Improving the Performance of HVAC Systems

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GSA #: GS-07F-239N

Schedule 84

Improving HVAC Performance

- HVAC Life-Cycle Analysis
- Defining “Effective” HVAC
- Applying Six Sigma
- HVAC Benchmark Data
- Project Energy Savings

HVAC Life-Cycle Analysis

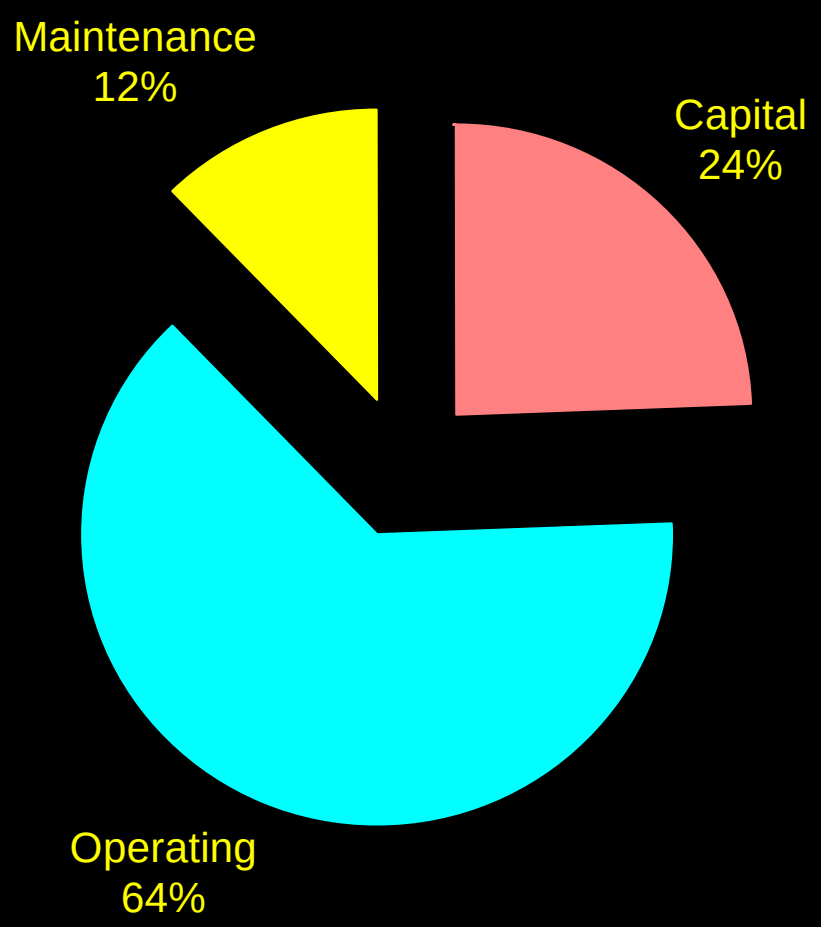
Capital Cost

Operating Costs

Maintenance Costs

Service Life

HVAC Life-Cycle Analysis



Improving HVAC Performance

HVAC Life-Cycle Analysis

Defining “Effective” HVAC

Defining an "Effective" HVAC System

Temperature

Humidity

Fresh Air / CO2

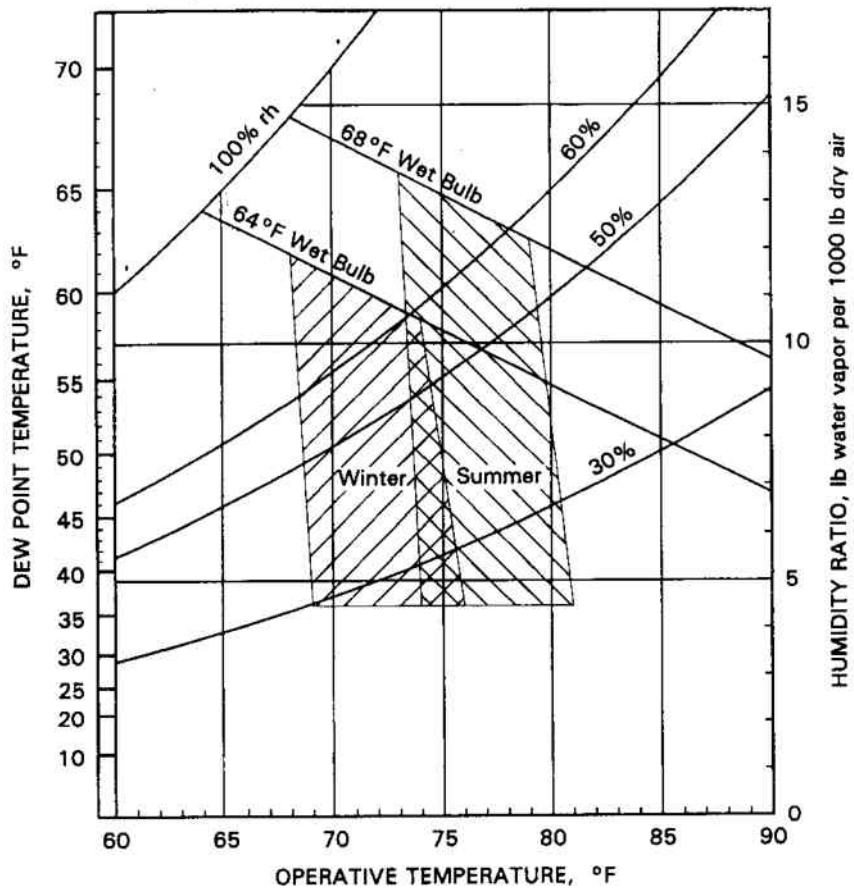


Fig. 2 ASHRAE Summer and Winter Comfort Zones
(Acceptable ranges of operative temperature and humidity for people in typical summer and winter clothing during primarily sedentary activity.)

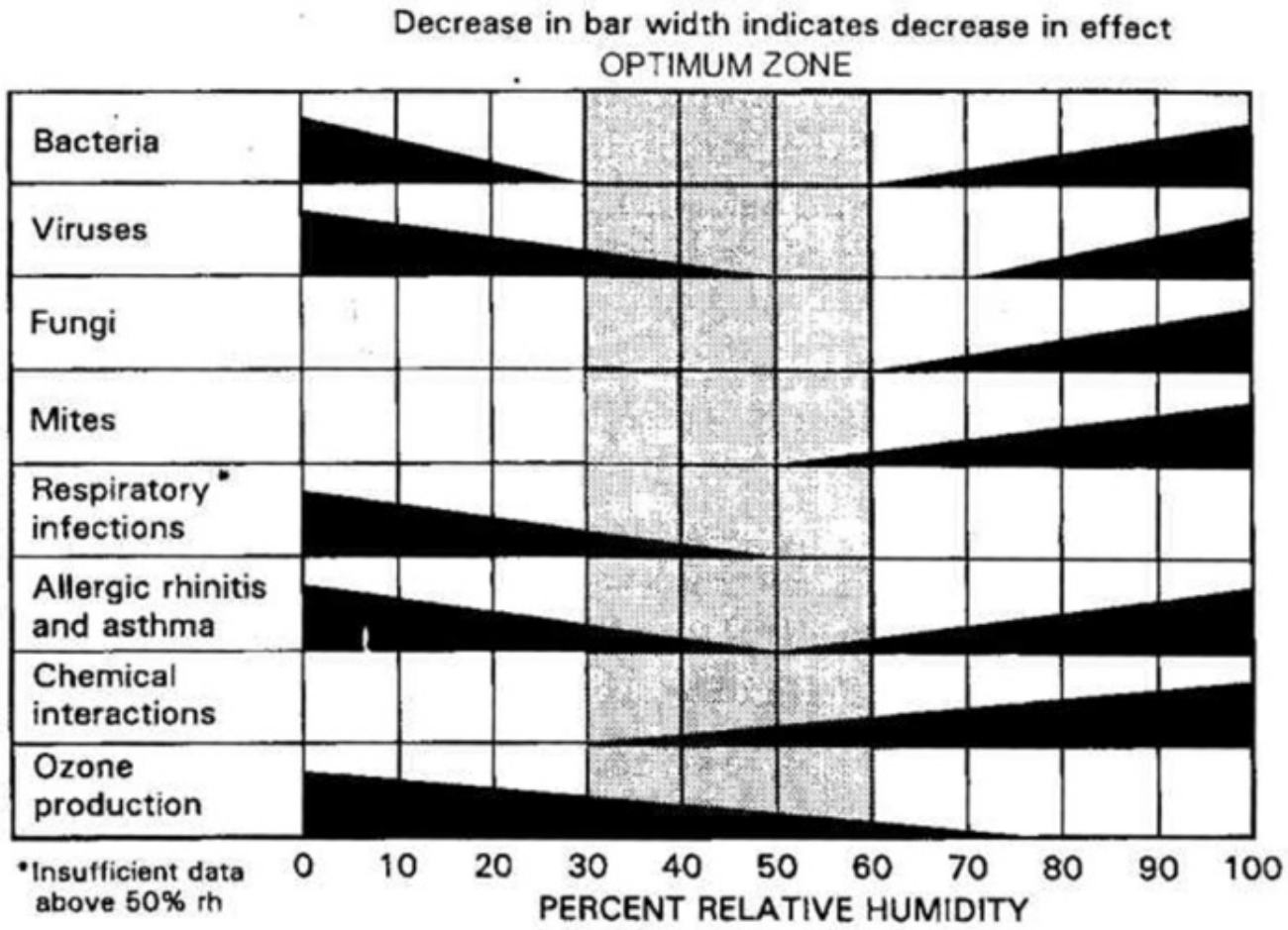
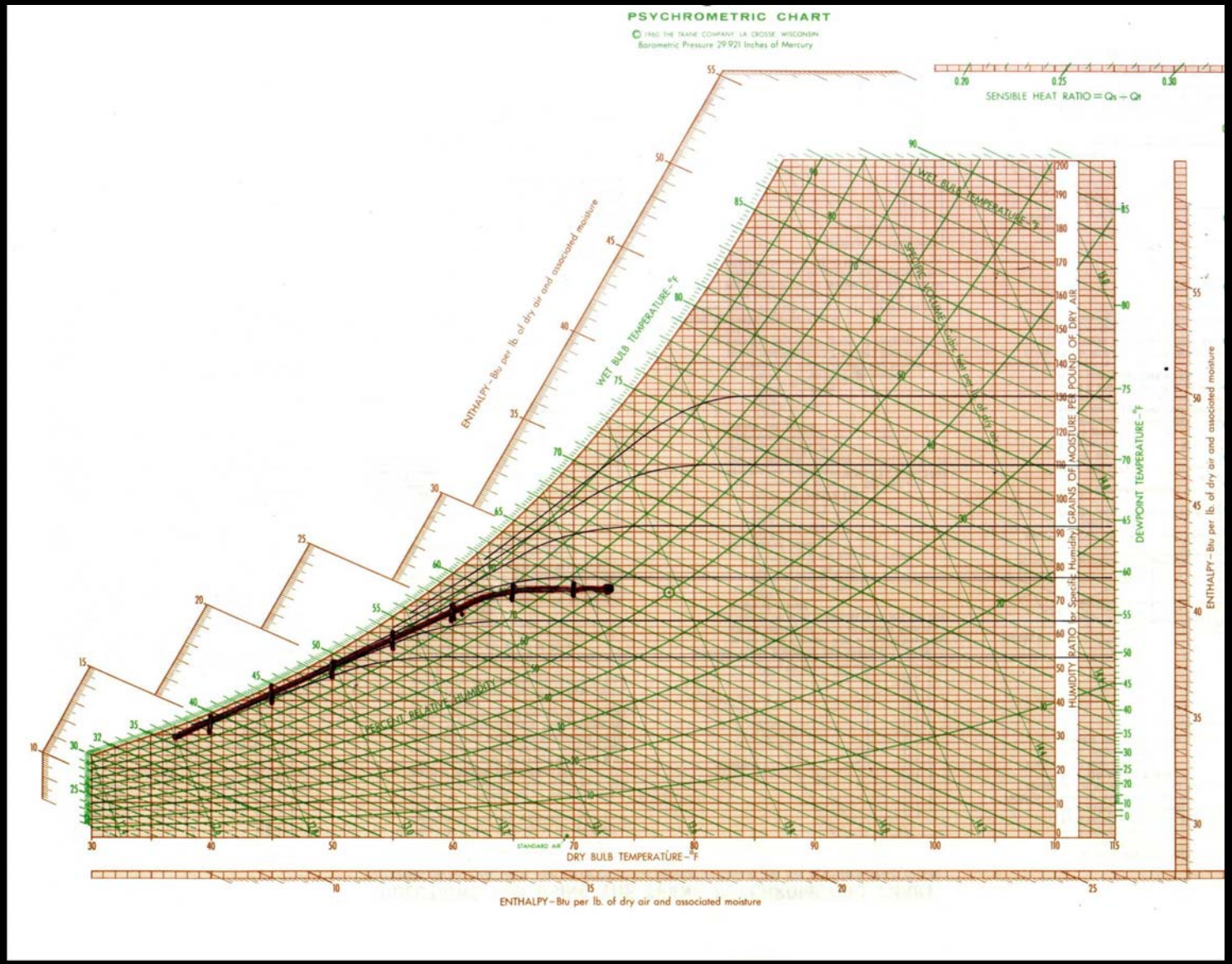


