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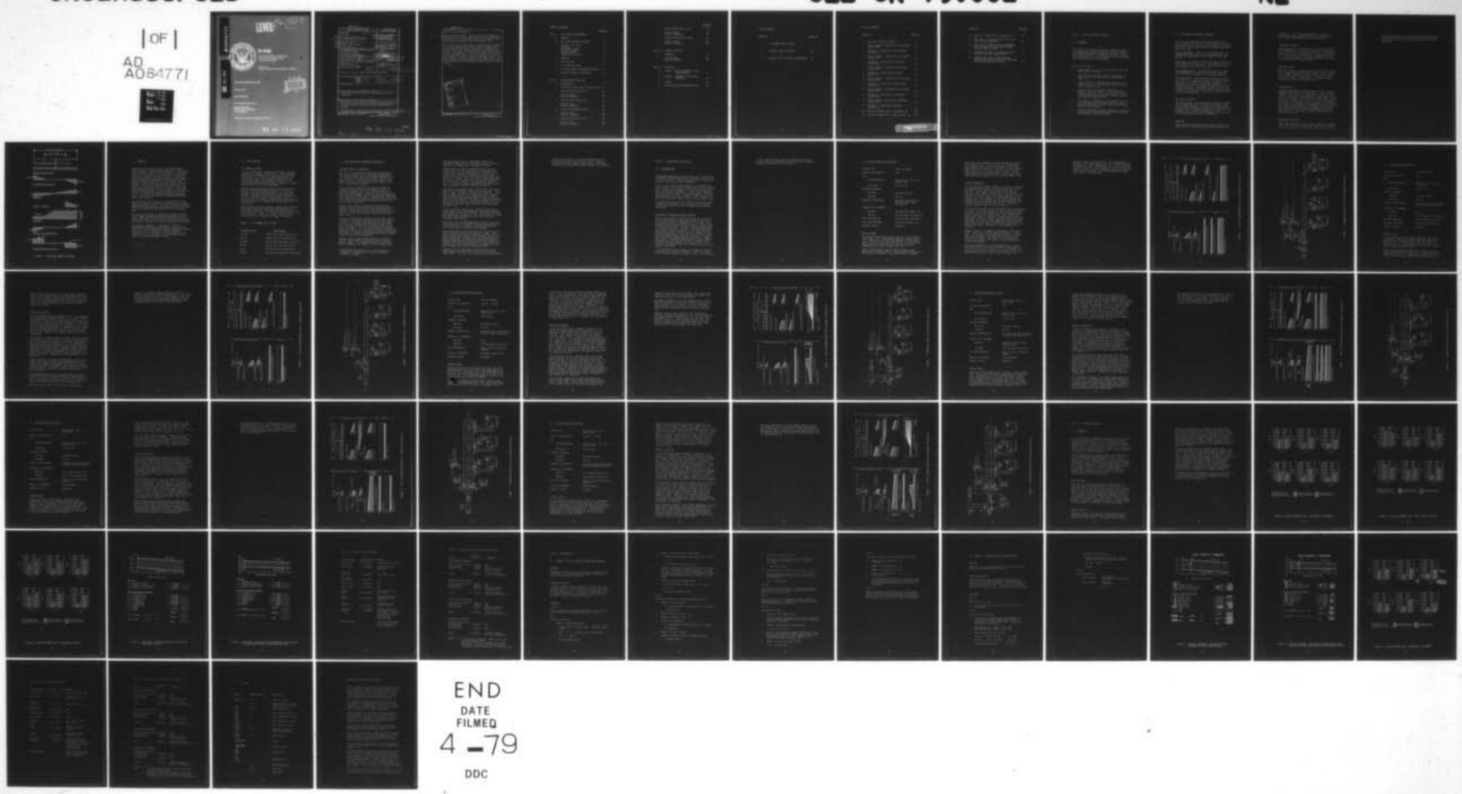

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CIVIL ENGINEERING LABORATORY
Naval Construction Battalion Center
Port Hueneme, California

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DEAD BAND CONTROLS GUIDE

November 1978

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An Investigation Conducted by

JOSEPH PAOLUCCIO
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La Jolla, California

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The purpose of this guide is to show methods of reducing energy consumption in new and existing heating, ventilating and air conditioning (HVAC) systems by using the Dead Band control strategy.

Dead Band control strategy and its application to HVAC systems is discussed for three representative climatic zones in the

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Block 20. Abstract (cont'd)

CONT

continental United States. Computer modeling techniques provide predictions on energy savings due to control system modifications for six types of HVAC systems and two types of building construction, thermally heavy and thermally light.

The operation of six HVAC systems is described and illustrated for existing and Dead Band control strategy. Computer simulation of these various systems demonstrates that substantial energy savings can be achieved by employing Dead Band control strategy. Bar graphs are provided illustrating relative energy used for each HVAC system. Engineering guidelines for the design of Dead Band control systems are presented in form of control schematics and logic diagrams for each HVAC system. Economic guidelines include techniques for estimating construction and maintenance cost, and performing economic analysis for each system.

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PART I   HVAC DEAD BAND CONTROLS

A   FOREWORD

This guide explains the Dead Band control strategy, a method used to control heating, ventilating and air conditioning (HVAC) systems to produce substantial energy savings. The Dead Band control strategy can be applied to new construction or used to modify existing controls in HVAC systems.

To use this guide:

1. Review PART I-B for an explanation of the Dead Band control strategy.
2. Determine the general type of HVAC system in your building according to the categories in PART I-D.
3. Consult PART II - ENGINEERING GUIDELINES, for a description of the Dead Band controls that apply to your system.
4. Consult PART III - ECONOMIC ANALYSIS, for economic considerations. Yearly heating and cooling energy costs for your project must be estimated or made available in order to determine retrofit feasibility.
5. See PART IV - APPENDICES, for examples of first cost, operation and maintenance cost, energy savings and dollar savings from a typical Dead Band controls project.
6. Provide this guide to your engineers, contractor or operations personnel when you install Dead Band controls in your building.

B THE DEAD BAND CONTROL STRATEGY

The Dead Band systems discussed in this guide rely on one single factor for temperature control--the temperature of the space being heated or cooled. Basically, the Dead Band control strategy considers three functions:

Throttling Range: A range of acceptable room air temperatures over which the system operates. The throttling range used in this study is 10F; 68F to 78F.

Dead Band: A portion of the throttling range during which neither heating nor cooling energy is used, but ventilation is provided. The Dead Band used in this study is 5F; 70.5F to 75.5F.

Space Demand Reset: A method by which the supply air temperature is adjusted to heat or cool the space in direct response to its thermal demand.

Dead Band control strategy can be applied to new construction or used to retrofit existing buildings. Typically, in a Dead Band retrofit project, only the controls of the existing HVAC systems are changed; existing fans, pumps, ductwork and piping remain unchanged. Dead Band control can be incorporated to control a variety of HVAC systems, some of which are illustrated in Figure 1 and explained in the following text.

Variable Fan Speed

Fan motor speed, and consequently system air volume, can be modulated over the throttling range using space demand feedback. Variable air volume (VAV) systems using conventional damper control have proven effective in reducing energy use. Special attention must be paid to ductwork design, or retrofit design, when varying air volume.

Humidity

Space humidity can be controlled as a function of space dry bulb temperature using Dead Band control strategy. This is accomplished on a high-limit reset basis; when dehumidification is needed, override of the temperature control system occurs.

Economizer Dampers

Economizer dampers, generally controlled by outdoor air temperature, are managed under the Dead Band control system using space demand feedback. This method allows the space to determine its required outside air volume for cooling purposes. Enthalpy override of economizer dampers is recommended when the system is in a mechanical cooling mode.

VAV With Reheat

Dead Band control strategy can be applied to variable air volume (VAV) systems with reheat. In this system, space demand feedback is used to control the reheat and cooling coils. The control strategy in a VAV system is similar to that used in a reheat system with modification for damper control.

Packaged Units

Packaged equipment is HVAC equipment which is factory-assembled and ready for installation. The extent of changes needed to employ Dead Band control strategy can vary from simple readjustment of the space thermostat to strategies used in the six common HVAC systems. Therefore, control modifications must be dealt with on a case-by-case basis due to the variety of packaged equipment. For example, with packaged units controlled by a single heating/cooling thermostat, Dead Band can be accomplished by setting the temperature selector for heating to 69F and the temperature selector for cooling to 77F, and adjusting the differential for each setting to 2F.

Single Zone Systems

The single zone unit uses a single temperatue control zone. The unit with heating and cooling coils may be installed within, or remote from, the space it serves and can operate with or without distributing ductwork. Dead Band control strategy can be incorporated with single zone systems to regulate heating and cooling equipment.

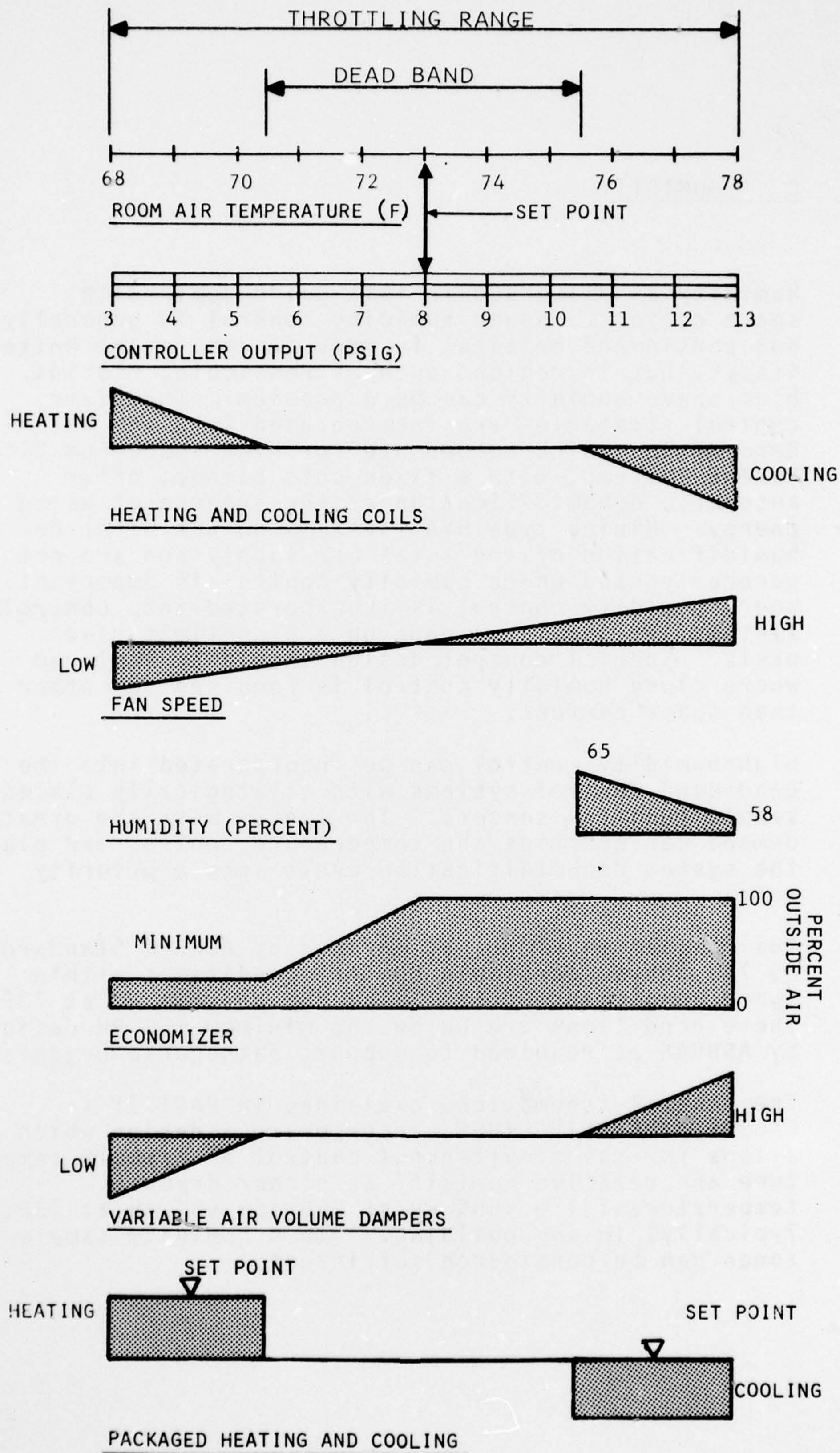

FIGURE 1. DEAD BAND CONTROL STRATEGY

C HUMIDITY

Humidity as discussed in this guide deals with space comfort. Space humidity control is generally not considered critical in many places in the United States, but in regions such as Pensacola, Florida, high space humidity can be a problem. Therefore, control strategies are incorporated into the Dead Band design which compensate for high space humidity. Reheat systems, with a fixed cold plenum, offer automatic dehumidification at the expense of using energy. Mixing type HVAC systems do not offer dehumidification of the total air supply and are not generally used where humidity control is important. Where humidity control is incorporated into control systems, it should be done on a high-limit reset basis. Special control design should be employed where close humidity control is required for other than space comfort.

High humidity control can be incorporated into the Dead Band control systems with strategically placed sample humidity sensors. The sensor with the greatest demand can override the temperature control and place the system dehumidification cycle into a priority mode.

The comfort envelope, as defined by ASHRAE Standard 55-74, shows acceptable comfort conditions within space conditions of 58% RH at 78F and 68% RH at 73F. These conditions are below the minimum 70% RH defined by ASHRAE as required to support pathogenic organisms.

The control schematics, explained in PART II - ENGINEERING GUIDELINES, incorporate a design which allows for the simultaneous control of drybulb temperature and relative humidity at higher drybulb temperatures; i.e. 58% RH at 78F and 68% RH at 73F. Typically, in any building, 1 to 4 humidity sample zones can be considered sufficient.

D HVAC SYSTEMS

Six Common Systems

The six common HVAC systems are divided into two categories, "reheat" and "mixing". Reheat systems first cool or preheat the incoming air to a fixed temperature (e.g. 55F) and then distribute this air to each zone. For maximum cooling, the air enters the zone without further treatment. For intermediate cooling and heating, zone coils reheat the air to satisfy the zone demand.

Mixing systems both heat and cool the incoming air, then mix the two streams to deliver air to the space at the desired temperature. In "dual duct" systems, parallel warm and cool air ducts extend to each zone where zone mixing dampers control the air mix. In "multizone" systems, each zone's mixing damper is located at the central air handling unit and mixed air is delivered to the zones in a single duct.

Within these two HVAC systems, "reheat" and "mixing", the control of the outside air distinguishes the three sub-divisions. The quantity of outside air is typically set at 100%, at a fixed minimum such as 15%, or is variable. These six types of HVAC systems, identified in this guide, are shown in Table 1.

TABLE 1 - SIX COMMON HVAC SYSTEMS

Identification	Description
RH-100	Reheat with 100% Outside Air
RH-15	Reheat with 15% Outside Air
RH-VAR	Reheat with Variable Outside Air
M-100	Mixing with 100% Outside Air
M-15	Mixing with 15% Outside Air
M-VAR	Mixing with Variable Outside Air

E BUILDING ENERGY CONSUMPTION ANALYSIS

Computer Analysis Technique

BLDSIM* is the computer simulation program which was used to predict relative energy consumption for buildings and control strategies addressed in this guide. Basically, the program utilizes four types of input: environmental data (weather and solar loads); building architecture; HVAC system type; and control strategy.

