A NETWORK APPROACH TO SELECTION OF AIR CONDITIONING SYSTEMS FOR ARCHITECTURAL PROJECTS

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CHAPTER I

THE PROBLEM

Introduction

In this study a network process is developed to serve as a guide for the preliminary selection of an air conditioning system for a particular building type. This network is formulated to provide the designer with an additional design tool to be used during the schematic development phase of the over-all project. The network provides a method of systematic conception of an air conditioning system for a particular project prior to the detailed design phases of the project.

This study also provides the designer with a brief description, advantages, and disadvantages for each of the major air conditioning systems being provided for present-day buildings. Each system is described in non-technical language with the aid of illustrations and diagrams that appear in the Appendix.

An example problem is presented in order to demonstrate how the network process functions.

Purpose of the Study

Many architects and other designers have no real feeling for the proper application of air conditioning systems. This study will provide these individuals with a design tool for guidance in the preliminary selection of a major air conditioning system for a particular building project.

At present no type of established network process is available for selecting air conditioning systems. Designers have their own methods but these methods as a rule are not well developed and not well documented. This study establishes a particular network method to analyze the different building types as well as the different air conditioning systems.

A working understanding of the major air conditioning systems is required as background information. Information provided herein includes; a brief description, advantages, and disadvantages for the individual systems.

Project Limitations

The air conditioning systems referred to in this study are individual systems. Many combinations of the different systems may be used, but before combinations of systems can be put together one must understand the individual systems. Such combinations will not be discussed in this study.

The development of the example problem has been limited to rating three air conditioning systems for one building type. Application of the method to other building types requires further development.

This project is not meant to provide a universally complete rating of the individual systems. The ratings must be individually established by designers who wish to use this network method for selecting air conditioning systems.

Definition of Terms

1. Air conditioning: the process of treating air so as to control simultaneously its temperature, humidity, cleanliness, and distribution to meet the requirements of the conditioned space.

2. Controller: a device which measures a controlled variable, such as temperature, humidity, and pressure, by means of a sensing element and compares the controlled variable with an input signal to produce a suitable action or impulse for transmission to the controlled device. Thermostats, humidistats, and pressure controllers are examples.

3. Controlled device: reacts to the signal received from a controller and varies the flow of the control agent. It may be a valve, damper, electric relay, or a motor driving a pump, fan, etc.

4. Transducer: converts the effect produced by the sensing element into an effect suitable for operation of the controlled device. In pneumatic systems, a mechanical transducer regulates the pressure of a compressed air energy source applied to the controlled device; in electric or electronic systems, the transducer regulates the flow of electrical energy.

5. Coanda effect: permits air to hug ceiling at reduced volumes, requires a non-obstructive single-plane ceiling, unless all ceiling breaks are at the end of the design throw.

CHAPTER II

DESCRIPTIONS OF AIR CONDITIONING SYSTEMS

All Air Systems

An all air system heats and cools at a central location. The conditioned air is then distributed throughout the building.

The all air system provides complete sensible and latent cooling capacity through the cold air supplied by the system. Heating is accomplished in the same location and additional heat may be provided at a remote zone with the use of a reheat element.

Advantages and disadvantages will be discussed with the individual systems.

Single Duct-Single Path

Single duct systems contain the main heating and cooling coils in a series flow air path, using a common duct distribution system at a common air temperature. Low velocity is generally used requiring larger ducts. Single duct-single path systems are usually single zone systems.

Advantages:

1. Low initial cost
2. Ease of control
3. Simple operation
4. Relative efficient performance
5. Uncomplicated central plant

6. Heat reclaim capabilities.

Disadvantages:

1. Generally poor control with low accuracy control of individual spaces.

2. Air balancing can be difficult when the system does not contain a built-in zone-balancing device.

3. The operation of the fans are continuous.

This system is well suited for:

1. Areas where the loads are generally uniform.

2. Good for low cost structure.

Dual Duct System

Dual duct systems contain the main heating and cooling coils in a parallel flow.

Air Path. This may be accomplished by a separate cold and warm air duct distribution system, which is blended at the terminal apparatus.

The dual duct system is suited for many types of structures.

1. Structures requiring many control points.

2. Buildings with highly variable sensible heat load.

3. Areas that have a reversing transmission load.

Advantages:

1. Individual room temperature control.

2. Centralized conditioning location.

3. Eliminates water, steam, drain piping, electrical equipment, wiring and filters from conditioned spaces.

4. Provides heating and cooling capacity at the same time.

5. Flexible air distribution system with economical operational cost.

6. Relatively efficient system.

Disadvantages:

1. Balancing is difficult if constant volume devices are not used.

2. Cost of establishing constant volume.

3. Space required due to handling air twice and provisions due to crossovers.

Multizone Systems

Multizone systems service a number of zones from a single central air handling unit. The requirements of the different zones are met by mixing cold and warm air through zone dampers at the central air handler in response to zone thermostats.

Advantages:

1. A separate supply duct is provided to each zone.

2. Individual zone temperature control.

3. Centralized conditioning, refrigeration, dehumidification, service and maintenance.

4. Relative economy of operation.

5. Quiet operation.

6. Relatively low income cost.

Disadvantages:

1. Packaged equipment usually limited to 12 zones.

2. Any zone thermostat handling more than one room can only control one room's temperature.

3. Addition of humidity is difficult to provide.

Variable Volume System

The variable volume system gets its name by the way the system functions. As the space load changes the volume of the conditioned air is regulated to meet the needs of the space. The variable volume concept may apply to volume variation in the main supply total air stream and/or to the zones of control.

Advantages:

1. May be applied to interior or perimeter zones.

2. Relatively inexpensive temperature control.

3. Heat recovery capability which lowers operating costs.

4. Unoccupied areas can be completely cut off from the system.

5. This system maintains a centralized conditioning and refrigeration plant. Centralized equipment provides for a common outdoor air intake as well as centralized service and maintenance.

Disadvantages:

1. The effects of minimum air distribution on the spaces air movement (Coanda effects).

2. Requires separate systems where interior and exterior zones are significant.

Air and Water Systems

In air and water systems both air and water are distributed to each space to perform the air conditioning function. The fan coil system is an exception. No centrally supplied air is provided and the heating may be done electrically instead of by water.

The heating and cooling functions are carried out by changing the air or water temperature, or both, to permit control of space temperatures during all seasons of the year.

Single Pipe System

During cold weather, hot water is circulated to the fan coil units. During hot weather, chilled water is circulated to the coil units. The operating engineer decides when to supply hot or chilled water.

Warning Statements

1. This system works well during those periods when only cooling or only heating is required in all the perimeter spaces.

2. When some spaces require heating while others require cooling the system is unable to satisfy the requirements. This system can be zoned to provide a degree of flexibility. Hot water can be supplied to some units while chilled water is supplied to other units.

3. This system has a low return air capability when the system is not located under windows.

Advantages:

1. Low initial cost.
2. Inexpensive individual room temperature control.
3. Confined room air circulation.
4. Economy of operation.
5. Minimum ductwork.
6. The units may be located under windows, over closets, in dropped ceilings, or furred down spaces.

Disadvantages:

1. All building layouts do not lend themselves to zoning.

2. Condensate from the fan coil unit must be disposed of. The condensate pan should be connected directly to a drain.

3. Outside air is sometimes difficult to achieve.

3 and 4 Pipe System

Multi-piping systems will contain either three or four pipes depending upon the selection of the system. The primary difference between the two systems is that a four-pipe system has a separate return line for both hot water and chilled water; while the three-pipe system contains a common return line for both hot and chilled water.

The multi-piping system provides hot and chilled water year-round at each fan-coil conditioner which then can function independently of other fan-coil conditioner.

Advantages:

1. The advantages listed for the single pipe system apply to this system.

2. Each fan-coil conditioner can either heat or cool depending on space needs.

3. Provides quick responses to thermostat settings.

4. Provides confined room air circulation.

Disadvantages:

1. The disadvantages listed for the single pipe system applies to these systems.

Additional Information:

1. The three pipe system has a lower initial cost than does the four pipe system.

2. The four pipe system has a lower annual operating cost than the three pipe system.

3. The four pipe system requires more space for piping than the three pipe system.

4. Three pipe systems limits flexibility and requires higher cold and hot water temperatures and therefore more water.

Fan Coil Conditioner

This type of system continuously recirculates air from within the perimeter space through a coil which is supplied with either hot or chilled water or electric heating coils. Thus the recirculated room air is either heated or cooled. This system can also be so designed to filter and remove moisture from the air as it is drawn into the unit enclosure.

The fan coil system is primarily suited for conditioning perimeter spaces. This system is often considered for multi-room buildings where ductwork cost may be prohibitive. There are two basic fan coil systems which consist of the single and multiple pipe system.

Induction System

Induction systems are primarily applicable to perimeter spaces in multi-story, multi-room buildings, subject to wide fluctuation in net sensible heat gain, and where unusual conditions of humidity control are not required. This type system is well suited for buildings that have reversing sensible heat characteristics.

The induction system is especially adaptable to handle the loads of modern skyscrapers where minimum space is desired for mechanical equipment.

Centrally conditioned primary air is supplied to the unit at high pressure. The high pressure air flows through small nozzles which induces secondary air flow from the room and over the secondary coil. Secondary air is either heated or cooled at the coil depending on the season, the room requirements, or both. The primary and secondary air is mixed and discharged to the room.

Advantages:

1. Individual room control is provided.

2. Smaller spaces are required with this system because the primary air is provided by a high velocity system. The space requirement for the central air handling apparatus is less because the system also uses the individual room air. The high velocity system means smaller ducts.

3. Under the window installation is available eliminating winter downdrafts.

4. The central location of the mechanical room provides central dehumidification, and quiet operation within the individual rooms.

5. When the building is unoccupied, since only a portion of the total load is handled by the air portion of the system, it may be turned off and the system will continue to function as a gravity heating system.

Disadvantages:

1. This system requires both an air and a steam, electrical, or hot water distribution system.

2. The units cannot be completely shut off.

3. This system requires changeover from heating to cooling.

4. This system may require zoning for changeover.

Terminal Reheat System

The reheat system is a modification of other all air or air and water systems. Its purpose is to permit zone or space control for areas of unequal loading; or to provide heating or cooling of perimeters areas with different exposures; or for process of comfort applications where close control of space conditions is required.

The reheat system is a secondary process being applied to either pre-conditioned primary air or induction air. The heating can be done by either water or electricity. The reheat boxes reduces pressure and attenuates noise as well as heats the air.

