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The repetitious nature of air conditioning calculation leads to arithmetic errors and a high cost of designing air conditioning systems. Short cut calculations are employed to limit the calculation and the chance of making errors.

Computers with their high speed of calculation and the ability to make limited "logic" decisions are ideally suited for air conditioning calculations.

Previously programs were developed to calculate the heating and cooling loads, design the duct system, design the water and steam pipes and to evaluate designed systems. No work had been done to develop a program for the air analysis for the building.

Most programs developed thus far are proprietory and thus not any engineers can use them. Also they use old data and methods of calculation.

This thesis discusses the development of two new programs.

The first is a new program to calculate the cooling and heating loads for buildings. This program incorporates the latest data and methods in calculating the solar loads.

The second is a new program to perform the air analysis for different types of air distribution systems. The two programs were tested on a small school structure. The results compared favorably with those obtained using the conventional method.

Computer and Heating and Air Conditioning

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COMPUTER AND HEATING AND AIR CONDITIONING

I. INTRODUCTION

Most heating and air conditioning calculations are of a repetitive nature. The same method of calculating the load for one room is essentially repeated for every room in the building which is a laborious and tiresome job. The long repetitive nature of the calculation leads to arithmetic errors.

Because of the large number of calculations required in calculating the heating and cooling loads, some simplification and short cut calculations are required in order to minimize arithmetic errors. This is evident especially in calculating the solar load through glass and the equivalent solar and conductive heat gain through walls. Also the load is calculated for only one time of the day and two days of the year rather than at different times. Thus the calculation depends to a large extent on the judgement of the engineer in picking the time that he thinks would give the maximum load.

To calculate the solar load through a window, the area of the window is multiplied by a solar heat gain factor and the shading factor for the window. The solar heat gain factors are calculated for different latitude, orientation and time of the day. These are put in the form of tables from which the proper value is chosen to calculate the solar load. The major flaw in this method is that the solar heat gain factor depends on the latitude of the place where the building is located. If information for the required latitude is not available in the table, the designer has to interpolate between the two bordering latitudes. A second flaw is that the solar heat gain factor depends on the type and thickness of the glass. The prepared tables do not take this into consideration. To compensate for all the simplifications and short cuts, the designer must multiply his final results by a substantial safety factor.

A further flaw of the whole method is that the load calculations by their nature are time consuming and thus they prevent the engineer from spending more time for creative work. This in turn increases the cost of designing air conditioning systems.

Air analysis, duct design and water and steam pipe sizing for air conditioning systems poses problems similar to the cooling and heating load calculation in terms of repetition and short cut calculation. The designer, for example, has to pick an air distribution system before doing any calculation to determine the air quantity and designing of the ducts for the system.

II. LITERATURE STUDY

Computer calculation is an ideal solution for this problem. Computers are fast calculators with a limited ability to make certain "logic" commands and decisions if certain numerical conditions exist during the course of the calculation. Computers can be programmed to do repetitive calculation with a varying set of conditions without ever making arithmetic errors. With the computer's high speed of computation, the ability to store certain parameters for later use and their capability for making limited "logic" decisions, calculation that would take days and weeks will only take a few minutes or seconds. These advantages would free the engineer to do more creative work, allowing him to design better and more efficient systems. These designs would be much freer of short cut calculation and assumptions. All the engineer has to do now to get the load for any job is prepare the input data and give it to a technician. The technician would prepare the data in a form required for the computer input, feed it to the computer and get the results. Thus saving on the cost in designing a better system.

Computer use in heating and air conditioning design is relatively new. The major effort has been spent in developing programs to calculate the cooling and heating loads and in the performance evaluation of a proposed system. A program has been developed for estimating surface areas and weights of sheetmetals for any duct system using rectangular or round shapes. There are other areas where computer programs are available. One is the sizing of pipe for any closed water system based on given flow rates, velocity and pressure drop limitation. A second is the calculation of the pump head for any water system based on a given flow rate, sizes, lengths and shape of pipes and number and types of fittings, valves and other components in the system. The control of the environment of large building complex by computer is receiving more attention. A program to calculate the size of the duct system after the load and air quantity has been calculated is under development. There is no program available yet to calculate the required air quantity for each room in the building taking into consideration the specific requirements of the different types of air distribution systems.

The major flaw of all the programs that have been developed up to now is that they are not readily available in the literature for engineering use. Most programs developed are the property of the companies that have developed them and only through those companies can an engineer get use of these programs. Thus little information is published or given about these programs. Most of the information published is about preparing the input data and the output obtained from the program. Little information is given about how the calculation is performed in arriving at the answer. What information that is available indicates that most of the available programs use the old method of calculating the solar heat load, as explained earlier, with very few improvements.

A new method for calculating the solar heat gain is presented in the 1967 edition of the ASHRAE Handbook of Fundamentals, (1, p. 478). The new method calculates the solar heat gain factor using information about the location of the building, the orientation and type of glass and the time of day and year using the equation given in the ASHRAE Handbook. This method was developed specifically for computer use. Information about available programs and the fact that these programs were developed before this method was published indicates that these programs do not use the new method in calculating the solar heat gain.

III. PROGRAM DEVELOPMENT

This thesis deals with the development of two computer programs. The first is a new program to calculate the cooling and heating loads. This program incorporates the new methods of calculating the solar heat load and the new improved data published. This program will be available for general use.

After the program was developed it was checked by calculating the loads for a structure for which the calculation had been done using the old laborious method. The results indicate that, except for the solar load and the use of new improved data, the results obtained using the new and old methods were identical.

As indicated earlier there are no programs available dealing with the air system analysis. The second program developed was to cover this vital area. The air analysis program will take the heating and cooling loads for each room as calculated by the cooling-heating load program and calculate the air requirements. The calculation will take into consideration the special requirements of the different air distribution systems including constant volume, variable volume, reheat, multizone, air induction and dual duct systems. The results of the calculations for each room will be summed up to give the building requirements.

The two programs were developed for use in the IBM 1620 using the Fortran II language and the CDC 3300 using the Fortran IV language. They can be readily modified for use on other computer systems.

IV. COOLING AND HEATING PROGRAM

Input Data

Knowing the input data and how to prepare it is the first important step toward understanding and using the computer program. There are three types of data required by the program; permanent data, wall data and room data. Each will be explained separately.

Permanent data. As the name implies these data do not change in any calculation regardless of building type, location, orientation and the time of day when the load is required. The only time these data need to be changed is when improved and more accurate values are available. The permanent data are essentially for calculating the solar heat gain through glass. They can be divided into two parts. First there is the absorptivity and transmissivity factors (A(J, I) and T(J,I)), (1, p. 479, Table 10).

The set of factors for each type of glass consist of six absorptivity factors and six transmissivity factors. These data are stored in the memory of the computer in the form of two dimensional arrays identified by the subscripts "I" and "J". J is the number that identifies the type of glass used in the calculation while I specifies the factor (one out of six) being used in any step of calculation. In any calculation of the solar load, all the six factors have to be used, therefore, specifying J is enough to call the required set of factors from the memory of the computer.

The second set of permanent data include AZ(N), B(N), C(N), DEL(N) and TE(N). These data depend on the time of year when the calculation is required. There are 12 values available for each factor calculated at the 21st of each month for the year (1, p. 478, Table 8). The data for each factor are arranged in the form of a one dimensional array. The subscript N is used for identification. N also identifies the month for which these values are intended.

Format statement 100 specify the form in which the absorptivity and transmissivity factors must be punched on cards. Each set of six factors are punched on a single card. Format statement 102 specify the form in which AZ(N), B(N), C(N), DEL(N) and TE(N) must be punched on cards. A single value for each factor is punched on one card with a total of 12 cards needed to specify all values. If data for AZ(N), B(N), C(N), DEL(N) and TE(N) are needed at different times they can be calculated by linear interpolation. They can be entered into the memory of the computer by assigning them a proper value for N (other than one through twelve) and punching the new data on a card to be added to the original set.

Wall data. As will be explained later the load calculation will be carried out in three steps. First, the heating or cooling load from every wall, roof, door and window in the same room will be calculated and summed together. Second, the cooling or heating load from heat sources within the room including ventilation and infiltration load are calculated. All the loads computed for the room are summed up to give the sensible, latent and transmission heating or cooling load for each room and zone in the building. The final step is summing the loads for every zone in the building to give the total building sensible, latent and transmission loads.

Values for the following data factors are needed in calculating the load from each wall:

ALT: Latitude for city or location, degrees.

DLTE: Equivalent temperature, $^{\circ}F$, (1, p. 491, Tables 26 and 27).

EPS: Wall slope in degree, 90° is used if the slope is more than 45° and 0° is used if slope is less than 45°.

GL, GW: Window dimensions, ft.

HO: Outer surface coefficient of convective heat transfer, Btu/hr. $ft.^{2}\ ^{\circ}F$.

HLF: Heat load factor through exposed perimeter of ground floor, Btu/hr, (1, p. 460, Table 2).

K: Zone number. Also used as signal to bypass summing the zone load to the building load when K is more than 800.

L: Array identification number for the absorptivity and transmissivity factors, specifying the value of J.

MI: A control factor which will be explained later.

N: Array identification number for AZ, B, C, DEL and TE.

NI: A control factor which will be explained later.

RHG: Ground reflectivity, (4, p. 533-534, Tables A-1 and A-2).

SC: Shading factor, (1, p. 482, Tables 15, 16 and 17).

When the door does not have glass or the dimension GL and GW are used to exclude areas from the calculation SC must be specified as zero.

TI, TO: The temperature inside the room and the outside or on the opposite side of the wall, ^{o}F.

TME: Minute from solar noon.

U: Coefficient of heat transfer through wall, Btu/hr. ^{o}F. ft.^{2}, (1, p. 429-452, Tables 1-15).

UG: Glass coefficient of heat transfer, Btu/hr. ^{o}F. ft.^{2}, (1, p. 477, Table 9).

WA: Wall azimuth, degree, zero facing south and positive going to the west.

WH, WW: Wall, roof or door dimensions, ft.

The data for each wall are punched on one card in the following order: K, NI, MI, L, WW, WH, GW, GL, TO, TI, EPS, ALT, U, UG, WA, TME, DLTE, RHG, HO, SC, HLF, and N. Format statement 101 specifies the form in which these data must be punched on cards.

Room and zone data. In addition to the permanent data each room and zone require the following data:

BN: Number of rooms in each zone.

FAL: Light heat load factor, Btu/hr. $ft.^2$, (5, p. 1-158).

FI: Air infiltration rate through cracks, $ft.^3$/hr-ft., (1, p. 409, Table 2).

FIT: Air infiltration rate through used outside doors per person, cfm. This factor is equated to zero when the door is not in frequent use, (3, p. 525, Table 17-10).

FL, FW: Floor dimension, ft.

HL: Latent heat dissipated per person, Btu/hr., (1, p. 497, Table 30).

HS: Sensible heat dissipated per person, Btu/hr., (1, p. 497, Table 30).

HSIL: Load from miscellaneous heat sources within the room, Btu/hr., (1, p. 498, Table 31).

JI: A control factor when equal to one directs the computer to calculate the room and zone summer loads, if other than one the computer will calculate the winter loads.

K: Zone number, also used as a signal to bypass the addition of the room and zone loads to the building total loads if K is over 800.

P: Number of persons in each room.

PN: Number of persons using outside door in each room per day.

PR: Effective infiltration crack length. Usually taken as half of the crack length of door or window, ft.

TI: Inside design temperature, ^{o}F.

TO: Outside design temperature, ^{o}F.

VPF: Required ventilation rate per person, cfm, (1, p. 112, Table 1).

Format statement 104 specifies the way in which these data must be punched on cards. These data for the room are punched in the following order: K, JI, FL, FW, P, HL, HS, FAL, WO, WI, VPF, PR, FI, FIT, TO, TI, PN, BN, N, HSIL.

The data explained so far are written and specified in only two ways:

1. AIB where:

   A: Indicates the number of successive values having the same specification.

   I: Indicates that the number is an integer.

   B: Number of digits reserved for the value of the data.

2. AFB. d where:

   A: Indicates the number of successive values having the same specification.

   F: Indicates that the number is in the floating point mode (with decimal point).

   B: Number of digits reserved for the value of the data.

   d: Number of significant digits to the right of the decimal point.

In preparing the data, the following points must be observed. Each wall takes one card of the wall data. On the last card giving the wall data for each room, which usually is for the roof, the value of NI must be 99. This is done to transfer control from the wall calculations to the room calculations.

Each room takes one card of the room data in addition to the wall data cards. If the data on the room data card are for summer, the value of JI must be one. If the data on the card are for winter, JI can have any value other than one. At the end of the summer data card deck one card must be added having the same format as for the wall data card but having a value for MI of 90. For the winter deck a card must be added having a value for MI more than 90. This is done to transfer the program from zone and room calculation to summing the building total loads. For regular wall data card the value of MI must be less than 90.

When NI is not used for control purposes (when the value is less than 99) it can be used to indicate the wall direction with one indicating that the wall is facing the north, two facing the west, three facing the south and four facing the east. This added information is not used in the calculation.

If MI is not used for control (when the value of MI is less than 90) it can be used to number the data cards.

At the end of the data cards deck a special card must be added having the same format as the wall data card but having a value for NI of 999. This card is used to terminate the program on the IBM 1620. For the CDC 3300 the special end of file card is used in place of the card with NI equal to 999.