The structure of BLDSIM is set up such that it sequences calculations which update building internal conditions, moist air states, building component temperatures, controller positions and heat transfer between system and building components on a minute-by-minute basis. Weather data and solar load data are also updated each minute from straight-line interpolation of hourly weather data and 20-minute solar load data.

Architectural data is required to describe the thermal storage and transmission characteristics of the building as well as the space and plenum air volumes. Building dimensions are input in terms of zone floor area, wall height, plenum height and glass area.

BLDSIM is designed to simulate various HVAC control strategies, including conventional and Dead Band systems. The control versions used in this study incorporate Dead Band and conventional operation with six HVAC systems (R-100, R-15, R-VAR, M-100, M-15 and M-VAR). The fact that BLDSIM calculates, once each minute, all significant system temperatures and moist air states makes possible direct, accurate simulation of control algorithms which have response times of one minute or greater.

Weather data for the BLDSIM program is derived from the U.S. Department of Commerce Climatic Center weather tapes. The tapes selected are ones that were recorded by the weather station nearest the

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* BLDSIM was developed by Dr. Gideon Shavit at Honeywell's Commercial Division, Arlington Heights, Illinois.

location under study: San Diego, California, Chicago's O'Hare Airport for Great Lakes, Illinois, and Mobile, Alabama, for Pensacola, Florida.

Weather data utilized by BLDSIM includes hourly values for dry bulb, dew point, wind velocity and cloud cover. To avoid unnecessary computer costs, a full year's energy consumption is calculated based on a simulation of one representative day per month, or 12 days. The first day is simulated twice to set up initial conditions and energy consumption for this day is ignored. The twelve-day weather year is a widely accepted compromise and gives excellent agreement with full 365-day simulation.

Basically, the weather tapes used contain an hour-by-hour record of weather for a ten-year period. From this, a year of data is selected for analysis. This data is then modified by a data reduction program which condenses one year of weather into 12 model days with each day representing the effective weather profile for one month. The twelve typical days contain coincident dry bulb, wet bulb, humidity ratio, barometric pressure, wind direction and wind speed for each hour.

Cloud cover data used in the simulation was taken from actual Local Climatological Data (LCD) supplied by the National Weather Service. Selected days from each month were chosen such that the average sky cover for these days was within 10% of the long-term average for the month.

Input data for the BLDSIM program used in this study includes extensive information on building construction, locations, occupancy, lighting and heating, ventilating and air conditioning systems.

Two representative building types are studied in this guide, thermally heavy and thermally light. Both buildings are four-story structures with most of the glass facing East and West with shading provided by window overhangs. Occupancy is one person per one hundred square feet during the day with lighting at three-to-four watts per square foot. The floors are divided into two exterior zones, including East and West window areas, and two interior zones.

Thermally heavy construction consists of 12-inch heavy-weight concrete walls with 1/4-inch regular sheet glass. The roof is built-up on 6-inch concrete with R-4 insulation. Light construction walls are 1-inch stucco, R-11 insulation, 5/8-inch gypsum board and 1/4-inch regular sheet glass. The roof is built-up on 5/8-inch plywood with R-19 insulation.

PART II ENGINEERING GUIDELINES

A INTRODUCTION

Recommended engineering guidelines for the design of Dead Band control systems are presented. Each of the six HVAC systems is discussed separately in terms of control logic and control schematics.

First, a brief system description is presented for each system. This system description is then followed by a discussion on control logic, existing and Dead Band, and control schematics. Next, logic diagrams are illustrated comparing existing control logic and Dead Band control logic. System schematics are also presented to illustrate controls at the central air handling apparatus, sample zones and non-sample zones.

It should be noted that all control logic and system schematics presented in this guide are for typical systems and are to be used for general engineering guidelines.

Designing a Dead Band Control System

Before a Dead Band control system can be applied to an existing project a detailed survey of the existing building and its components must be made. The survey must include an inventory of all control components to the extent that each control function and its adjustment limit is known. A working knowledge of the HVAC system is required, including the purpose and function of each fan, coil, pump and valve. The physical layout of the space and limits of the existing temperature zones must be known and considered before the sample zones are selected. Sample zones must be analyzed to determine if their thermal capacitance is representative and in harmony with the basic thermal behavior of the building. For example, a Southwest zone with windows usually is not a good sample zone.

In a Dead Band control system, the number of sample zones must be carefully selected. Usually, 25-40% of the building zones are sample zones. The controls of the remaining zones are also modified, but they do not affect the control of the central air handling apparatus heating or cooling coils.

B SYSTEM DESCRIPTION, RH-100

SYSTEM TYPE:	Terminal Reheat
OUTSIDE AIR QUANTITY:	100%
FUEL	
HEATING/COOLING:	Natural Gas, Oil, Coal, Electricity
AUXILIARY:	Electricity
CENTRAL EQUIPMENT	
HEATING:	Hot Water Boiler
COOLING:	Chiller
ENERGY DISTRIBUTION:	Hot Water and Chilled Water Piping, Pumps and Valves
PRIMARY AIR TREATMENT	
HEATING:	Hot Water Pre-heat Coil
COOLING:	Chilled Water Cooling Coil
AIR DISTRIBUTION:	Fans, Filters, Ductwork
ZONE AIR TREATMENT:	Hot Water Reheat Coils
CONTROL SYSTEM:	Pneumatic

Control Logic

In the existing control logic, Figure 2, zone thermostats have a 1.5F throttling range and a set point of 73F. Therefore, at 72.25F the reheat coil hot water valve is fully open, and at 73.75F it is fully closed. The cooling coil and pre-heat coil discharge air temperatures are held constant at 55F.

Under the Dead Band control logic, Figure 2, the sample zone controls have a 10F throttling range with the same 73F set point. The reheat coil is closed until the space temperature drops below 70.5F and is fully open at 68F. The cooling coil and pre-heat coil temperatures are reset according to the space temperature and humidity, if needed. Within the Dead Band, 70.5F to 75.5F, all coil valves are closed and no heating or cooling energy is used. As the space demands more cooling, the chilled water valve modulates from closed at 75.5F to fully open at 78F.

Control Schematics

In the Dead Band system schematic, Figure 3, discharge air temperature from the cooling and preheat coil is regulated by the sample zone calling for the most cooling. This sample zone produces the highest pressure signal which is then fed to the cooling coil controller. These controllers then regulate the coil control valves to maintain an optimum discharge air temperature. For example, as the space demands more cooling, the chilled water coil valve modulates from closed at 75.5F to fully open at 78F. Outside air remains fixed at 100% for all conditions.

The thermostat output, from the sample zone illustrated in Figure 3, is fed through a ratio relay which produces the required pressure to regulate the hot water control valve at the reheat coil. This thermostat output also goes to a pressure selector which selects the highest pressure signal from the sample zones and transmits it to the central apparatus control system. Note that if existing thermostats are to be used in sample zones, they must be modified to provide a wider throttling range. Otherwise, a new thermostat is required.

Another option is to employ temperature sensors with remote controllers rather than thermostats in each zone. This allows the controllers to be in a remote location preventing occupants from tampering with the control system. The output from a controller leads to the reheat coil and to a pressure selector as described above.

The space thermostat in a non-sample zone is set at approximately 69F, and the throttling range remains at its original 1.5F setting. In this situation, the thermostat causes the zone control valve to be fully open at about 68F and fully closed at about 70F.

Humidity sample zones allow for the simultaneous control of dry bulb temperature and relative humidity at higher dry bulb temperatures; i.e. 58% RH at 78F and 68% RH at 73F. The strategy is that the humidity sensor with the greatest demand can override temperature control and place the system dehumidification cycle into a priority mode.

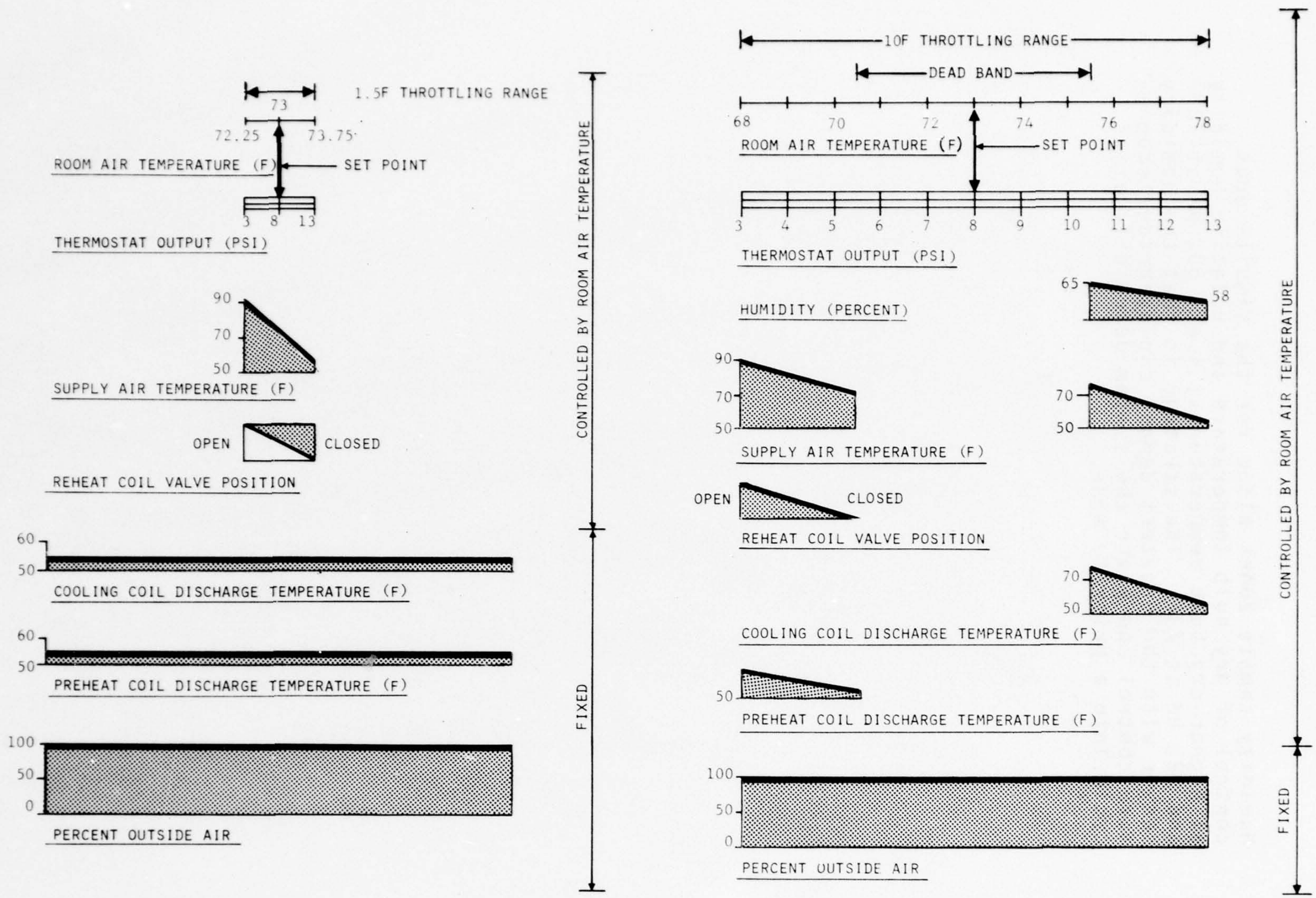


FIGURE 2. LOGIC DIAGRAM-REHEAT WITH 100 PERCENT OUTSIDE AIR

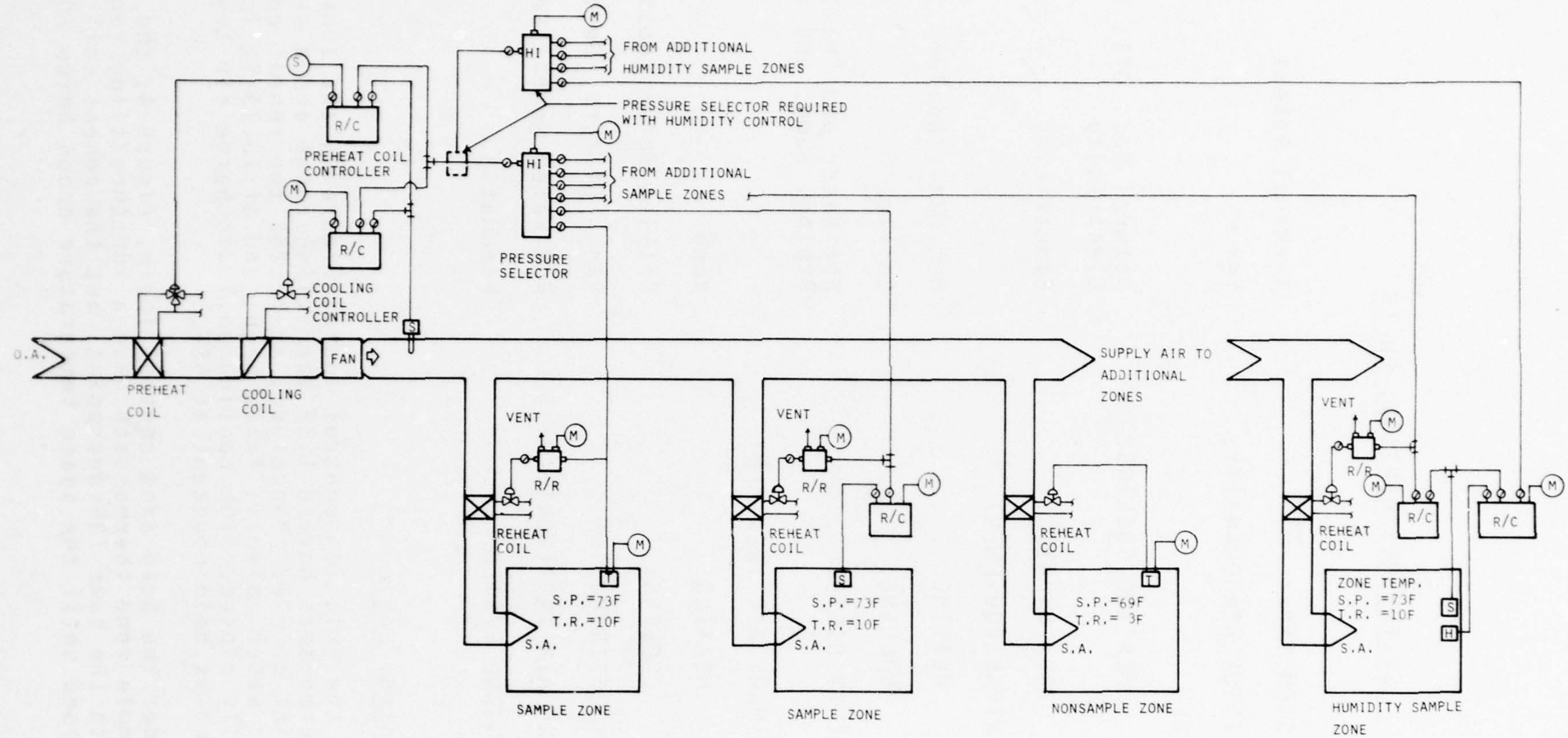


FIGURE 3. SCHEMATIC-REHEAT WITH 100 PERCENT OUTSIDE AIR

C SYSTEM DESCRIPTION, RH-15

SYSTEM TYPE:	Terminal Reheat
OUTSIDE AIR QUANTITY:	15%
FUEL	
HEATING/COOLING:	Natural Gas, Oil, Coal, Electricity
AUXILIARY:	Electricity
CENTRAL EQUIPMENT	
HEATING:	Hot Water Boiler
COOLING:	Chiller
ENERGY DISTRIBUTION:	Hot Water and Chilled Water Piping, Pumps and Valves
PRIMARY AIR TREATMENT	
HEATING:	None
COOLING:	Chilled Water Cooling Coil
AIR DISTRIBUTION:	Fans, Filters, Ductwork
ZONE AIR TREATMENT:	Hot Water Reheat Coils
CONTROL SYSTEM:	Pneumatic

Control Logic

In the existing control logic, Figure 4, the zone thermostats have a 1.5F throttling range and a set point of 73F. Therefore, at 72.25F the reheat coil hot water valve is fully open, and at 73.75 it is fully closed. The cooling coil discharge air temperature is held constant at 55F.

