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EUROPEAN ATOMIC ENERGY COMMUNITY - EURATOM

CODE CROOC
ORGEL REACTOR CONTAINMENT DESIGN PARAMETERS

by

R. SIMON and H. I. DE WOLDE

1969

ORGEL Program

Joint Nuclear Research Center
Ispra Establishment - Italy

ORGEL Project
and
Scientific Data Processing Center - CETIS

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ABSTRACT

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The code is fitted with a CALCOMP subroutine, so that all results can be plotted immediately.

KEYWORDS

C-CODES
TEMPERATURE
PRESSURE
ORGANIC COOLANT
LOSSES
ORGEL REACTOR

CODE CROOC

ORGEL reactor containment design parameters

Contents

Introduction *

The code CROOC** has been established in order to assess the variations of pressure, temperature and concentrations in an ORGEL reactor containment due to an important leakage of organic coolant, and to study the efficiency of such consequence-limiting safeguards as dousing systems and internal separations.

The code essentially describes the thermodynamic comportment of a mixture of air or nitrogen, hot reactor coolant HB-40 and dousing water. Whereas the state of air and water can be adequately described by simple and well-known state equations and gas laws, the thermodynamics of the reactor organic coolant mixture can only be correlated in a rather approximative manner.

For closed or vented rooms of the containment builing, into which the leakage gains access, the time dependent state variables temperature and pressure are computed for arbitrary time steps from the mass and energy balances. By means of steady-state equations, the code calculates the state in the vault, in which a severe coolant discharge occurs. It also determines the effect of a rupture disk, which relieves the overpressure in the vault to the adjacent reactor hall by computing the discharge rate to the hall and the resulting rise in hall pressure, temperature and density. The intervention of dousing systems is taken into account.

1. Description of the problem and calculating model

1.1 Containment system

The present safety studies for the ORGEL prototype have resulted in a containment building concept as presented schematically in Fig. 1.

** Consequences of Rupture Of Organic Circuits

* Manuscript received on 3 January 1969.

The piping of the primary organic circuit and the reactor core are enclosed in a concrete vault C, which takes in the lower part of a cylindrical containment vessel . The two vessels are supposed to be completely separated under normal operating conditions. A number of rupture disks between the hall and the vault are provided in order to relieve extreme over-pressures in case of very severe piping failures. Both the circuit vaults and the servicing hall, which forms the major part of the remaining containment space, are provided with water dousing systems.

The water dousing system is assumed to go into action with a delay due to detection, signal transmission and release mechanism inertia. As, during this delay, the temperature of the affected rooms has risen considerably, the injected water will evaporate completely if the dousing rate is low compared with the leak rate. In this case, the rise of temperature is attenuated, whereas a reduction of the temperature can only be expected after a decrease in leakage. With at least two independent water injection systems (dousing and sprinkler in the vault, dousing, sprinkler and wall cooling in the hall), installed, at least one system in each room can be assumed to operate on schedule. The remaining systems could most probably be taken into operation at a later moment.

1.2 The accident

The hypothetical accident is assumed as follows :

a) The coolant discharge

Immediately after the rupture of a coolant pipe, at zt = 0 of the elapsed time scale, the coolant mass discharge rate will assume its maximum and remains at this value until the interventive actions upon the circuit are effective. These interventions are the depressurization of the circuit by blowing-off the surge tank cover gas and the closing of the isolating valves situated on both sides of the primary piping penetrations of the containment.

The reduction for the leak rate due to these interventions is assimilated by an exponential decrease. Of course, time dependent functions of the leak rate that may fit the actual conditions better can be introduced as driving functions.

b) The consequences of the coolant discharge

The hot coolant leakage transfers a part of its thermal energy to the surrounding atmosphere, thereby raising its temperature and the pressure in the closed volume. Another part of the coolant energy serves to evaporate a fraction of the coolant, the vapour pressure of which adds to the pressure of the previously present gas N_2 or air to form the total pressure in the mixture.