Advantages:

1. The medium for heating may be hot-water, steam, or electricity.

2. Provides capability for very close control of space temperature and humidity.

3. Offers infinite zoning capabilities.

4. Small space requirements.

Disadvantages:

1. Can be costly to operate.

2. Can be costly to install.

3. When water is used for heating there is liquid throughout the building.

Multiple Units or Unitary Systems

Unitary equipment evaluated here consists of window, through the wall conditioners, rooftop units and unitary air conditioners.

These systems provide a wide range of advantages and disadvantages even before the individual systems are studied.

Advantages:

1. Individual room control is provided simply and inexpensively in each unit.

2. Each unit provides an individual air distribution system. The occupant is usually provided with a convenient and simple means of adjustment.

3. Heating and cooling capacity is available at all times, independent of the mode of operation of other spaces in the building.

4. Units contain the manufacturers-matched components assuring consistant performance. Certified rating, and usually published performance data can be obtained on these types of units.

5. Improved reliability and better quality control is provided by the manufacturers assembly and connection of components.

6. Only one terminal zone or condition is affected in the event of equipment malfunction.

7. These systems provide savings in the initial cost, the area required for the equipment and installation time.

8. Responsibility for performance of complete package(s) rest with one manufacturer and his agents.

9. Equipment servicing spaces and become vacant can be turned off without affecting occupied spaces.

Disadvantages:

1. There are relatively few options with respect to coil sizing, condenser sizing, blowers and control choices.

2. Permanent modular wall penetrations or shielding must usually be accounted for, both architecturally and structurally.

3. Servicing can become a problem with multiple equipment to maintain.

4. Units often are too compactly designed.

5. Units often manufactured from light duty materials.

Window and Through the Wall Units

These systems are suited for high rise structures, educational facilities and hospitals and nursing homes. These systems are applicable for renovating of existing buildings.[1]

Advantages:

1. Require only electrical hook ups to be in full operation.

2. Relatively low initial cost.

Disadvantages:

1. Contain no humidification system.

2. A relatively high noise level exist both inside and outside of the conditioned space.

3. The installation must be on the perimeter of the structure.

4. These systems should not be used where there are proportionally high sensible load requirements.

Rooftop Systems

A unitary rooftop system has at least the fan and evaporator mounted on the roof. The compressor and condensing section may be mounted remotely, but is more often packaged with the fan and evaporator. The heating equipment may be located in the supply ducts, but is usually built into the unit. As a part of the package unit, it can be pretested prior to arrival at the job site.

Advantages:

1. Economical method for year-round air conditioning of buildings with relatively flat roofs.

2. Desirable when separate and independent control of relatively small areas within the building are required.

3. Particularly applicable to one-or-two story buildings, however they have been successfully used for six story buildings.

4. This system does not require a large amount of space within the structures.

Disadvantages:

1. The roof structure must have the ability to withstand the equipment loads.

2. Consideration must be given to the limitations of available crane or helicopter service to lift the equipment into position.

3. Rooftop units contain rotating equipment which generates noise and vibrations, and vibration isolation must be provided. The noise level emanating from the unit must be low enough to that it is not disturbing to the occupants of nearby buildings.

4. In a rooftop system, the air handler is always outdoors and above the conditioned space; thus, special consideration must be given

to weather proofing. Rain and show and in some areas, sand must be prevented from entering the structure.

5. In cold climates steps must be taken to prevent freezing of coils, circulation water and the cooling of fuel oil where it will not atomize or burn properly.

Panel Heating and Cooling Systems

Radiant panel systems provide controlled temperature room surfaces, which may be located in the floor, wall, or ceiling. The temperature is maintained by circulating water, air or electricity. This type of system can be used either as a sole means of conditioning a space or as a supplementary system.

A controlled temperature surface is referred to as a radiant panel if 50 percent or more of the heat transfer is by radiation to other surfaces seen by the panel.

The radiant panel system is suited for several types of structures:

1. It can be used as a perimeter system for office buildings.

2. Schools provide an excellent application for this system, except for very large spaces like an auditorium or gymnasium. There is no noise from the mechanical equipment to interfere with the instructional activities.

3. Hospitals can use this system as a supplemental system. This system provides:

> A draft-free, thermally stable environment combined with the advantages of not having any mechanical equipment or bacteria and virus collectors in the space.

4. Radiant panels have been successfully used around swimming pools, in apartment buildings and for industrial applications.

Advantages:

1. Comfort levels are better than those experienced in any other conditioning system because radiant loads are treated directly, and air motion in the space is at normal ventilation levels.[2]

2. Panel systems do not require any mechanical equipment at the outside walls, thus simplifying the wall, floor, and structural systems.

3. All the pumps, fans, filters, etc., are centrally located, simplifying maintenance and operation.

4. Air quantities supplied may be very low to the space, usually not exceeding the amount required for ventilation and dehumidification.

5. No space is required within the air-conditioned room for mechanical equipment. This can prove to be an extremely important factor when space is at a premium or where maximum cleanliness is essential. This is only true when the requirements for cooling and ventilation air can be provided by using the air within the space itself.

6. Individual room control can be obtained by means of throttling the water flow the panels or by a change in the temperature differential.

7. Cooling and heating may be obtained simultaneously, without central zoning or seasonal changeover, when 3 or 4 pipe systems are used. However this system is a complicated and an expensive one.

Warning Statements

1. In building where glass areas become greater and load changes occur more rapidly, the slow response and override effect of masonry panels have proven to be a great limitation.

2. Two major factors in the consideration of electric radiant panels are local electric codes and basic energy cost.

3. Early evaluation is necessary to utilize the radiant panel system to its full advantage in optimizing the physical building design.

4. The air-side design must be capable of maintaining humidity levels at or below design conditions at all times to eliminate the possibility of condensation on panels.

5. Cooling panels should not be used in or adjacent to high humidity areas. (Example: at 75^{o}F DB and 50% RH condensation will occur on the panel should the panel drop below 63^{o}F.)

6. Thermal expansion of the ceiling and other devices in or adjacent to the ceiling should be anticipated. The maximum ceiling area should be used for radiant panels.

7. As with any hydronic system, attention must be applied to the piping system design to avoid entrained air, high velocity or high pressure drop devices, or from pump and pipe vibrations.

Heating/Cooling Generation and Distribution

This section deals with the location of mechanical equipment, type of distribution systems, along with heating and cooling generation systems.

Equipment

1. Centralized equipment can be utilized for groups of large buildings. Centralizing equipment provides higher diversity, greater efficiency, less maintenance cost, and lower labor cost, as compared to individual plants. The economics of these systems require maximum use of heat recovery, and boilers, gas turbine and steam driven centrifugals and absorption chillers may be installed in combination in one plant.

2. Decentralization of equipment means that each building contains its own central equipment plant. The equipment provided must meet the needs of only one building instead of the needs of a group of buildings as provided by the centralization of equipment.

Heat Distribution System

1. Hot water distribution systems consists of warming the water in a heater and circulating it by means of pumps to the units which transfer heat to the spaces requiring heat. Hot water systems are divided into three temperature ranges. Each of these systems are closed systems, free from air and under pressure to prevent the formation of steam.

Low pressure water systems are limited to allowable working pressure of 160 psig with maximum water temperatures of 250^{o}F. Low temperature systems supply water below 250^{o}F. Medium temperature systems are those with operating temperatures about 250^{o}F and below 350^{o}F. High temperature water systems are those operating above 350^{o}F. The usual practical limit of temperature is approximately 450^{o}F, due to pressure limitations on pipe fittings, equipment, and accessories.

2. Steam heating distribution system uses the vapor form of water to supply heat to a conditioned space. Water is vaporized to establish the temperature and pressure at which it is supplied to the transfer element of the terminal equipment. In transfer, it is condensed, slightly cooled and subsequently returned to the source of reheating.

Steam systems may be classified according to one, or a combination, of the following features:

1. Piping arrangements.
2. Operating temperature ranges are below 250°F, 250°F to 305°F, and 305°F to 350°F and above.
3. Means of providing the flow causing gradient.

Electric Distribution System

Electricity is energy in a refined form which is simple to distribute and control. Electricity is distributed by wire throughout the buildings for many different purposes. Before electricity can be used for heating it must be converted into heat.

Cooling Distribution Systems

1. Chilled Water Systems - chilled water systems are defined as those operating with a usual design supply temperature of 40° to 50°F. The range of water temperature available for this type of system are relatively few in order to provide adequate dehumidification and, at the same time to avoid the hazard of freeze-up in the chiller.

2. Dry Expansion System - dry expansion is a process of heat removal by a refrigerant in an evaporator fed by a flow control, responsive to temperature or pressure or both at some point in the

evaporator, or to the difference between high and low side pressures, and not to the liquid level in the evaporator; all entering refrigerant is evaporated before being recirculated.

Direct-expansion coils are used in this system.

Heat Generation Systems

The type of fuel to be burned affects the design of heat exchanger, furnace, boiler, etc., to obtain maximum efficiency and best performance requires the simultaneous consideration of fuel and fuel-burning equipment during the initial stages of equipment selection.

Solid Fuel. Coal is the most common solid fuel being used today. Mechanical stokers are provided to feed the fuel into a combustion chamber. An important consideration is the removal of the ash and refuse from the combustion chamber.

Liquid Fuel. Fuel oil can be used as a source of energy. Fuel oil must be combined with air under controlled conditions for combustion. Ignition is accomplished by an electric spark, gas pilot frame, or oil pilot flame.

Gas Fuel. Natural gas burners convey gas, or a mixture of gas and air, to the combustion zone. Gas flow is regulated and a pilot ignites the gas for burning.

Electricity for Heating. Electric heating systems are ideally suited to space heating because it is simple to distribute and control. This system is often used where minimum initial cost is the dominating factor.

An electric heating unit is a frame, casing, or other supporting means containing one or more heating elements, electric terminal connections or leads, and electrical wiring and insulation, all assembled into a unit.

Electric heating elements usually are composed of metalalloy wire or ribbons, non-metallic carbon compounds in rod or other shapes, or printed circuits. Heating elements may have exposed resistor coils mounted on insulators, metallic resistors embedded within refractory insulation encased in a protective metal sheath, or a printed circuit on glass sheets or vitrified panels.

Refrigeration Generation System

Absorption Machines. These machines are a form of water chiller. The absorption process consists of a salt solution to absorb some of the water from the evaporator. The remaining water is thereby cooled by evaporation. This refrigeration effect is accomplished by putting a coil in the evaporator tank. Water from this tank is pumped to a spray header which wets the coil. The evaporation of the spray chills water in the coil. The source of energy for this system is either steam or water above 220^{o}F.