Under the Dead Band control logic, Figure 4, the sample zone thermostats have a 10F throttling range with the same 73F set point, but the reheat coil is closed until the space temperature drops below 70.5F and is fully open at 68F. The cooling coil temperature is reset according to the space temperature and humidity, if needed. Within the Dead Band, all coil valves are closed and no heating or cooling energy is used. As the space demands more cooling, the chilled water coil valve modulates from closed at 75.5F to fully open at 78F.

Control Schematics

In the Dead Band system schematic, Figure 5, discharge air temperature from the cooling coil is regulated by the sample zone calling for the most cooling. This sample zone produces the highest pressure signal which is then fed to the cooling coil controller. This controller then regulates the coil control valve to maintain an optimum discharge air temperature. For example as the space demands more cooling, the chilled water coil valve modulates from closed at 75.5F to fully open at 78F. Outside air remains fixed at 15% for all conditions.

The thermostat output, from the sample zone illustrated in Figure 5, is fed through a ratio relay which produces the required pressure to regulate the hot water control valve at the reheat coil. This thermostat output also goes to a pressure selector which selects the highest pressure signal from the sample zones and transmits it to the central apparatus control system. Note that if existing thermostats are to be used in sample zones, they must be modified to provide a wider throttling range. Otherwise, a new thermostat is required.

Another option is to employ temperature sensors with remote controllers rather than thermostats in each zone. This allows the controllers to be in a remote location preventing occupants from tampering with the control system. The output from the controller leads to the reheat coil and to a pressure selector as described above.

The space thermostat in a non-sample zone is set at approximately 69F, and the throttling range remains at its original 1.5F setting. In this situation, the thermostat causes the zone control valve to be fully open at about 68F and fully closed at about 70F.

Humidity sample zones allow for the simultaneous control of dry bulb temperatures and relative humidity at higher dry bulb temperatures; i.e. 58% RH at 78F and 68% RH at 73F. The strategy is that the humidity sensor with the greatest demand can override the temperature control and place the system dehumidification cycle into a priority mode.

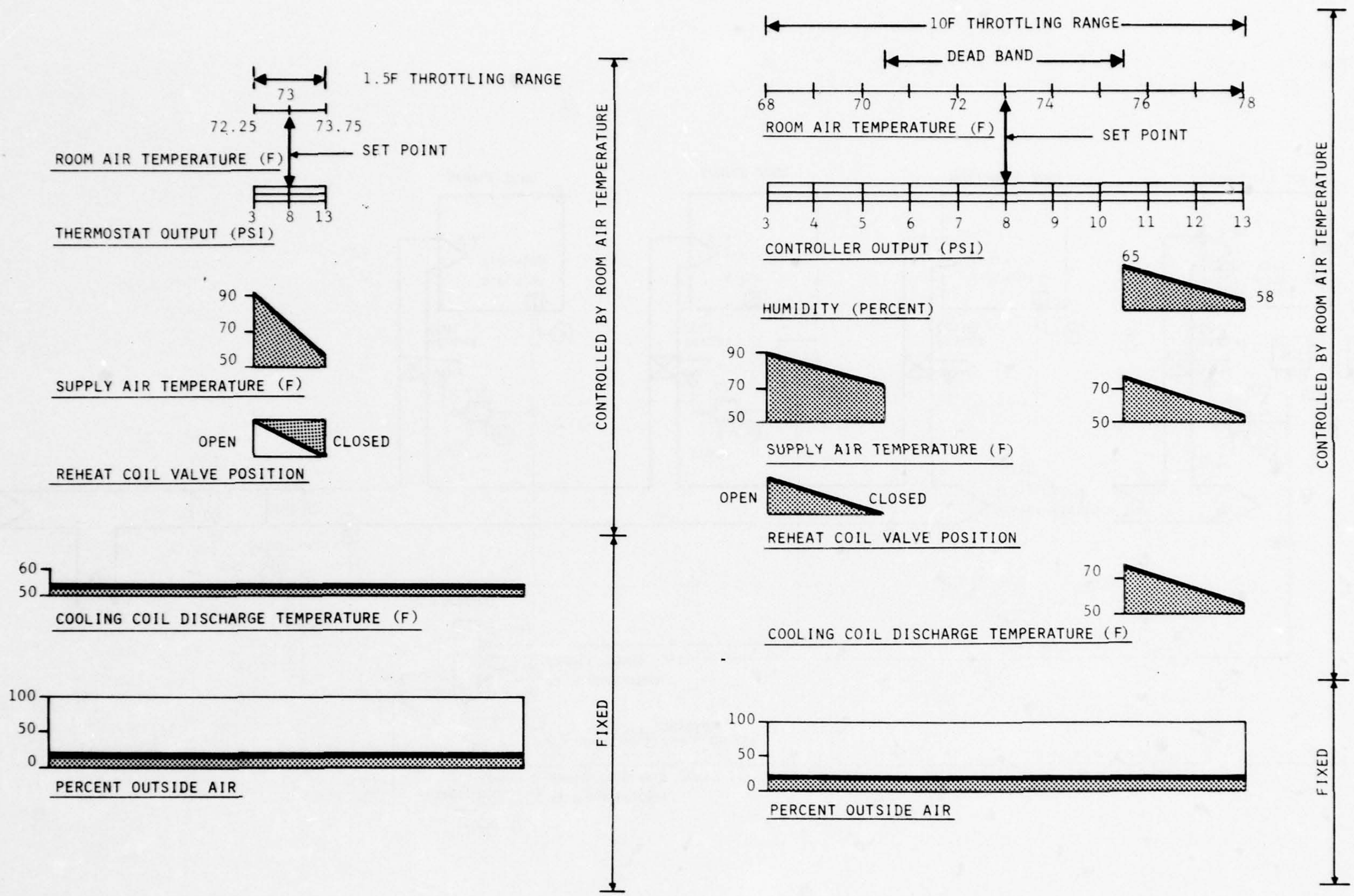


FIGURE 4. LOGIC DIAGRAM-REHEAT WITH 15 PERCENT OUTSIDE AIR

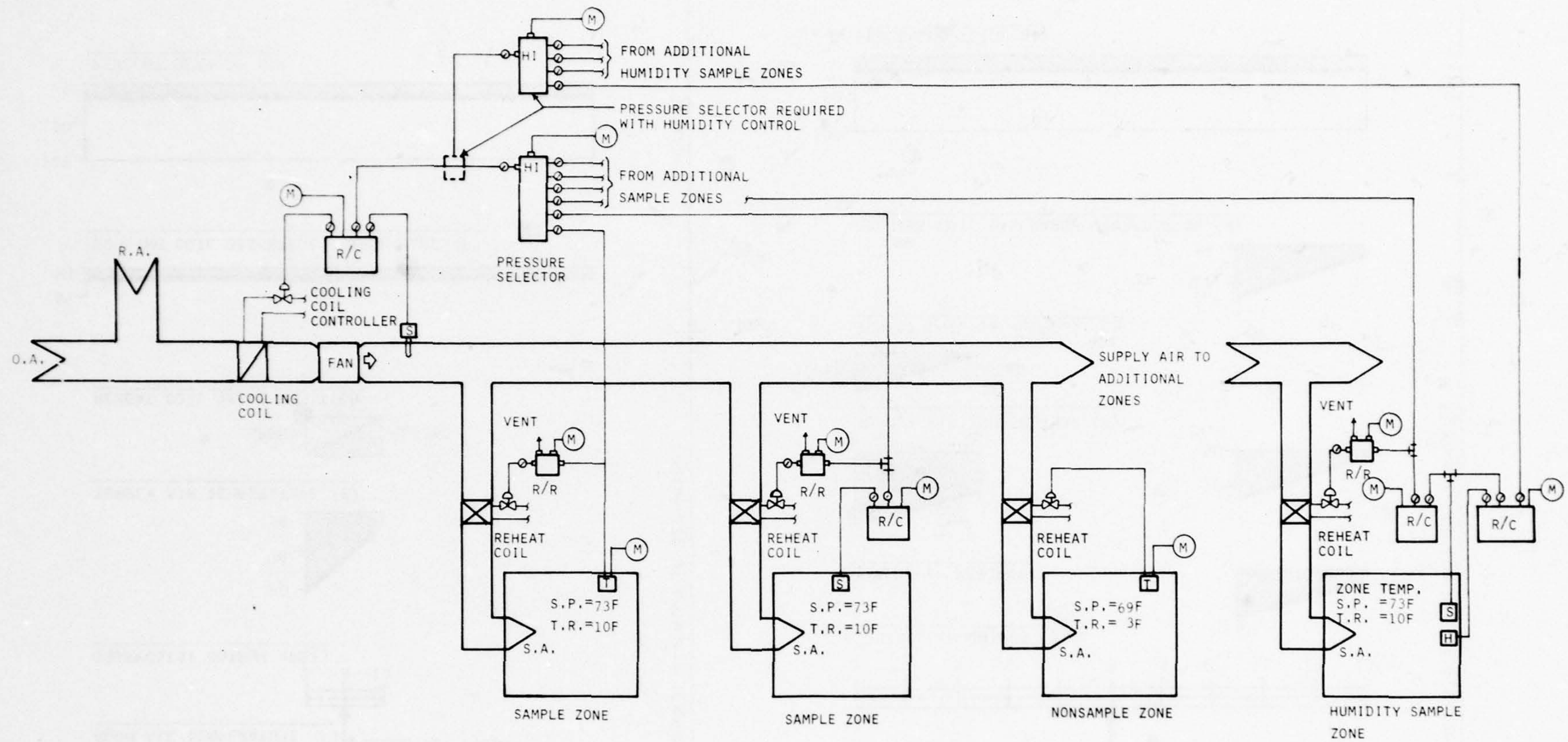


FIGURE 5. SCHEMATIC-REHEAT WITH 15 PERCENT OUTSIDE AIR

D SYSTEM DESCRIPTION, RH-VAR

SYSTEM TYPE:	Terminal Reheat
OUTSIDE AIR QUANTITY:	Varies: 15-100%
FUEL	
HEATING/COOLING:	Natural Gas, Oil, Coal, Electricity
AUXILIARY:	Electricity
CENTRAL EQUIPMENT	
HEATING:	Hot Water Boiler
COOLING:	Chiller
ENERGY DISTRIBUTION:	Hot Water and Chilled Water Piping, Pumps and Valves
PRIMARY AIR TREATMENT	
HEATING:	None
COOLING:	Chilled Water Cooling Coil
AIR DISTRIBUTION:	Fans, Filters, Ductwork, Dampers
ZONE AIR TREATMENT:	Hot Water Reheat Coils
CONTROL SYSTEM:	Pneumatic

Control Logic

In the existing control logic, Figure 6, the zone thermostats have a 1.5F throttling range and a set point of 73F. Therefore, at 72.25F the reheat coil hot water valve is fully open, and at 73.75F it is fully closed. An economizer system is used to regulate outside and return air dampers.

Under the Dead Band control logic, Figure 6, the sample zone thermostats have a 10F throttling range with the same 73F set point. The reheat coil is closed until the space temperature drops below 70.5F and is fully open at 68F. The cooling coil temperature is reset according to the space temperature and humidity, if needed. Within the Dead Band, all coil valves are closed and no heating or cooling energy is used. The existing economizer system which controls the outside and return air dampers has been modified to respond to the space temperature. At temperatures below 70.5F, outside air is at a minimum and at temperatures above 70.5F it varies as shown in Dead Band controls, Figure 6. The system also includes an enthalpy override feature which is activated only during the cooling mode to reduce outside air to a minimum when the outside air exceeds the heat content of the return air.

Control Schematics

In the Dead Band system schematic, Figure 7, discharge air temperature from the cooling coil is regulated by the sample zone calling for the most cooling. This sample zone produces the highest pressure signal which is then fed to the cooling coil controller. This controller then regulates the coil control valve to maintain an optimum discharge air temperature. For example, as the space demands more cooling, the chilled water coil valve modulates from closed at 75.5F to fully open at 78F. Economizer control is modified to regulate dampers based on a signal from the zone calling for the most cooling and from the temperature and humidity sensors in the outside air duct.

The thermostat output, from the sample zone illustrated in Figure 7, is fed through a ratio relay which produces the required pressure to regulate the hot water control valve at the reheat coil. This thermostat output also goes to a pressure selector which selects the highest pressure signal from the sample zones and transmits it to the central apparatus control system. Note that if existing thermostats are to be used in sample zones they must be modified to provide a wider throttling range. Otherwise, a new thermostat is required.

Still another strategy is to employ temperature sensors with remote controllers rather than thermostats in each zone. This allows the controllers to be in a remote location preventing occupants from tampering with the control system. The output from the controller leads to the reheat coil and to the pressure selector as described above.

The space thermostat in a non-sample zone is set at approximately 69F, and the throttling range remains at its original 1.5F setting. In this situation, the thermostat causes the zone control valve to be fully open at about 68F and fully closed at about 70F.

Humidity sample zones allow for the simultaneous control of drybulb temperatures and relative humidity at higher drybulb temperatures; i.e. 58% RH at 78F and 68% RH at 73F. The strategy here is that the humidity sensor with the greatest demand can override the temperature control and place the system dehumidification cycle into a priority mode.

