Simulation of climatic conditions in the subsurface

16.1 BACKGROUND

The complexities of the relationships that govern heat flow from the strata into ventilated underground openings are illustrated by the analyses given in section 15.2. Indeed, the routine use of those relationships become practical only through the availability of computer assistance. The first computer programs to simulate heat flow into mine workings were developed in South Africa (Starfield, 1966a,b). The early programs estimated strata heat flow from the Goch and Patterson tables (section 15.2.6), either by interpolation or from regression-fitted equations that approximated those tables. Since that time, simulation programs of increasing sophistication have been developed in a number of countries. Current programs recognize the influence of boundary layers close to the rock–air interface, allow for heat sources other than the strata (section 15.3) and predict the psychrometric effects of heat and moisture additions on the mine climate.

The common feature of mine climate simulation models is that they are based on solutions of the fundamental equation for heat conduction (equation (15.13)), and on utilization of the dimensionless Fourier and Biot numbers. However, the programs may vary in the manner in which they determine rock surfaces temperatures and heat transfer coefficients, and in the characterization and treatment of wet surfaces (Mousset-Jones, 1988).

Individual programs may be constrained to particular geometries of stopes or working faces, while others have been written for airways or headings. Some involve empirical relationships that are applicable only to specified layouts or methods of working. Again, some program packages allow combinations of airways, headings and working faces within a network structure while others are essentially ‘single airway’ simulators that must either be run separately for each branch or used in conjunction with a ventilation network analysis package (section 16.3.5).
In this chapter, we shall examine the essential features of mine climate simulation programs and how such programs may be utilized in the design of subsurface ventilation and air conditioning systems.

16.2 ELEMENTS OF MINE CLIMATE SIMULATION PROGRAMS

16.2.1 Organization of the programs

All mine climate simulations commence with the psychrometric condition of the air at the inlet end of the airway (or face) being defined by the user. This is normally accomplished by specifying the inlet wet bulb temperature, dry bulb temperature and barometric pressure. The program then divides the airway into incremental lengths, each of which is sufficiently short that wet and dry bulb temperatures may be assumed to be constant within the increment for the calculation of strata heat flows.

Each increment is traversed in the direction of airflow and the following parameters are calculated:

1. sensible and latent heat flows from the strata and other sources
2. change in moisture content of the air
3. change in dry bulb temperature
4. conversions between potential and thermal energies for shafts or inclined openings (autocompression)
5. change in barometric pressure
6. change in wet bulb temperature
7. other psychrometric parameters and indices of heat stress at the exit end of the increment

The conditions for the start of the next successive increment are then defined. Each incremental length is treated in this way until the complete airway has been traversed.

The following subsections outline the computational procedures involved in each of the steps listed.

16.2.2 Incrementation of airway length

The length of airway increment, $Y_i$, over which changes in temperature have no significant impact on strata heat flux will vary according to the magnitude of heat additions, the airflow and inclination of the airway. The value of $Y_i$ may be (i) fixed at some small value (say 10 or 20 m) within the program, (ii) a fixed fraction of the total length or (iii) chosen by the user. Some programs may accept all three but use the smallest of those values of $Y_i$ during the computational procedures.

16.2.3 Heat additions

In any incremental length of airway there will, in general, be transfers of both sensible and latent heat from one or more sources. In order to determine the corresponding