Centrifical Compressors. These machines operate at high speed. This type compressor has no valves or piston rings, which lower maintenance cost otherwise incurred with reciprocating compressors. Compression efficiency is lower however than with reciprocating compressors. These compressors can be driven by either steam or electricity.

<u>Reciprocating Compressors</u>. The reciprocating compressor is a positive displacement compressor in which the charge is internal volume of the compression chamber is accomplished by the reciprocating motion of one or more pistons. These compressors are electrically driven.

The majority of reciprocating refrigeration compressors are of the halocarbon and ammonia types. The most widely used is the halocarbon compressor.

Types of halocarbon compressors:

1. Open - Those in which the shaft extends through a seal in the crankcase for an external drive.

2. Semi-or bolted hermetic - those of bolted construction capable of field repair.

3. Welded shell hermetic - those which the motor-compressor is mounted inside a steel shell which in turn is sealed by welding.[3]

Ammonia compressors are manufactured only in the open type design.

Control Systems

Six basic types of control systems are used today. The systems are grouped according to primary sources of energy.

1. The Pneumatic System is the most commonly used system. This system utilizes compressed air, usually at a pressure of 15 to 25 psig. The air is supplied to the controller, which in turn regulates the pressure supplied to the controlled device.[4]

2. Self-Contained Systems combines the controlled, the controlled device in one unit and employs the power of the measuring system to effect the necessary corrective action.[5]

3. Hydraulic Systems utilizes suitable liquid under pressure. Hydraulic systems are mainly used where large forces are required to operate controlled devices.

4. Electric Systems consist of switching, adjusting electric circuits to govern electric motors, relays or solenoids. The individual units of this type of system are interconnected by line voltage or low voltage wiring.

5. Electronic Systems amplify electric energy to increase minute voltage variations. The increased voltage is required to operate standard electrically controlled devices.

6. Combination Electric-Pneumatic Systems utilize compressed air to operate the controlled devices. Electronic amplifier's output is converted into suitable air pressure changes by using an electronic-pneumatic transducer.[6]

Control systems are further subdivided into manual, automatic, two position, and modulating systems.

Manual Control Systems

These systems are regulated entirely by hand. They are not only turned on and off but are adjusted by an individual.

Automatic Control Systems

The automatic control system is responsive to changes of pressure, temperature or other property whose magnitude is to be regulated by means of independent sensing devices. Automatic controls enable more accurate control systems and conserve manpower.

Two-position systems are also referred to as "on and off" control or as "positive acting" control system. The two-position control system is the simplest method of providing regulation. Two-position systems are most generally used where the controlled device is a relay, valve, or switch. This is an economical control system.

Modulating controls are also known as gradual or graduated acting control or as "proportioning controls." Modulating control causes motion in the controlled device in proportion to motion produced in the controller by practical degree variations in the medium to which the controller is responsive.

When evaluating the control systems performance there are four main factors which requires special attention.

1. System Stability - the absence of periodic control oscillations.
2. Control Offset - the minimum difference between the set point and the actual control point under stable conditions.
3. System Response - the ability to correct rapidly for system disturbances.
4. Cost - initial and operating.

FOOTNOTES

[1]American Society of Heating, Refrigerating and Air Conditioning Engineers. ASHRAE Guide to Systems (New York, 1973), p. 6.4

[2]American Society of Heating, Refrigerating and Air Conditioning Engineers. ASHRAE Guide to Systems (New York, 1973), p. 8.1

[3]American Society of Heating, Refrigerating and Air Conditioning Engineers. ASHRAE Guide and Data Book Equipment (New York, 1969), p. 130.

[4]American Society of Heating, Refrigerating and Air Conditioning Engineers. ASHRAE Guide to Systems (New York, 1973), p. 34.10.

[5]American Society of Heating, Refrigerating and Air Conditioning Engineers. ASHRAE Guide to Systems (New York, 1973), p. 34.11.

[6]Ibid.

CHAPTER III

THE NETWORK SELECTION PROCESS

Design Categories

The network is made up of fifteen (15) design categories. These categories are presented according to the way in which the information generally becomes available during the development of the project. The fifteen categories are:

A. External Environmental Conditions and Locations
B. Make Up Air Requirements
C. Cost Considerations
D. Types of Contractural Arrangements
E. Internal Temperature and Humidity Requirements
F. Building Types
G. Duration of Design Conditions
H. Architects Design Concept
I. Diversity of Internal Loads
J. Physical Space Allocations
K. How the Air Will Enter the Space
L. Noise and Vibration Control
M. System Control
N. Preheating and Precooling Requirements
O. Pollution Discharge Requirements

Similar types of structures, that are of the same general size and used for the same purposes are classified as building types. Schools, churches and hospitals are examples of different building types.

Each category is rated according to its importance, for the particular building type being planned. Each category is given a percentage value (Total = 100%) which then becomes constant for the building type.

Pertinent Questions

The following questions are used in conjunction with both rating systems.

A. External Environmental Conditions and Locations

A1. How important is the geographical location?
A2. How important is the variation in temperature?
A3. How important is the variation in humidity?
A4. Prevailing wind direction and its average speed?
A5. Exposure to the sun or other heat exchanges?
A6. How important are the surrounding site conditions?

B. Make Up Air Requirements

B1. How important is the code requirement?
B2. How important is the amount of air to be exhausted?
B3. How important is the amount of air to be returned to the unit?
B4. How important is the amount of outside air for ventilation?

C. Cost Considerations

C1. How important is the investor's objective?
C2. How important is the initial cost of the system?
C3. How important is the operational cost of the system?
C4. How important is the cost of maintenance?

D. Types of Contractural Arrangements

D1. How important is self ownership?
D2. How important are rental agreements?
D3. How important are cooperative agreements?
D4. How important are condominium agreements?
D5. How important are dormitory agreements?

E. Internal Temperature and Humidity Requirements

E1. How important are the internal temperature range limits?
E2. How critical is the climatic environment?

F. Building Types

F1. Importance of one story or multi-story building?
F2. How important is a low ceiling with a floor above?
F3. How important is a high ceiling with a floor above?
F4. Importance of flexible or fixed plan?
F5. Importance of open or closed plan?
F6. Importance of high heat loss or low heat loss?

G. Duration of Design Conditions

G1. How important is the duration of the day and year for which the design conditions are required?

H. Architects Design Concept

H1. How important is the shape of the building?
H2. How important is north, south orientation?
H3. How important is the overhang and its location?
H4. How important is the amount and type of glass?
H5. How important is the type of building material?
H6. How important is the type of structural system?
H7. How important are the types of people using the structure?

I. Diversity of Internal Loads

I1. How important is the amount of latent heat in the structure?
I2. How important is the amount of sensible heat in the structure?
I3. How important is the occupancy loads?
I4. How important is the lighting load?
I5. How important is appliance loading?

J. Physical Space Allocations

J1. How important is the size of the equipment room?
J2. How important is the space allocation for the air conditioning system?

K. How is the Air to Enter the Space

K1. How important is it for the air to enter through the wall?
K2. How important is it for the air to enter through the ceiling?
K3. How important is the return air system?

L. Noise and Vibration Control

L1. How important is the control of the noise level due to mechanical equipment?
L2. How important is the control of the vibration noise due to mechanical equipment?
L3. How important is the control of the noise due to air velocity?
L4. How important is the control of the noise transmission between spaces?

M. System Controls

M1. How important is individual unit control?
M2. How important is zone control?

M3. How important is the ease of balancing the system?
M4. How important is the type of control desired?
M5. How important is the change over capability of the system?

N. Preheating and Precooling Requirements

N1. How important is the necessity and capability for preheating and precooling?

O. Pollution Discharge Requirements

O1. How important is the prevention of pollution into the air?
O2. How important is the prevention of pollution into the water system?

Rating Scale for "Buildings"

Since air conditioning systems perform differently when applied to different buildings, the rating value varies according to building type. Each of the pertinent questions are rated as to value for the particular building. A seven point scale is used for rating as follows:

+3 Extremely Important Consideration
+2 Important Consideration
+1 More than Average Requirement
0 An Average Requirement
-1 Less than Average Requirement
-2 Little Importance
-3 No Importance

Rating Scale for "Systems"

Since air conditioning systems have advantages and disadvantages, their rating values also vary. Each of the pertinent questions are rated as to the value of the specific system. A seven point value scale is used for rating as follows:

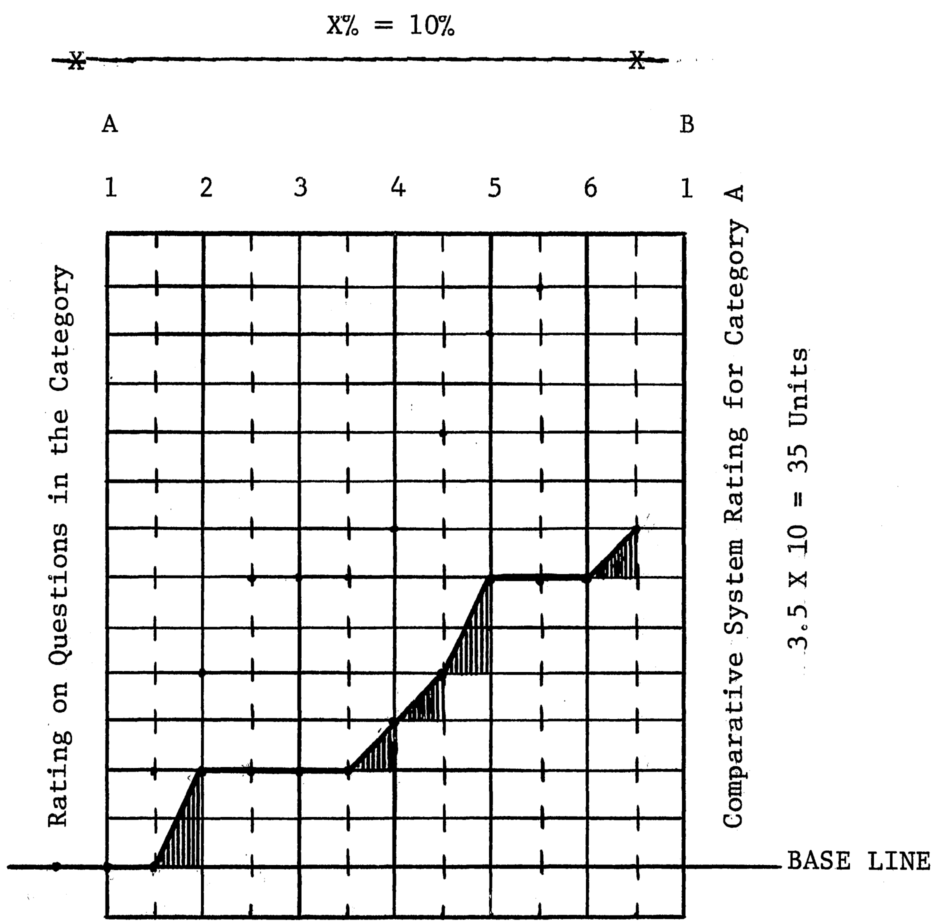
+3 System is Extremely Proficient
+2 System Performs Well Above Average
+1 System Performs Better than Average
0 System Performs Adequately

-1 System Performs Below Average
-2 System Performs Far Below Average
-3 Is Not Provided (impossible application of system)

Example Network

The physical make up of the network is graphically divided into fifteen design categories labeled A through O. The significance of a category depends on the percentage importance established by the designer. Each category has two parts per question. The resulting position on the solid vertical line on Figure 1 represents the rated value as applicable to the "building" while the position on the vertical dashed line represents the rated value of the "system." Once a rating is established, it need not be reestablished until further updating information is available with regard to the "building" or the "system".