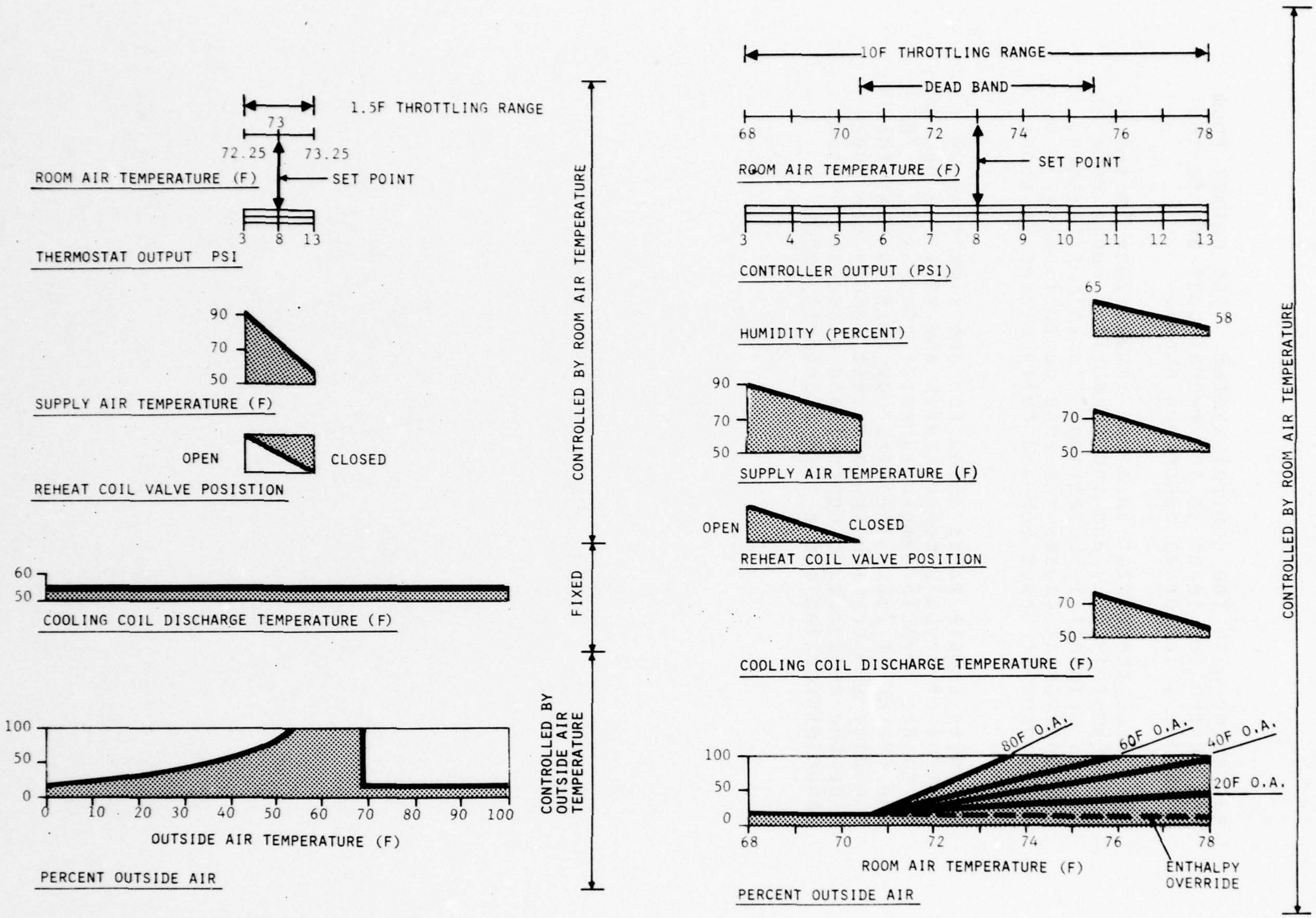


FIGURE 6. LOGIC DIAGRAM-REHEAT WITH VARIABLE OUTSIDE AIR

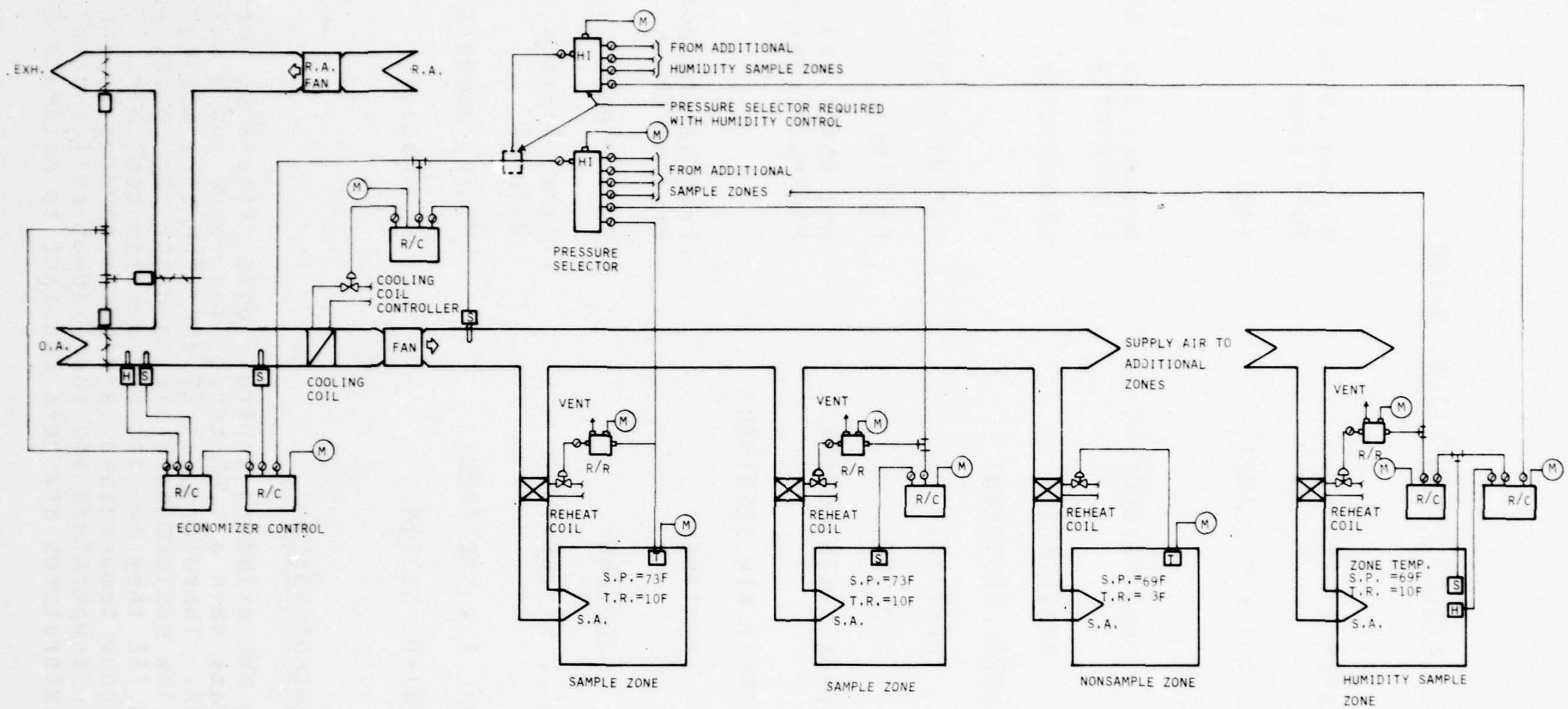


FIGURE 7. SCHEMATIC-REHEAT WITH VARIABLE OUTSIDE AIR

E SYSTEM DESCRIPTION, M-100

SYSTEM TYPE:	Mixing (Dual Duct or Multizone)
OUTSIDE AIR QUANTITY:	100%
FUEL	
HEATING/COOLING:	Natural Gas, Oil, Coal, Electricity
AUXILIARY:	Electricity
CENTRAL EQUIPMENT	
HEATING:	Hot Water Boiler
COOLING:	Chiller
ENERGY DISTRIBUTION:	Hot Water and Chilled Water Piping, Pumps and Valves
PRIMARY AIR TREATMENT	
HEATING:	Preheat and Hot Plenum Heating Coils
COOLING:	Cold Plenum Cooling Coil
AIR DISTRIBUTION:	Fans, Filters, Ductwork, Dampers
ZONE AIR TREATMENT:	Mixing Dampers
CONTROL SYSTEM:	Pneumatic

Control Logic

In the existing control logic, Figure 8, zone thermostats have a 1.5F throttling range and a set point of 73F. Therefore, at 72.25F the zone mixing dampers allow maximum warm air to enter the space, and at 73.75F they are set for maximum cool air. The hot plenum temperature is reset according to the outside air temperature and the preheat coil and cold plenum temperatures are held constant to maintain 55F.

Under the Dead Band control logic, Figure 8, the sample zone thermostats have a 10F throttling range with a 73F set point. Zone mixing dampers allow maximum warm air to enter the space when space temperatures range between 68F and 70.5F. At 75.5-78F, mixing dampers are set for maximum cool air. The hot plenum and cold plenum temperatures are both reset by space demand feedback. While the hot plenum heating coil valve is fully open at 68F, it is closed at 70.5F. The cold plenum cooling coil valve is fully open at 78F and closed at 75.5F. Within the Dead Band, all coil valves are closed and no heating or cooling energy is used. The pre-heat coil discharge temperature is held constant for this system.

Control Schematics

In the Dead Band system schematic, Figure 9, discharge air temperature from the cold plenum is regulated by the sample zone calling for the most cooling. This sample zone produces the highest pressure signal which is then fed to the cooling coil controller. This controller then regulates the coil control valve to maintain the optimum discharge air temperature. Discharge air temperature from the hot plenum is similarly controlled except the lowest pressure is used. The pre-heat coil controller regulates discharge air from the pre-heat coil at a nearly constant temperature. Outside air remains fixed at 100% for all conditions.

The thermostat output, from the sample zone illustrated in Figure 9, is fed through a ratio relay which produces the required pressure to regulate the zone mixing damper. This thermostat output also goes to a pressure selector which selects the highest and lowest pressure signals from the sample zone and transmits these signals to the central apparatus control system. Note that if existing thermostats are to be used in sample zones, they must be modified to provide a wider throttling range. Otherwise, a new thermostat is required.

Still another strategy is to employ temperature sensors with remote controllers rather than thermostats in each zone. This allows the controllers to be in a remote location preventing occupants from tampering with the control system. The output from the controller leads to the zone damper operator and to the pressure selector as described above.

The space thermostat in a non-sample zone is set at approximately 73F, but the throttling range remains at its original 1.5 setting. In this situation, the thermostat output causes the mixing dampers to be set for maximum warm air below about 72F and maximum cool air above about 74F.

