

Laboratories For The 21st Century
October 8, 2002

THE PROBLEM WITH SINGLE DUCT VAV:

The Built-In Inefficiency of a
Common Lab HVAC System



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Flack + Kurtz Inc.

OVERVIEW

- Laboratory Building Cooling Requirements
 - Laboratory Building Ventilation Requirements
 - Overview of Single Duct VAV
-
- Inefficiency of Single Duct VAV
 - Alternatives

COOLING LOADS WITHIN THE LABORATORY

- Lab Equipment
 - Often no precise information
 - Over-designed to allow for flexibility & future growth
- Lighting
- People
- Envelope

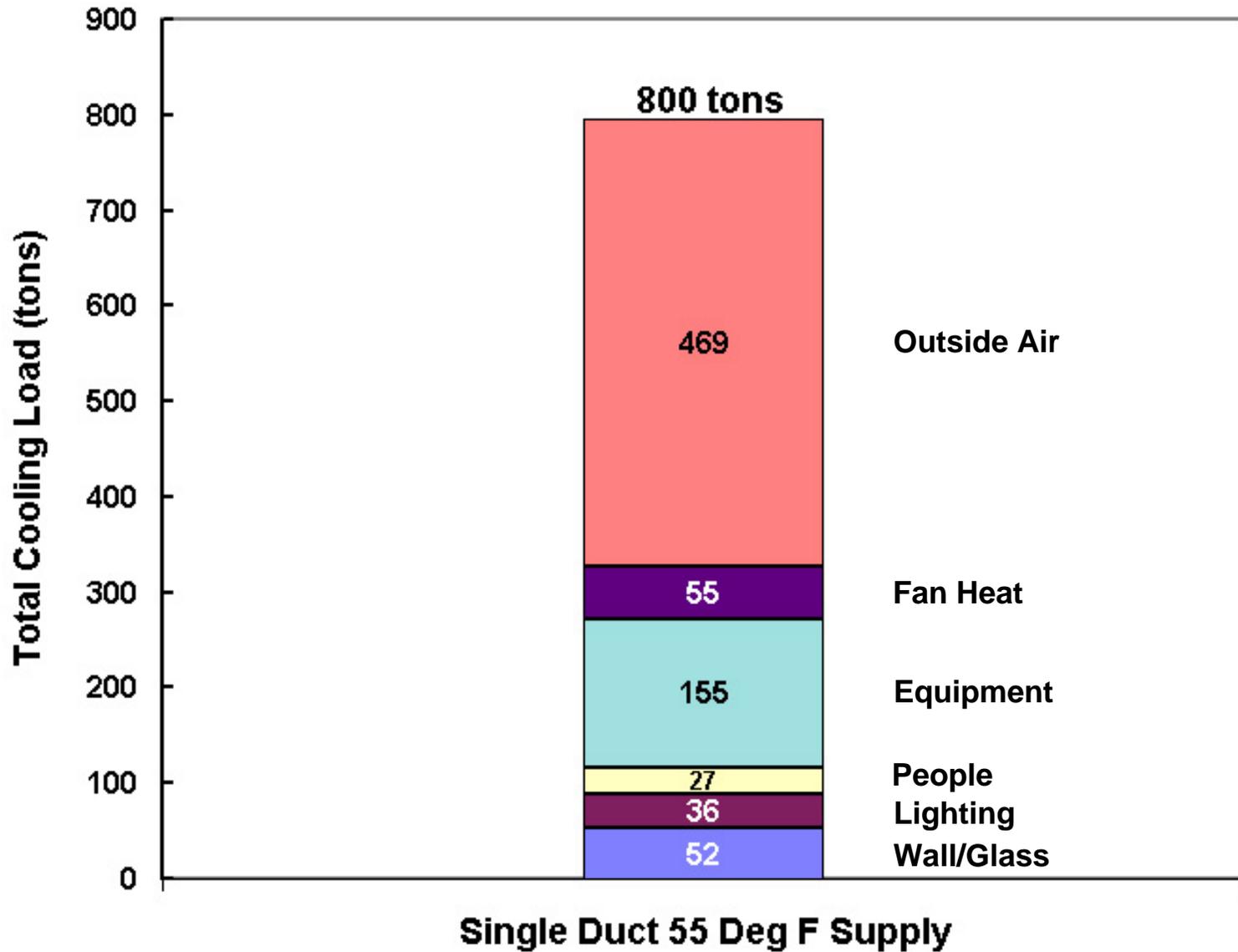
SPACE LOADS DETERMINE AIRFLOW VOLUME

COOLING LOADS

EXTERNAL TO THE LABORATORY

- Outside Air
 - Cool outside air to room temperature
 - Consider Temperature AND Humidity
- Fan Heat

SYSTEM DESIGN COOLING LOAD

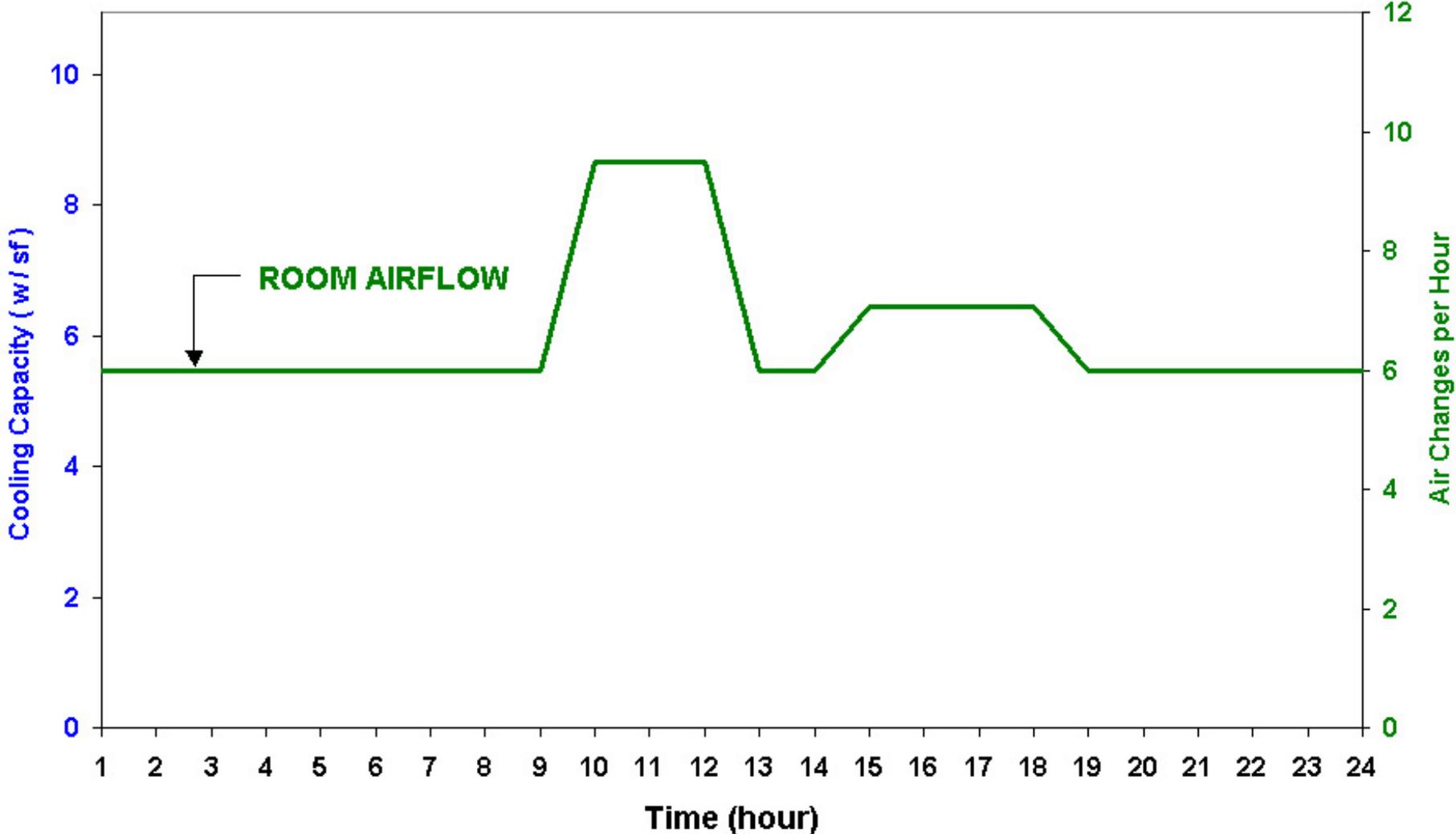


VENTILATION REQUIREMENTS

- Constant Airflow
 - Minimum Air Change Rate within Lab Space
 - 24 Hours/Day, 7 Days/Week
 - Historically: 10? 12? 15? per hour
 - Current Trends: 6 per hour (4???)
 - Snorkels, Gas Cabinets, Environmental Rooms, Toilet Rooms
- Variable Airflow
 - Fume Hoods (?)

