OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA

# PRESENTATION OF FINAL RESULTS

# ADVANCED HEATING, VENTILATING AND AIR CONDITIONING (HVAC) DISTRIBUTION SYSTEMS

SUBCONTRACT NO. 41Y-19748-C

PRESENTATION BY

GARD DIVISION
CHAMBERLAIN MANUFACTURING CORP.
NILES, IL

19 JUNE 1986

# PROGRAM OBJECTIVE AND SCOPE

PROGRAM OBJECTIVE:

TO EXPLORE THE POTENTIAL OF ADVANCED HVAC DISTRIBUTION SYSTEMS AND CONTROLS TO PROVIDE ACCEPTABLE COMFORT LEVELS AT SUBSTANTIALLY REDUCED ENERGY CONSUMPTION RATE BY 1) SIMULTANEOUS CONTROL OF MULTIPLE SETS OF THERMAL COMFORT VARIABLES AND 2) IMPROVED HVAC CONTROL AND DELIVERY TECHNIQUES TO REDUCE ENERGY CONSUMPTION BY FOLLOWING OCCUPANCY PATTERNS.

PROGRAM SCOPE:

1) SURVEY AND REVIEW EXISTING INFORMATION TO DETERMINE STATE-OF-THE-ART KNOWLEDGE OF THE EFFECT OF HVAC DISTRIBUTION SYSTEMS AND CONTROLS ON ENERGY CONSUMPTION.
2) ASSESS CONTROL OF MULTIPLE SETS OF THERMAL COMFORT VARIABLES TO REDUCE ENERGY CONSUMPTION.
3) ASSESS IMPROVED HVAC CONTROL AND DELIVERY TECHNIQUES TO REDUCE ENERGY CONSUMPTION BY FOLLOWING OCCUPANCY PATTERNS.

## TASK I OBJECTIVE

DEFINE STATE-OF-THE-ART KNOWLEDGE OF THE EFFECTS OF DISTRIBUTION SYSTEMS CONFIGURATION AND CONTROLS ON HVAC SYSTEM ENERGY CONSUMPTION TO PERMIT EFFECTIVE IDENTIFICATION AND SCREENING OF PROMISING CONCEPTS FOR TASKS II AND III AND TO AVOID DUPLICATION OF PREVIOUS WORK IN THE AREA.

## TASK I APPROACH

- COMPREHENSIVE COMPUTERIZED KEY WORD LITERATURE SEARCH OF DATA BASES
- PERSONAL INTERVIEWS
- TELEPHONE INTERVIEWS
- ACQUIRE / COPY LITERATURE
- REVIEW LITERATURE AND ANALYZE RESULTS OF INTERVIEWS
- IDENTIFY AND SUMMARIZE ADVANCED HVAC SYSTEMS AND CONTROLS
- DEVELOP ANNOTATED BIBLIOGRAPHY

## TASK I CONCLUSIONS

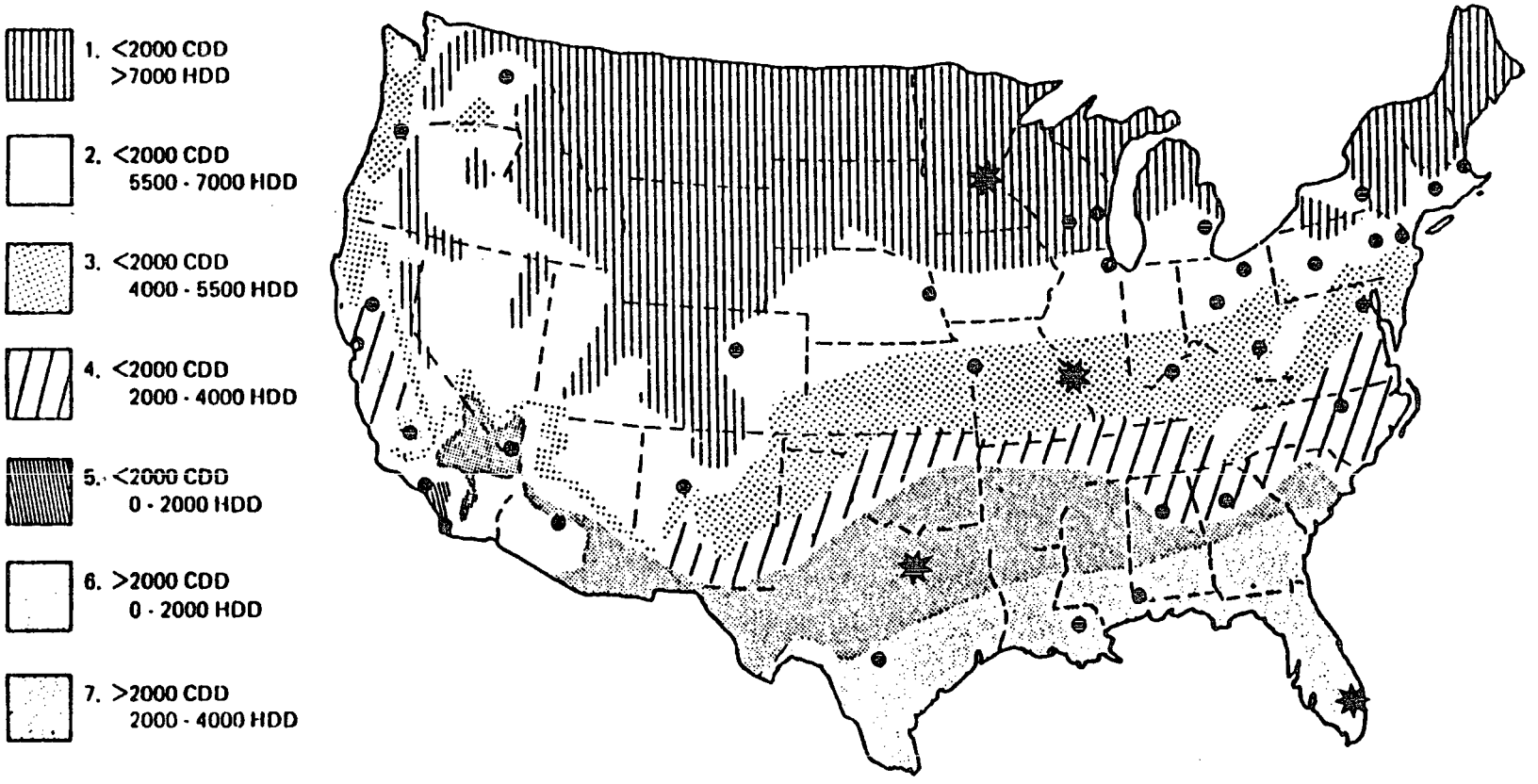
- THIS PROGRAM REPRESENTS AN EFFORT TO ADVANCE THE STATE-OF-THE-ART OF HVAC SYSTEMS AND CONTROLS.
- WORK DONE BY OTHERS COMPLEMENTS, BUT DOES NOT DUPLICATE THIS EFFORT.
- ASHRAE IS BEST SOURCE OF KNOWLEDGE IN RELEVANT AREAS.
- NO ONE IS AWARE OF THE COMMERCIAL APPLICATION OF STRATEGIES PLANNED FOR TASKS II AND III.
- NUMEROUS INNOVATIVE SYSTEMS EXIST WHICH COULD BENEFIT BY USING THESE STRATEGIES.

## TASK II OBJECTIVE

IDENTIFY AND ASSESS THE STATE-OF THE ART OF HVAC SYSTEMS WHICH PROVIDE THERMAL COMFORT WITH REDUCED ENERGY CONSUMPTION BY CONTROLLING APPROPRIATE COMBINATIONS OF ENVIRONMENTAL THERMAL COMFORT FACTORS. THESE FACTORS INCLUDE AIR TEMPERATURE, HUMIDITY, VELOCITY, AND MEAN RADIANT TEMPERATURE.

## TASK II APPROACH

- o PERFORM BUILDING LOAD/COMFORT VARIABLE ANALYSIS
  - CONFIGURE TYPICAL BUILDING
  - SELECT SIMULATION MODELS
  - PERFORM DESIGN DAY AND FULL YEAR SIMULATIONS
- o DEVELOP AND ANALYZE ADVANCED SYSTEM CONCEPTS
  - GENERATE CONCEPTS (INCLUDING BASELINE)
  - PERFORM SYSTEM SIMULATION RUNS
  - SUMMARIZE ENERGY SAVINGS
- o ASSESS ATTRACTIVE SYSTEM CONCEPTS
  - ESTIMATE INITIAL AND OPERATING COSTS
  - PERFORM LIFE-CYCLE COST ANALYSIS
  - DEVELOP MULTIATTRIBUTE UTILITY ANALYSIS
  - RECOMMEND RESEARCH EFFORTS




