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GASFLOW ANALYSIS OF A TRITIUM LEAK ACCIDENT

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ABSTRACT

The consequences of an earthquake-induced fire involving a tritium leak were analyzed using the GASFLOW computer code. Modeling features required by the analysis include ventilation boundary conditions, flow of a gas mixture in an enclosure containing obstacles, thermally induced buoyancy, and combustion phenomena.

Los Alamos National Laboratory and *Engineering & Scientific Software, Inc.

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INTRODUCTION

The GASFLOW computer code was used to analyze the consequences of an earthquake-induced accident in the mixing tank room of the Replacement Tritium Facility (RTF) at the Savannah River Site. The assumed accident sequence involves four simultaneous events.

1. Failure of a glovebox enclosure
2. Failure of process system pipe
3. Failure of an isolation valve
4. Initiation of a cable tray fire in the affected room

The principal objective of the analysis was to determine the amount of ditritium oxide formed by combustion from the tritium released to the room as a result of the failures listed above. This calculation is relevant to the analysis of containment structures because the gas dynamics involving flow in an enclosure containing obstacles with the occurrence of combustion are phenomena common to containment analysis.

MATHEMATICAL AND PHYSICAL MODELS

The finite-volume GASFLOW code can model complex three-dimensional geometries. Structures or compartments can be represented by separate computational domains that communicate through overlapping boundary conditions. Flow between compartments can be modeled using one-dimensional ventilation system models, and the ventilation system may be superimposed throughout the multiblock mesh. The model's ventilation system components include fans, dampers, and filters. Natural and forced convection may be modeled in both the one-dimensional ductwork and the three-dimensional compartments.

GASFLOW uses the time-dependent, three-dimensional, compressible Navier-Stokes equations as its equations of motion. An internal energy-transport equation relates the internal energy, density, pressure, and velocity fields with the exchange of heat and mass (condensation and evaporation) on distributed structures, walls, and slabs. Multiple-species transport equations model the transport of individual species through the gas mixture. The sum of the species transport equations is the total fluid density conservation equation. These equations, the Navier-Stokes equations, the internal energy equations, and the summed species transport equations model the conservation of momentum, energy, and mass, respectively. They relate the dynamics of the fluid to temporal and spatial influences, such as viscous stress, body force, turbulence, structural resistance, heat transfer, condensation, and combustion. Gas turbulence is simulated by an algebraic mixing model, a one-equation subgrid scale model, or a k-ε turbulence model with buoyancy production terms.

Heat transfer and condensation on walls and surfaces, such as internal structures, are calculated to model appropriate energy sinks. A modified Reynolds analogy for heat and mass transport to walls and structures accounts for the influence of the thermal boundary layer on the rates of heat transfer and condensation.

Chemical kinetics models for combustion simulate diffusion and propagating flames in complex geometries. A one-step global chemical kinetics model often is used for diffusion flames involving hydrogen or hydrocarbon fuels. This simplifies the actual chemical processes, which have many more elementary reaction steps and intermediate chemical species. However, the chemical reaction time scale is very short compared with fluid-dynamic motions, and meaningful calculations can be accomplished using this simplified chemical kinetics mechanism. The reaction rate in the finite-rate chemical kinetics equations is modeled by a modified Arrhenius law that accounts for both fuel-lean and fuel-rich mixtures.

Aerosol transport models compute the behavior of particulate matter in the gas flow fields. These one-way coupled models simulate the polydisperse transport, deposition, and entrainment of discrete-phase particles. The GASFLOW species transport model also functions as a continuum-particle-phase transport model.

TRITIUM DISCHARGE MODEL

A TRAC[1] model was developed to predict the blowdown rate of a tritium storage tank resulting from a pipe rupture. An update to TRAC-PFl/MOD2 was prepared to replace the hydrogen gas properties with those of tritium. The velocity of the tritium flowing from the 0.75-in.-i.d. outlet pipe was used as the source term for the GASFLOW calculations. The storage tank and broken outlet pipe were modeled with a two-celled PIPE component. The 1.50-cm^3 (1500-L) tank was modeled with one cell of the PIPE component. The initial tank pressure was 2.5338e05 Pa (2.50 atm), and the gas temperature was 297 K (75°F).

