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DISCRETE-EVENT SIMULATION OF NUCLEAR-WASTE TRANSPORT
IN GEOLOGIC SITES SUBJECT TO DISRUPTIVE EVENT.*

(Final Report)

by

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INTRODUCTION

This report outlines a methodology to study the effects of disruptive events on nuclear waste material in "stable" geologic sites. The methodology is based upon developing a discrete events model that can be simulated on the computer. This methodology allows a natural development of simulation models that use computer resources in an efficient manner. Accurate modeling in this area depends in large part upon accurate modeling of ion transport behavior in the storage media. Unfortunately, developments in this area are not at a stage where there is any consensus on proper models for such transport. Consequently, our work is directed primarily towards showing how disruptive events can be properly incorporated in such a model, rather than as a predictive tool at this stage. When and if proper geologic parameters can be determined, then it would be possible to use this as a predictive model. In the next section, we discuss our assumptions and their bases, and describe the mathematical and computer model that we have developed.

1. NATURE OF THE GEOLOGIC PROBLEM

The storage of nuclear waste material generated as a byproduct of nuclear power reactors is now recognized as one of the

greatest problems associated with that power source. To mitigate the possible environmental hazards associated with this waste material it has been proposed to store such substances in geologically stable and inert media. These media are generally considered to be either unfractured crystalline rock, such as granite, dense sedimentary rocks, such as shale, or evaporite deposits, such as rock salt. A review of some geologic considerations in waste storage is presented in deMarsily, et al (1977). In this study the parameters and assumptions used will be those for salt, although only moderate modification would allow application to alternative media.

The proposed storage of nuclear waste in salt layers has been under study at least since 1956 (Heroy, 1956). A review of the work in this area is presented in Bredehoeft, et al (1978).

The most commonly proposed waste disposal plan consists of excavation of an underground chamber within a bedded salt layer. Wastes in large metal containers are taken down a shaft and into these chambers. After the chamber is filled with cannisters, the entire opening is backfilled with loose salt material. Various types of seals across the excavated tunnels are planned to prevent leakage of hazardous materials through the disturbed media.

The cannisters will have some average lifetime under the conditions present in the storage layer. After a long period of time, the cannisters will fail, releasing the waste into the subsurface environment. Our study treats the behavior of these wastes after this release. Study of the rate of failure of

cannisters and related problems has been studied by TASC (1978). A diagram of this plan is shown as Figure 1.1.

Figure 1.1

For the most part workers have assumed that salt represents a material which is impervious to fluids and by virtue of its behavior as a viscoelastic material would represent a self-sealing system with effectively no release to the external environment.

While it is true that bedded salt and salt domes have extremely low permeabilities, they are not zero. Under the conditions where potential contamination risks may exist for hundreds of thousands of years, even the smallest permeabilities may become important. Laboratory measurements of salt permeabilities were conducted by Gloyne and Reynolds (1961) which resulted in values on the order of 10^{-2} millidarcys (a measure of permeability) for

bedded salt and 1 millidarcy for salt dome material. Although the measured values are quite small, they are comparable with other materials (Davis and De Wiest (1966)); see Table 1.1. As can

TABLE 1.1

Material	Permeabilities (millidarcys)
Medium grained sandstones	1 - 500
Carbonates	10^{-1} - 500
Igneous rock	10^{-3} - 10
Volcanic rocks - old	10^{-1} - 10
Alluvium	10^4 - 10^5

be seen, the values for salt are not greatly lower than minimum values for other materials. Most of the measurements for these low permeability materials have been taken only from laboratory studies. To determine in situ permeability requires long term observations and extremely precise monitors; such studies have yet to be conducted in detail.

Salt behaves as a viscoelastic material; that is, over sufficient pressure gradients and time periods it will flow plastically. This is best exemplified by the formation of salt domes. Salt domes are caused when lateral pressure on a salt stratum within the earth becomes greater than the confining or lithostatic pressure. At a zone of weakness such as a fault, the salt flows upward into the overlying material forming a diapir. Such formations are the loci of oil deposits in the U. S. Gulf Coast and in other worldwide locations.

During these tectonic episodes a great deal of strain is accumulated within the salt mass; this accounts for the difference in permeability between the bedded salt and the salt dome material.

The plasticity of the salt over time will allow it to flow into zones of lesser confining pressure or other stress. This allows for the "healing" of fractures or voids that may have been generated during some previous stage of the salt's geological evolution. These fractures might also be filled by deposition of salt from the very concentrated brines associated with the salt deposit. Such mobilization and redeposition of salt is also a function of a differential stress concentration.

Fluid Flow

The water in a body of salt and the flow through that body is principally contained in a myriad of micro-fractures. These micro-fractures are generated by external tectonic forces or by internal adjustments within the salt mass. Such fractures may be resealed over some time period although the formation and healing rate is in equilibrium in the long term.

Thus, while in detail a fracture-flow model may best represent the true nature of fluid flow in salt, a porous flow model may approximate the bulk flow rate. In the case of porous media the flow paths are in the voids between grains; in salt the flow paths are along the micro-fractures.

Fluid flow in porous media is approximated by assuming a network consisting of an assembly of prismatic, unconnected tubes. The path of fluid flow is complex and tortuous but is generally

analyzed by averaging over a large volume. Such approximations led to the formulation of Darcy's Law.

Porous flow may model the largest bulk of material in the salt mass. However, it is probable that significant major portions of fluid movement may occur along large fracture planes or in imperfectly healed shear zones and breccia pipes.

After release of wastes from the buried cannisters, various ions enter the ground water system within the salt as contaminants. The ions involved and a discussion of their relative hazard is presented in TASC (1978). The study of the migration of these ions is similar to the study of the movement of tracers within a system; this is discussed in detail in Bear (1972) and in other references.

Contaminants in the system move by two independent modes: molecular diffusion and mass transport. Molecular diffusion is the movement of atoms from an area of higher concentration to one of lower concentration. Mass transport is the physical movement of a fluid containing those atoms. Thus the total movement of contaminant atoms is the combination of these two factors.

The equations for the velocity of tracer movement by these various methods are discussed in Bear (1972) and are presented subsequently in this report.

Changes in the System

Outside forces may change the characteristics of a geologic system. One such outside force is an earthquake. Nearby earthquakes could have a profound effect on the flow regimes within

the salt mass. Although the probability is small, a new or rejuvenated fault could provide a conduit for fluids. Flow along such a fracture would overshadow the normal movement along the micro-fractures.

Lesser levels of seismic motion would serve to temporarily increase the permeability of the salt by increasing the micro-fracture density. The increase in micro-fractures would be directly proportional to the magnitude and proximity of any seismic event. A probabilistic method of determining earthquake size and effect will be discussed later in this paper. It is presumed that the increase in microfracture density would generally return to the original value (equilibrium) by "healing" over a specified time frame.

In addition to these transient changes, long term changes in the regional geologic environment may occur. Changes in the ground water regime, including variation on hydraulic head, and quantity of water available, could occur as a result of climatic change and/or tectonic movement.

Over a period approaching one million years, a major change in the tectonic framework of an area might occur. This could cause reactivation of old faults, mobilization of the salt as a whole, erosion of the overburden, or other major considerations.

Another set of variables is related to the emplacement, re-filling, and subsequent behavior of the nuclear wastes themselves. Principal among these would be the effect of an imperfect seal of the storage chamber. This would provide a superior conduit for

fluids to the surface.

Also, the decay of nuclear materials produces heat. A thermal gradient within a ground water system will distort the flow toward that irregularity. However, such changes may be compensated for by decreased permeability near heat sources. Thermal energy could modify the flow regimes by: 1) creating convection cells, 2) inducing local pressure gradients, 3) decreasing viscosity of fluids, 4) changing bulk permeability, 5) changing the rock state-of-stress, and 6) changing the chemical reaction characteristics (Bredehoeft, et al, 1978). In the methodology that we propose, we discuss handling of transient changes as well as a few simple categories of permanent changes. It is clear that to handle such events as climatic changes would require much more predictive information than is currently available.

2. DISCRETE EVENT MODELING

The approach that we will use in developing a computer simulation model for tracer transport in the region of emplacement is called discrete event modeling and simulation. The fundamental philosophy of discrete even simulation is that the simulation clock---and hence the model---is updated to the time of the next event. This can be compared with a discrete time model in which an integral time base is prescribed with the model update occurring at every unit time step. Discrete time models are usually the vehicle for defining all models based on ordinary or partial differential equations. By approximating using difference equations, one obtains a discrete time model. For our purposes, however,

the long time span that we simulate and the flow events that we process almost necessitate a discrete event approach.

The time base of a discrete event model is the real line. Events can thus occur at arbitrary points in time, although we impose the restriction that only a finite number of events can happen in any finite time interval. The goal of a discrete event model is to avoid computations at intermediate points in time (during the interevent period) when changes to the model need not be processed. Thus, "state changes" are only scheduled to be processed at event times. Actually, the true state of the model may change during this intermediate time interval; we only insist that state changes be predictable enough so that they only require updating at event times. The discrete event model can then be jumped from one event time to the next event time. Some of these interevent time periods between events may be rather short, and others may be extremely long. The model is limited only by the number of events to be processed, not by the time base.

In the next section, we shall consider events of importance to be such things as occurrence of earthquakes, formation of breccia pipes, formation of large fractures, etc. Although the model changes during the interevent period, the flow parameters only change at event time and we can delay updating until an event actually occurs. We need not do any processing in the interevent period. (If the state of the system was desired at an intermediate time point for some reason, the updating could easily be done as an event at that time.) Before discussing our specific discrete event

model, we discuss some general issues related to discrete event modeling.

A mechanism to handle the processing of event times is to keep a next events list. The next events list is a set of ordered pairs (E_i, T_i) with T_i being the time the event E_i is scheduled to occur. This time is often called the hatching time for even E_i . If our model is such that events can be referenced by absolute time (i.e., we have a clock available), then T_i is an absolutely scheduled time. Sometimes we wish to describe a discrete events model without using a global time clock. In this case, we specify the hatching time for event E_i relative to the current time and label the time until hatch to be σ_i . The information on future events is thus a set of pairs (E_i, σ_i) . For efficient processing, the next events list is invariably ordered by nondecreasing event times.

The prescheduling of events on a next events list is an appropriate approach whenever it can be assumed that changes to a component need not be processed until an event occurs. The processing of an event then involves several computations: The state of one or more components of the model is updated at event time; future scheduled events may be deleted or rescheduled; additional scheduled events may be added; and finally, the immediate next event to be processed is determined. The event driven simulation consequently moves autonomously from one event time to the next.

1 Conceptually, the handling of external (unpredictable) events must be treated differently. In this case, immediate processing

must take place, with an immediate update in the model state. In practice, however, all external events are normally determined using a pseudo-random number generator or some other deterministic mechanism for arriving at external event times. They can thus be scheduled on the next events list just as the internal events are. Consequently, external and internal events can be treated in a uniform manner.

Zeigler (1976) and Fishman (1978) are good sources for more information on discrete event modeling. They also discuss various simulation strategies---event scheduling, activity scanning, and process interaction---that can be used to determine the next event time. Our approach is essentially event scheduling. If desired, our model could also be formalized mathematically as a discrete event specified system (DEVS) (see Aggarwal and Peck (1979)). A DEVS model is a system theoretic formalization of discrete event models analogous to the sequential machine formalization for discrete time models. We now turn to a detailed discussion of our conceptual model.

3. THE CONCEPTUAL MODEL

Nature of Flow System

Most studies of flow in porous media are based on a modification of Darcy's Law. In the case of salt or other evaporite deposits, the standard formulation of Darcy's Law and its extensions can be used only as gross approximations. Fluid flow in normal porous media such as sands is intuitively analyzed by assuming a network of prismatic capillary tubes bounded by grain boundaries.

The path of flow of any particular quantum of water is complex and tortuous and may not be treated mathematically; however, behavior of the fluid averaging over a volume is well behaved. In a similar manner, the flow of tracers or contaminants may also be modeled.

Dynamics of Flow

Within a body of salt or other evaporite deposit the general conceptualization of porous flow breaks down. There are no grain boundaries or individual particles, as such, with open interstices. Within those bodies, however, are a myriad of microfractures. These are initiated by external forces acting on the salt during tectonic activity within the body itself as it undergoes plastic flow or other readjustment. These fractures are not a static property of the salt mass but may occur episodically upon application of forces. Assuming no external forces, the creation and healing (or sealing) of microfractures will attain a steady-state equilibrium.