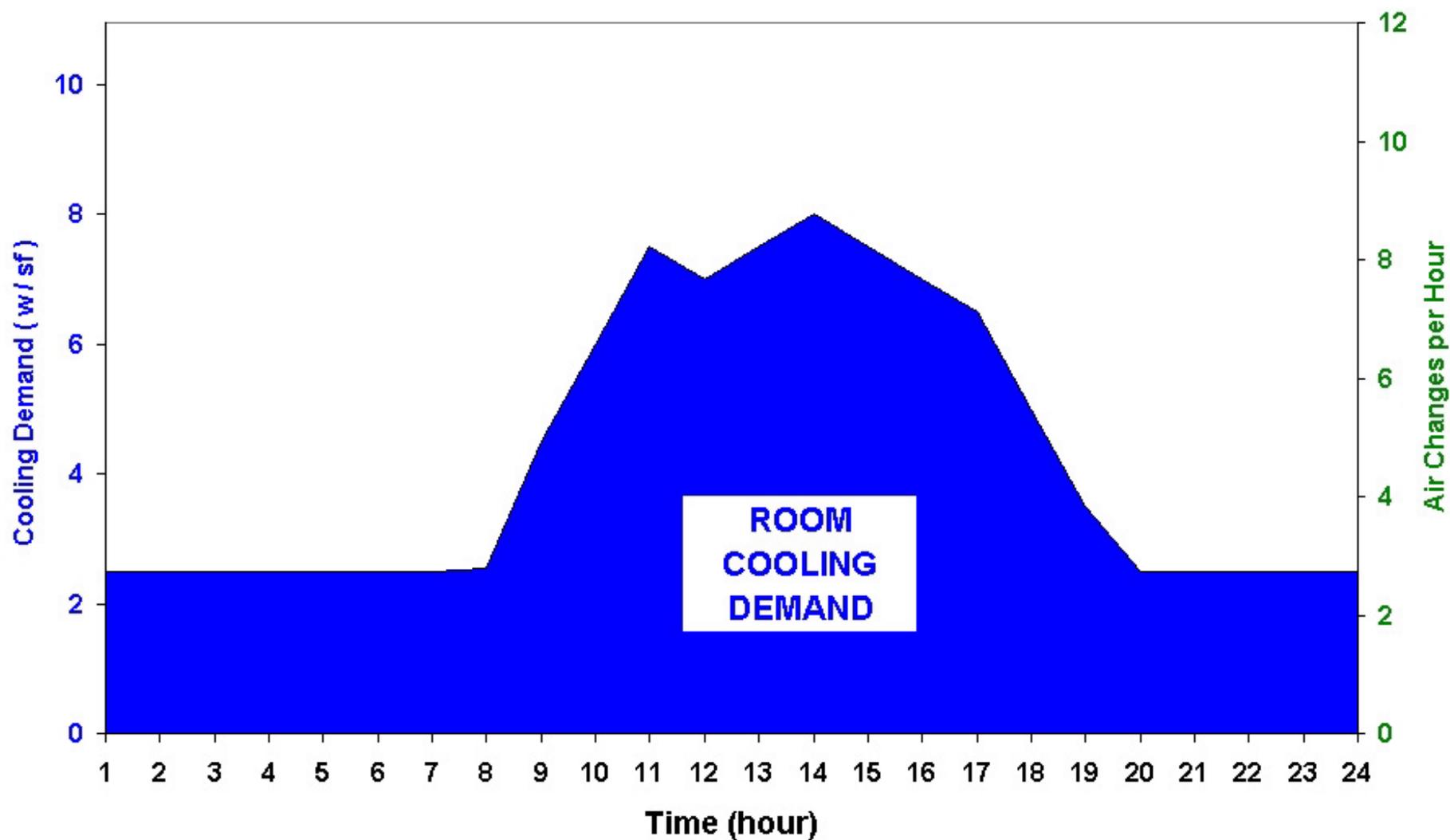
AIRFLOW VENTILATION DEMAND

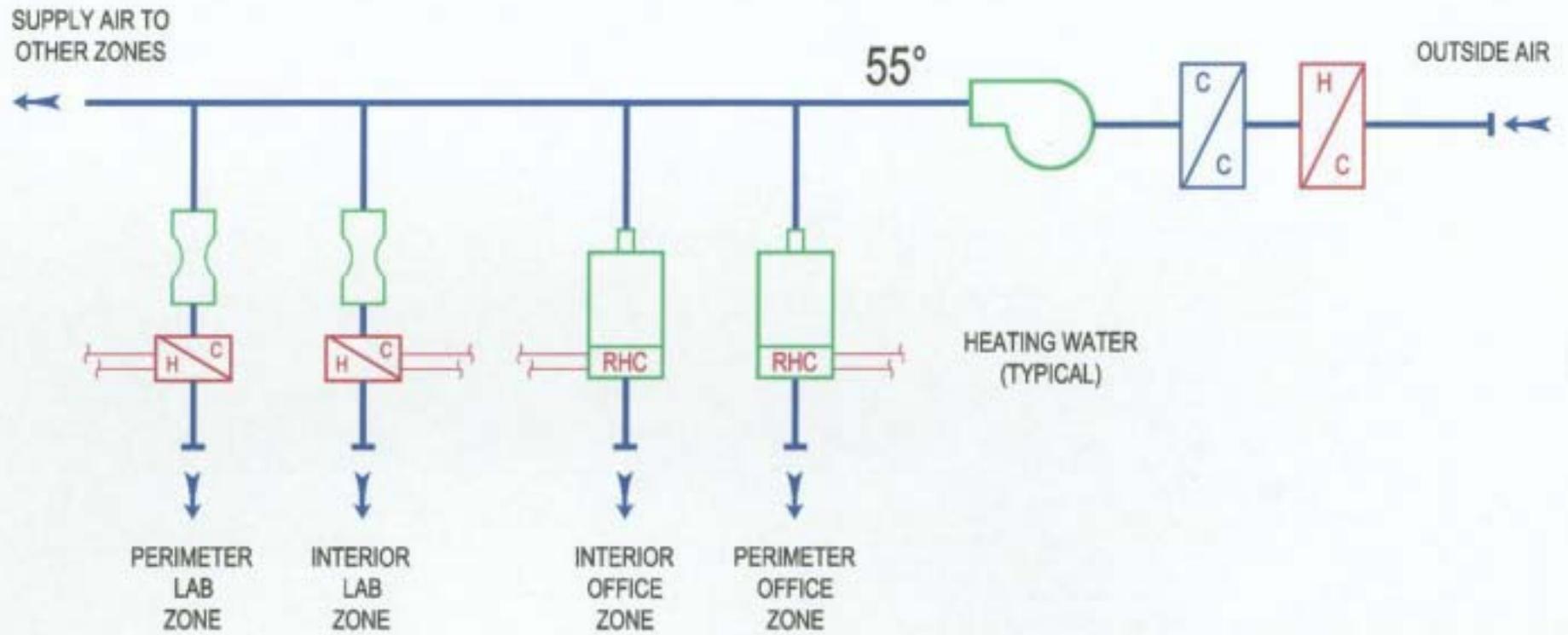
Materials Research Lab - 900 sf, 2 Gas Cabinets, 6' Hood



