

3. USING THE PROGRAM

To run program POET it is necessary to first calculate the building loads by using the building load program. The load program has been updated for this purpose and now incorporates internal building loads produced by people, lights and machines. It also groups the building loads for each zone (defined in the program) to provide a representative load profile to the plant serving those zones. The plant building loads are produced in a graphical or numerical format and are stored in data files to be read by program POET.

Program POET makes use of the following input data fed via the keyboard before executing:

(i) **Coil bypass factor** : this factor is an indication of the cooler coil's efficiency and is dependent on manufactured characteristics such as materials, fin density, tube thickness, and on the depth of the coil (number of rows). The designer estimates this factor based on previous experience or selects a coil from manufacturers catalogues and enters the appropriate factor for each plant. The effect of the bypass factor is as follows:

(a) Small bypass factor:

- possible smaller refrigeration machine
- less air and more coil heat transfer surface
- smaller piping for chilled water applications.

(b) Larger bypass factor:

- possible larger refrigeration machine
- more air implying a larger fan and motor
- more air and less coil heat transfer surface
- larger piping for chilled water application.

(ii) **Ventilation rates** : the program assumes a ventilation rate of 12 l/s. per person or 1.66 l/s per square metre of floor area provided a different rate is not required. Ventilation requirements are listed in the Government Gazette (Regulation Gazette No. 3805).

(iii) **Plant maximum temperature differential :** this temperature differential represents a limitation on the temperature drop across the cooler coil. It is determined from manufacturer's catalogues or may be estimated from personal past experience. It prevents the program from obtaining unrealistic off-coil temperatures.

(iv) **Supply and return fan and duct heat gain :** these gains represent the heat gain supplied to the air stream resulting from power frictional losses across fan blades and electric motor inefficiencies.

It may also represent heat gains to the air stream across the duct walls. These fan and duct gains are entered as percentages of the sensible heat load and may be determined using chart 3 in chapter 7 of reference 7. Fan heat gains are due to the heat of compression and the inefficiency of the fan. Duct heat gains are dependant on the duct layout, supply air temperature and surrounding ambient temperature.

(v) **Plant operating hours :** hourly refrigeration loads are computed for specified operating hours. These hours are assumed to be equal for all months.

4. A SIMPLE EXAMPLE COMPUTATION

For the purpose of illustration, consider the restaurant building presented in Appendix 3 comprising of a north zone and a south zone. Both these zones are to be air conditioned by separate plants. The thermal properties necessary for determining the sensible and latent building zone loads are presented in Appendix 4. Also presented in appendix 4 are the graphical and numerical representation of the building loads.

At this stage of the design proceedings, the designer decides on the type of plant to serve these areas. This decision is usually a compromise between what is ideal and what is practicable for a particular situation. Factors to consider in the decision includes first cost, capacity, space requirement, annual energy use and the available number of control zones both at the time of design and in the future. By considering these factors, outdoor roof mounted air-cooled units are selected to serve each zone.

From Appendix 4 (Tables A4.5 and A4.6) we see that the peak building sensible load for each zone are as follows:

North Zone : 10.8 kW @ 17h00

South Zone : 13.5 kW @ 17h00

The plant's refrigeration and total heating capacity is determined next by including the fresh air load with the building loads. Fresh air is an important part of the building load and with this installation, due to the large number of occupants, it is of overriding importance in its effect on the total load. Accordingly, the maximum plant load may occur when the outdoor enthalpy, and hence the outdoor wet-bulb, is at a maximum for cooling or minimum for heating. This occurs normally between 2 p.m. and 6 p.m.

The corresponding plant peak refrigeration loads computed by program PCET are:

Plant 1 25.7 kW @ 16h00

Plant 2 28.5 kW @ 16h00

5. CONCLUSIONS

A program capable of determining the peak and hourly refrigeration loads of a constant air volume flowrate airconditioning plant has been presented. The algorithms and analysis makes use of a building load data base created by a building load program. Program POET therefore forms part of the previous building program and requires its load data base for proper execution.

Program POET's partial load analysis has been developed for a constant volume flowrate plant with a preheat and reheat control cycle. These control cycles although energy inefficient provide excellent room temperature and humidity control which is essential for certain industrial and commercial applications. The program contains assumptions and limitations; namely:

- * Humidifier is provided and operates optimally.
- * Coil bypass factor is a straight line function.
- * Compressor operates in a single "on/off" mode.
- * Air volume flowrate remains constant.

