel cooler)
- Desiccant Drying
  - Desiccant Wheels (Parallel or Series)
  - Liquid or Multi-bed Desiccants
- Others
  - Cryogenic Dehumidification System (Liquid Air)
  - Desiccant Wheels added to low-stage desiccant wheel
  - Maintain Status Quo

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Two Options Selected Further Study

- Mechanical Drying
  - Refrigerant System Upgrade
    - R12 to R507A
    - TCE to Dynalene HC40
    - New industrial refrigeration system
    - New RC1 coils)
- Desiccant Drying
  - Desiccant Wheels (Parallel)

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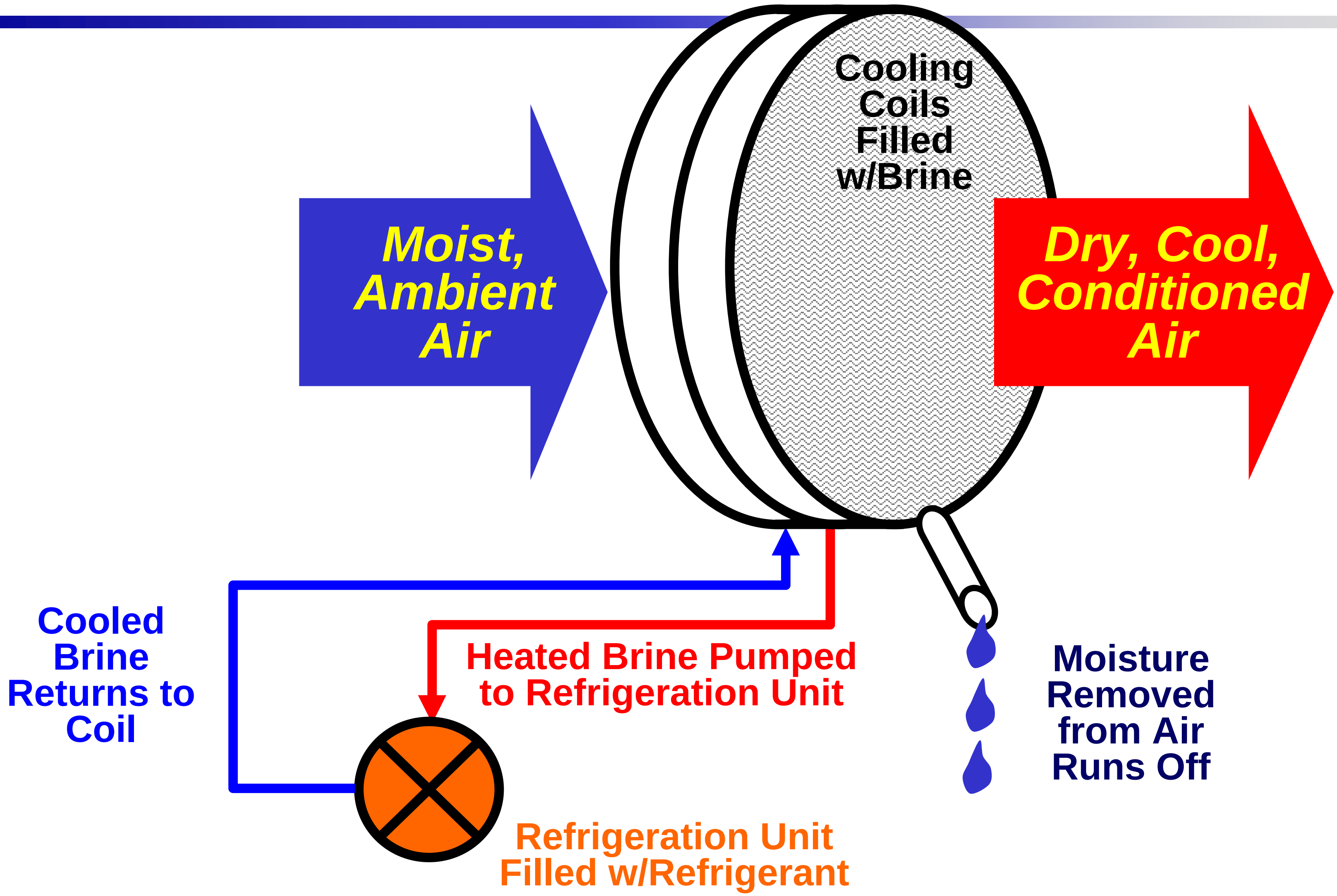
Mechanical Drying