ROOM COOLING DEMAND

Materials Research Lab - 900 sf, 2 Gas Cabinets, 6' Hood

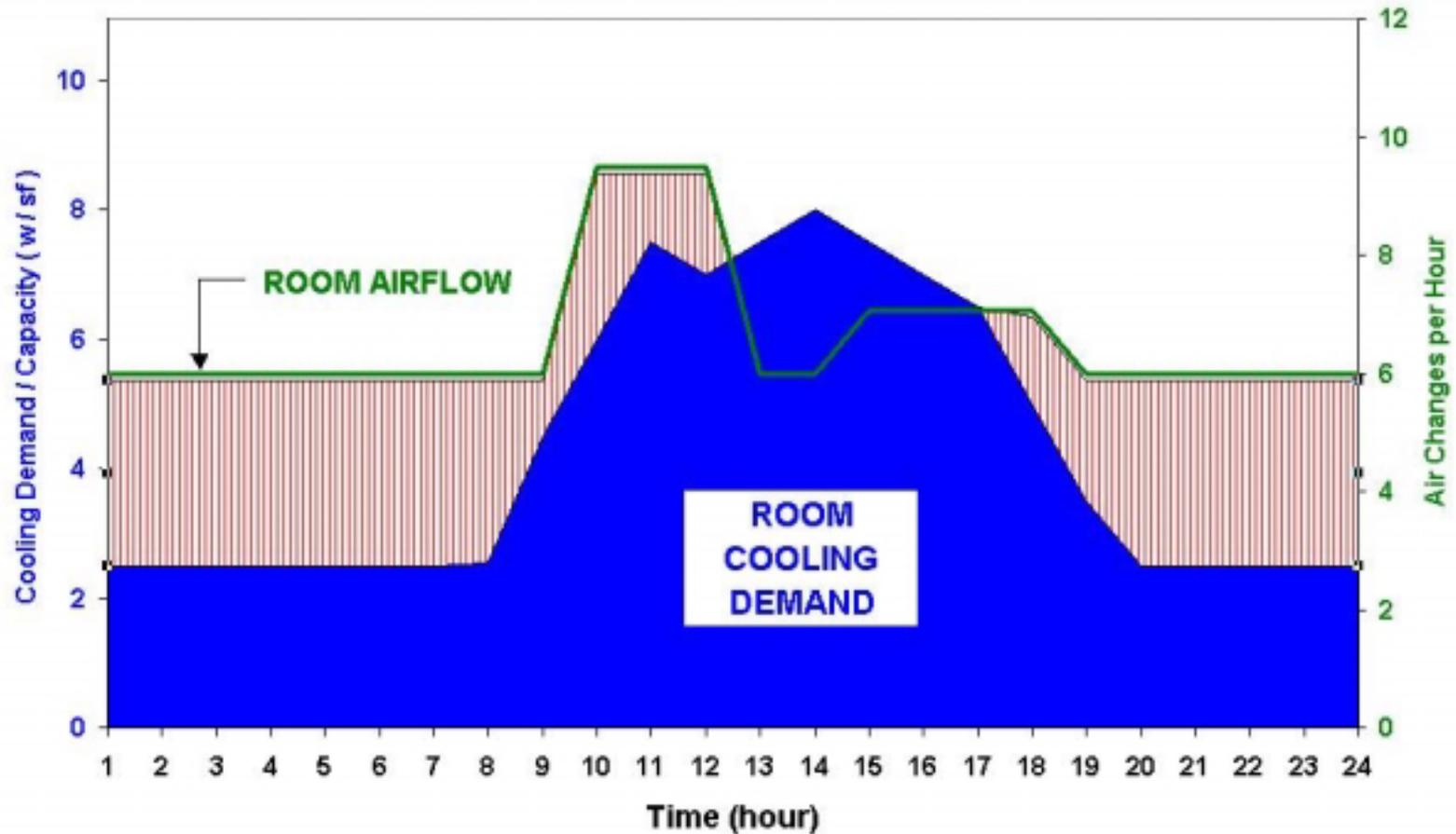




SINGLE DUCT WITH REHEAT

AIRFLOW COOLING CAPACITY vs. ROOM COOLING DEMAND

Materials Research Lab - 900 sf, 2 Gas Cabinets, 6' Hood



PROBLEM: One System Used for BOTH Cooling and Ventilation

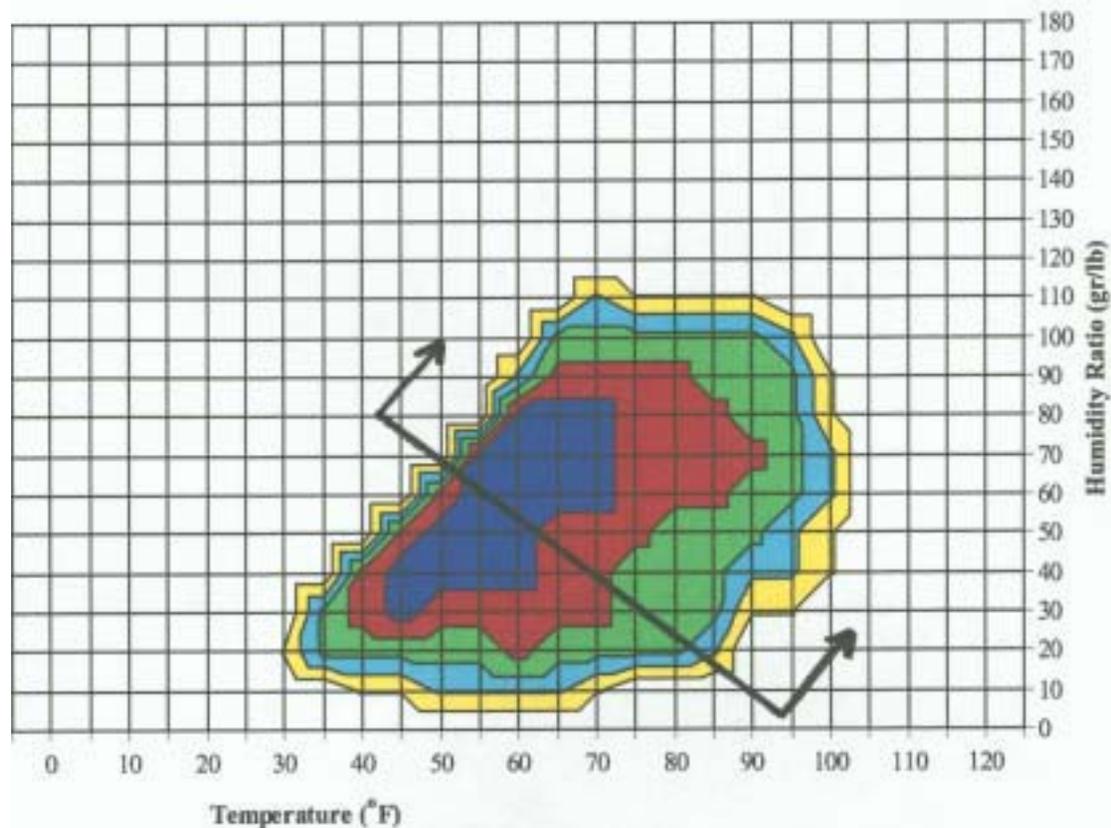
ENERGY WASTED: Ventilation Airflow > Cooling Airflow AND Outside Air Temp > Supply Air Temp

ONTARIO CA
Dry-Bulb Temperature Hours
 Period of Record = 1973 to 1996

| Temperature Range (°F) | Annual Totals | | | Total Obs | M C W B (°F) |
|------------------------|------------------|----------|----------|-----------|--------------------------|
| | Hour Group (LST) | | | | |
| | 01 To 08 | 09 To 16 | 17 To 00 | | |
| 130 / 134 | 0 | 0 | 0 | 0 | 84.7 |
| 125 / 129 | 0 | 0 | 0 | 0 | 82.0 |
| 120 / 124 | 0 | 0 | 0 | 0 | 82.1 |
| 115 / 119 | 1 | 0 | 0 | 1 | 80.7 |
| 110 / 114 | 1 | 1 | 0 | 2 | 76.2 |
| 105 / 109 | 0 | 13 | 1 | 14 | 71.1 |
| 100 / 104 | 0 | 45 | 3 | 48 | 70.6 |
| 95 / 99 | 0 | 124 | 15 | 139 | 69.8 |
| 90 / 94 | 1 | 221 | 41 | 263 | 68.6 |
| 85 / 89 | 4 | 267 | 87 | 357 | 66.7 |
| 80 / 84 | 17 | 312 | 152 | 481 | 64.5 |
| 75 / 79 | 56 | 331 | 228 | 615 | 62.3 |
| 70 / 74 | 150 | 370 | 328 | 847 | 60.3 |
| 65 / 69 | 323 | 382 | 429 | 1133 | 58.4 |
| 60 / 64 | 541 | 360 | 498 | 1399 | 56.0 |
| 55 / 59 | 552 | 279 | 491 | 1322 | 52.3 |
| 50 / 54 | 496 | 159 | 377 | 1032 | 48.2 |
| 45 / 49 | 380 | 49 | 186 | 616 | 43.8 |
| 40 / 44 | 272 | 9 | 69 | 349 | 39.2 |
| 35 / 39 | 99 | 1 | 13 | 113 | 34.6 |
| 30 / 34 | 23 | 0 | 2 | 25 | 30.0 |
| 25 / 29 | 3 | 0 | 0 | 3 | 25.5 |
| 20 / 24 | 0 | 0 | 0 | 0 | 21.0 |

6621 Hours
> 55° F
(75% of Year)

Long Term Psychrometric Summary



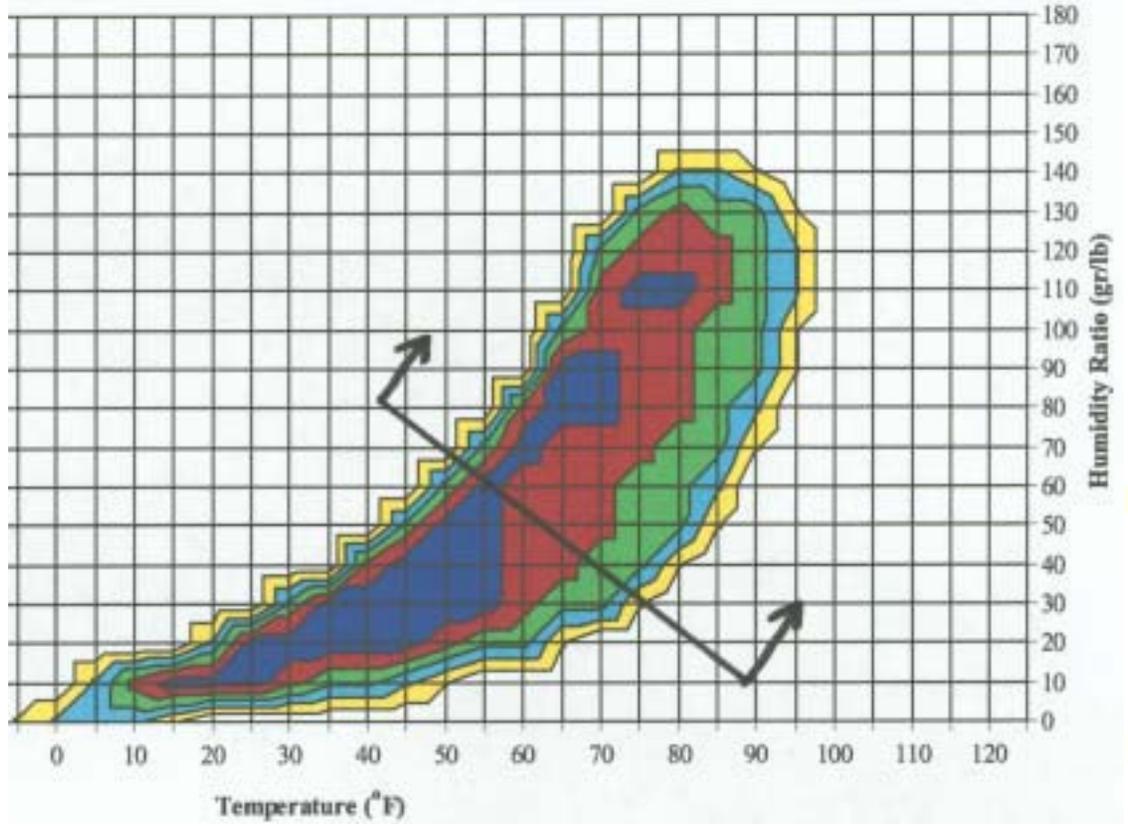
- 50% of all observations
- 80% of all observations
- 95% of all observations
- 97.5% of all observations
- 99% of all observations

ST. LOUIS/LAMBERT MO
Dry-Bulb Temperature Hours
 Period of Record = 1973 to 1996

| Temperature Range (°F) | Annual Totals | | | Total Obs | M C W B (°F) |
|------------------------|------------------|----------|----------|-----------|--------------|
| | Hour Group (LST) | | | | |
| | 01 To 08 | 09 To 16 | 17 To 00 | | |
| 105 / 109 | | 0 | 0 | 0 | 78.0 |
| 100 / 104 | | 7 | 2 | 9 | 77.4 |
| 95 / 99 | 0 | 36 | 11 | 47 | 76.9 |
| 90 / 94 | 0 | 123 | 49 | 172 | 75.4 |
| 85 / 89 | 11 | 233 | 128 | 371 | 73.0 |
| 80 / 84 | 82 | 280 | 216 | 578 | 70.6 |
| 75 / 79 | 208 | 280 | 273 | 761 | 68.2 |
| 70 / 74 | 301 | 252 | 296 | 849 | 65.1 |
| 65 / 69 | 285 | 207 | 245 | 737 | 60.5 |
| 60 / 64 | 269 | 199 | 227 | 695 | 56.1 |
| 55 / 59 | 233 | 188 | 208 | 629 | 51.4 |
| 50 / 54 | 210 | 173 | 194 | 577 | 46.8 |
| 45 / 49 | 211 | 173 | 192 | 576 | 42.6 |
| 40 / 44 | 228 | 181 | 200 | 609 | 38.5 |
| 35 / 39 | 230 | 182 | 200 | 612 | 34.1 |
| 30 / 34 | 245 | 157 | 188 | 590 | 29.9 |
| 25 / 29 | 149 | 95 | 109 | 353 | 25.0 |
| 20 / 24 | 92 | 60 | 67 | 219 | 20.3 |
| 15 / 19 | 60 | 41 | 49 | 150 | 15.6 |
| 10 / 14 | 49 | 27 | 34 | 110 | 10.9 |
| 5 / 9 | 29 | 14 | 16 | 59 | 6.3 |
| 0 / 4 | 17 | 7 | 8 | 32 | 1.3 |
| -5 / -1 | 7 | 3 | 3 | 13 | -2.9 |
| -10 / -6 | 5 | 2 | 2 | 9 | -7.1 |
| -15 / -11 | 2 | 1 | 1 | 4 | -11.9 |
| -20 / -16 | 1 | | | 1 | -16.2 |

