Heat flow into subsurface openings

15.1 INTRODUCTION
Heat is emitted into subsurface ventilation systems from a variety of sources. In the majority of the world’s coal mines, the airstream itself is sufficient to remove the heat that is produced. In deep metal mines, heat is usually the dominant environmental problem and may necessitate the use of large-scale refrigeration plant. Conversely, in cold climates, the intake air may require artificial heating in order to create conditions that are tolerable for both personnel and equipment.

In section 9.3.4, quantification of the heat emitted into a mine or section of a mine was required in order to assess the airflow needed to remove that heat. Hence, a sensible place to commence the study of heat flow into mine openings is to classify, analyse and attempt to quantify the various sources of heat. The three major heat sources in mines are the conversion of potential energy to thermal energy as air falls through downcasting shafts or slopes (autocompression), machinery, and geothermal heat from the strata. The latter is, by far, the most complex to analyse in a quantitative manner. We shall deal with this separately in section 15.2, then quantify other sources of heat in section 15.3.

15.2 STRATA HEAT

15.2.1 Methods of determining strata heat load
In reviewing the literature for means of determining the amount of heat that will be emitted from the strata, the ventilation engineer is faced with a bewildering array of methods varying from the completely empirical, through analytical and numerical, to computer simulation techniques. The basic difficulty is the large number of variables, often interacting with each other, that control the flow of strata heat into mine airways. These include

1. the length and geometry of the opening,
2. depth below surface and inclination of the airway,
3. wetness of the surfaces,
4. roughness of the surfaces,
5. rate of mineral production or rock breaking,
6. time elapsed since the airway was driven,
7. volume flow of air,
8. barometric pressure, and wet and dry bulb temperatures at the inlet,
9. virgin (natural) rock temperature,
10. distance of the workings from downcast shafts or slopes,
11. geothermic step or geothermic gradient,
12. thermal properties of the rock, and
13. other sources of heating or cooling such as machines and cooling plant.

With such a variety of parameters, it is hardly surprising that traditional methods of predicting strata heat loads have been empirical. Perhaps the simplest and most common of these has been to quote strata heat flux in terms of heat load per unit rate of mineral production; for example, kW per tonne per day. As the rate of production is only one of the several variables listed above, it is obvious that this technique may lead to gross errors if it is applied where the value of any one of those variables is significantly different from the original sets of measurements used to establish the (kW/tonne)/day value.

The more sophisticated empirical techniques extend their range of application by incorporating estimated corrections for depth, distance, age, inlet conditions or, indeed, any of the listed variables considered to be of local importance.

The purely analytical methods of quantifying heat flow from the strata are somewhat limited for direct practical application because of the complexity of the equations that describe three-dimensional, time-transient heat conduction. Indeed, they can be downright frightening. However, the theory that has evolved from analytical investigations has provided the basis for numerical modelling which, in turn, has resulted in the development of pragmatic computer simulation packages for the detailed prediction of variations in the mine climate.

A hybrid method has grown out of experience in running climatic simulation packages. It is often the case that, for particular conditions, some of the input variables have a very limited effect on the results. By ignoring those weaker parameters it is then sometimes possible to develop simple equations that give an approximation of the heat flow.

In view of these alternative methodologies, what is the mine environmental engineer to do when faced with the practical problems of system design? Experience gained from major planning projects has indicated the following recommended guidelines.

1. If the objective is to plan the further development of an existing mine, or if there are neighbouring mines working similar deposits at equivalent depths and with the same methods of working, then the empirical approach should be adopted for the overall strata heat load on the whole mine or major sections of