A base line is established for the comparison of several systems for the particular building at hand. As each "building" rating is placed on the graph its position becomes a new working point for the "system" rating. This position becomes the starting point for the next question. A portion of a network flow chart is shown on Figure 1.



Design Category "A"

The distance from A to B represents the importance of the category compared to the entire system e.g. X%.

——— The solid lines are the building ratings.

- - - Dashed lines are the systems rating.

QUESTION	"BUILDING"	"SYSTEM"
A1	+0	+0
A2	+2	+0
A3	0	0
A4	+1	-1 +1
A5	+2	+0
A6	-0	+0 +1

Figure 1. Example Portion of the Network Flow Chart for Single Duct System

In order to establish a comparative rating for the system, either of the following two procedures may be used.

The "area under the curve" is accumulated for each of the fifteen (15) categories. The area of a category is multiplied by the percentage value for that category. Once the fifteen (15) category values are determined they are added together to form the comparative system rating. In Figure 1 category A is presented as an example. The shaded portion of the network represents the area under the graph. This area is 4.5 units. The percentage value in this case is X%, therefore, to arrive at the category value the area (4.5) is multiplied by the percentage value (X) to produce the category rating. This rating along with the fourteen (14) others makes up the total comparative system rating.

The comparative system rating can also be determined by taking the vertical difference between the starting point of a category and the final point of that category. This value is multiplied by the category percentage value and divided by two (2). The individual category values are added together forming the comparative system rating. For category A in Figure 1, the difference in vertical heights between the starting point and the final point is nine (9) units. Nine is then multiplied by the percentage value (X) and then divided by two (2) in order to get the category rating. This rating along with the fourteen (14) others are added together forming the comparative system rating.

Upon completion of the analyses of all the comparative system ratings, the best system may be selected; it will be the one with the largest comparative system value.

CHAPTER IV

EXAMPLE APPLICATION OF NETWORK PROCESS

Building Project Description

This example problem is developed utilizing a school to illustrate how each portion of the network functions. The school is located in Oklahoma with a sunny south exposure in a high socio-economic area with high buildings located to the north of the school.

The school contains facilities for six hundred (600) middle school students. This facility is three stories tall. The classrooms are designed to work mainly from a double loaded corridor scheme. The classrooms themselves are designed on a fixed planned scheme. The building contains 30% ordinary glass on the north and south while the east and west exposures contains 10% glass.

The mechanical equipment room is centrally located in the basement of the building. The central location provides many advantages; for example, shorter runs both vertically and horizontally for the duct work.

A concrete framing system is employed for this building with precast tees for the roof. The building envelope is constructed of brick. The building contains twelve (12) foot high ceilings throughout the first floor with eight (8) foot ceilings on the second and third floors. The built up roof used on this building consists of 2" concrete topping on the tees with 1 1/2" rigid insultation with 20 year built up roof.

The school is designed to be used year round. Its main hours of operation are 9 a.m. to 3:30 p.m. and from 7 to 10 in the evening. Both heating and cooling must be provided to meet the year round temperature conditions.

Systems Under Consideration

The network analysis method will be applied to three individual air conditioning systems. The systems are (1) single duct air system, (2) dual duct air system, and (3) an air and water induction system. For detailed information concerning these systems see Chapter II.

Importance of Design Categories

The fifteen (15) design categories are rated according to their importance as estimated by the designer. These values may become constant for buildings of similar type and size. The categories and weighting values selected for use in this study of a school are as follows:

A	External Environmental Conditions and Locations	10%
B	Make Up Air Requirements	3%
C	Cost Considerations	10%
D	Type of Contractural Arrangements	3%
E	Internal Temperature and Humidity Requirements	10%
F	Building Type	5%
G	Duration of Design Conditions	10%
H	Architects Design Concept	10%
I	Diversity of Internal Loads	7%
J	Physical Space Allocations	3%
K	How the Air Will Enter the Space	5%
L	Noise and Vibration Control	10%
M	System Control	6%
N	Preheating and Precooling Requirements	3%
O	Pollution Discharge Requirements	5%
	Totaling	100%

Rating Scales for "Buildings" and "Systems"

The building designer must rate each of the pertinent questions found listed for the fifteen (15) categories. The "building" rating scale establishes the degree of importance of the function for the specific building. The "systems" rating scale provide how well the particular system will perform in accordance to the question. The rating scales are listed below.

"Buildings"

+3 Extremely Important Consideration
+2 Important Consideration
+1 More than Average Requirement
0 An Average Requirement
-1 Less than Average Requirement
-2 Little Importance
-3 No Importance

"Systems"

+3 System is Extremely Proficient
+2 System Performs Well Above Average
+1 System Performs Better than Average
0 System Performs Adequately
-1 System Performs Below Average
-2 System Performs Far Below Average
-3 Is Not Provided

Pertinent Questions and Replies

The pertinent questions discussed in Chapter III are asked for each category. Under the question is found the "building" rating and a brief explanation for its rating. The "system" rating is then listed with a brief explanation for its rating.

The system being considered in this example is the dual duct air system.

A External Environmental Conditions and Locations

Question A_1 How important is the geographical location?

"Building" Oklahoma is centrally located in the United States with no extreme conditions.

Rating: Average Requirement 0

"System" Dual duct performs well in this climate.

Rating: Performs Well Above Average +2

Question A_2 How important is the variation in temperature?

"Building" Oklahoma has a wide range of temperatures. Temperature variation has a significant effect on the learning process.

Rating: Important Consideration +2

"System" Dual duct accommodates temperature changes very well.

Rating: Performs Well Above Average +2

Question A_3 How important is the variation in humidity?

"Building" An average humidity condition exist in Oklahoma.

Rating: Average Requirement 0

"System" D.D. permits only average humidity control.

Rating: Performs Adequately 0

Question A_4 Prevailing wind direction and its average speed.

"Building" A south, southeast wind direction prevails in Oklahoma with an average speed of 15 m.p.h.

Rating: More than Average Requirement +1

"System" D.D. will handle load changes due to wind conditions (infiltration) very well.

Rating: Important Consideration +2

Question A_5 Exposure to the sun or other heat exchanges.

"Building" A very hot sun prevails in Oklahoma.

Rating: Important Consideration +2

"System" D.D. accommodates loads changes due to solar conditions quite well.

Rating: Better Than Average +1

Question A_6 How important are the surrounding site conditions?

"Building" No extreme conditions exist around this project.

Rating: Average Requirement

"System" D.D. is extremely flexible permitting accommodation of possible changing conditions.

Rating: Extremely Proficient +3

B Make Up Air Requirements

Question B_1 How important is the code requirement?

"Building" Code requirements for schools are not extreme.

Rating: Average Requirement 0

"System" D.D. systems can meet code requirements.

Rating: Performs Adequately 0

Question B_2 How important is the amount of air to be exhausted?

"Building" Only a small amount is exhausted if any due to amount of infiltration.

Rating: Less Than Average Requirement -1

"System" D.D. can exhaust a sufficient quantity of air.

Rating: Performs Adequately 0

Question B_3 How important is the amount of air to be returned to the unit?

"Building" For economy of operation return of most air is desirable.

Rating: More Than Average Requirement +1

"System" D.D. can return any amount of air.

Rating: Performs Better Than Average +1

Question B_4 How important is the amount of outside air for ventilation?

"Building" Due to the social level high ventilation rates are not required.

Rating: Less Than Average Requirement -1

"System" D.D. can provide large amounts of ventilation air.

Rating: Performs Well Above Average +2

C Cost Considerations

Question C_1 How important is the investor's objective?

"Building" This being a public building requires the most economical system to be used.

Rating: Important Consideration +2

"System" D.D. is a satisfactory long range investment.

Rating: Performs Adequately 0

Question C_2 How important is the initial cost of the system?

"Building" Initial cost is of less importance than the long range investment.

Rating: Less Than Average Requirement -1

"System" Initial cost of a dual duct system is higher than many other systems.

Rating: Performs Below Average -1

Question C_3 How important is the operational cost of the system?

"Building" School systems require economical operation.

Rating: More Than Average Requirement +1

"System" D.D. provides relatively economic operation.

Rating: Extremely Proficient +3

Question C_4 How important is the economy of fuel?

"Building" School systems require the most economical fuel consumption.

Rating: More Than Average Requirement +1

"System" D.D. adapts well to any fuel.

Rating: Extremely Proficient +3

D Types of Contractural Arrangements

Question D_1 How important is self ownership?

"Building" This is a public owned project with an average contractural arrangement.

Rating: Average Requirement 0

"System" D.D. systems adapt satisfactorily to any type of ownership.

Rating: Performs Better Than Average +1

Question D_2 How important are rental agreements?

"Building" Not applicable.

Rating: No Importance -3

"System" Not applicable.

Rating: Performs Adequately 0

Question D_3 How important are cooperative agreements?

"Building" Not applicable.

Rating: No Importance -3

"System" Not applicable.

Rating: Performs Adequately 0

Question D_4 How important are condominium agreements?

"Building" Not applicable.

Rating: No Importance -3

"System" Not applicable.

Rating: Performs Adequately 0

Question D_5 How important are dormitory agreements?

"Building" Not applicable.

Rating: No Importance -3

"System" Not applicable.