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Refrigerant System Upgrade

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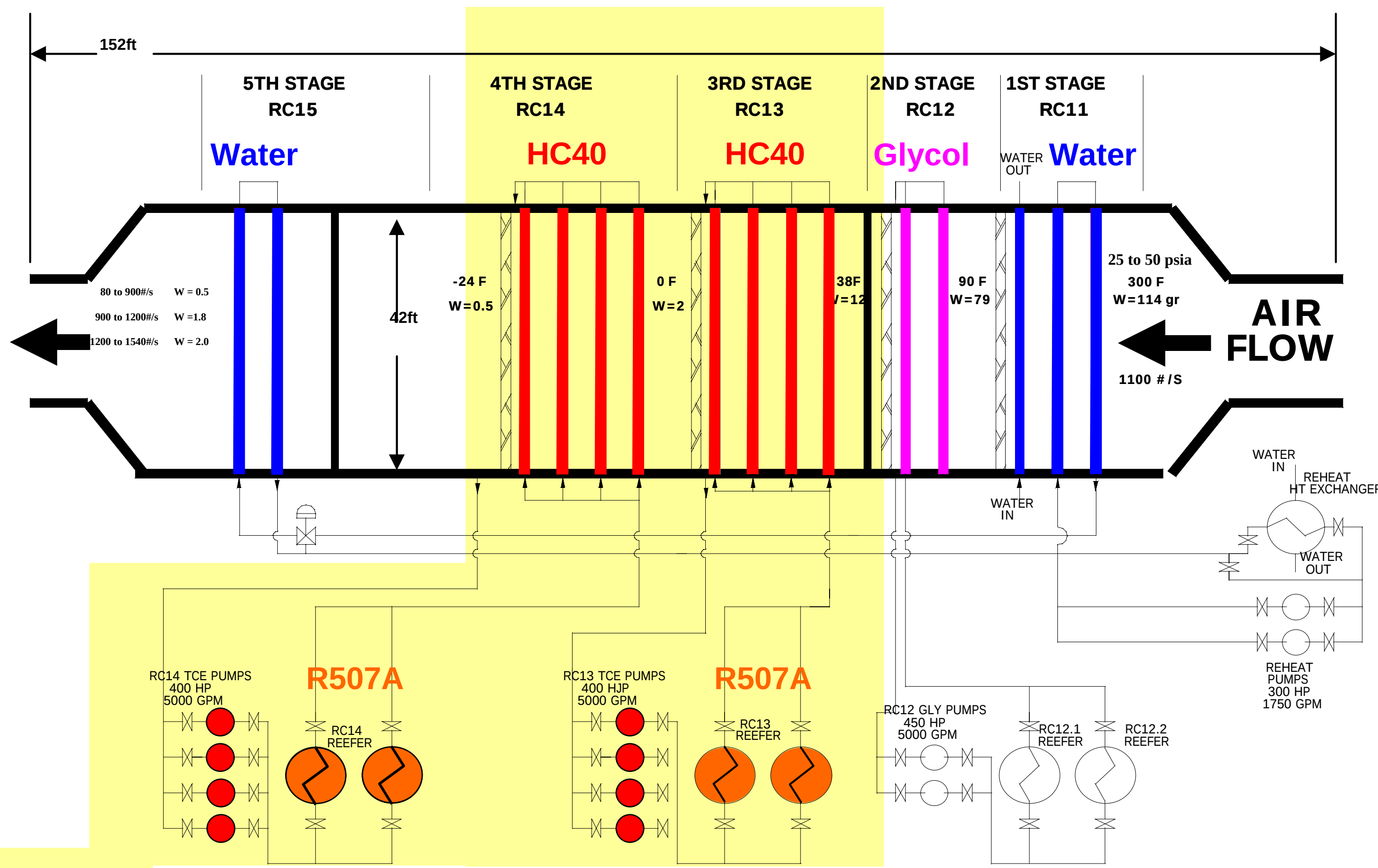
RC-1 LOW STAGE COOLER

Water

Glycol

Dynalene HC40

R507A



3rd and 4th Stages

- Dynalene HC40 replaces TCE
- R507A Refrigerant replaces R12

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Refrigerant System Upgrade

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Life Cycle Cost

- Known maintenance costs
- System sustainment costs will mirror current costs
- 15-20% more pumping power required for Dynalene over TCE
- Risk that use of selected fluids (R507A refrigerant and Dynalene HC40 brine) will be restricted later

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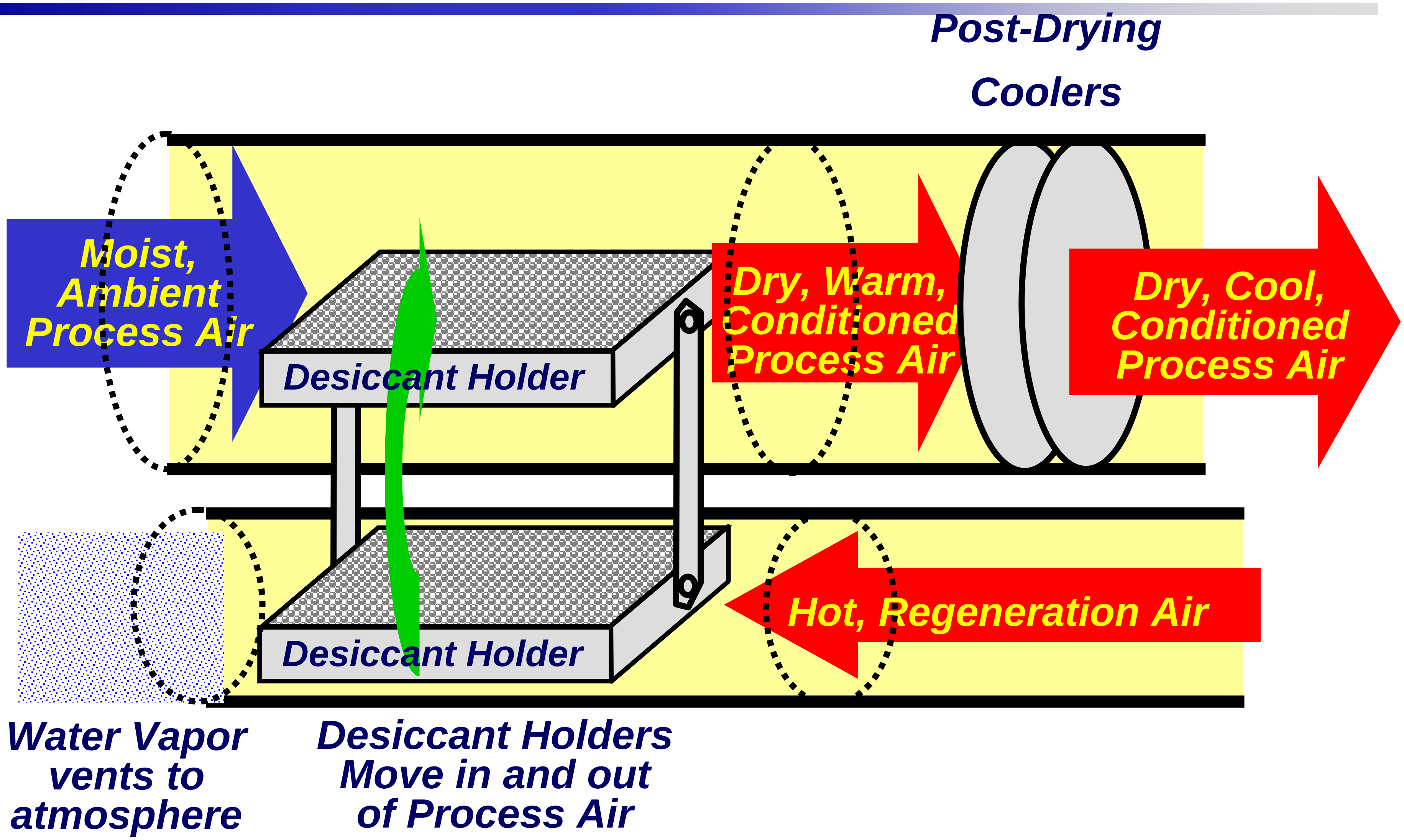
Desiccant Drying