Cities Selected For Analysis

- Minneapolis
- St. Louis
- Dallas
- Miami

DOE CLIMATE ZONES

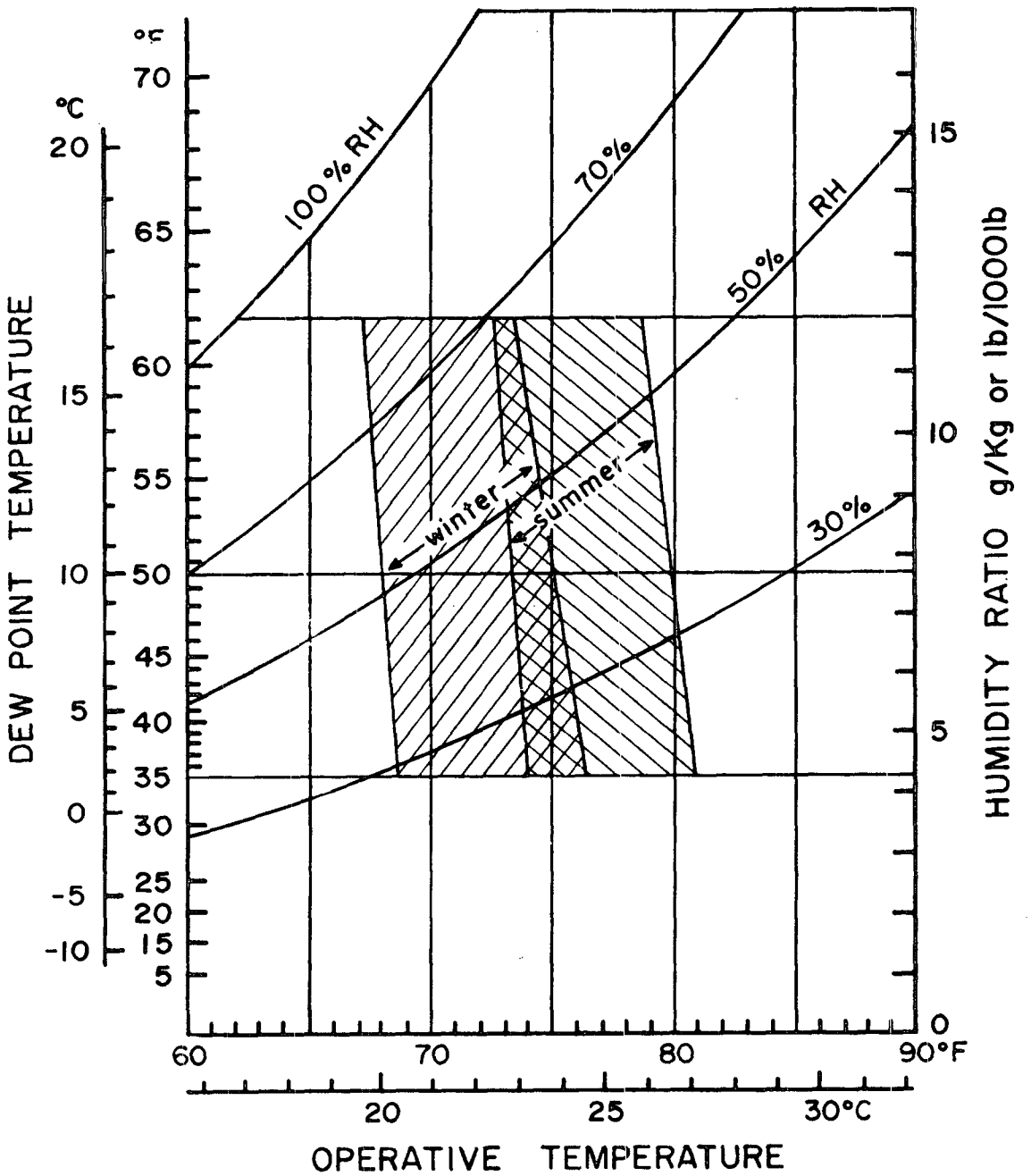
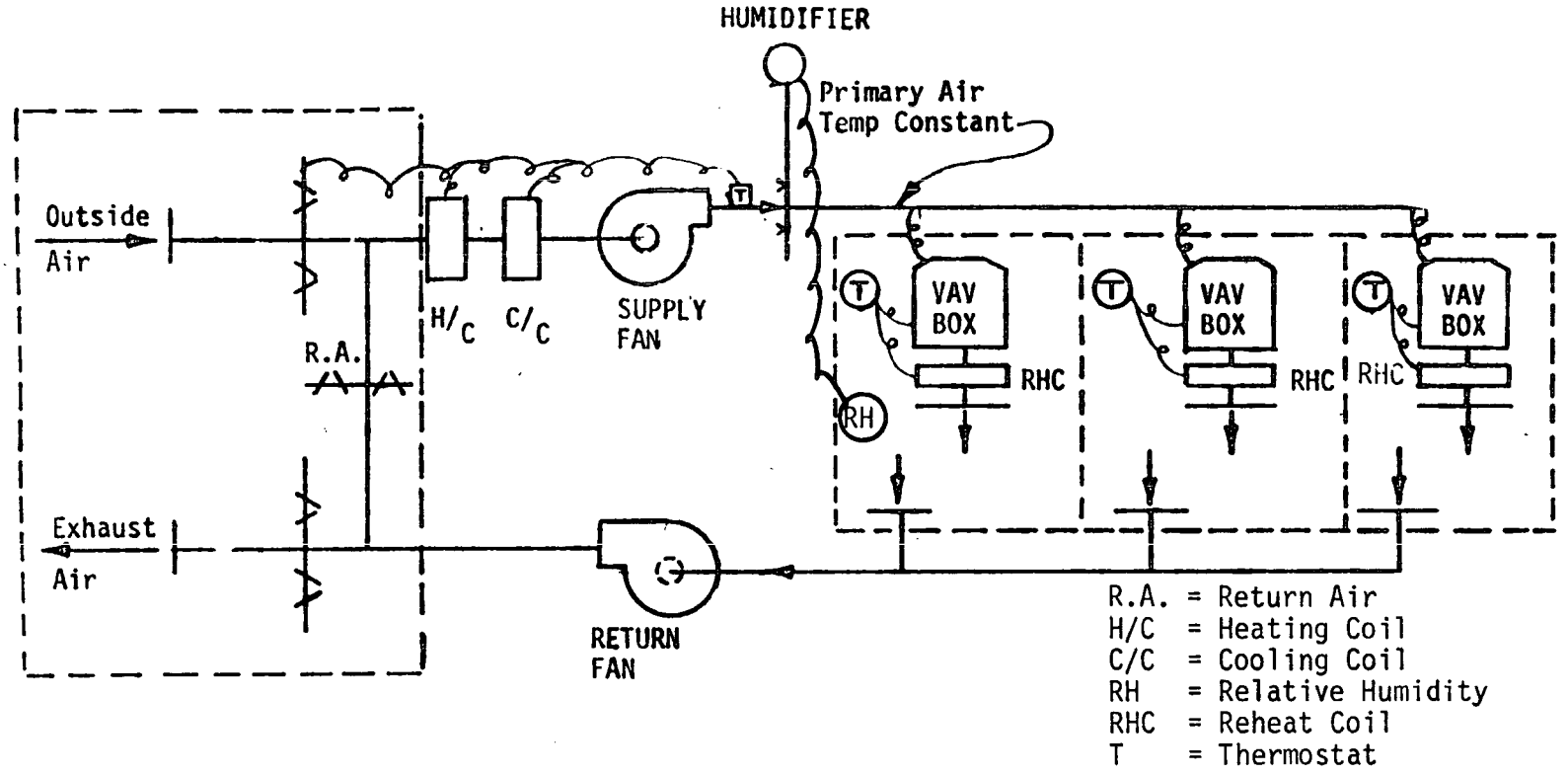
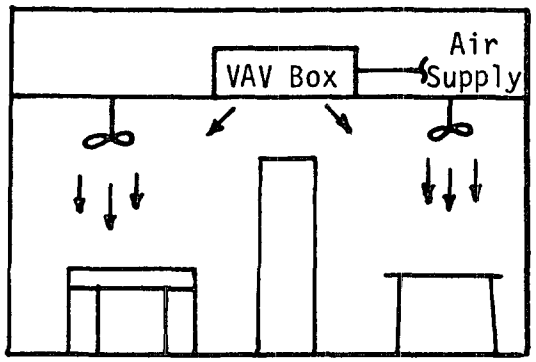


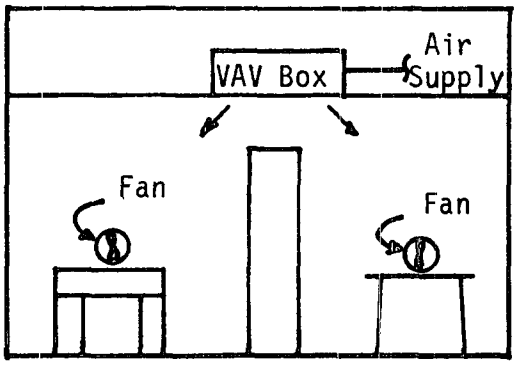

**Figure 2** Acceptable ranges of operative temperature and humidity for persons clothed in typical summer and winter clothing, at light, mainly sedentary, activity (≦ 1.2 met).



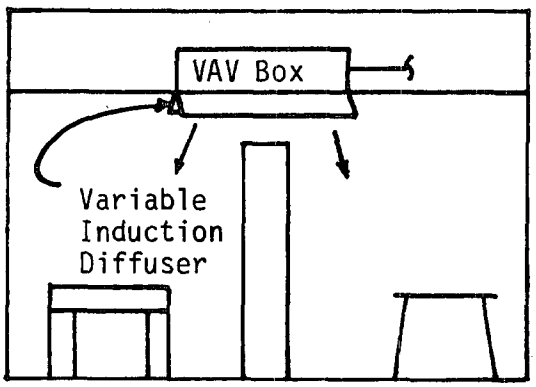

VAV FAN SYSTEM WITH ZONE REHEAT WITH CENTRAL HUMIDIFICATION
(Baseline System)



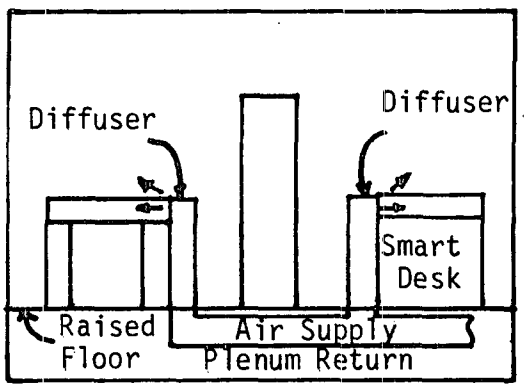

a. Ceiling Fans



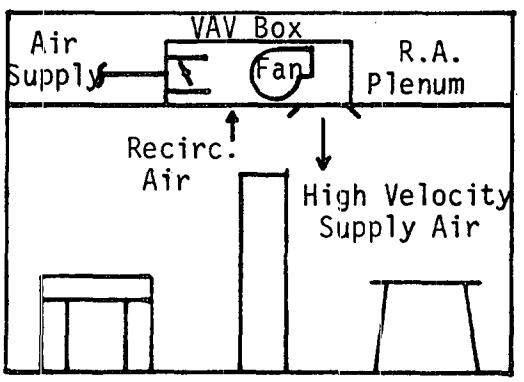

b. Personal Fans




c. Variable Induction Diffusers

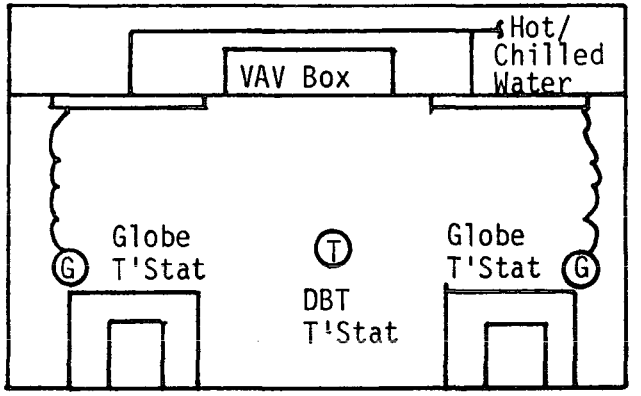



d. "Smart Desks"