Several authors such as Irmay (1955) employ narrow capillary fissures in a model representing a porous medium. The solution to these models is based on an average velocity solution of the Navier-Stokes equation. By considering these solutions in three dimensions, an account of anisotropic permeability may be obtained. Similar models were also suggested by Snow (1965) and Parsons (1965). However, when compared over a large region, these solutions do not differ significantly from those of a generalized porous formulation such as that used in this study. Although a difference does exist, the standard formulations have been used as simplifying assumptions due to the further complexity involved when the effects

of dispersion and diffusion are included. This is consistent with the averaging of the Navier-Stokes equation over a large volume as has been done by many investigators (Irmay, 1958; Whitaker, 1966; etc.). A recent discussion of fracture flow and contaminant transport in fracture flow is presented by Grisak and Pickens (1980). For this study we have used equations for tracer flow in three dimensions presented by Bear (1972). These are described in Section 4 of this report.

Parameter Estimates

Having assumed a simplified form of flow pattern, the next task is to derive suitable parameters for inclusion into the flow equations. The flow model consists of a layer of interest (storage medium) with a vertical hydraulic gradient due to an underlying pressurized aquifer. This follows a worst-case scenario originally devised by TASC (1978).

The principal parameter controlling the movement of fluid through the salt body is the permeability. Studies of porosities, permeabilities, dispersion, and related coefficients have been conducted by various groups (Golder Associates, 1977; Geotechnical Engineers, 1977a, 1977b). These indicate permeability coefficients in normal salt to be on the order of 10^{-5} to 10^{-9} (cm/sec). This tends to agree with the laboratory studies of Gloyne and Reynolds (1961). (Note that in one study k is presented, where in the others, K . These differ as the first (k) is intrinsic permeability which is a property of the medium alone; K takes into account the physical configuration of the medium (grain size,

etc.).) In this study we have used a base value of 10^{-7} allowing increase to 10^{-5} during transients; these will be discussed below.

To simplify our model we follow Bear (1972) and combine the dispersion and diffusion terms into a single term (D). Since we are dealing with an assumed isotropic material with a vertical flow, the vertical component of D will be larger than the two horizontal components. We have chosen arbitrarily a factor of 2 for this ratio. We have further used a common approximation that D is proportional to v^2 (Bear, 1972).

The values of D used in the study are again based on the permeability references mentioned above. Although we have not addressed the issues of retardation or absorption of ions in this study; they could be included to some extent by variation in D .

System Transients

Under normal conditions once contaminant migration was initiated it would undergo flow based solely on the effective permeability of the medium, the dispersion, diffusion, retardation, and absorption of the contaminant in the medium, and the hydraulic gradient imposed on the system. At some locations within the modeled system, these parameters would change due to local geologic features or remnants of emplacement operations. Some of these encounters could be so severe as to cause extremely rapid migration and near surface contamination. These could include such things as preexisting major fractures, breccia pipes, exploratory boreholes, emplacement backfill, etc. These are treated separately in

the computer model.

Other transients are accepted in the continuous model. The principal cause of these temporal transients are earthquakes which will be discussed in detail below. The geologic phenomenon of faulting or generating a large-scale fracture within the medium or reactivating such a fracture would be treated separately in the model. The likelihood of such a fault within the flow regimes is of extremely low probability.

Seismic Hazard

In our conceptual model, we consider earthquakes to be the major short-term external event. To model the possible seismic hazard at a typical site, we conducted a probabilistic study. An area with moderate seismicity such as southeastern New Mexico-western Texas was selected. This study used historic earthquake data recorded instrumentally over the past 20 years in the region around the site. Historic, major earthquakes have been recorded for a period of over 200 years; however, this data is incomplete in the lower magnitude range.

The basic outline of this seismic risk technique follows that published by Cornell and Vanmarke (1969), Cornell (1971), and Merz and Cornell (1973). The programs and further discussion of the methodology are contained in McGuire (1976). Special emphasis has been placed on the relationships between attenuation of ground motion with distance and the distribution and size of events with respect to the local seismological and geological environments. Some of these considerations are discussed more fully in Donovan

(1972,1973) and Donovan and Bornstein (1975).

A probabilistic study requires the acceptance of several assumptions regarding earthquakes. Such assumptions include:

1. The geology and seismic history of the region are sufficiently well known to permit an estimate of the seismic history of a region. For this study, it is assumed that earthquakes are random, independent occurrences with time. This is not consistent with the hypothesis that earthquakes are the result of the release of slowly accumulating strain nor does it account for foreshock and aftershock sequences. At the present time there is not sufficient data available to assume more refined and more complex distributions of events in time. If better distributions become available they may easily be considered as this is independent of the discrete events model.

2. That the distribution between large and small earthquakes can be expressed by the equation

$$\log N = a - bM$$

where N is the number of recorded events with magnitudes equal to or greater than M , and " a " and " b " are constants dependent on the seismicity of the area.

3. That the attenuation of motion with distance from the seismic source is known and can be expressed in the form of an attenuation equation relating magnitude to the ground motion parameters.

While major events in the seismic history of the site have been adequately recorded over a period of 200 years, the data for

earthquakes with magnitude 4 or greater appear to be uniformly complete only over the last 20 years (Sanford and Topozada, 1974). The seismic activity rate has been chosen on the basis of the more recent data and confirmed in a qualitative way with the longer term record of the larger events.

Earthquakes were generated as occurring either as random events throughout a specified area or on known active faults. For each such region or fault, an upper-bound earthquake magnitude and focal depth were prescribed.

The model was run with a probability of certain ground motion levels occurring, based on the activity of a particular source, the size of earthquake possible on that particular source, and the distance from the site of that particular source. In this study many of the parameters were generalized, since a typical rather than a specific site was to be considered.

To preserve conservatism in this procedure, due to total uncertainty of the location or geologic conditions of the site, the following values for mean recurrence interval were utilized:

TABLE 3.1

Peak Horizontal Acceleration	Mean Recurrence Interval
0.30g	5000 years
0.50g	60000 years
0.75g	> 1000000 years

Effects of Seismic Ground Motion

Based on our premises regarding the nature of flow within a medium such as salt, the fluid and entrained contaminants flow in microfractures within the salt. These microfractures are a result of the reaction of the salt to tectonic forces, external and internal. Thus, the application of the seismic motion would contribute to the formation of the new, additional microfractures. Discussion on the behavior of a mass of salt material is contained in Baar (1977).

By observation on the effects of seismic ground motion on subterranean structures and excavations, it was considered that ground motion levels less than 0.30g (the threshold value) would have no significant effect on the generation of microfractures. Only a small increase would occur before reaching a 0.50g level. Above 0.50g the microfracture generation could increase significantly. The number and length of microfractures, assuming other parameters to remain constant, show up as a direct increase on the permeability of the medium, the velocity of fluid through the medium, and the dispersion and diffusion of the contaminants within the medium.

There is an exponential relationship between earthquakes above the threshold and the increase in fluid velocity. Less than 10% of earthquakes above the threshold value would increase the velocity by as much as a single order of magnitude and these increases would only be temporary. The range used allowed for a potential increase in fluid velocity of two orders of magnitude, from 10^{-7} to 10^{-5} cm/sec. The corresponding values for the combined effects

of diffusion and dispersion ranged over four orders of magnitudes. Only 1 out of 100 earthquakes above the threshold would, on the average, cause a system change of this magnitude. All earthquakes generated, but below the threshold level, were discarded.

System Restoration

Based on the dynamics within a salt system (Baar, 1977), the salt is mobile and tends to "heal" fractures by at least two processes: 1) physical plastic flow of the salt into areas of lower pressure, and 2) the dissolution of salt into brine at a point of higher pressure and its precipitation at a point of lower pressure, such as a fracture.

Thus, over a period of time the increase of microfractures induced by the rare, large earthquakes would dissipate and system would return to normal. Remnant zones of weakness along healed fractures may continue to exist, but these are not considered to be significant.

No rheological studies were made as to such healing time. As an arbitrary solution the fluid velocity was decreased by one-half its increase during an earthquake every 1000 years until it returned to normal.

System Changes

The effects of large fractures, breccia pipes, and imperfections in emplacement of contaminants require transfer from the continuous model to a step model having entirely different distributions of fluids and contaminants. This is discussed in detail in

Section 4. The probability of encounter of any of these phenomena during model operation has been estimated at 10^{-9} (TASC, 1978).

Long term changes in the geologic environment of the site have not been explicitly included. These could consist of change in ground water flow patterns, erosion, tectonic uplift, change in seismic activity, etc. The discrete event model may be modified for their inclusion.

4. THE MATHEMATICAL MODELS

Before describing the computer simulation model, we first discuss updating of the tracer concentration (mass per unit volume of a specific radioactive contaminant) between event times. Recall that there exists a "background" flow through the burial site media because of the existence of a hydraulic gradient. We treat this flow as incompressible fluid flow through isotropic porous media. Until the occurrence of a large fracture, our basic assumption is that the microfracturing is uniformly distributed, allowing us to use a porous media model. Density changes in this porous media will occur only at event times, and all parameters are constant during the interevent period. We thus seek the proper formulation to determine tracer concentration in such a flow field. The tracer, of course, is subject to both diffusion as well as dispersion (see Bear, 1972).

The Fundamental Flow Equation

Let $C = C(x_1, x_2, x_3, t)$ be the tracer concentration (of a particular contaminant) at time t and at some point (x_1, x_2, x_3)

in the burial media. Suppose $V = (V_1, V_2, V_3)$ is the average velocity vector through the pore space. If q is the filtration velocity (volume of fluid through a unit area per unit time), then $V = q/e$ where e is the porosity. Scheidegger (1961) and Bear (1972) discuss the derivation of the conservation equation that applies to tracer distribution moving with an incompressible homogeneous fluid in isotropic porous media:

$$\frac{\partial C}{\partial t} = \text{div}(D \text{ grad } C) - V \text{ grad } C \quad (4.1)$$

D is a symmetric second-order tensor that incorporates influences due to both mechanical dispersion as well as diffusion. By letting one of the coordinate axes coincide with the direction of the velocity vector V , and restricting ourselves to the three-dimension burial site of interest, we have:

$$\frac{\partial C}{\partial t} = \sum_{i=1}^3 D_i \frac{\partial^2 C}{\partial x_i^2} - \sum_{i=1}^3 V_i \frac{\partial C}{\partial x_i} \quad (4.2)$$

By identifying the direction x_3 with the velocity vector V , we see that the parameters that need to be specified are $D = (D_1, D_2, D_3)$ with $D_1 = D_2$ (isotropic media) and $V = (V_1, V_2, V_3)$ with $V_1 = V_2 = 0$.

If we let the initial concentration at time 0 be:

$$C(x_1, x_2, x_3, 0) = \phi(x_1, x_2, x_3), \quad (4.3)$$

then we seek a solution to the initial value problem represented by equations 4.2 and 4.3, subject to any appropriate boundary conditions. Our interest is in obtaining a fast method to determine the concentration at the next event time; call it t_1 . This

event time will then become the initial time for any subsequent update, using new parameters. The new parameters will, of course, be determined by the nature of the event at time t_1 .

Gershon and Nir (1969) discuss the character of the solution subject to varying boundary conditions and show that the solution changes by only a small percentage. Since the initial burial location is quite a distance from any aquifer, the boundary conditions play a minimal role in the resulting solution. Consequently, we shall require only some reasonable (from a physical point of view) boundedness conditions on the solution.

The following is a well known mathematical result (Oddson, 1979).

Let $X = (x_1, x_2, x_3)$ and suppose $\varphi(X) \in C^0$ (continuous), and is bounded on R^n . Then the initial value problem:

$$\left. \begin{aligned} u(X,t) &\in C^0 && \text{and bounded on } R^n \times [0, \infty) \\ \frac{\partial^2 u}{\partial x_i^2}, \frac{\partial u}{\partial t} &\text{ exist} \\ \text{div } u - \frac{\partial u}{\partial t} &= 0 \end{aligned} \right\} \quad \text{on } R^n \times (0, \infty)$$

$$u(X,0) = \varphi(X) \quad (4.4)$$

has a unique solution that is given by:

$$U(X,t) = \begin{cases} \frac{1}{(4\pi t)^{n/2}} \iint_{R^n} e^{-\frac{\|X-\xi\|^2}{4t}} \varphi(\xi) d\xi & \text{on } R^n \times (0, \infty) \\ \varphi(x) & \text{on } R^n \times \{0\} \end{cases} \quad (4.5)$$

By an appropriate change of variable, the initial value problem represented by equation 4.2 and 4.3 has the unique solution:

$$C(x_1, x_2, x_3, t) = \begin{cases} \frac{e^{-\frac{t}{4} \sum \frac{v_i^2}{D_i} + \frac{1}{2} \sum \frac{v_i x_i}{D_i} - \frac{1}{4t} \sum \frac{x_i^2}{D_i} - \sum \frac{v_i x_i}{2D_i}}}{(4\pi t)^{3/2} \sqrt{D_1 D_2 D_3}} \iiint e^{\varphi(\xi_1, \xi_2, \xi_3)} d\xi_1 d\xi_2 d\xi_3} & \text{on } R^3_x(0, \infty) \\ \varphi(x_1, x_2, x_3) & \text{on } R^3_x\{0\} . \end{cases} \quad (4.6)$$

The assumptions that allow this to be the unique solution are physically met and correspond to the boundedness assumptions and existence of partial derivations of equation 4.4, plus the assumption that D and V are constant.