Required Output

There are two types of output obtained from the program in each complete cycle of calculation. The first set is the room and zone output which include:

Per Room

Total sensible and latent loads including ventilation loads (CLRS and CLRL for summer and HLRS and HLRL for winter).

Total sensible and latent loads not including ventilation loads (RSCLAA and RLCLAA for summer and RSHLAA and RLHLAA for winter).

Sensible and latent infiltration load through cracks (AVS and AVL).

Sensible and latent infiltration load through used outside doors (AVPHS and AVPHL).

Sensible and latent ventilation load (VHS and VHL).

Sensible and latent load from occupants in the room (PQRS and

PQRL).

Equivalent solar and transmission cooling load for summer (SQTRW).

Solar heat gain through windows (SHQ).

Cooling loads from the lights (GHL).

Transmission load through walls, roof and doors (STLR).

Combined solar and transmission load from windows (SGHQ).

Heating or cooling load from the exposed perimeter of the ground floor (FHLS).

Load from miscellaneous heat sources within the room (HSIL).

Per Zone

Total sensible, latent and transmission heating and cooling loads (CLRSZ, CLRLZ and ZSTL for summer and ZHLRS, ZHLRL and ZSTLR for winter).

For CLRS, HLRS, VHS, AVS, AVPHS, STLR, CLRSZ, ZHLRS, ZSTL and ZSTLR the negative sign means that they are heating loads and the positive sign means that they are cooling loads. The units for all the loads are Btu per hour.

Because of limited space on the output line for the IBM 1620, the results for each room and zone are punched on three output lines.

After punching the results for all zones, the computer punches the total load for the building with and without adding a five percent safety factor. The building results are:

Summer with five percent safety factor (TCLL and TCLS).

Summer without five percent safety factor (CLODL, CLODS, BSCL and BLCL).

Winter with five percent safety factor (THLL, THLS and TSTL).

Winter without five percent safety factor (HLODL, HLODS, HZSTL, BSHL and BLHL).

The units for the building total loads are in Btu per hour.

Program Description

Before starting the general description of the program, one point must be made clear. Every time the word zone is mentioned, it will mean the group of rooms that have the same heating and cooling loads, not just the same pattern but the same values as well. This step is taken to simplify the calculation and save computer time. These are not control zones.

The following steps were taken in order to make the program as general as possible. First the solar and transmission heat gain or loss through the walls, doors, windows and the roof of the room are calculated separately. The results for the walls, doors, windows and the roof are summed to give the room solar and transmision loads.

The second step is to calculate the cooling and heating loads from sources within the room, infiltration and ventilation. All the appropriate loads will be summed to give the sensible and latent room heating and cooling loads. The room loads are multiplied by the number of rooms in each zone to give the zone cooling and heating loads.

The last step is to sum all the zone sensible and latent loads to give the building total cooling and heating loads with and without the ventilation loads. The building and room loads with the ventilation loads not included are used to calculate the air requirements.

This method of calculation will not be restricted by the shape of any particular room in the building.

The flow chart of the program is shown on Figures 1 and 2 followed by a tabulation of functions calculated in each step and the whole program as used on the IBM 1620 and the CDC 3300.

The first operation in the program is the reading of the dimension statements which specify the number of memory locations that are required to store the permanent data and other elements that will be referred to by the computer from time to time. The format statement which specifies the way in which the data are to be fed into the computer and how the output is to be typed or punched are read next.

The permanent data are read and stored in the memory of the computer. The first factors to be read are A(J, I) and T(J, I). At the time when this program was developed values for T(J, I) and A(J, I) were available for only three types of window glass. These are; standard double strength glass where J is given the value of one,

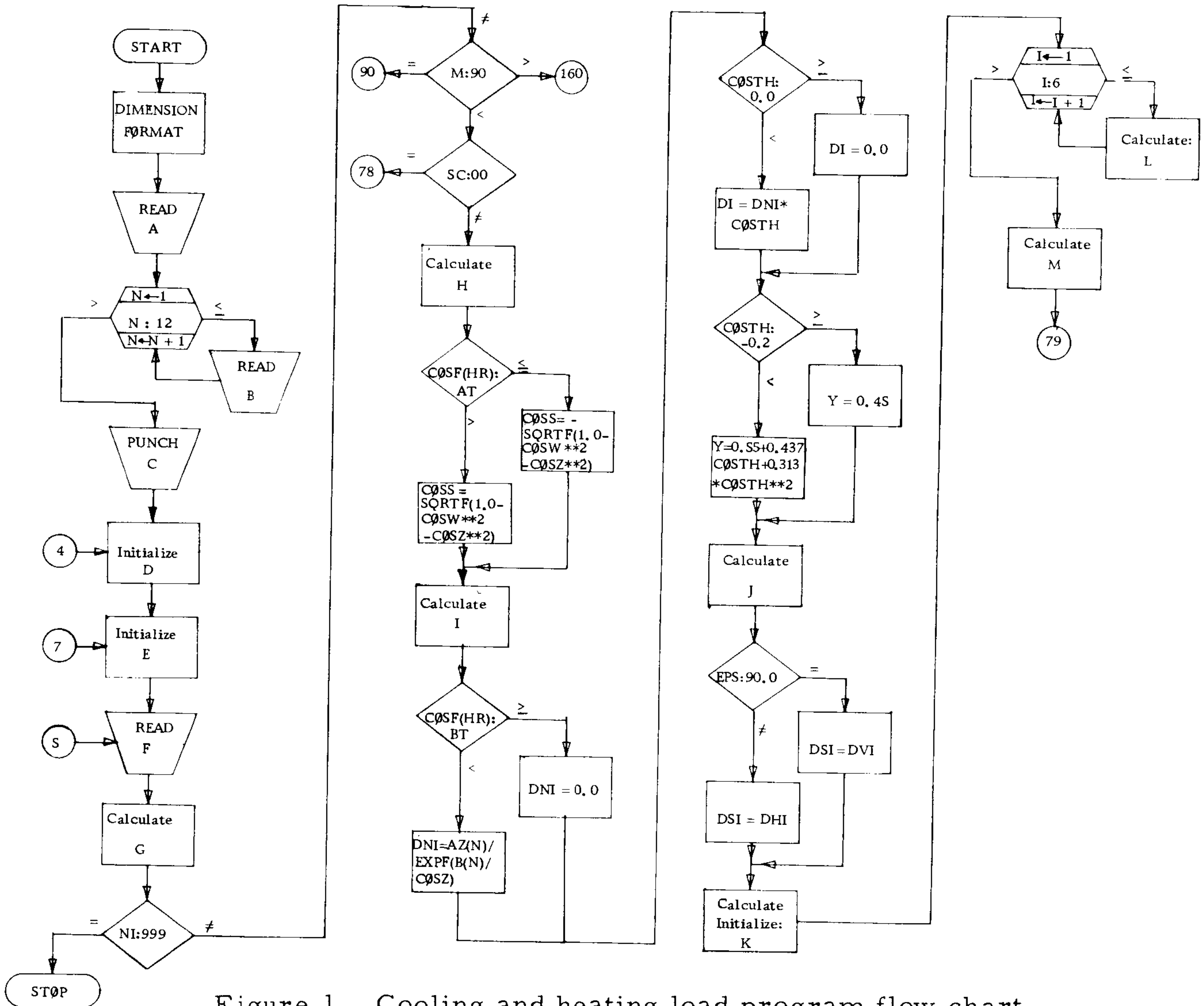

Figure 1. Cooling and heating load program flow chart.

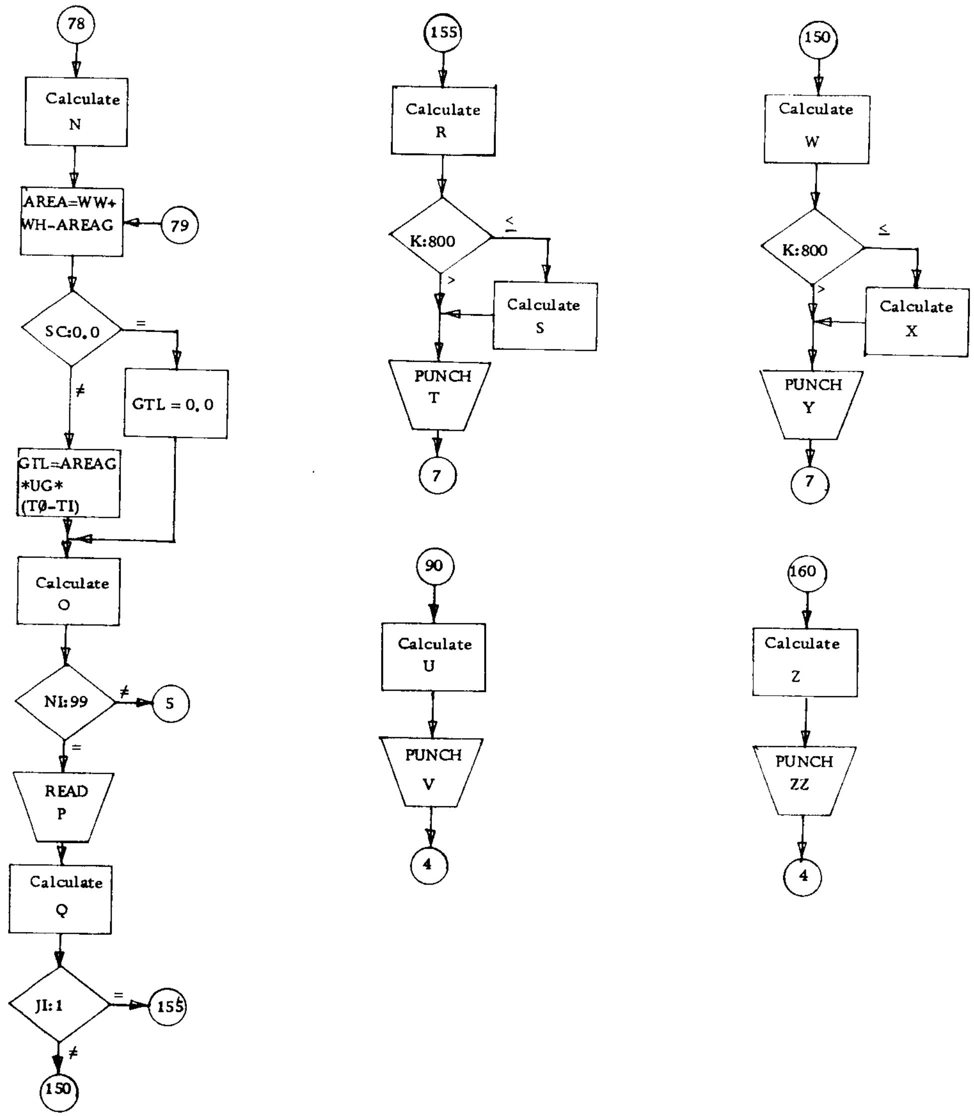

Figure 2. Cooling and heating load program flow chart.