The second cell of the PIPE component was used to model the broken outlet pipe. The flow area of the 0.75-in.-i.d. pipe was 2.8502e-04 m^2, and the length was assumed to be 1.0 m. An atmospheric pressure (1.0135e05 Pa) boundary was specified at the broken end of the outlet pipe with a BREAK component.

The tritium discharge velocity computed by the TRAC model is shown in Fig. 1.

ROOM MODEL

The accident simulation was performed using the GASFLOW[2] code.

The room was modeled in GASFLOW by a 15 x 15 x 60 array of computational cells. One glovebox was assumed to remain intact and was modeled as a set of obstacle cells. The upper and lower structures of the other glovebox also were assumed to remain intact. These sections also were modeled as obstacle cells. The gloveboxes and ventilation supply and exhaust passages are arranged as shown in Figs. 2 and 3.

The glass wall section of the affected glovebox was treated as a wall component during the initial phase of the computation to establish the room velocity field before the accident phase. During the accident phase of the analysis, the affected glovebox walls were removed, and tritium was injected into the center of the glovebox region at the upper surface of the lower obstacle structure. The burning cable trays were modeled as internal boundary conditions maintained at a temperature of 1000 K (1340.6°F) for the duration of the accident phase of the calculation. Consequently, any tritium transported to the cable trays would react with the available oxygen.

ANALYSIS METHOD AND RESULTS

The accident calculation was performed in two steps. The first was a hydrodynamic calculation to establish the steady-state velocity field before initiation of the accident. Boundary conditions for the hydrodynamics are defined by the room ventilation system. Both gloveboxes are intact during the hydrodynamic calculation. Figures 2 and 3 show examples of the velocity solution in and around the ventilation ducts.

The second step of the analysis was to simulate the accident sequence starting with the initial conditions established by the hydrodynamic solution. For this calculation, the affected glovebox walls were removed, the glovebox enclosure was filled with nitrogen, and the simulated tritium leak was introduced at the center of the glovebox support structure. The results of the accident calculation are shown in Figs. 4 and 5. The tritium leak rate declines to zero in 400 s (see Fig. 1.) The accident simulation was run to 800 s.

The ditritium oxide inventory is shown in Fig 5. The mass flows of ditritium oxide leaving the room through the exhaust ducts are shown in Fig. 6. Integrating the exhaust flows yields the mass of ditritium oxide escaping through the ventilation exhaust—a total of 40 g of ditritium oxide from both vents. Figure 5 shows that 6 g of ditritium oxide remain in the room at the end of the computation. Thus, 46 g of ditritium oxide were produced, which corresponds to 2.06 moles of tritium reacting out of the total of 77.4 moles released from the leak. Therefore, 2.66% of the released tritium reacted to form ditritium oxide. These results show that the objectives of the analysis were achieved, and they illustrate the utility of performing this kind of computation with GASFLOW.

REFERENCES

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2. J. R. Travis and T. L. Wilson, "HMS: Theory and Computational Model," Los Alamos National Laboratory report LA-12459-MS/NUREG/CR-5948 (1992).