When $\varphi(x) = M\delta(x)$, the Dirac delta function with total mass at the origin, we get the solution:

$$C(x_1, x_2, x_3) = \begin{cases} \frac{M}{(4\pi t)^{3/2} \sqrt{D_1 D_2 D_3}} e^{-\frac{t}{4} \sum \frac{v_i^2}{D_i} - \frac{1}{4t} \sum \frac{x_i^2}{D_i} + \frac{1}{2} \sum \frac{v_i x_i}{D_i}} & \text{on } R^3_x(0, \infty) \\ M\delta(x_1, x_2, x_3) & \text{on } R^3_x\{0\} . \end{cases} \quad (4.7)$$

Computer Implementable Solutions

It is clear that the integral solution to the initial value problem does not result in a convenient method to update the concentrations at event times. Solutions by integral approximations would be extremely slow (and depend upon the time interval), and in addition, there is the problem of properly specifying the

initial concentration $\varphi(x_1, x_2, x_3)$ for a computer solution.

Our first attempt to get around these difficulties was to try to obtain useful solutions for an initial Dirac delta function. For convenience, and to be more graphic, we call such a function a spike function. The idea was to obtain iterative solutions for the first few event times E_1, E_2, E_3 , in terms of the parameters at these event times. Equation 4.7 is a solution for the first event time E_1 . Unfortunately, although a rather complex solution could be obtained for the next event E_2 , the did not lend itself to an iterative formulation, and further reasonable solutions were not forthcoming.

Our next approach was to use the normal solution to the spike function to eventually obtain future solutions through aggregation. We now turn to a discussion of this solution and its ramifications.

The Normal Distribution Solution

The solution to an initial spike function of mass M at the origin is equation 4.7. By a shift in viewpoint---considering a coordinate system moving with the average flow---the solution can be conveniently simplified. Thus, if we let $\mu_i = v_i t$ and $\sigma_i = \sqrt{2D_i t}$, we can transform equation 4.7 into:

$$C(x_1, x_2, x_3, t) = \frac{1}{(2\pi)^{3/2} \sigma_1 \sigma_2 \sigma_3} e^{-\frac{1}{2} \sum \left(\frac{x_i - \mu_i}{\sigma_i} \right)^2} \quad (4.8)$$

The above equation is simply the density function of a tri-variate normally distributed random variable $X = (X_1, X_2, X_3)$ where

the X_i are independent univariate normal distributions. The mean $\mu = (\mu_1, \mu_2, \mu_3) = (V_1 t, V_2 t, V_3 t)$ and the covariance matrix is

$$\sigma^2 = \begin{bmatrix} \sigma_1^2 & 0 & 0 \\ 0 & \sigma_2^2 & 0 \\ 0 & 0 & \sigma_3^2 \end{bmatrix}.$$

Basically, we may think of the tracer concentration from an initial spike function as decaying into a distribution that is normal in each axis direction with a mean that is moving with the average velocity flow. (See also Bear (1972) and Scheidegger (1961).)

The normal distribution solution results in a practical way for us to generate solutions to an arbitrary initial concentration $\phi(x_1, x_2, x_3)$. We consider two points: (1) By the linearity property of the original solution, we can first approximate the initial concentration by spike functions, and then sum the resulting normally distributed solutions to obtain the concentration at an event time; and (2) given the normal solution to a spike function, we need to be able to approximate this normally distributed solution function by some number of spike functions so that we can iterate the process for future events.

Notice that the aggregations that we are performing are aggregations in space and not in time. This is compatible with the discrete event methodology. We wish the amount of time to perform an update to be independent of the interevent time period. We wish emphatically to avoid any updating procedure that implicitly becomes updating by breaking the interevent period into small time intervals. This would defeat the purpose of the

discrete event approach. The aggregation that we do perform is, in fact, just as fast regardless of the interevent time. The faithfulness of the approximation of course depends upon the number of spike functions to which we reduce the resulting tri-variate distribution. This is where the specific computation speed of the computer becomes important. On a faster machine, we would be able to consider finer approximations. The method of the update is also ideal for parallel processing. We now illustrate the aggregation process.

Aggregating the Concentration Field

In the actual simulation model (described in the next section), we decided to aggregate a univariate normal distribution into three spike functions of equal mass. Thus, the trivariate normal distribution that results from an initial spike is approximated by 27 spikes with identical mass. As discussed before, the approximations could be made finer with a resulting increase in computation time.

Consider a (univariate) uniform normal distribution $N(0,1)$ with mean 0 and variance 1. If we wish to locate three representative positions to aggregate the total mass under the curve (the total is, of course, one), what would they be? Clearly, 0 is an obvious point to choose. For the other two points, we choose ± 1.0908 . The reasoning is as follows. Since we wish each point to represent $1/3$ mass, the spike at 0 represents the aggregation from some $-x_0$ to $+x_0$ with $x_0 > 0$, such that:

$$\int_{-x_0}^{+x_0} xf(x)dx = \frac{1}{3} \quad (4.9)$$

where $f(x)$ is the density function of $N(0,1)$. The value of x_0 for the equation 4.9 is 0.43. Now, to aggregate the mass under the curve for $x < -x_0$, we wish to find a point that is representative in the interval $(-\infty, -x_0)$. The point that we chose was the mean point for this area. That is:

$$3 \int_{-\infty}^{-0.43} xf(x)dx = -1.0908. \quad (4.10)$$

A symmetric argument gives $+1.0908$ as the "right" spike. It is worth noting that the amount of concentration in the "tails" of the distribution that we are pushing inwards to the spike is:

$$\int_{-\infty}^{-1.0908} f(x)dx \approx 0.1379 \approx 14\%. \quad (4.11)$$

Thus, we are being nonconservative at about a 15% level each time we process an event and perform an aggregation. This aggregation of the tail would naturally be less inaccurate if we chose more than three spike functions at which to aggregate. Choosing proper representative points to aggregate is clearly a technical matter that does not affect the methodology of our general approach.

Gridupdate

Except for one further type of aggregation, we have essentially defined the operation of the procedure gridupdate that

updates the concentration between events. Suppose we have k spike functions with mass $m(k)$ at time t_0 . Assume the next event that occurs to change the flow parameters happens at t_1 . Then for every spike function i , $1 \leq i \leq k$, we determine the concentration at time t_1 using the flow parameters, the interevent time period $T = t_1 - t_0$, and the aggregation into 27 new spikes for each spike i . Notice that the mass that we have located at each of the 27 spike points is simple $m(i)/27$. Furthermore, the position of these spike points can obviously be adjusted to reflect a normal distribution that is not $N(0,1)$ but rather $N(\mu, \sigma^2)$.

The further aggregation that arises is necessitated by the combinatorial explosion that results by expanding each spike into 27 spikes. Clearly, for n events we will have 27^n spike functions if we proceed as described. For n any larger even than 3, it becomes a problem to process (and store) this number of spikes. To avoid this, we place a maximum size (say 10,000) on the number of spike functions that we wish to handle. If this number would be exceeded by the next event, we aggregate nearby spike functions to create a new spike function with mass the sum of the aggregated functions, and a location that is the weighted mean of the aggregated functions. In this way, we are able to control the combinatorial explosion. Clearly, the amount of aggregation to be done will depend on how much processing power we have available. We discuss some further issues regarding gridupdate in the next section.

5. THE COMPUTER MODEL

In this section, we discuss some important features of the computer implemented simulation model. A detailed listing is provided in Appendix A.

The external events that are to occur are kept on a linked list (future events chain) that is ordered by time. Currently, the following even types can occur on the future events chain: (1) QUAKE; (2) HEALING; (3) FRACTURE; and (4) BRECCIA. Procedures that correspond to FRACTURE and BRECCIA, however, have not yet been implemented, since we wish to handle these events in a different fashion than we handle moderate intensity quakes. As discussed previously, this will involve linking up a pipe flow model representing a nonhealing fracture, together with the background porous flow. We hope to do this in the next version of the computer simulation program.

Each time an event occurs, several things happen. First, the state of the model is updated to the current time, using the current parameters of the porous flow equation that are assumed constant in the interevent time interval. This updating is implemented by a call to the procedure GRIDUPDATE (described later). Next, new values for the flow coefficients are established. Finally, zero or more new events are generated and inserted into the future events chain at the proper location. Let us now consider the handling of the various events individually.

QUAKE Procedure

The quake procedure represents the occurrence of a moderate intensity earthquake. Associated with the event quake occurring at a particular time is the intensity of the quake, measured in microstrain units (microstrain units are used because they relate to microfracture density). For purposes of this program, a moderate quake is between 10^3 and 10^5 microstrain units. This range of microstrain levels is made to correspond to peak horizontal accerations of 0.3g to 0.75g , as discussed in Section 3. An event below 10^3 microstrain units is assumed to have no effect on the burial site. (Note: all intensities are ground motions felt at the site; the actual severity of the earthquake would depend on its source parameters.) Similarly, a quake that has intensity greater than 10^5 will be scheduled as a FRACTURE, since it has a much greater effect in that it results in nonhealing large fractures.

Upon invoking the QUAKE procedure, the first step is to call GRIDUPDATE to update the state of the burial region. GRIDUPDATE, of course, uses the flow coefficient values as of the last event to occur.

Next, new values for the flow coefficients are established depending on the value of STRAIN. We use the following equations to determine the new values of the velocity flow (V) in each direction and the new values of the coefficients that represent the combined effect of dispersion and diffusion (D).

$$\begin{aligned}
 V_i(\text{new}) &= V_i(\text{old}) \cdot \text{STRAIN} \cdot 10^{-3} \\
 D_i(\text{new}) &= D_i(\text{old}) \cdot (\text{STRAIN} \cdot 10^{-3})^2
 \end{aligned}
 \tag{5.1}$$

Thus, an earthquake of 10^4 microstrain units results in a ten-fold increase in the velocity vector.

The occurrence of a moderate earthquake also generates the next moderate earthquake and the microstrain value (STRAIN) of this next quake. We assume that moderate earthquakes occur with a mean of 5000 years and with an exponential waiting time. The strain level of the (moderate) earthquake is set at:

$$\text{STRAIN} = e^{-0.046 \cdot \text{RANDOM} + 11.546} \tag{5.2}$$

where RANDOM is a uniformly distributed pseudo-random number between 0 and 100 . The coefficients in this formula are based on the seismic hazards study discussed previously in Section 3. This results in microstrain values between 10^3 and 10^5 with the lower values being more likely. The next moderate earthquake is inserted into the future events chain at the proper location.

Recall that our basic assumption is that the effect of moderate earthquakes is to "temporarily" cause an increase in the microfracture densities and consequently an increase in the parameters of the porous flow equation. Since the effect is temporary, we must assume some functional way in which the flow parameters return to their previous values. The actual process by which the healing takes place is known, but the speed at which this occurs can only be guessed at by geologists. Currently, we allow several healing events to take place at equally spaced time intervals.

Thus, the earthquake procedure needs to generate the total healing time and know the number of healing events in order to schedule the HEAL events. We use the following heuristic to determine the total healing time:

$$\text{HEALTIME} = V_3 \cdot 10^3. \quad (5.3)$$

This results in healing times between approximately 15 and 1500 years. We elaborate further on healing when we discuss the HEAL procedure. Having generated the appropriate future events and processed the moderate earthquake, control is returned to the main program that determines the next event to be processed.

HEAL Procedure

As discussed above, the effect of moderate quakes are transient on the flow parameters. In general, for each flow parameter, there will be a curve as in Figure 5.1 that represents the variation of this parameter due to healing.

FIGURE 5.1

The exact shape of the curve can only be guessed at. We assume that given a total healttime, healing takes place in step decrements that are uniformly spaced in time and the decremented values are determined by a simple linear relationship. For example,

if there are three healing events in 1500 years after a moderate earthquake, the solid line in Figure 5.2 represents the flow parameter values.

FIGURE 5.2

Each heal event has associated with it the time the heal event is to occur, and which heal event is it. Thus, this information is sufficient to modify each parameter of the flow equation as indicated above. Upon invoking the HEAL procedure, GRIDUPDATE is first called to update the state of the model. Next, the new values of the flow parameters are determined. If it happens that a healing event were to be scheduled after the next quake, it is discarded. This is consistent with what would be expected geologically with reference to the microfracture density.

FRACTURE and BRECCIA Procedures

As mentioned before, these procedures have not been implemented. We would assume that these are very infrequent events and may not even occur during a typical run. Once this event does occur (BRECCIA or FRACTURE), it results in fracture(s) that

do not heal. It is thus necessary to include these fractures in future updates. There are two generic ways that this could be handled. (1) It could be assumed that once a fracture occurs, the porous flow model is no longer valid, and we could switch GRIDUPDATE to only reflect movement through the fractures, treating tracer movement as modeled by pipe flow models. Thus, since the flow through these fractures would be so dominant, we would need only concentrate on this region of the site. (2) We could attempt to superimpose fracture flow on top of the porous flow model. This would necessitate modification of GRIDUPDATE to handle this feature.