COOLING AND HEATING LOAD PROGRAM FOR IBM 1620

```
C       PROGRAM  COOLHEAT LOAD
        DIMENSION A(3,6),T(3,6),AZ(12),B(12),C(12),DEL(12),TE(12),DELT(12)
  100 FORMAT(6F8.5)
  101 FORMAT(2I3,2I2,4F5.1,4F3.0,2F4.3,2F4.0,F4.1,F3.3,2F3.2,F3.0,I2)
  102 FORMAT(2F3.0,2F4.3,F4.1)
  104 FORMAT(2I3,2F5.1,F4.0,5F4.1,4F3.1,4F3.0,F5.0)
  105 FORMAT(I3,5(2X,F8.0),3(1X,F8.0))
  106 FORMAT(I3,6(2X,F8.0),2(2X,F6.0))
  107 FORMAT(8(F8.0,2X))
  108 FORMAT(I3,5(3X,F8.0))
  111 FORMAT(80H K         CLRS       SQTRW        SGHQ        PQRS        GHL
     2  VHS        AVS        AVPHS )
  112 FORMAT(77H K         CLRL       PQRL         VHL         AVL         AVPHL
     2 STLR       FHLS       HSIL)
  113 FORMAT(58H K          CLRLZ       CLRSZ        ZSTL        RSCLAA      RLCL
     2AA)
  115 FORMAT(60H    CLODL        TCLL       CLODS        TCLS        BSCL        BL
     2CL   )
  116 FORMAT(80H K         HLRS       STLR         SHQ         PQRS        GHL
     2 VHS        AVS         AVPHS )
  117 FORMAT(77H K         HLRL       PQRL         VHL         AVL         AVPHL
     2 STLR       FHLS       HSIL)
  118 FORMAT(58H K          ZHLRS       ZHLRL        ZSTLR       RSHLAA      RLHL
     2AA)
  119 FORMAT(80H    HLODL        THLL       HLODS        THLS        HZSTL       TS
     2TL        BSHL        BLHL    )
  119 FORMAT(88H     HLODL        THLL        HLODS        THLS        HZSTL
     2      TSTL        BSHL        BLHL    )
  120 FORMAT(40H     COOLING AND HEATING LOAD CALCULATION)
        READ 100, ((A(J,I),I=1,6),J=1,3)
        READ 100, ((T(J,I),I=1,6),J=1,3)
        DO 2 N=1,12
    2 READ 102,AZ(N),DEL(N),B(N),C(N),TE(N)
        PUNCH 120
    4 CLODL=0.0
        CLODS=0.0
        HLODL=0.0
        HLODS=0.0
        HZSTL=0.0
        BSCL=0.0
        BLCL=0.0
        BSHL=0.0
        BLHL=0.0
    7 SHQ=0.0
        STLR=0.0
        SQTRW=0.0
        SGTL=0.0
        FHLS=0.0
    5 READ 101, K,NI,MI,L,WW,WH,GW,GL,TO,TI,EPS,ALT,U,UG,WA,TME,DLTE,RHG
     2,HO,SC,HLF,N
        IF(NI-999)24,200,24
    8 EPSR=3.1416*EPS/180.0
        WAR=3.1416*WA/180.0
        AL=3.1416*ALT/180.0
        DELT(N)=3.1416*DEL(N)/180.0
   24 IF(MI-90)29,90,160
   29 IF(SC-0.0)33,78,33
```

```
33 H=0.25*(TME+TE(N))
   HR=3.1416*H/180.0
   XL=COSF(EPSR)
   YM=SINF(WAR)
   ZN=COSF(WAR)
26 COSZ=SINF(AL)*SINF(DELT(N))+COSF(AL)*COSF(DELT(N))*COSF(HR)
27 COSW=COSF(DELT(N))*SINF(HR)
28 AT=(SINF(DELT(N))*COSF(AL))/(COSF(DELT(N))*SINF(AL))
   IF(COSF(HR)-AT)10,10,9
 9 COSS=SQRTF(1.0-COSW**2-COSZ**2)
   GO TO 12
10 COSS=-SQRTF(1.0-COSW**2-COSZ**2)
12 COSTH=XL*COSZ+YM*COSW+ZN*COSS
   BT=-(SINF(DELT(N))*SINF(AL))/(COSF(DELT(N))*COSF(AL))
   IF(COSF(HR)-BT)35,35,30
30 DNI=AZ(N)/EXPF(B(N)/COSZ)
   GO TO 38
35 DNI=0.0
38 IF(COSTH-0.0)45,45,40
40 DI=DNI*COSTH
   GO TO 48
45 DI=0.0
48 IF(COSTH+0.2)55,55,50
50 Y=0.55+0.437*COSTH+0.313*COSTH**2
   GO TO 58
55 Y=0.45
58 DHI=C(N)*DNI
   DVI=DNI*(C(N)*Y+(RHG/2.0)*(C(N)+COSZ))
   IF(EPS-90.0)60,65,60
60 DSI=DHI
   GO TO 80
65 DSI=DVI
80 FNI=UG/HO
   AJ=0.0
   TJ=0.0
   AJI=0.0
   TJI=0.0
   DO 70 I=1,6
   R=I
   AJ=AJ+A(L,I)*COSTH**(I-1)
   TJ=TJ+T(L,I)*COSTH**(I-1)
   AJI=AJI+A(L,I)/(R+1.0)
70 TJI=TJI+T(L,I)/(R+1.0)
75 SHGF=DI*TJ+2.0*DSI*TJI+FNI*(DI*AJ+2.0*DSI*AJI)
   AREAG=GL*GW
   SHG=SHGF*SC*AREAG
   GO TO 79
78 AREAG=GL*GW
   SHG=0.0
79 AREA=WW*WH-AREAG
   IF(SC-0.0)67,68,67
68 GTL=0.0
   GO TO 83
67 GTL=AREAG*UG*(TO-TI)
83 FHL=WW*HLF
   QTR=U*DLTF*AREA
   TLW=(U*AREA+UG*AREAG)*(TO-TI)
   SGTL=SGTL+GTL
   STLR=STLR+TLW
   SHQ=SHQ+SHG
   SQTRW=SQTRW+QTR
```

```
      FHLS=FHLS+FHL
   25 IF(NI-99)5,85,5
   85 READ 104, K,JI,FL,FW,P,HL,HS,FAL,WO,WI,VPF,PR,FI,FIT,TO,TI,PN,BN,
     2HSIL
   95 PQRS=P*HS
      PQRL=P*HL
      AREAF=FL*FW
      GHL=FAL*AREAF
      VHS=(60.0*0.244*P*VPF*(TO-TI))/14.15
      VHL=(60.0*3.0*P*VPF*(WO-WI))/(20.0*14.15)
      AVS=(0.244*FI*(PR/2.0)*(TO-TI))/14.15
      AVL=(3.0*FI*(PR/2.0)*(WO-WI))/(20.0*14.15)
      AVPHS=(60.0*0.244*PN*FIT*(TO-TI))/14.15
      AVPHL=(3.0*60.0*PN*FIT*(WO-WI))/(20.0*14.15)
      RLINL=AVL+AVPHL
      RSINL=AVS+AVPHS
      RIMLL=GHL+HSIL
      SGHQ=SHQ+SGTL
      IF(JI-1)150,155,150
  155 CLRS=SQTRW+SHQ+PQRS+GHL+VHS+AVPHS+AVS+HSIL+FHLS+SGTL
      CLRL=PQRL+VHL+AVL+AVPHL
      RSCLAA=SQTRW+SHQ+PQRS+GHL+AVS+AVPHS+HSIL+SGTL+FHLS
      RLCLAA=PQRL+AVL+AVPHL
      CLRSZ=BN*CLRS
      CLRLZ=BN*CLRL
      ZSTL=BN*STLR
      IF(K-800)157,157,158
  157 CLODL=CLODL+CLRLZ
      CLODS=CLODS+CLRSZ
      BSCL=BSCL+BN*RSCLAA
      BLCL=BLCL+BN*RLCLAA
  158 PUNCH 111
      PUNCH 105, K,CLRS,SQTRW,SGHQ,PQRS,GHL,VHS,AVS,AVPHS
      PUNCH 112
      PUNCH 106, K,CLRL,PQRL,VHL,AVL,AVPHL,STLR,FHLS,HSIL
      PUNCH 113
      PUNCH 108, K,CLRLZ,CLRSZ,ZSTL,RSCLAA,RLCLAA
      GO TO 7
   90 TCLL=1.05*CLODL
      TCLS=1.05*CLODS
      PUNCH 115
      PUNCH 107, CLODL,TCLL,CLODS,TCLS,BSCL,BLCL
      GO TO 4
  150 HLRS=STLR+FHLS+PQRS+SHQ+GHL+AVS+AVPHS+HSIL+VHS
      HLRL=PQRL+AVL+AVPHL+VHL
      RSHLAA=STLR+FHLS+PQRS+SHQ+GHL+AVS+AVPHS+HSIL
      RLHLAA=PQRL+AVL+AVPHL
      ZHLRS=BN*HLRS
      ZHLRL=BN*HLRL
      ZSTLR=BN*STLR
      IF(K-800)151,151,152
  151 HLODS=HLODS+ZHLRS
      HLODL=HLODL+ZHLRL
      HZSTL=HZSTL+ZSTLR
      BSHL=BSHL+BN*RSHLAA
      BLHL=BLHL+BN*RLHLAA
  152 PUNCH 116
      PUNCH 105, K,HLRS,STLR,SHQ,PQRS,GHL,VHS,AVS,AVPHS
      PUNCH 117
      PUNCH 106, K,HLRL,PQRL,VHL,AVL,AVPHL,STLR,FHLS,HSIL
      PUNCH 118
```

```
      PUNCH 108, K,ZHLRS,ZHLRL,ZSTLR,RSHLAA,RLHLAA
      GO TO 7
  160 THLL=1.05*HLODL
      THLS=1.05*HLODS
      TSTL=1.05*HZSTL
      PUNCH 119
      PUNCH 107, HLODL,THLL,HLODS,THLS,HZSTL,TSTL,BSHL,BLHL
      GO TO 4
  200 STOP
      END
```

PERMANENT DATA FOR COOLING-HEATING LOAD PROGRAM

```
+0001838+0192497-0889134+1840197-1748648+0617544
+0001406+0415958-1506279+2718492-2388518+0803650
+0001154+0077674-0394657+0857881-0838135+0301188
-0000885+0271235-0062062-0707329+0975995-0389922
-0001201+0213037+0113834-1007925+1244162-0483285
-0000835+0092766+0215721-0871429+0987152-0377728
390-2001420058-112
385-1101440060-139
37600001560071-075
360 1201800097+011
350 2001960121 033
345 2302050134-014
344 2102070136-062
351 1202010122-024
365 00017700920075
378-1101600073+154
387-2001490063 138
391-2301420057+016
```