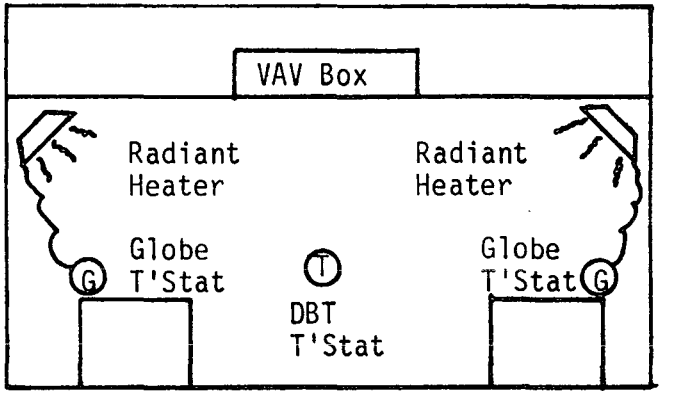



e. VAV Box with Integral Fan

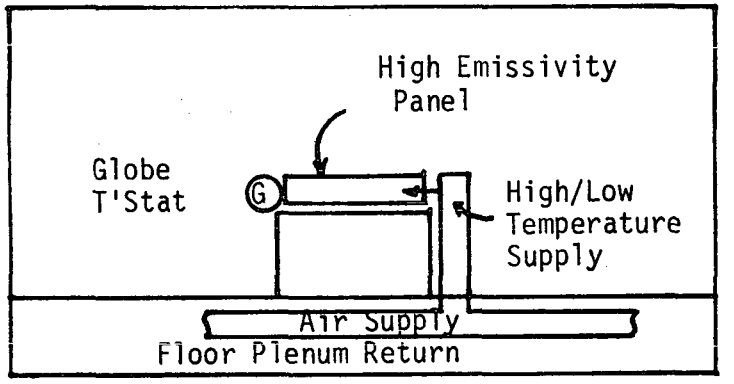
CONTROLLED AIR VELOCITY SYSTEMS




a. Low Temperature Ceiling Panels

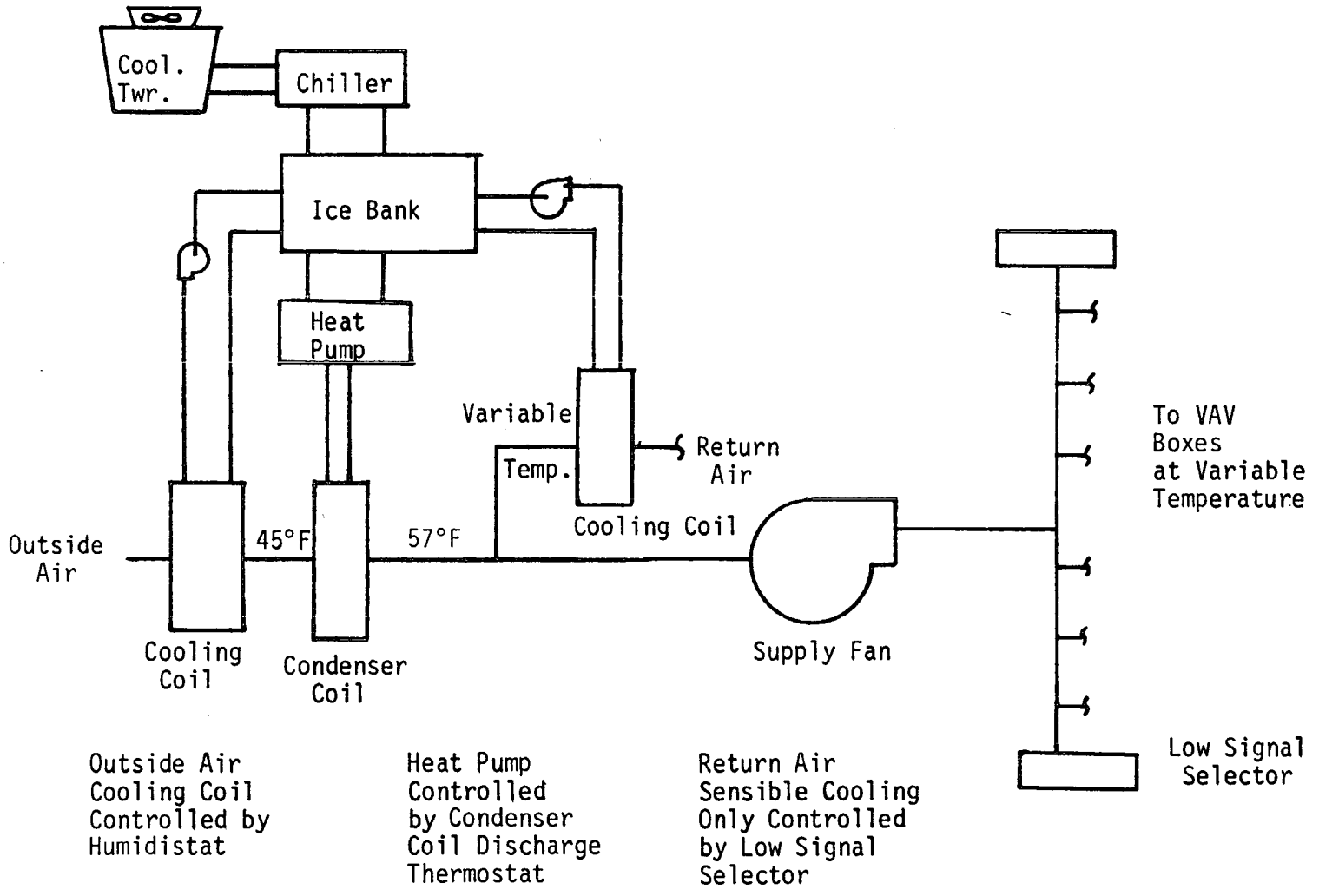



b. High Temperature Radiant Heaters

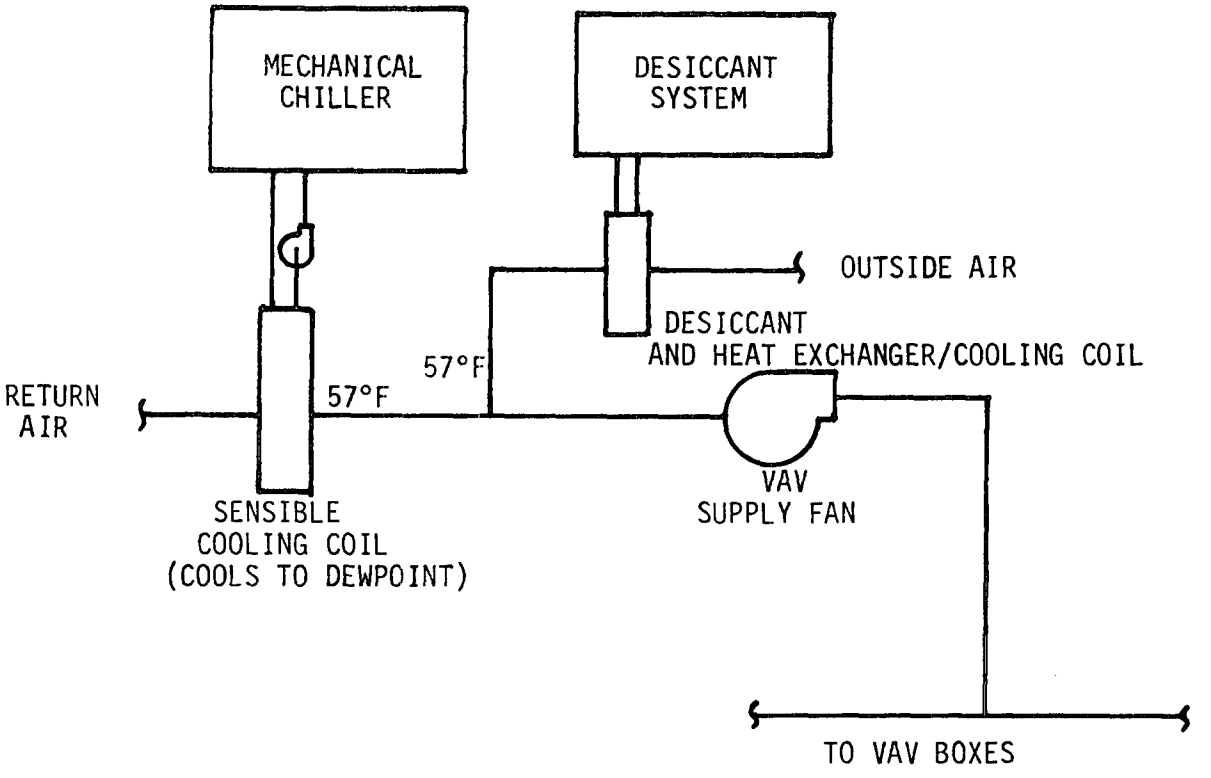



c. Smart Desk with High Emissivity Panels

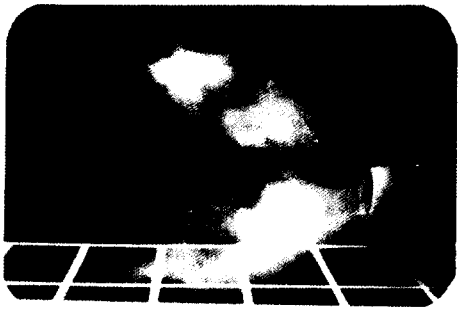
CONTROLLED MEAN RADIANT TEMPERATURE SYSTEMS




ICE BANK HEAT PUMP




DESICCANT DEHUMIDIFICATION SYSTEM



France
& Germany

100% Occupancy

ANNUAL ENERGY SAVINGS SUMMARY FOR LIBRARY SYSTEMS

PMV=0 OPTIMAL THERMAL COMFORT ~~(+1, -1 PMV)~~

| System Type | Minneapolis Total MBTU | Minneapolis MBTU Savings | Minneapolis Percent Savings | St. Louis Total MBTU | St. Louis MBTU Savings | St. Louis Percent Savings | Dallas Total MBTU | Dallas MBTU Savings | Dallas Percent Savings | Miami Total MBTU | Miami MBTU Savings | Miami Percent Savings |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VAV Systems | | | | | | | | | | | | |
| With Humidification | 8,571 | 0 | 0.0% | 6,964 | 0 | 0.0% | 5,797 | 0 | 0.0% | 5,836 | 0 | 0.0% |
| Without Humidification | 8,792 | (221) | -2.6% | 6,797 | 167 | 2.4% | 5,685 | 112 | 1.9% | 5,836 | 0 | 0.0% |
| Controlled Air Velocity | | | | | | | | | | | | |
| Ceiling Fans | 8,323 | 248 | 2.9% | 6,601 | 363 | 5.2% | 5,377 | 419 | 7.2% | 5,385 | 451 | 7.7% |
| Personal Fans | 8,323 | 248 | 2.9% | 6,601 | 363 | 5.2% | 5,377 | 419 | 7.2% | 5,385 | 451 | 7.7% |
| Variable Ind. Diffusers | 8,820 | (249) | -2.9% | 7,348 | (384) | -5.5% | 6,486 | (689) | -11.9% | 6,311 | (476) | -8.2% |
| Smart Desks | 8,588 | (17) | -0.2% | 7,003 | (39) | -0.6% | 5,975 | (179) | -3.1% | 6,001 | (165) | -2.8% |
| VAV Box w/Integral Fan | 8,405 | 166 | 1.9% | 6,724 | 239 | 3.4% | 5,559 | 237 | 4.1% | 5,623 | 212 | 3.6% |
| Controlled MRT | | | | | | | | | | | | |
| Ceiling Panels | 7,265 | 1,306 | 15.2% | 5,880 | 1,083 | 15.6% | 5,353 | 444 | 7.7% | 5,638 | 198 | 3.4% |
| Radiant Heaters | 7,028 | 1,543 | 18.0% | 5,946 | 1,018 | 14.6% | 5,508 | 288 | 5.0% | NA | NA | NA |
| Smart Desk w/High Emissivity Panel | 7,265 | 1,306 | 15.2% | 5,880 | 1,083 | 15.6% | 5,352 | 445 | 7.7% | 5,638 | 198 | 3.4% |
| Reduced Humidity | | | | | | | | | | | | |
| Desiccant | 11,962 | (3,391) | -39.6% | 12,658 | (5,694) | -81.8% | 12,404 | (6,607) | -114.0% | 19,586 | (13,750) | -235.6% |
| Ice Bank | 8,559 | 12 | 0.1% | 7,016 | (52) | -0.8% | 6,191 | (394) | -6.8% | 6,212 | (376) | -6.4% |

Notes: Numbers in parentheses indicate increased energy consumption.
Conversion factor for electricity is 3,413 BTU's per KWH.

ANNUAL ENERGY SAVINGS SUMMARY FOR LIBRARY SYSTEMS

MARGINAL THERMAL COMFORT (PMV=±1)

| System Type | Minneapolis | | | St. Louis | | | Dallas | | | Miami | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total MBTU | MBTU Savings | Percent Savings | Total MBTU | MBTU Savings | Percent Savings | Total MBTU | MBTU Savings | Percent Savings | Total MBTU | MBTU Savings | Percent Savings |
| **VAV Systems** | | | | | | | | | | | | |
| With Humidification | 4,921 | 0 | 0.0% | 3,866 | 0 | 0.0% | 4,001 | 0 | 0.0% | 4,665 | 0 | 0.0% |
| Without Humidification | 4,914 | 6 | 0.1% | 4,004 | (137) | -3.5% | 4,076 | (75) | -1.9% | 4,665 | 0 | 0.0% |
| **Controlled Air Velocity** | | | | | | | | | | | | |
| Ceiling Fans | 4,761 | 160 | 3.2% | 3,631 | 235 | 6.1% | 3,749 | 252 | 6.3% | 4,190 | 475 | 10.2% |
| Personal Fans | 4,761 | 160 | 3.2% | 3,631 | 235 | 6.1% | 3,749 | 252 | 6.3% | 4,190 | 475 | 10.2% |
| Variable Ind. Diffusers | 5,211 | (290) | -5.9% | 4,308 | (442) | -11.4% | 4,749 | (747) | -18.7% | 5,121 | (456) | -9.8% |
| Smart Desks | 4,942 | (21) | -0.4% | 3,993 | (126) | -3.3% | 4,075 | (73) | -1.8% | 4,737 | (73) | -1.6% |