In case of a severe piping rupture, the pressure in the vault may rise to the design pressure of the vault walls before any interventive counteractions can reasonnably be assumed to be effective. In order to avoid damage to the concrete vault, a number of rupture disks will relieve the vault pressure to the hall, when a pressure limit is exceeded.

The mixture of coolant vapour and nitrogen, which is discharged from the vault to the hall, will provoke a temperature increase and an over-pressure in the hall. In the course of the discharge, the nitrogen is gradually purged from the vault, in which the coolant vapour pressure rapidly attains saturation.

As long as the coolant leakage rate is important, the differential pressure between vault and hall is high enough to admit critical flow through the orifice. Then, as the leak rate is cut down, the flow in the hall gradually decreases and the pressure difference between the two rooms disappears.

b) The decline of the pressure and temperature

As seen as the transfer rate of energy from the coolant to the room atmosphere is surpassed by the amount of energy primarily absorbed by the water and dissipated to the environment by heat transfer and building leakage, the temperature and the pressure in the containment decrease.

As the code CROOC was written essentially to determine the time and magnitude of the peak pressures and temperature, the subsequent decline of these two state variables after their peak values is calculated in a simplified manner, taking the conservative assumptions that heat transfer and leakage to the outside are negligible.

1.3 Physical properties of involved fluids

1.3.1. The reactor coolant

The hydrogenated terphenyl coolant HB-40 was chosen by the industriel group in charge of the ORGEL Prototype preliminary design, but the code may be adapted to ether coolants. To take account of the changements of compositions due to continuous irradiation and heating, a mixture containing roughly 20 % high boilers and 15 % light boilers was assumed to present the equilibrium coolant. For the liquid phase data concerned the following mean constant values were used :

Liquid density : ρ_o = 800 kg/m^3
Liquid heat capacity : c_o = 2500 J/g °C

For the coolant vapour, no data except the saturated vapour pressure as function of the temperature t (°C) were available :

$$P_{osat} = e^{1.18.10^{-2}(t - 244)} \qquad \text{(bar)}$$

The remaining data needed for the calculation of phase equilibrium and the mass and energy balances had to be estimated.

The following model was applied to obtain a somewhat realistic, but conservative assessment of the thermodynamic comportment of the coolant :

The coolant is composed of only two fractions, of which the lighter one has the characteristics of diphenyl, whereas the heavier fraction, having a very low fugacity, is not considered present in vapour phase.

The vapour heat capacity of the light fraction is assumed to equal the liquid heat capacity c_o (in reality, it is probably about 20 % lower).

The mass proportion of $\frac{\text{light fraction}}{\text{total coolant}}$

is defined as a compressibility factor K_1

The partial pressure of non-saturated coolant vapour P_{og} is determined with the gas equation from the mean coolant density (ϱ_o = total coolant mass present per unit of volume)

$$P_{og} = \frac{\varrho_o \cdot R_o \cdot (t + 273,15)}{K_1 \cdot 10^5} \qquad \text{(bar)}$$

where R_o is the gas constant of diphenyl

$$R_o = 36,8 \quad \text{J/kg °K}$$

1.3.2 Air and nitrogen

As specific heat and the normal density of air differ only slightly (2% and 3% respectively) from those of nitrogen, the mean physical properties of the hall and vault atmospheres are considered to be equal :

Spec. heat at constant vol.	c_{v1}	=	720 J/Kg °C
Gas constant	R_1	=	287 J/Kg °K

All state variables are determined from the gas equation.