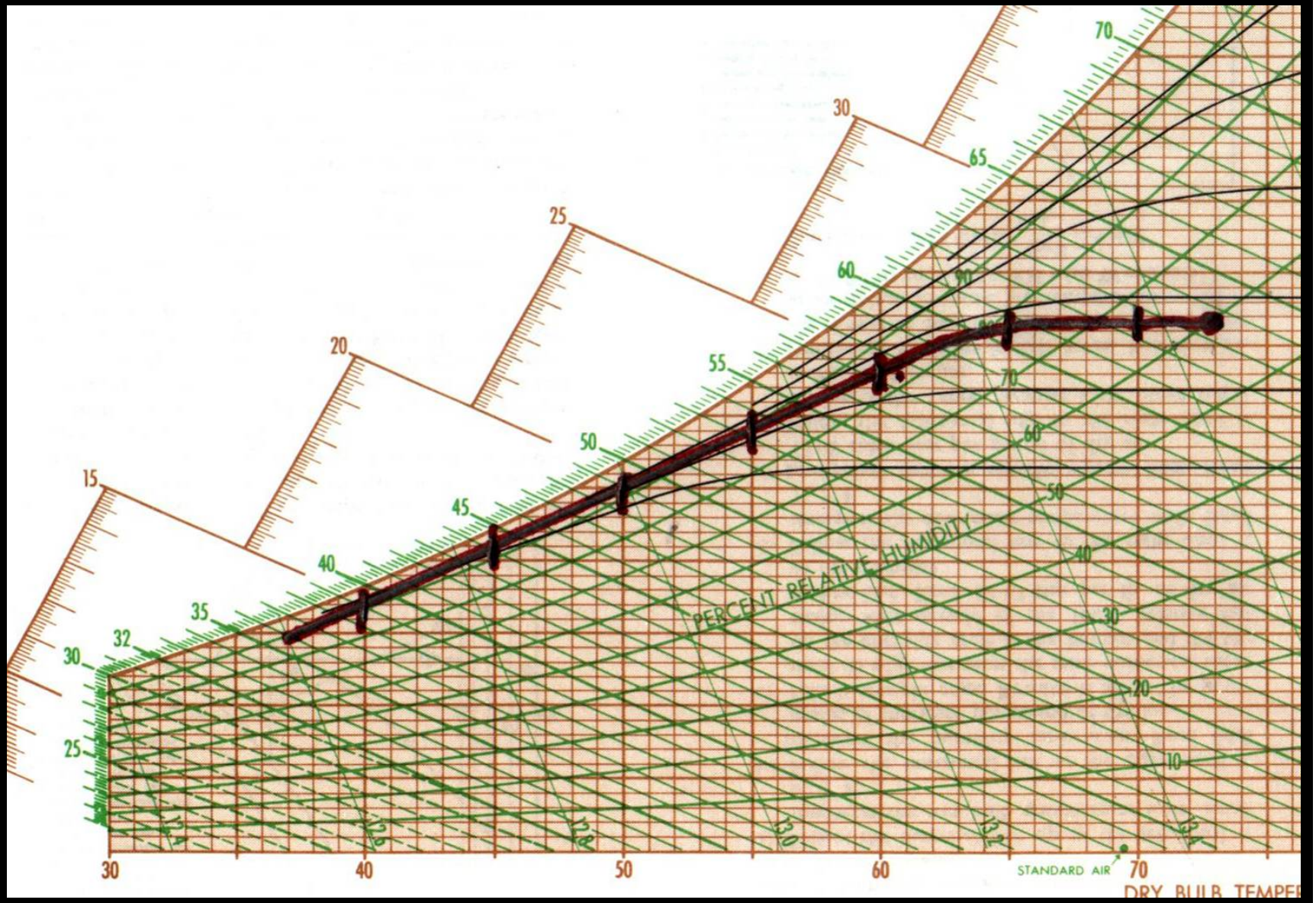
Fig. 1 Optimum Humidity Range for Human Comfort and Health

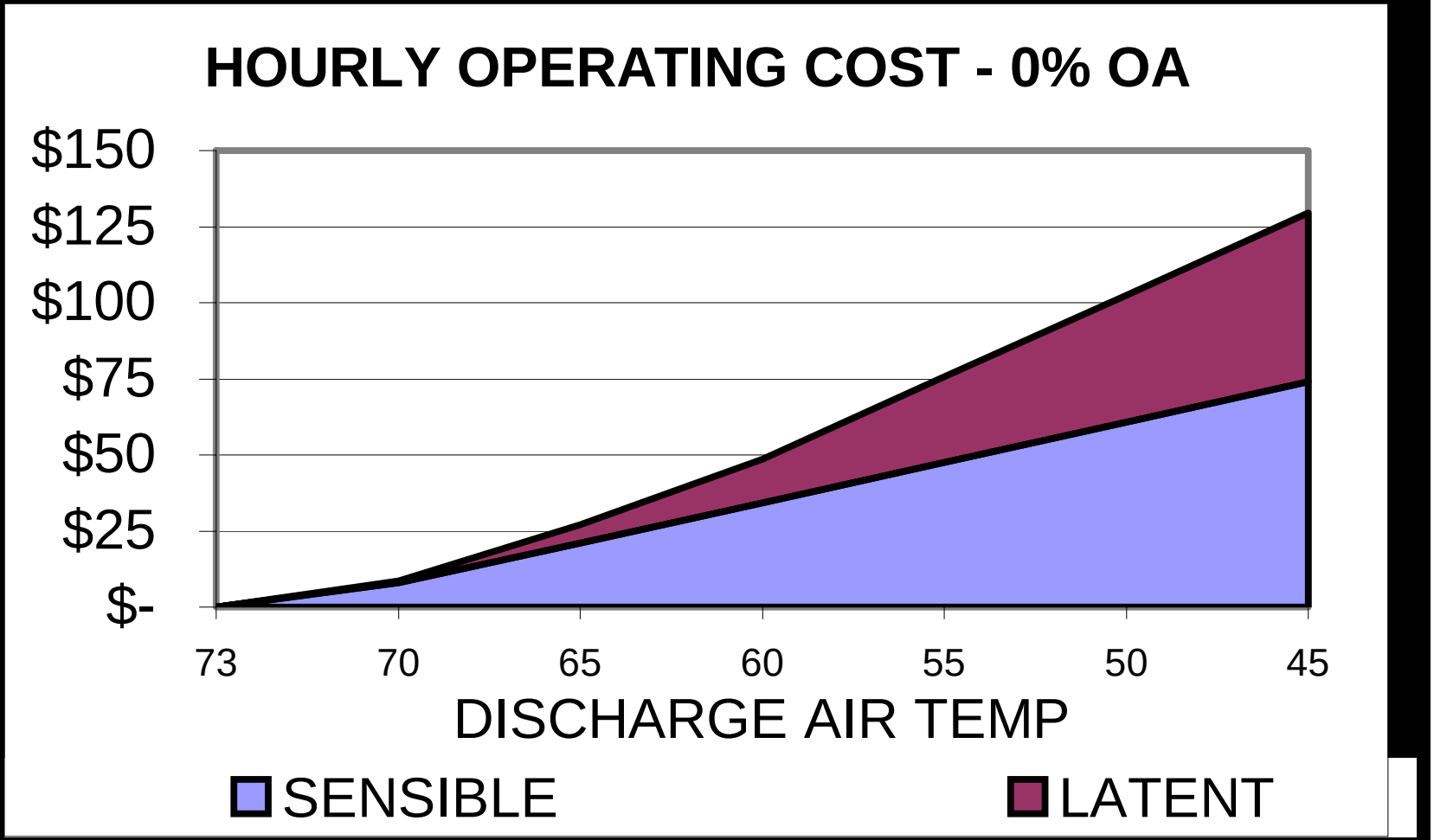
(Adapted from Sterling et al. 1985)