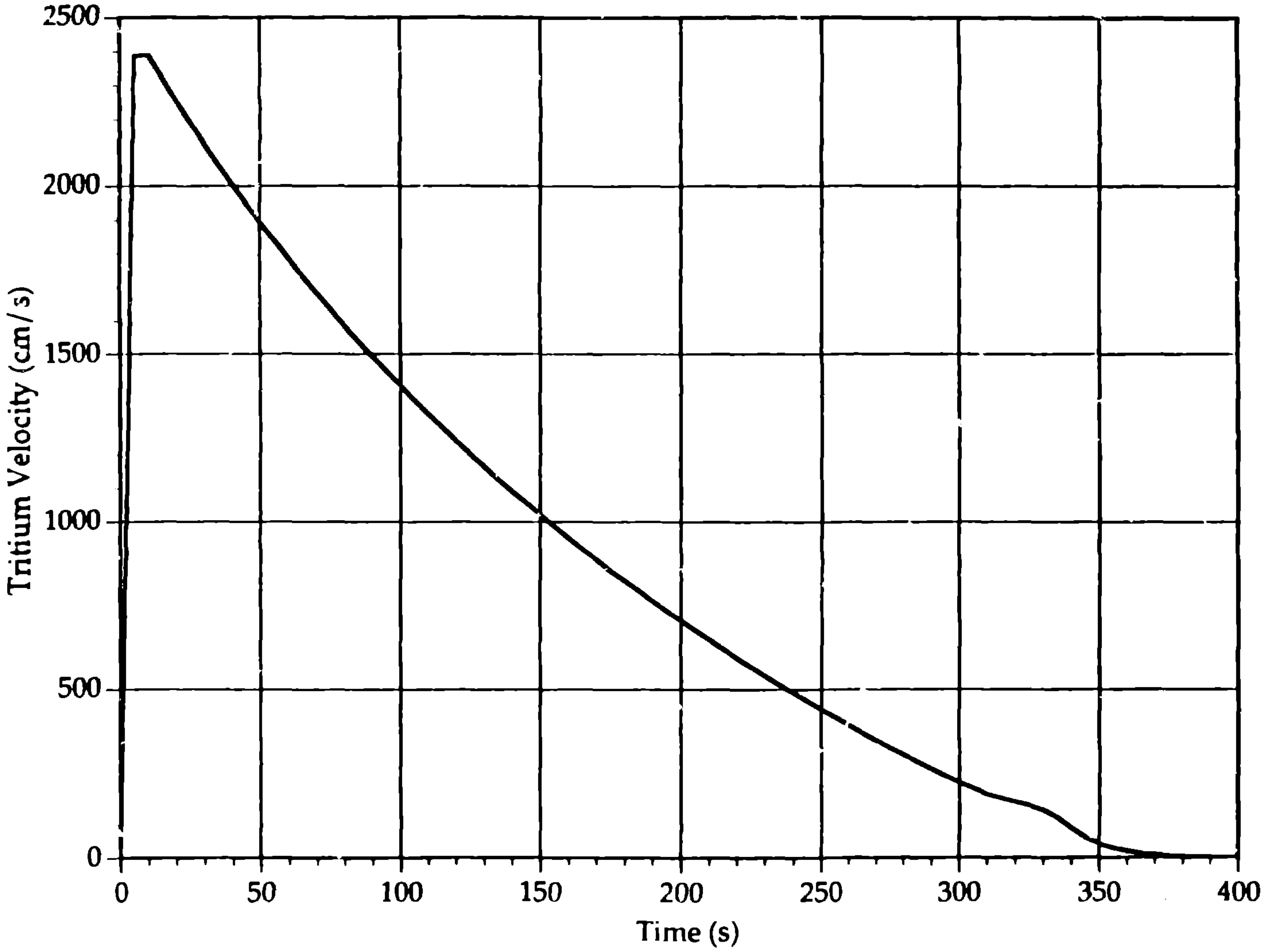


Fig. 1. TRAC prediction of Savannah River RTF tritium mixing tank blowdown.