1.3.3 Water

The pressure of the saturated vapour P_{wsat} results from the integration of the Claurius-Clapagron equation :

$$P_{hw} = e^{\,49,487 - \frac{6850}{(t+273,15)} - 5,25 \ln(t+273,15)} \qquad \textbf{(bar)}$$

The state of non-saturated vapour is computed from the gas equation with

$$Rw = 460,0 \text{ J/Kg °K}$$

In order to simplify the energy balance, the enthalpy of the water and the heat of evaporation were lumped to a mean heat o evaporation r_m :

$$r_m = 2.5 \cdot 10^6 \quad \text{J/Kg}$$

1.3.4 Coolant-air-water mixture

For the determination of the mass discharge, it can be assumed that only a part of the coolant leakage is airborn and thus likely to be carried over to the hall once the rupture disk is open.

This fraction is defined as "mist fraction".

$$\mu = \frac{\text{mass of airborne coolant}}{\text{total mass of coolant}}$$

The density of the coolant-air-water mixture is the sum of densities of airborne coolant, water vapour and air :

$$\rho_g = \mu \cdot \rho_o + \rho_w + \rho_L \qquad \text{kg/m}^3$$

The flow of this mixture through the orifice is adiabatic, the exponent of the adiabatic expansion is assmed

$$n = 1{,}135 \qquad (-)$$

as for the saturated water vapour. For this exponent, the critical pressure ratio is :

$$C_1 = 0{,}577 \qquad (-)$$

1.4 Calculation process

1.4.1 General procedure

A general scheme of the calculation is presented in Fig. 2. The independent variable in the main process of calculation is the elapsed time zt, which is divided into a suitable number of time steps Δz.

The conditions at the beginning of the first time step are known. With these initial conditions, the state at the end of the time step is computed. The obtained results serve to calculate the conditions after the following time step and so on.

The step-by-step procedure is stopped at a chosen time limit.

1.4.2 Known data

a) The physical properties (s.1.3)

CVL, CO, Ri, Rw, rm, K1, n,

b) The parameters (varying with the cases) :

"Mist fraction"	μ
Initial coolant leak rate	Z_{o1}
Initial dousing rate in vault	Z_{w1}
Initial dousing rate in hall	Z_{hw}
Time of intervention for dousing vault	z_s
Time of intervention for dousing hall	z_{hs}
Temperature of leakage	t_o
Vault volume	V_K
Hall volume	V_H
Free section of rupture disk	$\emptyset$
Design pressure of rupture disk	P_b
Duration of each time step	Δz

c) Initial conditions (time zt = 0)

Density of atmosphere in vault	ρ_{1i}
Density of atmosphere in hall	ρ_{h11}
Temperature in vault	t_1
Temperature in hall	t_{h1}
Mass of coolant spilled	$M_{o1} = 0$

1.4.3. State in the vault

For the determination of the mean temperature t_{i+1} in the vault at the end of time step ΔZ_{i+1}, a simplified balance of energy gives :

$$t_{i+1} = \frac{\rho_{1i} \cdot V_k \cdot c_{v1} \cdot t_i + M_{oi} \cdot c_o \cdot t_i + Z_{oi+1} \cdot C_o \cdot \Delta z \cdot t_o - Z_{wi+1} \cdot \Delta z \cdot r_m}{\rho_{1i} \cdot V_k \cdot c_{v1} + (M_{oi} + Z_{oi+1} \cdot \Delta z) \cdot c_o}$$

(°K) 1

Wherein the leak rate Z_{oi} and the dousing rate Z_{wi} are only functions of the elapsed time known in advance. The mass of coolant dispersed per unit of vault volume is :

$$\rho_{oi+1} = \frac{M_{oi} + Z_{oi+1} \cdot \Delta z}{V_k} \qquad \left(\frac{Kg}{m3}\right) \qquad 2$$

As long as the vault atmosphere is not satured with coolant vapour, the partial pressure of the latter is given by the gas equation :

$$P_{ogi+1} = \frac{\rho_{oi+1}^{+} \cdot R_o \cdot (t_{i+1} + 273,15)}{K_I \cdot 10^5} \qquad (bar) \qquad 3$$

The atmosphere is satured when the pressure attains :

$$P_{osi+1} = e^{1.18.10^{-2} (t_{i+1} - 244)} \quad \text{(bar)} \qquad 4$$

The partial vapour pressure of the coolant p_{oi+1} for a given temperature t_{i+1} is always the lower value resulting of 3 and 4.