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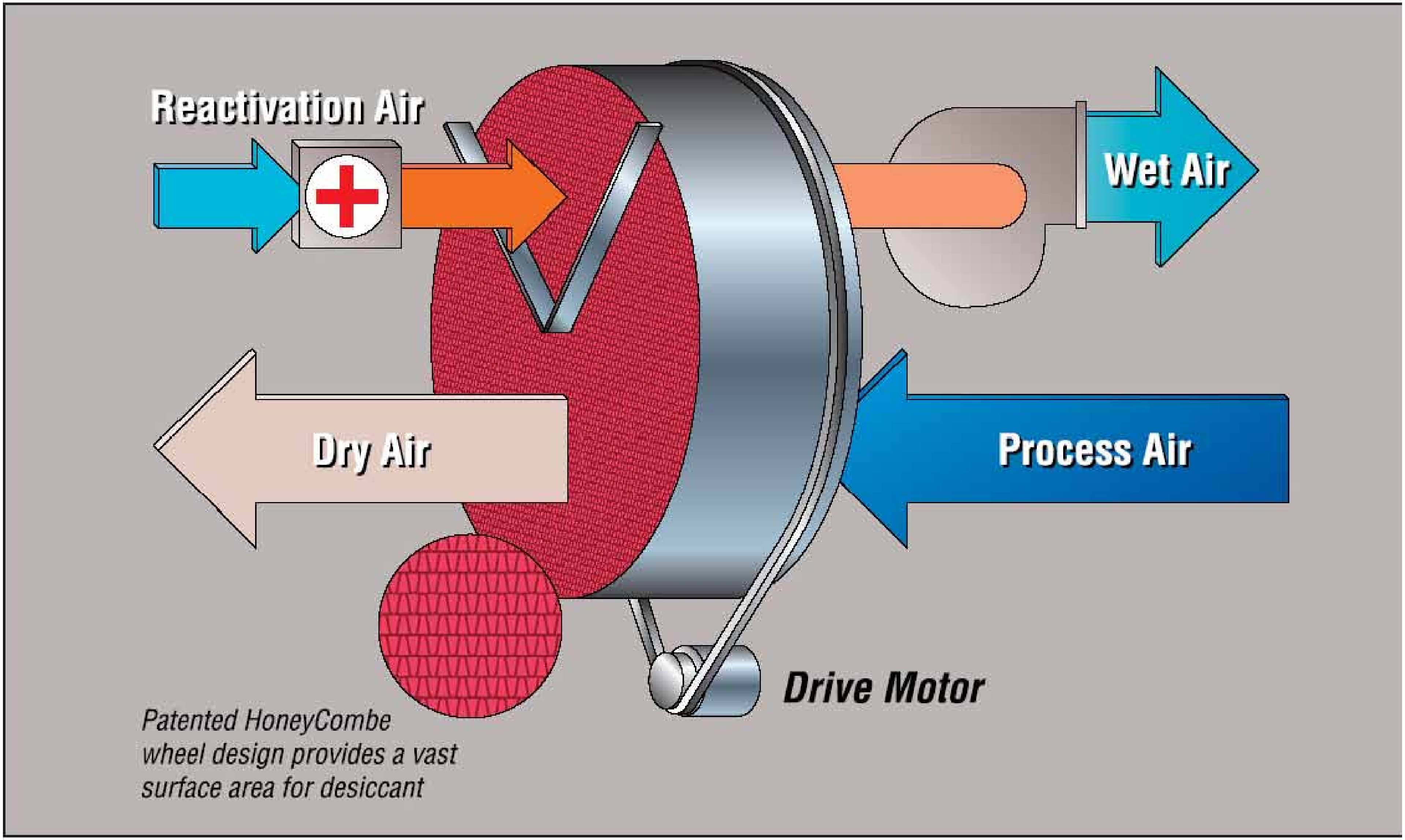
Desiccant Wheel Principal