| VAV Box w/Integral Fan | 4,824 | 97 | 2.0% | 3,719 | 147 | 3.8% | 3,919 | 82 | 2.1% | 4,409 | 255 | 5.5% |
| **Controlled MRT** | | | | | | | | | | | | |
| Ceiling Panels | 4,232 | 689 | 14.0% | 3,220 | 646 | 16.7% | 3,578 | 424 | 10.6% | 4,425 | 240 | 5.1% |
| Radiant Heaters | 4,168 | 753 | 15.3% | 3,303 | 564 | 14.6% | 3,765 | 236 | 5.9% | NA | NA | NA |
| Smart Desk w/High Emissivity Panel | 4,232 | 689 | 14.0% | 3,220 | 646 | 16.7% | 3,578 | 424 | 10.6% | 4,425 | 240 | 5.1% |
| **Reduced Humidity** | | | | | | | | | | | | |
| Desiccant | 6,946 | (2,025) | -41.2% | 12,404 | (8,537) | -220.8% | 8,365 | (4,364) | -109.1% | 13,908 | (9,243) | -198.1% |
| Ice Bank | 4,932 | (11) | -0.2% | 6,191 | (2,324) | -60.1% | 4,288 | (287) | -7.2% | 5,007 | (342) | -7.3% |

Note: Numbers in parentheses indicate increased energy consumption.
Conversion factor for electricity is 3,413 BTU's per KWH.

## SYSTEM ATTRIBUTES ANALYZED

- PRESENT VALUE OF ENERGY COST
- INITIAL COST
- PRESENT VALUE OF MAINTENANCE COST
- UNIFORMITY OF COMFORT
- STABILITY OF COMFORT
- DRAFTS
- AIR DIFFUSION
- FLEXIBILITY
- DEVELOPMENT COST
- EASE OF RETROFIT
- BARRIERS TO COMMERCIALIZATION
- SAFETY

SUMMARY RESULTS FOR MULTIATTRIBUTE UTILITY ANALYSIS FOR
LIBRARY OPTIMAL THERMAL COMFORT

| System Type | Minneapolis | | | St. Louis | | | Dallas | | | Miami | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Weighted MUA Value | % Change | Rank | Weighted MUA Value | % Change | Rank | Weighted MUA Value | % Change | Rank | Weighted MUA Value | % Change | Rank |
| VAV Systems | | | | | | | | | | | | |
| With Humidification | 3,970 | 0 | 5 | 4,220 | 0 | 5 | 4,640 | 0 | 5 | 3,728 | 0 | 5 |
| Without Humidification | 4,020 | 1 | 4 | 4,383 | 4 | 4 | 4,745 | 2 | 4 | 3,728 | 0 | 4 |
| CAV Systems | | | | | | | | | | | | |
| Ceiling Fans | 4,455 | 12 | 3 | 5,083 | 20 | 3 | 5,390 | 16 | 2 | 4,695 | 26 | 2 |
| Personal Fans | 4,665 | 18 | 2 | 5,345 | 27 | 1 | 5,695 | 23 | 1 | 4,885 | 31 | 1 |
| VAV Box w/Integral Fan | 4,685 | 18 | 1 | 5,110 | 21 | 2 | 5,320 | 15 | 3 | 4,480 | 20 | 3 |
| Controlled MRT Ceiling Panels | 2,305 | -42 | 6 | 2,335 | -45 | 6 | 1,960 | -58 | 6 | 1,675 | -55 | 6 |

MARGINAL THERMAL COMFORT

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VAV Systems | | | | | | | | | | | | |
| With Humidification | 5,700 | 0 | 5 | 5,760 | 0 | 5 | 6,000 | 0 | 5 | 3,380 | 0 | 5 |
| Without Humidification | 5,950 | 4 | 4 | 5,860 | 2 | 4 | 6,200 | 3 | 4 | 3,380 | 0 | 4 |
| CAV Systems | | | | | | | | | | | | |
| Ceiling Fans | 6,085 | 7 | 3 | 6,635 | 15 | 3 | 6,535 | 9 | 3 | 4,485 | 33 | 2 |
| Personal Fans | 6,590 | 16 | 1 | 7,155 | 24 | 1 | 7,090 | 18 | 1 | 4,635 | 37 | 1 |
| VAV Box w/Integral Fan | 6,445 | 13 | 2 | 6,800 | 18 | 2 | 6,545 | 9 | 2 | 4,340 | 28 | 3 |
| Controlled MRT Ceiling Panels | 2,515 | -56 | 6 | 2,520 | -56 | 6 | 2,515 | -58 | 6 | 1,750 | -48 | 6 |

# TASK II RESULTS

- o CAV STRATEGIES ARE COST-EFFECTIVE IN ALL DOE ZONES

- o RADIANT HEATERS ARE TOO COSTLY
  - SUPPLEMENT CENTRAL SYSTEMS
  - HIGHER MAINTENANCE COSTS

- o CEILING PANELS ARE TOO COSTLY
  - ENERGY EFFICIENT SYSTEMS
  - DO NOT PAY BACK DUE TO OUTSIDE AIR REQUIREMENT

- o SMART DESKS REQUIRE RAISED FLOOR
  - ONLY COMPETITIVE IF THE COST OF THE FLOOR IS EXCLUDED
  - SUPERIOR AIR DISTRIBUTION AND COMFORT CONTROL

- o HUMIDITY CONTROL SYSTEMS DO NOT SAVE SIGNIFICANT ENERGY because we are driving R.H to <35%
  - COST OF HUMIDIFICATION OFFSETS TRANSMISSION BENEFIT
  - COST OF DESICCANT DEHUMIDIFICATION EXCEEDED $ SAVINGS
  - DESICCANT PAYBACK IS DUE TO GAS-ELECTRICITY PRICE DIFFERENTIAL
  - ICE BANK IS NOT ATTRACTIVE DUE TO AIR QUALITY CONCERNS (LOW AIR DISTRIBUTION) PLUS ADDED COST OF EQUIPMENT