Rating: Performs Adequately 0

E Internal Temperature and Humidity Requirements

Question E_1 How important are the internal temperature range limits?

"Building" Schools require only an average temperature range. No extreme conditions exist.

Rating: Average Requirement 0

"System" D.D. can provide very good climatic control.

Rating: Performs well above average. +2

Question E_2 How critical is the climatic environment?

"Building" The internal climatic environment is of an average nature.

Rating: Average Requirement 0

"System" D.D. can provide very good climatic control.

Rating: Performs Well Above Average +2

F Building Types

Question F_1 Importance of multi-story buildings?

"Building" This three story building poses no real problem

Rating: Average Requirements 0

"System" D.D. provides good conditioning for multi-story buildings.

Rating: Performs Well Above Average +2

Question F_2 How important is a low ceiling with a floor above?

"Building" Not applicable.

Rating: No Importance -3

"System" Not applicable.

Rating: Performs Adequately 0

Question F_3 How important is a high ceiling with a floor above?

"Building" Its a condition which requires some thought.

Rating: More Than Average Requirement +1

"System" D.D. systems can usually be accommodated with ducts occurring in furred down areas with mixing boxes and low pressure ductworks in restricted ceiling spaces.

Rating: Performs Adequately 0

Question F_4 Importance of flexible plan?

"Building" When things are subject to change from time to time flexibility becomes of great importance.

Rating: Extremely Important Consideration +3

"System" D.D. adapts to flexible plans very well.

Rating: Performs Better Than Average +1

Question F_5 Importance of a closed plan.

"Building" The major characteristic of the space is known and must be provided for.

Rating: Important Consideration +2

"System" D.D. can be designed to fit closed plans very well.

Rating: Performs Better Than Average +1

Question F_6 Importance of high heat loss or low heat loss.

"Building" Due to three story construction the heat loss is a small consideration.

Rating: Less Than Average Requirement -1

"System" D.D. accommodates high and low heat loss better than most systems.

Rating: Performs Better Than Average. +1

G Duration of Design Load

Question G_1 How important is the duration of the day and year for which the design conditions are required?

"Building" The school is used from 9 a.m. to 3:30 p.m. and 7 to 10 in the evening, throughout the year.

Rating: Average Requirement 0

"System" D.D. handles the design conditions adequately.

Rating: Performs Adequately 0

H Architects Design Concept

Question H_1 How important is the shape of the building?

"Building" The building is a conventional design.

Rating: Average Requirement 0

"System" D.D. adapts to conventional designs well.

Rating: More Than Average Requirement +1

Question H_2 How important is north, south orientation?

"Building" The orientation of this project adapts well to the hot Oklahoma sun conditions.

Rating: More Than Average Requirement 1

"System" D.D. can accommodate north, south orientation.

Rating: Performs Adequately 0

Question H_3 How important is the overhang and its location?

"Building" The overhang on this building is very limited.

Rating: Less Than an Average Amount -1

"System" D.D. can adapt to varying loads resulting from shade or unshaded areas better than most systems

Rating: Performs Well Above Average +2

Question H_4 How important is the amount and type of glass?

"Building" 30% glass on north and south, 10% on the east and west. Clear plate glass is used in normal school construction.

Rating: Average Requirement 0

"System" D.D. adapts well to limited glass area design.

Rating: Performs Better Than Average +1

Question H_5 How important is the type of building materials?

"Building" The building is constructed from both heavy and light materials.

Rating: Average Requirement 0

"System" D.D. systems can adapt to either heavy or light construction very well.

Rating: Performs Better Than Average +1

Question H_6 How important is the type of structural system?

"Building" A concrete structural system can be designed to provide minimum structural depth.

Rating: More Than Average Requirement +1

"System" D.D. systems adapt well to minimum structural depth systems.

Rating: Performs Better Than Average +1

Question H_7 How important are the types of people using the structure?

"Building" The people using this structure are for the most part young individuals.

Rating: Average Requirement 0

"System" D.D. are generally arranged so that they are out of the reach of children.

Rating: Performs Adequately 0

I Diversity of Internal Loads

Question I_1 How important is the amount of latent heat in the structure?

"Building" Due to the large number of people this becomes an above average consideration.

Rating: More Than Average Requirement +1

"System" D.D. handles latent loads well.

Rating: Performs Well Above Average +2

Question I_2 How important is the amount of sensible heat in the structure?

"Building" Due to relatively high occupancy and lighting loads this becomes an above average condition.

Rating: More Than Average Requirement +1

"System" D.D. handle sensible loads well above average.

Rating: Performs Better Than Average +1

Question I_3 How important is the occupancy loads?

"Building" This is an important consideration due to the air distribution and ventilation requirements.

Rating: Important Consideration +2

"System" D.D. accommodates large occupancy considerations

Rating: Performs Well Above Average +2

Question I_4 How important is the lighting load?

"Building" Due to a high lighting level being required this is an important consideration.

Rating: Important Consideration +2

"System" D.D. accommodates lighting load as well as most systems.

Rating: Performs Adequately 0

Question I_5 How important is appliance loading?

"Building" Schools have relatively few appliances.

Rating: Average Requirement 0

"System" D.D. can accommodate appliance loads reasonably well.

Rating: Performs Adequately 0

J Physical Space Allocations

Question J_1 How important is the size of the equipment room?

"Building" This becomes an important consideration due to better utilization of space.

Rating: Important Consideration +2

"System" D.D. require larger spaces than most systems.

Rating: Below Average -1

Question J_2 How important is the above ceiling space allocation for the air conditioning system?

"Building" The amount of space between the floor and ceiling is of major concern.

Rating: Important Consideration +2

"System" D.D. require larger spaces than most systems.

Rating: Below Average -1

K How is the Air to Enter the Space

Question K_1 How important is it for the air to enter through the wall?

"Building" Not applicable.

Rating: No importance -3

"System" D.D. cannot accommodate both ducts and mixing boxes in the corridor ceiling so sidewall registers cannot be used.

Rating: Is Not Provided -3

Question K_2 How important is it for the air to enter through the ceiling?

"Building" Opportunity for draft free space is of importance.

Rating: Important Consideration +2

"System" D.D. provides good air distribution through the ceiling.

Rating: Performs Well Above Average +2

Question K_3 How important is the return air system?

"Building" To comply with fire codes for high occupancy usage this is an extremely important consideration.

Rating: Extremely Important Condition +3

"System" D.D. can accommodate most return air systems pretty well.

Rating: Performs Better Than Average +1

L Noise and Vibration Control

Question L_1 How important is the control of noise level due to mechanical equipment?

"Building" This is of some concern since a school is a relatively quiet atmosphere.

Rating: Important Consideration +1

"System" D.D. adequately handles noise from the equipment.

Rating: Performs Adequately 0

Question L_2 How important is the control of the vibration noise due to mechanical equipment?

"Building" Distracting noise must be prevented from the equipment.

Rating: More Than Average Requirement +1

"System" D.D. provides adequate protection from vibration noises.

Rating: Performs Adequately 0

Question L_3 How important is the control of the noise due to air velocity?

"Building" This type of noise cannot be allowed in school rooms.

Rating: Important Consideration +2

"System" D.D. uses good sound attenuation in mixing boxes.

Rating: Performs Better Than Average +1

Question L_4 How important is the control of noise transmission between spaces?

"Building" This must be prevented, the concern here is that noise transmitted by the way of ducts or openings for ducts.

Rating: Extremely Important Consideration +3

"System" D.D. can accommodate adequately for noise control between spaces.

Rating: Performs Adequately 0

M System Control

Question M_1 How important is individual ~~zone~~ unit control?

"Building" Each room requires individual control.

Rating: Extremely Important Consideration +3

"System" D.D. provides well for individual unit control.

Rating: Extremely Proficient +3

Question M_2 How important is individual zone control?

"Building" Each zone requires individual control.

Rating: Extremely Important Consideration +3

"System" D.D. provides individual zone control.

Rating: Extremely Proficient +3

Question M_3 How important is the ease of balancing the system?

"Building" Balancing the system becomes a concern due to varied loads.

Rating: More Than Average Requirement +1

"System" D.D. provides better then average balancing capabilities.

Rating: Performs Better Than Average +1

Question M_4 How important is the type of control desired?

"Building" A good quality control system is required for reliability and maintenance.

Rating: More Than Average Requirement +1

"System" D.D. permits use of a good control system.

Rating: Performs Better Than Average +1

Question M_5 How important is the change over capability of the system?

"Building" Due to changing load conditions sudden change from heating to cooling may be required.

Rating: Extremely Important Condition +3

"System" D.D. permits heating and cooling simultaneously.

Rating: Extremely Proficient +3

N Preheating and Precooling Requirements

Question N_1 How important is the necessity and capability for preheating and precooling?

"Building" This capability is important to minimize personnel operating cost.

Rating: Important Consideration +2

"System" D.D. can adequately handle preheating and precooling requirements.

Rating: Performs Adequately 0

O Pollution Discharge Requirements

Question O_1 How important is the prevention of pollution into the air?

"Building" The building must meet the current standards.

Rating: Average Requirement 0

"System" D.D. can adequately prevent air pollution.

Rating: Performs Adequately 0

Question O_2 How important is the prevention of pollution into the water?

"Building" The building must meet the current standards.

Rating: Average Requirement 0

"System" D.D. can adequately prevent water polluation.

Rating: Performs Adequately 0

The single duct air system and the air and water induction system were evaluated in the same manner. The rating values for these systems have been provided for comparison purposes.

Table I provides an easy form for coordinating the "building" rating and the "system" rating. The rating values listed in the table are used in establishing the graphical network for the individual systems.

System Selection

The comparison of the graphical plots of the individual air conditioning systems is used in selecting the best system. The graphical plots are shown in Figures 2, 3, and 4. The mathematical calculations for the individual systems are shown in Table 2. The calculations show that the dual duct system is the best system for this particular school project. The dual duct system has a rating of 310 units, while the induction system has 277 units, and the single duct system has only 149 units.

Should two of the systems have ended with the same number of units, a question then arises as to which system to select. The designer then may choose the system to be used. His decision may be based on previous experience or his familiarity of one system over the other. Either system will be equally acceptable by the network process.

The "building" ratings and the "system" ratings for this example problem were confirmed by Mr. James C. Netherton, Jr., who is a principal of Netherton, Solnok and Associates, Consulting Engineers, Tulsa, Okla.