Once the dousing has begun, the quantity of water present in the mixture at the time i+1 is :

$$M_{wi+1} = M_{wi} + Z_{wi+1} . \Delta z \qquad \text{(kg)} \qquad 5$$

where

$$M_{wi} = \sum_{o}^{i} Z_{w} . \Delta z \qquad \text{(kg)} \qquad 6$$

The density of the water dispersed in the vault is :

$$\rho_{wi+1} = \frac{M_{wi} + Z_{wi+1} . \Delta z}{V_k} \qquad \frac{\text{(kg)}}{\text{(m3)}} \qquad 7$$

As complete evaporation is assumed, the partial pressure of the water vapour is :

$$P_{wi+1} = \rho_{li+1} . R_1 . (t_{i+1} + 273).10^{-5} \text{ (bar)} \qquad 8$$

and the partial pressure of the nitrogen

$$P_{1i+1} = \rho_{1i+1} \cdot R_1 \cdot (t_{i+1} + 273) \cdot 10^{-5} \qquad \text{(bar)} \qquad 9$$

wherein

$$\rho_{1i+1} = \rho_{1i} \qquad \left(\frac{kg}{m3}\right) \qquad 10$$

as long as tne vault remains closed.

The total pressure in the vault P_{vg} of the mixture of coolant, water and nitrogen adds up to

$$P_{gi+1} = P_{oi+1} + P_{wi+1} + P_{1i+1} \qquad \text{(bar)} \qquad 11$$

and the density of the mixture is :

$$\rho_{vgi+1} = \mu \cdot \rho_{oi+1} + \rho_{wi+1} + \rho_{1i+1} \qquad \left(\frac{kg}{m3}\right) \qquad 12$$

The mass concentrations of coolant X_{i+1} and water Y_{i+1} in the mixture are :

$$X_{i+1} = \frac{\mu \cdot \rho_{oi+1}}{\rho_{gi+1}} \qquad (-) \qquad 13$$

$$Y_{i+1} = \frac{\rho_{wi+1}}{\rho_{gi+1}} \qquad (-) \qquad 14$$

To determine, whether the rupture disk has opened, the disk design pressure P_b is compared with the total vault pressure P_{gi+1} computed in eq. 11 :

If $P_{gi+1} < P_b$; the vault remains a closed volume and the state in the hall is unchanged.

The development in the vault during the following time step $i+2$ can than be performed directly, as all conditions at the end of Δt_{i+1} i.e. Partial and total pressures, temperature, density and the concentrations are known.

1.4.4 The discharge from the vault

If $P_{gi-1} > P_b$, the rupture disk has burst and the calculation proceeds to the calculation of the discharge from the vault. The discharge of the gas-coolant-water mixture is assumed to be isentropic. The critical pressure ratio $C_1 = 0{,}577$ corresponds to that of satured water steam with the exponent $n = c_p/c_v = 1.135$, therefore if

$$\lambda_{i+1} = P_{hgi}/P_{gi+1} \leqslant C_1$$

(P_{hg} : total hall pressure, p_g : total vault pressure)
The flow through the orifice is critical, and the flow coefficient is a constant :

$$\Psi_{i+1} = C_1^{\frac{1}{n}} \sqrt{\frac{n}{n-1} \quad (1- C_1^{\frac{n-1}{n}})} \qquad (-) \quad 15$$

For $\lambda_{i+1} = P_{hi}/P_{gi+1} < C_1$

The flow is subcritical and the flow coefficient is

$$\psi_{i+1} = \lambda_{i+1}^{\frac{1}{n}} \sqrt{\frac{n}{n-1}\left(1 - \lambda_{i+1}^{\frac{n-1}{n}}\right)} \quad (-) \qquad 16$$