The implication of the optimum operation of the humidifier is that moisture is added to the air stream at constant dry-bulb temperature. This implies that only steam humidifiers are allowed. Generally a steam humidifying process is not isothermal as a small sensible heat transfer component is imparted to the air stream. The magnitude of the sensible heat transfer is low relative to other parameters that have greater influences on the plant and therefore it may be ignored. The humidifier is also assumed to operate proportionally to the humidity requirements.

It is common for the air mass flowrate to vary (up to 20%) due to the clogging of air filters. This has the effect of increasing system resistance thereby reducing air volume flow. As this process is extended over a relatively long period it is reasonable to assume the volume flowrate remains constant. Fan speed control devices may be installed in the system to compensate for varying system resistances.

During periods of favourable outdoor conditions the program determines whether refrigeration will be required to maintain room conditions within the specified limits. Should refrigeration not be required it is assumed that the refrigeration machine will switch off. The implication of 0% to 100% control capacity is that the partial load analysis of the program is suitable for airconditioning applications requiring small refrigeration machines.

Small single compressor machines normally operate on an "on/off" control cycle and are generally the most economical for "small" installations. The peak refrigeration load analysis, however, is valid for large and small airconditioning applications as well as for variable air volume flowrate systems.

The refrigeration load analysis is based on psychrometric correlations of cooling load to the physical performance of the equipment and then including this equipment performance in the actual calculation of the refrigeration load. This calculation is accomplished by calculating the effective surface temperature, bypass factor and effective sensible heat factor which simplifies the calculation of the supply air quantity.

The effective surface temperature for the cooling and dehumidification process is considered to be the dewpoint of the apparatus and is at the point where the Grand Sensible Heat Factor (GSHF) line intersects the saturation line on the psychrometric chart.

The constancy of the coil bypass factor allows geometrical relationships to be used in the program to access the performance of the cooling coil under partial load conditions. Changes in the state of air entering the coil and variations in the temperature of the coolant have virtually no effect on the bypass factor. However, a progressive increase in the temperature of the fluid flowing onto the coil, the flowrate of fluid being constant, causes the mean coil surface temperature to rise to a limiting point on the saturation curve where the bypass factor may no longer be determined by geometrical methods. In the program this point is never reached since it is assumed that the humidifier operates optimally and the reheater imposes an artificial load on the coil.

The reheat cycle is required under partial load conditions to reheat the air to a temperature consistent with the sensible cooling load. It follows that part of the cooling load is wasted by the reheat. This is a consequence of the need to dehumidify the air first, and heat afterwards. Under design conditions the off-coil condition is selected by the program to avoid the use of reheat.

The program initiates a preheat cycle when the outside air condition has a very low moisture content and temperature. Under these conditions the air needs to be preheated before adding humidity.

For the purpose of program illustration the building example was simulated for one design day of December.

The outdoor temperature values of the design day were specified to simulate summer cooling and winter heating conditions. It can be seen from Table A5.4, for partial load operation that, in general, the reheat requirement increases as the outdoor enthalpy decreases. This is due to the relatively large fresh air requirements for the building example.

The program is arranged that under conditions of maximum building loads, latent and sensible, the state of the air leaving the cooler coil is satisfactory in both these respects and therefore reheat or humidification is not required. This is not so for partial load operation. The reason being that room sensible and latent loads are usually independent of each other and consequently the air has to be reheated to a temperature consistent with the cooling load.

This is verified in the partial load performance values (Tables A5.4 and A5.5). As the sensible load decreases the reheating capacity increases until the maximum value is reached. From the above tables this value constitutes the winter heating design value. Figure 5.1 illustrates the psychrometric process involved for partial load conditions for plant 1 at 12h00. Figure 5.2 illustrates the winter heating psychrometric process at 24h00.