COOLING AND HEATING LOAD PROGRAM FOR CDC 3300

```
      PROGRAM COLHEATL
      DIMENSION A(3,6),T(3,6),AZ(12),B(12),C(12),DEL(12),TL(12),DELT(12)
  100 FORMAT(6F8.5)
  101 FORMAT(2I3,2I2,4F5.1,4F3.0,2F4.3,2F4.0,F4.1,F3.3,2F3.2,F3.0,I2)
  102 FORMAT(2F3.0,2F4.3,F4.1)
  104 FORMAT(2I3,2F5.1,F4.0,5F4.1,4F3.1,4F3.0,F5.0)
  105 FORMAT(1H ,I3,2(F9.0,2X),9(F8.0,2X),F9.0)
  106 FORMAT(1H ,I3,3(F9.0,2X),3(F8.0,2X))
  107 FORMAT(1H ,8(F9.0,2X))
  108 FORMAT(1H ,I3,3(F9.0,2X),8(F8.0,2X))
  111 FORMAT(124H K        CLRS       RSCLAA       SQTRW        SGHQ        PQRS
     2   RIMLL       RSINL          VHS         STLR          FHLS         ZSTL        CL
     3RS7)
  112 FORMAT(66H K         CLRL       RLCLAA        CLRLZ         PQRL        RLINL
     2       VHL    )
  115 FORMAT(66H     CLODL          TCLL        CLODS          TCLS         BSCL
     2      BLCL    )
  116 FORMAT(116H K         HLRS       RSHLAA        ZHLRS       ZSTLR        STLR
     2         SHQ         PQRS       RIMLL       RSINL          VHS       FHLS     )
  117 FORMAT(66H K         HLRL       RLHLAA        ZHLRL         PQRL        RLINL
     2       VHL    )
  119 FORMAT(88H     HLODL          THLL        HLODS          THLS        HZSTL
     2      TSTL         BSHL          BLHL    )
  120 FORMAT(40H     COOLING AND HEATING LOAD CALCULATION)
      READ(60,100)((A(J,I),I=1,6),J=1,3)
      IF(EOFCKF(60).EQ.2)3,200
    3 READ(60,100)((T(J,I),I=1,6),J=1,3)
      IF(EOFCKF(60).EQ.2)6,200
    6 DO 2 N=1,12
    2 READ(60,102)AZ(N),DEL(N),B(N),C(N),TE(N)
      WRITE(61,120)
    4 CLODL=0.0
      CLODS=0.0
      HLODL=0.0
      HLODS=0.0
      HZSTL=0.0
      BSCL=0.0
      BLCL=0.0
      BSHL=0.0
      BLHL=0.0
    7 SHQ=0.0
      STLR=0.0
      SQTRW=0.0
      SGTL=0.0
      FHLS=0.0
    5 READ(60,101)K,NI,MI,L,WW,WH,GW,GL,TO,TI,EPS,ALT,U,UG,WA,TME,DLTE,
     2RHG,HO,SC,HLF,N
      IF(EOFCKF(60).EQ.2)8,200
    8 EPSR=3.1416*EPS/180.0
      WAR=3.1416*WA/180.0
      AL=3.1416*ALT/180.0
      DELT(N)=3.1416*DEL(N)/180.0
   24 IF(MI-90)29,90,160
   29 IF(SC-0.0)33,78,33
   33 H=0.25*(TME+TE(N))
      HR=3.1416*H/180.0
      XL=COSF(EPSR)
```

```
      YM=SINF(WAR)
      ZN=COSF(WAR)
   26 COSZ=SINF(AL)*SINF(DELT(N))+COSF(AL)*COSF(DELT(N))*COSF(HR)
   27 COSW=COSF(DELT(N))*SINF(HR)
   28 AT=(SINF(DELT(N))*COSF(AL))/(COSF(DELT(N))*SINF(AL))
      IF(COSF(HR)-AT)10,10,9
    9 COSS=SQRTF(1.0-COSW**2-COSZ**2)
      GO TO 12
   10 COSS=-SQRTF(1.0-COSW**2-COSZ**2)
   12 COSTH=XL*COSZ+YM*COSW+ZN*COSS
      BT=-(SINF(DELT(N))*SINF(AL))/(COSF(DELT(N))*COSF(AL))
      IF(COSF(HR)-BT)35,35,30
   30 DNI=AZ(N)/EXPF(B(N)/COSZ)
      GO TO 38
   35 DNI=0.0
   38 IF(COSTH-0.0)45,45,40
   40 DI=DNI*COSTH
      GO TO 48
   45 DI=0.0
   48 IF(COSTH+0.2)55,55,50
   50 Y=0.55+0.437*COSTH+0.313*COSTH**2
      GO TO 58
   55 Y=0.45
   58 DHI=C(N)*DNI
      DVI=DNI*(C(N)*Y+(RHG/2.0)*(C(N)+COSZ))
      IF(EPS-90.0)60,65,60
   60 DSI=DHI
      GO TO 80
   65 DSI=DVI
   80 FNI=UG/HO
      AJ=0.0
      TJ=0.0
      AJI=0.0
      TJI=0.0
      DO 70 I=1,6
      R=I
      AJ=AJ+A(L,I)*COSTH**(I-1)
      TJ=TJ+T(L,I)*COSTH**(I-1)
      AJI=AJI+A(L,I)/(R+1.0)
   70 TJI=TJI+T(L,I)/(R+1.0)
   75 SHGF=DI*TJ+2.0*DSI*TJI+FNI*(DI*AJ+2.0*DSI*AJI)
      AREAG=GL*GW
      SHG=SHGF*SC*AREAG
      GO TO 79
   78 AREAG=GL*GW
      SHG=0.0
   79 AREA=WW*WH-AREAG
      IF(SC-0.0)67,68,67
   68 GTL=0.0
      GO TO 83
   67 GTL=AREAG*UG*(TO-TI)
   83 FHL=WW*HLF
      QTR=U*DLTE*AREA
      TLW=(U*AREA+UG*AREAG)*(TO-TI)
      SGTL=SGTL+GTL
      STLR=STLR+TLW
      SHQ=SHQ+SHG
      SQTRW=SQTRW+QTR
      FHLS=FHLS+FHL
   25 IF(NI-99)5,85,5
   85 READ(60,104)K,JI,FL,FW,P,HL,HS,FAL,WO,WI,VPF,PR,FI,FIT,TO,TI,PN,BN
```

```
      2,HSIL
      IF(EOFCKF(60).EQ.2)95,200
   95 PQRS=P*HS
      PQRL=P*HL
      AREAF=FL*FW
      GHL=FAL*AREAF
      VHS=(60.0*0.244*P*VPF*(TO-TI))/14.15
      VHL=(60.0*3.0*P*VPF*(WO-WI))/(20.0*14.15)
      AVS=(0.244*FI*(PR/2.0)*(TO-TI))/14.15
      AVL=(3.0*FI*(PR/2.0)*(WO-WI))/(20.0*14.15)
      AVPHS=(60.0*0.244*PN*FIT*(TO-TI))/14.15
      AVPHL=(3.0*60.0*PN*FIT*(WO-WI))/(20.0*14.15)
      RLINL=AVL+AVPHL
      RSINL=AVS+AVPHS
      RIMLL=GHL+HSIL
      SGHQ=SHQ+SGTL
      IF(JI-1)150,155,150
  155 CLRS=SQTRW+SHQ+PQRS+GHL+VHS+AVPHS+AVS+HSIL+FHLS+SGTL
      CLRL=PQRL+VHL+AVL+AVPHL
      RSCLAA=SQTRW+SHQ+PQRS+GHL+AVS+AVPHS+HSIL+SGTL+FHLS
      RLCLAA=PQRL+AVL+AVPHL
      CLRSZ=BN*CLRS
      CLRLZ=BN*CLRL
      ZSTL=BN*STLR
      IF(K-800)157,157,158
  157 CLODL=CLODL+CLRLZ
      CLODS=CLODS+CLRSZ
      BSCL=BSCL+BN*RSCLAA
      BLCL=BLCL+BN*RLCLAA
  158 WRITE(61,111)
      WRITE(61,105)K,CLRS,RSCLAA,SQTRW,SGHQ,PQRS,RIMLL,RSINL,VHS,STLR,FH
     2LS,ZSTL,CLRSZ
      WRITE(61,112)
      WRITE(61,106)K,CLRL,RLCLAA,CLRLZ,PQRL,RLINL,VHL
      GO TO 7
   90 TCLL=1.05*CLODL
      TCLS=1.05*CLODS
      WRITE(61,115)
      WRITE(61,107)CLODL,TCLL,CLODS,TCLS,BSCL,BLCL
      GO TO 4
  150 HLRS=STLR+FHLS+PQRS+SHQ+GHL+AVS+AVPHS+HSIL+VHS
      HLRL=PQRL+AVL+AVPHL+VHL
      RSHLAA=STLR+FHLS+PQRS+SHQ+GHL+AVS+AVPHS+HSIL
      RLHLAA=PQRL+AVL+AVPHL
      ZHLRS=BN*HLRS
      ZHLRL=BN*HLRL
      ZSTLR=BN*STLR
      IF(K-800)151,151,152
  151 HLODS=HLODS+ZHLRS
      HLODL=HLODL+ZHLRL
      HZSTL=HZSTL+ZSTLR
      BSHL=BSHL+BN*RSHLAA
      BLHL=BLHL+BN*RLHLAA
  152 WRITE(61,116)
      WRITE(61,108)K,HLRS,RSHLAA,ZHLRS,ZSTLR,STLR,SHQ,PQRS,RIMLL,RSINL,V
     2HS,FHLS
      WRITE(61,117)
      WRITE(61,106)K,HLRL,RLHLAA,ZHLRL,PQRL,RLINL,VHL
      GO TO 7
  160 THLL=1.05*HLODL
      THLS=1.05*HLODS
      TSTL=1.05*HZSTL
      WRITE(61,119)
      WRITE(61,107)HLODL,THLL,HLODS,THLS,HZSTL,TSTL,BSHL,BLHL
      GO TO 4
  200 STOP
      END
```

one-half inch regular plate glass where J is given the value of two and one-quarter inch heat absorbing plate glass where J is given the value of three. For other types of plate and sheet glass, the manufacturer should be consulted for the proper values of A(J, I) and T(J, I). These new factors can be added to the ones already in the program by assigning a J value for the new type, increasing the subscript corresponding to J in the dimension statement by one for each new kind of glass and punching the needed data cards to be added to the present cards. The data for A(J, I) are read first followed by T(J, I).

A: READ: A(J, I), T(J, I)

I = 1 → 6

J = 1 → 3

B: READ: AZ(N), DEL(N), B(N), C(N), TE(N): N = 1 → 12

C: PUNCH: COOLING AND HEATING LOAD CALCULATION

D: SET: CLODL, CLODS, HLODL, HLODS, HZSTL, BSCL, BLCL, BSHL,

BLHL to: 0.0

E: SET: SHQ, STLR, SQTRW, SGTL and FHLS to: 0.0

F: READ: K, NI, MI, L, WW, WH, GW, GL, TO, TI, EPS, ALT, U, UG, WA,

TME, DLTE, RHG, HO, SC, HLF, N

G: EPSR = 3.1416*EPS/180.0

WAR = 3.1416*WA/180.0

DELT(N) = 3.1416*DEL(N)/180.0

AL = 3.1416*ALT/180.0

```
H: H = 0. 25*(TME+TE(N))
   HR = 3. 1416*H/ 180. 0
   XL = COSF(EPSR)
   YM = SINF(WAR)
   ZN = COSF(WAR)
   COSZ = SINF(AL)*SINF(DELT(N))+COSF(AL)*COSF(DELT(N))*
          COSF(HR)
   COSW = COSF(DELT(N))*SINF(HR)
   AT = (SINF(DELT(N))*COSF(AL))/(COSF(DELT(N))*COSF(AL))
I: COSTH = XL*COSZ+ZM*COSW+ZN*COSS
   BT = -(SINF(DELT(N))*SINF(AL))/(COSF(DELT(N))*COSF(AL))
J: DHI = C(N)*DNI
   DVI = DNI*(C(N)*Y+(RHG/2. 0)*(C(N)+COSZ))
K: FNI = UG/HO
   AJ = TJ = AJI = TJI = 0. 0
L: R = I
   AJ = AJ+A(L, I)*COSTH**(I-1)
   TJ = TJ+T(L, I)*COSTH**(I-1)
   AJI = AJI+A(L, I)/(R+1. 0)
   TJI = TJI+T(L, I)/(R+1. 0)
   I = 1 → 4
M: SHGF = DI*TJ+2. 0*DSI*TJI+FNI*(DI*AJ+2. 0*DSI*AJI)
   AREAG = GL*GW
```

```
   SHG = SHGF*SC*AREAF
N: AREAG = GL*GW
   SHG = 0. 0
O: FHL = WW*HLF
   QTR = U*DLTE*AREA
   TLW = (U*AREA+UG*AREAG)*(TO-TI)
   SGTL = SGTL+GTL
   STLR = STLR+TLW
   SHQ = SHQ+SHG
   SQTRW = SQTRW+QTR
   FHLS = FHLS+FHL
P: READ: K, JI, FL, FW, P, HL, HS, FAL, WO, WI, VPF, PR, FI, FIT,
         TO, TI, PN, BN, HSIL
Q: PQRS = P*HS
   PQRL = P*HL
   AREAF = FL*FW
   GHL = FAL*AREAF
   VHS = (60. 0*0. 244*P*VPF*(TO-TI))/ 14. 15
   VHL = (60. 0*3. 0*P*VPF*(WO-WI))/ (20. 0*14. 15)
   AVS = (0. 244*FI*(PR/ 2. 0)*(TO-TI))/ 14. 15
   AVL = (3. 0*FI*(PR/ 2. 0)*(WO-WI))/ (20. 0*14. 15)
   AVPHS = (60. 0*0. 244*PN*FIT*(TO-TI))/ 14. 15
   AVPHL = (60. 0*3. 0*PN*FIT*(WO-WI))/ (20. 0*14. 15)
```

```
   RLINL = AVL+AVPHL
   RSINL = AVS+AVPHS
   RIMLL = GHL+HSIL
   SGHQ = SHQ+SGTL
R: CLRS = SQTRW+SHQ+PQRS+GHL+VHS+AVS+AVPHS+HSIL+FHLS+
          SGTL
   CLRL = PQRL+VHL+AVL+AVPHL
   RSCLAA = SQTRW+SHQ+PQRS+GHL+AVPHS+AVS+HSIL+FHLS+
            SGTL
   RLCLAA = PQRL+AVL+AVPHL
   CLRSZ = BN*CLRS
   CLRLZ = BN*CLRL
   ZSTL = BN*STLR
S: CLODL = CLODL+CLRLZ
   CLODS = CLODS+CLRSZ
   BSCL = BSCL+BN*RSCLAA
   BLCL = BLCL+BN*RLCLAA
T: PUNCH: K, CLRS, SQTRW, SGHQ, PQRS, GHL, VHS, AVS, AVPHS,
          K, CLRL, PQRL, VHL, AVL, AVPHL, STLR, FHLS, HSIL,
          K, CLRLZ, CLRSZ, ZSTL, RSCLAA, RLCLAA
U: TCLL = 1.05*CLODL
   TCLS = 1.05*CLODS
V: PUNCH: CLODL, TCLL, CLODS, TCLS, BSCL, BLCL
```

```
W: HLRS = STLR+FHLS+PQRS+SHQ+GHL+AVS+AVPHS+HSIL+VHS
   HLRL = PQRL+AVL+AVPHL+VHL
   RSHLAA = STLR+FHLS+PQRS+SHQ+GHL+AVS+AVPHS+HSIL
   RLHLAA = PQRL+AVL+AVPHL
   ZHLRS = BN*HLRS
   ZHLRL = BN*HLRL
   ZSTLR = BN*STLR
X: HLODS = HLODS+ZHLRS
   HLODL = HLODL+ZHLRL
   HZSTL = HZSTL+ZSTLR
   BSHL = BSHL+BN*RSHLAA
   BLHL = BLHL+BN*RLHLAA
Y: PUNCH: K, HLRS, STLR, SHQ, PQRS, GHL, VHS, AVS, AVPHS
          K, HLRL, PQRL, VHL, AVL, AVPHL, STLR, FHLS, HSIL
          K, ZHLRS, ZHLRL, ZSTLR, RSHLAA, RLHLAA
Z: THLS = 1.05*HLODS
   THLL = 1.05*HLODL
   TSTL = 1.05*HZSTL
ZZ: PUNCH: HLODL, THLL, HLODS, THLS, HZSTL, TSTL, BSHL,
           BLHL
```

The rest of the permanent data which include AZ(N), DEL(N), B(N), C(N) and TE(N) are read after A(J, I) and T(J, I) and the program moves to the initialization step. Initialization is done in two steps. The first step starts at statement four where the values of CLODL, CLODS, HLODL, HLODS, HZSTL, BSCL, BSHL, BLCL and BLHL are set to zero. This step is repeated only once in each sequence of calculating the total building loads. At statement seven the values of SHQ, STLR, SQTRW, SGTL and FHLS are set to zero. This step is repeated each time the computer starts on a new zone.

Following the initialization the computer reads the first data set for a wall in a room of the first zone and checks the value of SC. If the value of SC is zero, the computer bypasses the solar heat load calculation and moves to statement 78 setting the value of SHG and GTL to zero.

If the value of SC is more than zero the computer goes through the steps of calculating the solar heat gain. The method of calculation used here is the new method introduced in the 1967 ASHRAE Handbook of Fundamentals (1, p. 478). In the program the method is incorporated by statements 29 through 75 which results in the calculation of the solar heat gain factor (SHGF).

The solar heat gain (SHG) is calculated after SHGF by multiplying SHGF by the glass area (AREAG). The transmission heat load through glass is calculated by multiplying AREAG by UG and the difference between TO and TI.

All the heat gain calculations through glass explained thus far would be bypassed if the value of SC were zero.

At statement 78 the computer calculates the area of the wall (minus the area of the window), the area of the door or the area of the roof (AREA), the equivalent solar and transmission heat gain through the wall (QTR), the transmission heat gain or loss through walls or roof (TLW) and the heat transfer through the exposed perimenter of the ground floor (FHL). The method used in the calculation here is the conventional method explained in Chapters 27 and 28 of the 1967 ASHRAE Handbook of Fundamentals (1, p. 457-511).