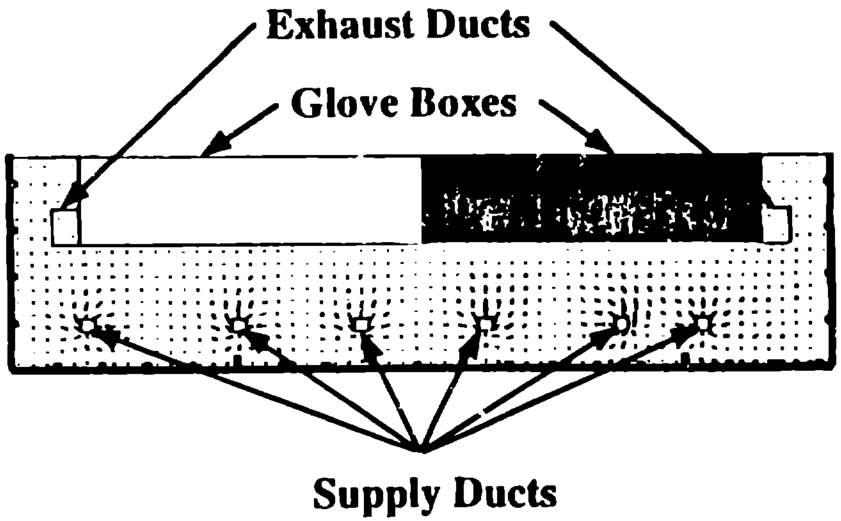
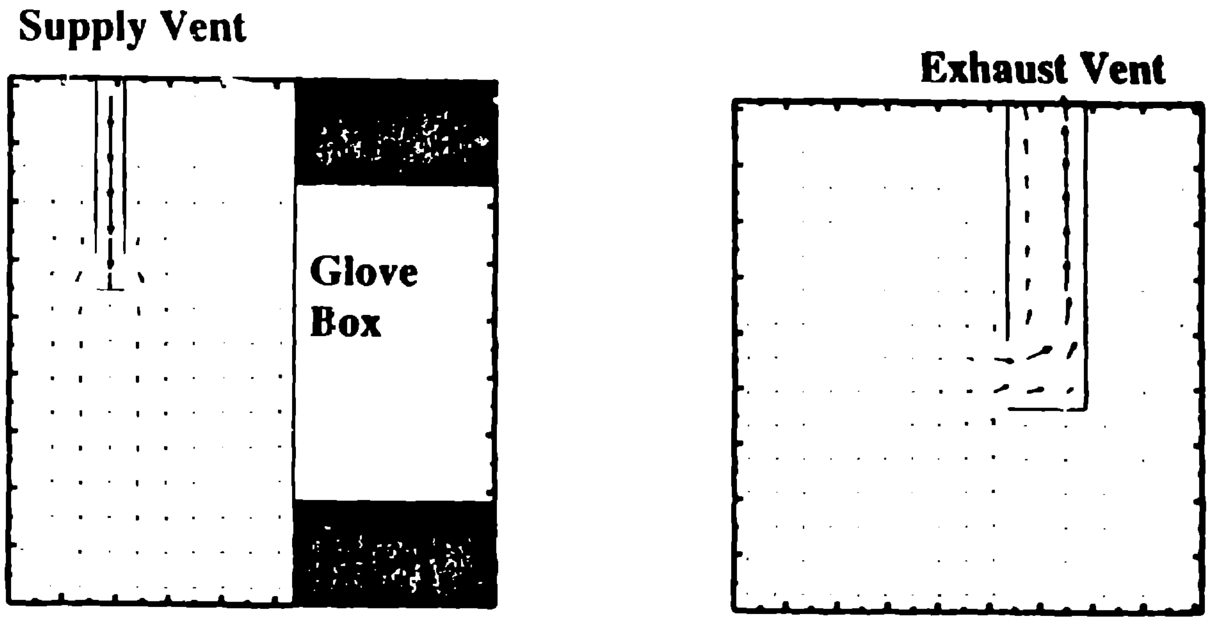


Fig. 2. GASFLOW model (plan view of Room 9 at 12 ft elevation).



(7 ft from "west" end)

(57 ft from "west" end)

Fig. 3. GASFLOW model (end views).