The mass discharge rate G through the rupture disk orifice with a section O results from the flow equation

$$G_{i+1} = O \cdot \psi_{i+1} \sqrt{2P_{gi+1} \cdot \rho_{gi+1} \cdot 10^5}$$

The partial mass discharge rates of coolant A_o, water A_w and nitrogen A_1 that flow into the hall are :

$$A_{oi+1} = X_{i+1} \cdot G_{i+1} \qquad (kg/s) \qquad 17$$

$$A_{Wi+1} = Y_{i+1} \cdot G_{i+1} \qquad (kg/s) \qquad 18$$

$$A_{1i+1} = G_{i+1} - A_{oi+1} - A_{wi+1} \qquad (kg/s) \qquad 19$$

1.4.5 Influence of discharge on conditions in vault

Due to the discharge the masses of coolant M_o and water M_w in the vault at the end of time step i+1 are

$$M_{oi+1} = N_{oi} + Z_{oi+1} \cdot \Delta z - A_{oi+1} \cdot \Delta z \qquad (Kg) \qquad 20$$

$$M_{wi+1} = M_{wi} + Z_{wi+1} \cdot \Delta z - A_{oi+1} \cdot \Delta z \qquad (kg) \qquad 21$$

The nitrogen density ρ_1 is reduced to

$$\rho_{1i+1} = \rho_{1i} - \frac{A_{1i+1} \cdot \Delta z}{Vk} \qquad \left(\frac{kg}{m3}\right) \qquad 22$$

As a considerable mass of coolant is not in gaseous phase, the expansion of the vault atmosphere is assumed isothermal. In view of the vault pressure this is a conservative assumption.

1.4.6. Influence of discharge on conditions in vault

Once the rupture disk is burst, the temperature t_h and the total pressure P_h in the reactor hall rise due to

- a) heat exchange with the discharged coolant-water-nitrogen mixture

- b) compression by the inflowing masses

The temperature of the hall after complete mixing and heat exchange is

$$t_{hmi+1} = \frac{(\rho_{hli} \cdot V_h \cdot c_{vl} + M_{hoi} \cdot c_o) \cdot t_{hi} + (A_{oi+1} \cdot c_o + A_{li+1}\ c_{vl}) \cdot \Delta z \cdot t_{i+1} - Z_{hwi}\ \Delta z \cdot r_m}{(\rho_{hli} \cdot V_h + A_{li+1} \cdot \Delta z) C_{vl} + (M_{hoi} + A_{pi+1} \Delta z) \cdot c_o}$$

$$(°C) \qquad 23$$

The masses of coolant and water dispersed in the hall at the end of time step i+1 are :

$$M_{hoi+1} = M_{hoi} + A_{oi+1} \cdot \Delta z$$

$$M_{hwi+1} = M_{hwi} + (Z_{hwi+1} + A_{hwi+1}) \cdot \Delta z$$

The density of the hall atmosphere (nitrogen and air are lumped) for completely gaseous inflow would rise to

$$\rho_{hi+1} = \rho_{hi} + \frac{G_{i+1} \cdot \Delta z}{V_h} \qquad \frac{(kg)}{(m3)} \qquad 24$$

However, as the coolant fraction of the discharge A_o is not completely gaseous and the water fraction A_w is rather unimportant, only the nitrogen - air density is considered in the present version :

$$\rho_{hli+1} = \rho_{hli} + \frac{A_{li+1} \cdot \Delta z}{V_h} \qquad \frac{(kg)}{(m3)} \qquad 25$$

Due to the isentroptic compression the hall temperature rises to :

$$t_{hi+1} = (t_{hmi+1} + 273,15)\left(\frac{\rho_{hli+1}}{\rho_{hli}}\right)^{0,4} - 273,15 \qquad (°C) \qquad 26$$