We expect to implement the handling of such features in the next version of the simulation model.

GRIDUPDATE Procedure

A call to GRIDUPDATE will update the tracer concentration distribution to the current time. Assuming the porous flow equation model (see Section 4), the update is performed by determining the new spike functions that will represent the concentration. In order to perform the update, the following information is needed: (1) the interevent time (T) since the previous update; (2) the values of parameters of the flow equation during the interevent time; and (3) the collection of spike functions at the time of the previous update (stored in Array GRID).

As discussed in Section 4, each (previously defined) spike results in 27 new spikes that are the result of the approximation of the resulting trinormal distribution. (The value of 27

is, of course, the result of the desired approximation and can be increased or decreased.) Clearly, the exponential growth in the number of spikes that results as a function of the number of events processed must somehow be handled. This is done by procedure AGGREGATE. We shall indicate two general methods to handle this issue, and then describe what is actually done. It should be clear that any other method to handle this large number of spikes can be easily implemented due to the modularity of the program.

One approach is to allow a maximum number of spikes (say 100,000) and then aggregate each new spike generated with the closest previously stored spike in Array GRID. Unless the original distribution of spikes is uniformly distributed in space, this would result in comparing the Euclidean distance between the new spike to be added at each spike in GRID. Once this is determined the masses of the two could be summed, giving the new value of the aggregate (of 2) spikes and a new three-dimension location that could be determined by a weighted average.

A second method to handle the inability (due to data size constraints) to keep more than some fixed number of spikes (example, 100,000) would be to aggregate spikes once the fixed normal has been exceeded by aggregating to some small (relatively) number of spikes (say 1,000). This would allow possibly several GRIDUPDATE's to be performed before AGGREGATE would have to be again invoked. The method of aggregation would be to divide the actual region bounded by the original spikes of GRID into 1,000 regions (probably rectangular parallelpipeds). Then, all spikes within

each region could be summed to obtain a single spike representing that region. Again, if desired, the spikes within a region could determine a new location for the aggregate spike by performing a weighted average of the individual spike locations.

The second method is what is actually done, although due to the limitations of testing the program on a microcomputer, the actual number of spikes retained is very small.

It should be kept in mind that the averaging that we are doing is a space average and not a time average. On a larger computer system, it is clear that enough spikes can be retained to give an excellent picture of the tracer concentration field in the burial region.

Other Procedures

We have outlined the main procedures of the model above. The other procedures relate to actually implementing the model as a discrete event model (such as ADDEVENT) and include other utility procedures necessary in any computer program. The program has been designed to be interactive and user-oriented so that it is very easy to set up and conduct an actual simulation run. The simulation program is written in PASCAL and has been running on a microcomputer.

Appendix A is a listing of the program and gives an example of a typical run.

Conclusion

We have shown that the discrete event approach is the proper

way to develop simulation models to analyze post emplacement risks. The nature of the disruptive events affecting the transport of nuclear waste is ideally suited to such an approach. It is clear that the model we have developed so far is only a first step and needs to be used with caution. However, it is felt that the approach outlined is the most promising one for the development of a truly predictive model. We expect that a more detailed simulation model incorporating the addition features we have discussed and more extensive geological information could be a significant investigative tool for prediction and evaluation of alternate burial sites.

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```

PROGRAM NWM;

{MAIN Program file (NC include files) }

{Simulation of nuclear waste dispersing thru a geologic disposal site}

CCNS1 INITI1 = 1.5168E-6 ;
      INITI2 = INITI1 ;
      INITI3 = 1.5168E-3 ;

      INITV1 = 0.0;
      INITV2 = 0.0;
      INITV3 = 0.015168 ;

      MAXTIME=1.0E5;

      SPECIF=1000; {"Length" of Grid}
      CHOSIN=36;   {"Length" of aggregated Grid}

      N=2; {N is the max. number of Healing events per moderate quake.}

TYPE EVENTKIND = (QUAKE, HEALING, FRACTURE, BRECCIA, FINAL);
      LINK=EVENT;
      EVENT=RECORD
              KIND:EVENTKIND;
              TIME:REAL;
              INFO:REAL;
              FPTR:LINK
      END;

VAR COMMAND:CHAR;
      OUTNAME:STRING;
      STCF,IGNCRANT:POCIEAN;

      EASE,CURRENTEVENT:LINK;

      FREE:LINK;

      SEED:REAL; {Seed of random # generator, URAND}

```

CLOCK,CICLOCK:REAL;

E1,E2,E3,
V1,V2,V3:REAL;

{These are global variables required by Melody's GRIDUPDATE Procedure: }

SIZE, {Number of points in Grid}

XDIM,YDIM,ZDIM : INTEGER; {"size" of 3-dir. grid IN TERMS OF
DATA POINTS per each direction}

SMALLX,EIGX,SMALLY,EIGY,SMALLZ,EIGZ:REAL; {extrema of the
Three-Space Coordinates}

GRID:ARRAY[1..SPECIF,1..4] OF REAL; {1..3 are coord's; 4 is mass}

{Forward references for general utility routines : }

PROCEDURE ALLEVENT(E:EVENTKIND; T,I:REAL); FORWARD;
FUNCTION URAND : REAL ; FORWARD;
FUNCTION IRANDCM(RANGE:INTEGER) : INTEGER; FORWARD;

PROCEDURE INIT;

BEGIN

E1:=INITE1;

E2:=INITE2;

E3:=INITE3;

V1:=INITV1;

V2:=INITV2;

V3:=INITV3;

SMALLX:=0.0;

EIGX:=0.0;

SMALLY:=0.0;

EIGY:=0.0;

SMALLZ:=0.0;

EIGZ:=0.0;

CLOCK:=0.0;
CLOCK:=0.0;

FREE:=NIL;

CUTNAME:='PRINTER:' ;

{Now get a seed for the random number generator, URAND}
WRITELN;
WRITELN('Enter a "random" number between 1.0 and 10.0 with about');
WRITE('nine decimals --> ',CHR(29));
READLN(SEED);
WRITELN;

{Now initialize the ring: }

NEW(EASE);

WITH BASE DO BEGIN KIND:=FINAL;
TIME:=MAXTIME;
INFO:=0.0;
FPTR:=BASE

END;

{ frig --| }
{ v }

ADDEVENT(CUAKE,((-5000.0 * LN(URAND)) { +4000.0 }), {distart "random" time}
(EXP(-0.046 * IRANDCM(100) + 11.546))); {strain}

{Now initialize the grid: }

GRID[1,1]:=0.0;

GRID[1,2]:=0.0;

GRID[1,3]:=0.0;

GRID[1,4]:=100.0; {Initial point mass at disposal site}

SIZE:=1;

XIIM:=1;

YIIM:=1;

ZIIM:=1;

END; { Irit }

```

PROCEDURE HELP;
BEGIN
  WRITE(CHR(12) );
  WRITELN;
  WRITELN;
  WRITELN;
  WRITELN('Newdata allows you to change defaults and initial conditions.');
```

```

  WRITELN;
  WRITELN('Simulate begins the model run.');
```

```

  WRITELN;
  WRITELN('Quit exits the program.');
```

```

  WRITELN('You are now back in Command Mode.')
```

```

END;
```

```

PROCEDURE NEWDATA;
VAR NEWCOMMAND:CHAR;
```

```

BEGIN
```

```

  WRITE(CHR(12) );
```

```

  WRITELN('Newdata: DUMP' );
```

```

  WRITE(CHR(13), 'P(rinter , R(emote , S(creen , or N(one ? ');
```

```

  READ(NEWCOMMAND);
```

```

  CASE NEWCOMMAND OF
```

```

    'P', 'P':OUTNAME:='PRINTER';
```

```

    'N', 'I':OUTNAME:='NONE';
```

```

    'S', 'S':OUTNAME:='SYSTEM';
```

```

    'R', 'R':OUTNAME:='REMOTE';
```

```

  END;
```

```

END; { N e w d a t a }
```

```

{General utility procedures follow (some have been fwd ref'd) : }
```

```

PROCEDURE ALDEVENT; { (E:EVENTKIND; T,I:REAL) (Forward Referenced) }
```

```

VAR P,Q:LINK;
```

```

BEGIN
  IF ( T < MAXTIME ) THEN
    BEGIN
      IF ( FREE = NIL )
        THEN NEW(P)
        ELSE BEGIN
          F:=FREE;
          FREE:=P^.FPTR
        END;

      Q:=BASE;
      WHILE ( Q^.FPTR^.TIME <= T ) DO Q:=Q^.FPTR;

      {Now insert the new event right after Q}
      P^.KIND:=E;
      P^.TIME:=T;
      P^.INFC:=I;

      P^.FPTR:=Q^.FPTR;
      Q^.FPTR:=P
    END
  END; { Addevent (Forward Referenced) }

```

```

FUNCTION URAND { : REAL } ; { (Forward Referenced) }
{Returns a "random" real number:  0.0 <= Urand < 1.0 }

BEGIN
  SEED:=SEED*27.182813 + 31.415927;
  SEED:=SEED-TRUNC(SEED);
  URAND:=SEED + 1.0E-20
END; {of Function Ur a n d }

```

```

FUNCTION IRANDOM { (RANGE:INTEGER) : INTEGER } ; { (Forward referenced) }
{Returns a "random" integer (using Urand) between 1 and Range inclusive. }

BEGIN
  IRANDOM:=TRUNC( 1 + ( RANGE*(URAND) ) )
END; { Function Irandom }

```

```

PROCEDURE DUMP;
CONST MAX=100;
VAR F:INTERACTIVE;
    I:INTEGER;
    E:LINK;
    LIMIT:INTEGER;

BEGIN
  WRITELN('Dumping to ',OUTNAME);

  IF ( OUTNAME <> 'NCNE' )
  THEN
    BEGIN
      REWRITE(F, OUTNAME );

      WRITELN(F, 'Time = ',CLOCK:9:1, ' ; The Grid has ',SIZE, ' points. ');
      WRITELN(F, 'Here is the Grid (1st. ',MAX, ' pts. max. : ');
      WRITELN(F);

      IF (SIZE < MAX)
      THEN LIMIT:=SIZE
      ELSE LIMIT:=MAX;

      FOR I:=1 TO LIMIT DO
        WRITELN(F, 'X= ',GRID[I,1]:6:2,
                  'Y= ',GRID[I,2]:6:2,
                  'Z= ',GRID[I,3]:8:2,
                  'Mass= ',GRID[I,4]:6:3 );

      WRITE(P,CHR(10),CHR(10),CHR(10),CHR(10),CHR(10),CHR(10),CHR(10),CHR(10));
      WRITELN(F, 'Here is the "Ring" of pending events at T= ',CLOCK:9:1, ' ');

      I:=BASE.FPTR;
      WHILE (E <> BASE) DO
        BEGIN
          WRITELN(P, 'T = ',E.TIME, ' Ord(Kind) = ',CRD(E.KIND),
                  ' Info = ',E.INFO);

          E:=E.FPTR
        END;

      WRITE(P,CHR(12));
      CLOCSE(P);
    END
  END;
END;

```

PROCEDURE GRIDUPLATE(VAR T:REAL);{T is time SINCE last event}

{L+,L+}

PROCEDURE AGGREGATE;{TO REDUCE GRID TO A PRIOR CHCSEN NC
AND ARRANGEMENT OF FTS}

VAR J,K,I,A,B,C,GRIDNO,LSCAN,
SKIP,E: INTEGER;
XSIZE,YSIZE,ZSIZE:REAL;
CCNC: ARRAY[1..CHCSEN] OF REAL;

BEGIN

WRITELN('AGGREGATE');

BIGX:=TRUNC(BIGX)+1;
SMALLX:=TRUNC(SMALLX)-1;
BIGY:=TRUNC(BIGY)+1;
SMALLY:=TRUNC(SMALLY)-1;
BIGZ:=TRUNC(BIGZ)+1;
SMALLZ:=TRUNC(SMALLZ)-1;

XLIM:=3;
YLIM:=3; {This is a frig. }
ZLIM:=4;

XSIZE:=(BIGX-SMALLX)/XLIM;
YSIZE:=(BIGY-SMALLY)/YLIM;
ZSIZE:=(BIGZ-SMALLZ)/ZLIM; {BLOCK (1.e. r-hccd of each grid)
SIZES for each Dimension }

FOR I:=1 TO CHCSEN DO CCNC[I]:=0; {INITIALIZE CCNS TO 0}

{THE BELOW SEGMENT OF THE PROCEDURE ASSIGNS THE CONCENTRATIONS
IN THE EXISTING GRID TO THEIR PROPER BLOCK IN THE SHRUNK GRID}

FOR I:=1 TO SIZE DC

BEGIN{FOR LOOP}

A:=TRUNC((GRID[D,1]-SMALLX)/XSIZE);

IF (A = 0) THEN A:=1;

B:=TRUNC((GRID[D,2]-SMALLY)/YSIZE);

IF (B = 0) THEN B:=1;