4848 Hours
> 55° F
(55% of Year)

Long Term Psychrometric Summary



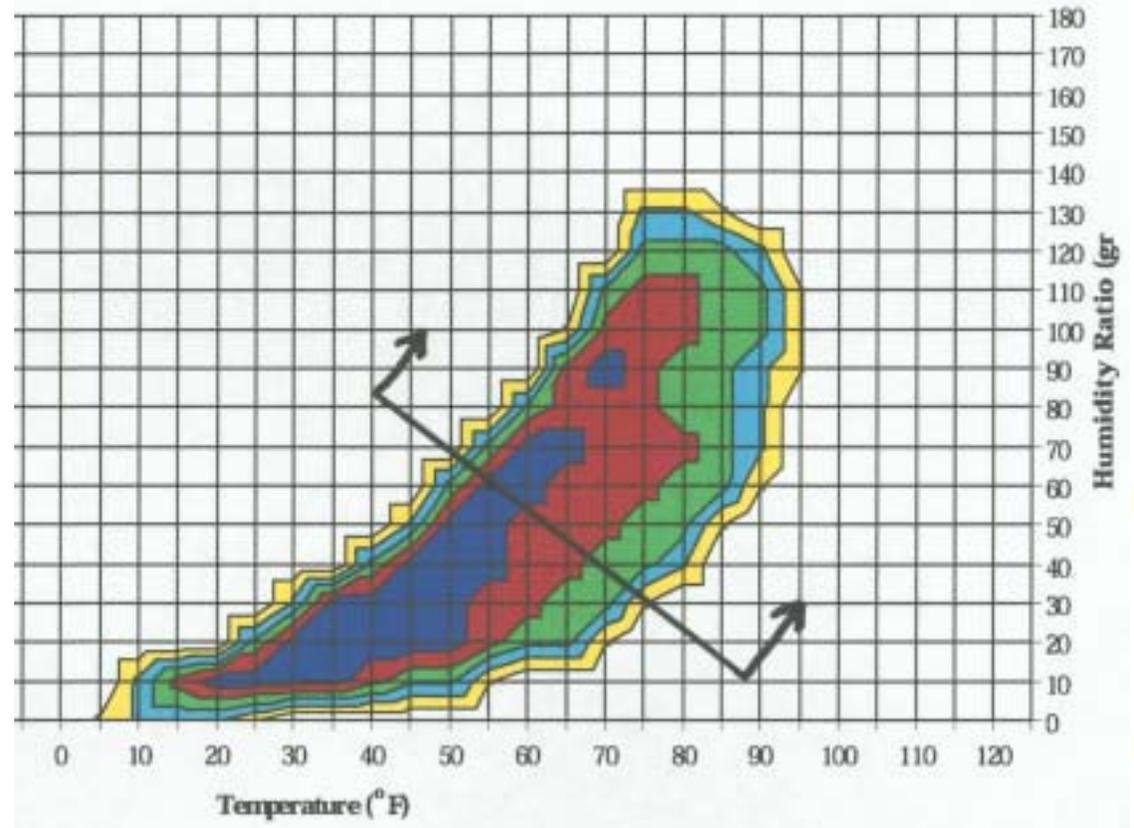
- 50% of all observations
- 80% of all observations
- 95% of all observations
- 97.5% of all observations
- 99% of all observations

NEWARK INTL AIRPORT NJ
Dry-Bulb Temperature Hours
Period of Record = 1973 to 1995

| Temperature Range (°F) | Annual Totals | | | Total Obs | M C W B (°F) |
|------------------------|------------------|----------|----------|-----------|--------------------------|
| | Hour Group (LST) | | | | |
| | 01 To 08 | 09 To 16 | 17 To 00 | | |
| 105 / 109 | | 0 | | 0 | 81.3 |
| 100 / 104 | | 1 | 0 | 2 | 78.7 |
| 95 / 99 | 0 | 19 | 4 | 23 | 75.8 |
| 90 / 94 | 1 | 68 | 24 | 93 | 74.0 |
| 85 / 89 | 5 | 160 | 72 | 237 | 71.5 |
| 80 / 84 | 41 | 252 | 158 | 452 | 69.3 |
| 75 / 79 | 163 | 274 | 255 | 692 | 67.5 |
| 70 / 74 | 306 | 254 | 298 | 858 | 64.5 |
| 65 / 69 | 285 | 227 | 241 | 753 | 59.9 |
| 60 / 64 | 258 | 225 | 251 | 735 | 55.6 |
| 55 / 59 | 231 | 214 | 225 | 671 | 50.9 |
| 50 / 54 | 259 | 225 | 252 | 736 | 46.5 |
| 45 / 49 | 245 | 225 | 238 | 708 | 41.8 |
| 40 / 44 | 266 | 230 | 260 | 756 | 37.4 |
| 35 / 39 | 273 | 198 | 233 | 705 | 32.8 |
| 30 / 34 | 229 | 143 | 173 | 546 | 28.3 |
| 25 / 29 | 139 | 93 | 108 | 340 | 23.6 |
| 20 / 24 | 104 | 55 | 70 | 229 | 19.2 |
| 15 / 19 | 69 | 25 | 40 | 133 | 14.9 |
| 10 / 14 | 34 | 9 | 14 | 57 | 10.5 |
| 5 / 9 | 13 | 4 | 5 | 22 | 5.7 |
| 0 / 4 | 5 | 2 | 2 | 9 | 1.0 |
| -5 / -1 | 2 | 0 | 0 | 2 | -2.9 |
| -10 / -6 | 0 | 0 | 0 | 1 | -6.9 |

4516 Hours
> 55° F
(52% of Year)

Long Term Psychrometric Summary



- 50% of all observations
- 80% of all observations
- 95% of all observations
- 97.5% of all observations
- 99% of all observations