The last thing in the wall calculation is the summing of SHG, GTL, FHL, QTR and TLW to the room loads SHQ, SGTL, FHLS, SQTRW and STLR respectively.

The computer checks the value of NI after completing the calculation for each wall. If the value of NI is less than 99 the computer transfers control to statement five to read a new set of data for the next wall or the roof of the room and repeats the same calculation. If the value of NI is equal to 99 the computer transfers control to statement 85 to read the rest of the data for the room.

The rest of the loads for the room are calculated following statement 85. This includes calculating the sensible and latent occupant cooling loads (PQRS and PQRL), the lighting cooling load (GHL), the sensible and latent ventilation load (VHS and VHL), the sensible and latent load from infiltration through cracks (AVS and AVL) and the sensible and latent load from infiltration through used outside doors (AVPHS and AVPHL). The method of calculating the lighting cooling loads was obtained from the Handbook of Air Conditioning Heating and Ventilating, (5, p. 1-158). There is no special calculation required for the load from miscellaneous heat sources within the room (HSIL) since the unit is already in Btu per hour. The cooling loads from light (GHL) and the miscellaneous heat sources (HSIL) are added to give RIMLL. Also the computer combines the infiltration loads from cracks (AVL and AVS) and outside doors (AVPHL and AVPHS) to give RLINL and RSINL and sums the solar heat gain (SHQ) to the transmission load through glass (SGTL) to give SGHQ. The last operation in the room calculation is the checking of the value of JI read at statement 85.

When the value of JI is equal to one, it indicates that the data read at statements 85 are for summer and the computer transfers control to statement 155. There the computer calculates the room sensible and latent cooling loads including ventilation (CLRS and CLRL), the sensible and latent cooling loads not including ventilation (RSCLAA and RLCLAA) and the zone sensible and latent cooling loads including ventilation (CLRSZ and CLRLZ). The computer sums RSCLAA, RLCLAA, CLRSZ and CLRLZ to the building total summer sensible and latent cooling loads (BSCL, BLCL, CLODS and CLODL respectively). The computer multiplies RSCLAA and RLCLAA by the number of rooms in the zone (BN) before adding them to BSCL and BLCL. The next is to print, or punch, out the room and zone results which includes K, CLRS, SQTRW, SGHQ, PQRS, GHL, VHS, AVS, AVPHS, CLRL, PQRL, VHL, AVL, AVPHL, STLR, FHLS, HSIL, CLRLZ, CLRSZ, RSCLAA and RLCLAA and the control will be transferred to statement seven to calculate the loads for a new room and zone. When upon reading the data at statement five the computer encounters a value for MI equal to 90, indicating that the cooling loads for all the zones in the building have been calculated, the computer transfers control to statement 90. Statement 90 specifies that the building sensible and latent cooling loads including ventilation (CLODS and CLODL) are to be multiplied by a five percent safety factor to give TCLS and TCLL respectively. The total building loads CLODL, TCLL, CLODS, TCLS, BSCL and BLCL are printed, or punched, by the output unit of the computer and control is transferred to statement four for another round of calculation of the building load at new design conditions.

When the value of JI is either less or more than one, it indicates that the data read at statement 85 are for winter design condition and the computer transfers control to statement 150. There the total room heating load is calculated. Since there was no available information to calculate the winter equivalent solar and transmission heating load through walls, only the transmission heat transfer was used. This does not result in large error as the solar load on walls during the winter is much lower than during the summer. In addition the solar load will generally help the air conditioning unit rather than opposing it as is the case for summer. For summer conditions the transmission load is not added to the room total since it is already included in the room equivalent load (SQTRW). It is printed only to help in determining the load pattern for the zone.

At statement 150 the computer calculates the room total sensible and latent heating loads with ventilation (HLRS and HLRL) and without ventilation (RSHLAA and RLHLAA), the total sensible and latent zone heating loads including ventilation (ZHLRS and ZHLRL) and the zone transmission heating load (ZSTLR). The results of the calculation for that room are printed, or punched, following the calculation. The printed, or punched, results includes K, HLRS, STLR, SHQ, PQRS, GHL, VHS, AVS, AVPHS, HLRL, PQRL, VHL, AVL, AVPHL, STLR, FHLS, HSIL, ZHLRS, ZHLRL, ZSTLR, RSHLAA and RLHLAA. Control returns to statement seven following the printing of the results to start on the next zone. Before printing the zone results the computer adds the room and zone loads (RSHLAA, RLHLAA, ZHLRS, ZHLRL and ZSTLR) to BSHL, BLHL, HLODS, HLODL, and HZSTL respectively. The computer multiplies RSHLAA and RLHLAA by the number of rooms in zone (BN) before adding them to BSHL and BLHL.

When upon reading the data at statement five the computer encounters a value for MI which is more than 90 indicating that the heating load calculations for all the zones in the building is finished, control transfers to statement 160. There the total building heating loads including ventilation (HLODS and HLODL) and the building transmission heating load (HZSTL) are multiplied by a five percent safety factor to give THLS, THLL and TSTL respectively. The results for the building which includes HLODL, THLL, HLODS, THLS, HZSTL, TSTL, BSHL and BLHL are printed, or punched, by the output unit of the computer. Control then returns to statement four to start a new cycle of calculation for the building at a new set of design conditions.

In both the summer and winter calculation if the zone number (K) is more than 800, the results of the zone calculation will be printed but will not be added to the building total load. This feature is useful in determining the load pattern by calculating the zone maximum (or minimum) load which may be different than that used in determining the building maximum load. Also, the room maximum load is needed in designing the ducts and the room air conditioning units.

If after returning to statement four the computer upon reading a new data card encounters a value for NI equal to 999, control will be transferred to statement 200 which is the stop statement and the program will terminate without any further calculation. The last step for terminating the program is used for the IBM 1620 computer system. On some other computers such as the CDC 3300 this step is not required. Other steps are provided to terminate the program. For example for the CDC 3300 a special end of file card is provided to be placed as the last data card. Every time the computer reads a data card, a special end of file check IF statement checks to see if the card read is that special end of file card. If it is, control transfers to the stop statement (or any other statement desired) in order to terminate the program. If the card is not the end of file card, the computer continues with the calculation.

This program was tried on a small school with seven zones. It was run on both the IBM 1620 and the CDC 3300. On the IBM 1620 the computer took about 15 minutes to give the results while on the CDC 3300 it took only 12. 8 seconds. This calculation would take over three days with conventional methods. The results obtained from the computer compared favorably with those obtained using the conventional hand calculation except in the case of the solar heat gain through windows and the equivalent cooling load through walls. This exception is due to the use of the new and more accurate method of calculating the solar heat gain factor and new improved data for the equivalent temperature.

Because of the longer output line possible on the CDC 3300, the results for each zone were arranged on two lines instead of the three required by the IBM 1620. To make this possible, the sensible and latent infiltration load through cracks (AVS and AVL) and used doors (AVPHS and AVPHL) are combined together to give RSINL and RLINL. Also the light heating load (GHL) and the heating load from miscellaneous heat sources in the room (HSIL) were combined to give RIMLL.

V. AIR SYSTEM PROGRAM

Input Data

There are three types of input data required for this program. First there are the permanent data. This includes TSS(I), TWS(I), WSS(I), WWS(I), SSPV(I) and WSPV(I). The permanent data stays the same for each cycle of calculating the air requirement for the whole building. They are stored in the memory of the computer at the beginning of calculation in the form of a one dimensional array with the subscript I acting as the identification factor.

The second set of data is for the preliminary calculation of the building air requirement for dual duct systems. This calculation is done mainly to find the ratio (X) of outside air to the total supply air for the main duct of the dual duct system. This set includes:

BSCL. Building sensible cooling load not including ventilation.

This is obtained from the heating and cooling load program discussed earlier, Btu/hr.

PB: Number of occupant in the building.

TI: Inside design temperature, ^{o}F.

TSC: Supply temperature in the main duct of the dual duct system, ^{o}F.

VPF: Required ventilation rate per person, cfm, (1, p. 112, Table 1).

The third set of data is the room and zone data which includes:

RN: Number of rooms in the zone.

HFGS: Enthalpy of water vapor (h_{fg}) at summer supply condition for an air induction system, Btu/lb. This is obtained from the steam tables (1, p. 365, Table 2).

HFGW: Enthalpy of water vapor (h_{fg}) at winter supply condition for an air induction system, Btu/lb., (1, p. 365, Table 2).

K: Zone number

N: A factor used to switch the program from room calculations to the summing of the total building air requirements.

RLCLAA: Room latent cooling load obtained from the cooling-heating load program, Btu/hr.

RLHLAA: Room latent heating load obtained from the cooling-heating load program, Btu/hr.

RSCLAA: Room sensible cooling load obtained from the cooling-heating load program, Btu/hr.

RSHLAA: Room sensible heating load obtained from the cooling-heating load program, Btu/hr.

TSC: Summer supply air temperature in the main duct of a dual duct system, $^{\circ}F$.

TSI: Summer inside design temperature, $^{\circ}F$.

TSW: Winter supply air temperature in the main duct of the dual duct system, $^{\circ}F$.

TWI: Winter inside design temperature, $^{\circ}F$.

VPF: Ventilation rate per person, cfm., (1, p. 112, Table 1).

WSI: Humidity ratio inside the room during the summer, lb_{water}/lb_{air}. This is obtained from the psychrometric chart.

WWI: Winter room humidity ratio, lb_{water}/lb_{air}. This is obtained from the psychrometric chart.

In preparing the data the following points must be kept in mind. If the calculation for one of the zone is not to be added to the total building load, 800 must be added to the zone number provided that the zone number does not exceed or equal 999. This is done if the maximum air requirement of the zone is not at the building maximum. The maximum room air quantity is required for designing the ducts for the room.

On the data card for the last zone the value of N must be 99 so the program will switch from room calculation to summing the building air requirements and adding a five percent safety factor.

Before and after the data deck two special cards must be added. The first one at the beginning of the deck must not have the number 999 in the first three columns. This card is present to satisfy statement 14, a read statement. This card can be blank. The second special card contains the number 999 in the first three columns and is placed at the end of the deck. At the start of each cycle of calculations the program checks this card and when the computer encounters the number 999 it will stop the execution of the program. This number is designated by the letter M and is specified by format statement 100. If more than one deck of data is going to be entered into the program, M can be used to designate each deck by giving it a number less than 999.

Required Output

There are two types of output, room output and building output. Room output includes:

BN: Number of rooms in the zone.

DAIR: Room air requirements in the main duct of the dual duct air systems, cfm.

DCAIR: Air required in the main duct of the dual duct systems to satisfy the room sensible cooling load, cfm.

DHAIR: Air required in the main duct of the dual duct systems to satisfy the room sensible heating load, cfm.

DVAIR: Air required in the main duct of the dual duct systems to satisfy the room ventilation requirements, cfm.

K: Zone number.

QAIR: Required ventilation air per room, cfm.

SAIR(I): Summer air required to satisfy the room sensible cooling load using a single duct system, cfm.

SAIR2(I): The air required to satisfy half the room sensible cooling load, cfm.

SAIR4(I): The air required to satisfy three-fourths the room sensible cooling load, cfm.

SIAIR(I): Air quantity required to satisfy the room latent cooling load, cfm.

TSS(I): Summer supply temperature for the single duct systems, ^{o}F.

TWS(I): Winter supply temperature for the single duct systems, ^{o}F.

WAIR(I): The air required to satisfy the room sensible heating load, cfm.

WAIR2(I): The air required to satisfy half the room sensible heating load, cfm.

WAIR4(I): The air required to satisfy three-fourths the room sensible heating load, cfm.

WIAIR(I): The air required to satisfy the room latent heating load, cfm.

Each air quantity denoted by the subscript (I) is calculated four times. Each time at a different supply temperature (TSS(I) and TWS(I)) or supply humidity ratio (WSS(I) and WWS(I)) and the different air specific volume (SSPV(I) and WSPV(I)). For each room the computer prints, or punches, a line containing K, BN, DHAIR, DCAIR, DVAIR, DAIR and QAIR. Following that the computer prints, or punches, four output lines. Each line consists of a single value for SAIR(I), SAIR2(I), SAIR4(I), WAIR(I), WAIR2(I), WAIR4(I), WIAIR(I), SIAIR(I), TSS(I), TWS(I), and I. Each line is at a different supply condition.

Total building output includes:

TDAIR: Total air required in the main duct of the dual duct system to satisfy the building requirement, cfm.

TSAIR(I): The air required to satisfy the building sensible cooling load using a single duct system, cfm.

TSIAIR(I): Air required to satisfy the building summer requirement using an air induction system, cfm.

TSS(I): Summer supply temperature for the single duct system, $^{\circ}$F.

TWAIR(I): Air required to satisfy the building sensible heating load using a single duct system, cfm.

TWIAIR(I): Air required to satisfy the building winter requirement using an air induction system, cfm.

TWS(I): Winter supply temperature for the single duct systems, $^{\circ}$F.

STDAIR: Total air required in the main duct of the dual duct system to satisfy the building requirements and includes a five percent safety factor, cfm.

STSAIR(I): Total air required to satisfy the building sensible cooling load and includes a five percent safety factor, cfm.