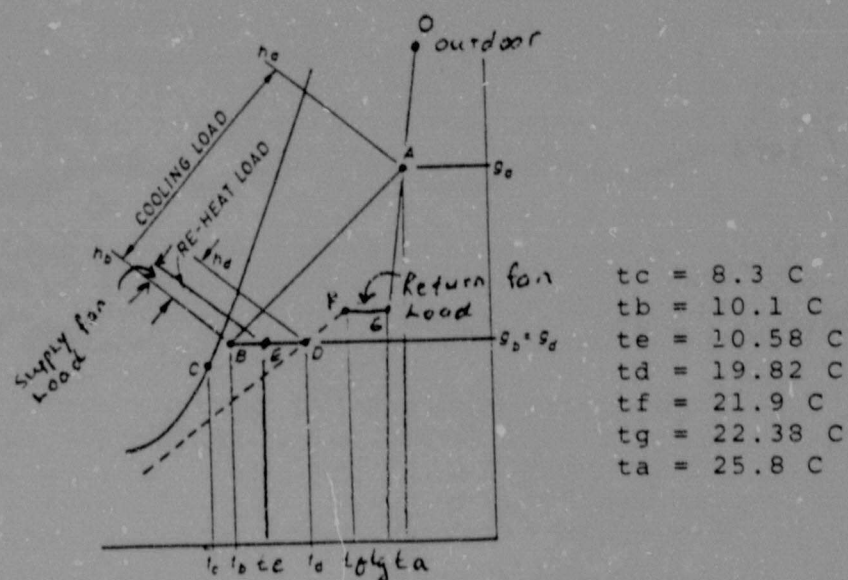


Figure 5.1 Partial load cooling psychrometric processes

From Figure A5.1, return air at 25.8 C (ta) is dehumidified to 10.1 C (tb). The dehumidification is controlled by a dewpoint thermostat, positioned after the coil. The air is then heated to 10.58 C as a result of duct and fan heat gains. It is then reheated to 19.82 C (td) by the heater battery controlled by a return air or room thermostat.

Figure 5.2 illustrates the humidification process which is assumed to be isothermal. Humidification is needed because the outdoor air has a very low moisture content. When this air is heated to the required temperature the relative humidity in the space will be below design levels. For humidification to be effective the program firstly determines the on coil temperature and compares it to the design cooling off-coil temperature.

Should the on-coil temperature be less than the cooling on-coil temperature then the air is assumed to pass a preheater bank and heated to the room design temperature, pass through the steam humidifier, where it undergoes isothermal saturation, and then to reheat it to a temperature at which it must be supplied to the room. For the given operating time in the building example a preheater is not required and humidify is added after the preheater.

For the peak refrigeration load and air quantity to be calculated, the program computes these values for all the specified operating times and corresponding outdoor conditions. The peak cooling and air volume flowrate values are then selected and used in the partial load analysis.

In conclusion, program POET accurately analyses the load requirements, taking into account all the factors involved and thereby ensuring the lowest plant capital and running costs. This analysis indicates:

- * the true cooling and heating requirements for the given control cycle;
- * the possibilities for greatest load reduction at lowest cost (eg. reducing fresh air quantities);
- * the most economical equipment selection (eg. varying coil bypass factors to optimize volume flowrates);

and results in considerable design time and plant cost savings and competitiveness against less accurate assessments which could be made by others.

6. RECOMMENDATIONS

Program POET constitutes an important first step after the building load calculation by determining the steady state psychrometric design states for any airconditioning plant and by determining the partial load operating states for a constant volume flowrate plant.

Therefore, to increase the program's effectiveness and usefulness it is recommended that the following additions be incorporated:

- * fresh air economy cycles operating under dry-bulb temperature or enthalpy control;
- * other airconditioning processes such as:
 - sensible cooling;
 - sensible heating;
 - evaporative cooling;
- * partial-load analysis for variable volume air flowrate systems;
- * partial-load analysis for refrigeration equipment with multi-step unloading capacity control;
- * water injection humidifying cycle analysis
- * thermal storage system analysis

The above improvements may be incorporated by adding subroutines which address the moist air subroutines.

APPENDIX 1 : BUILDING LOAD PROGRAM SUMMARY

A1.1 BACKGROUND

The instantaneous heat gain in a typical application is derived from sun, lights, people, transmission through walls roof and glass, infiltration and ventilation air and in some cases machinery, appliances, electric calculation machines, etc. A large portion of this instantaneous heat gain is radiant which does not become an instantaneous load on the air conditioning equipment but is absorbed into the fabric of the building to become a cooling load at some later time. A heat load program was developed previously by the author to compute these loads using the Total Equivalent Temperature Differential (TETD) method, in which instantaneous heat transfer is calculated as a function of both the instantaneous temperature differential and the differential at an earlier time. This method gives qualitatively better results than the steady-state method.

For the purpose of writing program POET it was necessary to update the solar program by including the gains due to people, lights and machines as well as incorporating the load zones into air conditioning plants. The load data may now be represented according to zones or plant and in graphical or numerical form. Both these forms of data representation are presented in Appendix 4 for the worked example.