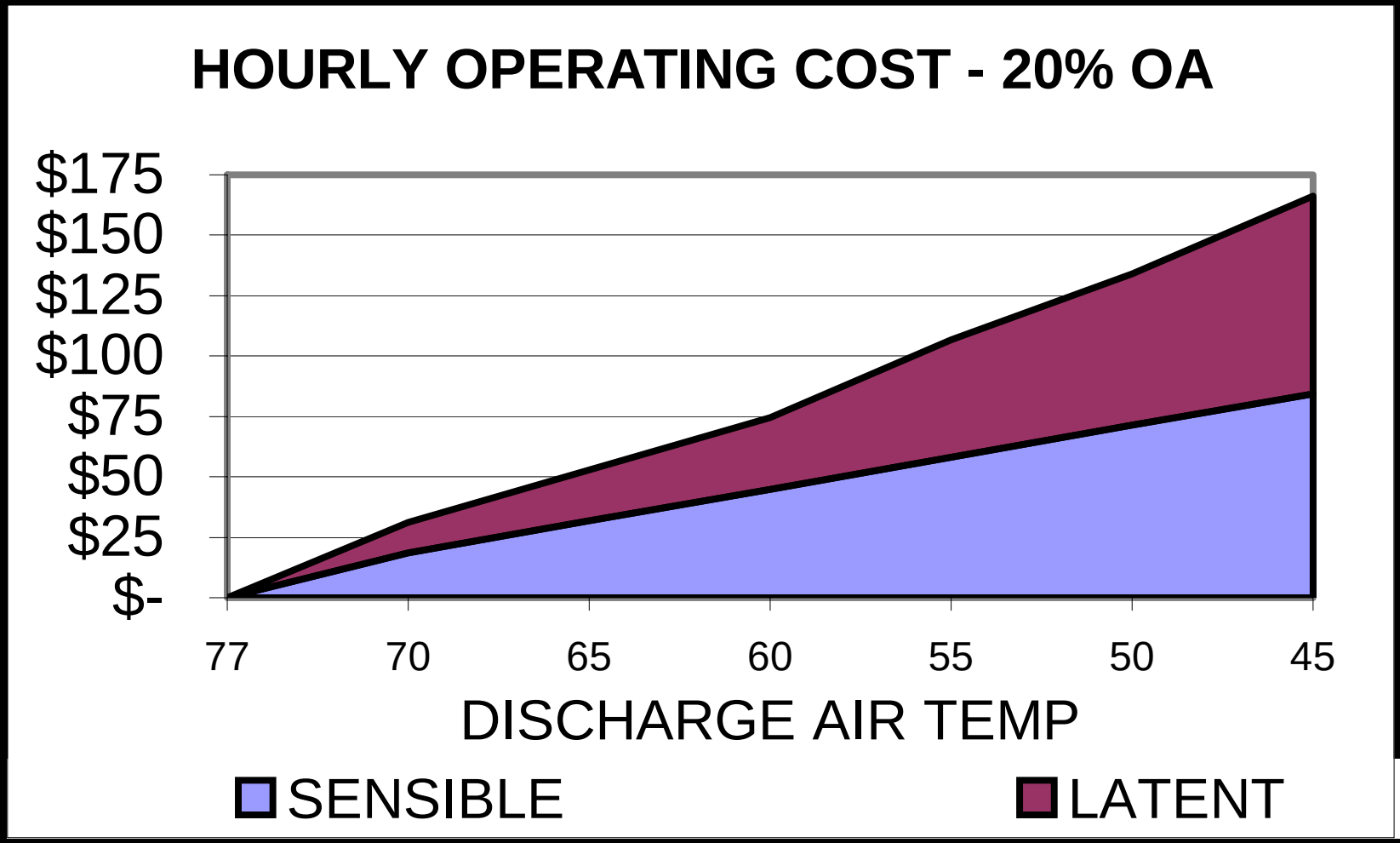
Moisture Control in HVAC

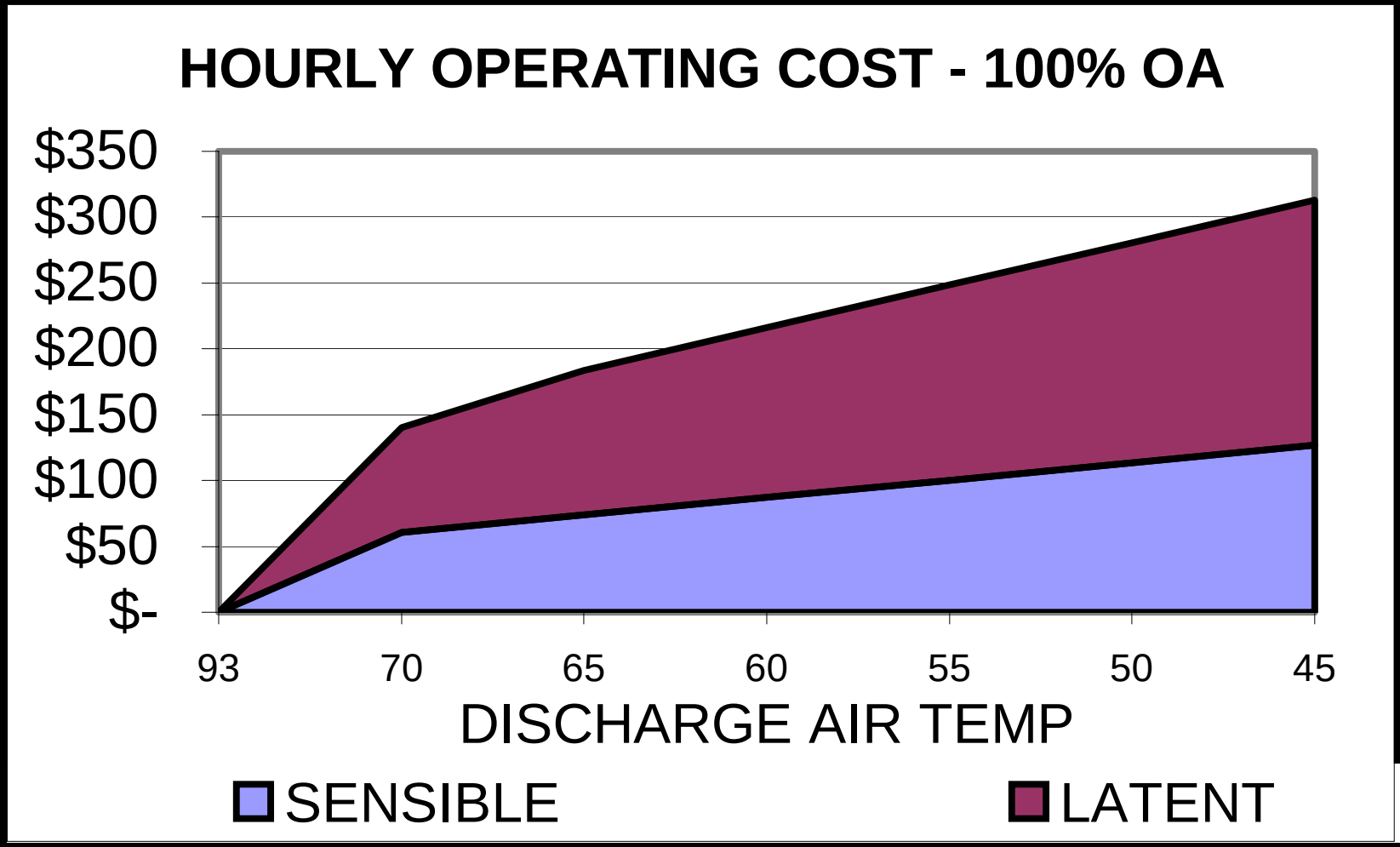
- Sources of Moisture
  - People
  - Misc. equipment
  - Outside Air / Infiltration
- Locations –Wherever de-humidification occurs
- Space Conditions – 73 deg F / 60%RH
  - 75 grains of moisture / # dry air

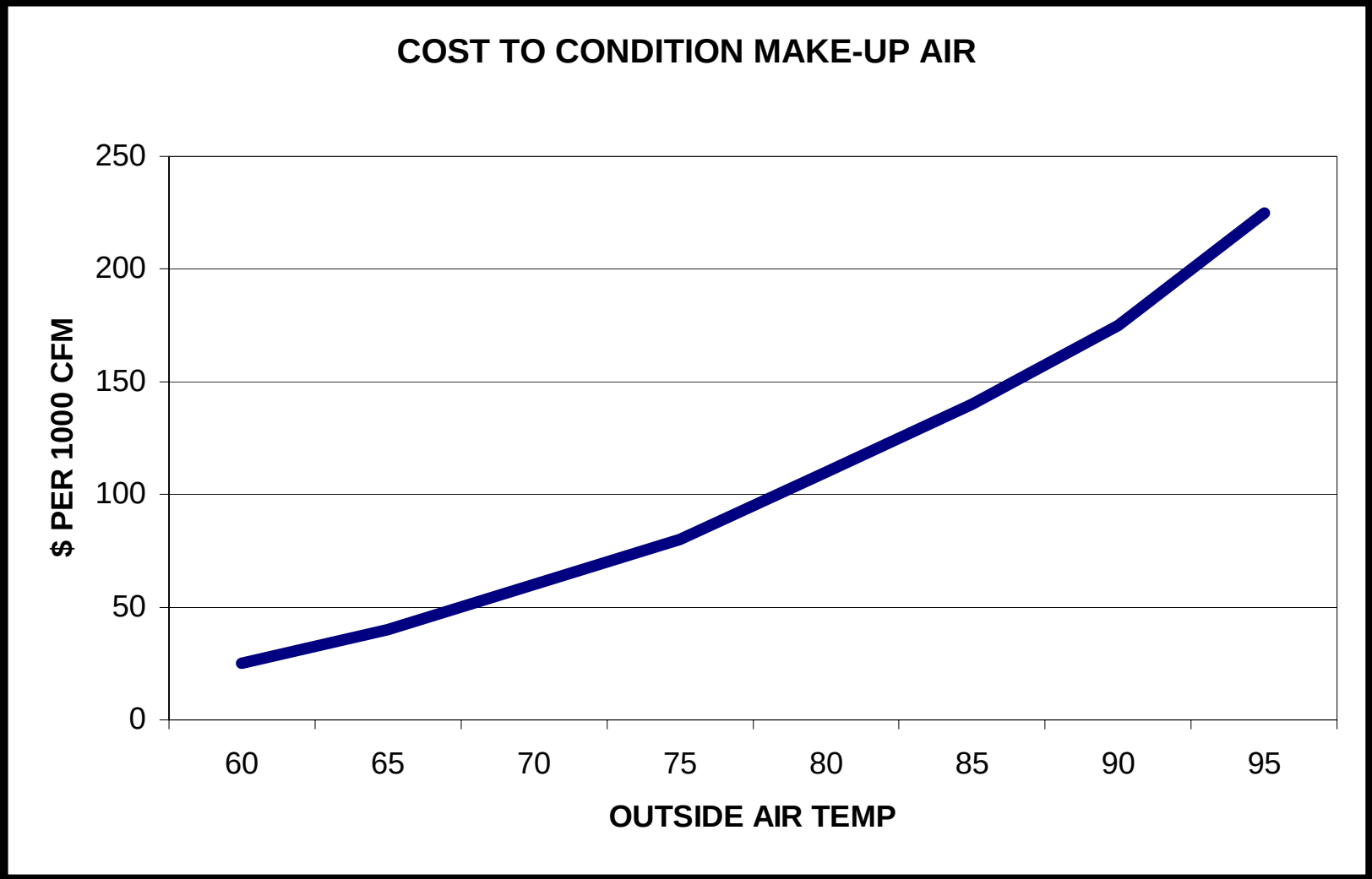

PSYCHROMETRIC CHART
© 1960 THE TRANE COMPANY LA CROSSE, WISCONSIN
Barometric Pressure 29.921 Inches of Mercury
SENSIBLE HEAT RATIO = Qs ÷ Qt
ENTHALPY – Btu per lb. of dry air and associated moisture
WET BULB TEMPERATURE – °F
WET BULB TEMPERATURE – °F
SPECIFIC VOLUME – Cu. ft. per lb. of dry air
RELATIVE HUMIDITY
HUMIDITY RATIO or Specific Humidity GRAINS OF MOISTURE PER POUND OF DRY AIR
DEWPOINT TEMPERATURE – °F
ENTHALPY – Btu per lb. of dry air and associated moisture
STANDARD AIR
DRY BULB TEMPERATURE – °F
ENTHALPY – Btu per lb. of dry air and associated moisture