RALEIGH-DURHAM NC

Dry-Bulb Temperature Hours

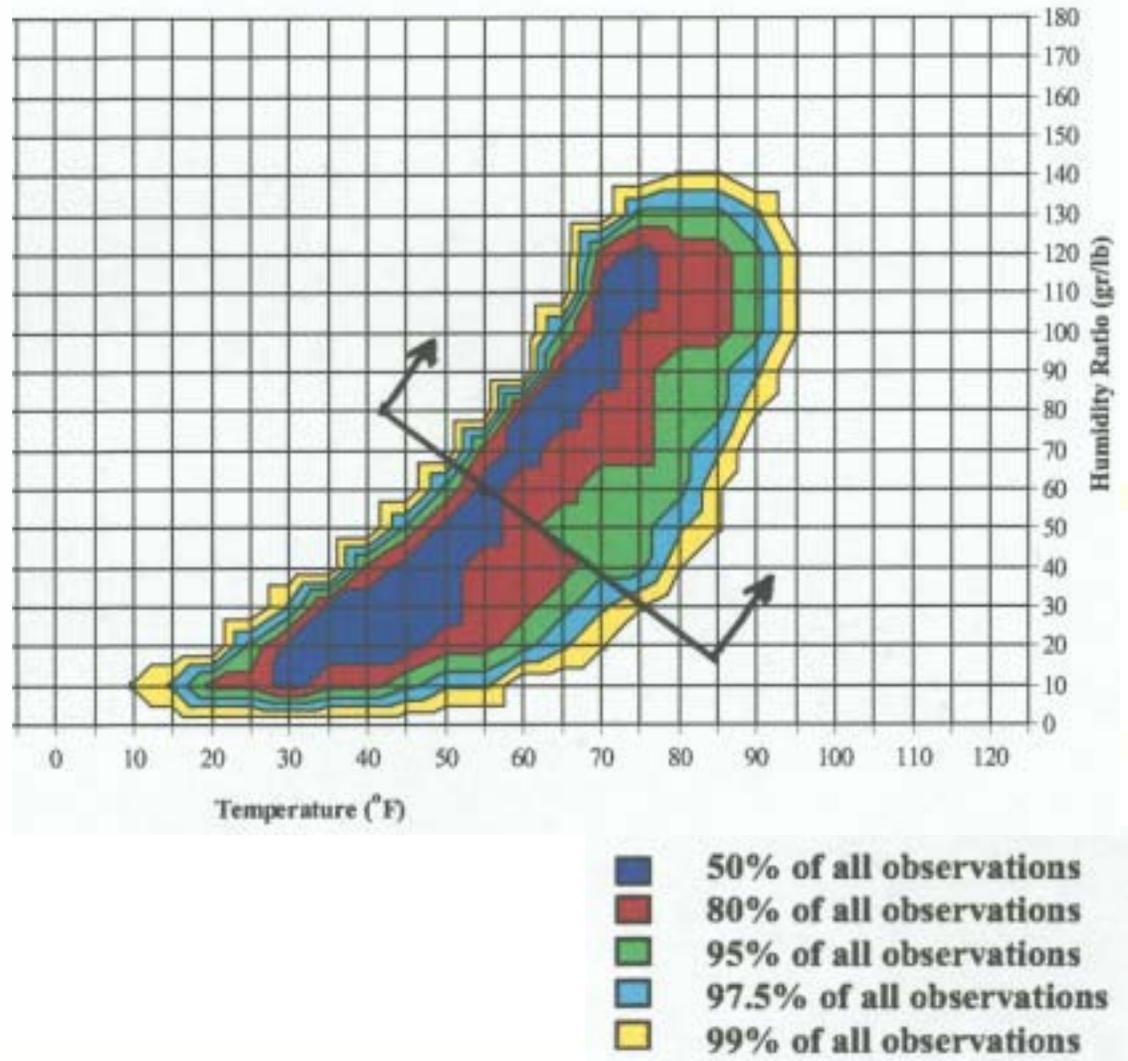
Period of Record = 1973 to 1996

Annual Totals

| Temperature Range (°F) | Hour Group (LST) | | | Total Obs | M C W B (°F) |
|------------------------|------------------|----------|----------|-----------|--------------|
| | 01 To 08 | 09 To 16 | 17 To 00 | | |
| | 100 / 104 | | 1 | | |
| 95 / 99 | | 17 | 4 | 21 | 76.3 |
| 90 / 94 | | 100 | 26 | 126 | 75.7 |
| 85 / 89 | 0 | 252 | 81 | 333 | 73.4 |
| 80 / 84 | 13 | 343 | 163 | 519 | 71.2 |
| 75 / 79 | 119 | 348 | 288 | 755 | 69.1 |
| 70 / 74 | 399 | 308 | 405 | 1113 | 66.9 |
| 65 / 69 | 372 | 257 | 332 | 961 | 62.0 |
| 60 / 64 | 306 | 238 | 277 | 821 | 56.9 |
| 55 / 59 | 278 | 226 | 256 | 760 | 51.9 |
| 50 / 54 | 257 | 217 | 246 | 720 | 46.9 |
| 45 / 49 | 238 | 194 | 235 | 667 | 42.4 |
| 40 / 44 | 243 | 159 | 210 | 613 | 38.1 |
| 35 / 39 | 235 | 124 | 174 | 534 | 33.5 |
| 30 / 34 | 213 | 80 | 122 | 416 | 29.1 |
| 25 / 29 | 135 | 35 | 63 | 234 | 24.3 |
| 20 / 24 | 62 | 13 | 22 | 97 | 19.7 |
| 15 / 19 | 30 | 6 | 9 | 45 | 15.3 |
| 10 / 14 | 15 | 2 | 4 | 21 | 10.9 |
| 5 / 9 | 4 | 0 | 1 | 5 | 6.0 |
| 0 / 4 | 1 | 0 | 0 | 1 | 0.6 |
| -5 / -1 | 0 | 0 | 0 | 0 | -4.8 |
| -10 / -6 | 0 | | | 0 | -7.3 |