```

C:=TRUNC((GRID[E,3]-SMALLZ)/ZSIZE);
IF ( C = 0 ) THEN C:=1;
GRIDNC:=(A-1)*YDIM*ZDIM+((E-1)*ZDIM)+C;

```

```

{ WRITEIN('Gridno = ',GRIDNO); }

```

```

CONC[GRIDNO]:=CONC[GRIDNO]+GRID[D,4] {SUMS FOR NEW GRIDPTS}
END;{FOR LCOP}

```

{THE BELOW SEGMENT TAKES THE LOWEST, INNERMOST BLOCK PTS
AS THE NEW GRIDPTS AND ASSOCIATES WITH THEM THE PROPER
CONCENTRATION}

```

GRIDNO:=0;

```

```

SMALLX:=SMALLX + (0.5 * XSIZE);  BIGX:=BIGX - (0.5 * XSIZE);
SMALLY:=SMALLY + (0.5 * YSIZE);  BIGY:=BIGY - (0.5 * YSIZE);
SMALLZ:=SMALLZ + (0.5 * ZSIZE);  BIGZ:=BIGZ - (0.5 * ZSIZE);

```

```

FOR I:=0 TO (XLIM-1) DO
  FOR J:=0 TO (YDIM-1) DO
    FOR K:=0 TO (ZDIM-1) DO

```

```

      BEGIN
        GRIDNC:=GRIDNO+1;
        GRID[GRIDNO,1]:=SMALLX+I*YSIZE;
        GRID[GRIDNO,2]:=SMALLY+J*YSIZE;
        GRID[GRIDNO,3]:=SMALLZ+K*ZSIZE;
        GRID[GRIDNO,4]:=CONC[GRIDNO]

```

```

      END;

```

```

SIZE:=GRIDNC

```

```

END; {of Aggregate}

```

```

{ E-,I-}

```

```

{$D+,I+} {Proc # 11}

```

```

PROCEDURE CREATE;{CREATES 27 NEW GRIDPTS FOR EACH EXISTING GRIDPT}

```

```

CONST  A=-1.092E;
        B=-A;

```



```

VAR    L,I,J,K,I:INTEGER;
        X,Y,Z:ARRAY[1..3] OF REAL;
        SIG1,SIG2,SIG3, { std. dev.'s ("SIGma") }
        M3, { mean ("Mu") }
        M:REAL; { Mass }

```

```

PROCEDURE EXPAND; {Inserted by Campbell only to handle "proc too long"}

```

```

BEGIN
  { WRITELN('EXPAND'); }

  FOR I:= 1 TO 3 DO
    FOR J:= 1 TO 3 DO
      FOR K:= 1 TO 3 DO
        BEGIN
          I:=L+1;

          { WRITELN('L = ',L); }

          GRID[L,1]:=RCUNE(X[I]*10)/10;
          GRID[L,2]:=RCUNE(Y[J]*10)/10;
          GRID[L,3]:=ROUND(Z[K]);
          GRID[L,4]:=M/27

```

6

```

        END;
      END; {of Procedure Expand}

```

```

BEGIN {Create}

```

```

  WRITELN('CREATE');

  L:=SIZE;
  SIG1:=SQRT(2*I1*T);
  SIG2:=SQRT(2*I2*T);
  SIG3:=SQRT(2*I3*T);
  M3:=V3*T; {Mean shifted by upward flow only }

```

```

  FOR D:=1 TO SIZE DO
    BEGIN
      M:=GRID[D,4];
      X[1]:=A*SIG1+GRID[D,1];

```

```

IF ((X[1]-SMALLX)<0) THEN
  SMALLX:=ROUND(X[1]);
X[2]:=GRID[D,1];
X[3]:=P*SIG1+GRID[I,1];
IF ((X[3]-BIGX)>0) THEN
  BIGX:=ROUND(X[3]);
Y[1]:=A*SIG2+GRID[I,2];
IF ((Y[1]-SMALLY)<0) THEN
  SMALLY:=ROUND(Y[1]);
Y[2]:=GRID[D,2];
Y[3]:=P*SIG2+GRID[I,2];
IF ((Y[3]-BIGY)>0) THEN
  BIGY:=ROUND(Y[3]);
Z[1]:=A*SIG3+M3+GRID[I,3];
IF ((Z[1]-SMALLZ)<0) THEN
  SMALLZ:=ROUND(Z[1]);
Z[2]:=M3+GRID[D,3];
Z[3]:=P*SIG3+M3+GRID[I,3];
IF ((Z[3]-BIGZ)>0) THEN
  BIGZ:=ROUND(Z[3]);

EXPAND;

FOR I:=1 TO 4 DO GRID[D,I]:=GRID[I,I];

I:=I-1;
END; {of For loop}

SIZE:=I;

XLIM:=XDIM * 3;
YLIM:=YDIM * 3;
ZLIM:=ZDIM * 3

END; {CREATE}

{$D-,I-}

BEGIN { Grid _ update }

  WRITEIN('GRID_UPDATE');

  IF ( (27*SIZE) > SPECIF ) THEN AGGREGATE;

  CREATE

```

```

END; { Grid _ update
{Actual simulation procedures follow: }

PROCEDURE QUAKEPRCC; {Moderate intensity quakes only}
VAR DELT,STRAIN:REAL;

PROCEDURE NEXTQUAKE;
TYPE QEVENT=RECORD
    TIME:REAL;
    INFC:REAL;
END;

VAR NEWQUAKE:QEVENT;
    HEAL:ARRAY[1..N] OF QEVENT;

    CTIME:REAL;

    I:INTEGER;
    CCNT:BOOLEAN;

PROCEDURE GENQUAKE(CTIME:REAL);
VAR IRAND:INTEGER;
    STRAIN:REAL;
    IT:REAL;

BEGIN
    IRAND:=IRANICM(100);
    STRAIN:=EXP( -0.046 * IRAND + 11.546); {microstrain units = 10**3 to 10**5}
    IT:= -5000 * LN(URAND);

    WRITELN('The next quake will be ',IT:7:1,' years from now. ');

    NEWQUAKE.TIME:=CTIME + IT;
    NEWQUAKE.INFC:=STRAIN;
END;

PROCEDURE GENHEAL(CTIME:REAL); {NOTE: These events may NOT all be used}
VAR I:INTEGER;
    HEALTIME:REAL;

```

```

BEGIN
  HEALTIME:=V3 * 1.0E3;           {used to be "10**9" (now it's too low) }

  WRITELN('Healtime = ',HEALTIME/7:1);

  FOR I:=1 TO N DO
    BEGIN
      HEAL[I].INFC:=1;
      HEAL[I].TIME:=CTIME + I*(HEALTIME/N)
    END;

    {WRITEIN(      'Time of first healing = ',HEAL[1].TIME,
      'Time of second healing = ',HEAL[2].TIME) }

  END;

BEGIN { of Nextquake }
  CTIME:=CURRENTEVENT.TIME;

  GENQUAKE(CTIME);

  GENHEAL(CTIME);

  CCNT:= ( HEAL[1].TIME < NEWQUAKE.TIME );
  I:=1;
  WHILE ( CONT ) DO
    BEGIN
      ALLEVENT(HEALING,HEAL[I].TIME,HEAL[I].INFO);
      I:=I+1;
      IF ( I <= N ) THEN CCNT:=( HEAL[I].TIME < NEWQUAKE.TIME )
        ELSE CCNT:=FALSE
    END;

    {Now schedule the next moderate quake}
    ALLEVENT(QUAKE,NEWQUAKE.TIME,NEWQUAKE.INFC)
  END; {of Nextquake }

  PROCEDURE FLOWCOEFF(STRAIN:REAL); {Local to Quakeprcc}

  {Simulates quakes' effect on flow coefficients by increasing them.
  "Healing" consists mainly of returning them to their initial values.}

```

```

BEGIN
  V1:=V1*(STRAIN*1.0E-3);
  V2:=V2*(STRAIN*1.0E-3);
  V3:=V3*(STRAIN*1.0E-3);

  I1:=I1*( (STRAIN*1.0E-3) * (STRAIN*1.0E-3) );
  I2:=I2*( (STRAIN*1.0E-3) * (STRAIN*1.0E-3) );
  I3:=I3*( (STRAIN*1.0E-3) * (STRAIN*1.0E-3) )
END;

```

```

BEGIN { of Quake proc }
  CLCCK:=CURRENTEVENT^.TIME;
  IFIT:=CLCCK - OLDCLCCK;

  GRIDUPDATE(DELTA);

  OLDCLCCK:=CLCCK; {Reset oldclock value to "current time"}
  STRAIN:=CURRENTEVENT^.INFO;

  FLOWCOEFF(STRAIN);          {Modifies flow coefficients}

  NEXTQUAKE {Generate this quake's healings and the next moderate quake}
END; { Quake proc }

```

```

PROCEDURE HEALFRCC;
  VAR DELTA:REAL;
  STEP:REAL;
  HEALNUM:REAL;

```

```

BEGIN
  CLCCK:=CURRENTEVENT^.TIME;
  IFIT:=CLCCK - OLDCLCCK;

  GRIDUPDATE(DELTA);

  OLDCLCCK:=CLCCK; {Reset oldclock value to "current time"}

  {Now step coefficients down to "normal" }
  HEALNUM:=CURRENTEVENT^.INFO;
  IF ( HEALNUM = N )

```

```

THEN BEGIN {reset coefficients to "normal" values}
    L1:=INITL1;
    L2:=INITL2;
    L3:=INITL3;
    V1:=INITV1;
    V2:=INITV2;
    V3:=INITV3
END

ELSE BEGIN {decrement coefficients one linear step}
    STEP:=1.0 / ( (N-HEALNUM) + 1 );
    L1:=L1 - ( STEP * (L1 - INITL1) );
    L2:=L2 - ( STEP * (L2 - INITL2) );
    L3:=L3 - ( STEP * (L3 - INITL3) );
    V1:=V1 - ( STEP * (V1 - INITV1) );
    V2:=V2 - ( STEP * (V2 - INITV2) );
    V3:=V3 - ( STEP * (V3 - INITV3) )
END

END; { H e a l p r o c }
-----
PROCEDURE FRACPRCC;
VAR DELT:REAL;

BEGIN
    CIOCK:=CURRENTEVENT^.TIME;
    IEIT:=CLCK - CIOCK;

    GRIDUPLATE(IEIT);

    OLDCLK:=CLK; {Reset oldclock value to "current time"}
    END; { F r a c p r o c }

PROCEDURE BRECCIAPRCC;
VAR DELT:REAL;

BEGIN
    CIOCK:=CURRENTEVENT^.TIME;
    IEIT:=CLCK - OLDCLK;

    GRIDUPLATE(IEIT);

    CIOCK:=CIOCK; {Reset oldclock value to "current time"}
    END; { B r e c c i a p r o c }

```

```

PROCEDURE FINAIPROC;
BEGIN
  STCP:=TRUE;

  WRITELN(CHR(29) );
  WRITELN(CHR(29) );
  WRITELN('End of Nuclear Waste Management Program. ');
  WRITELN(CHR(29) )
END;

BEGIN {Driver : NW }
  GOTOXY(0,0);
  WRITELN('Nuclear Waste Management Program. ');

  INIT;

  WRITE(CHR(12) );
  GCICXY(0,3);
  WRITE(
    'If you need help, type "H" when the Command Mode prompt line appears. ');
  STCP:=FALSE;
  REPEAT { C o m m a n d M o d e }
    GOTOXY(0,0);
    WRITE('Command Mode: H(elp N(ewdata S(imulate Q(uit ?', CHR(29) );
    WRITE(CHR(12),CHR(29),CHR(13),CHR(29));
    GOTOXY(51,0);

    IGNORANT:=TRUE;
    READ(KEYBOARD,COMMAND);
    CASE COMMAND OF
      'N','n':BEGIN
        IGNORANT:=FALSE;
        NEWDATA
      END;
      'S','s':BEGIN
        IGNORANT:=FALSE;