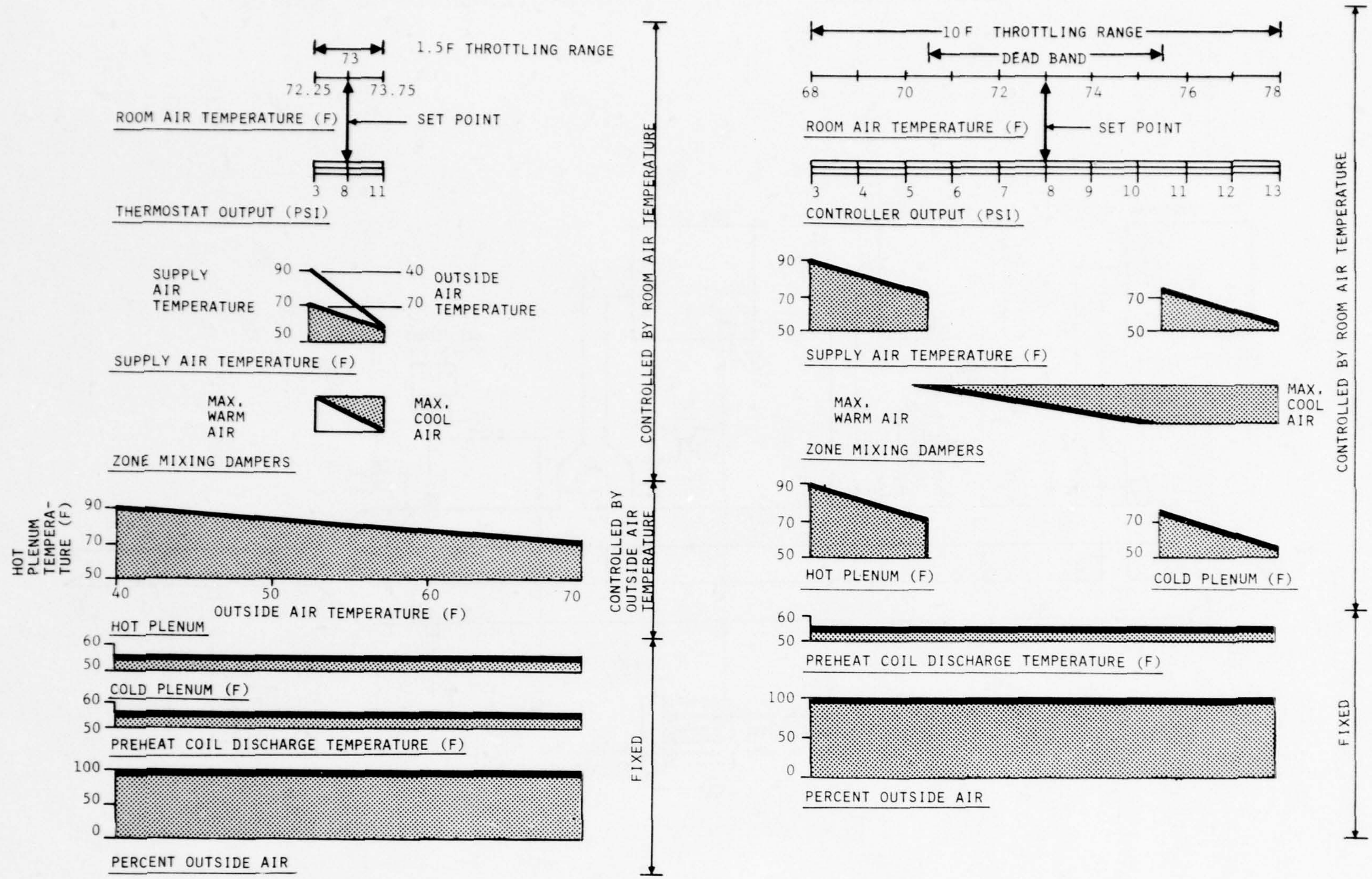


FIGURE 8. LOGIC DIAGRAM-MIXING WITH 100 PERCENT OUTSIDE AIR

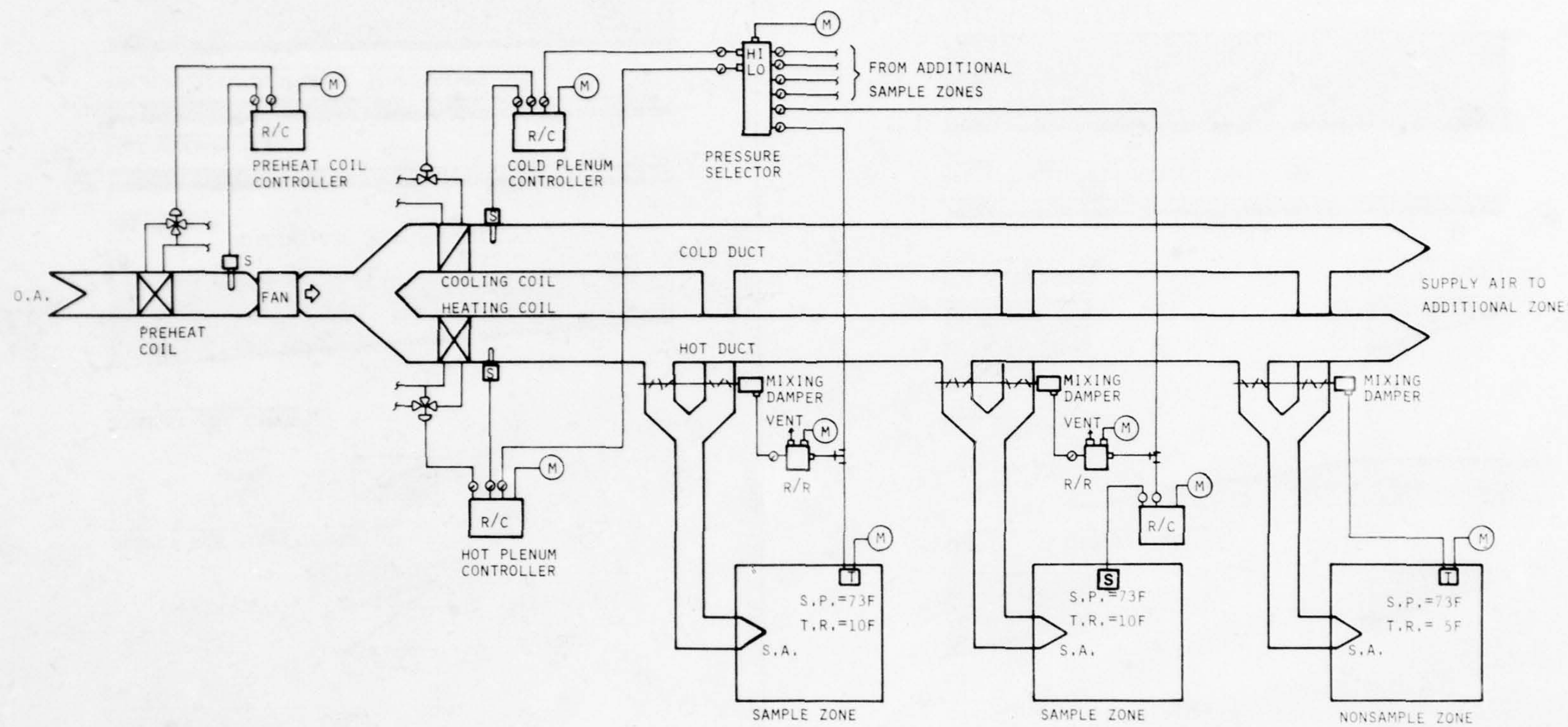


FIGURE 9. SCHEMATIC-MIXING WITH 100 PERCENT OUTSIDE AIR

F SYSTEM DESCRIPTION, M-15

SYSTEM TYPE:	Mixing (Dual Duct or Multizone)
OUTSIDE AIR QUANTITY:	15%
FUEL	
HEATING/COOLING	Natural Gas, Oil, Coal, Electricity
AUXILIARY:	Electricity
CENTRAL EQUIPMENT	
HEATING:	Hot Water Boiler
COOLING:	Chiller
ENERGY DISTRIBUTION:	Hot Water and Chilled Water Piping, Pumps and Valves
PRIMARY AIR TREATMENT	
HEATING:	Hot Plenum Heating Coil
COOLING:	Cold Plenum Cooling Coil
AIR DISTRIBUTION:	Fans, Filters, Ductwork, Dampers
ZONE AIR TREATMENT:	Mixing Dampers
CONTROL SYSTEM:	Pneumatic

Control Logic

In the existing control logic, Figure 10, zone thermostats have a 1.5F throttling range and a set point of 73F. Therefore, at 72.25F the zone mixing dampers allow maximum warm air to enter the space and at 73.75F they are set for maximum cool air. The hot plenum temperature is reset according to the outside air temperature, and the preheat coil and cold plenum temperatures are held constant.

Under the Dead Band control logic, Figure 10, the sample zone thermostats have a 10F throttling range with a 73F set point. Zone mixing dampers allow maximum warm air to enter the space when space temperatures range between 68F and 70.5F. At 75.5F-78F, mixing dampers are set for maximum cool air.

The hot plenum and cold plenum temperatures are both reset by space demand feedback. The hot plenum heating coil valve is fully open at 68F and closed at 70.5F; the cold plenum cooling coil valve is fully open at 78F and closed at 75.5F. Within the Dead Band, all coil valves are closed and no heating or cooling energy is used.

Control Schematics

In the Dead Band system schematic, Figure 11, discharge air temperature from the cold plenum is regulated by the sample zone calling for the most cooling. This sample zone produces the highest pressure signal which is then fed to the cooling coil controller. This controller then regulates the coil control valve to maintain the optimum discharge air temperature. Discharge air temperature from the hot plenum is similarly controller, except the lowest pressure is used. Outside air remains fixed at 100% for all conditions.

The thermostat output, from the sample zone illustrated in Figure 11, is fed through a ratio relay which produces the required pressure to regulate the zone mixing damper. This thermostat output also goes to a pressure selector which selects the highest and lowest pressure signals from the sample zones and transmits these signals to the central apparatus control system. Note that if existing thermostats are to be used in sample zones, they must be modified to provide a wider throttling range. Otherwise, a new thermostat is required.

Still another strategy is to employ temperature sensors with remote controllers rather than thermostats in each zone. This allows the controllers to be in a remote location preventing occupants from tampering with the control system. The output from the controller leads to the zone damper operator and to the pressure selector as described above.

The space thermostat in a non-sample zone is set at approximately 73F, but the throttling range remains at its original 1.5 setting. In this situation the thermostat output causes the mixing dampers to be set for maximum warm air below about 72F and maximum cool air above about 74F.

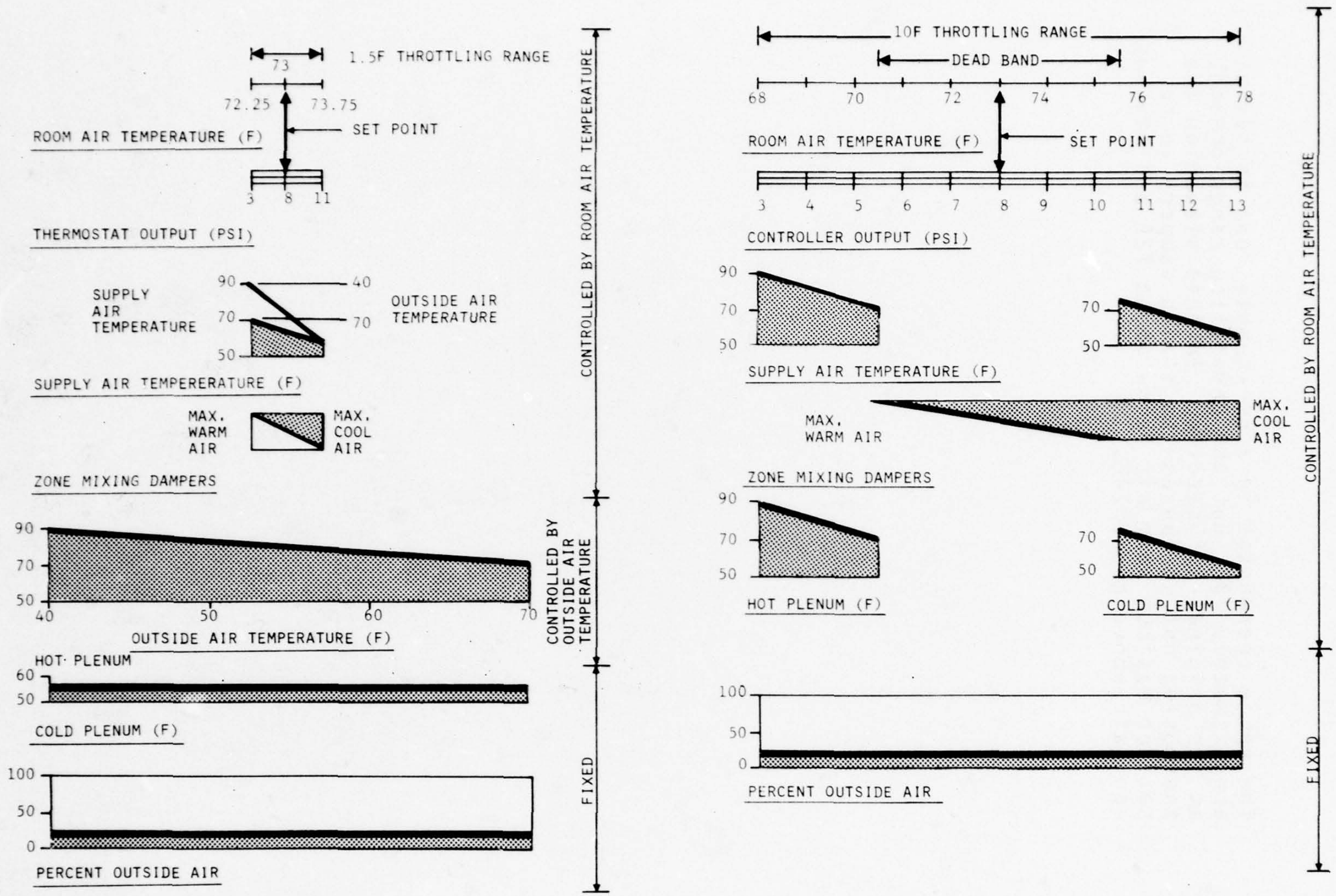


FIGURE 10. LOGIC DIAGRAM-MIXING WITH 15 PERCENT OUTSIDE AIR

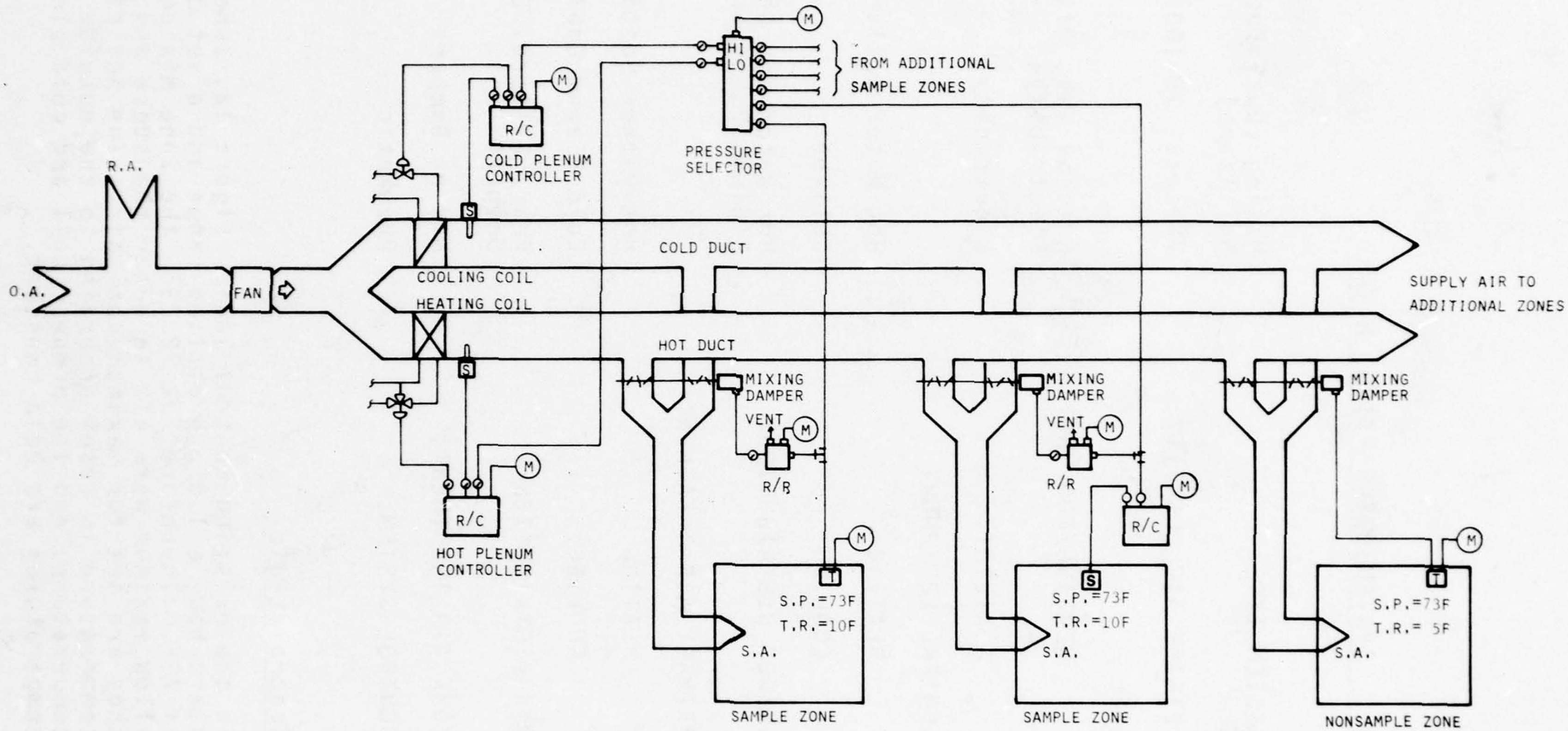


FIGURE 11. SCHEMATIC-MIXING WITH 15 PERCENT OUTSIDE AIR

G SYSTEM DESCRIPTION, M-VAR

SYSTEM TYPE:	Mixing (Dual Duct or Multizone)
OUTSIDE AIR QUANTITY:	Varies: 15-100%
FUEL	
HEATING/COOLING:	Natural Gas, Oil, Coal, Electricity
AUXILIATY:	Electricity
CENTRAL EQUIPMENT	
HEATING:	Hot Water Boiler
COOLING:	Chiller
ENERGY DISTRIBUTION:	Hot Water and Chilled Water Piping, Pumps and Valves
PRIMARY AIR TREATMENT	
HEATING:	Hot Plenum Heating Coil
COOLING:	Cold Plenum Cooling Coil
AIR DISTRIBUTION:	Fans, Filters, Ductwork, Dampers
ZONE AIR TREATMENT:	Mixing Dampers
CONTROL SYSTEM:	Pneumatic

Control Logic

In the existing control logic, Figure 12, zone thermostats have a 1.5F throttling range and a set point of 73F. Therefore, at 72.25F the zone mixing dampers allow maximum warm air to enter the space and at 73.75F they are set for maximum cool air. The hot plenum temperature is reset according to the outside air temperature, and the preheat coil and cold plenum temperatures are held constant.

Under the Dead Band control logic, Figure 12, the sample zone thermostats have a 10F throttling range with a 73F set point. Zone mixing dampers allow maximum warm air to enter the space when space temperatures range between 68F and 70.5F. At 75.5-78F, mixing dampers are set for maximum cool air. The hot plenum and cold plenum temperatures are both reset by space demand feedback. While the hot plenum heating coil valve is fully open at 68F, it is closed at 70.5F. The cold plenum cooling coil valve is fully open at 78F and closed at 75.5F. Within the Dead Band, all coil valves are closed and no heating or cooling energy is used.

Control Schematic

In the Dead Band system schematic, Figure 13, discharge air temperature from the cold plenum is regulated by the sample zone calling for the most cooling. This sample zone produces the highest pressure signal which is then fed to the cooling coil controller. This controller then regulates the coil control valve to maintain optimum discharge air temperature. Discharge air temperature from the hot plenum is similarly controlled, except the lowest pressure is used. The economizer control is modified to regulate dampers based on the space temperature. Below 70.5F, outside air is at a minimum; above 70.5F it varies as shown in the Dead Band control logic, Figure 13. The system also includes an enthalpy override which reduces outside air to a minimum when it is too hot and humid.

The thermostat output from the sample zone illustrated in Figure 13 is fed through a ratio relay which produces the required pressure to regulate the zone mixing damper. This thermostat output also goes to a pressure selector which selects the highest and lowest pressure signals from the sample zones and transmits these signals to the central apparatus control system. Note that if existing thermostats are to be used in sample zones, they must be modified to provide a wider throttling range. Otherwise, a new thermostat is required.

Still another strategy is to employ temperature sensors with remote controllers rather than thermostats in each zone. This allows the controllers to be in a remote location preventing occupants from tampering with the control system. The output from the controller leads to the zone damper operator and to the pressure selector as described above.