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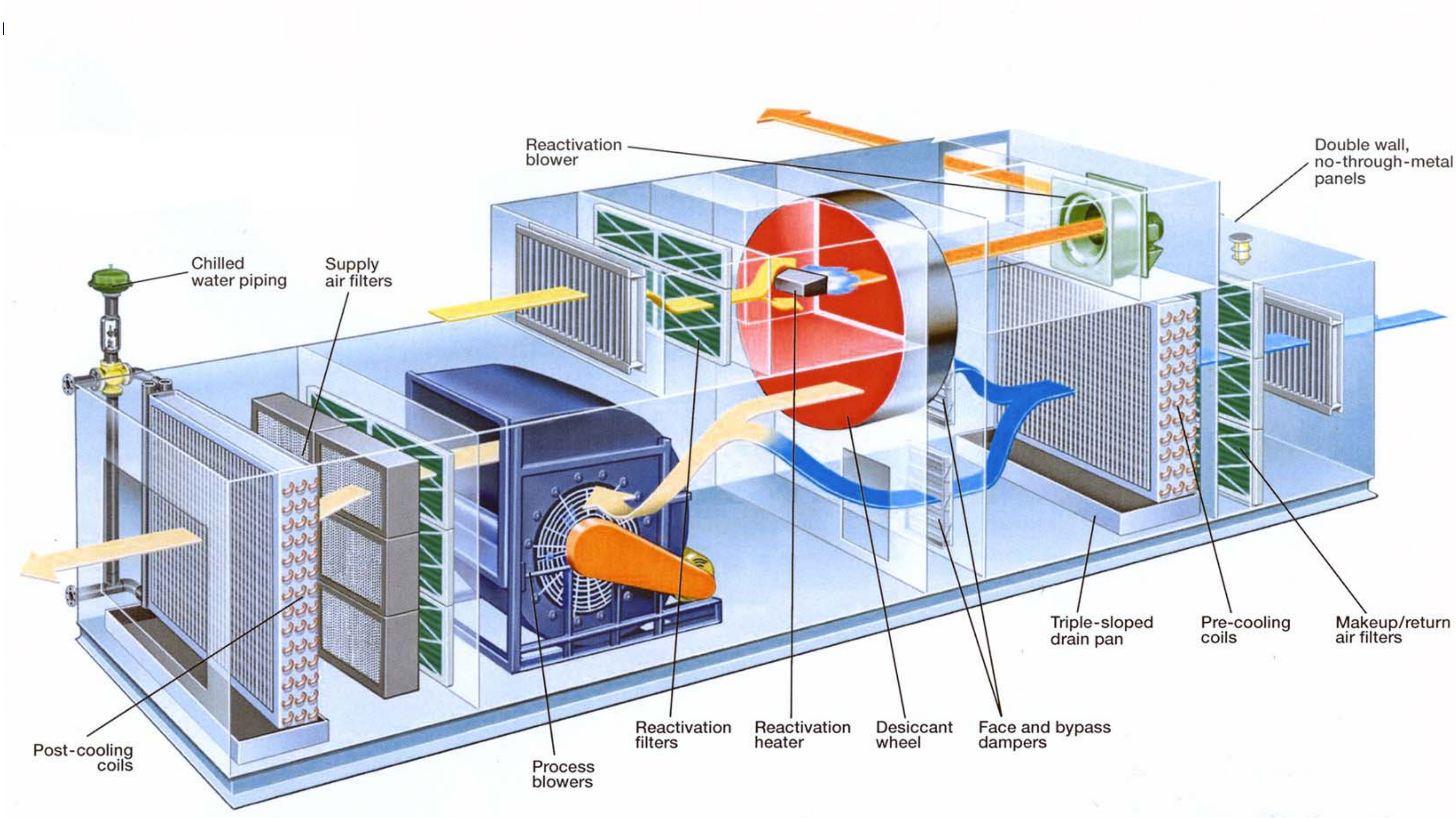
Desiccant Wheels