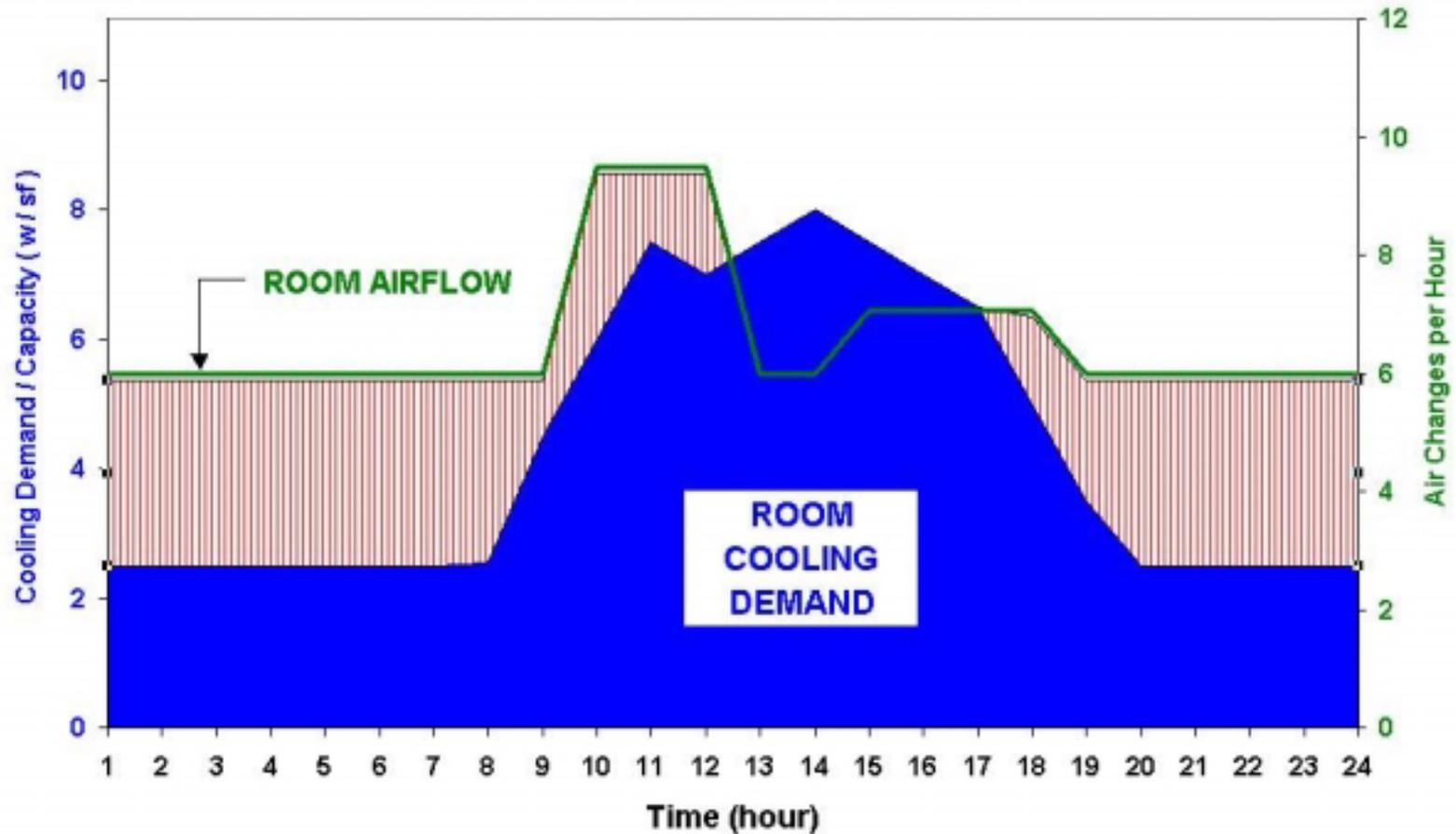
**5410 Hours
> 55° F
(61% of Year)**

Long Term Psychrometric Summary



AIRFLOW COOLING CAPACITY vs. ROOM COOLING DEMAND

Materials Research Lab - 900 sf, 2 Gas Cabinets, 6' Hood

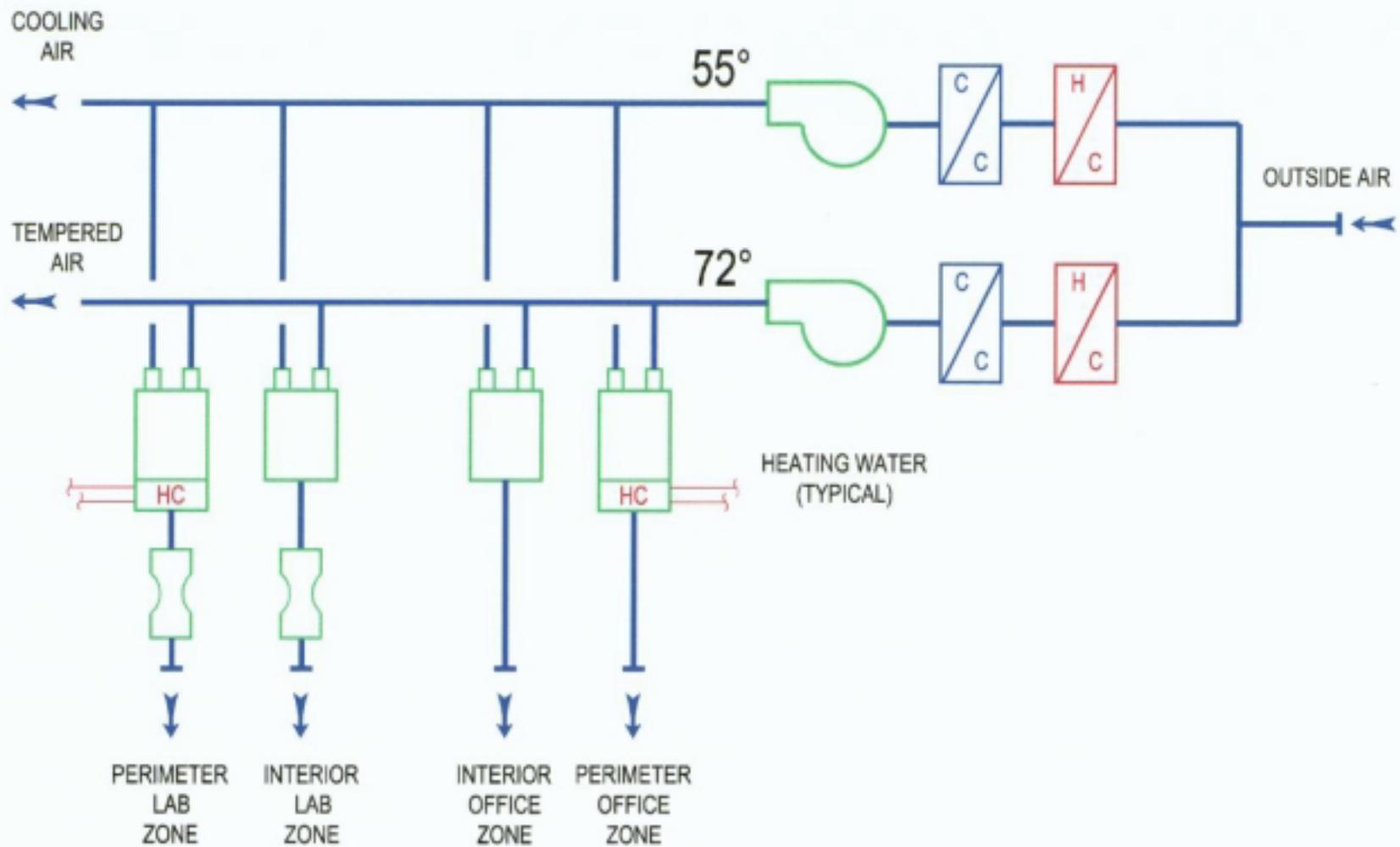


PROBLEM: One System Used for BOTH Cooling and Ventilation

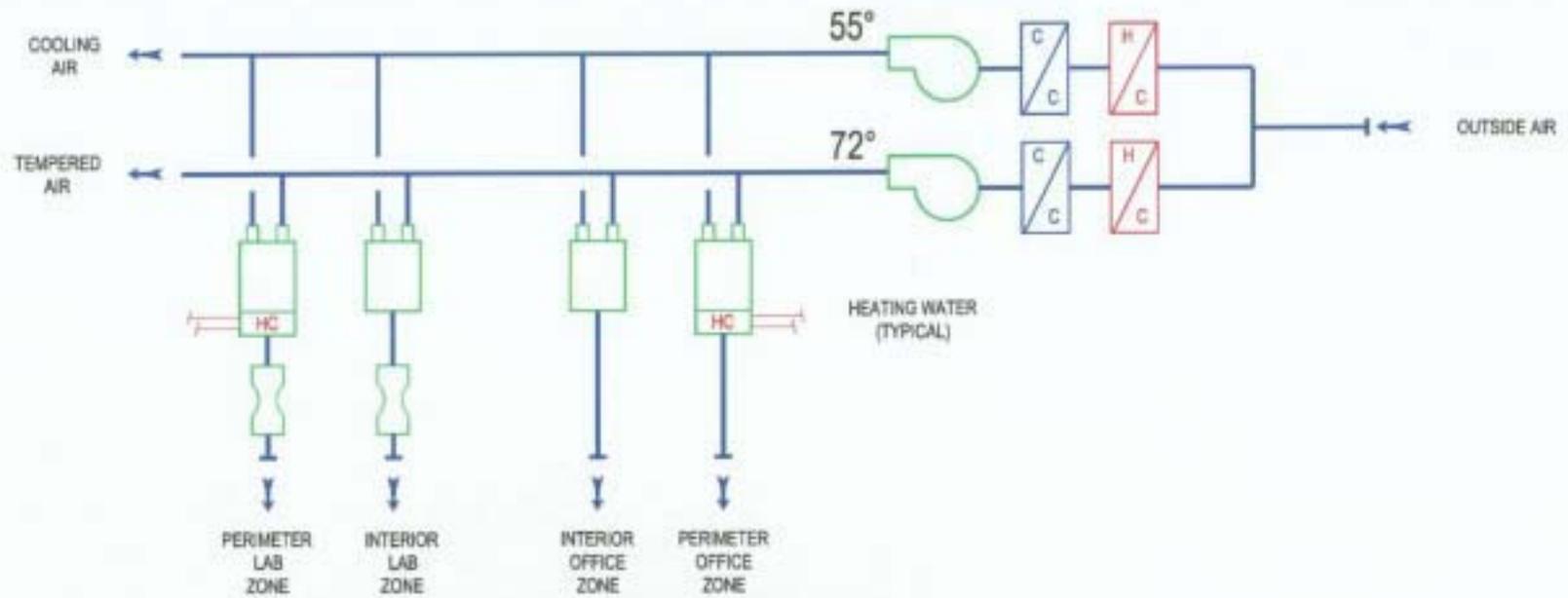
SOLUTION: SEPARATE Systems for Cooling and Ventilation

SEPARATE COOLING AND VENTILATION

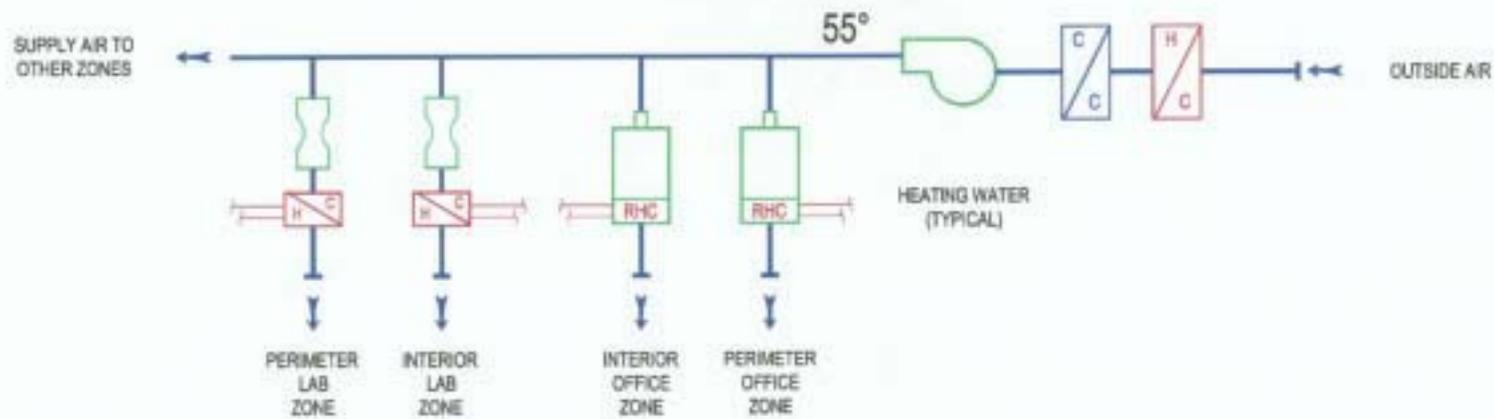
- Local Cooling
 - Fan Coils
 - Radiant Cooling ?
- Dual Temperature Central System