PERCENT RELATIVE HUMIDITY
STANDARD AIR
DRY BULB TEMPER

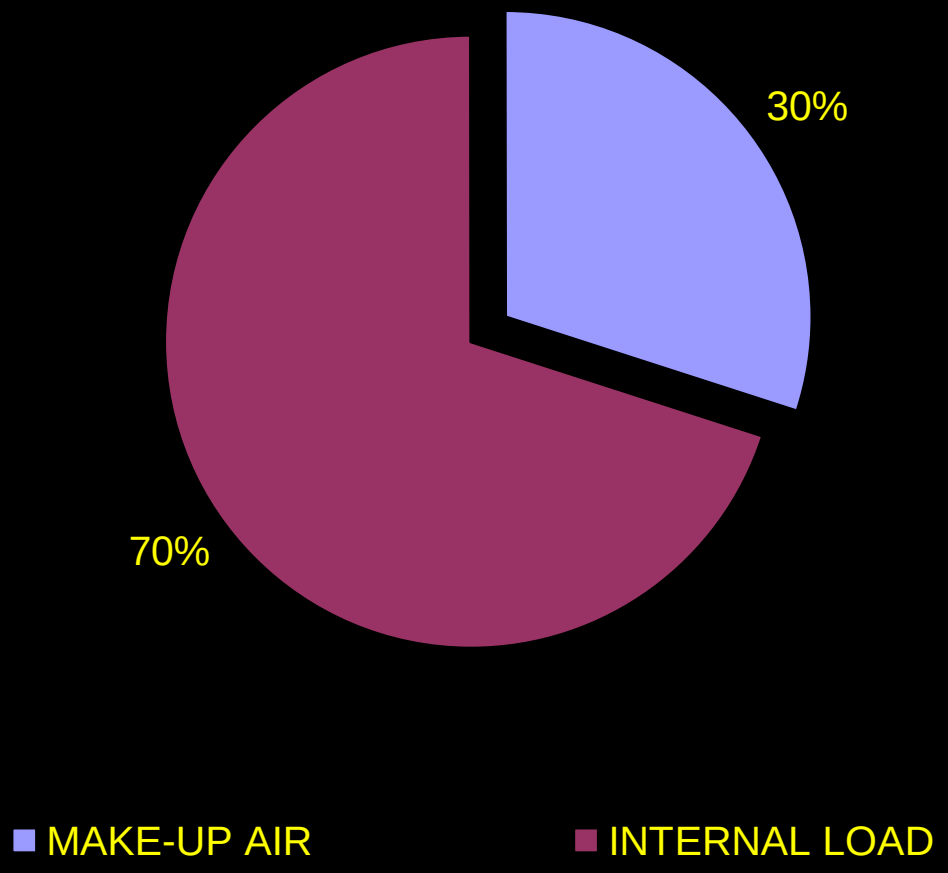

HOURLY OPERATING COST - 0% OA
$150
$125
$100
$75
$50
$25
$-
73
70
65
60
55
50
45
DISCHARGE AIR TEMP
SENSIBLE
LATENT


HOURLY OPERATING COST - 20% OA
$175
$150
$125
$100
$75
$50
$25
$-
77
70
65
60
55
50
45
DISCHARGE AIR TEMP
SENSIBLE
LATENT


HOURLY OPERATING COST - 100% OA
$350
$300
$250
$200
$150
$100
$50
$-
93
70
65
60
55
50
45
DISCHARGE AIR TEMP
SENSIBLE
LATENT


COST TO CONDITION MAKE-UP AIR
250
200
150
100
50
0
$ PER 1000 CFM
60
65
70
75
80
85
90
95
OUTSIDE AIR TEMP

Impact of Make-up Air on Building Load



Defining an "Effective" HVAC System

Temperature

Humidity

Fresh Air / CO2

Minimize HVAC Energy

Improving HVAC Performance

- HVAC Life-Cycle Analysis
- Defining “Effective” HVAC
- Applying Six Sigma

The Six Sigma Approach

Highly analytical quality control program developed to minimize waste and reduce costs in a manufacturing process.

The Six Sigma Approach

DEFINE where performance is below acceptable standards

MEASURE the process in greater detail

ANALYZE the data to develop methods to increase performance

IMPROVE the process to minimize errors

CONTROLS are put in place to assure acceptable performance continues

Technology Issues

Building Controls

- Analog electronic
- Pneumatic
- Centralized EMS systems
- LAN-based distributed controls

Improving HVAC Performance

- HVAC Life-Cycle Analysis
- Defining “Effective” HVAC
- Applying Six Sigma
- HVAC Benchmark Data