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Desiccant Wheel

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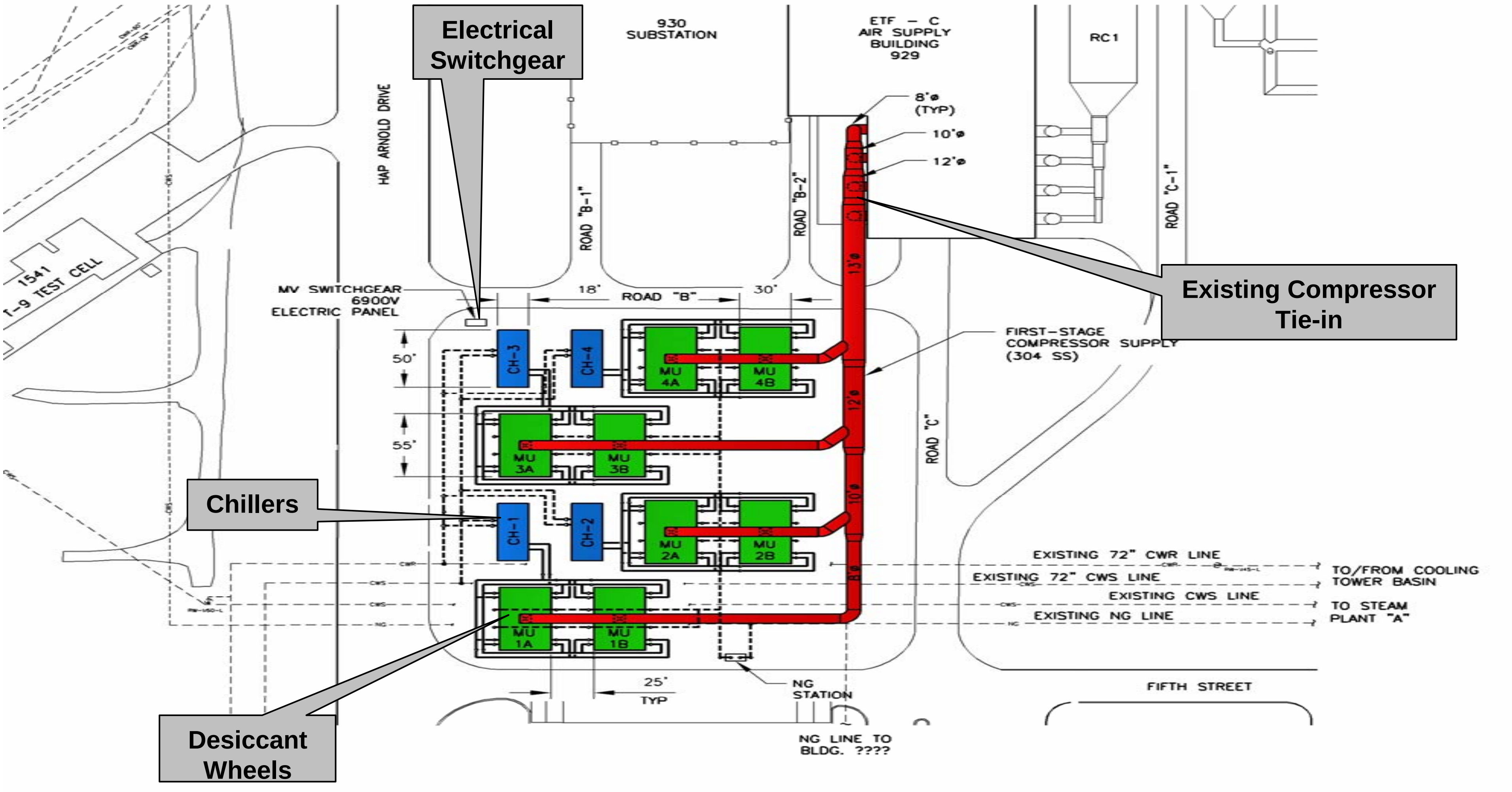
Desiccant Drying Equipment Installation



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Desiccant Drying

Life Cycle Cost

Desiccant Dryer Quad-Units

Four 10’ desiccant wheels per quad-unit

Eight 8 Quad-Units required

A total of 32 individual wheels

No commercial installation of this magnitude exists.

Commercial large dry-air --- up to 120 lbs/sec.

This concept needs 1,200 lbs/sec.!

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Desiccant Drying

Life Cycle Cost

Long life of desiccant wheels (10 – 15 years)

O&M costs estimated based on power use and contractor maintenance cost data

Uncertainty of natural gas costs

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Economic Analysis Approach

Construction Cost

Operations Cost

Maintenance Cost

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Construction Cost Estimate Approach

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Engineers estimated labor & material cost for each item.
Example of scope for one Work Package

MECHANICAL UTILITIES - Work Package 1	
Replace RC14 System	
Replace RC14 System	
	P&I new base for custom built RC14 chiller
	P&I new bases for new RC14 brine pumps
Subtotal	
Equipment - Replace RC14 System	
	P&I new custom built RC14 chiller. (includes condensers, evaporators, compressors, vessels, & related chiller piping)
	Demo RC14 Coils within RC1 cooler (Coils K,L,M,N)
	Demo Existing RC14 brine pumps (14.1, 14.2, 14.3, 14.4)
	Demo existing RC14 brine expansion tank
	P&I new brine pumps for RC14 circuit
	P&I new RC14 brine expansion tank
	P&I new RC14 coils within RC1 cooler Coils
	Demo old RC14 chiller and remaining related RC14 equipment

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Economic Analysis – Point 2

The EA analyst will develop some of the supporting cost estimates. In these cases, an understanding of the system is necessary to develop a credible cost estimate for each EA cost area.

If the estimate is provided the EA analyst must understand and concur with that cost estimate information.

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Construction Cost Estimate Approach

The construction cost estimates for both approaches were close to each other.

The primary difference was that the Desiccant Wheel option construction costs are earlier than for the Mechanical Drying approach.

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Operations Cost Estimate Approach

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Example of calculations based on power requirements.

