CHAPTER

THREE

TRNSYS MODEL{ TC "TRNSYS MODEL" \l 1 }

A TRNSYS subroutine, Type 71, is created to solve the UTC system equations (see Appendix A). This model uses information on the collector, building, weather, and air flow rates to calculate the outputs including outlet air temperature, solar efficiency, and energy saved by the UTC system.

3.1 Type 71 Flow Logic{ TC "3.1 Type 71 Flow Logic" \l 2 }

The UTC system subroutine determines m_{out} to minimize the auxiliary energy, as discussed in Section 2.3. The outdoor air flow rate must be between a minimum and maximum value. As shown in Figure 3.1.1, the subroutine starts with the minimum outdoor air flow rate because this is the most common flow rate at which the system operates. If T_{mix} is less than T_{sup}, then auxiliary energy is needed to meet the heating load on the building (see Figure 2.3.2). The auxiliary energy and other subroutine outputs are calculated, and the simulation is complete for that time step. If T_{mix} is greater than T_{sup}, then no auxiliary energy is needed, and the calculation continues.

T_{mix} is next calculated for the maximum outdoor air flow ($\gamma = 1$). If this value of T_{mix} is greater than T_{sup} (see Figure 2.3.4), then the building overheats and the subroutine outputs a warning. If T_{mix} is less than T_{sup}, then there is an outdoor air flow rate between the minimum and maximum at which the UTC system is operated with no auxiliary energy (see Figure 2.3.3).

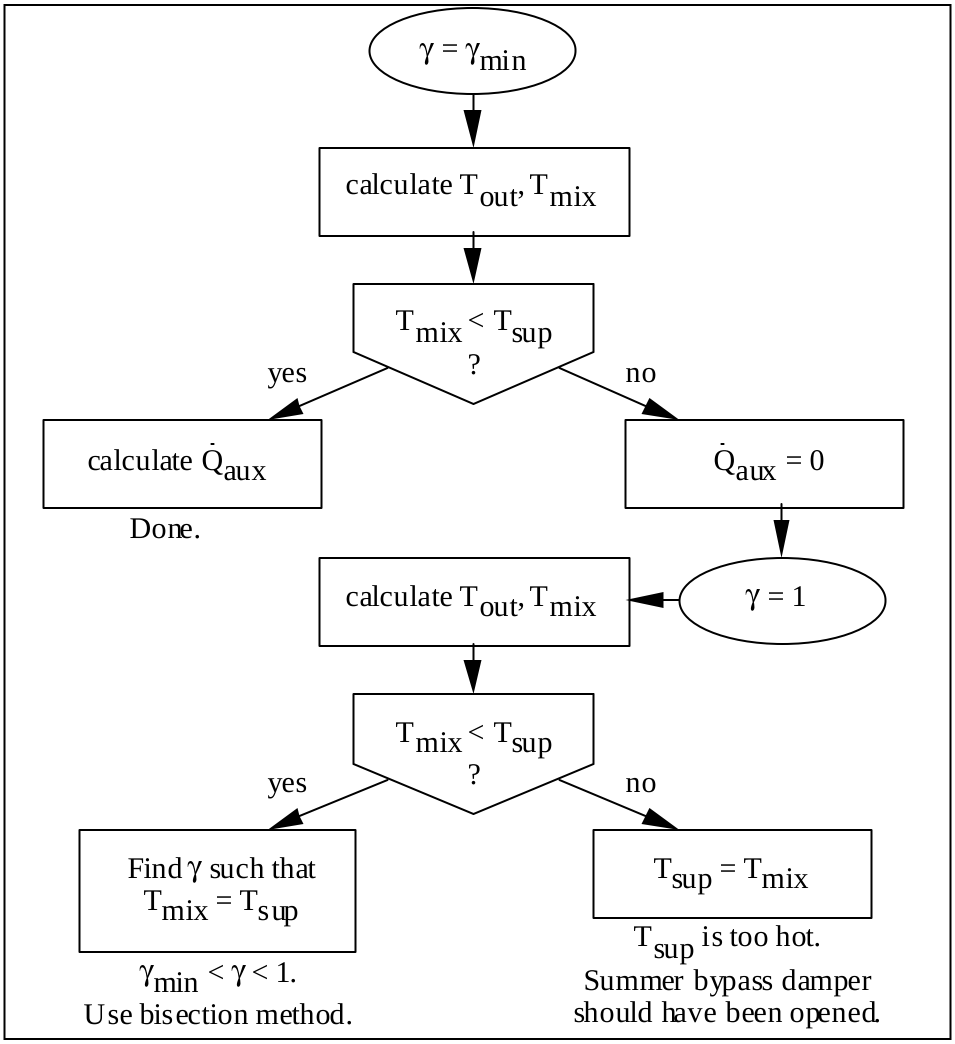

Figure 3.1.1. Flowchart of TRNSYS subroutine for UTC systems.**{** TC "Figure 3.1.1. Flowchart of TRNSYS subroutine for UTC systems." \l 5 **}**

Once T_{out} is calculated for a given γ, finding T_{mix} is fairly straightforward from Equation 2.3.6. However, to obtain T_{out}, a non-linear system of eight equations with eight unknowns must be solved simultaneously. Solving these eight equations is discussed in Section 3.2.