associated issue is wires life in humidifying spaces. x

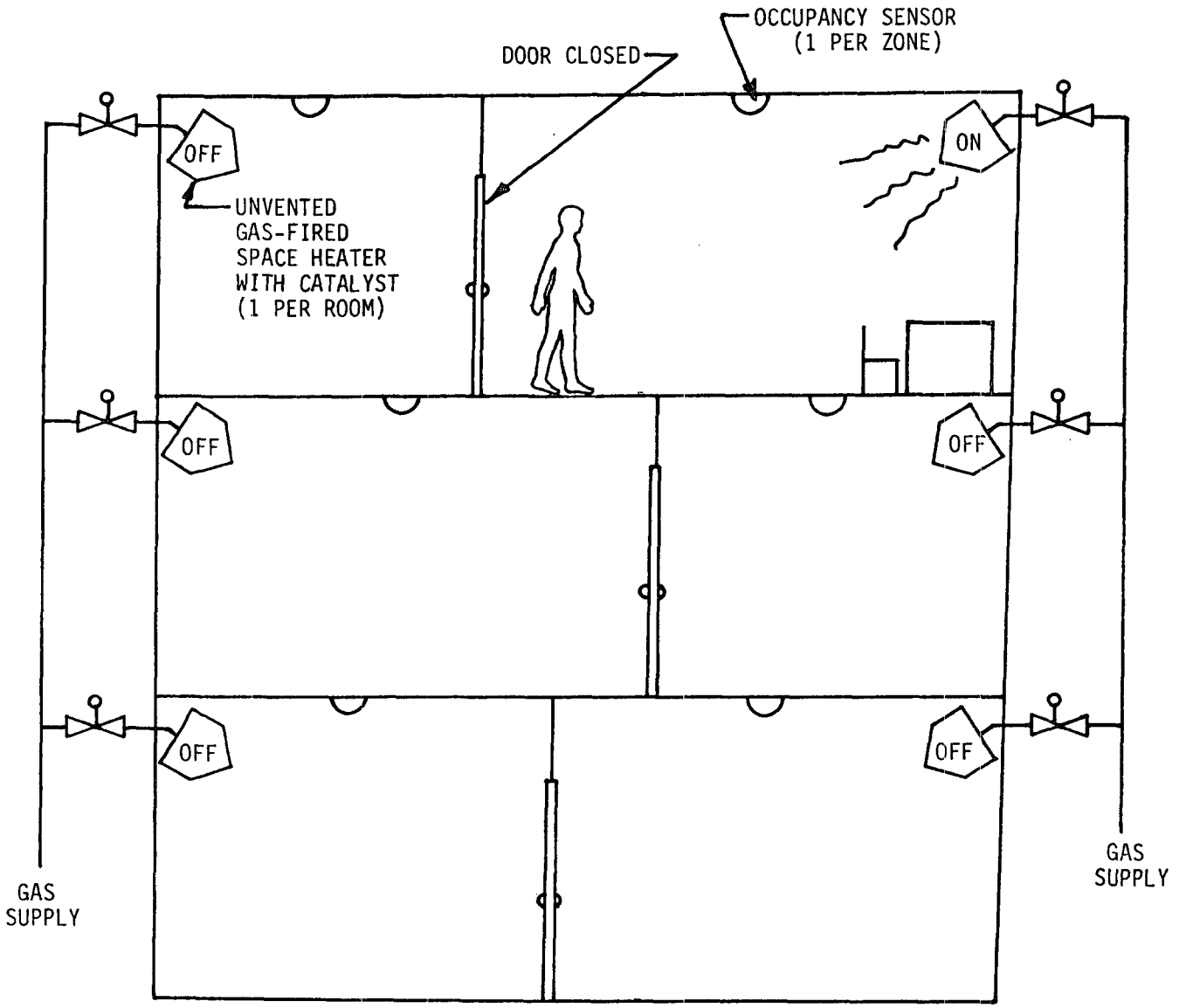
need will look up data for U.S.

## TASK III OBJECTIVE

IDENTIFY AND ASSESS THE STATE-OF THE ART OF HVAC DISTRIBUTION AND CONTROL SYSTEMS WHICH PROVIDE ACCEPTABLE THERMAL COMFORT WHILE MINIMIZING ENERGY CONSUMPTION BY IMPROVED TIME AND LOCATION SELECTIVITY AND CONTROL IN THE DELIVERY OF CONDITIONING CAPABILITY FOR SELECTED VARIABLE OCCUPANCY BUILDING/CLIMATE COMBINATIONS.

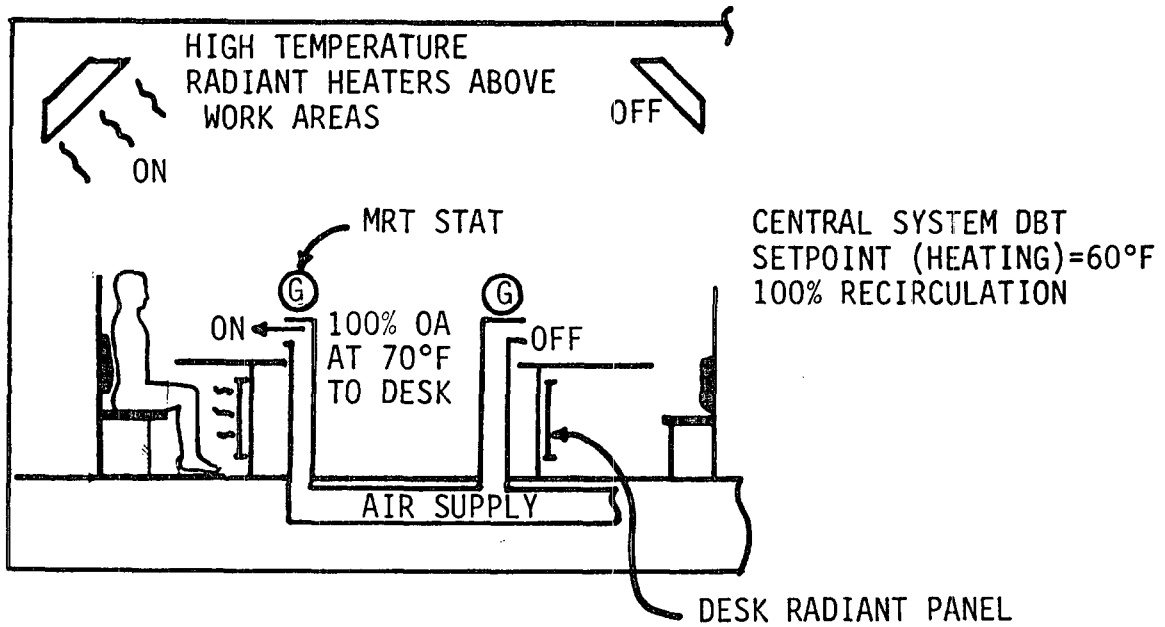
# TASK III APPROACH

- o PERFORM BASELINE BUILDING/CONTROL STRATEGY ANALYSIS
  - CONFIGURE OFFICE AND RESIDENCE
  - SELECT SIMULATION MODEL
  - PERFORM ANNUAL SIMULATIONS
- o DEVELOP AND ANALYZE SYSTEM CONCEPTS
  - GENERATE CONCEPTS
  - PERFORM SYSTEM SIMULATION RUNS
  - SUMMARIZE ENERGY SAVINGS
- o ASSESS ATTRACTIVE SYSTEM CONCEPTS
  - SIMILAR TO TASK II
  - PERFORM SENSITIVITY ANALYSIS