Calculation Approach Example Only	Comp Pwr	Elct Pwr	Nat Gas
Description	TON	BHP	CFH
Compressor power			
RC12 Stage	9000	6000	
RC13 Stage	4000	7000	
Brine Pump power			
RC12 Stage		1000	
RC13 Stage		1500	
Condenser water pumps			
RC12		1700	
RC13		700	
RC11a and RC11B		150	
RC11C		300	
Brine spray reboilers			9000
Brine spray pump #1		10	
Brine spray pump #2		10	
TOTAL:		18370	9000
TOTAL (KW) = 0.5 * TOTAL (BHP)			9,185
TOTAL ($/HR electricity) = 0.1* TOTAL (KW)			$ 919
TOTAL ($/HR gas) = 0.02* TOTAL (CFH)			$ 180
TOTAL ($/HR) = Electricity ($/HR) + Gas ($/HR)			$ 1,099
Monthly - 16hrs/day x 30 days			$527,280

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Operations Cost Estimate Approach

Mechanical Drying

Electric power requirements are large for the refrigeration system.

Desiccant Dryer

Natural gas costs for the regeneration heater is the primary component.

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Maintenance Cost Estimate Approach

Mechanical Drying – based on historical costs for the current system.

Desiccant Wheel Dryers – based on contractor rates for maintenance of this equipment.

The Mx costs are lower than the Operations costs.

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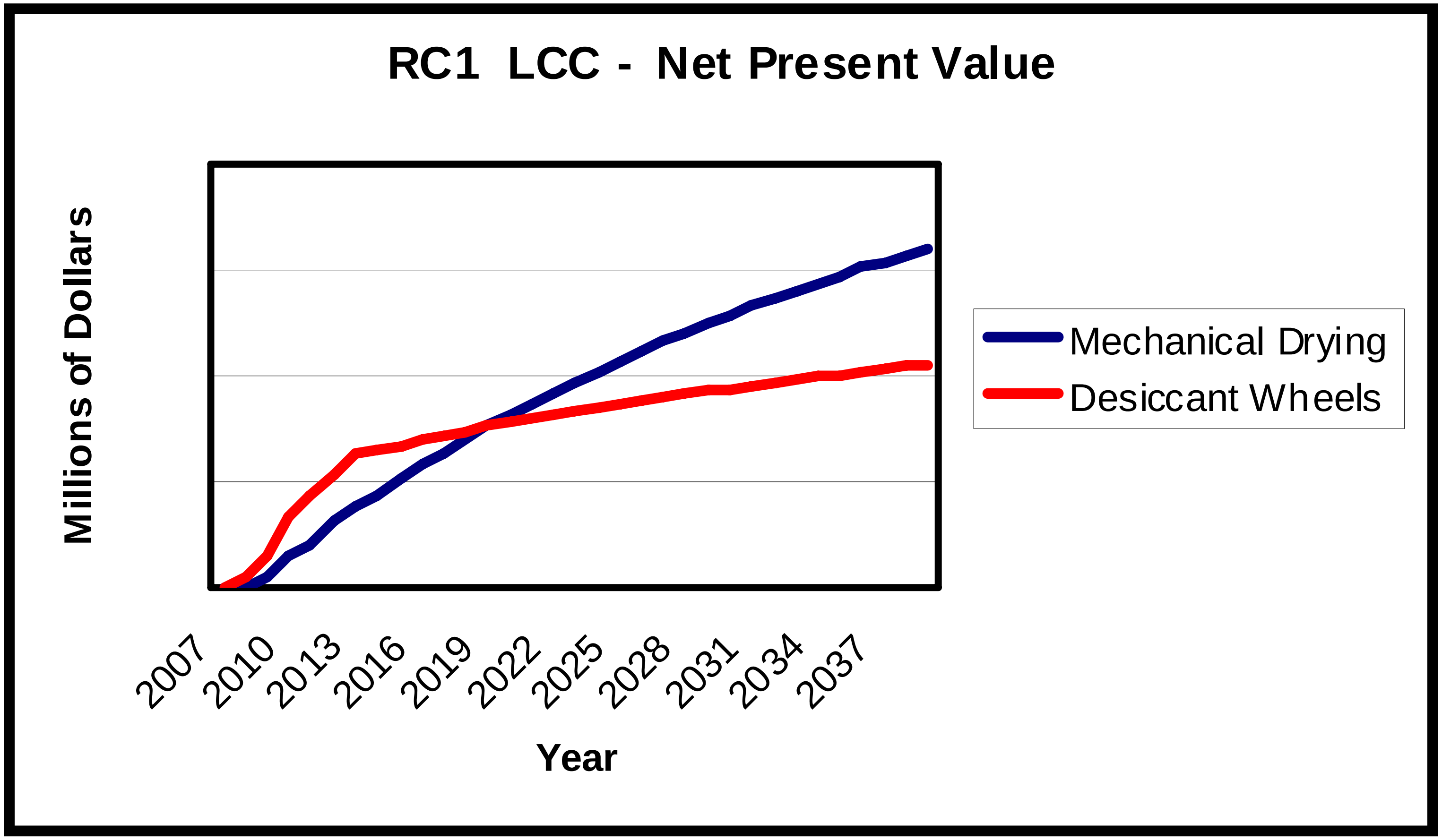
Net Present Value Chart



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Economic Analysis – Point 3

Be be able to explain the reasons for the EA cost differences between the alternatives.

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Net Present Value Observation

The construction costs were about the same except for the timing of the expenditures

The maintenance costs were both relatively low

The larger operations cost for the Mechanical Drying option causes it's NPV to become much larger over time

Operations is the NPV cost driver.

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Economic Analysis – Point 4

The EA results are only one component of a decision making process. The decision process will assess and weigh several decision criteria.

An assignment of the “relative value” for each decision criteria will help in developing and defending the final decision.