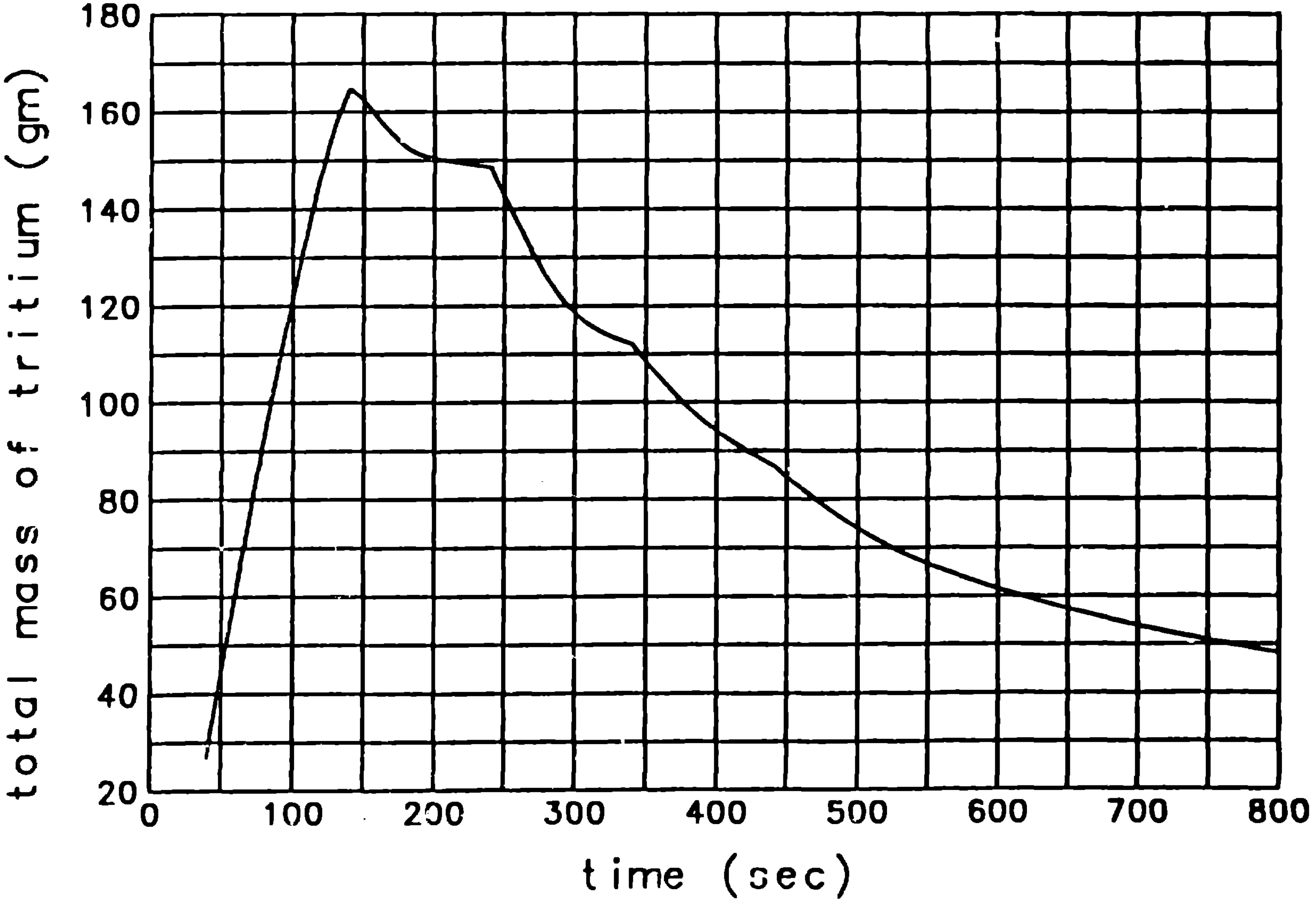


Fig. 4. Tritium inventory.