TABLE I

TABULATION OF RATINGS FOR THREE AIR CONDITIONING SYSTEMS FOR APPLICATION IN A MIDDLE SCHOOL

"BUILDING"					"SYSTEMS"						
	QUESTION	SCHOOL	RATING			SINGLE DUCT		DUAL DUCT		INDUCTION	
	A1		0			0		+2		+2	
	A2		2			0		+2		+2	
	A3		0			0		0		0	
	A4		1			+1		+2		+2	
	A5		2			0		+1		+1	
	A6		0			+1		+3		+3	
	B1		0			0		0		+1	
	B2		-1			0		0		0	
	B3		1			0		+1		+1	
	B4		-1			+2		+2		+2	
	C1		2			0		0		0	
	C2		-1			+2		-1		-2	
	C3		1			+1		+3		+3	
	C4		1			0		+3		-1	
	D1		0			+1		+1		+1	
	D2		-3			0		0		0	
	D3		-3			0		0		0	
	D4		-3			0		0		0	
	D5		-3			0		0		0	
	E1		0			0		+2		+3	
	E2		0			-1		+2		+3	
	F1		0			0		+2		+2	
	F2		-3			0		0		0	
	F3		1			+1		0		0	
	F4		+3			+1		+1		+1	
	F5		2			0		+1		-1	
	F6		-1			0		+1		+1	
	G1		0			0		0		0	
	H1		0			0		+1		+2	
	H2		1			0		0		0	
	H3		-1			0		+2		+2	
	H4		0			-1		+1		+1	
	H5		0			0		+1		0	
	H6		1			0		+1		0	
	H7		0			0		0		-1	
	I1		1			0		+2		+1	
	I2		1			0		+1		+1	
	I3		2			0		+2		+1	
	I4		+2			0		0		0	
	I5		0			0		0		+1	
	J1		2			+1		-1		0	
	J2		2			+2		-1		0	
	K1		-3			-3		-3		-3	
	K2		2			+1		+2		-3	
	K3		3			+1		+1		+3	
	L1		1			0		0		0	
	L2		1			0		0		0	
	L3		2			-1		+1		+1	
	L4		3			0		0		+2	
	M1		3			0		+3		+3	
	M2		+3			0		+3		+3	
	M3		1			+2		+1		0	
	M4		1			0		+1		+1	
	M5		3			-1		+3		+1	
	N1		2			0		0		0	
	O1		0			0		0		0	
	O2		0			0		0		0	