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Overall Evaluation Criteria

- Function (21%)
  - Simplicity, Training, Ease of Operations
- Reliability, Availability, and Maintainability
  - Operations, Degradation, Maintenance
- Viability (12%)
  - Capital, Operations and Maintenance Costs
- Supportability (10%)
  - Maintenance Requirements, Logistics Support,
- Liability (15%)
  - Safety, Hygiene, Impacts, Energy Conservation
- Acquisition Planning (10%)
  - MILCON, R&M Funds
- Technical Risk (7%)
  - Obsolescence, Mitigation, Contamination
- Schedule (5%)
  - Duration of Repair, Ops & Mx Impacts

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Evaluation Matrix

Criteria		Weighting	
Functionality		21%	
Reliability, Availability and Maintainability		20%	
Viability		12%	
	Capital cost		7%
	Annual operating costs		5%
Supportability		10%	
	Annual maintenance costs		7%
	Logistics support		2%
	Freq/Amount of replacement costs		1%
Liability		15%	
Acquisition Planning		10%	
Technical Risk		7%	
Schedule		5%	

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Economic Analysis Interim Results

At this point, the Desiccant Wheel approach has the smaller Net Present Value

However, also at this time (mid-March 2007) technical changes were required that will change the results.

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Economic Analysis – Point 5

Systems analysis and evaluations often are dynamic.

Due to technical, programmatic, funding and other concerns or constraints the alternatives are redefined.

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Technical Changes

The set of alternatives was modified to three options:

Option 1: Mechanical Drying (Previous Option)

Option 2: Mechanical Drying (Previous Option)
+ High-Stage Desiccant Drying

Option3: Desiccant Wheels (Previous Option)
+ Low Stage Mechanical Drying

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Option 1: Mechanical Drying

Same as the earlier Mechanical Drying Alternative

No change in the Economic Analysis

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Option 2: Option 1 + High-Stage Desiccant Drying

Add High-Stage Desiccant Drying to the Mechanical Drying Alternative.

- Install 8 Desiccant Dryer Units upstream of the high stage compressors
- Pre cooling coils remove about 2/3 moisture
- Desiccant wheels remove remaining moisture
- Regeneration with natural gas burners

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Option 2: Desiccant Dryer Unit

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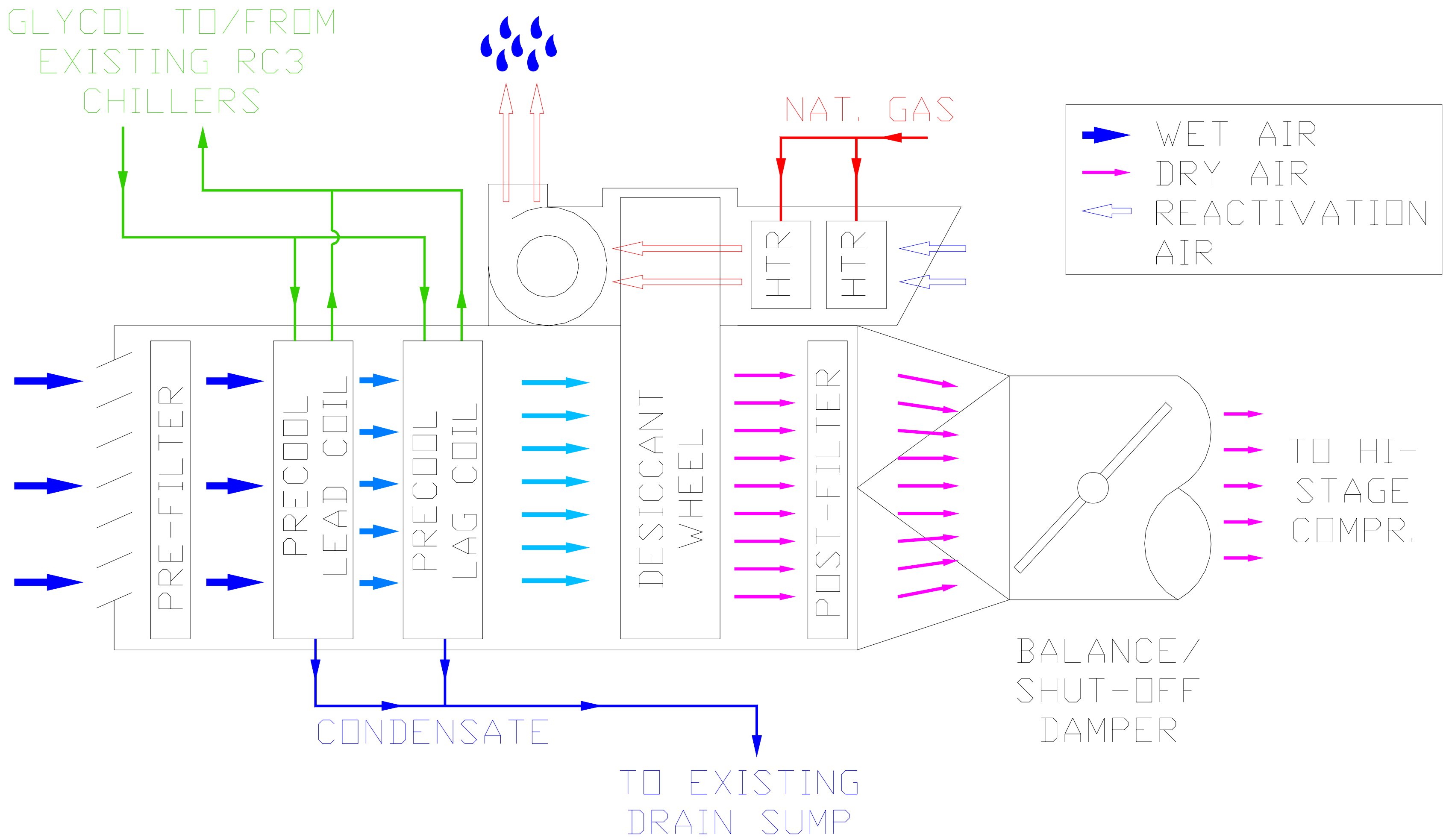