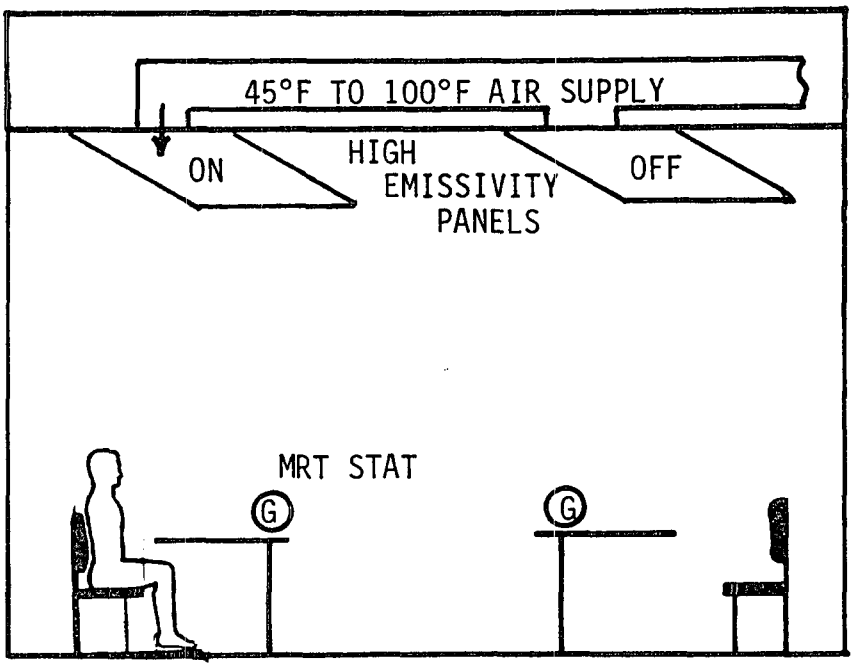



EXAMPLE: ZONE CONTROL BASED ON OCCUPANCY SENSOR USING UNVENTED GAS-FIRED SPACE HEATERS

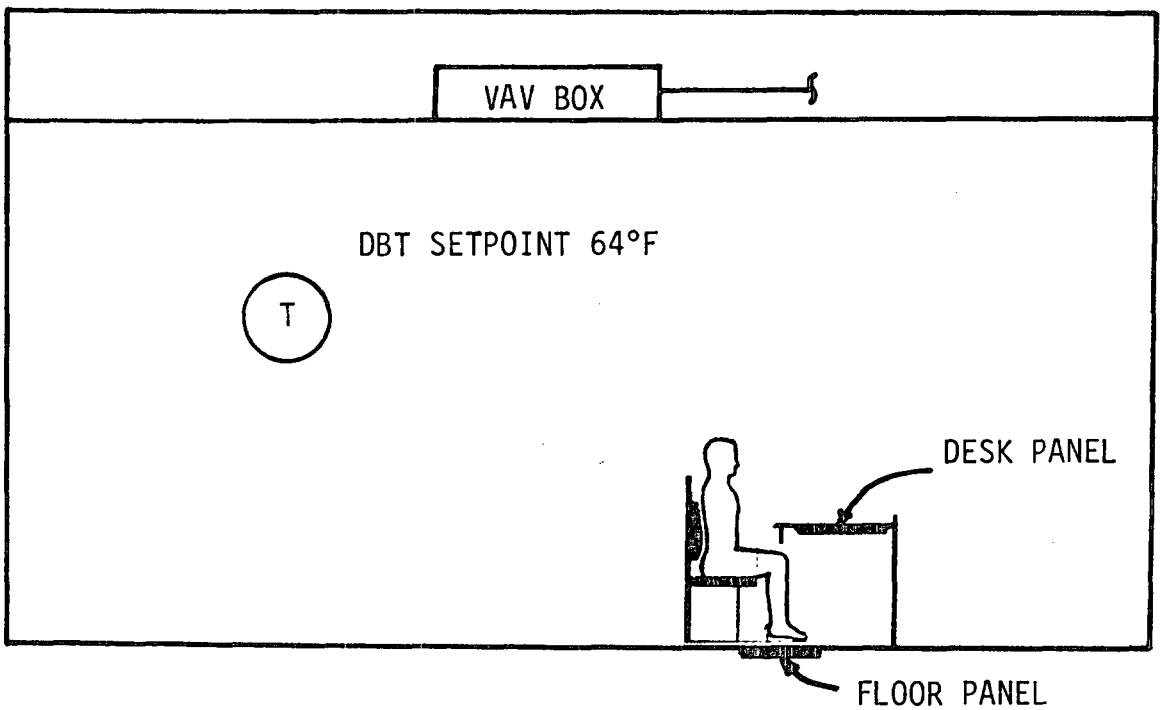
NON-VENTED GAS-FIRED SPACE HEATER WITH CATALYST




RADIANT HEATERS WITH LOCAL DIFFUSERS

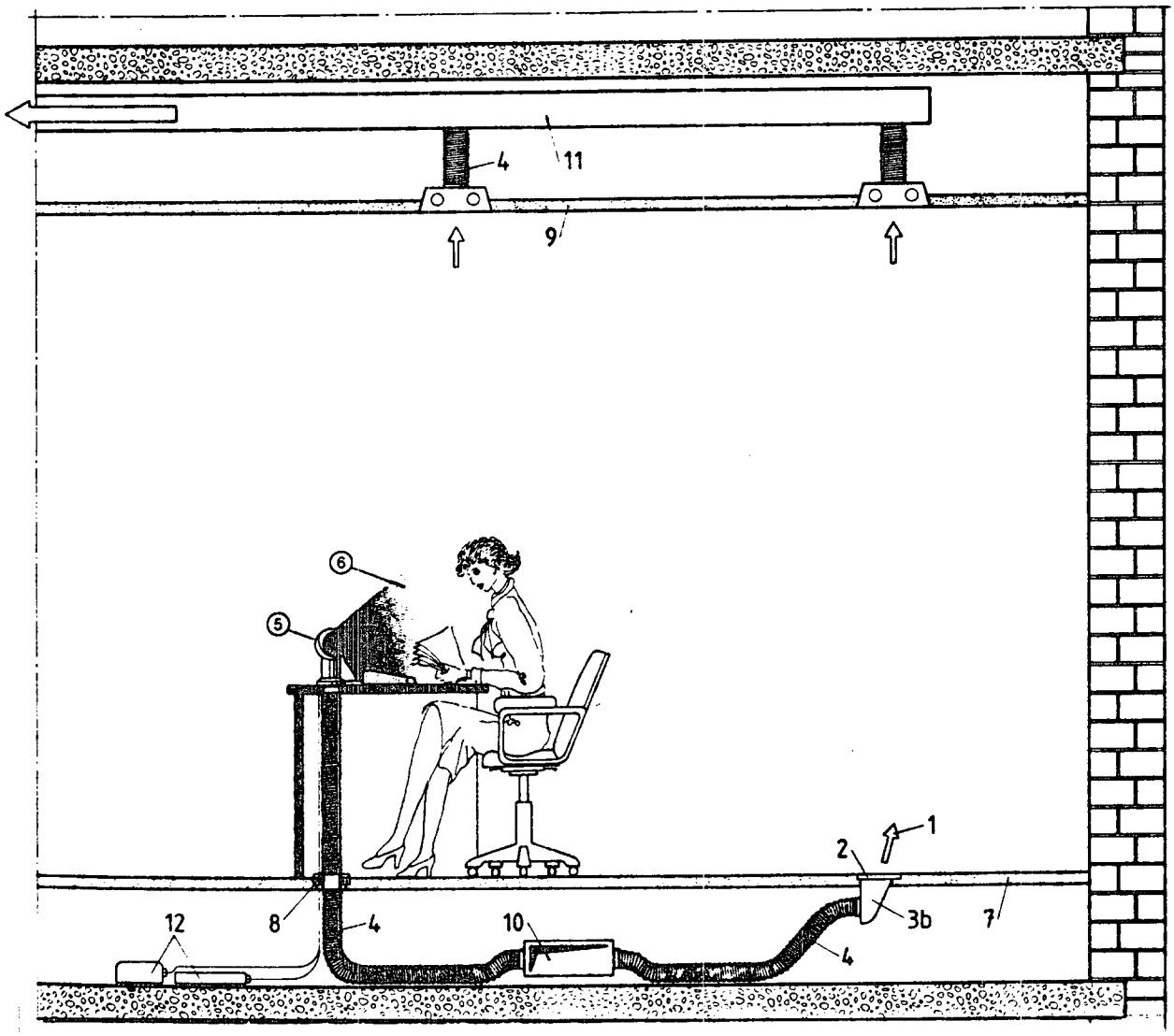



HIGH EMISSIVITY PANELS



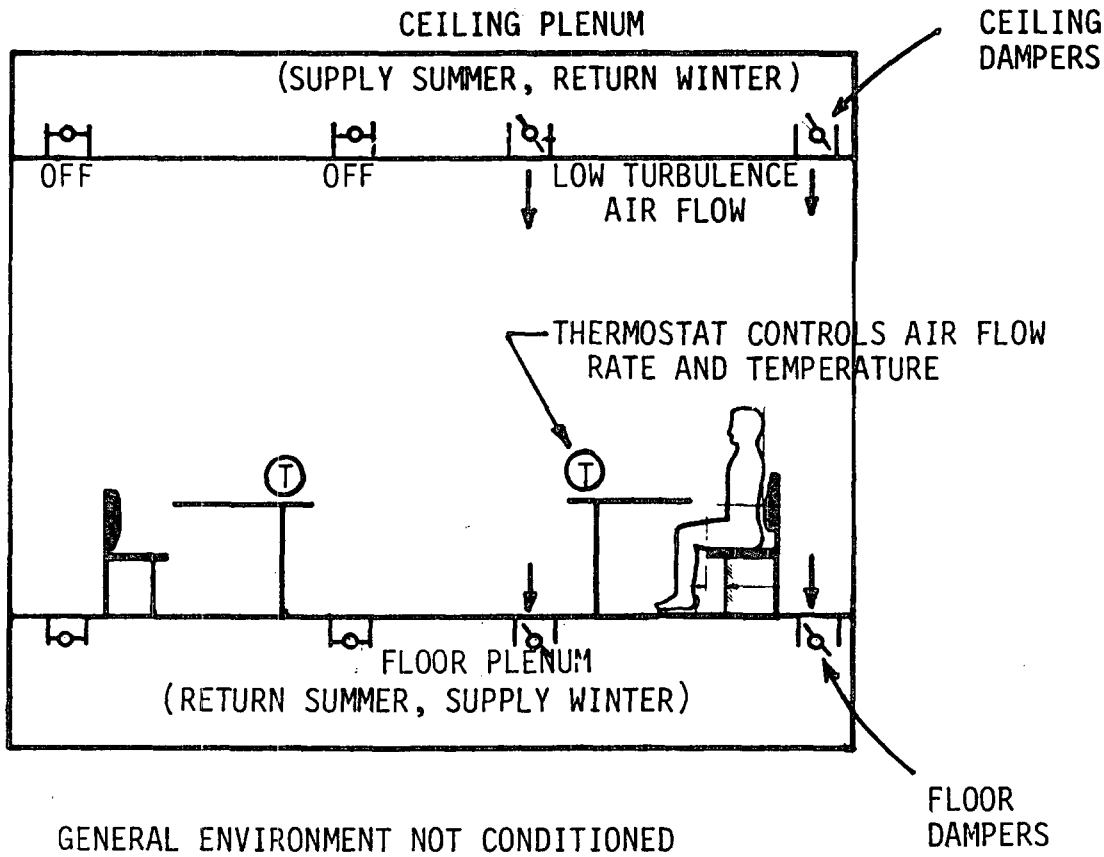

PANELS WARM HANDS AND FEET, INCREASING COMFORT AT REDUCED DBT SETPOINT

FLOOR AND DESK PANELS

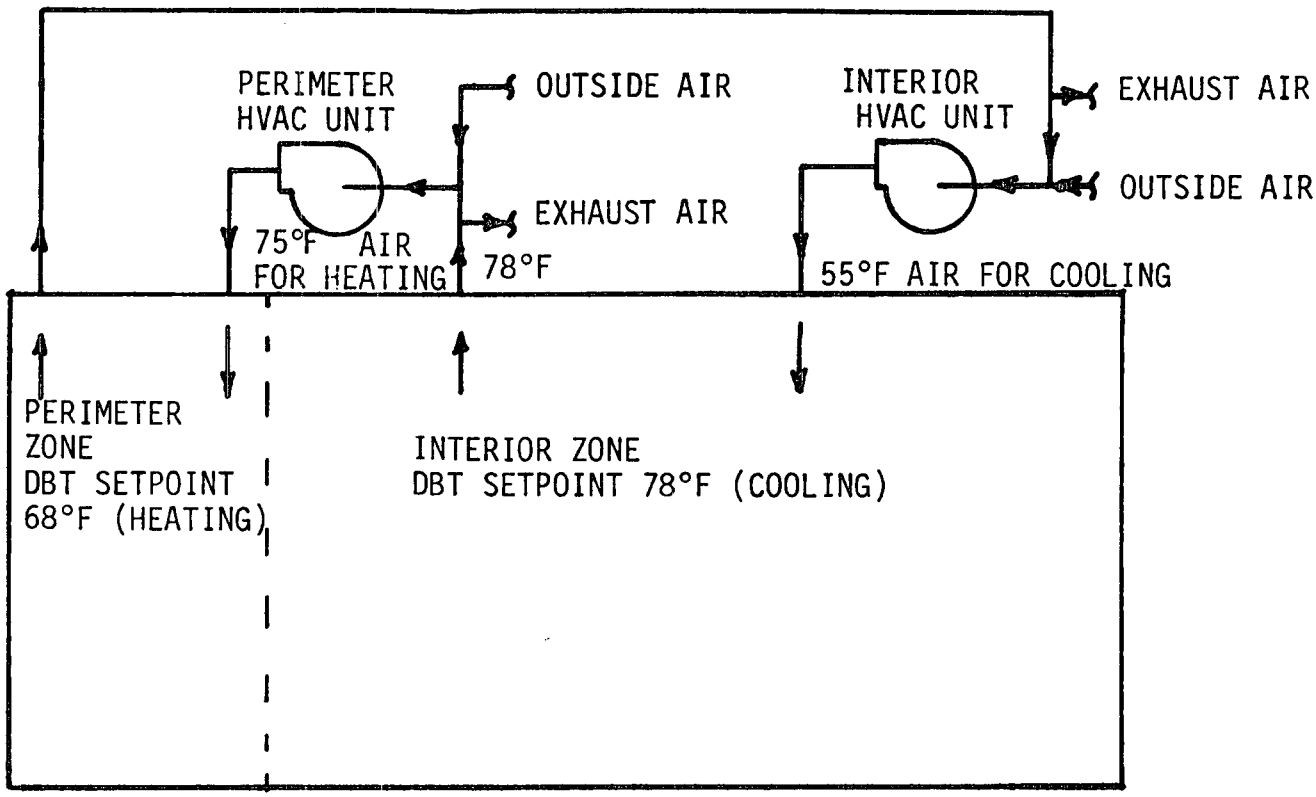



① supply air
② floor air outlet
③a adjusting cap BK
③b adjusting cap BS
④ flexible pipe
⑤ desk air outlet
⑥ micro-climate
⑦ raised floor
⑧ underfloor coupling
⑨ false ceiling
⑩ supply air duct
⑪ return air duct
⑫ electricity and telecommu-
nications supply

TYPICAL FLOOR/DESK DISTRIBUTION SYSTEM
UTILIZING "SMART DESKS"
(Courtesy Krantz Co.)