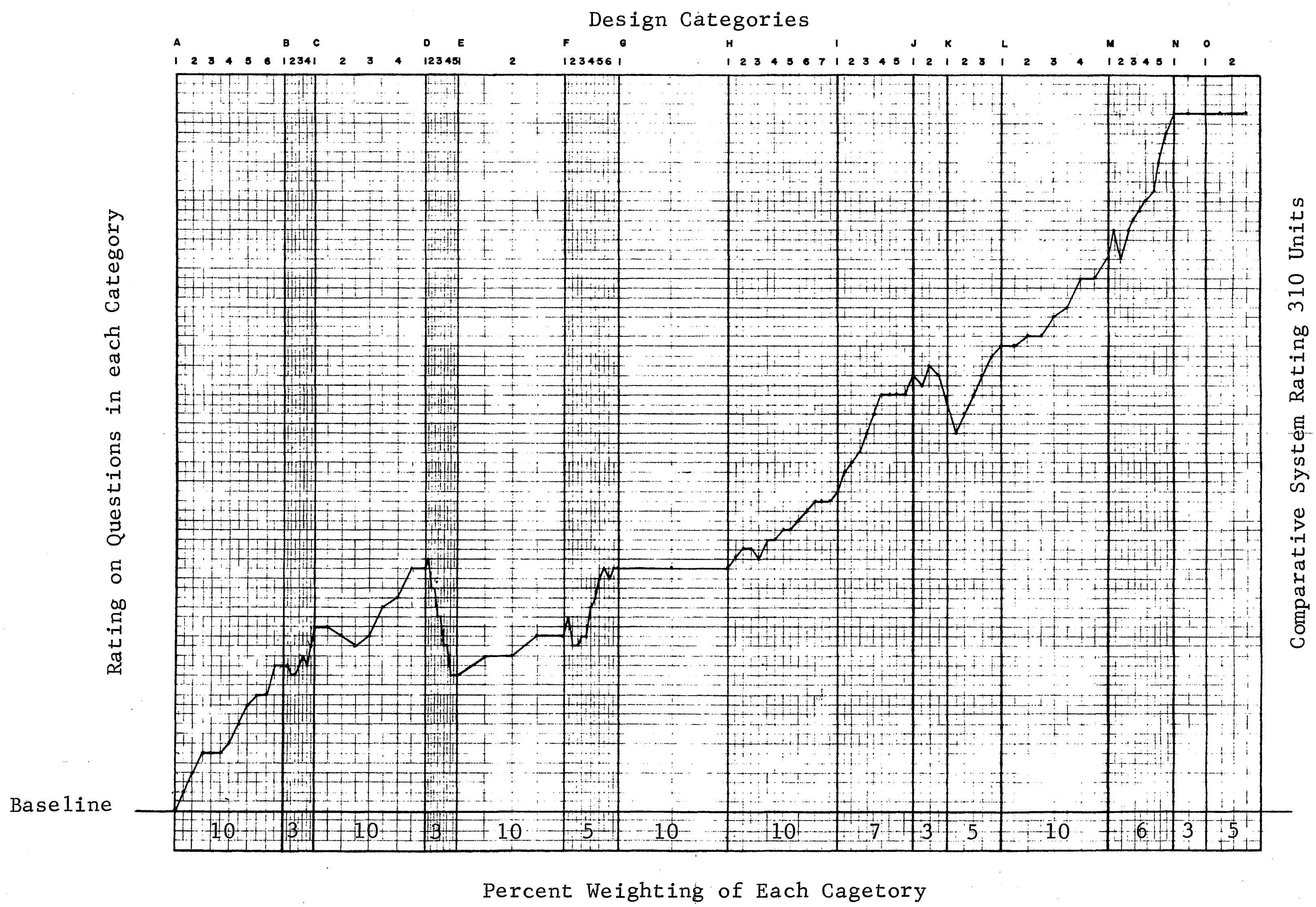


Figure 2. Example Network for Dual Duct System

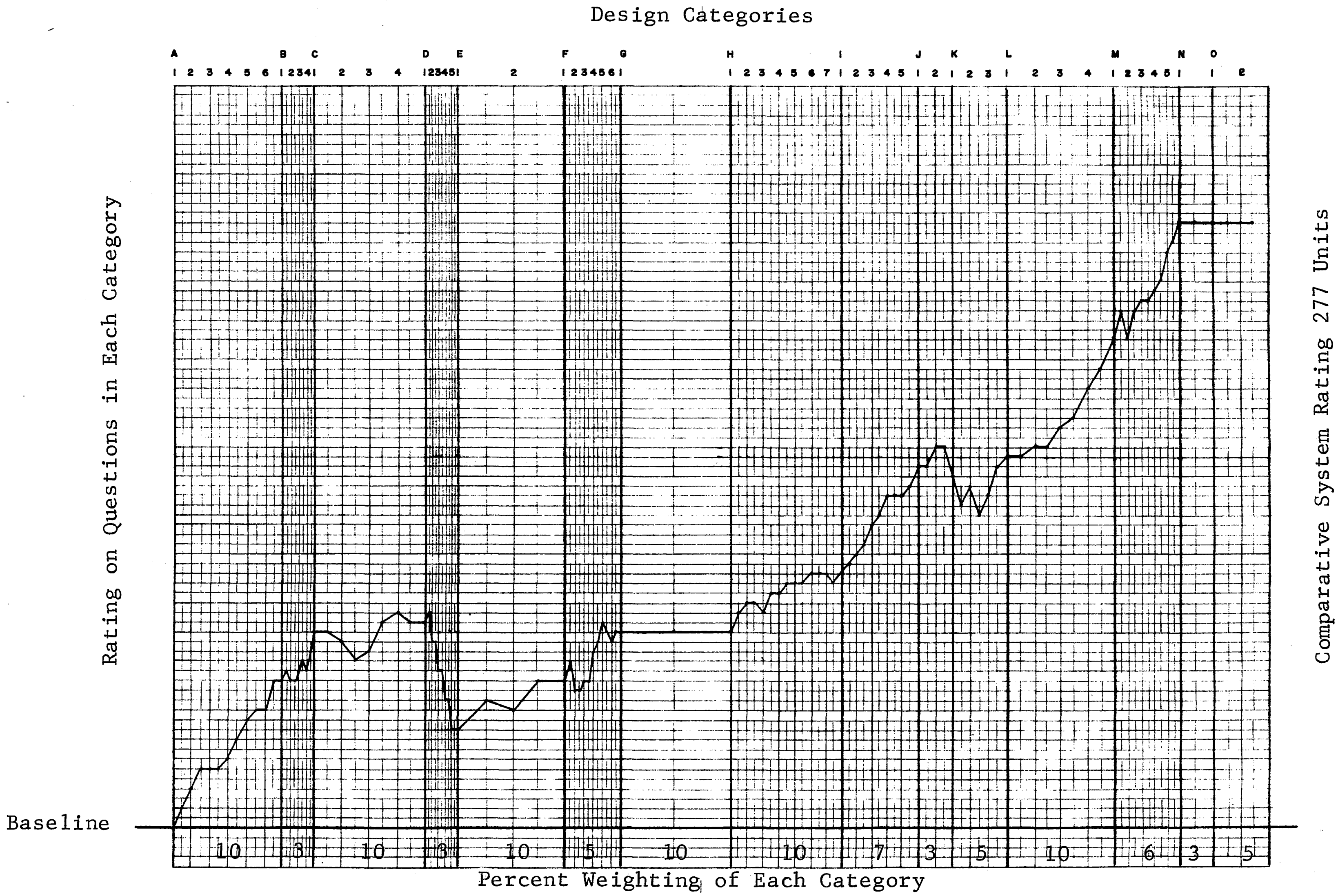


Figure 3. Example Network for Induction System

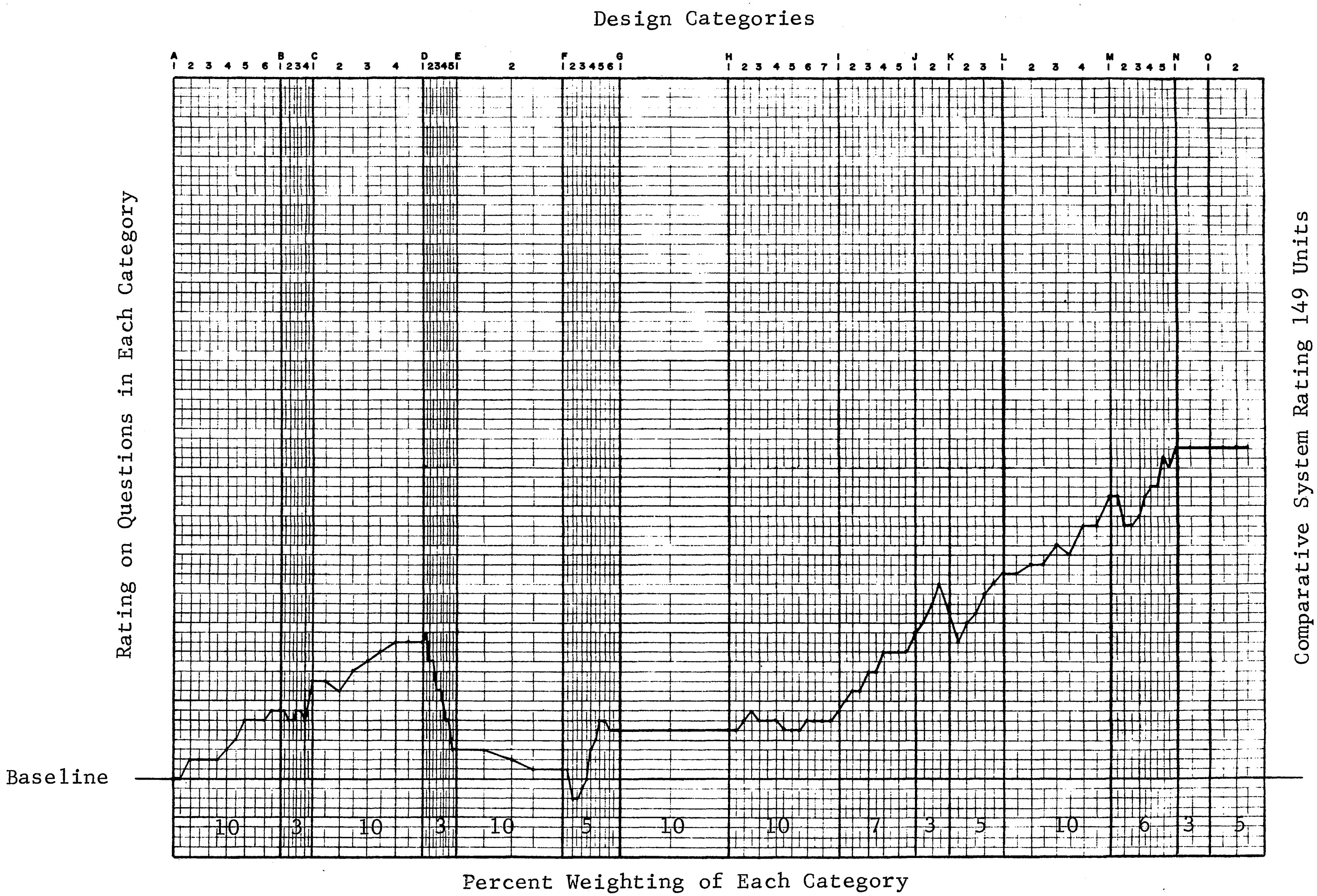


Figure 4. Example Network for Single Duct System

TABLE II

TABULAR VALUES FOR SELECTING THE BEST AIR CONDITIONING SYSTEM FOR THE MIDDLE SCHOOL

BUILDING		SYSTEMS		
CATEGORIES	WEIGHTING (%) W_i	SINGLE DUCT	DUAL DUCT	INDUCTION
A	10	7	15	15
B	03	3	4	5
C	10	4	6	1
D	03	-11	-11	-11
E	10	- 2	4	5
F	05	4	7	5
G	10	0	0	0
H	10	2	8	6
I	07	8	12	11
J	03	2	0	- 1
K	05	4	6	2
L	10	8	9	12
M	06	5	12	12
N	03	0	0	0
O	03	0	0	0
Comparative System Rating		149	310	277

$$\sum_{i=A}^{O} \frac{W_i X_i \text{ (col sys)}}{2} = \text{Comparative Rating System}$$

CHAPTER V

SUMMARY AND CONCLUSIONS

The network selection process developed in this study provides architects and designers with a design tool which facilitates the preliminary selection of a major air conditioning system. A working understanding of many of the major air conditioning systems is provided as background information to be used in the network process.

A network process is developed for the preliminary selection of an air conditioning system. The network includes fifteen (15) design categories. Each design category contains pertinent questions concerning the project. Each question is rated twice, once for the "Building" system and once for the air conditioning "System". Once values are established for the categories, "Building" system and air conditioning "System", these values are placed on the network flow chart. The outcome of the network chart provides a bases for selecting the best "system" for the project.

The network provides advantages in that a visual comparison of the system results. The graphical network provides a method of checking the selection of the system.

This network process allows for the reuse of the category and "system" values. These values become constant for a particular building type.

The different "systems" need not be evaluated for a large number of building types the first time the network is used. As the designer works on different buildings, more and more building types will be evaluated. This procedure will eventually cut down the time required for selection of an air conditioning system considerably, once a sizable repertoire of network charts has been developed.

Recommendation for Further Study

The network approach for selecting air conditioning systems could be modified and expanded in a number of ways. Combinations of the different air conditioning systems could be used in the network. These combinations would provide a wider range of systems, allowing the designer a better choice of systems for a project.

The category importance weightings have not been specifically dealt with in this project. Assumed values have been used merely for illustrative purposes. How the category percentages are determined is a most important part of the network, which could be studied in the future.

The graphical network provides a critical method for air conditioning system selection; however, it is a time consuming process. A mathematical process might be utilized to simplify the selection and reduce the time required for selection.

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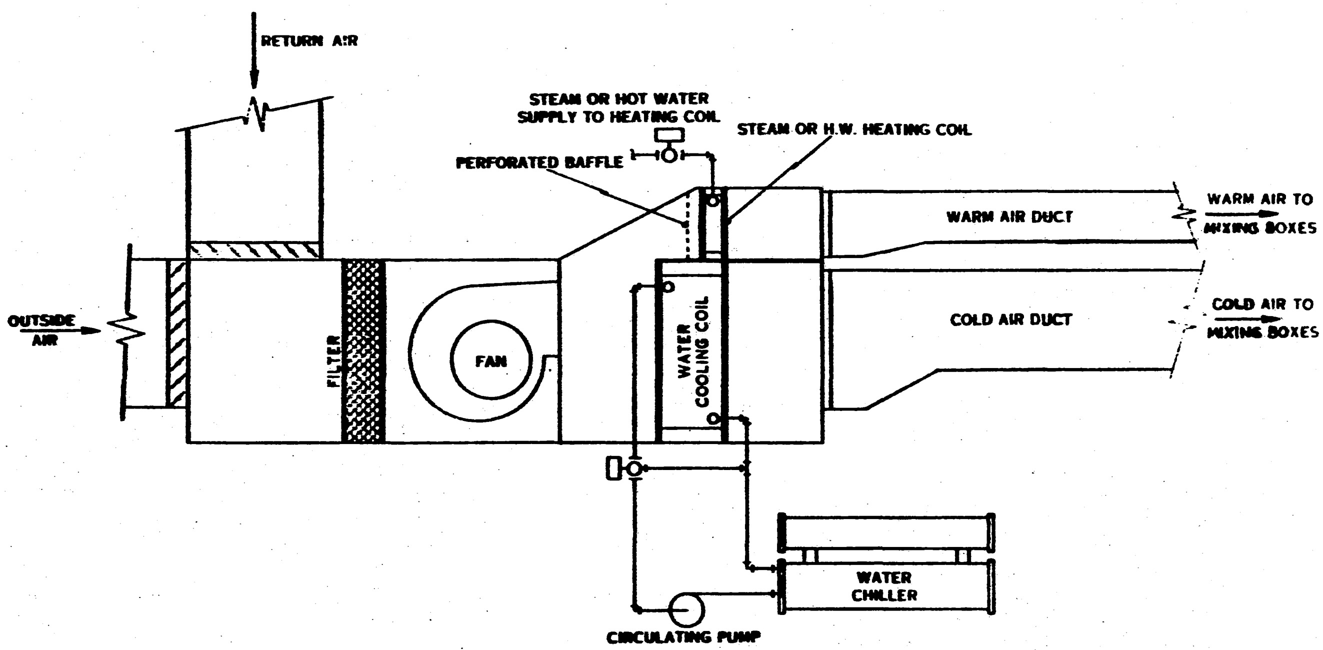
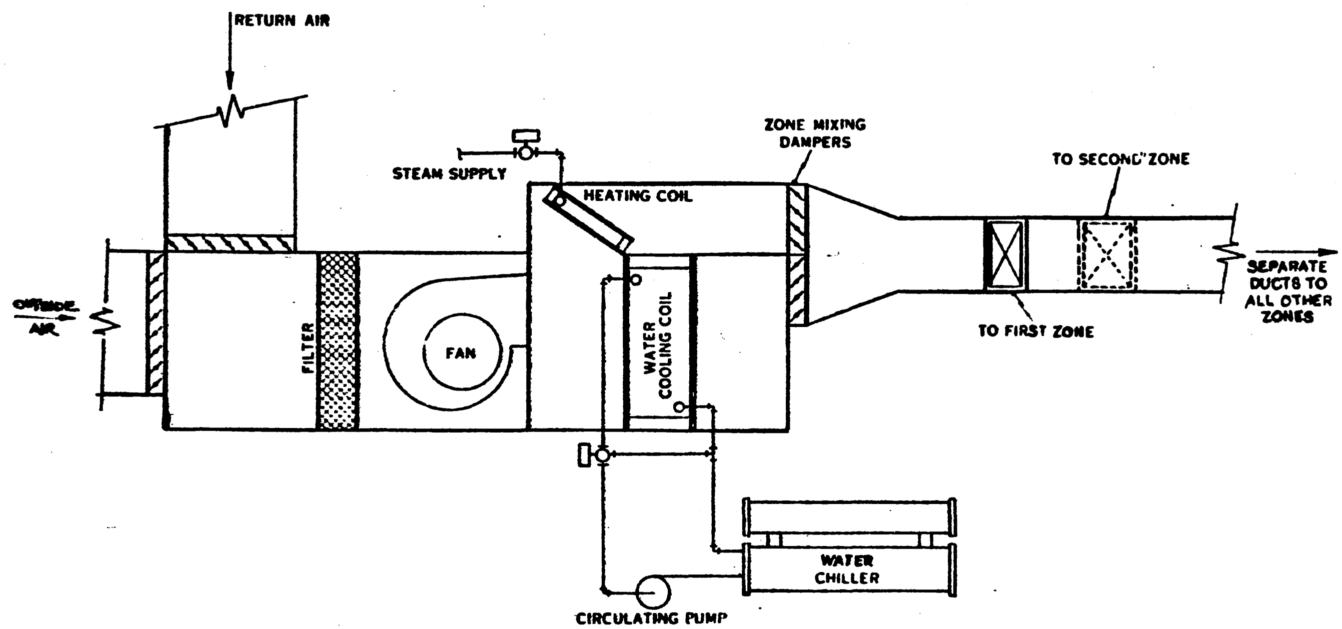
APPENDIX