DUAL TEMPERATURE SUPPLY AIR WITH TERMINAL HEATING



DUAL TEMPERATURE SUPPLY AIR WITH TERMINAL HEATING



SINGLE DUCT WITH REHEAT

CSIRO Energy Centre, Newcastle, NSW

Project Team

Client - CSIRO Energy Technology Division

Architect - Cox Richardson

Consulting Engineers –

GHD Flack + Kurtz

Flack + Kurtz San Francisco

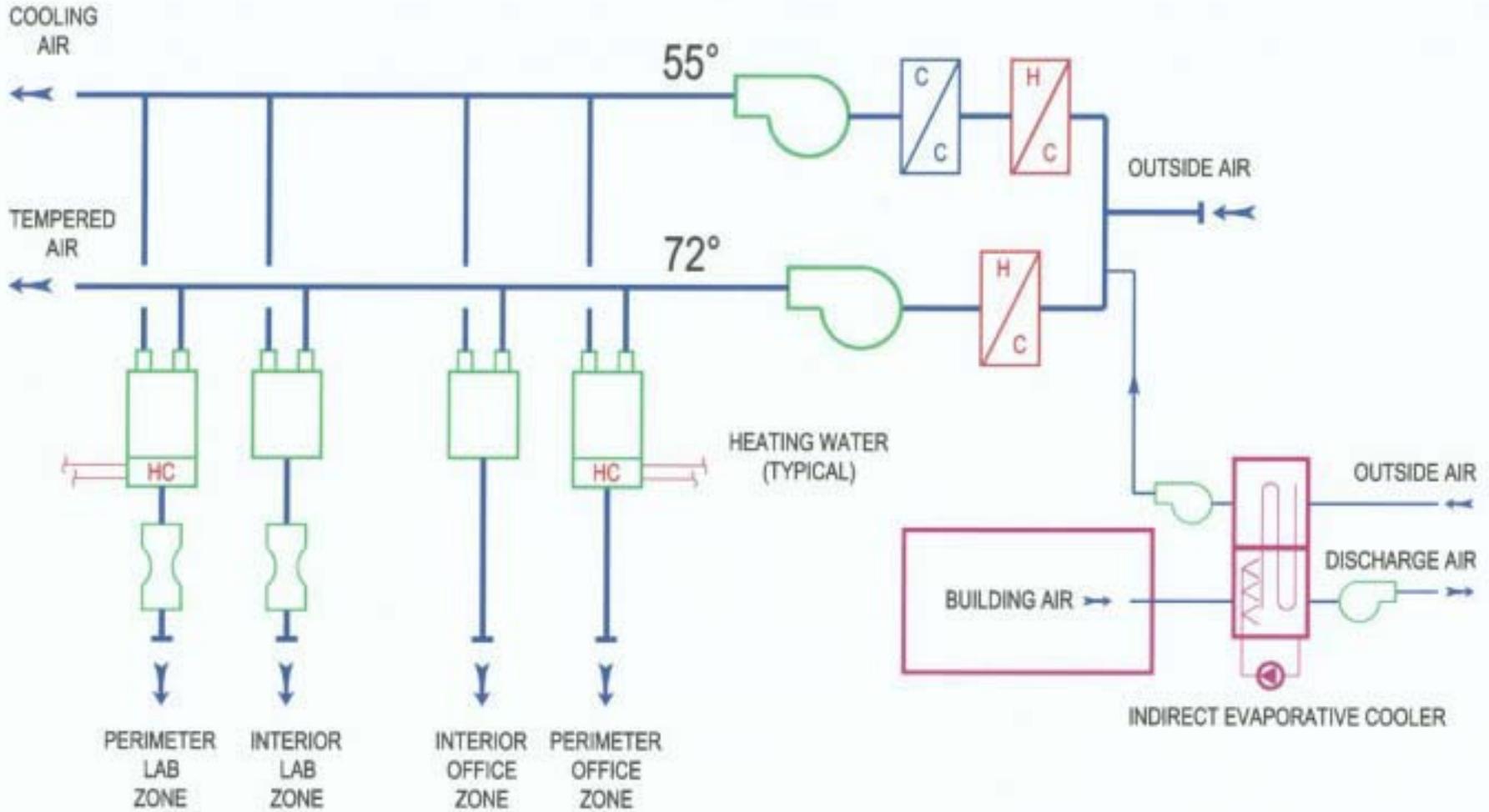


- **95,000 sf Labs and Offices**
- **Energy Research**

Pfizer Building 220

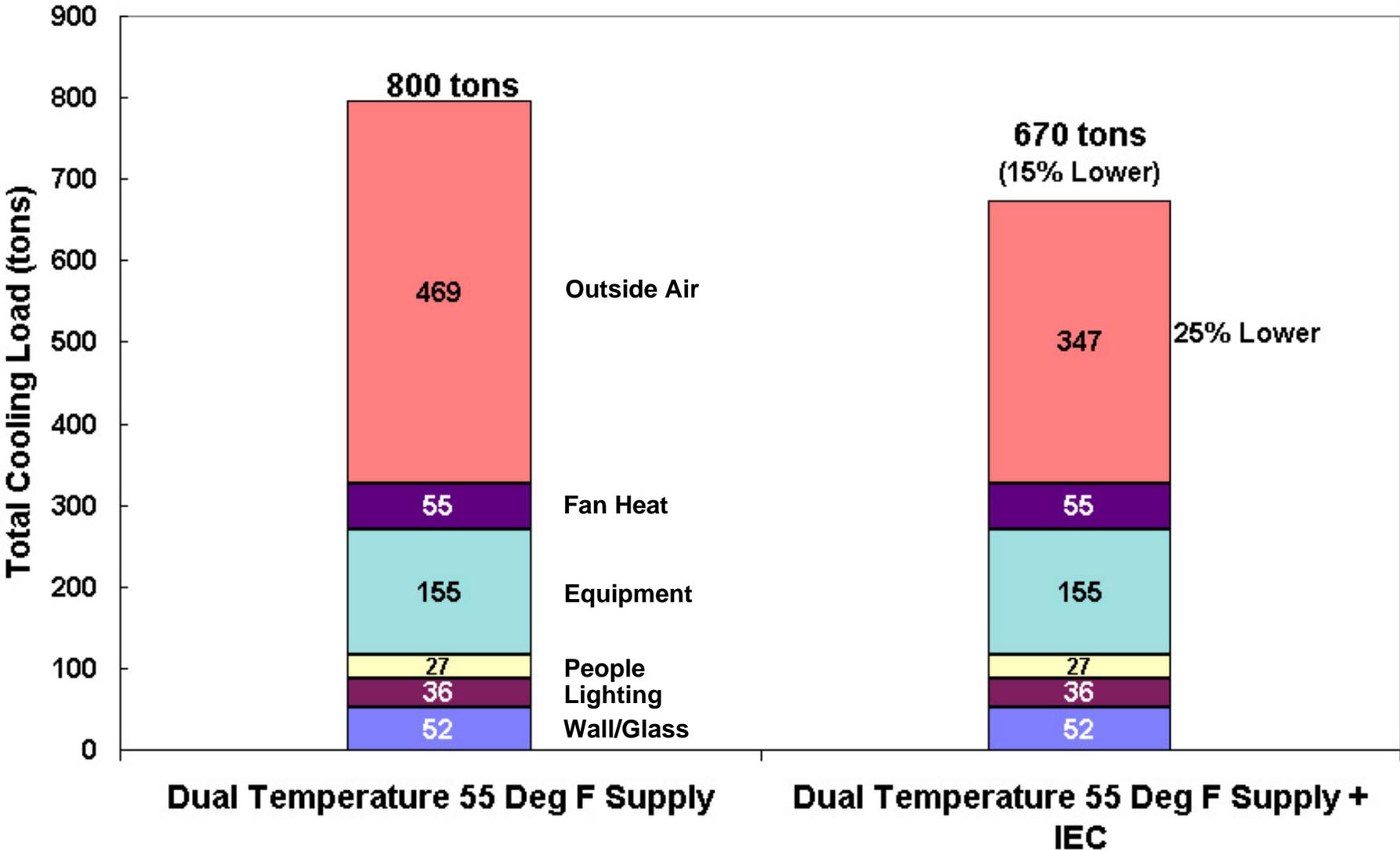
- Architect/Engineer: CUH2A
- 60,000 sf labs
- 1200 sf lab modules, each with six hoods
 - 11,000 cfm per module