The partial pressures of air P_{hl}, water P_{hw} and coolant P_{ho} in the reactor hall at the end of time step i+1 are :

$$P_{hli+1} = \rho_{hli+1} \cdot R_l \, (t_{hi+1} \cdot 273,15) . 10^{-5} \qquad (bar) \qquad 27$$

$$P_{hwi+1} = \frac{M_{hwi+1}}{V_h} \, R_w \, (t_{hi+1} + 273,15) . 10^{-5} \qquad (bar) \qquad 28$$

$$P_{hoi+1} = \frac{M_{hoi+1}}{K_i . V_h} \; R_o \; (t_{hi+1} + 273,15) . 10^{-5} \qquad \text{(bar)} \qquad 29$$

or , at saturation

$$P_{hoi+1} = e^{1.18.10^{-2} \; (t_{hi+1} - 244)} \qquad \text{(bar)} \qquad 30$$

As for the partial coolant in the vault, the calculation proceeds with the lower value obtained from eqs. 29 or 30.

At the end of time step i+1, the total pressure in the reactor hall P_{hg} has risen to

$$P_{hgi+1} = P_{hli+1} + P_{hwi+1} + P_{hoi+1} \qquad \text{(bar)} \qquad 31$$

This completes the calculation of the containment conditions in one time step. If the elapsed time $zt = \Sigma \Delta z$ is within the predetermined time limit, the next step i+2 is calculated with the input :

$$\rho_{li+1}, \; t_{i+1}, \; M_{oi+1}, \; M_{wi+1}, \; M_{hoi+1}, \; M_{hwi+1}, \rho_{hci+1}, \; t_{hi+1}$$

If the elapsed time equals or exceeds the time limit, the cycle is interrupted and the calculation of the case is ended.

1.5 Various possible applications

1.5.1. Pressure relief containment concept

In this containment concept, the initial surge of energy released by a severe piping failure is vented off to the environment by special valves in the buiding. These valves are immediately shut, when the radioactivity in the building exceeds a certain limit. In this way a release of fission products to the environment is prevented without necessity of containing the entire energy of the coolant in a costly high-pressure leak-tight containment.

However, due to the uncertainty in calculating the delay between the rupture and the fission product release on one hand and the very stringent requirements as to the availability and reliability of the valve closing mechanisms on the other, this concept cannot be applied for all reactors.

In order to compute the pressures, temperatures and discharge rates for such a concept with CROOC, the following procedure is recommended.

All input data concerning the vault in the present version are replaced by the corresponding values for the reactor building. The section of the venting valves substitutes the rupture disk section and the atmosphere around the buiding is assimilated by taking a very high value, say 10^{10} m^3, for the "hall" volume.

The action of the valves is introduced by changing 2 or 3 statements in the code in such a manner, that the discharge section is initially open and closes at a certain elapsed time.

1.5.2. Leakage to the reactor hall

A failure of the fuel handling machine or an upper channel seal are the only imaginable accidents, that would provoke a direct leakage of organic coolant to the reactor hall.

This case can be computed by substituting the input data assigned to the vault. i.e volume and dousing rate by the respective values of the reactor hall and vice versa.

1.5.3. Other cases

A number of other applications may be imagined, which are more or less variations of the original problem, such as the calculation of the pressure difference between two chambers of the vault. Allthough CROOC was only intended to treat very specific problems of an ORGEL Prototype, it may readily be adapted to similar cases of a gas-cooled reactor.

1.6 Example

The present preliminary design of an ORGEL 250 Mwe Prototype is provided with a leak-tight containment. The reactor, the auxiliary coolant circuits and the main coolant piping are installed in an inertized vault of 4500 m3 free volume.
It is assumed, that one dousing system will inject 167 kg/s water into the vault during at least 30 secs beginning 3 secs after the accident. The reactor servicing hall and the other locals of the building total 38.000 m^3. The reactor servicing hall is provided with a powerfull dousing system, that also goes into action 3 secs after the accident, delivering 800 kg/s continously.