        WRITE(CHR(12) );
        WRITELN('Simulation in progress. ');
        WRITELN(CHR(29) );
      END;
    END;
  UNTIL STCP;
END;

```

REPEAT

DUMP;

CURRENTEVENT:=BASE^.FPTR;

CASE CURRENTEVENT^.KIND OF

QUAKE : QUAKEPROC;

HEALING : HEALPROC;

FRACTURE : FRACPROC;

BRECCIA : BRECCIAPROC;

FINAL : FINALPROC

END; {Case Kind of}

BASE^.FPTR:=CURRENTEVENT^.FPTR;

CURRENTEVENT^.FPTR:=FREE;

FREE:=CURRENTEVENT

UNTIL (STOP)

END; {Case "s" of Command}

'Q', 'q': IGNORANT:=FALSE;

'H', 'h': IGNORANT:=TRUE

END; {Case Command of}

IF IGNORANT THEN HELP

UNTIL ((COMMAND IN ['Q', 'q']) OR (STOP))

END.

Time = 0.0 ; The Grid has 1 points.
Here is the Grid (1st. 100 pts, max.) :

X= 0.00 Y= 0.00 Z= 0.00 Mass= 100.000

Here is the "Ring" of pending events at T= 0.0 :
I = 1.34344E3 Ord(Kind) = 0 Info = 4.11920E4

Time = 1343.4 ; The Grid has 27 points.
Here is the Grid (1st. 100 pts, max.) :

X= 0.10	Y= 0.10	Z= 23.00	Mass= 3.704
X= -0.10	Y= -0.10	Z= 18.00	Mass= 3.704
X= -0.10	Y= -0.10	Z= 20.00	Mass= 3.704
X= -0.10	Y= -0.10	Z= 23.00	Mass= 3.704
X= -0.10	Y= 0.00	Z= 18.00	Mass= 3.704
X= -0.10	Y= 0.00	Z= 20.00	Mass= 3.704
X= -0.10	Y= 0.00	Z= 23.00	Mass= 3.704
X= -0.10	Y= 0.10	Z= 18.00	Mass= 3.704
X= -0.10	Y= 0.10	Z= 20.00	Mass= 3.704
X= -0.10	Y= 0.10	Z= 23.00	Mass= 3.704
X= 0.00	Y= -0.10	Z= 18.00	Mass= 3.704
X= 0.00	Y= -0.10	Z= 20.00	Mass= 3.704
X= 0.00	Y= -0.10	Z= 23.00	Mass= 3.704
X= 0.00	Y= 0.00	Z= 18.00	Mass= 3.704
X= 0.00	Y= 0.00	Z= 20.00	Mass= 3.704
X= 0.00	Y= 0.00	Z= 23.00	Mass= 3.704
X= 0.00	Y= 0.10	Z= 18.00	Mass= 3.704
X= 0.00	Y= 0.10	Z= 20.00	Mass= 3.704
X= 0.00	Y= 0.10	Z= 23.00	Mass= 3.704
X= 0.10	Y= -0.10	Z= 18.00	Mass= 3.704
X= 0.10	Y= -0.10	Z= 20.00	Mass= 3.704
X= 0.10	Y= -0.10	Z= 23.00	Mass= 3.704
X= 0.10	Y= 0.00	Z= 18.00	Mass= 3.704
X= 0.10	Y= 0.00	Z= 20.00	Mass= 3.704
X= 0.10	Y= 0.00	Z= 23.00	Mass= 3.704
X= 0.10	Y= 0.10	Z= 18.00	Mass= 3.704
X= 0.10	Y= 0.10	Z= 20.00	Mass= 3.704

APPENDIX II
Sample Run

Here is the "Ring" of pending events at T= 1343.4 :

T = 1.65584E3	Ord(Kind) = 1	Info = 1.00000
T = 1.96824E3	Ord(Kind) = 1	Info = 2.00000
T = 1.15313E4	Ord(Kind) = 0	Info = 4.32427E3

Time = 1655.8 ; The Grid has 729 points.
Here is the Grid (1st. 100 pts, max.) :

X= 1.50	Y= 1.50	Z= 262.00	Mass= 0.137
X= 1.30	Y= 1.30	Z= 257.00	Mass= 0.137
X= 1.30	Y= 1.30	Z= 259.00	Mass= 0.137
X= 1.30	Y= 1.30	Z= 262.00	Mass= 0.137
X= 1.30	Y= 1.40	Z= 257.00	Mass= 0.137
X= 1.30	Y= 1.40	Z= 259.00	Mass= 0.137
X= 1.30	Y= 1.40	Z= 262.00	Mass= 0.137
X= 1.30	Y= 1.50	Z= 257.00	Mass= 0.137
X= 1.30	Y= 1.50	Z= 259.00	Mass= 0.137
X= 1.30	Y= 1.50	Z= 262.00	Mass= 0.137
X= 1.40	Y= 1.30	Z= 257.00	Mass= 0.137
X= 1.40	Y= 1.30	Z= 259.00	Mass= 0.137
X= 1.40	Y= 1.30	Z= 262.00	Mass= 0.137
X= 1.40	Y= 1.40	Z= 257.00	Mass= 0.137
X= 1.40	Y= 1.40	Z= 259.00	Mass= 0.137
X= 1.40	Y= 1.40	Z= 262.00	Mass= 0.137
X= 1.40	Y= 1.50	Z= 257.00	Mass= 0.137
X= 1.40	Y= 1.50	Z= 259.00	Mass= 0.137
X= 1.40	Y= 1.50	Z= 262.00	Mass= 0.137
X= 1.50	Y= 1.30	Z= 257.00	Mass= 0.137
X= 1.50	Y= 1.30	Z= 259.00	Mass= 0.137
X= 1.50	Y= 1.30	Z= 262.00	Mass= 0.137
X= 1.50	Y= 1.40	Z= 257.00	Mass= 0.137
X= 1.50	Y= 1.40	Z= 259.00	Mass= 0.137
X= 1.50	Y= 1.40	Z= 262.00	Mass= 0.137
X= 1.50	Y= 1.50	Z= 257.00	Mass= 0.137
X= 1.50	Y= 1.50	Z= 259.00	Mass= 0.137
X= -1.30	Y= -1.30	Z= 174.00	Mass= 0.137
X= -1.30	Y= -1.30	Z= 218.00	Mass= 0.137
X= -1.30	Y= -1.30	Z= 262.00	Mass= 0.137
X= -1.30	Y= 0.10	Z= 174.00	Mass= 0.137
X= -1.30	Y= 0.10	Z= 218.00	Mass= 0.137
X= -1.30	Y= 0.10	Z= 262.00	Mass= 0.137

X=	-1.30	Y=	1.50	Z=	174.00	Mass=	0.137
X=	-1.30	Y=	1.50	Z=	218.00	Mass=	0.137
X=	-1.30	Y=	1.50	Z=	262.00	Mass=	0.137
X=	0.10	Y=	-1.30	Z=	174.00	Mass=	0.137
X=	0.10	Y=	-1.30	Z=	218.00	Mass=	0.137
X=	0.10	Y=	-1.30	Z=	262.00	Mass=	0.137
X=	0.10	Y=	0.10	Z=	174.00	Mass=	0.137
X=	0.10	Y=	0.10	Z=	218.00	Mass=	0.137
X=	0.10	Y=	0.10	Z=	262.00	Mass=	0.137
X=	0.10	Y=	1.50	Z=	174.00	Mass=	0.137
X=	0.10	Y=	1.50	Z=	218.00	Mass=	0.137
X=	0.10	Y=	1.50	Z=	262.00	Mass=	0.137
X=	1.50	Y=	-1.30	Z=	174.00	Mass=	0.137
X=	1.50	Y=	-1.30	Z=	218.00	Mass=	0.137
X=	1.50	Y=	-1.30	Z=	262.00	Mass=	0.137
X=	1.50	Y=	0.10	Z=	174.00	Mass=	0.137
X=	1.50	Y=	0.10	Z=	218.00	Mass=	0.137
X=	1.50	Y=	0.10	Z=	262.00	Mass=	0.137
X=	1.50	Y=	1.50	Z=	174.00	Mass=	0.137
X=	1.50	Y=	1.50	Z=	218.00	Mass=	0.137
X=	-1.50	Y=	-1.50	Z=	169.00	Mass=	0.137
X=	-1.50	Y=	-1.50	Z=	213.00	Mass=	0.137
X=	-1.50	Y=	-1.50	Z=	257.00	Mass=	0.137
X=	-1.50	Y=	-0.10	Z=	169.00	Mass=	0.137
X=	-1.50	Y=	-0.10	Z=	213.00	Mass=	0.137
X=	-1.50	Y=	-0.10	Z=	257.00	Mass=	0.137
X=	-1.50	Y=	1.30	Z=	169.00	Mass=	0.137
X=	-1.50	Y=	1.30	Z=	213.00	Mass=	0.137
X=	-1.50	Y=	1.30	Z=	257.00	Mass=	0.137
X=	-0.10	Y=	-1.50	Z=	169.00	Mass=	0.137
X=	-0.10	Y=	-1.50	Z=	213.00	Mass=	0.137
X=	-0.10	Y=	-1.50	Z=	257.00	Mass=	0.137
X=	-0.10	Y=	-0.10	Z=	169.00	Mass=	0.137
X=	-0.10	Y=	-0.10	Z=	213.00	Mass=	0.137
X=	-0.10	Y=	-0.10	Z=	257.00	Mass=	0.137
X=	-0.10	Y=	1.30	Z=	169.00	Mass=	0.137
X=	-0.10	Y=	1.30	Z=	213.00	Mass=	0.137
X=	-0.10	Y=	1.30	Z=	257.00	Mass=	0.137
X=	1.30	Y=	-1.50	Z=	169.00	Mass=	0.137
X=	1.30	Y=	-1.50	Z=	213.00	Mass=	0.137
X=	1.30	Y=	-1.50	Z=	257.00	Mass=	0.137
X=	1.30	Y=	-0.10	Z=	169.00	Mass=	0.137
X=	1.30	Y=	-0.10	Z=	213.00	Mass=	0.137

X=	1.30	Y=	-0.10	Z=	257.00	Mass=	0.137
X=	1.30	Y=	1.30	Z=	169.00	Mass=	0.137
X=	1.30	Y=	1.30	Z=	213.00	Mass=	0.137
X=	-1.50	Y=	-1.50	Z=	171.00	Mass=	0.137
X=	-1.50	Y=	-1.50	Z=	215.00	Mass=	0.137
X=	-1.50	Y=	-1.50	Z=	259.00	Mass=	0.137
X=	-1.50	Y=	-0.10	Z=	171.00	Mass=	0.137
X=	-1.50	Y=	-0.10	Z=	215.00	Mass=	0.137
X=	-1.50	Y=	-0.10	Z=	259.00	Mass=	0.137
X=	-1.50	Y=	1.30	Z=	171.00	Mass=	0.137
X=	-1.50	Y=	1.30	Z=	215.00	Mass=	0.137
X=	-1.50	Y=	1.30	Z=	259.00	Mass=	0.137
X=	-0.10	Y=	-1.50	Z=	171.00	Mass=	0.137
X=	-0.10	Y=	-1.50	Z=	215.00	Mass=	0.137
X=	-0.10	Y=	-1.50	Z=	259.00	Mass=	0.137
X=	-0.10	Y=	-0.10	Z=	171.00	Mass=	0.137
X=	-0.10	Y=	-0.10	Z=	215.00	Mass=	0.137
X=	-0.10	Y=	-0.10	Z=	259.00	Mass=	0.137
X=	-0.10	Y=	1.30	Z=	171.00	Mass=	0.137
X=	-0.10	Y=	1.30	Z=	215.00	Mass=	0.137
X=	-0.10	Y=	1.30	Z=	259.00	Mass=	0.137
X=	1.30	Y=	-1.50	Z=	171.00	Mass=	0.137
X=	1.30	Y=	-1.50	Z=	215.00	Mass=	0.137
X=	1.30	Y=	-1.50	Z=	259.00	Mass=	0.137

Here is the "Ring" of pending events at T= 1655.8 :

T =	1.90E24E3	Ord(Kind) =	1	Info =	2.00000
T =	1.15313E4	Ord(Kind) =	0	Info =	4.32427E3

Time = 1968.2 ; The Grid has 972 points.
Here is the Grid (1st. 100 pts, max.) :

X=	-0.40	Y=	-0.40	Z=	163.00	Mass=	0.000
X=	-0.40	Y=	-0.40	Z=	229.00	Mass=	0.549
X=	-0.40	Y=	-0.40	Z=	295.00	Mass=	1.097
X=	-0.40	Y=	-0.40	Z=	361.00	Mass=	0.000