HVAC BENCHMARK DATA

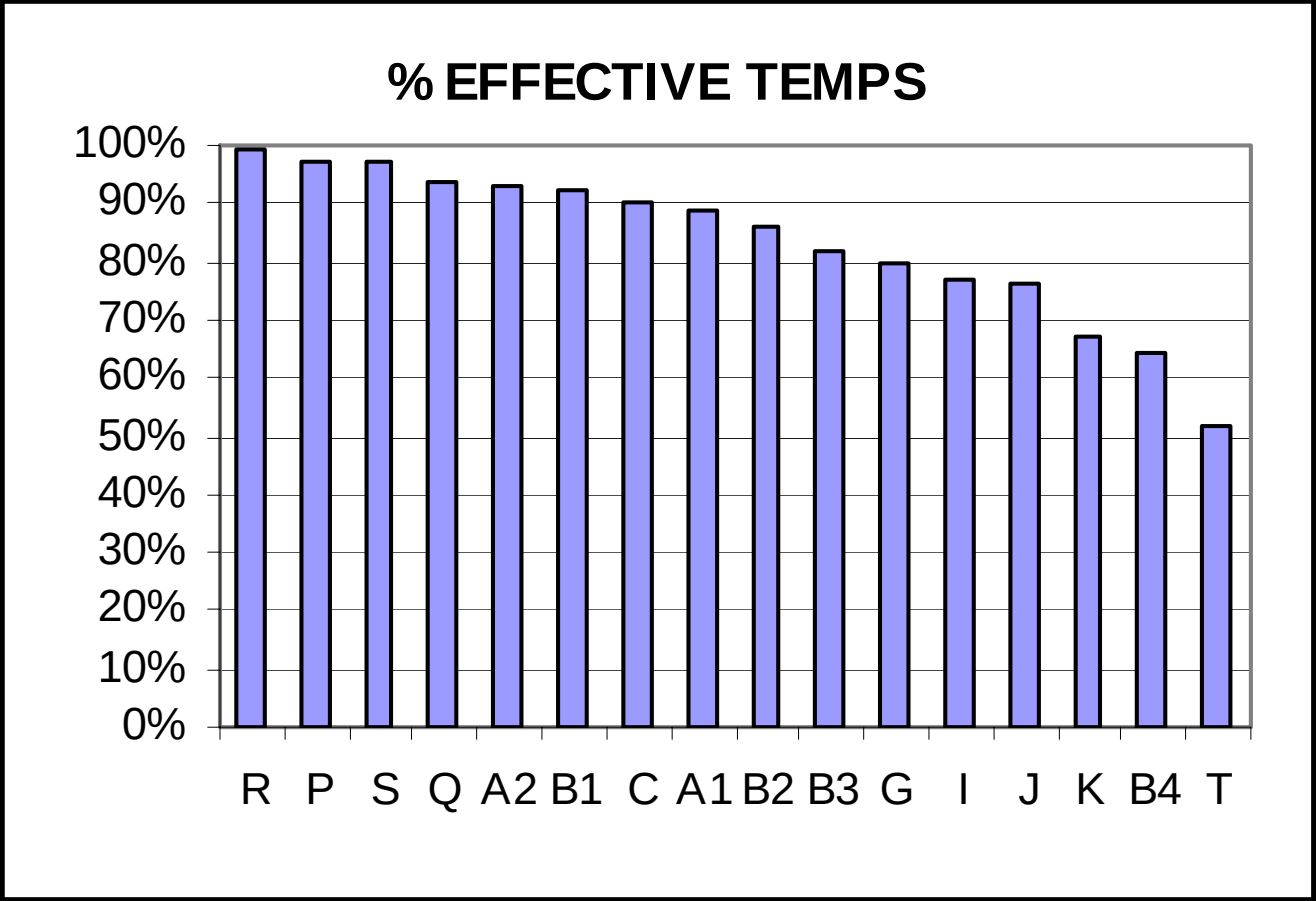
10M sq. ft. Surveyed

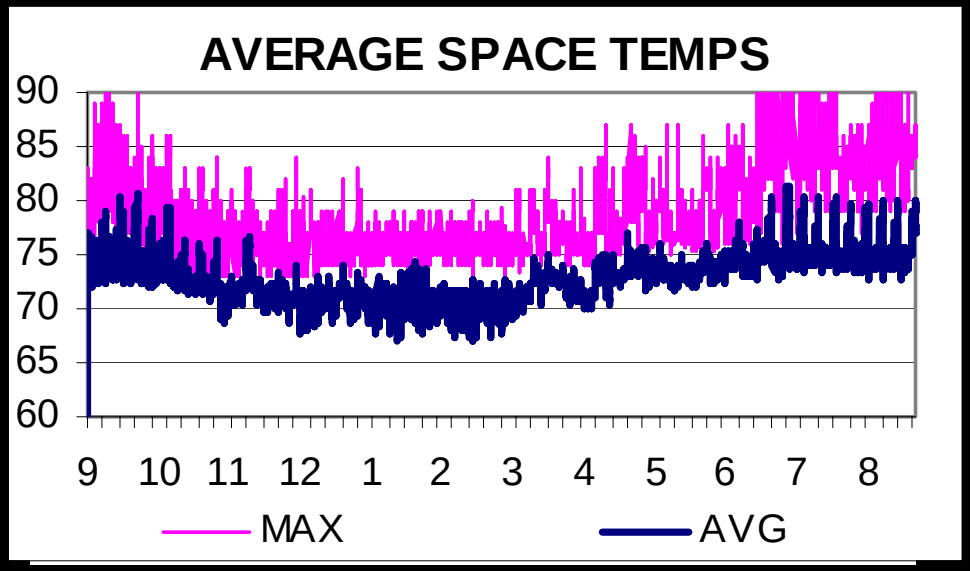
Multiple System Types

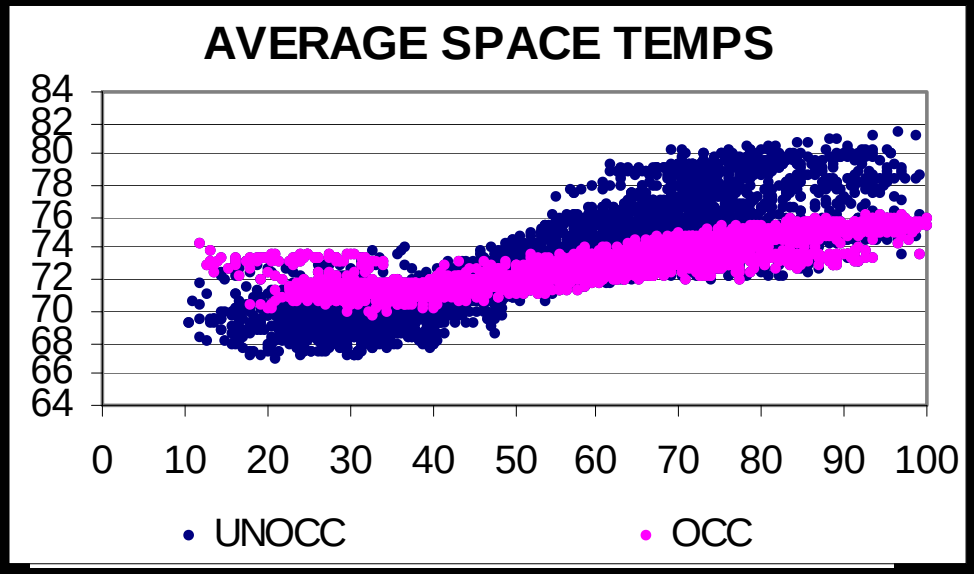
Multiple Building Types

Data Collected Over 7 Years

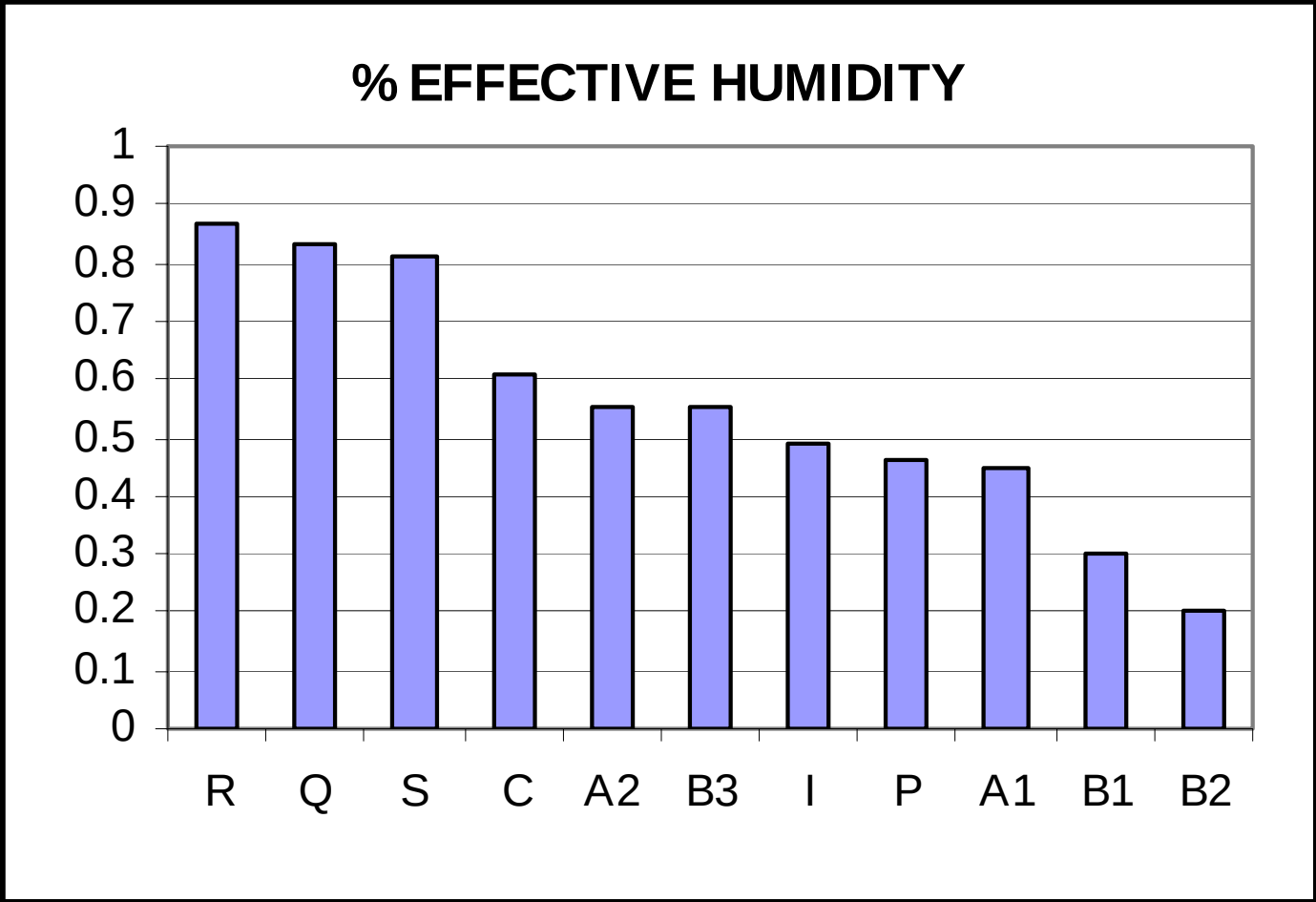
HVAC BENCHMARK DATA

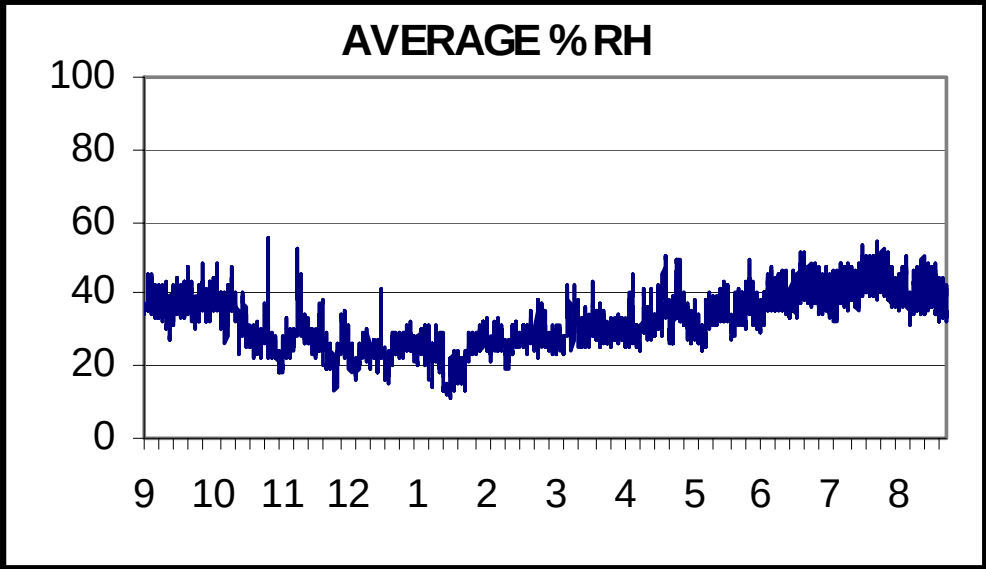


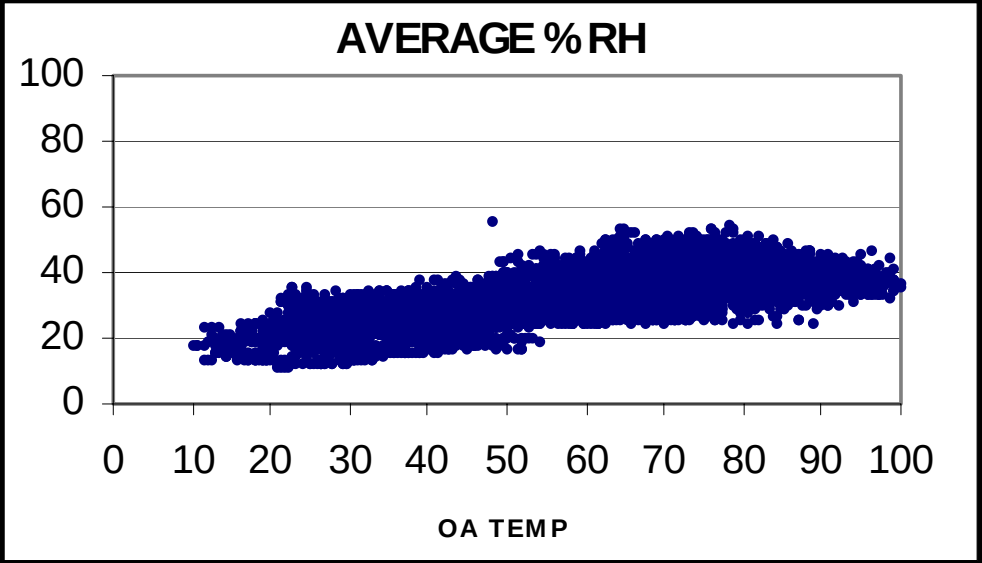

AVERAGE SPACE TEMPS
90
85
80
75
70
65
60
9
10
11
12
1
2
3
4
5
6
7
8
MAX
AVG

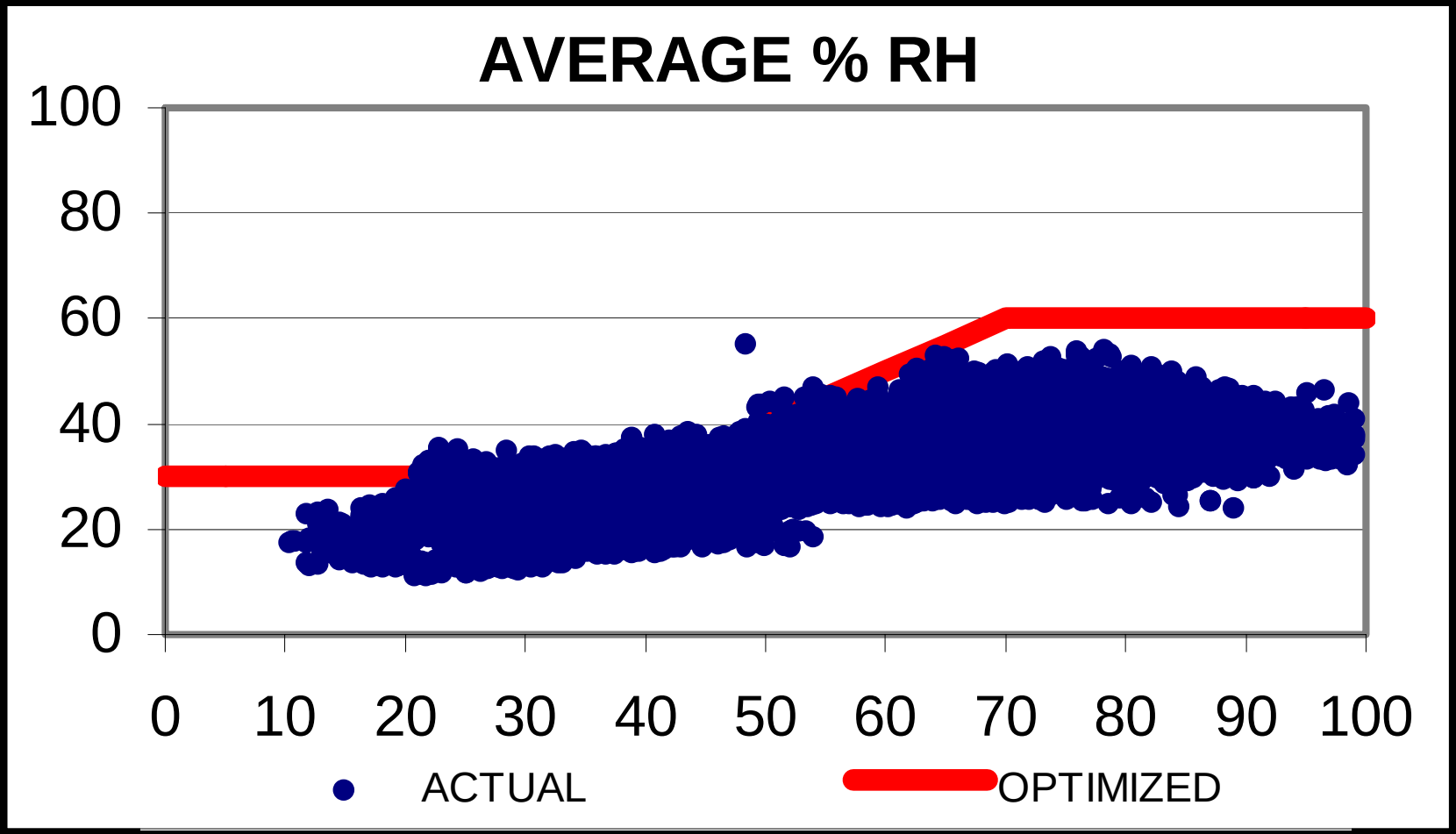

AVERAGE SPACE TEMPS
84
82
80
78
76
74
72
70
68
66
64
0
10
20
30
40
50
60
70
80
90