LAMINAR FLOW "AIR CURTAINS"



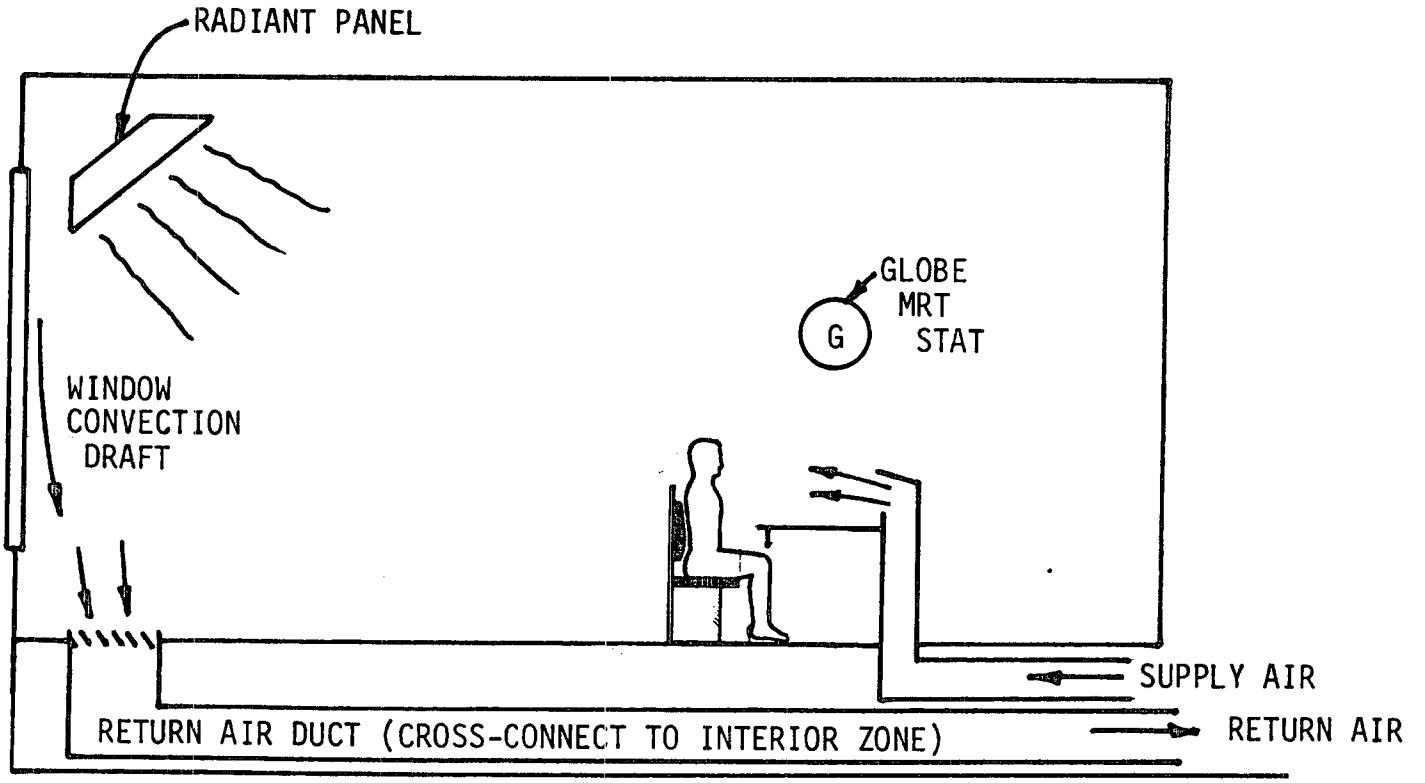

WARM INTERIOR RETURN AIR AT 78°F PROVIDES HEAT TO PERIMETER ZONE AT SETPOINT OF 68°F

RETURN AIR CROSS CONNECTION

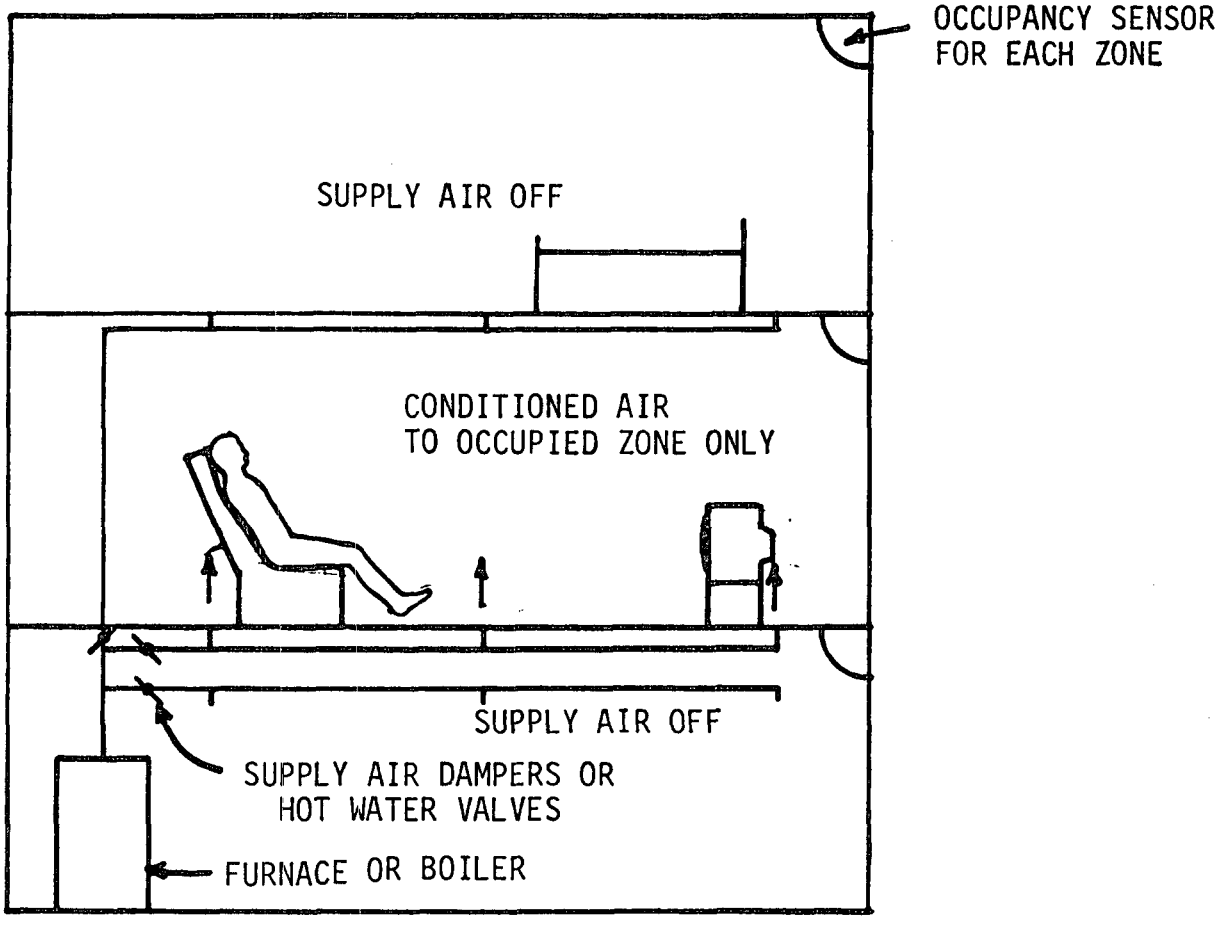
Occupancy / unit area

1 person / 100 ft² office

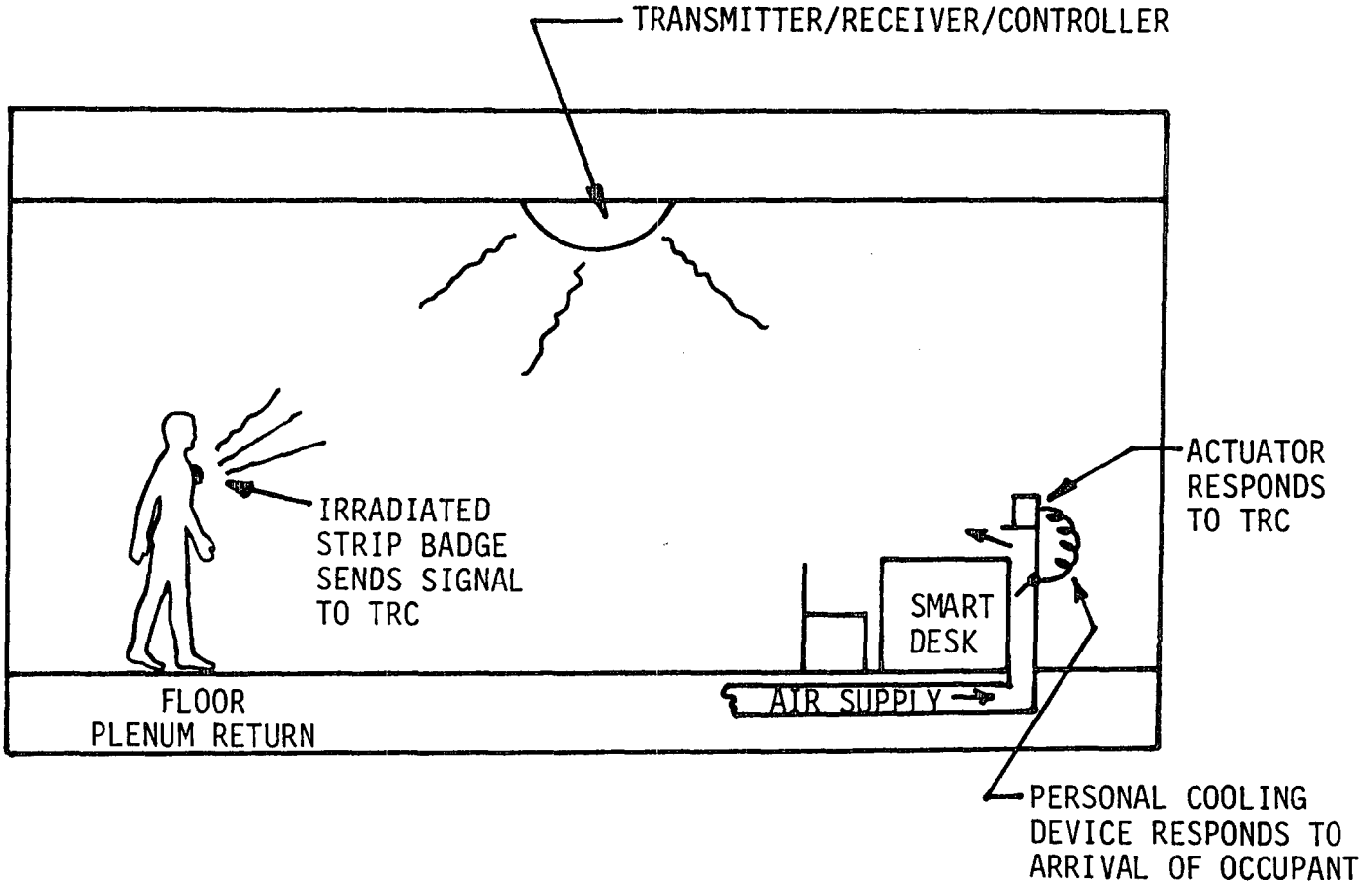
200 ft² / person in residential




PERIMETER FLOOR RETURNS




RESIDENTIAL ROOM ZONING




IRRADIATED STRIP BADGES

ANNUAL ENERGY SAVINGS SUMMARY FOR
OFFICE AND RESIDENTIAL SYSTEMS

OFFICE

| System/Control Strategy | Minneapolis | | | St. Louis | | | Dallas | | | Miami | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total MBTU | MBTU Savings | Percent Savings | Total MBTU | MBTU Savings | Percent Savings | Total MBTU | MBTU Savings | Percent Savings | Total MBTU | MBTU Savings | Percent Savings |
| Day/Night Setback | 1,694 | 0 | 0.0% | 1,306 | 0 | 0.0% | 1,239 | 0 | 0.0% | 758 | 0 | 0.0% |
| Continuous Operation | 2,313 | (619) | -36.5% | 1,826 | (519) | -39.8% | 1,576 | (337) | -27.2% | 971 | (213) | -28.1% |
| Comfort Envelope | 886 | 809 | 47.7% | 699 | 608 | 46.5% | 711 | 528 | 42.6% | 490 | 267 | 35.3% |
| Non-Vented Heaters | 1,183 | 512 | 30.2% | 936 | 370 | 28.3% | 912 | 328 | 26.4% | NA | NA | NA |
| Radiant Heaters | 1,374 | 320 | 18.9% | 1,075 | 231 | 17.7% | 1,033 | 206 | 16.6% | NA | NA | NA |
| Air Curtains | 1,412 | 282 | 16.6% | 1,082 | 224 | 17.2% | 1,011 | 228 | 18.4% | 652 | 106 | 13.9% |
| High Em. Panels | 1,368 | 326 | 19.2% | 1,073 | 233 | 17.8% | 1,032 | 207 | 16.7% | 766 | (8) | -1.1% |
| Smart Desks | 1,463 | 232 | 13.7% | 1,126 | 180 | 13.8% | 1,069 | 170 | 13.7% | 707 | 51 | 6.7% |
| Floor Returns | 1,573 | 121 | 7.2% | 1,196 | 110 | 8.4% | 1,143 | 96 | 7.8% | NA | NA | NA |
| Cross Connection | 1,422 | 273 | 16.1% | 1,112 | 194 | 14.8% | 1,070 | 169 | 13.6% | NA | NA | NA |
| Desk Panels | 1,298 | 396 | 23.4% | 960 | 346 | 26.5% | 947 | 293 | 23.6% | NA | NA | NA |

RESIDENCE

| System/Control Strategy | Minneapolis | | | St. Louis | | | Dallas | | | Miami | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total MBTU | MBTU Savings | Percent Savings | Total MBTU | MBTU Savings | Percent Savings | Total MBTU | MBTU Savings | Percent Savings | Total MBTU | MBTU Savings | Percent Savings |
| Day/Night Setback | 252 | 0 | 0.0% | 157 | 0 | 0.0% | 81 | 0 | 0.0% | 43 | 0 | 0.0% |
| Continuous Operation | 340 | -88 | -35.1% | 213 | -56 | -35.5% | 114 | -33 | -40.3% | 54 | -11 | -25.6% |
| Comfort Envelope | 210 | 42 | 16.5% | 101 | 57 | 35.9% | 32 | 49 | 60.7% | 11 | 32 | 74.2% |
| Non-Vented Heaters | 169 | 83 | 32.8% | 102 | 55 | 35.2% | 54 | 28 | 34.2% | NA | NA | NA |
| Room Zoning | 228 | 23 | 9.2% | 130 | 28 | 17.5% | 58 | 24 | 29.0% | 32 | 11 | 24.8% |

MUA

SUMMARY RESULTS FOR MULTIATTRIBUTE UTILITY ANALYSIS FOR
OFFICE AND RESIDENCE

OFFICE

| System Type | Minneapolis Weighted MUA Value | Minneapolis % Change | Minneapolis Rank | St. Louis Weighted MUA Value | St. Louis % Change | St. Louis Rank | Dallas Weighted MUA Value | Dallas % Change | Dallas Rank | Miami Weighted MUA Value | Miami % Change | Miami Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Night Setback | 1,990 | 0 | 4 | 2,560 | 0 | 4 | 2,880 | 0 | 5 | 3,210 | 0 | 1 |