STSIAR(I): Total air required by the building in summer using an air induction system and includes a five percent safety factor, cfm.

STWAIR(I): Total air required to satisfy the building sensible heating load and includes a five percent safety factor, cfm.

STWIAR(I): Total air required by the building in winter using an air induction system and includes a five percent safety factor, cfm.

The computer prints, or punches, a line for TDAIR and STDAIR followed by four output lines. Each of the four output lines have a value for each of the quantities TSAIR(I), STSAIR(I), TWAIR(I), STWAIR(I), TSIAIR(I), STSIAR(I), TWIAIR(I), STWIAR(I), TSS(I), TWS(I), and I. Each line is at a different supply condition.

Program Description

In order to simplify the calculations, the duct systems in use are divided into three general groups which depend on similarities in the calculations. The first group is the dual duct systems. The second group is the air induction systems. The third group combine the following single duct systems; constant volume, variable volume, reheat and multizone systems.

The method used in calculating the amount of air needed for dual duct systems was taken from Chapter 2, of the 1966-67 ASHRAE Guide, Book of Application (2, p. 11-24). The quantity of air necessary to satisfy the cooling load, the heating load and the ventilation requirement is calculated for each room separately and the highest value obtained is taken as the room air requirement. The air requirements of each zone, which is the room requirement multiplied by the number of rooms in the zone, are summed up to give the total building air supply. The equation used in calculating the air quantity necessary to satisfy the cooling and heating load is:

$$Q_a = \frac{h_{sr}}{1.08(T_i - T_s)}$$

where:

Q_a (DCAIR or DHAIR): Room air requirements, cfm.

h_{sr} (RSCLAA or RSHLAA): Room sensible cooling or heating load, Btu/hr.

T_i (TSI or TWI): Summer or winter room design temperature, ^oF.

T_s (TSC or TSW): Summer or winter supply air temperature, ^oF.

The expressions shown inside the parenthesis are the ones used in the program to denote the value of the expression shown outside the parenthesis. The expressions used to denote the cooling and heating loads (RSCLAA and RSHLAA) are the same as in the cooling-heating loads program explained earlier. The cooling and heating loads must have the same sign as given by the previous program. The air quantity calculated using this method is for the main duct of the dual duct system. The air flow in the secondary duct is usually taken as 80 percent of the main duct air flow.

The air quantity necessary to satisfy room requirements using an air induction system must satisfy either the ventilation requirements or the room latent load which ever is the greatest. This is because the third factor to be satisfied which is the sensible load is satisfied at the room outlet of the system. This leaves only the ventilation requirement and the room latent load to be satisfied. The equation used to calculate the air quantity necessary to satisfy the latent load is:

$$Q_{ai} = \frac{h_{cr} \cdot v_s}{60.0 h_{fg} \cdot (W_i - W_s)}$$

where:

Q_{ai} (SIAIR(I) or WIAIR(I): Air requirements, cfm.

h_{cr} (RLCLAA or RLHLAA): Room latent load, Btu/hr.

v_s (SSPV(I) or WSPV(I)): Specific volume of the supply air, ft.^{3}/lb.

h_{fg} (HFGS or HFGW): Enthalpy of water vapor at the supply condition, Btu/hr-lb.

W_i (WSI or WWI): Humidity ratio of the room air, lb_{water}/lb_{air}.

W_s (WSS(I) or WWS(I)): Humidity ratio of the supply air, lb_{water}/lb_{air}.

The equation used to calculate the ventilation air requirements is:

$$Q_{va} = P \cdot VPF$$

where:

P: Number of persons in the room

VPF: Required ventilation rate per person, cfm.

Q_{va}(QAIR): The room ventilation air requirements, cfm.

The quantity required to satisfy the latent load is calculated at four different supply conditions. The zones air requirements (either from ventilation or from the latent load) are summed up to give the building air requirements. The zone air quantity is found by multiplying the room requirement by the number of rooms in the zone.

The requirements for the third group is to satisfy either the required ventilation air or the sensible heating or cooling load which ever is the greatest. The same equation used to calculate the air quantity for the dual duct system is used for this group except that T_s stands for TSS(I) or TWS(I) in this calculation. In order to satisfy all of the systems in this group, the air quantity is calculated at four different supply temperatures for both the heating and cooling load air requirements. Also the air quantity is calculated at three-fourths and one-half of the design load and at four different supply temperatures. This is done to satisfy the requirement for calculating the air quantities for the variable volume systems.

The flow chart of the program is shown in Figure 3 followed by a tabulation of the functions calculated in each step and the whole

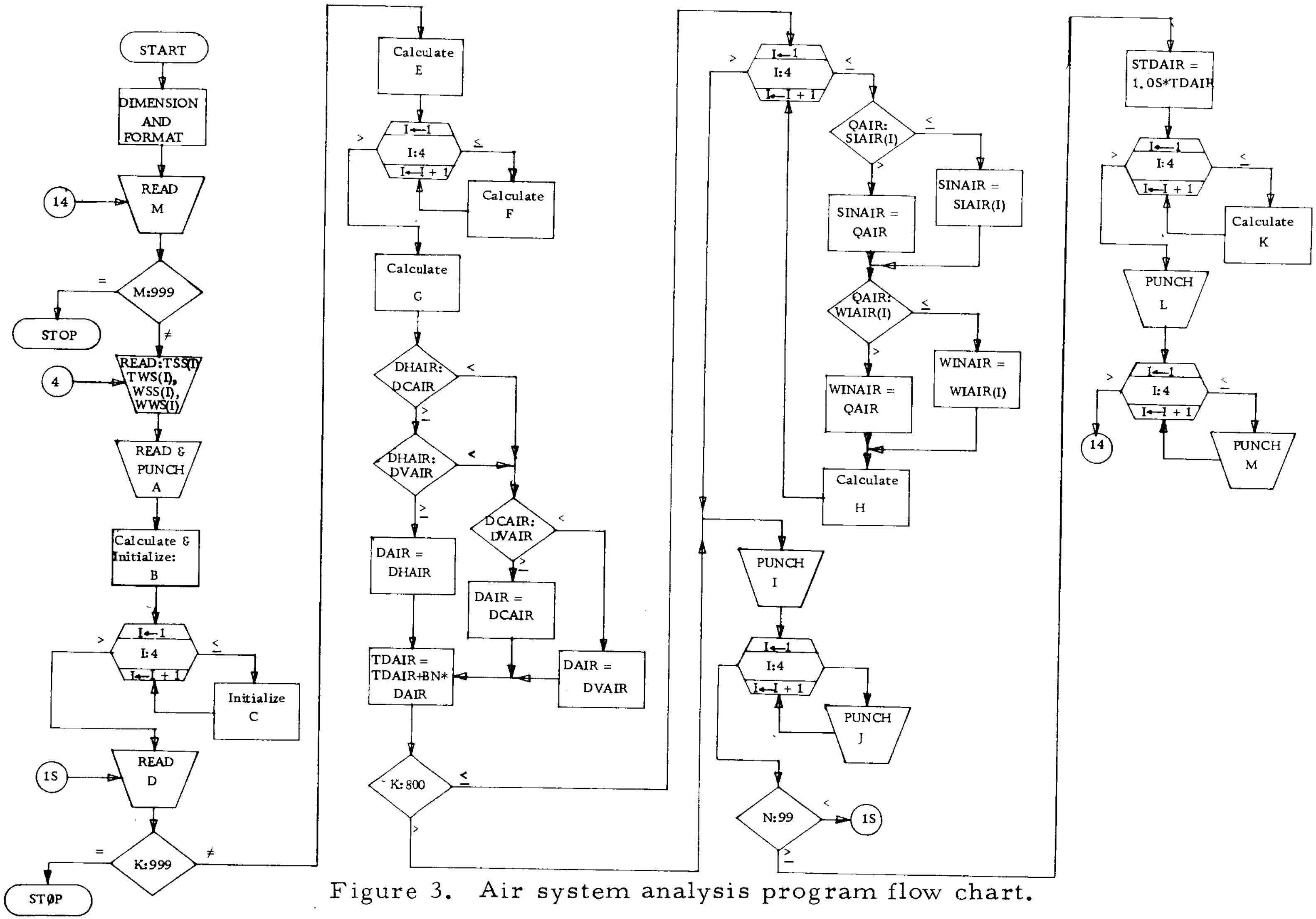

Figure 3. Air system analysis program flow chart.

AIR ANALYSIS PROGRAM FOR IBM 1620

```
C     PROGRAM AIR SYSTEM ANALYSIS
      DIMENSION SAIR(4),SAIR2(4),SAIR4(4),WAIR(4),WAIR2(4),WAIR4(4)
      DIMENSION TSAIR(4),TWAIR(4),TSS(4),TWS(4),WSS(4),WWS(4),SIAIR(4)
      DIMENSION WIAIR(4),TSIAIR(4),TWIAIR(4),STSAIR(4),STWAIR(4)
      DIMENSION STSIAR(4),STWIAR(4),SSPV(4),WSPV(4)
  101 FORMAT(8F3.0,8F5.4)
  102 FORMAT(I3,F2.0,4F9.0,F3.0,F4.1,4F3.0,2F5.4,2F4.0,I2)
  103 FORMAT(F8.0,F4.0,F4.1,2F3.0)
  104 FORMAT(I3)
  105 FORMAT(I3,F3.0,5(F8.0,3X))
  106 FORMAT(5(F8.0,1X),3F8.0,2F4.0,I3)
  107 FORMAT(2(F8.0,4X))
  108 FORMAT(8F5.3)
  110 FORMAT(61H K   BN    DHAIR       DCAIR      DVAIR          DAIR        QA
     2IR    )
  111 FORMAT(80H   SAIR      SAIR2     SAIR4     WAIR      WAIR2     WAIR4
     2WIAIR    SIAIR TSS TWS I  )
  112 FORMAT(24H   TDAIR        STDAIR       )
  113 FORMAT(80H   TSAIR    STSAIR    TWAIR    STWAIR    TSIAIR    STSIAR  T
     2WIAIR   STWIAR TSS TWS I  )
  114 FORMAT(24H       AIR SYSTEM ANALYSIS)
   14 READ 104, M
      IF(M-999)4,200,4
    4 READ 101, (TSS(I),I=1,4),(TWS(I),I=1,4),(WSS(I),I=1,4),(WWS(I),I=1
     2,4)
    8 READ 108, (SSPV(I),I=1,4),(WSPV(I),I=1,4)
    5 READ 103, BSCL,PB,VPF,TI,TSC
      PUNCH 114
      TVAIR=PB*VPF
      TAIR=BSCL/(1.08*(TI-TSC))
      X=TVAIR/TAIR
    7 TDAIR=0.0
      DO 10 I=1,4
      TSIAIR(I)=0.0
      TWIAIR(I)=0.0
      TSAIR(I)=0.0
   10 TWAIR(I)=0.0
   15 READ 102, K,BN,RSCLAA,RLCLAA,RSHLAA,RLHLAA,P,VPF,TWI,TSI,TSW,TSC,
     2WSI,WWI,HFGW,HFGS,N
      IF(K-999)18,200,18
   18 RSHLA2=0.5*RSHLAA
      RSHLA4=0.75*RSHLAA
      RSCLA2=0.5*RSCLAA
      RSCLA4=0.75*RSCLAA
      DO 20 I=1,4
      SAIR(I)=RSCLAA/(1.08*(TSI-TSS(I)))
      SAIR2(I)=RSCLA2/(1.08*(TSI-TSS(I)))
      SAIR4(I)=RSCLA4/(1.08*(TSI-TSS(I)))
      WAIR(I)=RSHLAA/(1.08*(TWI-TWS(I)))
      WAIR2(I)=RSHLA2/(1.08*(TWI-TWS(I)))
      WAIR4(I)=RSHLA4/(1.08*(TWI-TWS(I)))
      SIAIR(I)=(RLCLAA*SSPV(I))/((WSI-WSS(I))*HFGS*60.0)
   20 WIAIR(I)=(RLHLAA*WSPV(I))/((WWI-WWS(I))*HFGW*60.0)
      DHAIR=RSHLAA/(1.08*(TWI-TSW))
      DCAIR=RSCLAA/(1.08*(TSI-TSC))
      QAIR=P*VPF
      DVAIR=QAIR/X
```

```
      IF(DHAIR-DCAIR)25,30,30
   30 IF(DHAIR-DVAIR)25,40,40
   40 DAIR=DHAIR
      GO TO 50
   25 IF(DCAIR-DVAIR)35,45,45
   35 DAIR=DVAIR
      GO TO 50
   45 DAIR=DCAIR
   50 IF(K-800)75,75,80
   75 DO 85 I=1,4
      IF(QAIR-SIAIR(I))90,90,95
   90 SINAIR=SIAIR(I)
      GO TO 94
   95 SINAIR=QAIR
   94 IF(QAIR-WIAIR(I))96,96,97
   96 WINAIR=WIAIR(I)
      GO TO 98
   97 WINAIR=QAIR
   98 TSIAIR(I)=TSIAIR(I)+BN*SINAIR
      TSAIR(I)=TSAIR(I)+SAIR(I)*BN
      TWIAIR(I)=TWIAIR(I)+BN*WINAIR
   85 TWAIR(I)=TWAIR(I)+WAIR(I)*BN
      TDAIR=TDAIR+BN*DAIR
   80 PUNCH 110
      PUNCH 105, K,BN,DHAIR,DCAIR,DVAIR,DAIR,QAIR
      PUNCH 111
      DO 65 I=1,4
   65 PUNCH 106, SAIR(I),SAIR2(I),SAIR4(I),WAIR(I),WAIR2(I),WAIR4(I),
     2WIAIR(I),SIAIR(I),TSS(I),TWS(I),I
      IF(N-99)15,55,55
   55 STDAIR=1.05*TDAIR
      DO 60 I=1,4
      STWAIR(I)=1.05*TWAIR(I)
      STSAIR(I)=1.05*TSAIR(I)
      STSIAR(I)=1.05*TSIAIR(I)
   60 STWIAR(I)=1.05*TWIAIR(I)
      PUNCH 112
      PUNCH 107, TDAIR,STDAIR
      PUNCH 113
      DO 70 I=1,4
   70 PUNCH 106, TSAIR(I),STSAIR(I),TWAIR(I),STWAIR(I),TSIAIR(I),
     2STSIAR(I),TWIAIR(I),STWIAR(I),TSS(I),TWS(I),I
      GO TO 14
  200 STOP
      END
```