AIR CONDITIONING SYSTEMS DIAGRAMS



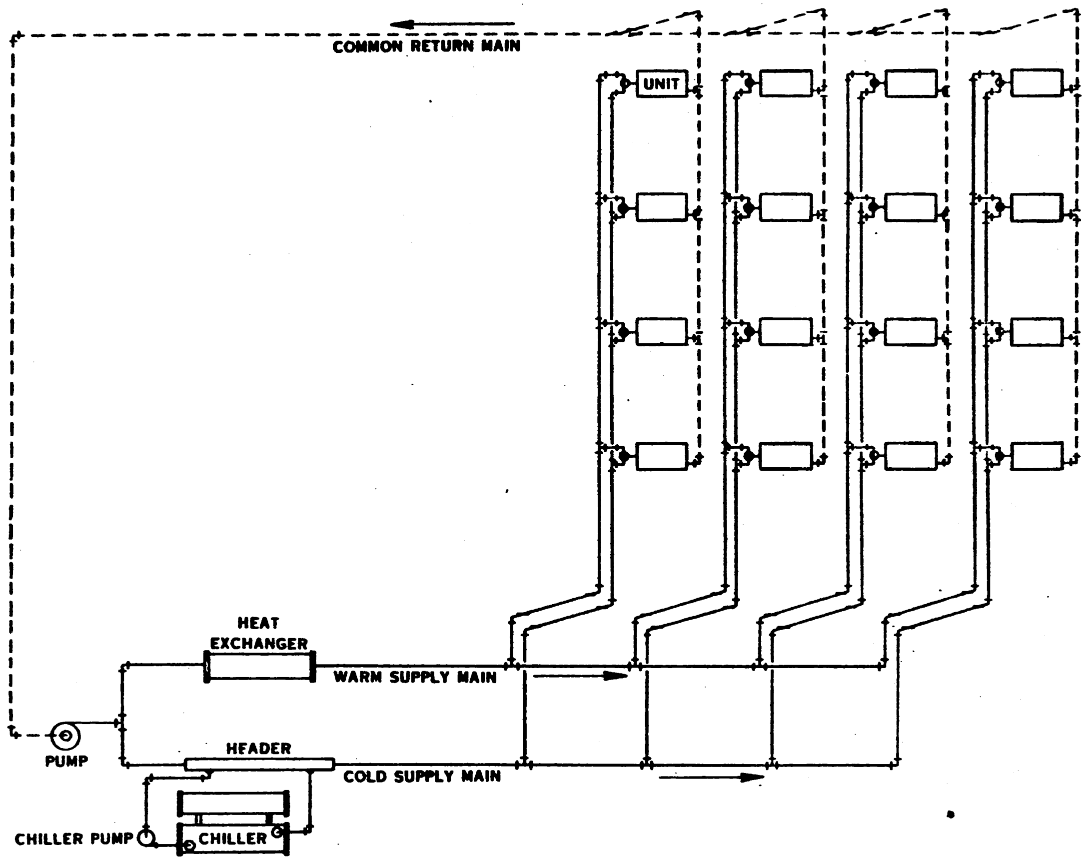
Source: Trane Company, Trane Air Conditioning Manual, 1966.

Figure 5. Schematic Diagram of Dual Duct System



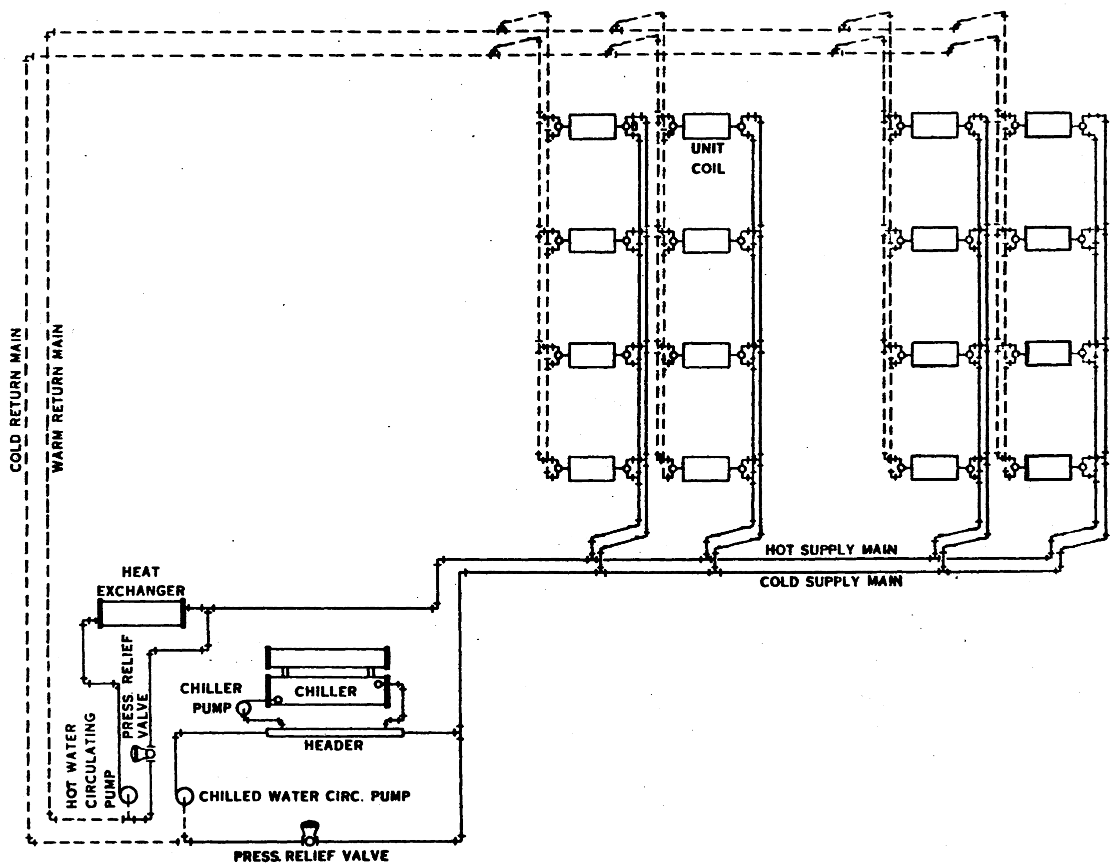
Source: Trane Company, Trane Air Conditioning Manual, 1966.

Figure 6. Schematic Diagram of Multizone System



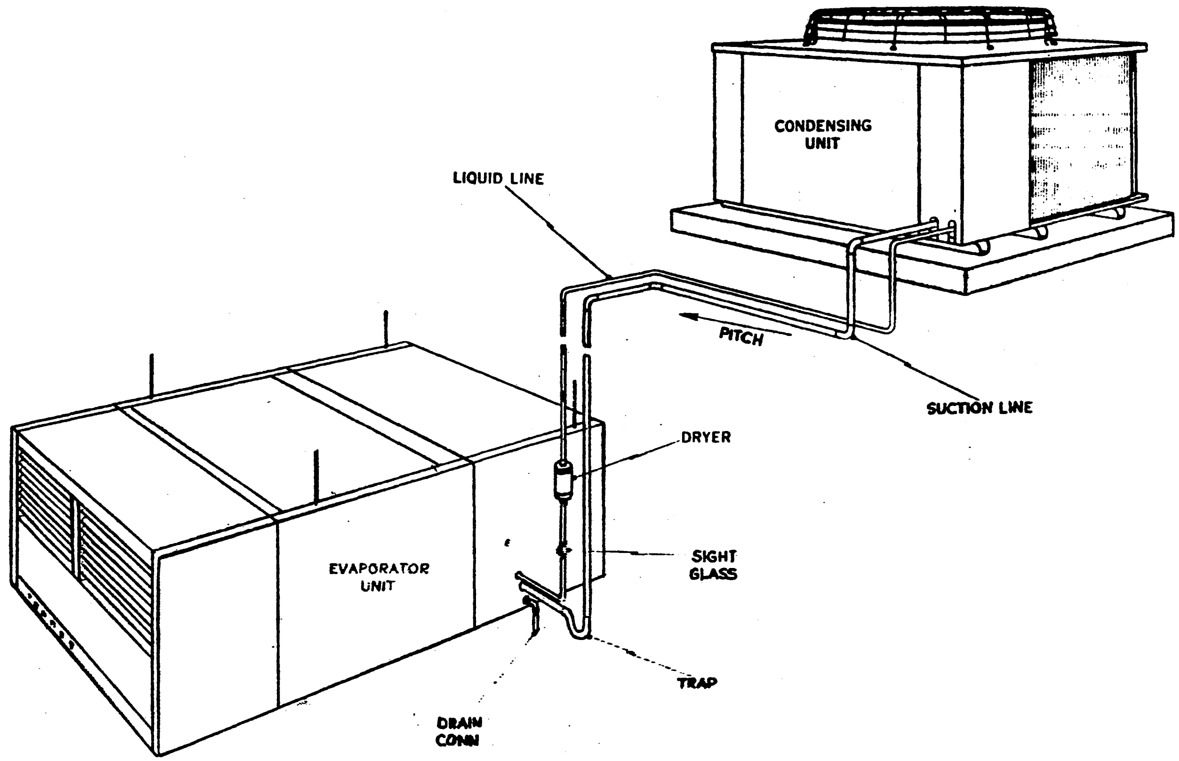
Source: Trane Company, Trane Air Conditioning Manual (1966).

Figure 7. Schematic Diagram of a Three Pipe System



Source: Trane Company, Trane Air Conditioning Manual (1966).

Figure 8. Schematic Diagram of a Four Pipe System



Source: Trane Company, Trane Air Conditioning Manual (1966).

Figure 9. Schematic Diagram of a Rooftop System

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VITA

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