The highly varying and relatively sharp peak of the instantaneous solar heat gain results in a large part of it being stored at the time of peak solar heat gain as illustrated in Fig. A1.1. (8)

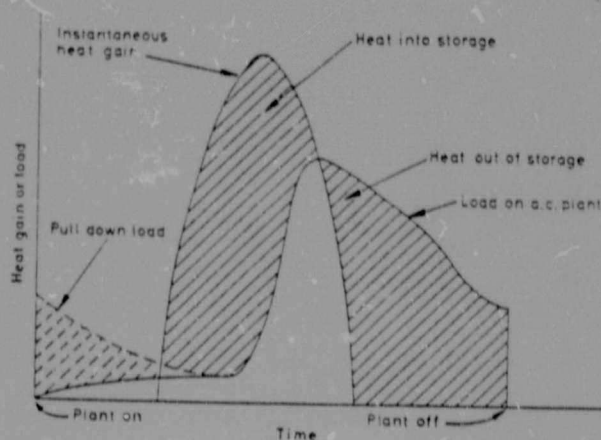


Figure A1.1 - Building sensible cooling load.

The upper curve is typical of the solar heat gain and the lower curve is the actual cooling load that results in an average construction application with the space temperature held constant.

The Solar Load program allows a maximum of 12 zones, each with a maximum of 12 external facades. A maximum of 8 air conditioning plants may be allocated to the 12 zones - loads are computed hourly for the design day of each month for any building location (altitude above sea level and latitude) in the Southern Hemisphere. Outdoor temperatures and solar intensities are simulated for the building's location.

The list of equations for the load computation is not listed here and more information on this program can be obtained from reference 4.

APPENDIX 2 : PROGRAM FLOW DIAGRAMS

A2.1 Figure A2.1 displays the program and subroutine structures.

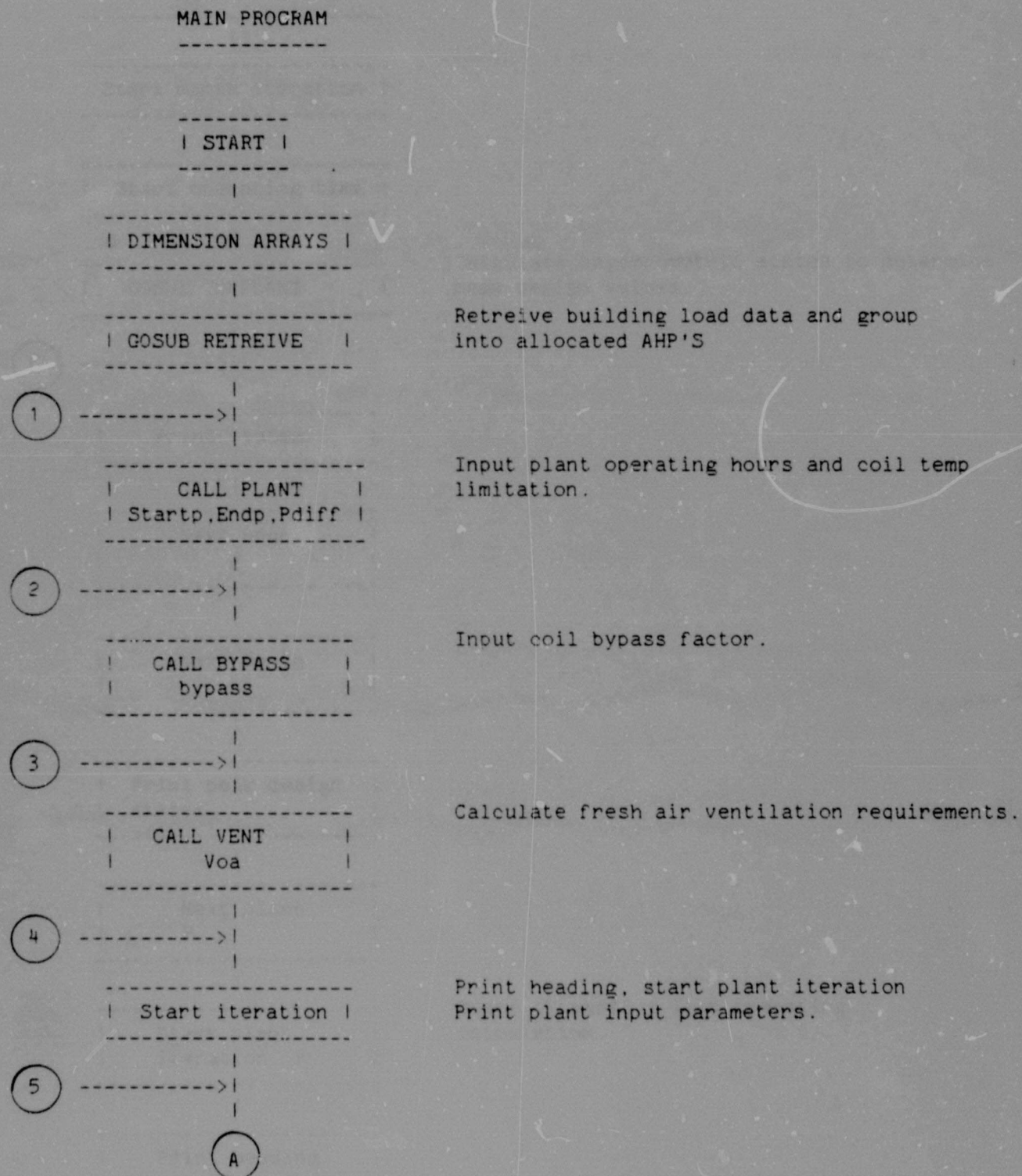


Figure A2.1 : Program flow diagrams.