The space thermostat in a non-sample zone is set at approximately 73F, but the throttling range remains at its original 1.5F setting. In this situation the thermostat output causes the mixing dampers to be set for maximum warm air below about 72F and maximum cool air above about 74F.

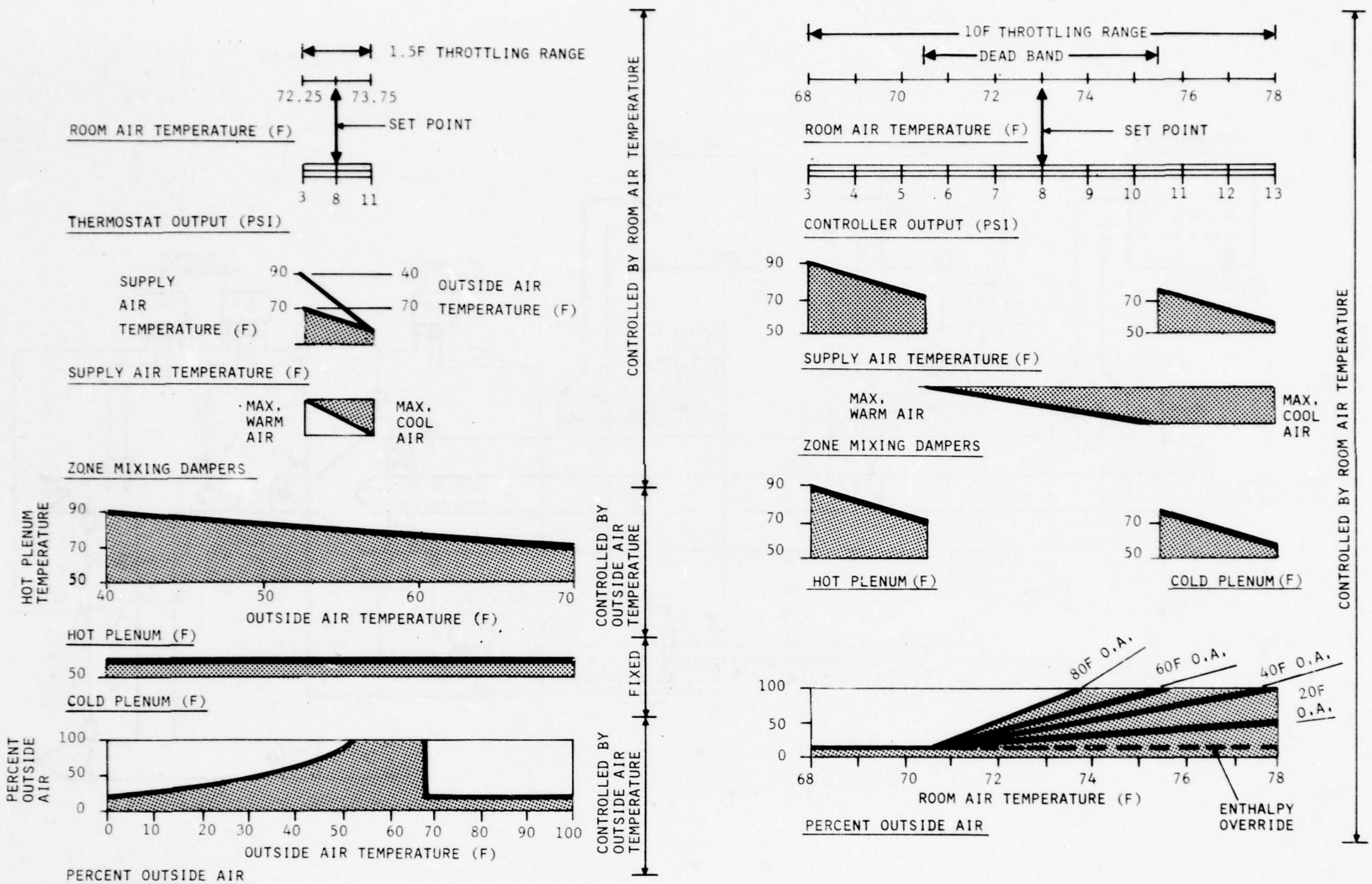


FIGURE 12. LOGIC DIAGRAM-MIXING WITH VARIABLE OUTSIDE AIR

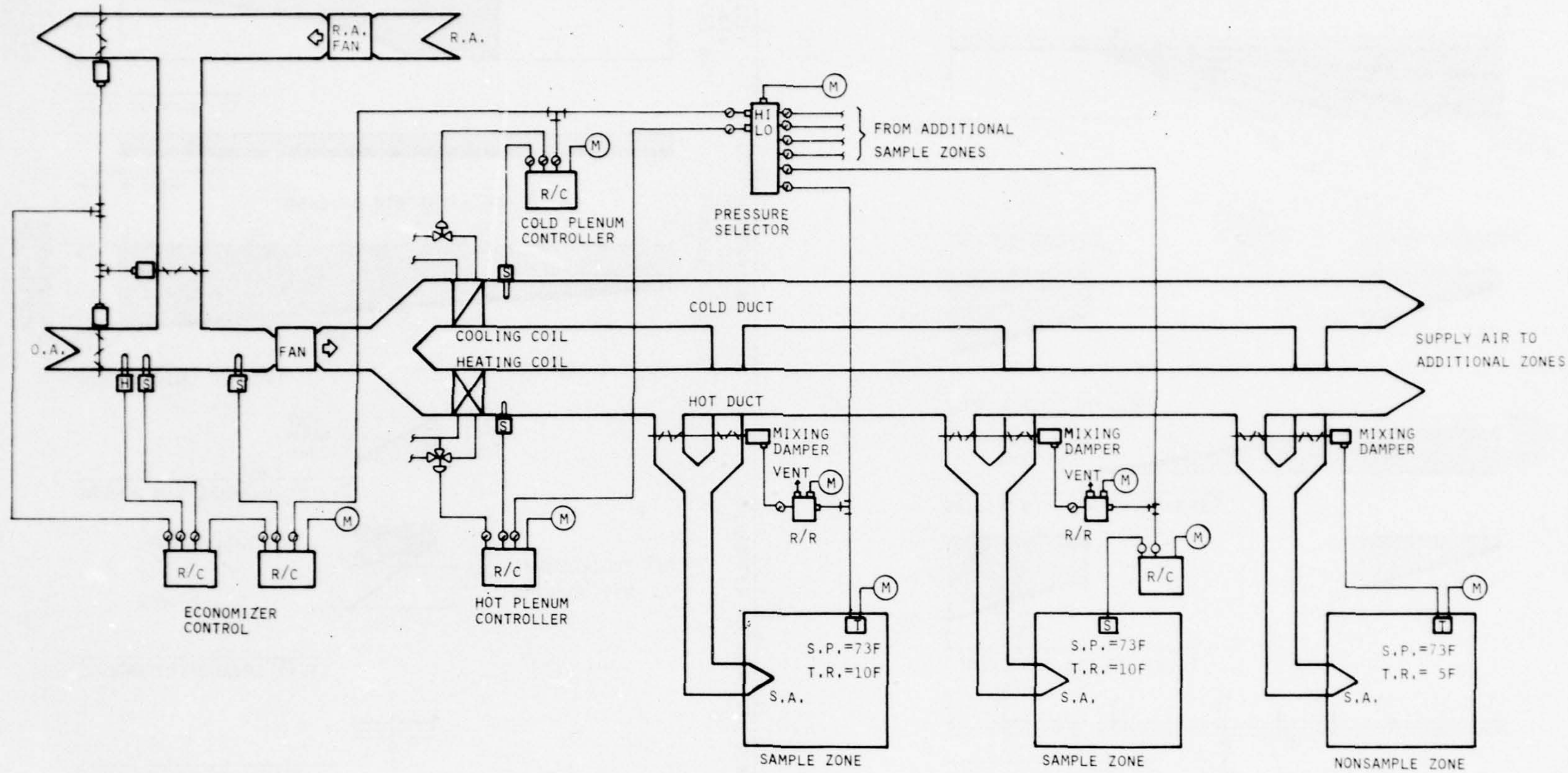


FIGURE 13. SCHEMATIC-MIXING WITH VARIABLE OUTSIDE AIR

PART III ECONOMIC ANALYSIS

A ECONOMICS

The first cost of a Dead Band control system retrofit will depend on many factors. The type of system, number of sample zones, building construction type, and the cost of equipment (i.e. heating coil controls, economizers, etc.) must all be considered. In some cases, certain existing control items, such as thermostats, can be modified while in other cases they must be replaced with new equipment.

The estimated cost of various items required to retrofit a building with Dead Band control is shown in Table 2 - RETROFIT COST ESTIMATES. Work sheets for installation cost estimate and operation and maintenance cost estimate for Dead Band controls are provided in Figures 17 and 18. The assumptions used to determine fixed installation costs for Dead Band retrofit are listed in Table 3 - RETROFIT COST ESTIMATE ASSUMPTIONS. Fixed costs are given on these work sheets, but nonhumidity sample zone cost must be interpolated from the given graph.

Cost Estimate

The cost of a Dead Band control retrofit will vary with the type of system required. For example, a mixing system of the multi-zone type will have a minimum cost because new tubing runs between the selected sample zones and central apparatus are not needed. Still another system may have old equipment and difficult working conditions thereby having maximum cost associated with retrofit. Typically, in any building 25-40% of all zones are sample zones. In cases where humidity control is needed, 1-4 humidity sample zones can be considered sufficient for most buildings.

Payback Analysis

Dead Band control strategy will produce substantial economic savings when applied to the HVAC systems described in this guide. The actual savings will depend on many factors, including the HVAC system involved, the price of fuel saved, the climate and the thermal characteristics of the building. Figures 14, 15 and 16 compare relative energy used for a Dead Band retrofit with conventional control strategies. These graphs are intended as guidelines for predicting energy savings. Actual savings may vary from the guidelines to the extent that a candidate building and environment differ from the simulated conditions described in PART I, E.

Economic savings may be expressed in many ways. The illustrated method is the simple payback period--the time it takes the accumulated savings to equal first cost. Table 2 and Figures 14-18 can be used to calculate installation costs, annual increase in operation and maintenance costs, and annual dollar savings associated with a Dead Band control system modification. This data may then be used to calculate a simple payback, life cycle cost, or ECIP project justification. It should be noted that annual heating and cooling energy costs for your project must be obtained, or estimated, for payback analysis.

An example of a simple payback calculation is given in the APPENDICES. Historical payback periods for retrofitted buildings range from three to fifteen months in the San Diego area.