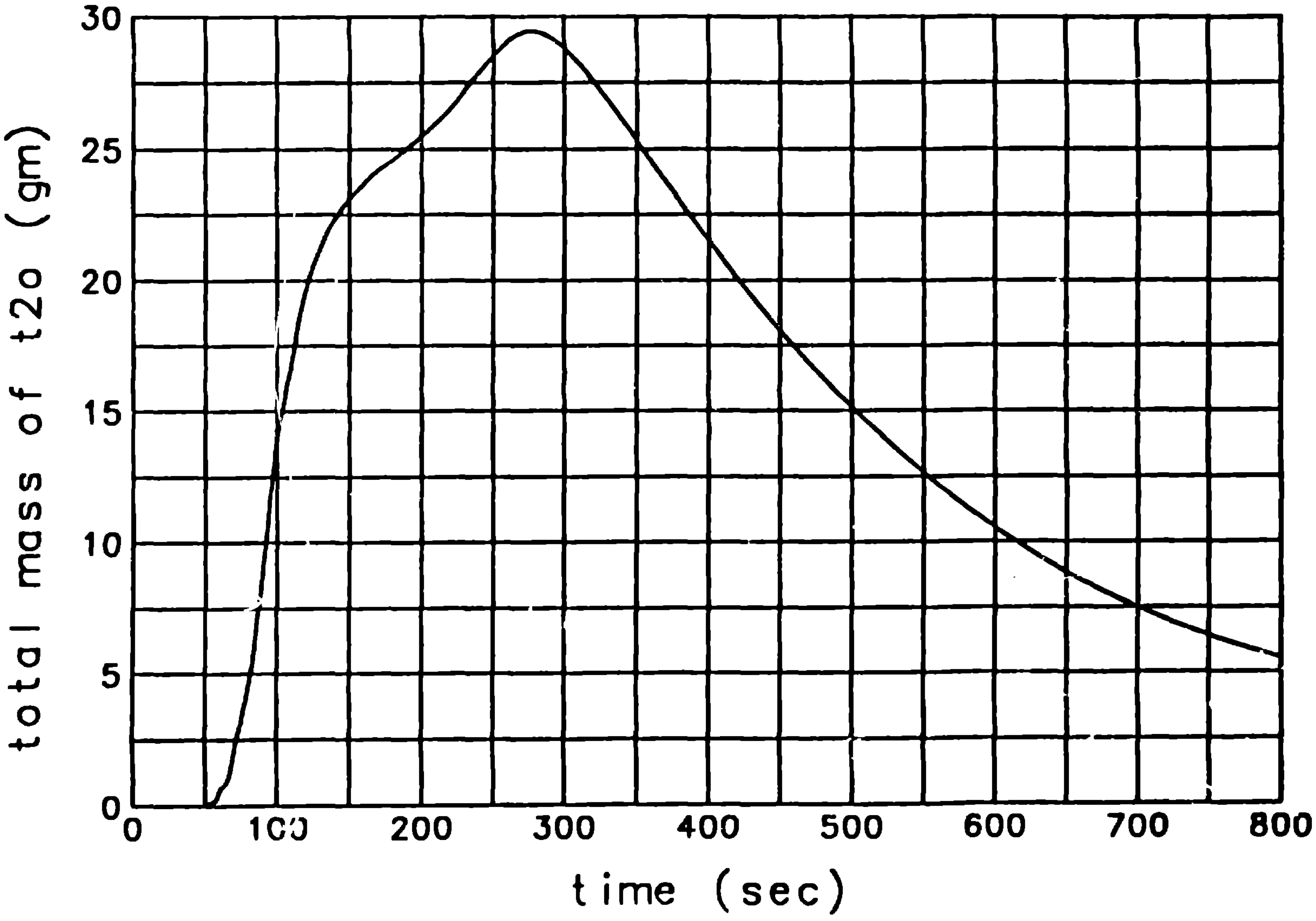


Fig. 5. T_2O inventory.