X=	-0.40	Y=	1.00	Z=	163.00	Mass=	0.000
X=	-0.40	Y=	1.00	Z=	229.00	Mass=	0.274
X=	-0.40	Y=	1.00	Z=	295.00	Mass=	0.549
X=	-0.40	Y=	1.00	Z=	361.00	Mass=	0.000
X=	-0.40	Y=	2.30	Z=	163.00	Mass=	0.000
X=	-0.40	Y=	2.30	Z=	229.00	Mass=	0.000
X=	-0.40	Y=	2.30	Z=	295.00	Mass=	0.000
X=	-0.40	Y=	2.30	Z=	361.00	Mass=	0.000
X=	1.00	Y=	-0.40	Z=	163.00	Mass=	0.000
X=	1.00	Y=	-0.40	Z=	229.00	Mass=	0.274
X=	1.00	Y=	-0.40	Z=	295.00	Mass=	0.549
X=	1.00	Y=	-0.40	Z=	361.00	Mass=	0.000
X=	1.00	Y=	1.00	Z=	163.00	Mass=	0.000
X=	1.00	Y=	1.00	Z=	229.00	Mass=	0.137
X=	1.00	Y=	1.00	Z=	295.00	Mass=	0.274
X=	1.00	Y=	1.00	Z=	361.00	Mass=	0.000
X=	1.00	Y=	2.30	Z=	163.00	Mass=	0.000
X=	1.00	Y=	2.30	Z=	229.00	Mass=	0.000
X=	1.00	Y=	2.30	Z=	295.00	Mass=	0.000
X=	1.00	Y=	2.30	Z=	361.00	Mass=	0.000
X=	2.30	Y=	-0.40	Z=	163.00	Mass=	0.000
X=	2.30	Y=	-0.40	Z=	229.00	Mass=	0.000
X=	2.30	Y=	-0.40	Z=	295.00	Mass=	0.000
X=	2.30	Y=	-0.40	Z=	361.00	Mass=	0.000
X=	2.30	Y=	1.00	Z=	163.00	Mass=	0.000
X=	2.30	Y=	1.00	Z=	229.00	Mass=	0.000
X=	2.30	Y=	1.00	Z=	295.00	Mass=	0.000
X=	2.30	Y=	1.00	Z=	361.00	Mass=	0.000
X=	2.30	Y=	2.30	Z=	163.00	Mass=	0.000
X=	2.30	Y=	2.30	Z=	229.00	Mass=	0.000
X=	2.30	Y=	2.30	Z=	295.00	Mass=	0.000
X=	2.30	Y=	2.30	Z=	361.00	Mass=	0.000
X=	-2.30	Y=	-2.30	Z=	101.00	Mass=	0.000
X=	-2.30	Y=	-2.30	Z=	132.00	Mass=	0.000
X=	-2.30	Y=	-2.30	Z=	163.00	Mass=	0.000
X=	-2.30	Y=	-1.30	Z=	101.00	Mass=	0.000
X=	-2.30	Y=	-1.30	Z=	132.00	Mass=	0.000

X=	-2.30	Y=	-1.30	Z=	163.00	Mass=	0.000
X=	-2.30	Y=	-0.40	Z=	101.00	Mass=	0.000
X=	-2.30	Y=	-0.40	Z=	132.00	Mass=	0.000
X=	-2.30	Y=	-0.40	Z=	163.00	Mass=	0.000
X=	-1.30	Y=	-2.30	Z=	101.00	Mass=	0.000
X=	-1.30	Y=	-2.30	Z=	132.00	Mass=	0.000
X=	-1.30	Y=	-2.30	Z=	163.00	Mass=	0.000
X=	-1.30	Y=	-1.30	Z=	101.00	Mass=	0.000
X=	-1.30	Y=	-1.30	Z=	132.00	Mass=	0.000
X=	-1.30	Y=	-1.30	Z=	163.00	Mass=	0.000
X=	-1.30	Y=	-0.40	Z=	101.00	Mass=	0.000
X=	-1.30	Y=	-0.40	Z=	132.00	Mass=	0.000
X=	-1.30	Y=	-0.40	Z=	163.00	Mass=	0.000
X=	-0.40	Y=	-2.30	Z=	101.00	Mass=	0.000
X=	-0.40	Y=	-2.30	Z=	132.00	Mass=	0.000
X=	-0.40	Y=	-2.30	Z=	163.00	Mass=	0.000
X=	-0.40	Y=	-1.30	Z=	101.00	Mass=	0.000
X=	-0.40	Y=	-1.30	Z=	132.00	Mass=	0.000
X=	-0.40	Y=	-1.30	Z=	163.00	Mass=	0.000
X=	-0.40	Y=	-0.40	Z=	101.00	Mass=	0.000
X=	-0.40	Y=	-0.40	Z=	132.00	Mass=	0.000
X=	-2.30	Y=	-2.30	Z=	167.00	Mass=	0.549
X=	-2.30	Y=	-2.30	Z=	198.00	Mass=	0.549
X=	-2.30	Y=	-2.30	Z=	229.00	Mass=	0.549
X=	-2.30	Y=	-1.30	Z=	167.00	Mass=	0.549
X=	-2.30	Y=	-1.30	Z=	198.00	Mass=	0.549
X=	-2.30	Y=	-1.30	Z=	229.00	Mass=	0.549
X=	-2.30	Y=	-0.40	Z=	167.00	Mass=	0.549
X=	-2.30	Y=	-0.40	Z=	198.00	Mass=	0.549
X=	-2.30	Y=	-0.40	Z=	229.00	Mass=	0.549
X=	-1.30	Y=	-2.30	Z=	167.00	Mass=	0.549
X=	-1.30	Y=	-2.30	Z=	198.00	Mass=	0.549
X=	-1.30	Y=	-2.30	Z=	229.00	Mass=	0.549
X=	-1.30	Y=	-1.30	Z=	167.00	Mass=	0.549
X=	-1.30	Y=	-1.30	Z=	198.00	Mass=	0.549
X=	-1.30	Y=	-1.30	Z=	229.00	Mass=	0.549
X=	-1.30	Y=	-0.40	Z=	167.00	Mass=	0.549
X=	-1.30	Y=	-0.40	Z=	198.00	Mass=	0.549
X=	-1.30	Y=	-0.40	Z=	229.00	Mass=	0.549
X=	-0.40	Y=	-2.30	Z=	167.00	Mass=	0.549
X=	-0.40	Y=	-2.30	Z=	198.00	Mass=	0.549
X=	-0.40	Y=	-2.30	Z=	229.00	Mass=	0.549
X=	-0.40	Y=	-1.30	Z=	167.00	Mass=	0.549

X=	-0.40	Y=	-1.30	Z=	198.00	Mass=	0.549
X=	-0.40	Y=	-1.30	Z=	229.00	Mass=	0.549
X=	-0.40	Y=	-0.40	Z=	167.00	Mass=	0.549
X=	-0.40	Y=	-0.40	Z=	198.00	Mass=	0.549
X=	-2.30	Y=	-2.30	Z=	233.00	Mass=	1.097
X=	-2.30	Y=	-2.30	Z=	264.00	Mass=	1.097
X=	-2.30	Y=	-2.30	Z=	295.00	Mass=	1.097
X=	-2.30	Y=	-1.30	Z=	233.00	Mass=	1.097
X=	-2.30	Y=	-1.30	Z=	264.00	Mass=	1.097
X=	-2.30	Y=	-1.30	Z=	295.00	Mass=	1.097
X=	-2.30	Y=	-0.40	Z=	233.00	Mass=	1.097
X=	-2.30	Y=	-0.40	Z=	264.00	Mass=	1.097
X=	-2.30	Y=	-0.40	Z=	295.00	Mass=	1.097
X=	-1.30	Y=	-2.30	Z=	233.00	Mass=	1.097
X=	-1.30	Y=	-2.30	Z=	264.00	Mass=	1.097
X=	-1.30	Y=	-2.30	Z=	295.00	Mass=	1.097

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Here is the "Ring" of pending events at T= 1968.2 :
 I = 1.15313F4 Ord(Kird) = 0 Irfo = 4.32427F3

Time = 11531.3 ; The Grid has 972 points.
 Here is the Grid (1st. 100 pts, max.) :

X=	-1.80	Y=	-1.80	Z=	223.00	Mass=	0.325
X=	-1.80	Y=	-1.80	Z=	306.00	Mass=	1.951
X=	-1.80	Y=	-1.80	Z=	389.00	Mass=	0.650
X=	-1.80	Y=	-1.80	Z=	472.00	Mass=	0.000
X=	-1.80	Y=	0.20	Z=	223.00	Mass=	0.041
X=	-1.80	Y=	0.20	Z=	306.00	Mass=	0.244
X=	-1.80	Y=	0.20	Z=	389.00	Mass=	0.081
X=	-1.80	Y=	0.20	Z=	472.00	Mass=	0.000
X=	-1.80	Y=	2.20	Z=	223.00	Mass=	0.000
X=	-1.80	Y=	2.20	Z=	306.00	Mass=	0.000
X=	-1.80	Y=	2.20	Z=	389.00	Mass=	0.000
X=	-1.80	Y=	2.20	Z=	472.00	Mass=	0.000

X=	0.20	Y=	-1.80	Z=	223.00	Mass=	0.241
X=	0.20	Y=	-1.80	Z=	306.00	Mass=	0.244
X=	0.20	Y=	-1.80	Z=	389.00	Mass=	0.281
X=	0.20	Y=	-1.80	Z=	472.00	Mass=	0.280
X=	0.20	Y=	0.20	Z=	223.00	Mass=	0.005
X=	0.20	Y=	0.20	Z=	306.00	Mass=	0.030
X=	0.20	Y=	0.20	Z=	389.00	Mass=	0.010
X=	0.20	Y=	0.20	Z=	472.00	Mass=	0.000
X=	0.20	Y=	2.20	Z=	223.00	Mass=	0.000
X=	0.20	Y=	2.20	Z=	306.00	Mass=	0.000
X=	0.20	Y=	2.20	Z=	389.00	Mass=	0.000
X=	0.20	Y=	2.20	Z=	472.00	Mass=	0.000
X=	2.20	Y=	-1.80	Z=	223.00	Mass=	0.000
X=	2.20	Y=	-1.80	Z=	306.00	Mass=	0.000
X=	2.20	Y=	-1.80	Z=	389.00	Mass=	0.000
X=	2.20	Y=	-1.80	Z=	472.00	Mass=	0.000
X=	2.20	Y=	0.20	Z=	223.00	Mass=	0.000
X=	2.20	Y=	0.20	Z=	306.00	Mass=	0.000
X=	2.20	Y=	0.20	Z=	389.00	Mass=	0.000
X=	2.20	Y=	0.20	Z=	472.00	Mass=	0.000
X=	2.20	Y=	2.20	Z=	223.00	Mass=	0.000
X=	2.20	Y=	2.20	Z=	306.00	Mass=	0.000
X=	2.20	Y=	2.20	Z=	389.00	Mass=	0.000
X=	2.20	Y=	2.20	Z=	472.00	Mass=	0.000
X=	-2.20	Y=	-2.20	Z=	212.00	Mass=	0.325
X=	-2.20	Y=	-2.20	Z=	217.00	Mass=	0.325
X=	-2.20	Y=	-2.20	Z=	223.00	Mass=	0.325
X=	-2.20	Y=	-2.00	Z=	212.00	Mass=	0.325
X=	-2.20	Y=	-2.00	Z=	217.00	Mass=	0.325
X=	-2.20	Y=	-2.00	Z=	223.00	Mass=	1.325
X=	-2.20	Y=	-1.80	Z=	212.00	Mass=	0.325
X=	-2.20	Y=	-1.80	Z=	217.00	Mass=	0.325
X=	-2.20	Y=	-1.80	Z=	223.00	Mass=	0.325
X=	-2.00	Y=	-2.20	Z=	212.00	Mass=	0.325
X=	-2.00	Y=	-2.20	Z=	217.00	Mass=	0.325
X=	-2.00	Y=	-2.20	Z=	223.00	Mass=	1.325
X=	-2.00	Y=	-2.00	Z=	212.00	Mass=	0.325
X=	-2.00	Y=	-2.00	Z=	217.00	Mass=	0.325
X=	-2.00	Y=	-2.00	Z=	223.00	Mass=	1.325
X=	-2.00	Y=	-1.80	Z=	212.00	Mass=	0.325
X=	-2.00	Y=	-1.80	Z=	217.00	Mass=	0.325
X=	-2.00	Y=	-1.80	Z=	223.00	Mass=	0.325
X=	-1.80	Y=	-2.20	Z=	212.00	Mass=	0.325
X=	-1.80	Y=	-2.20	Z=	217.00	Mass=	0.325

X=	-1.80	Y=	-2.20	Z=	223.00	Mass=	0.325
X=	-1.80	Y=	-2.00	Z=	212.00	Mass=	0.325
X=	-1.80	Y=	-2.00	Z=	217.00	Mass=	0.325
X=	-1.80	Y=	-2.00	Z=	223.00	Mass=	0.325
X=	-1.80	Y=	-1.80	Z=	212.00	Mass=	0.325
X=	-1.80	Y=	-1.80	Z=	217.00	Mass=	0.325
X=	-2.20	Y=	-2.20	Z=	294.00	Mass=	1.951