| Non-Vented Heaters | 1,446 | -27 | 6 | 1,493 | -42 | 6 | 1,570 | -45 | 6 | | | |
| Radiant Heaters | 1,116 | -44 | 7 | 1,173 | -54 | 7 | 1,235 | -57 | 7 | | | |
| High Emissivity Panels | 1,886 | -5 | 5 | 2,068 | -19 | 5 | 2,175 | -24 | 5 | | | |
| Smart Desks | 2,360 | 19 | 1 | 2,793 | 9 | 2 | 3,135 | 9 | 2 | 2,130 | -34 | 2 |
| RA Cross-Connect | 2,183 | 10 | 3 | 2,725 | 6 | 3 | 3,030 | 5 | 3 | | | |
| Desk Panels | 2,315 | 16 | 2 | 2,930 | 14 | 1 | 3,220 | 12 | 1 | | | |

RESIDENCE

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Night Setback | 1,395 | 0 | 1 | 1,565 | 0 | 2 | 1,745 | 0 | 2 | 1,193 | 0 | 2 |
| Non-Vented Heaters | 1,239 | -11 | 3 | 1,256 | -20 | 3 | 1,073 | -38 | 3 | - | - | - |
| Room Zoning | 1,294 | -7 | 2 | 1,801 | 15 | 1 | 2,209 | 27 | 1 | 1,589 | 33 | 1 |

# TASK III RESULTS

- o ALL SYSTEMS ANALYZED OFFER SIGNIFICANT REGIONAL ENERGY SAVINGS POTENTIAL

- o ADVANCED SYSTEMS OFFERING COST-EFFECTIVE SAVINGS IN AT LEAST 1 DOE CLIMATE ZONE INCLUDE:
  - NON-VENTED HEATERS
  - HIGH EMISSIVITY PANELS
  - SMART DESKS
  - RETURN AIR CROSS CONNECTION
  - DESK PANELS
  - ROOM ZONING

- o IMPACT OF INTANGIBLE FACTORS
  - SAFETY & CODE BARRIERS HURT NON-VENTED HEATERS AND RADIANT HEATERS
  - SMART DESKS AND DESK PANELS OFFER GOOD POTENTIAL
  - HIGH EMISSIVITY PANELS REQUIRE FURTHER INVESTIGATION

## RECOMMENDED RESEARCH REQUIREMENTS

| SYSTEM | RESEARCH NEEDS | DEVELOPMENT TIME (YRS) |
|---|---|---|
| CEILING FANS | FAN SPEED SENSOR/CONTROLLER | 1 |
| PERSONAL FANS | INFINITE VARIABLE SPEED CONTROLLER | 0.5 |
| VAV BOX W/ INTEGRAL FAN | FAN SPEED SENSOR/CONTROLLER | 1 |
| MEAN RADIANT TEMPERATURE CONTROL CONCEPTS | EMPIRICAL RESEARCH ON COMFORT IMPACT AND ACHIEVABLE SAVINGS; SENSOR/CONTROLLERS | 5-10 |
| HUMIDITY CONTROL CONCEPTS | HEALTH/PRODUCTIVITY IMPACT COMFORT CONTROL | 5-10 |
| SMART DESKS | AIR QUALITY IMPACT WHOLE BUILDING COSTS | 5-20 |
| NON-VENTED SPACE HEATERS | DEVELOPMENT AND TESTING OF EMISSION SENSOR/CONTROLLER, CATALYST, SAFETY CONTROLS AND ZONE CONTROLLER | 5-10 |
| HIGH EMISSIVITY PANELS | INFLUENCE ON AIR DIFFUSION CHARACTERISTICS | 2-5 |
| | ENERGY PERFORMANCE CHARACTERISTICS | 1-2 |
| PERSONAL SENSORS | EQUIPMENT DEVELOPMENT | 2-5 |
| | TESTING | 2 |
| SMART DESKS | DEVELOP TEST LABORATORY FOR AIR DIFFUSION AND COMFORT CONTROL TESTS | 5 |
| DESK PANELS | DEVELOP CONTROLS AND TEST IMPACT ON COMFORT | 1-2 |

# CONCLUSIONS

- o CURRENT STATE-OF-THE-ART IS ADVANCED
  - FURTHER SAVINGS MORE COSTLY
- o AIR DISTRIBUTION AND AIR QUALITY PROBLEMS PERSIST WITH CURRENT SYSTEMS
  - FURTHER RESEARCH REQUIRED FROM A TOTAL BUILDING PERSPECTIVE
- o SEVERAL SYSTEMS ARE CLOSE TO COMMERCIAL VIABILITY
  - HIGH EMISSIVITY PANELS
  - DESK PANELS
  - RA CROSS CONNECTION
  - CAV SYSTEMS
  - RADIANT HEATERS
- o LONGER TERM RESEARCH NEEDED FOR
  - SMART DESKS
  - NON-VENTED HEATERS