100
UNOCC
OCC

HVAC BENCHMARK DATA

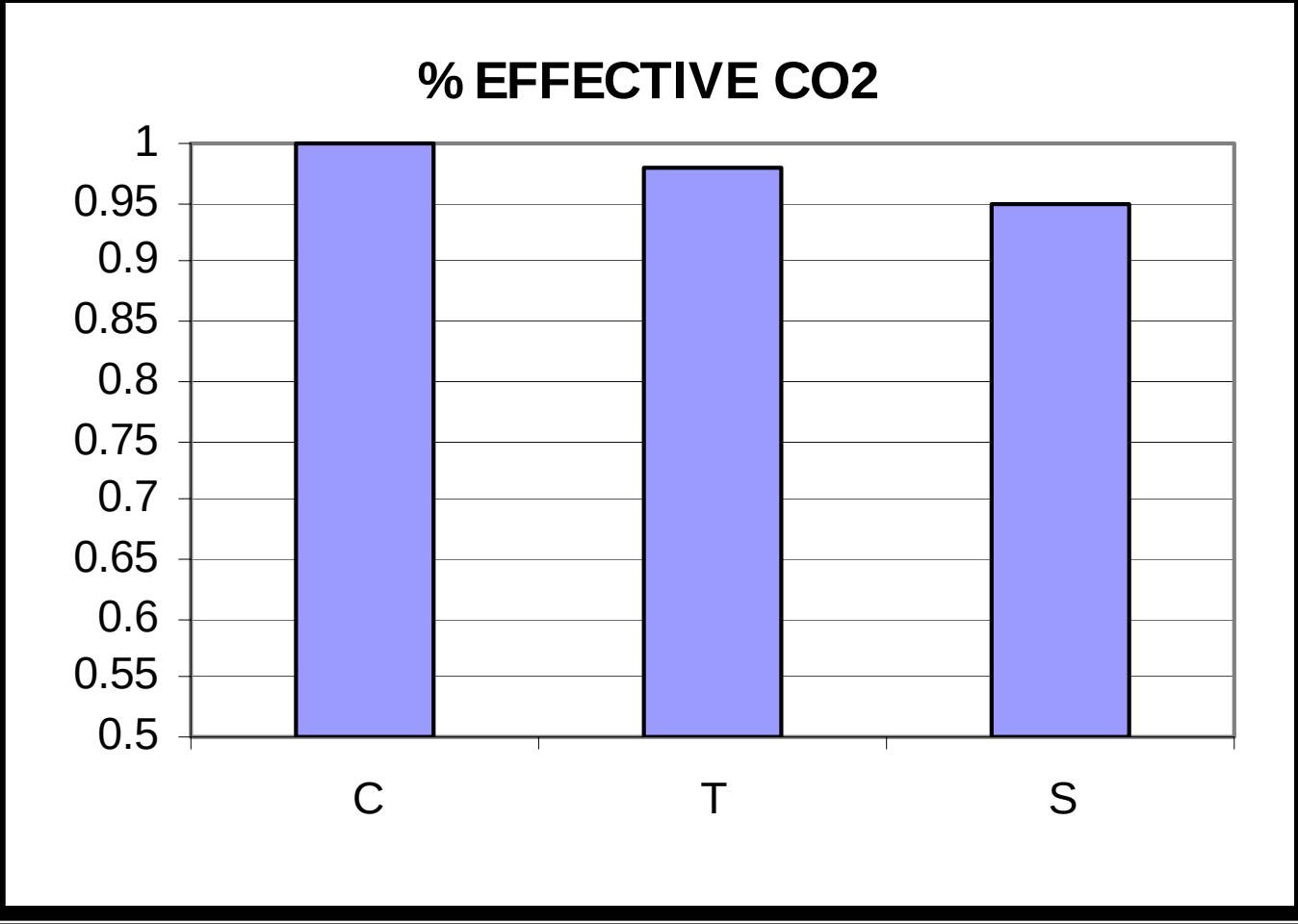


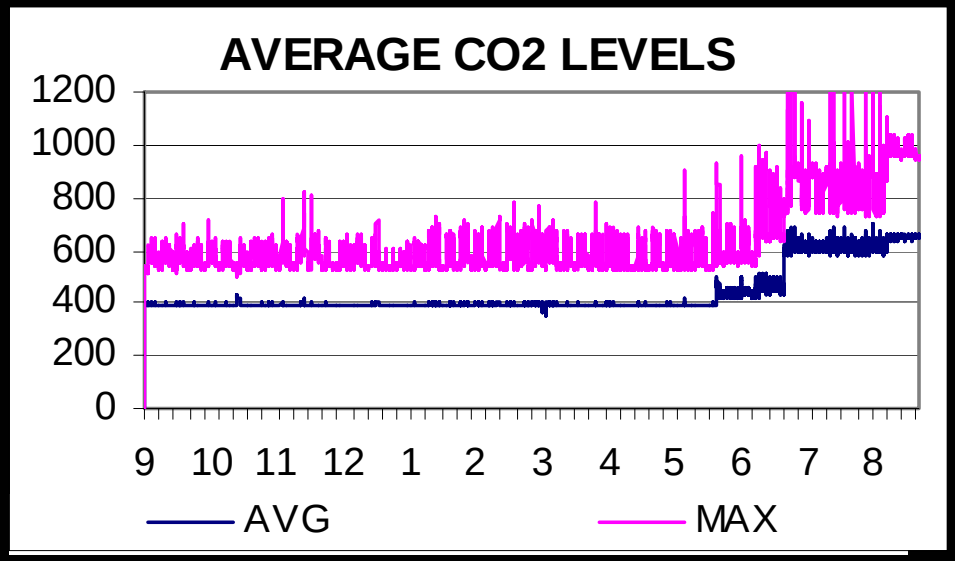

AVERAGE % RH
100
80
60
40
20
0
9
10
11
12
1
2
3
4
5
6
7
8

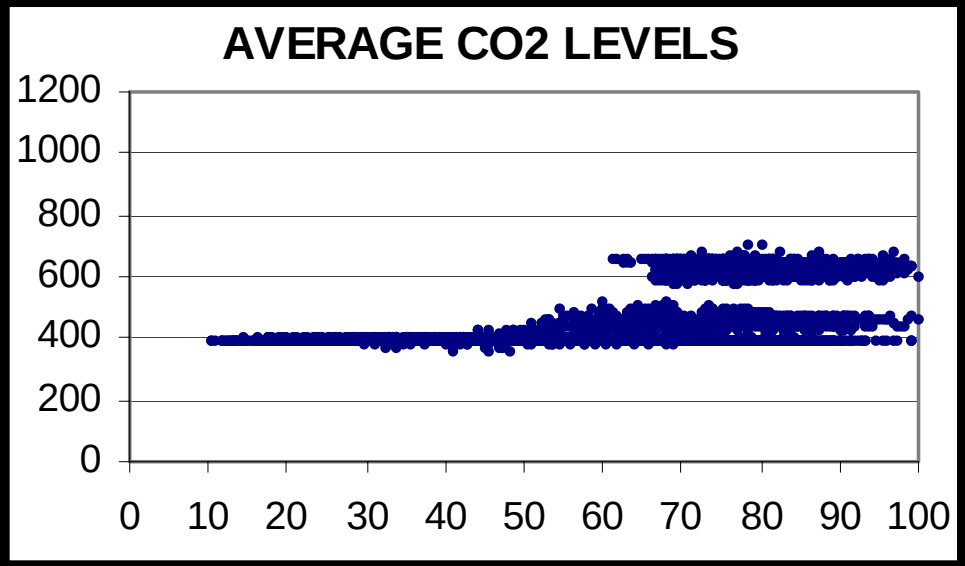

AVERAGE % RH
100
80
60
40
20
0
0
10
20
30
40
50
60
70
80
90
100
OA TEMP

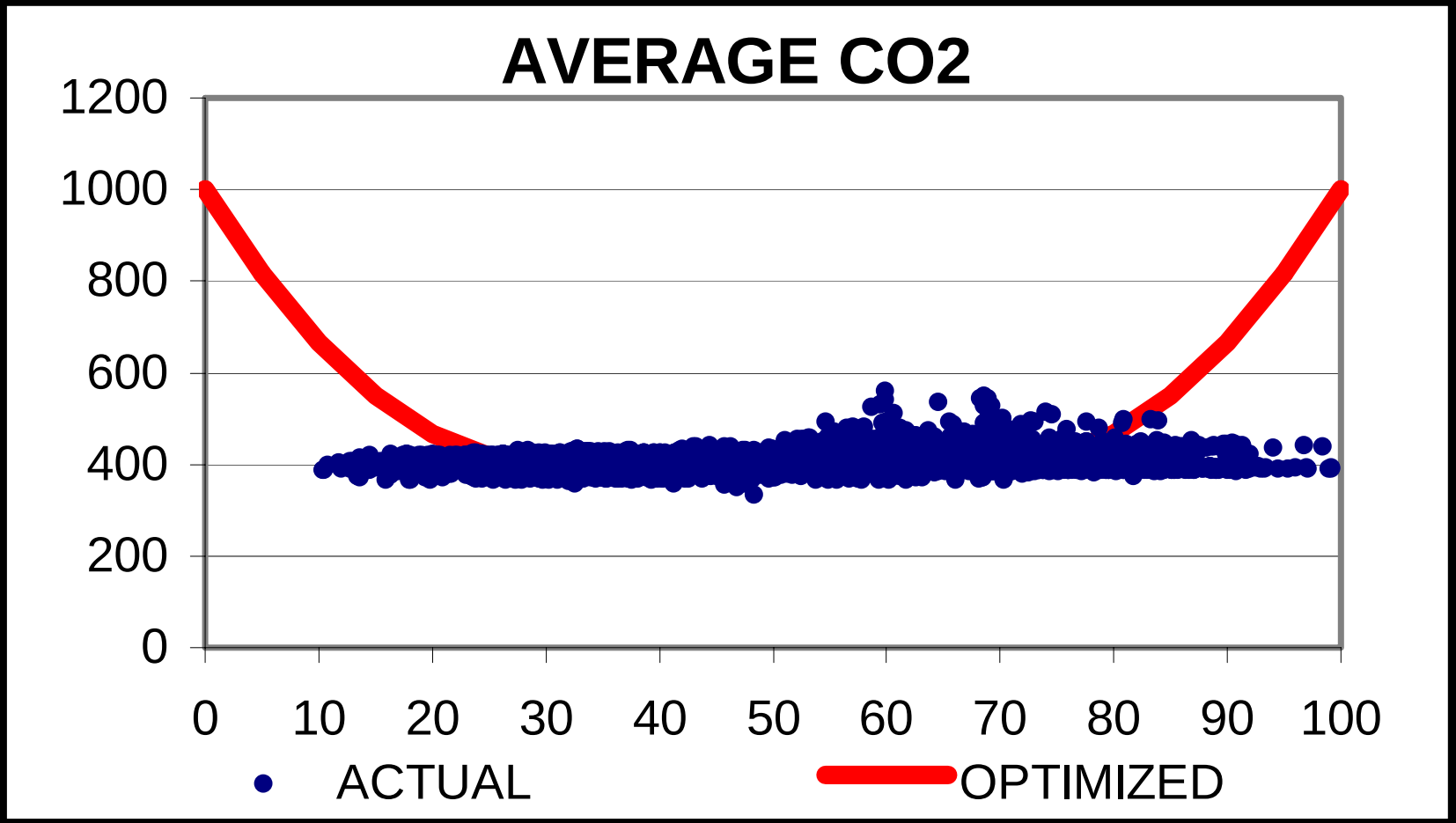

AVERAGE % RH
100
80
60
40
20
0
0
10
20
30
40
50
60
70
80
90
100
ACTUAL
OPTIMIZED

HVAC BENCHMARK DATA

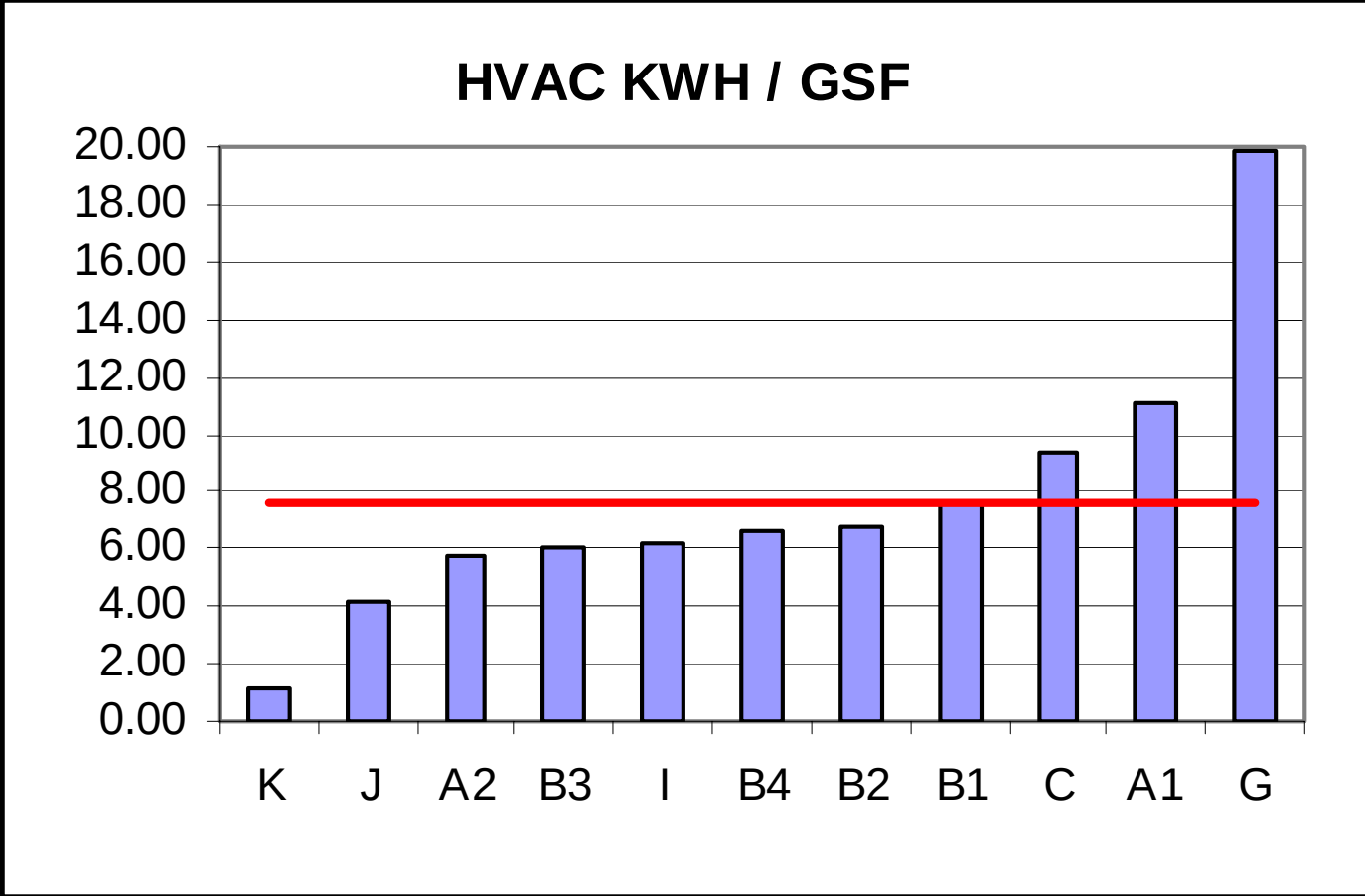



AVERAGE CO2 LEVELS
1200
1000
800
600
400
200
0
9
10
11
12
1
2
3
4
5
6
7
8
AVG
MAX

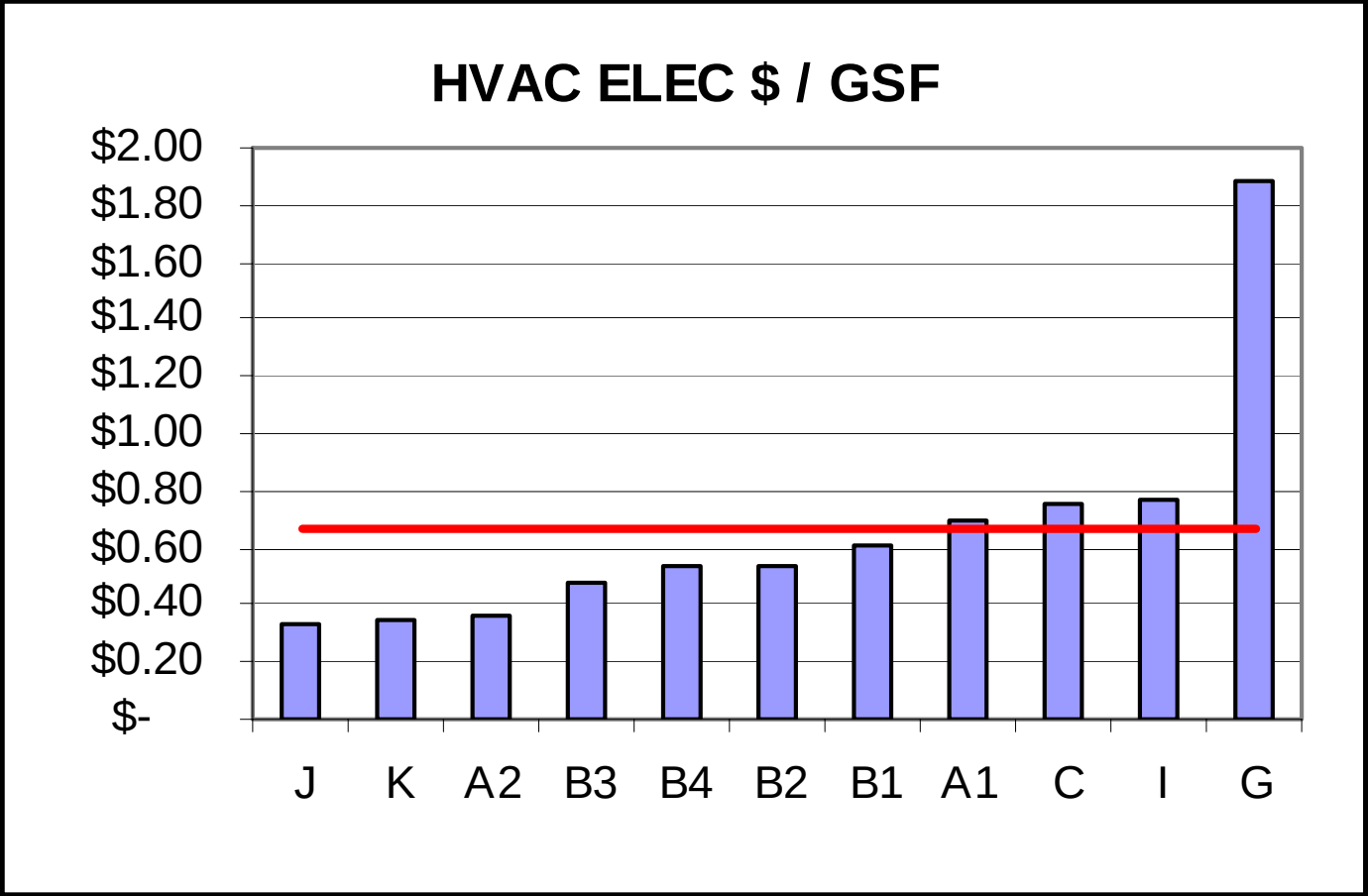