AIR ANALYSIS PROGRAM FOR CDC 3300

```
      PROGRAM AIRANLYS
      DIMENSION SAIR(4),SAIR2(4),SAIR4(4),WAIR(4),WAIR2(4),WAIR4(4)
      DIMENSION TSAIR(4),TWAIR(4),TSS(4),TWS(4),WSS(4),WWS(4),SIAIR(4)
      DIMENSION WIAIR(4),TSIAIR(4),TWIAIR(4),STSAIR(4),STWAIR(4)
      DIMENSION STSIAR(4),STWIAR(4),SSPV(4),WSPV(4)
  101 FORMAT(8F3.0,8F5.4)
  102 FORMAT(I3,F2.0,4F9.0,F3.0,F4.1,4F3.0,2F5.4,2F4.0,I2)
  103 FORMAT(F8.0,F4.0,F4.1,2F3.0)
  104 FORMAT(I3)
  105 FORMAT(1H ,I3,F3.0,5(F8.0,3X))
  106 FORMAT(1H ,8(F9.0,3X),2(F5.0,3X),I3)
  107 FORMAT(1H ,2(F8.0,4X))
  108 FORMAT(8F5.3)
  110 FORMAT(61H K   BN    DHAIR        DCAIR       DVAIR           DAIR        QA
     2IR    )
  111 FORMAT(115H        SAIR          SAIR2          SAIR4           WAIR          WAI
     2R2          WAIR4          WIAIR          SIAIR       TSS        TWS      I )
  112 FORMAT(24H  TDAIR        STDAIR       )
  113 FORMAT(115H        TSAIR         STSAIR         TWAIR          STWAIR         TSIA
     2IR          STSIAR         TWIAIR         STWIAR       TSS        TWS      I )
  114 FORMAT(24H       AIR SYSTEM ANALYSIS)
   14 READ(60,104)M
      IF(EOFCKF(60).EQ.2)4,200
    4 READ(60,101)(TSS(I),I=1,4),(TWS(I),I=1,4),(WSS(I),I=1,4),(WWS(I),I
     2=1,4)
    8 READ(60,108)(SSPV(I),I=1,4),(WSPV(I),I=1,4)
    5 READ(60,103)BSCL,PB,VPF,TI,TSC
    9 WRITE(61,114)
      TVAIR=PB*VPF
      TAIR=BSCL/(1.08*(TI-TSC))
      X=TVAIR/TAIR
    7 TDAIR=0.0
      DO 10 I=1,4
      TSIAIR(I)=0.0
      TWIAIR(I)=0.0
      TSAIR(I)=0.0
   10 TWAIR(I)=0.0
   15 READ(60,102)K,BN,RSCLAA,RLCLAA,RSHLAA,RLHLAA,P,VPF,TWI,TSI,TSW,TSC
     2,WSI,WWI,HFGW,HFGS,N
   17 IF(EOFCKF(60).EQ.2)18,200
   18 RSHLA2=0.5*RSHLAA
      RSHLA4=0.75*RSHLAA
      RSCLA2=0.5*RSCLAA
      RSCLA4=0.75*RSCLAA
      DO 20 I=1,4
      SAIR(I)=RSCLAA/(1.08*(TSI-TSS(I)))
      SAIR2(I)=RSCLA2/(1.08*(TSI-TSS(I)))
      SAIR4(I)=RSCLA4/(1.08*(TSI-TSS(I)))
      WAIR(I)=RSHLAA/(1.08*(TWI-TWS(I)))
      WAIR2(I)=RSHLA2/(1.08*(TWI-TWS(I)))
      WAIR4(I)=RSHLA4/(1.08*(TWI-TWS(I)))
      SIAIR(I)=(RLCLAA*SSPV(I))/((WSI-WSS(I))*HFGS*60.0)
   20 WIAIR(I)=(RLHLAA*WSPV(I))/((WWI-WWS(I))*HFGW*60.0)
      DHAIR=RSHLAA/(1.08*(TWI-TSW))
      DCAIR=RSCLAA/(1.08*(TSI-TSC))
      QAIR=P*VPF
      DVAIR=QAIR/X
```

```
      IF(DHAIR-DCAIR)25,30,30
   30 IF(DHAIR-DVAIR)25,40,40
   40 DAIR=DHAIR
      GO TO 50
   25 IF(DCAIR-DVAIR)35,45,45
   35 DAIR=DVAIR
      GO TO 50
   45 DAIR=DCAIR
   50 IF(K-800)75,75,80
   75 DO 85 I=1,4
      IF(QAIR-SIAIR(I))90,90,95
   90 SINAIR=SIAIR(I)
      GO TO 94
   95 SINAIR=QAIR
   94 IF(QAIR-WIAIR(I))96,96,97
   96 WINAIR=WIAIR(I)
      GO TO 98
   97 WINAIR=QAIR
   98 TSIAIR(I)=TSIAIR(I)+BN*SINAIR
      TSAIR(I)=TSAIR(I)+SAIR(I)*BN
      TWIAIR(I)=TWIAIR(I)+BN*WINAIR
   85 TWAIR(I)=TWAIR(I)+WAIR(I)*BN
      TDAIR=TDAIR+BN*DAIR
   80 WRITE(61,110)
      WRITE(61,105)K,BN,DHAIR,DCAIR,DVAIR,DAIR,QAIR
      WRITE(61,111)
      DO 65 I=1,4
   65 WRITE(61,106)SAIR(I),SAIR2(I),SAIR4(I),WAIR(I),WAIR2(I),WAIR4(I),W
     2IAIR(I),SIAIR(I),TSS(I),TWS(I),I
      IF(N-99)15,55,55
   55 STDAIR=1.05*TDAIR
      DO 60 I=1,4
      STWAIR(I)=1.05*TWAIR(I)
      STSAIR(I)=1.05*TSAIR(I)
      STSIAR(I)=1.05*TSIAIR(I)
   60 STWIAR(I)=1.05*TWIAIR(I)
      WRITE(61,112)
      WRITE(61,107)TDAIR,STDAIR
      WRITE(61,113)
      DO 70 I=1,4
   70 WRITE(61,106)TSAIR(I),STSAIR(I),TWAIR(I),STWAIR(I),TSIAIR(I),STSIA
     2R(I),TWIAIR(I),STWIAR(I),TSS(I),TWS(I),I
      GO TO 14
  200 STOP
      END
```

program as used in the IBM 1620 and the CDC 3300.

```
A: READ: SSPV(I), WSPV(I), BSCL, PB, VPF, TI, TSC
   PUNCH: AIR SYSTEM ANALYSIS
B: TVAIR = PB*VPF
   TAIR = BSCL/(1.08*(TI-TSC))
   X = TVAIR/TAIR
   TDAIR = 0.0
C: TSIAIR(I) = 0.0
   TWIAIR(I) = 0.0
   TSAIR(I) = 0.0
   TWAIR(I) = 0.0: I = 1 → 4
D: READ: K, BN, RSCLAA, RLCLAA, RSHLAA, RLHLAA, P, VPF, TWI,
         TSI, TSW, TSC, WSI, WWI, HFGW, HFGS, N
E: RSHLA2 = 0.5*RSHLAA
   RSHLA4 = 0.75*RSHLAA
   RSCLA2 = 0.5*RSCLAA
   RSCLA4 = 0.75*RSCLAA
F: SAIR(I) = RSCLAA/(1.08*(TSI-TSS(I)))
   SAIR2(I) = RSCLA2/(1.08*(TSI-TSS(I)))
   SAIR4(I) = RSCLA4/(1.08*(TSI-TSS(I)))
   WAIR(I) = RSHLAA/(1.08*(TWI-TWS(I)))
   WAIR2(I) = RSHLA2/(1.08*(TWI-TWS(I)))
   WAIR4(I) = RSHLA4/(1.08*(TWI-TWS(I)))
```

```
    SIAIR(I) = (RLCLAA*SSPV(I))/((WSI-WSS(I))*HFGS*60.0)

    WIAIR(I) = (RLHLAA*WSPV(I))/((WWI-WWS(I))*HFGW*60.0)

    I = 1 → 4

G:  DHAIR = RSHLAA/(1.08*(TWI-TSW))

    DCAIR = RSCLAA/(1.08*(TSI-TSC))

    QAIR = P*VPF

    DVAIR = QAIR/X

H:  TSIAIR(I) = TSIAIR(I)+BN*SINAIR

    TWIAIR(I) = TWIAIR(I)+BN*WINAIR

    TSAIR(I) = TSAIR(I)+BN*SAIR(I)

    TWAIR(I) = TWAIR(I)+BN*WAIR(I)

I:  PUNCH: K, BN, DHAIR, DCAIR, DVAIR, DAIR, QAIR

J:  PUNCH: SAIR(I), SAIR2(I), SAIR4(I), WAIR(I), WAIR2(I), WAIR4(I),

           SIAIR(I), WIAIR(I), TSS(I), TWS(I), I,  I = 1 → 4

K:  STWAIR(I) = 1.05*TWAIR(I)

    STSAIR(I) = 1.05*TSAIR(I)

    STWIAR(I) = 1.05*TWIAIR(I)

    STSIAR(I) = 1.05*TSIAIR(I)

    I = 1   4

L:  PUNCH: TDAIR, STDAIR

M:  PUNCH: TSAIR(I), STSAIR(I), TWAIR(I), STWAIR(I), TSIAIR(I),

           STSIAR(I), TWIAIR(I), STWIAR(I), TSS(I), TWS(I), I

           I = 1 → 4
```

The program starts by first reading the dimension and format statements followed by the reading and the checking of the value of M. If M is less than 999, the computer proceeds with the calculation. If M is equal to 999 the computer terminates the execution of the program. Following the checking of M, the computer reads the permanent data and stores it in the memory.

The first calculation the computer performs is finding the value of the ratio (X) of the outside air requirements to the total air needed. This is followed by initializing the values of TDAIR, TSAIR(I), TSIAIR(I), TWAIR(I) and TWIAIR(I) to zero. The computer then reads the first set of data for a room in the first zone and checks the value of K. This is a safety precaution taken in case the programmer has forgotten to put in the card having a N value of 99. If the computer reads the card having a M value equal to 999 without having encountered a N value of 99, the computer will not return to statement 14 and thus will not terminate the program as required. Since K occupies the same location on the data card as M it therefore can be used as this safety precaution. Whenever the computer encounters a value of K equal to 999 the computer would terminate the program even if it does not encounter a card having a N value of 99 to return it to statement 14. After checking the value of K and finding it less than 999 the computer proceeds with calculating the air requirements for the room. The computer first calculates the air requirements for the single duct systems including induction systems. These calculations include SAIR(I), SAIR2(I), SAIR4(I), WAIR(I), WAIR2(I), WAIR4(I), WIAIR(I) and SIAIR(I). SAIR2(I) and WAIR2(I) are the air requirements at one-half the design sensible loads while SAIR4(I) and WAIR4(I) are at three-fourths the design sensible load. The calculation is repeated four times by means of a DO loop and each time at a different air supply condition. The air supply conditions (TSS(I), TWS(I), WSS(I), WWS(I), SSPV(I) and WSPV(I)) are specified in the permanent data. The calculation for the dual duct systems follows the single duct calculations. Here the program calculates the air needed to satisfy the room sensible cooling and heating loads and the ventilation requirements, check for the one with the highest value and takes this value as the room air requirements. The computer then checks the value of K read at statement 15. If K is less than 800 the computer proceeds to sum the room air requirements to the building requirements. The computer compares the values of the air needed to satisfy the room latent loads (SIAIR(I) and WIAIR(I)) with the ventilation air requirements and adds the one with the highest value, multiplied by the number of rooms in the zone (BN) (zone air requirements), to the building air requirements for air induction systems. This is followed by the summing of the zone single duct air requirements to the building air requirements. The zone air requirements are arrived at by multiplying the room air requirements by the number of rooms in the zone.

In adding the zone requirements for the single duct systems to the building requirements, a DO loop is used to perform the summation for the four different supply conditions. Finally the computer adds the zone air requirements for the dual duct system to the building requirements, prints, or punches, the results for the room and checks the value of N.