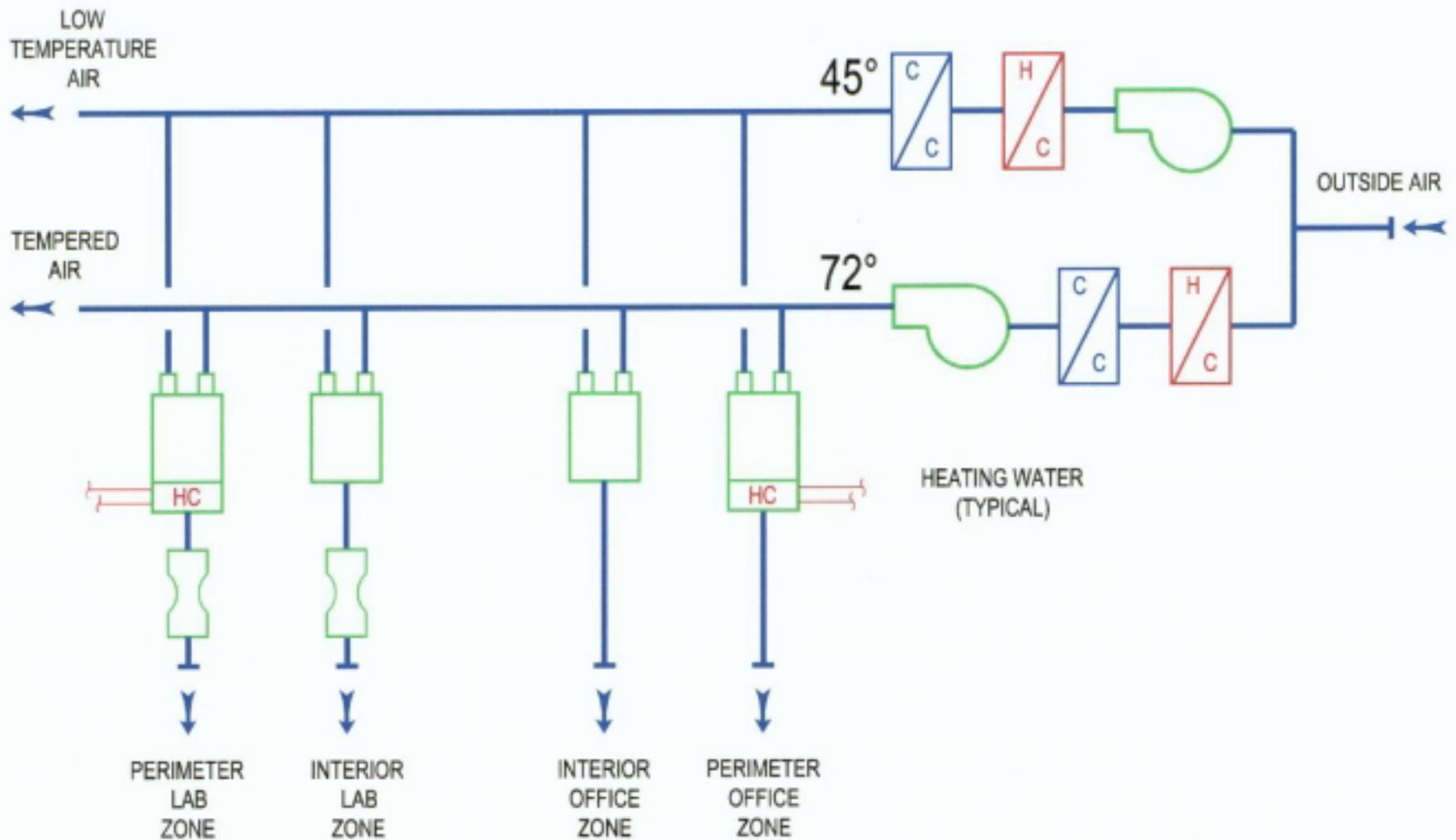




DUAL TEMPERATURE SUPPLY AIR WITH TERMINAL HEATING AND HEAT RECOVERY WITH INDIRECT EVAPORATIVE COOLING

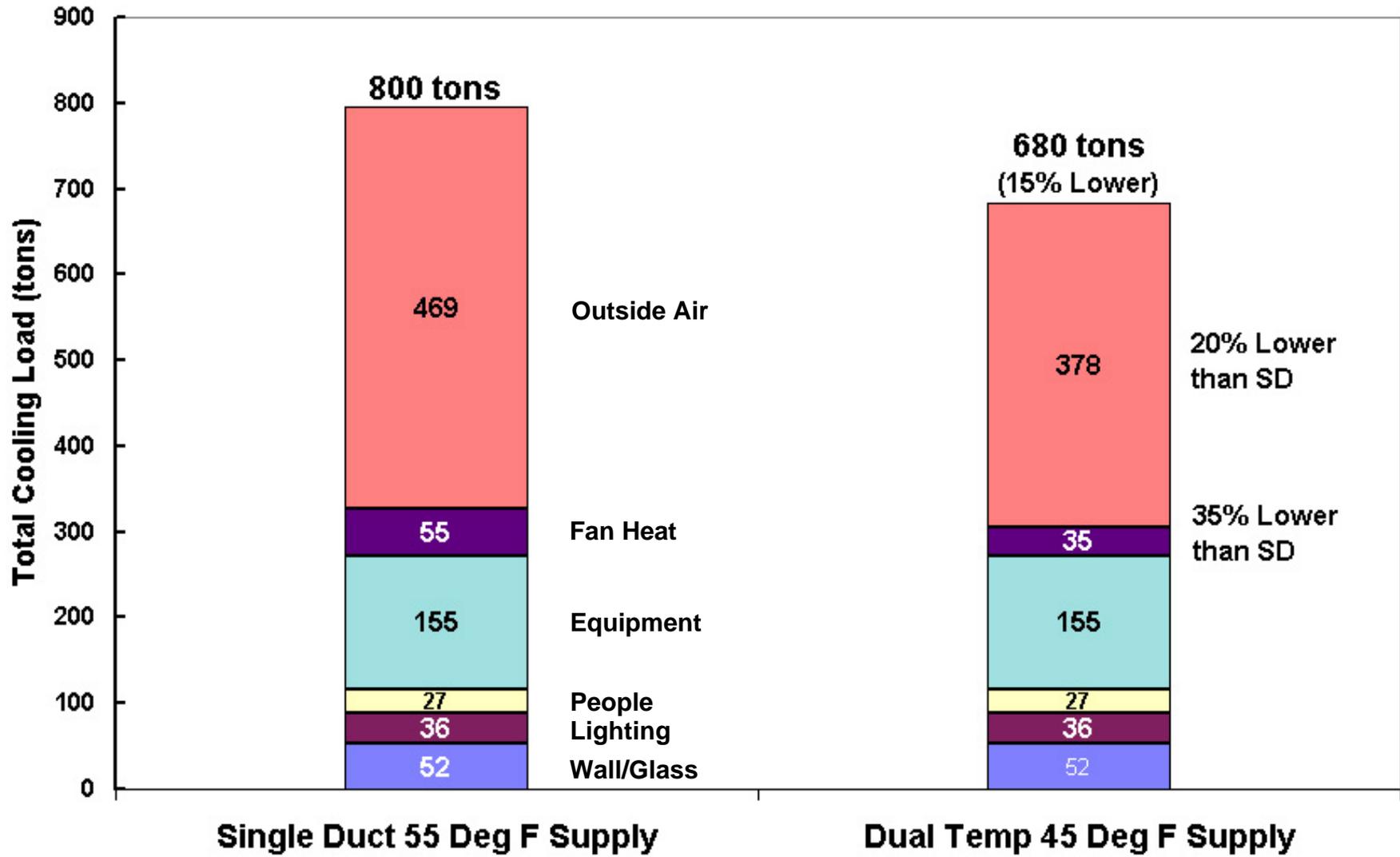
SYSTEM DESIGN COOLING LOAD





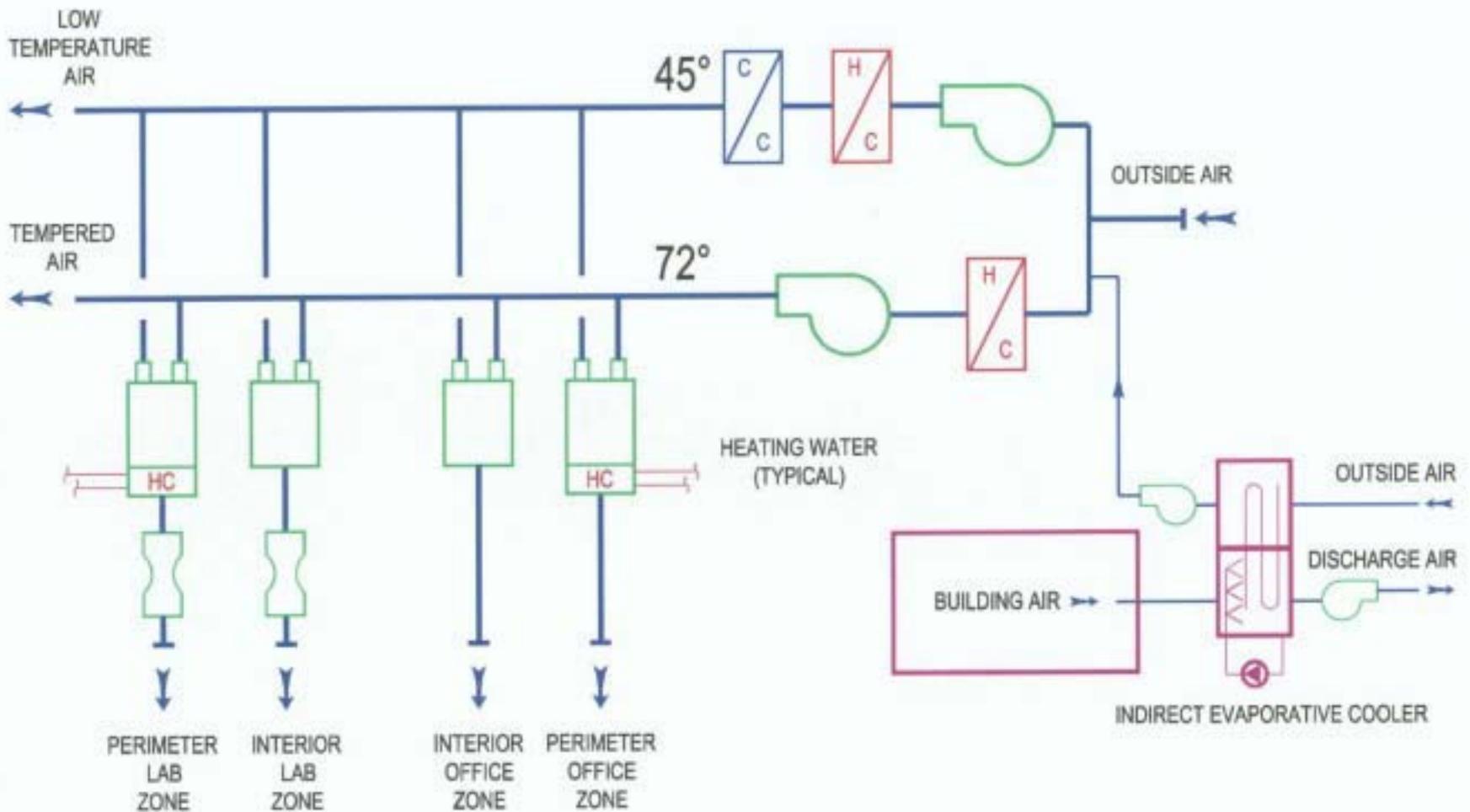
LOW TEMPERATURE AIR, DUAL TEMPERATURE WITH TERMINAL HEATING

SYSTEM DESIGN COOLING LOAD



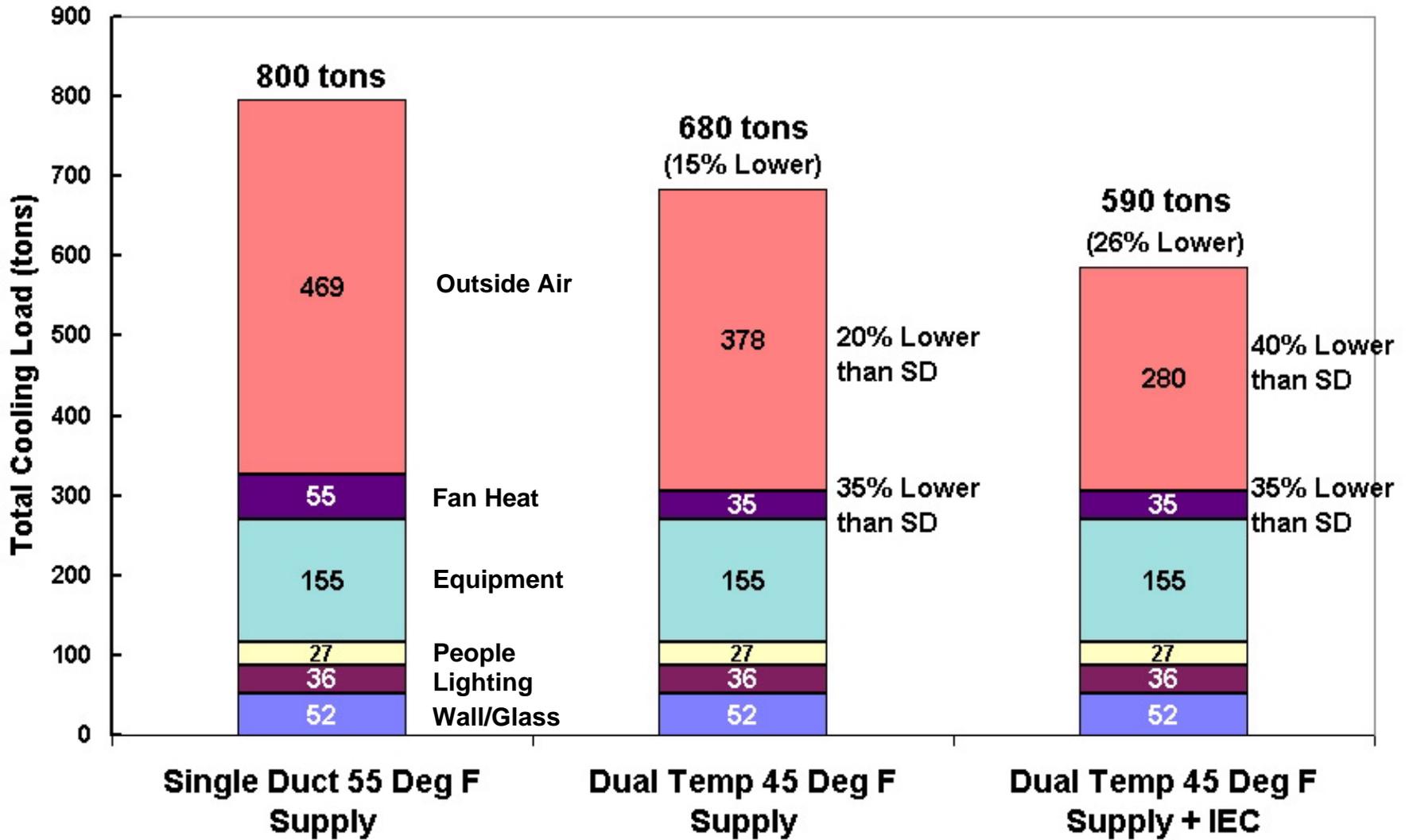
**COST COMPARISON:
SINGLE DUCT REHEAT vs.
DUAL TEMPERATURE, LOW TEMPERATURE AIR
90,000 SF Laboratory**

| SYSTEM COMPONENT | COST CHANGE FOR DUAL TEMPERATURE |
|------------------------------|----------------------------------|
| Air Handlers | (\$87,500) |
| Ductwork | \$120,000 |
| Terminal Units | \$97,500 |
| Controls, Test, & Balance | \$27,500 |
| Reheat & Distribution Piping | (\$141,100) |
| TOTAL COST CHANGE | \$16,400 |



LOW TEMPERATURE AIR, DUAL TEMPERATURE WITH TERMINAL HEATING AND HEAT RECOVERY INDIRECT EVAPORATIVE COOLING

SYSTEM DESIGN COOLING LOAD



SUMMARY

- Labs require COOLING and VENTILATION
- COMBINED Cooling and Ventilation is Inefficient
- SEPARATE SYSTEMS for Cooling and Ventilation Raises Efficiency
 - Local Cooling
 - **Dual Temperature Central Systems**

Laboratories For The 21st Century
October 8, 2002

THE PROBLEM WITH SINGLE DUCT VAV:

The Built-In Inefficiency of a
Common Lab HVAC System



Michael Morehead, P.E.
Flack + Kurtz Inc.