X=	-2.20	Y=	-2.20	Z=	300.00	Mass=	1.951
X=	-2.20	Y=	-2.20	Z=	306.00	Mass=	1.951
X=	-2.20	Y=	-2.00	Z=	294.00	Mass=	1.951
X=	-2.20	Y=	-2.00	Z=	300.00	Mass=	1.951
X=	-2.20	Y=	-2.00	Z=	306.00	Mass=	1.951
X=	-2.20	Y=	-1.80	Z=	294.00	Mass=	1.951
X=	-2.20	Y=	-1.80	Z=	300.00	Mass=	1.951
X=	-2.20	Y=	-1.80	Z=	306.00	Mass=	1.951
X=	-2.00	Y=	-2.20	Z=	294.00	Mass=	1.951
X=	-2.00	Y=	-2.20	Z=	300.00	Mass=	1.951
X=	-2.00	Y=	-2.20	Z=	306.00	Mass=	1.951
X=	-2.00	Y=	-2.00	Z=	294.00	Mass=	1.951
X=	-2.00	Y=	-2.00	Z=	300.00	Mass=	1.951
X=	-2.00	Y=	-2.00	Z=	306.00	Mass=	1.951
X=	-2.00	Y=	-1.80	Z=	294.00	Mass=	1.951
X=	-2.00	Y=	-1.80	Z=	300.00	Mass=	1.951
X=	-2.00	Y=	-1.80	Z=	306.00	Mass=	1.951
X=	-1.80	Y=	-2.20	Z=	294.00	Mass=	1.951
X=	-1.80	Y=	-2.20	Z=	300.00	Mass=	1.951
X=	-1.80	Y=	-2.20	Z=	306.00	Mass=	1.951
X=	-1.80	Y=	-2.00	Z=	294.00	Mass=	1.951
X=	-1.80	Y=	-2.00	Z=	300.00	Mass=	1.951
X=	-1.80	Y=	-2.00	Z=	306.00	Mass=	1.951
X=	-1.80	Y=	-1.80	Z=	294.00	Mass=	1.951
X=	-1.80	Y=	-1.80	Z=	300.00	Mass=	1.951
X=	-2.20	Y=	-2.20	Z=	377.00	Mass=	0.650
X=	-2.20	Y=	-2.20	Z=	383.00	Mass=	0.650
X=	-2.20	Y=	-2.20	Z=	389.00	Mass=	0.650
X=	-2.20	Y=	-2.00	Z=	377.00	Mass=	0.650
X=	-2.20	Y=	-2.00	Z=	383.00	Mass=	0.650
X=	-2.20	Y=	-2.00	Z=	389.00	Mass=	0.650
X=	-2.20	Y=	-1.80	Z=	377.00	Mass=	0.650
X=	-2.20	Y=	-1.80	Z=	383.00	Mass=	0.650
X=	-2.20	Y=	-1.80	Z=	389.00	Mass=	0.650
X=	-2.00	Y=	-2.20	Z=	377.00	Mass=	0.650
X=	-2.00	Y=	-2.20	Z=	383.00	Mass=	0.650
X=	-2.00	Y=	-2.20	Z=	389.00	Mass=	0.650

Here is the "Ring" of perding events at T= 11531.3 :

T = 1.15641E4 Ord(Kind) = 1 Info = 1.00000
 T = 1.15969E4 Ord(Kind) = 1 Info = 2.00000
 T = 1.51423E4 Ord(Kind) = 0 Info = 1.24888E3

Time = 11564.1 ; The Grid has 972 points.
 Here is the Grid (1st. 100 pts, max.) :

X=	-2.00	Y=	-2.00	Z=	125.00	Mass=	0.412
X=	-2.00	Y=	-2.00	Z=	225.00	Mass=	2.469
X=	-2.00	Y=	-2.00	Z=	326.00	Mass=	0.823
X=	-2.00	Y=	-2.00	Z=	426.00	Mass=	0.000
X=	-2.00	Y=	0.00	Z=	125.00	Mass=	0.000
X=	-2.00	Y=	0.00	Z=	225.00	Mass=	0.000
X=	-2.00	Y=	0.00	Z=	326.00	Mass=	0.000
X=	-2.00	Y=	0.00	Z=	426.00	Mass=	0.000
X=	-2.00	Y=	2.00	Z=	125.00	Mass=	0.000
X=	-2.00	Y=	2.00	Z=	225.00	Mass=	0.000
X=	-2.00	Y=	2.00	Z=	326.00	Mass=	0.000
X=	-2.00	Y=	2.00	Z=	426.00	Mass=	0.000
X=	0.00	Y=	-2.00	Z=	125.00	Mass=	0.000
X=	0.00	Y=	-2.00	Z=	225.00	Mass=	0.000
X=	0.00	Y=	-2.00	Z=	326.00	Mass=	0.000
X=	0.00	Y=	-2.00	Z=	426.00	Mass=	0.000
X=	0.00	Y=	0.00	Z=	125.00	Mass=	0.000
X=	0.00	Y=	0.00	Z=	225.00	Mass=	0.000
X=	0.00	Y=	0.00	Z=	326.00	Mass=	0.000
X=	0.00	Y=	0.00	Z=	426.00	Mass=	0.000
X=	0.00	Y=	2.00	Z=	125.00	Mass=	0.000
X=	0.00	Y=	2.00	Z=	225.00	Mass=	0.000
X=	0.00	Y=	2.00	Z=	326.00	Mass=	0.000
X=	0.00	Y=	2.00	Z=	426.00	Mass=	0.000
X=	2.00	Y=	-2.00	Z=	125.00	Mass=	0.000
X=	2.00	Y=	-2.00	Z=	225.00	Mass=	0.000
X=	2.00	Y=	-2.00	Z=	326.00	Mass=	0.000
X=	2.00	Y=	0.00	Z=	125.00	Mass=	0.000
X=	2.00	Y=	0.00	Z=	225.00	Mass=	0.000
X=	2.00	Y=	0.00	Z=	326.00	Mass=	0.000
X=	2.00	Y=	0.00	Z=	426.00	Mass=	0.000

[illegible]

X=	-2.00	Y=	-2.00	Z=	224.00	Mass=	2.469
X=	-2.00	Y=	-2.00	Z=	225.00	Mass=	2.469
X=	-2.00	Y=	-2.00	Z=	222.00	Mass=	2.469
X=	-2.00	Y=	-2.00	Z=	224.00	Mass=	2.469
X=	-2.00	Y=	-2.00	Z=	225.00	Mass=	2.469
X=	-2.00	Y=	-2.00	Z=	222.00	Mass=	2.469
X=	-2.00	Y=	-2.00	Z=	224.00	Mass=	2.469
X=	-2.00	Y=	-2.00	Z=	225.00	Mass=	2.469
X=	-2.00	Y=	-2.00	Z=	222.00	Mass=	2.469
X=	-2.00	Y=	-2.00	Z=	224.00	Mass=	2.469
X=	-2.00	Y=	-2.00	Z=	225.00	Mass=	2.469
X=	-2.00	Y=	-2.00	Z=	222.00	Mass=	2.469
X=	-2.00	Y=	-2.00	Z=	224.00	Mass=	2.469
X=	-2.00	Y=	-2.00	Z=	225.00	Mass=	2.469
X=	-2.00	Y=	-2.00	Z=	222.00	Mass=	2.469
X=	-2.00	Y=	-2.00	Z=	323.00	Mass=	0.823
X=	-2.00	Y=	-2.00	Z=	324.00	Mass=	0.823
X=	-2.00	Y=	-2.00	Z=	326.00	Mass=	0.823
X=	-2.00	Y=	-2.00	Z=	323.00	Mass=	0.823
X=	-2.00	Y=	-2.00	Z=	324.00	Mass=	0.823
X=	-2.00	Y=	-2.00	Z=	326.00	Mass=	0.823
X=	-2.00	Y=	-2.00	Z=	323.00	Mass=	0.823
X=	-2.00	Y=	-2.00	Z=	324.00	Mass=	0.823
X=	-2.00	Y=	-2.00	Z=	326.00	Mass=	0.823
X=	-2.00	Y=	-2.00	Z=	323.00	Mass=	0.823
X=	-2.00	Y=	-2.00	Z=	324.00	Mass=	0.823
X=	-2.00	Y=	-2.00	Z=	326.00	Mass=	0.823

Here is the "Ring" of pending events at T= 11564.1 :

T =	1.15969E4	Ord(Kind) =	1	Info =	2.000000
T =	1.51423E4	Ord(Kind) =	0	Info =	1.24888E3

Time = 11596.9 ; The Grid has 972 points.
Here is the Grid (1st. 100 pts, max.) :

X=	-2.00	Y=	-2.00	Z=	161.00	Mass=	2.881
X=	-2.00	Y=	-2.00	Z=	238.00	Mass=	4.823
X=	-2.00	Y=	-2.00	Z=	314.00	Mass=	0.000
X=	-2.00	Y=	-2.00	Z=	391.00	Mass=	0.000
X=	-2.00	Y=	0.00	Z=	161.00	Mass=	0.000
X=	-2.00	Y=	0.00	Z=	238.00	Mass=	0.000
X=	-2.00	Y=	0.00	Z=	314.00	Mass=	0.000
X=	-2.00	Y=	0.00	Z=	391.00	Mass=	0.000
X=	-2.00	Y=	2.00	Z=	161.00	Mass=	0.000
X=	-2.00	Y=	2.00	Z=	238.00	Mass=	0.000
X=	-2.00	Y=	2.00	Z=	314.00	Mass=	0.000
X=	-2.00	Y=	2.00	Z=	391.00	Mass=	0.000
X=	0.00	Y=	-2.00	Z=	161.00	Mass=	0.000
X=	0.00	Y=	-2.00	Z=	238.00	Mass=	0.000
X=	0.00	Y=	-2.00	Z=	314.00	Mass=	0.000
X=	0.00	Y=	-2.00	Z=	391.00	Mass=	0.000
X=	0.00	Y=	0.00	Z=	161.00	Mass=	0.000
X=	0.00	Y=	0.00	Z=	238.00	Mass=	0.000
X=	0.00	Y=	0.00	Z=	314.00	Mass=	0.000
X=	0.00	Y=	0.00	Z=	391.00	Mass=	0.000
X=	0.00	Y=	2.00	Z=	161.00	Mass=	0.000
X=	0.00	Y=	2.00	Z=	238.00	Mass=	0.000
X=	0.00	Y=	2.00	Z=	314.00	Mass=	0.000
X=	0.00	Y=	2.00	Z=	391.00	Mass=	0.000
X=	2.00	Y=	-2.00	Z=	161.00	Mass=	0.000
X=	2.00	Y=	-2.00	Z=	238.00	Mass=	0.000
X=	2.00	Y=	-2.00	Z=	314.00	Mass=	0.000
X=	2.00	Y=	-2.00	Z=	391.00	Mass=	0.000
X=	2.00	Y=	0.00	Z=	161.00	Mass=	0.000
X=	2.00	Y=	0.00	Z=	238.00	Mass=	0.000
X=	2.00	Y=	0.00	Z=	314.00	Mass=	0.000
X=	2.00	Y=	0.00	Z=	391.00	Mass=	0.000
X=	2.00	Y=	2.00	Z=	161.00	Mass=	0.000
X=	2.00	Y=	2.00	Z=	238.00	Mass=	0.000
X=	2.00	Y=	2.00	Z=	314.00	Mass=	0.000
X=	2.00	Y=	2.00	Z=	391.00	Mass=	0.000
X=	-2.00	Y=	-2.00	Z=	159.00	Mass=	2.881
X=	-2.00	Y=	-2.00	Z=	160.00	Mass=	2.881

X=	-2.00	Y=	-2.00	Z=	236.00	Mass=	0.823
X=	-2.00	Y=	-2.00	Z=	238.00	Mass=	0.823
X=	-2.00	Y=	-2.00	Z=	235.00	Mass=	0.823
X=	-2.00	Y=	-2.00	Z=	236.00	Mass=	0.823
X=	-2.00	Y=	-2.00	Z=	312.00	Mass=	0.000
X=	-2.00	Y=	-2.00	Z=	313.00	Mass=	0.000
X=	-2.00	Y=	-2.00	Z=	314.00	Mass=	0.000
X=	-2.00	Y=	-2.00	Z=	312.00	Mass=	0.000
X=	-2.00	Y=	-2.00	Z=	313.00	Mass=	0.000
X=	-2.00	Y=	-2.00	Z=	314.00	Mass=	0.000
X=	-2.00	Y=	-2.00	Z=	312.00	Mass=	0.000
X=	-2.00	Y=	-2.00	Z=	313.00	Mass=	0.000
X=	-2.00	Y=	-2.00	Z=	314.00	Mass=	0.000
X=	-2.00	Y=	-2.00	Z=	312.00	Mass=	0.000
X=	-2.00	Y=	-2.00	Z=	313.00	Mass=	0.000
X=	-2.00	Y=	-2.00	Z=	314.00	Mass=	0.000

Here is the "Ring" of pending events at T= 11596.9 :
 T = 1.51423E4 Ord(Kind) = 0 Info = 1.24888E3