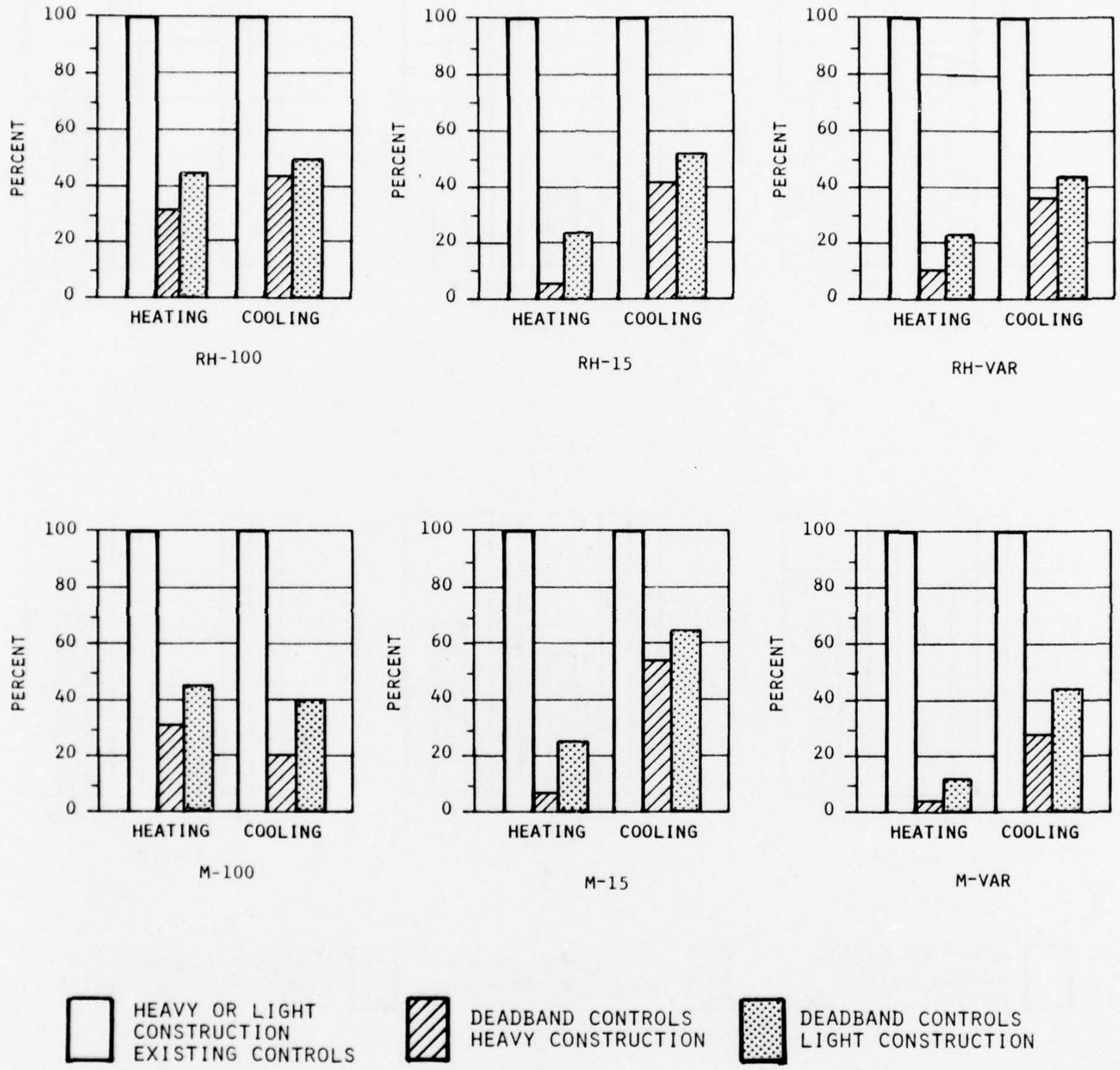


FIGURE 14, RELATIVE ENERGY USE - SAN DIEGO, CALIFORNIA

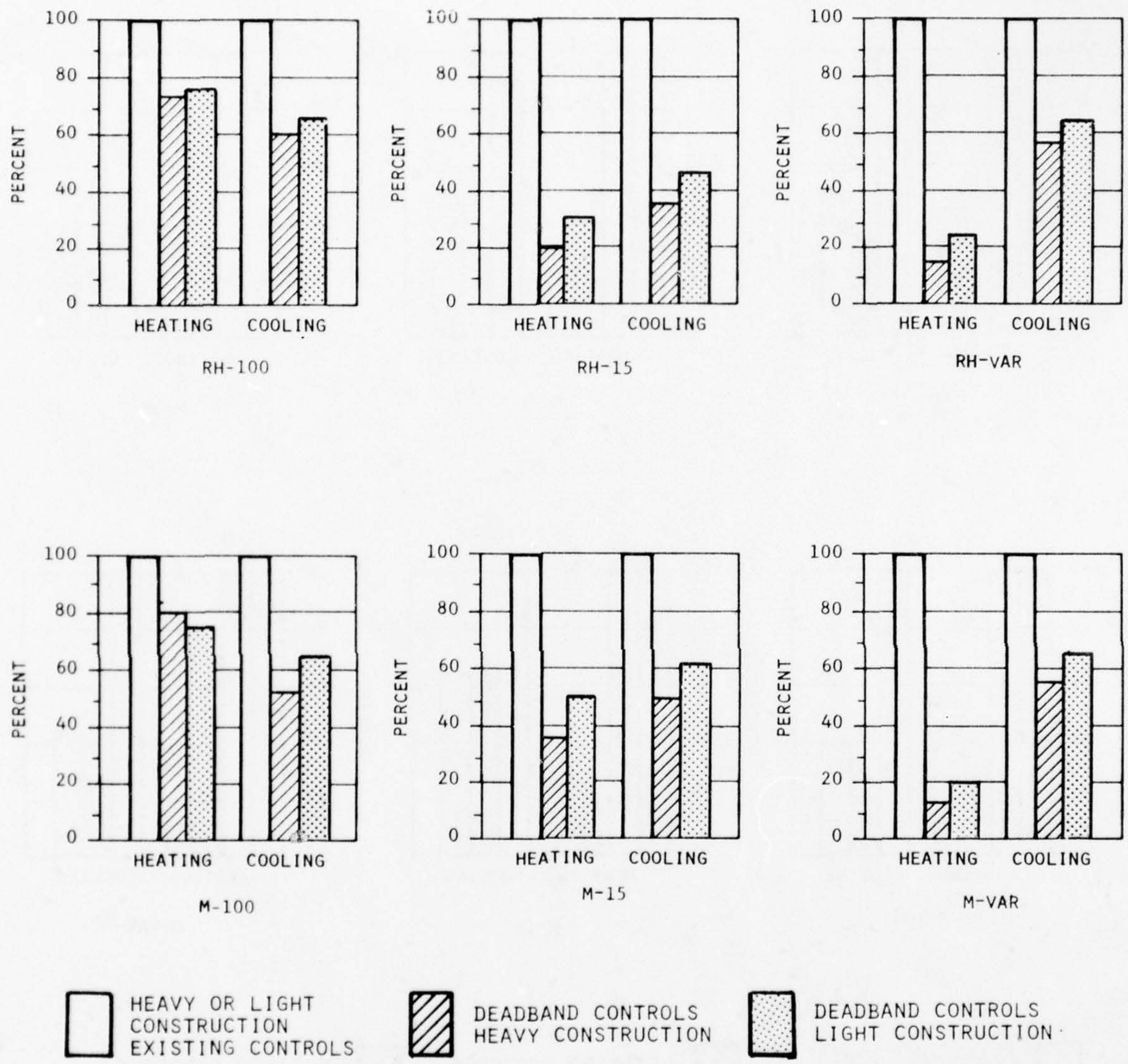


FIGURE 15, RELATIVE ENERGY USE - GREAT LAKES, ILLINOIS

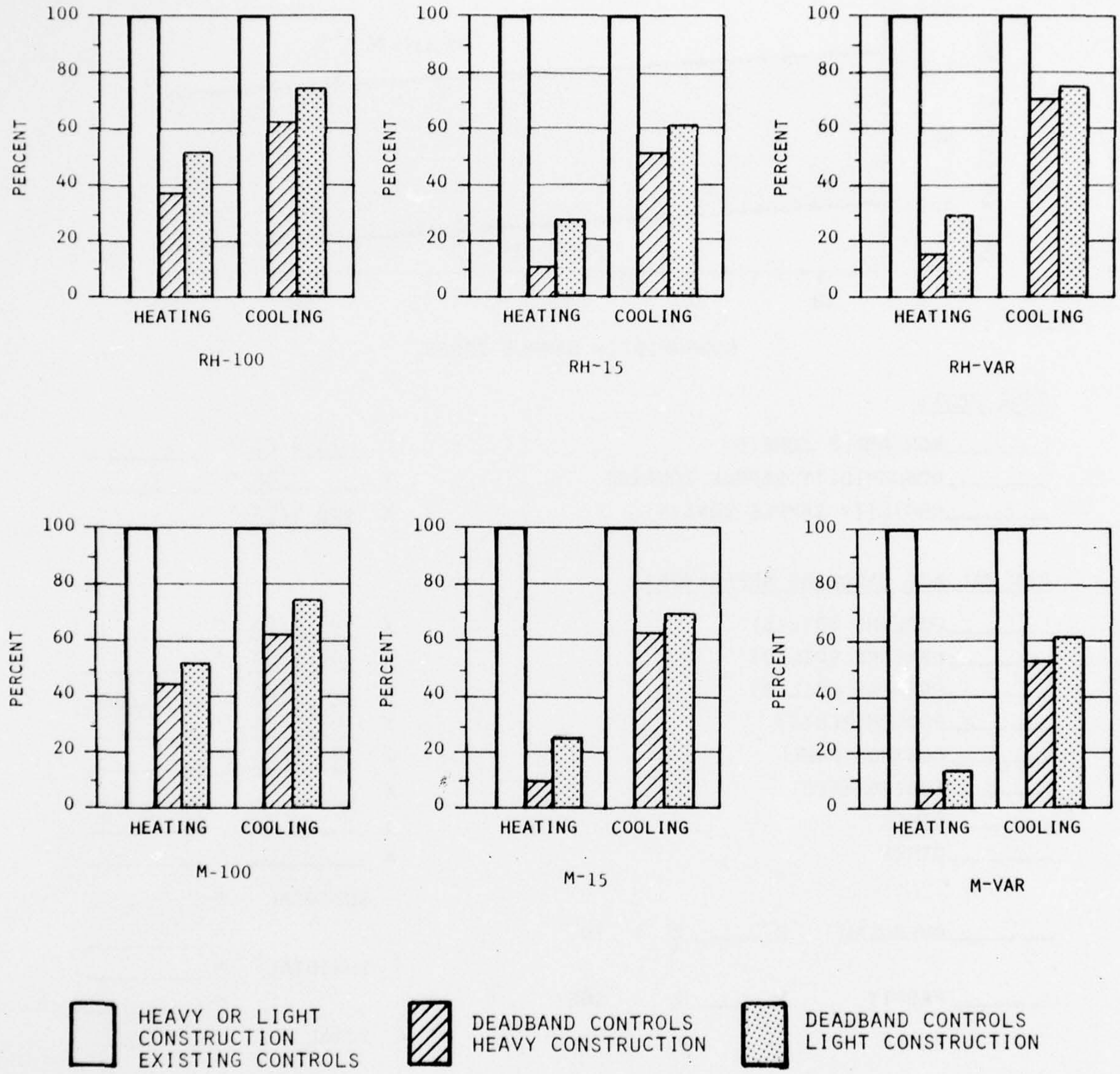
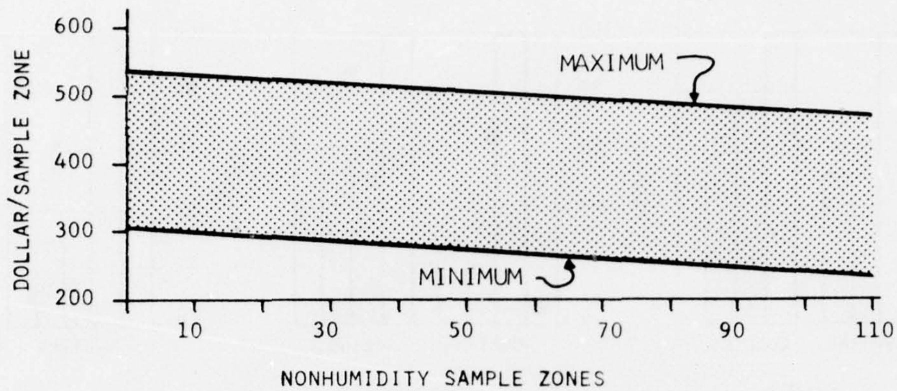


FIGURE 16, RELATIVE ENERGY USE - PENSACOLA, FLORIDA



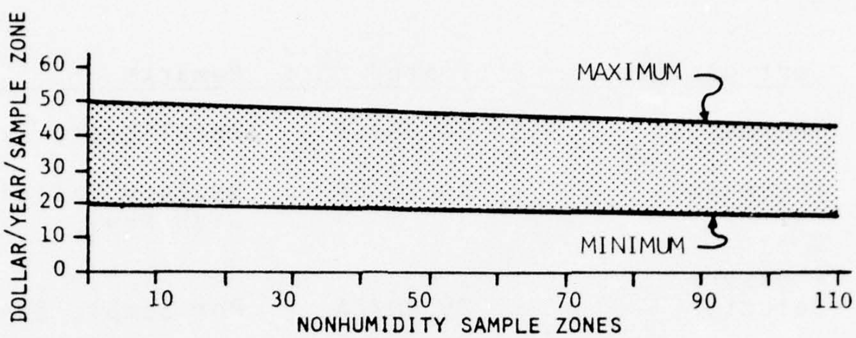
ZONE DATA:

________	NONSAMPLE ZONE(S)	X	20 $/EA	=	________
________	NONHUMIDITY SAMPLE ZONE(S)	X	$/EA	=	________
________	HUMIDITY SAMPLE ZONE(S)	X	600 $/EA	=	________

CENTRAL AIR HANDLING APPARATUS:

________	COOLING COIL(S)	X	400 $/EA	=	________
________	HEATING COIL(S)	X	400 $/EA	=	________
________	PREHEAT COIL(S)	X	400 $/EA	=	________
________	ECONOMIZER(S)	X	700 $/EA	=	________
________	CONTROL PANEL	X	250 $/EA	=	________
________	TUBING (FEET)	X	________		________
________	OTHER	X	________		________
________	OTHER	X	________		________
			SUBTOTAL	=	________
________	OVERHEAD	X ______ % ÷ 100		=	________
			SUBTOTAL	=	________
________	PROFIT	X ______ % ÷ 100		=	________
			TOTAL	=	________

FIGURE 17. WORKSHEET, INSTALLATION COST ESTIMATE FOR DEAD BAND RETROFIT



ZONE DATA:

______	NONSAMPLE ZONE(S)	X	0	$/YR =	______
______	NONHUMIDITY SAMPLE ZONE(S)	X	______	$/YR =	______
______	HUMIDITY SAMPLE ZONE(S)	X	70	$/YR =	______

CENTRAL AIR HANDLING APPARATUS:

______	COOLING COIL(S)	X	25	$/YR =	______
______	HEATING COIL(S)	X	25	$/YR =	______
______	PREHEAT COIL(S)	X	25	$/YR =	______
______	ECONOMIZER(S)	X	40	$/YR =	______
______	OTHER	X	______	$/YR =	______
______	OTHER	X	______	$/YR =	______
				SUBTOTAL =	______
______	OVERHEAD X ______ % ÷ 100			=	______
				SUBTOTAL =	______
______	PROFIT X ______ % ÷ 100			=	______
				TOTAL =	______

FIGURE 18, WORKSHEET, OPERATION AND MAINTENANCE COST ESTIMATE FOR DEAD BAND CONTROL SYSTEM MODIFICATIONS

Table 2 - RETROFIT COST ESTIMATES

Control Item	Estimated Cost	Remarks
Thermostat	$ 20.00/EA	Recalibrate Existing
Thermostat	$ 80.00/EA	Replace Existing with New
Pressure Selector	$ 25.00/EA	Per Sample Zone
Receiver/ Controller	$ 200.00/EA	New
Ratio Relay	$ 40.00/EA	New
Duct Sensor	$ 100.00/EA	New
Control Panel	$ 250.00/EA	One Control Panel Per System
Room Sensor	$ 80.00/EA	Replace Existing Thermostat with Sensor
Control Valve	$ 100.00/EA	Recalibrate Main Control Valve
Pneumatic Tubing	$ 0.20/ to 2.00/LF	Tubing Cost Varies With Type (Plastic or Copper), Building Construction, Complexity and Accessibility.
Miscellaneous		Cost for Adjustments Are Included in the Above Estimates.

TABLE 3 - RETROFIT COST ESTIMATE ASSUMPTIONS

Item	Estimated Cost	Remarks
Cooling Coil Controls		
Receiver/Controller	$ 200.00	New
Duct Sensor	100.00	New
Control Valve	100.00	Recalibrate Main Control Valve
TOTAL	$ 400.00	Typical Controls Cost for Cooling Coil
Heating Coil Controls		
Receiver/Controller	$ 200.00	New
Duct Sensor	100.00	New
Control Valve	100.00	Recalibrate Main Control Valve
TOTAL	$ 400.00	Typical Controls Cost for Heating Coil
Preheat Coil Controls		
Receiver/Controller	$ 200.00	New
Duct Sensor	100.00	New
Control Valve	100.00	Recalibrate Main Control Valve
TOTAL	$ 400.00	Typical Controls Cost for Preheat Coil
Economizer Controls		
Receiver/Controller (2 Required)	$ 400.00	New
Duct Sensors (3 Required)	300.00	New
TOTAL	$ 700.00	Typical Control Cost for Economizer

Notes:
1. For Economizer control, damper repair may require consideration.
2. No tubing costs are included in the above estimates. Typically 150 to 200 feet of tubing may be considered per air handling unit.

PART IV APPENDICES

A EXAMPLE - COST ESTIMATE OF DEAD BAND RETROFIT

PROBLEM:

Determine installation cost and annual operation and maintenance cost for Dead Band control system modifications of example building.

EXAMPLE BUILDING:

A reheat system with an economizer is used in a three-story building. There is one air handling unit and 20 zones per floor, five of which are selected as non-humidity sample zones. Humidity is considered to be a problem, therefore, one humidity sample zone will be used for each air handling system.

SOLUTION:

Step 1:

Refer to Figure 19, Example Work Sheet, Installation Cost Estimate for Dead Band Retrofit, page 58.

Step 2:

Determine Zone Data

a. Number of Non-sample Zones

= (Total Zones - Sample Zones - Humidity Sample Zones)

= (20 - 5 - 1) = 14 Non-sample Zones/Floor

= (14 x 3 Floors)

= 42 Non-sample Zones

b. Number of Non-humidity Sample Zones

= (Non-humidity Sample Zone/Floor x No. Floors)

= (5 x 3)

= 15 Non-humidity Sample Zones.

c. Refer to "Non-humidity Sample Zone Chart", page 58 for non-humidity sample zone cost. For this example, the tubing runs and working conditions are not considered difficult; therefore, a median value of $410/Sample Zone is selected from the chart.

d. Number of Humidity Sample Zones

= (Humidity Sample Zones/Floor x No. Floors)

= (1 x 3)

= 3 Humidity Sample Zones

Step 3:

Determine Central Air Handling Apparatus Data

a. Number of Cooling Coils

= (1 Cooling Coil/Air Handling Unit x 3 Floors)

= 3 Cooling Coils

b. Number of Heating Coils = 0

c. Number of Preheat Coils = 0

d. Number of Economizers

= (1 Economizer/Air Handling Unit x 3 Floors)

= 3 Economizers

e. Number of Control Panels

Assume 1 Control Panel/Air Handling System

= 3 Control Panels

f. Length of Tubing Required

Generally, 150-200 feet per air handling unit is required; therefore, for this example (3 x 150)

= 450 Feet/Tubing

g. Determine Cost of Tubing from Table 2, page 61.