3.2 Method of Solution{ TC "3.2 Method of Solution" \l 2 }

There are eight equations with eight unknowns that need to be solved simultaneously to find T_{out}. These equations are three energy balance equations and five rate equations: Equations 2.2.3, 2.2.10, 2.2.8, 2.2.6, 2.1.1, 2.1.4, 2.1.3, 2.2.7. The equations are rearranged.

$$-\varepsilon_{HX}\, T_{col} + T_{plen} = T_{amb}\,(1 - \varepsilon_{HX}) \tag{3.2.1}$$

$$Q_{rad,col\text{-}sur} - \varepsilon_{col}\, \sigma_{sb}\, A_s\, T_{col}^4 = -\varepsilon_{col}\, \sigma_{sb}\, A_s\, T_{sur}^4 \tag{3.2.2}$$

$$\begin{aligned} Q_{rad,wall\text{-}col} &- \sigma_{sb}\, A\, T_{wall}^4 / (1/\varepsilon_{wall} + 1/\varepsilon_{col} - 1) \\ &+ \sigma_{sb}\, A\, T_{col}^4 / (1/\varepsilon_{wall} + 1/\varepsilon_{col} - 1) = 0 \end{aligned} \tag{3.2.3}$$

$$\begin{aligned} Q_{conv,wall\text{-}air} &- h_{conv,wall\text{-}air}\, A\, T_{wall} \\ &+ h_{conv,wall\text{-}air}\, A\, T_{plen} = 0 \end{aligned} \tag{3.2.4}$$

$$Q_{conv,col\text{-}air} - \gamma\, m_1\, c_p\, T_{plen} = -\gamma\, m_1\, c_p\, T_{amb} \tag{3.2.5}$$

$$-Q_{rad,wall\text{-}col} + Q_{conv,col\text{-}air} + Q_{rad,col\text{-}sur} = Q_{abs} \tag{3.2.6}$$

$$Q_{cond,wall} - Q_{conv,wall\text{-}air} - Q_{rad,wall\text{-}col} = 0 \tag{3.2.7}$$

$$Q_{cond,wall} + U_{cond,wall}\, A\, T_{wall} = U_{cond,wall}\, A\, T_{room} \tag{3.2.8}$$

These equations can be written in matrix form.

$$[A]\,[x] = [b] \tag{3.2.9}$$

The radiation terms in Equations 3.2.2 and 3.2.3 are linearized, and the system of equations is solved using standard matrix techniques. Once these simultaneous equations are solved, the energy balance Equation 2.1.2 is used to find T_{out}.

$$T_{out} = T_{plen} + Q_{conv,wall\text{-}air} / (\gamma\, m_1\, c_p) \tag{3.2.10}$$

3.3 TMY Weather Data{ TC "3.3 TMY Weather Data" \l 2 }

The Solar Energy Laboratory at Madison provides Typical Meteorological Year (TMY) data files that only contain weather data that are important for solar thermal energy systems. Unlike most solar collectors, the only significant heat loss mechanism in the UTC system is radiation to the surroundings. Therefore, accurate knowledge of the sky temperature is important for an accurate simulation. However, the sky temperature is not provided in the TMY files. A TRNSYS subroutine, Type 69, uses the algorithm of Martin and Berdahl [1984] to estimate the sky temperature from cloud cover data in the original TMY file (see Appendix B). The simulations in this thesis use TMY weather data for Madison, WI, unless otherwise noted.

The UTC system model does not account for wind or shading on the collector. Although TMY data contains wind information, forced convection loss due to wind off the edge of the UTC plate are negligible for approach velocities above 0.02 m/s and large collector areas [Kutscher, 1992]. There is no reasonable way to include the effects of shading on the UTC system. The assumption of a uniform collector temperature would not be valid with shaded regions. When applying the findings of this thesis to a specific building, the shading of the south wall should be considered.

3.4 Warnings{ TC "3.4 Warnings" \l 2 }

The UTC system subroutine outputs warnings to a file when TRNSYS is run. The warnings alert the user if the UTC system model over predicts the performance of the UTC system or if the UTC system over heats the building.

The pressure drop across the collector must be at least 25 Pa to ensure a uniform flow and temperature distribution over the collector [Kutscher, 1992]. The efficiency of the UTC system is reduced when the temperature distribution is not uniform because the hot spots on the collector increase the radiation loss to the surroundings. Since the TRNSYS subroutine assumes a uniform collector temperature, it over predicts the efficiency of the UTC system under these conditions. TRNSYS outputs a warning when the collector pressure drop is below 25 Pa.

The approach velocity must be at least 0.02 m/s to ensure there is no convection loss to the surroundings, as discussed in Section 2.1. Since the TRNSYS subroutine assumes no convection loss, it over predicts the efficiency of the UTC system if there is convection loss to the surroundings. If the approach velocity is less than 0.02 m/s, TRNSYS outputs a warning.

As discussed in Section 2.3, there may be time steps during the UTC system simulation that the mixed air temperature is greater than the desired supply air temperature. The summer bypass damper should be opened but is not because the ambient temperature is below the summer bypass set temperature. Under these conditions, a warning is output from TRNSYS.