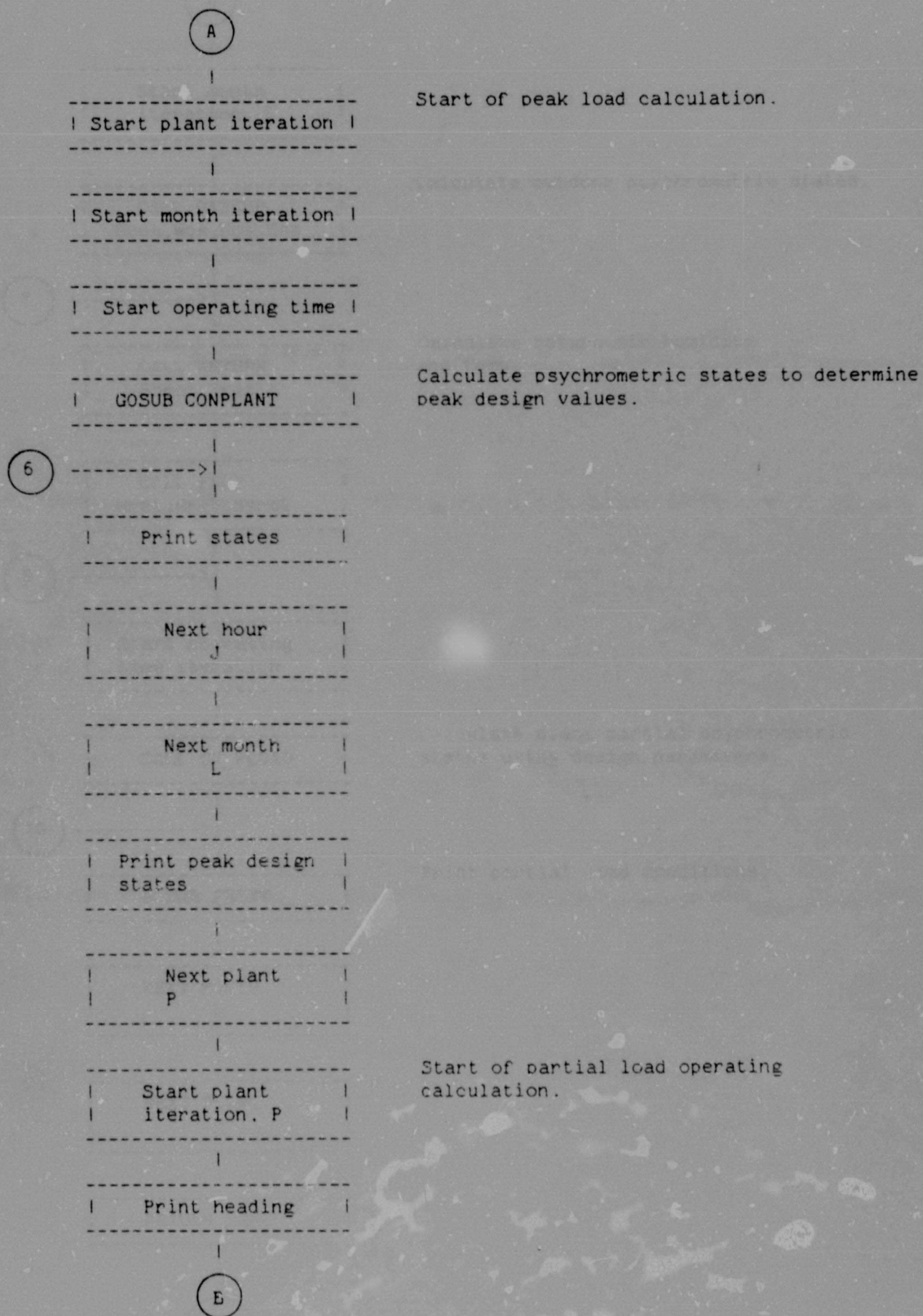


Figure A2.1 : (Cont)

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