Plastic tubing is used for this example and installation conditions are considered to be not difficult;

cost = \$0.35/Foot

Step 4:

Enter above data on Figure 19, Example Work Sheet, Installation Cost Estimate for Dead Band Retrofit, page 58, and calculate cost.

Step 5:

Refer to Figure 20, Example Work Sheet, Operation and Maintenance Cost Estimate for Dead Band Control System Modifications, page 59.

Step 6:

Determine Zone Data

a. Number of Non-sample Zones.

Operation and maintenance cost remains unchanged for non-sample zones; no new costs are incurred because of retrofit.

b. Number of Non-humidity Sample Zones

= 15; See Step 2b.

c. Refer to "Non-humidity Sample Zone Chart", page 59, for non-humidity sample zone operation and maintenance cost. For this example, use a median value of \$35/Sample Zone.

d. Number of Humidity Sample Zones

= 3; See Step 2d

Step 7:

Determine Central Air Handling Apparatus Data

a. Number of Cooling Coils = 3
   See Step 3a

b. Number of Heating Coils = 0

c. Number of Preheat Coils = 0

d. Number of Economizers = 3
   See Step 3d

e. If a maintenance contract is to be obtained, overhead and profit may be considered. For this example, overhead and profit are not included.

Step 8:

Enter the above data on Figure 20, Example Work Sheet, Operation and Maintenance Cost Estimate page 59, and calculate total annual operation and maintenance cost incurred by Dead Band retrofit.

B EXAMPLE - PAYBACK OF DEAD BAND RETROFIT

PROBLEM:

Determine the simple payback period for the example building with Dead Band retrofit.

EXAMPLE BUILDING:

Recall that a reheat system with an economizer is used in a three-story building. The building is located in San Diego, California, and is considered to be heavy construction. Existing annual heating and cooling costs are $2,120 and $23,859 respectively.

SOLUTION:

Step 1:

Determine First Cost

a. From Figure 19, total first cost was found to be $15,728.

Step 2:

Determine Energy Savings

a. The percent energy savings for heating and cooling can be found from Graph RH-VAR, Figure 14, RELATIVE ENERGY USED - SAN DIEGO, CALIFORNIA. See page

Heating Savings = 100% - 11% = 89%
Cooling Savings = 100% - 36% = 64%

b. Annual Energy Dollar Savings

Heating = (0.89 x 2,120) = $ 1,887

Cooling = (0.64 x 23,859) = $15,270

Total Annual Savings = $17,157

c. Net Annual Dollar Savings

= (Annual Energy Dollar Savings - Annual Operation & Maintenance Cost Increase)

= (\$17,157 - \$930)

= \$16,227.

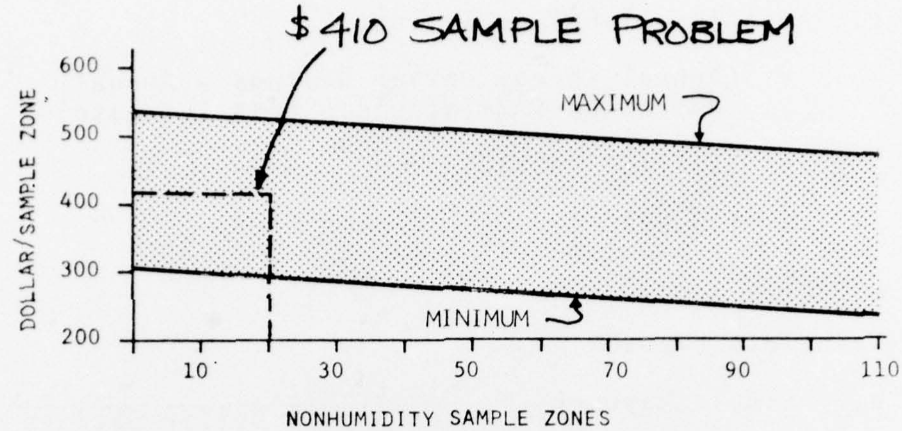
Step 3:

Calculate Payback

a. Simple Payback = $\frac{\text{First Cost}}{\text{Net Annual Dollar Savings}}$

Simple Payback = $\frac{\$15,728}{\$16,227/\text{YR}}$

= 0.97 YR



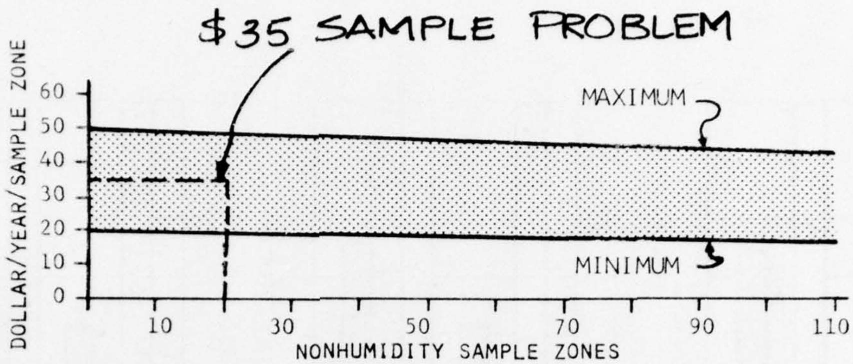
ZONE DATA:

42	NONSAMPLE ZONE(S)	X	20 $/EA	=	840
15	NONHUMIDITY SAMPLE ZONE(S)	X	410 $/EA	=	6150
3	HUMIDITY SAMPLE ZONE(S)	X	600 $/EA	=	1800

CENTRAL AIR HANDLING APPARATUS:

3	COOLING COIL(S)	X	400 $/EA	=	1200
0	HEATING COIL(S)	X	400 $/EA	=	–
0	PREHEAT COIL(S)	X	400 $/EA	=	–
3	ECONOMIZER(S)	X	700 $/EA	=	2100
3	CONTROL PANEL	X	250 $/EA	=	750
450	TUBING (FEET)	X	.35$/FT		158
	OTHER	X			
	OTHER	X			
			SUBTOTAL	=	12998
12998	OVERHEAD	X 10 % ÷ 100		=	1300
			SUBTOTAL	=	14298
14298	PROFIT	X 10 % ÷ 100		=	1430
			TOTAL	=	15728

FIGURE 19, EXAMPLE WORKSHEET, INSTALLATION COST ESTIMATE FOR DEAD BAND RETROFIT



ZONE DATA:

42	NONSAMPLE ZONE(S)	X	0	$/YR	=	–
15	NONHUMIDITY SAMPLE ZONE(S)	X	35	$/YR	=	525
3	HUMIDITY SAMPLE ZONE(S)	X	70	$/YR	=	210

CENTRAL AIR HANDLING APPARATUS:

3	COOLING COIL(S)	X	25	$/YR	=	75
0	HEATING COIL(S)	X	25	$/YR	=	–
0	PREHEAT COIL(S)	X	25	$/YR	=	–
3	ECONOMIZER(S)	X	40	$/YR	=	120
	OTHER	X		$/YR	=	
	OTHER	X		$/YR	=	
				SUBTOTAL	=	930
	OVERHEAD X ____ % ÷ 100				=	–
				SUBTOTAL	=	930
	PROFIT X ____ % ÷ 100				=	–
				TOTAL	=	930

FIGURE 20, EXAMPLE WORKSHEET, OPERATION AND MAINTENANCE COST ESTIMATE FOR DEAD BAND CONTROL SYSTEM MODIFICATIONS

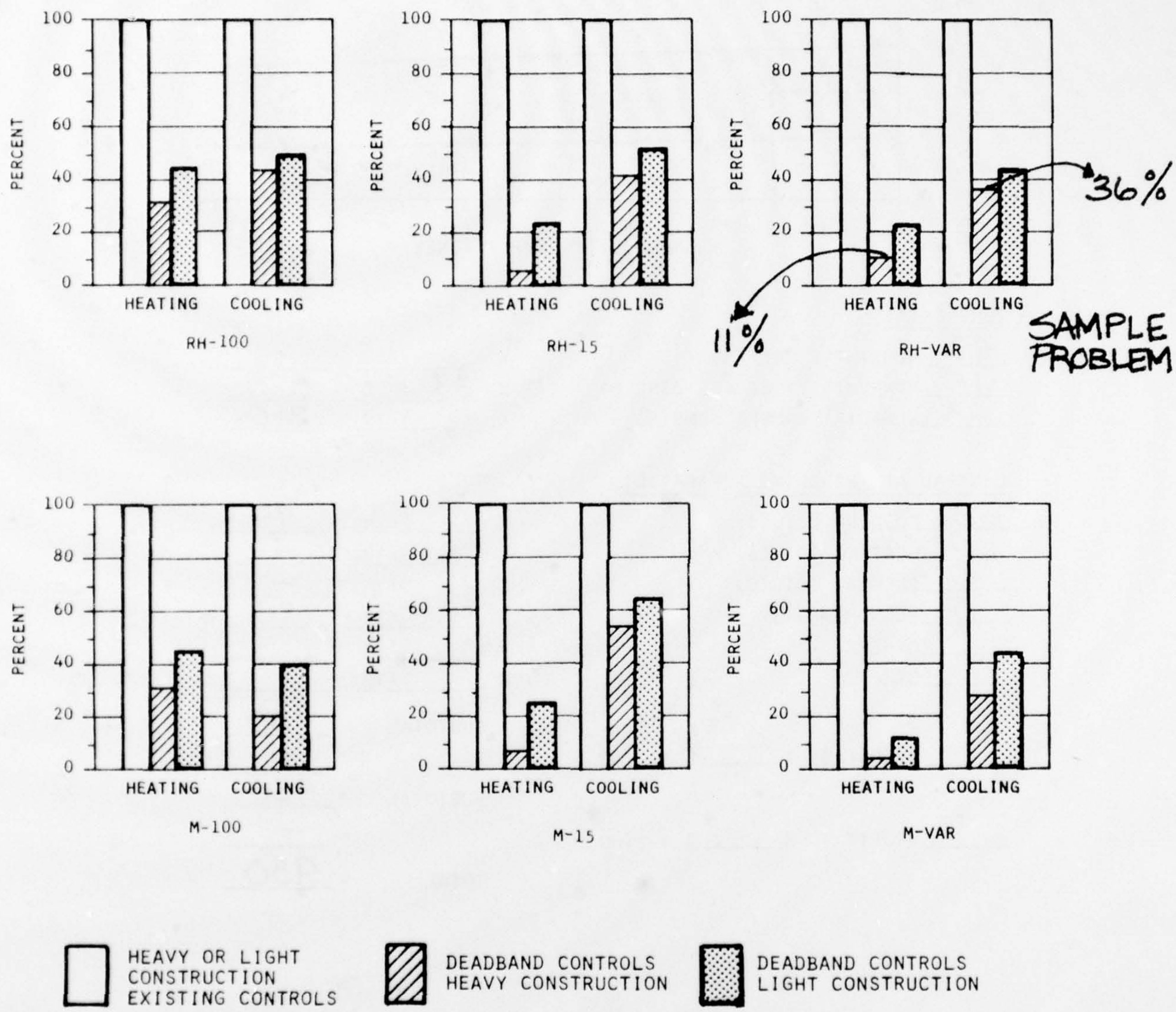


FIGURE 14. RELATIVE ENERGY USE - SAN DIEGO, CALIFORNIA

Table 2 - RETROFIT COST ESTIMATES

Control Item	Estimated Cost	Remarks
Thermostat	$ 20.00/EA	Recalibrate Existing
Thermostat	$ 80.00/EA	Replace Existing with New
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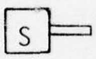
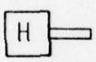
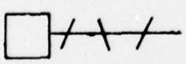
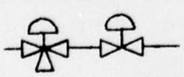
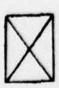
Receiver/ Controller	$ 200.00/EA	New
Ratio Relay	$ 40.00/EA	New
Duct Sensor	$ 100.00/EA	New
Control Panel	$ 250.00/EA	One Control Panel Per System
Room Sensor	$ 80.00/EA	Replace Existing Thermostat with Sensor
Control Valve	$ 100.00/EA	Recalibrate Main Control Valve
Pneumatic Tubing	$ 0.20/ to 2.00/LF	Tubing Cost Varies With Type (Plastic or Copper), Building Construction, Complexity and Accessibility.
Miscellaneous		Cost for Adjustments Are Included in the Above Estimates.

TABLE 3 - RETROFIT COST ESTIMATE ASSUMPTIONS

Item	Estimated Cost	Remarks
Cooling Coil Controls		
Receiver/Controller	$ 200.00	New
Duct Sensor	100.00	New
Control Valve	100.00	Recalibrate Main Control Valve
TOTAL	$ 400.00	Typical Controls Cost for Cooling Coil
Heating Coil Controls		
Receiver/Controller	$ 200.00	New
Duct Sensor	100.00	New
Control Valve	100.00	Recalibrate Main Control Valve
TOTAL	$ 400.00	Typical Controls Cost for Heating Coil
Preheat Coil Controls		
Receiver/Controller	$ 200.00	New
Duct Sensor	100.00	New
Control Valve	100.00	Recalibrate Main Control Valve
TOTAL	$ 400.00	Typical Controls Cost for Preheat Coil
Economizer Controls		
Receiver/Controller (2 Required)	$ 400.00	New
Duct Sensors (3 Required)	300.00	New
TOTAL	$ 700.00	Typical Control Cost for Economizer

Notes:
1. For Economizer control, damper repair may require consideration.
2. No tubing costs are included in the above estimates. Typically 150 to 200 feet of tubing may be considered per air handling unit.

C LEGEND

Symbol	Abbreviation	Description
	M	Main Air Supply
	HI,LO	Highest Pressure Signal, Lowest Pressure Signal
	STAT	Space Thermostat
	H	Space Humidity Sensor
	S	Space Temperature Sensor
		Duct Temperature Sensor
		Duct Humidity Sensor
	R/C	Receiver Controller (Master/Submaster)
	R/R	Ratio Relay
		Damper
		Control Valves
		Heating Coil
		Cooling Coil
	T.R.	Throttling Range
	S.P.	Set Point
	S.A.	Supply Air

D PRECAUTIONS AND TECHNICAL NOTES

1. It is critical that the set points of the sample zone thermostats remain properly adjusted as the sample zone thermostats control the temperatures at the central air handling units. A single thermostat can cause the entire system to use more energy than necessary by forcing the air temperatures too high or too low.

   To eliminate thermostat tampering, the use of non-adjustable temperature sensors with remote controllers is recommended. Alternately, the covers of adjustable thermostats can be replaced with covers that discourage tampering.

2. Sample zones must be selected with great care as all sample zones must be representative of the building's general heat transfer characteristics. For example, a Southwest zone with large window loads and no sun shade devices would not be a good sample zone.

3. It may be necessary to perform air and water balance for the HVAC system to obtain maximum performance from a Dead Band retrofit.

4. Ratio relays are used in conjunction with existing control valves and damper operators to make them compatible with the Dead Band controls. Control valves equipped with pilot positioners may not need a ratio relay.

5. Existing space thermostats may be incorporated if they are recalibrated to provide a throttling range of 10F.

6. Dead Band control strategies shown in this guide are in terms of pneumatic control instrumentation. The fact that an existing HVAC system may be equipped with an electric or electronic control system does not eliminate it as a candidate for Dead Band retrofit. For example, with electric controls a variable voltage output would be analagous to a variable air pressure output, and control sequences would be arranged accordingly.

7. All computer simulations were performed at constant fan motor speed. Further study is needed to determine exact savings from varying fan motor speed.