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Option3: Desiccant Wheels + Low Stage Mechanical Drying

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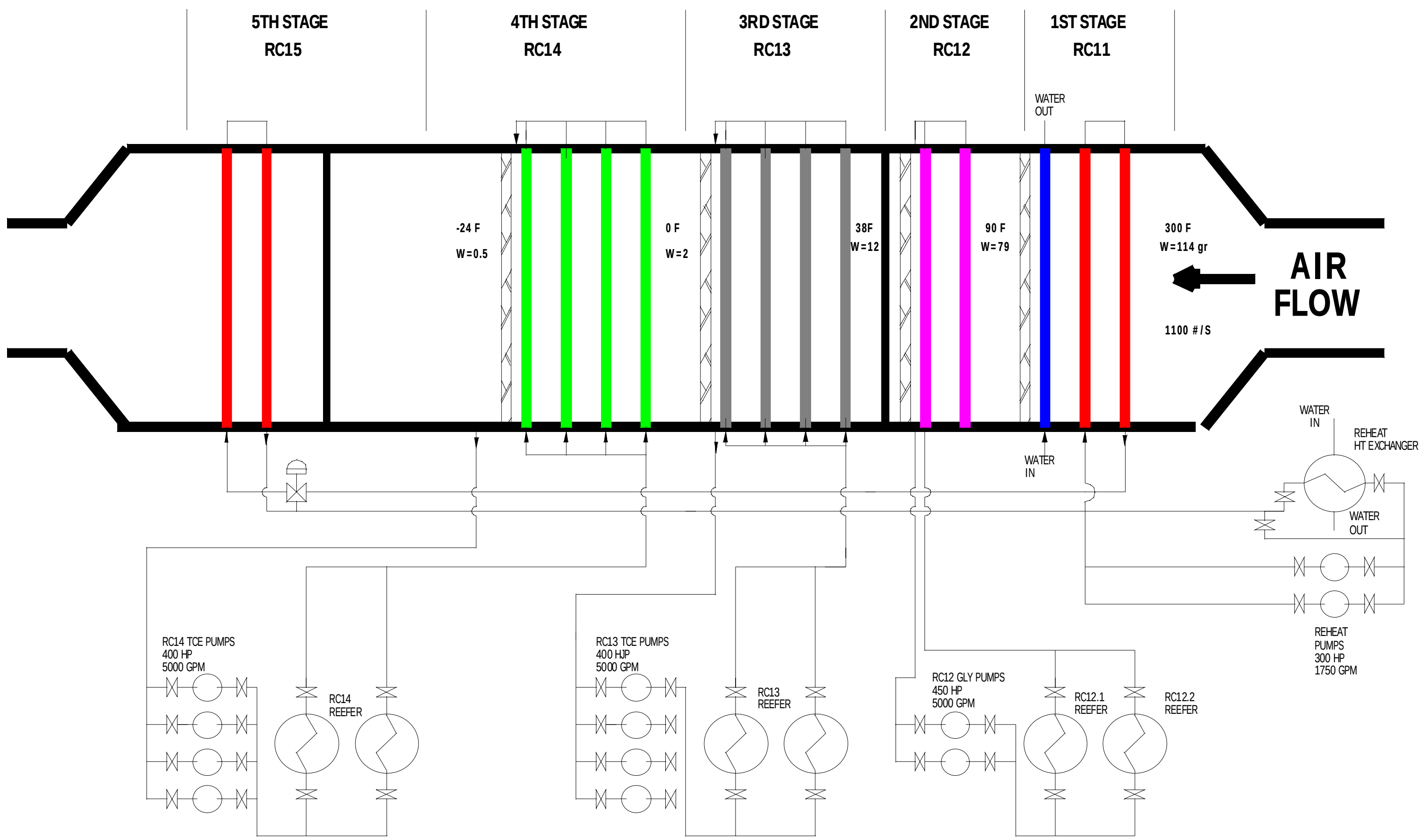
RC1 LOW STAGE COOLER



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Option3: Desiccant Wheels + Low Stage Mechanical Drying

Add Low-Stage Mechanical Drying to the Desiccant Wheel Alternative

- Modify the existing RC1 cooler system
- Provide new cooler coils and refrigeration
- Replace the R12 and Trichloroethylene
- Replace secondary coolant & brine systems
- Replace centrifugal with screw type chillers

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Economic Analysis – Point 6

Due to the often dynamic nature of the alternative process the EA process will continue to be dynamic.

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Economic Analysis – Point 7

As of the submission date for this paper (April 9) the parameters associated with these changes are being defined by the members of the technical team.

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Economic Analysis – Point 8

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The EA process will continue upon availability of that data.

Updated information will be provided at the
ISPA-SCEA 2007 Joint Conference
June 12-15, 2007