If N is less than 99 the computer returns to statement 15 to read a new set of data for another room and repeat the same calculation. If N is equal to 99 the computer multiplies the building air requirements by a five percent safety factor, prints, or punches, the results for the building with and without the five percent safety factor and control is transferred to statement 14. If the value of K is more than 800 the computer will bypass the adding of the room air requirements to the building air requirements but would still print the results for the room. The reason for this action is the same one as in the cooling-heating load program.

The method of terminating the program by specifying M as 999 is used for the IBM 1620. For the CDC 3300 the last card having M or K equal to 999 must be replaced by the special end of file card.

This program was tried on the same school using the room loads obtained from the heating-cooling load programs. The results compared favorably with the results obtained by hand calculation. The program took less than ten minutes on the IBM 1620 while on the CDC 3300 the program took less than eight seconds to give the results. These same results would take days in the old fashioned method of calculation.

VI. CONCLUSION

The two programs developed here offer an easy and simple way out of the drudgery of the long laborious calculations encountered in designing air conditioning systems. They give more complete and accurate results. These results are obtained faster and at a lower cost than with the old method of calculation. Yet these two programs are not the best programs one can devise. The more knowledge one obtains about programming the more one realizes the improvements that can be added to these programs. One of the improvements that could be added to this program is developing a method of calculating the equivalent temperature rather than looking it up in the tables. Another improvement that could be made in this program would eliminate the requirements for the designer to specify the time and design temperature. Using a DO loop, it is possible to have the computer repeat the room calculations several times and each at a different time of day. Also the temperature variation during the day can be put in the form of an equation, or of tables, as a function of time. Each time the computer repeats the calculation, it would calculate a new outside temperature at the new chosen time. These are only two improvements. Using these programs in actual calculation should point to other areas of possible improvements.

The two programs, for calculating the cooling and heating loads and the air analysis, are just the start. Areas for future developments include designing the ducts using the results obtained from the air system analysis program. This could be followed by a cost analysis and a performance evaluation of the designed system.

Computer calculation has opened a new and a bright era in the field of heating and air conditioning. A great deal has been done previous to this work and a great deal is to be done.

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APPENDIX

Nomenclature

A. Cooling-Heating Load Program

A(J, I): Absorptivity factors.

AJ: A factor used in calculating the solar heat gain factor.

AJI: A factor used in calculating the solar heat gain factor.

ALT: Latitude of place where building is located, degrees.

AL: Latitude of place where building is located, radians.

AT: Tan(DELT(N))/Tan(AL), a factor used in calculating the solar load.

AVL: Latent heating (or cooling) load due to infiltration through cracks, Btu/hr.

AVPHL: Latent heating (or cooling) load due to infiltration from used outside doors, Btu/hr.

AVPHS: Sensible heating (or cooling) load due to infiltration from used outside doors, Btu/hr.

AVS: Sensible heating (or cooling) load due to infiltration through cracks, Btu/hr.

AZ(N): A factor used in calculating solar intensity.

B(N): A factor used in calculating solar intensity.

BLCL: Building latent cooling load not including ventilation load, Btu/hr.

BLHL: Building latent heating load not including ventilation load, Btu/hr.

BSCL: Building sensible cooling load not including ventilation load, Btu/hr.

BSHL: Building sensible heating load not including ventilation load, Btu/hr.

BN: Number of rooms in each zone.

BT: - Tan(DELT(N))*Tan(AL), a factor used in calculating the solar load.

C(N): A factor used in calculating solar intensity.

CLODL: Building latent cooling load including ventilation, Btu/hr.

CLODS: Building sensible cooling load including ventilation, Btu/hr.

CLRL: Room summer latent cooling load including ventilation, Btu/hr.

CLRLZ: Zone summer latent cooling load, Btu/hr.

CLRS: Room sensible cooling load including ventilation, Btu/hr.

CLRSZ: Zone sensible cooling load including ventilation, Btu/hr.

COSS: Direction cosine of solar beam.

COSTH: Cosine of the incident angle

COSW: Direction cosine of solar beam.

COSZ: Direction cosine of solar beam.

DEL(N): Declination angle, degree.

DELT(N): Declination angle, radian.

DHI: Horizontal diffuse radiation, Btu/hr. $ft.^2$.

DI: Direct solar irradiation, Btu/hr. $ft.^2$.

DLTE: Equivalent temperature differential, ^oF.

DNI: Direct normal solar irradiation, Btu/hr. $ft.^2$.

DSI: Diffuse radiation, Btu/hr. $ft.^2$.

DVI: Vertical diffuse radiation, Btu/hr. ft.^{2}.

EPS: Wall slope, degree.

EPSR: Wall slope, radian.

FAL: Light heat gain factor, Btu/hr. ft.^{2}.

FHL: Heat loss (or gain) from exposed perimeter of the ground floor per wall, Btu/hr.

FHLS: Room heat loss (or gain) from exposed perimenter of the ground floor, Btu/hr.

FI: Air infiltration rate through cracks, ft.^{2}/hr.

FIT: Air infiltration rate through used outside doors, ft.^{3}/min. person.

FL, FW: Floor dimension, ft.

FNI: Fraction of the absorbed solar energy that is transferred to the room from the glass.

GHL: Lighting cooling load per room, Btu/hr.

GL, GW: Window dimension, feet.

GTL: Heating or cooling transmission load through glass, Btu/hr.

H: Hour angle, degree.

HR: Hour angle, radian.

HL: Latent heat dissipated per person, Btu/hr.

HLF: Heat loss (or gain) factor from exposed perimenter of ground floor, Btu/hr. ft.

HLODL: Building latent heating load including ventilation, Btu/hr.

HLODS: Building sensible heating load including ventilation, Btu/hr.

HLRL: Room latent heating load including ventilation, Btu/hr.

HLRS: Room sensible heating load including ventilation, Btu/hr.

HO: Outer surface coefficient of convective heat transfer, Btu/hr. ft.^{2} ^{o}F.

HS: Sensible heat dissipated per person, Btu/hr.

HSIL: Sensible load from miscellaneous heat sources in the room, Btu/hr.

JI: A program control factor.

K: Zone number. Also used as a program control factor.

L: Array identification number for absorptivity and transmissivity.

MI: A program control factor.

N: Array identification number for AZ(N), B(N), C(N), DEL(N) and TE(N).

P: Number of persons in a room.

PN: Number of persons using outside door in each room per day.

PQRL: Room occupant latent load, Btu/hr.

PQRS: Room sensible occupant load, Btu/hr.

PR: Effective infiltration crack length, ft.

QTR: Equivalent solar and tranmission load through walls, Btu/hr.

RIMLL: Room sensible load from lighting and miscellaneous heat sources, Btu/hr.

RLCLAA: Room latent cooling load not including ventilation, Btu/hr.

RLHLAA: Room latent heating load not including ventilation, Btu/hr.

RLINL: Combined room latent cracks and doors infiltration load, Btu/hr.

RSCLAA: Room sensible cooling load not including ventilation, Btu/hr.

RSHLAA: Room sensible heating load not including ventilation, Btu/hr.

RSINL: Combined room sensible cracks and doors infiltration load, Btu/hr.

RHG: Ground reflectivity.

SC: Shading factor.

SHG: Solar heat gain per window, Btu/hr.

SHGF: Solar heat gain factor, Btu/hr. $ft.^2$.

SGTL: Room transmission heat gain (or loss) through glass, Btu/hr.

SGHQ: Combined room solar and transmission loads through glass, Btu/hr.

SQTRW: Room equivalent solar and transmission loads through walls (less windows), Btu/hr.

STLR: Room transmission heat gain (or loss), Btu/hr.

T(J, I): Glass transmissivity factors.

TE(N): Time equation, used in calculating solar heat load, minute.

TCLL: Building latent cooling load including a five percent safety factor, Btu/hr.

TCLS: Building sensible cooling load including a five percent safety factor, Btu/hr.

THLL: Building latent heating load including a five percent safety factor, Btu/hr.

THLS: Building sensible heating load including a five percent safety factor, Btu/hr.

TI: Temperature inside room or zone, ^{o}F.

TJ: A factor used in calculating solar heat gain factor.

TJI: A factor used in calculating solar heat gain factor.

TLW: Room transmission load, Btu/hr.

TME: Minute from solar noon.

TO: Temperature outside room or on the opposite side of the wall, ^{o}F.

TSTL: Building transmission load including a five percent safety factor, Btu/hr.

U: Wall coefficient of heat transfer, Btu/hr. ^{o}F. ft.^{2}.

UG: Glass coefficient of heat transfer, Btu/hr. ^{o}F. ft.^{2}.

VHL: Room latent ventilation load, Btu/hr.

VHS: Room sensible ventilation load, Btu/hr.

VPF: Required ventilation rate per person, cfm.

WA: Wall azimuth, degree.

WAR: Wall azimuth, radian.

WH, WW: Wall, door or roof dimension, ft.

WI: Humidity ratio of room air, lb_{water}/lb_{air}.

WO: Humidity ratio of atmospheric air, lb_{water}/lb_{air}.

XL, YM, ZN: Wall's direction cosine.

Y: Diffuse intensity.

ZHLRL: Zone latent heating load, Btu/hr.

ZHLRS: Zone sensible heating load, Btu/hr.

ZSTL: Zone transmission cooling load, Btu/hr.

ZSTLR: Zone transmission heating load, Btu/hr.

B. Air Analysis Program

BSCL: Building sensible cooling load, Btu/hr.

BN: Number of rooms in a zone.

DAIR: Room air requirements in the main duct of dual duct systems, cfm.

DCAIR: Air required to satisfy the room sensible cooling load, cfm.

DHAIR: Air required to satisfy the room sensible heating load, cfm.

DVAIR: Air required to satisfy the room ventilation requirements, cfm.

HFGS: Enthalpy of water vapor at summer air supply condition, Btu/hr. lb_{water}.

HFGW: Enthalpy of water vapor at winter air supply condition, Btu/hr. lb_{water}.

K: Zone number, also used as program control factor.

N: A program control factor, also used to number the data cards.

P: Number of occupant in the room.

PB: Number of occupant in the building.

QAIR: Room required ventilation air, cfm.

RLCLAA: Room latent cooling load, Btu/hr.

RLHLAA: Room latent heating load, Btu/hr.

RSCLAA: Room sensible cooling load, Btu/hr.

RSCLA2: One-half of the room sensible cooling load, Btu/hr.

RSCLA4: Three-fourths of the room sensible cooling load, Btu/hr.

RSHLAA: Room sensible heating load, Btu/hr.

RSHLA2: One-half of the room sensible heating load, Btu/hr.

RSHLA4: Three-fourths of the room sensible heating load, Btu/hr.

SAIR(I): Summer air requirement per room using single duct systems, cfm.

SAIR2(I): Summer air requirements per room using single duct systems at half the cooling load, cfm.

SAIR4(I): Summer room air requirements using single duct systems at three-fourths the cooling load, cfm.

SIAIR(I): Air quantity required to satisfy the room latent cooling load, cfm.

SINAIR: Summer room air requirements using air induction systems, cfm.

STSAIR(I): Total summer building air requirements using single duct systems including five percent safety factor, cfm.

STSIAR(I): Building summer air requirements for air induction system including five percent safety factor, cfm.

STWAIR(I): Building winter air requirements using a single duct system including five percent safety factor, cfm.

STWIAR(I): Building winter air requirements using an air induction system including a five percent safety factor, cfm.

STDAIR: Building air requirements in the main duct of dual duct system including a five percent safety factor, cfm.

SSPV(I): Specific volume of summer supply air for induction systems, cfm.

TAIR: Building air requirements at dual duct supply temperature, cfm.

TDAIR: Building air requirements in the main duct of dual duct systems not including five percent safety factor, cfm.

TI: Room temperature, ^{o}F.

TSC: Summer air supply temperature in the main duct of dual duct systems, ^{o}F.

TSS(I): Summer air supply temperature for single duct systems, ^{o}F.

TSAIR(I): Building air requirements using a single duct system not including a five percent safety factor, cfm.

TSIAIR(I): Building air requirements using an air induction system not including a five percent safety factor, cfm.

TSI: Summer room temperature, ^{o}F.

TSW: Winter supply temperature for dual duct systems, ^{o}F.

TVAIR: Total building ventilation air requirements, cfm.

TWAIR(I): Building air requirements using a single duct system not including a five percent safety factor, cfm.

TWIAIR(I): Building air requirements using air induction system not including a five percent safety factor, cfm.

TWS(I): Winter supply temperature for single duct systems, ^{o}F.

TWI: Winter room temperature, ^{o}F.

VPF: Required ventilation rate per person, ft.^{3}/min.

WAIR(I): Room air required to satisfy the sensible heating load using a single duct system, cfm.

WAIR2(I): Winter room air requirements using a single duct system at half the design heating load, cfm.

WAIR4(I): Winter room air requirements using a single duct system at three-fourths the design heating load, cfm.

WIAIR(I): Winter air required to satisfy the room latent load, cfm.

WINAIR: Room winter air requirements using an air induction system, cfm.

WSI: Humidity ratio of room air during summer, lb_{water}/lb_{air}.

WSS(I): Humidity ratio of summer supply air, lb_{water}/lb_{air}.

WSPV(I) Specific volume of winter supply air for induction systems, $ft.^3/lb$.

WWI: Winter room air humidity ratio, lb_{water}/lb_{air}.

WWS(I): Humidity ratio of winter supply air, lb_{water}/lb_{air}.

X: Ratio of required building ventilation air to total building air requirements.