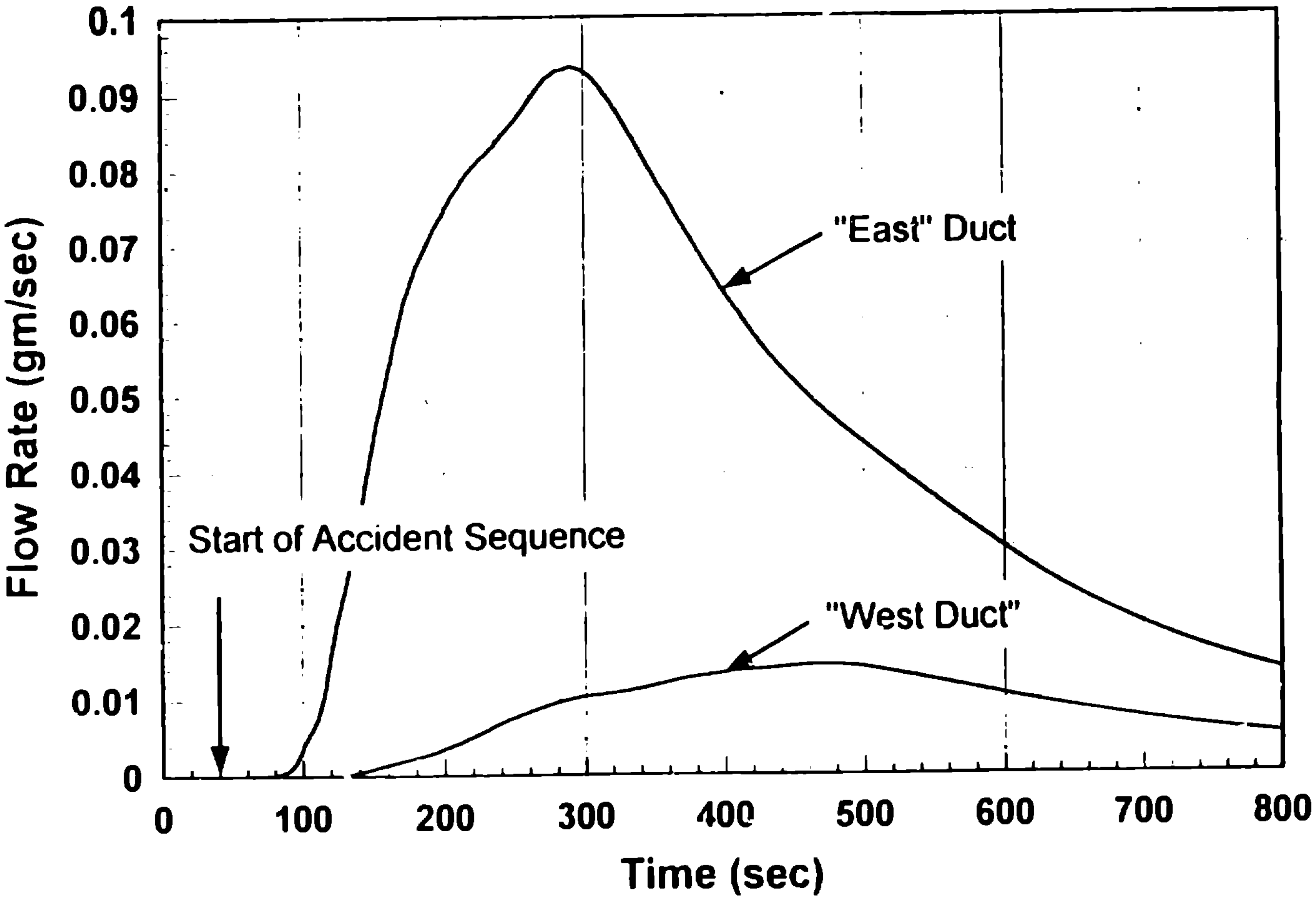


Fig. 6. T_2O flow into exhaust.