AVERAGE CO2 LEVELS
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
70
80
90
100


AVERAGE CO2
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
70
80
90
100
ACTUAL
OPTIMIZED

HVAC BENCHMARK DATA



HVAC BENCHMARK DATA



Improving HVAC Performance

- HVAC Life-Cycle Analysis
- Defining “Effective” HVAC
- Applying Six Sigma
- HVAC Benchmark Data
- Project Energy Savings

PROJECT ENERGY SAVINGS

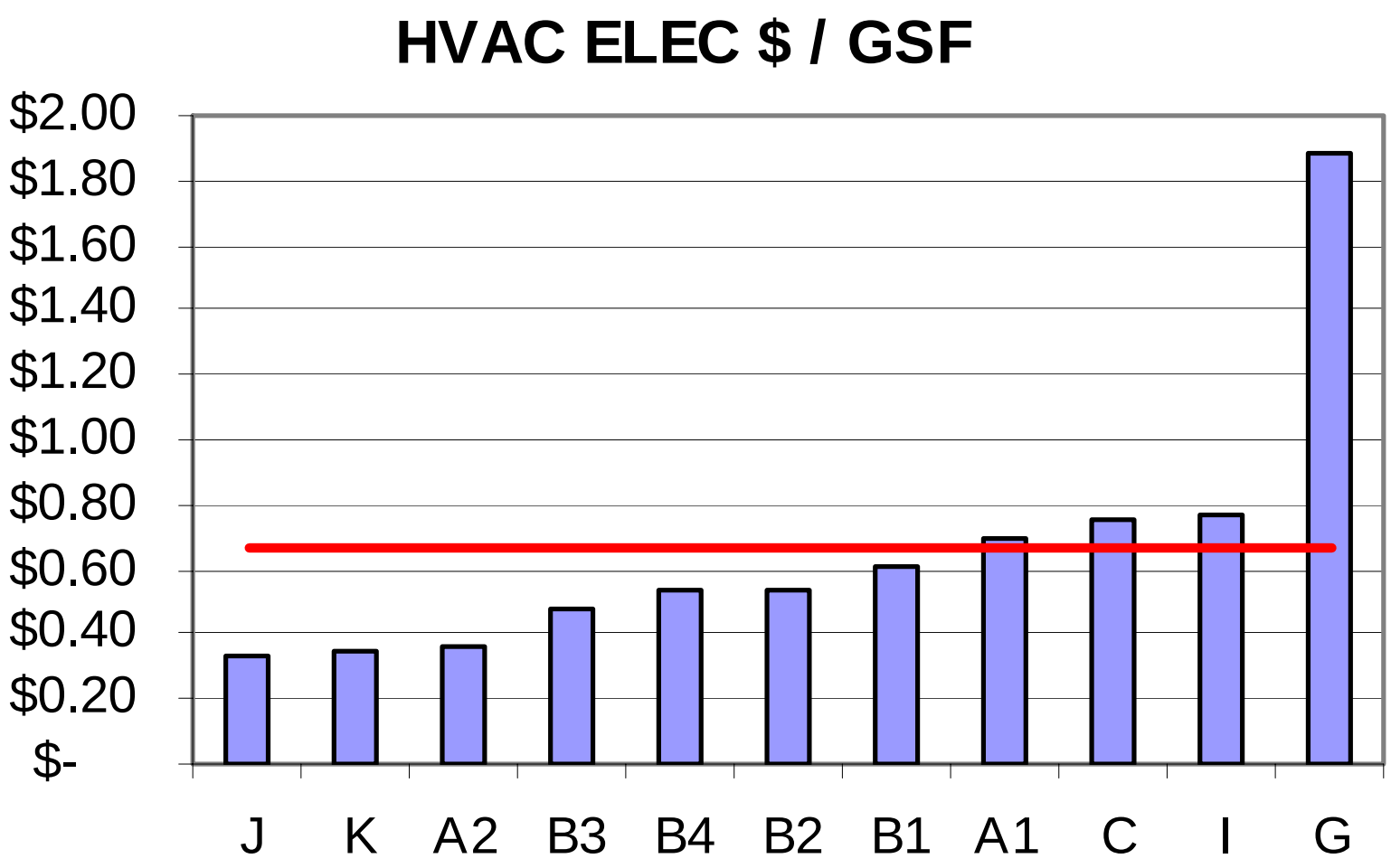
$.02 per square foot per year in energy savings on O & M projects.

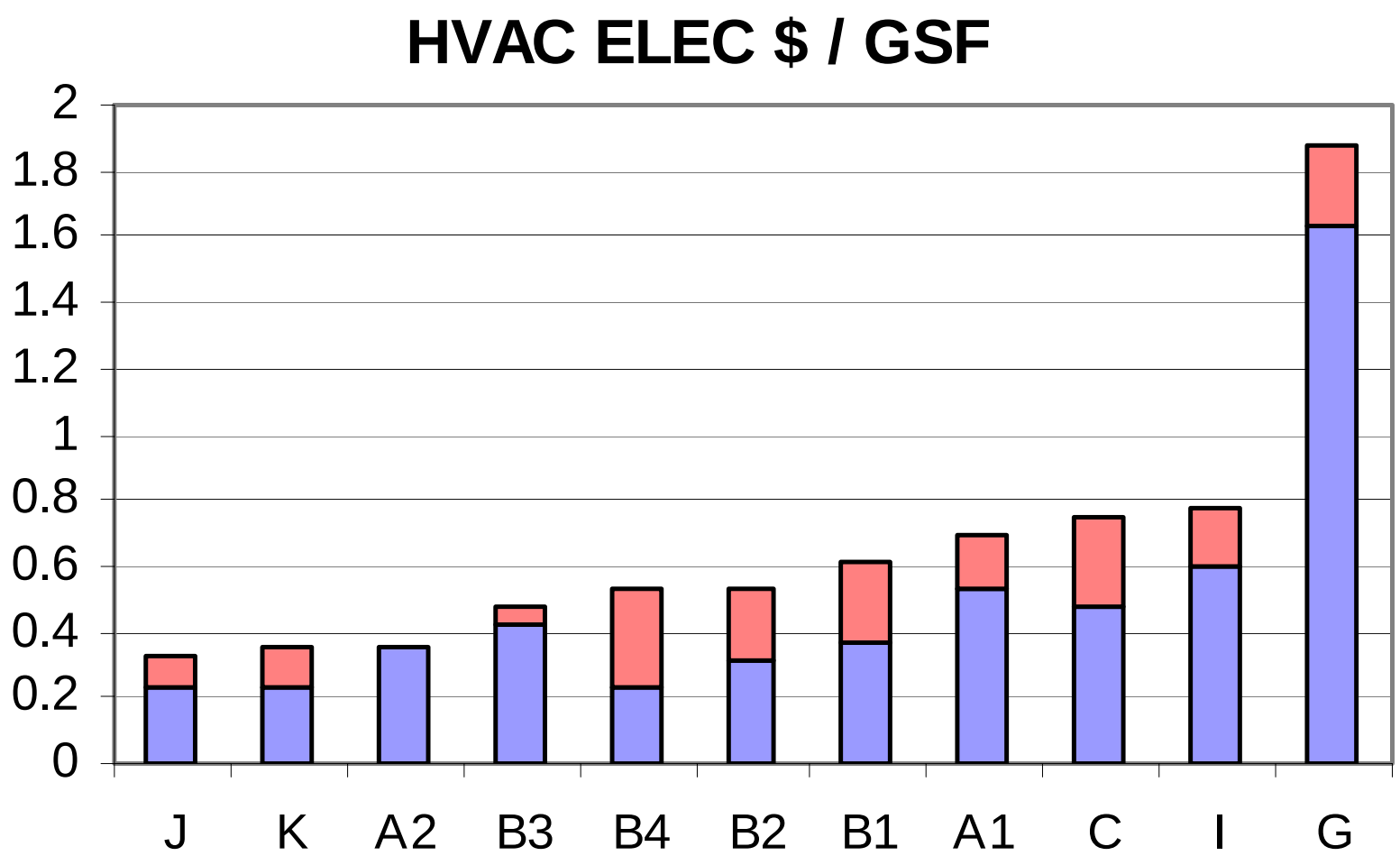
$.15 per square foot a year in energy savings on capital projects.

Capital projects have typically shown a payback of under three years.

PROJECT ENERGY SAVINGS

E3 SCORECARD					Jun-04
SQUARE FEET	O&M CHANGES		CAPITAL PROJECTS		SAVINGS
	SAVINGS	COST	SAVINGS	COST	PER SQ FT
10,175,000	$ 232,562	$ 177,500	$ 1,595,187	$3,926,200	$ 0.16


HVAC ELEC $ / GSF
$2.00
$1.80
$1.60
$1.40
$1.20
$1.00
$0.80
$0.60
$0.40
$0.20
$-
J
K
A2
B3
B4
B2
B1
A1
C
I
G


HVAC ELEC $ / GSF
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
J
K
A2
B3
B4
B2
B1
A1
C
I
G

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