A rupture disk between vault and hall with a section of 7 m^2 relieves the vault pressure, as soon as it attains 2 bar. The initial leak rate for a complete rupture of the 600 cm inner diameter coolant outlet line has been assessed to 6680 kg/s. It is assumed, that the circuit pressure and the coolant vapour pressure maintain this discharge rate during 12 secs. After this delay the venting of the circuit and the closing of the main isolation valves produce an exponential decrease of the leak rate with a period of 1 sec.
A time step length of Δz_1 = 0,02 sec for the cycles before the opening of the rupture disk, and a Δ_2 = 0,2 secs for the remaining time were chosen.
The total computed time is chosen to 25 secs.

The resulting time dependent values of partial coolant, water and air (nitrogen) as will as for the total pressures and temperatures in the vault and the reactor hall are presented in Fig. 3-14. The peak values for the vault pressure and temperature are

$P_{v\ max}$ = 2.173 bar abs at . elapsed time zt = 12.64 secs.

and

$t_{v\ max}$ = 333.15 °C at zt = 2,84 secs

The corresponding values for the reactor hall are

$P_{h\ max}$ = 2.13 bar at zt = 21.84 secs and

$t_{h\ max}$ = 113,39 °C at zt = 13.04 secs

It should be noted, that, as the code has not yet been adapted to treat the state of saturated and condensing steam, the calculation of the partial water pressure in the hall is slightly incorrect from the 19 th. second onward. As at this moment the increase of partial water pressure cannot continue beyond the saturation value, while the temperature decreases, the actual peak pressure is obtained, when the steam is saturated at $P_{w\ sat}$ = 0.615 bar and $t_{w\ sat}$ = 86.7 °C (zt = 18.84 secs).
The subsequent decrease of temperature and pressure has been determined by hand calculation (s. dotted line Fig.11)

2. The program CROOC

2.1 General

The program CROOC performs the calculations, as described in part 1 of this report, and may draw graphs of the calculated results. CROOC is a FORTRAN-4 program, written for the I.B.M. 360/65 combined with a CALCOMP PLOTTER, as used at the EURATOM centre in ISPRA, ITALY. However, by removing the last part of the program i.c. the drawing of the graphs, the program may be used on other FORTRAN adapted computers also, The presented version needs about 32.000 storage places. A properly shortened version, without graph drawing, will do with about 5000 storage places as the biggest part of the necessary memory is used for storing of the calculated results. The program may calculate up to 10 different cases in one run. Neither the number of requested graphs nor the number of curves in each graph is limited. CROOC is self-resetting, that is for each case to be calculated, the input parameters are given a defined value and only the non-standard values have to be specified in the input.
The standard values are given in the next table.

Input parameters and standard value for CROOC			
Par. Number	FORTRAN name	Description	Standard value
1	VOLV	The volume of the vault	3800 m^3
2	OPSECV	Initial coolant leak rate	7500 kg/sec
3	TEMORG	Temperature of the coolant	360 °C
4	HU	Mist fraction	1
5	WPSECV	Initial dousing rate in the vault	167 kg/sec
6	ZS	Intervention time for dousing in the vault	3 sec.
7	DELZ	Initial time steps [until rupture disk opens]	0.02 sec
8	PB	Design pressure of rupture disk	2 bar
9	DELZA	Time steps after opening of rupture disk	0.2 sec
10	ZMAX	Total time	20 sec
11	OSURF	Free section of rupture disk	7 m^2
12	VOLH	Volume of the hall	38000 m^3
13	WPSECH	Initial dousing rate in the hall	149 kg/sec
14	ZSH	Intervention time for dousing in the hall	3 sec
15	ZO2	Leak interruption time	10 sec
16	ZOHALF	Half time of leak interruption	1 sec
17	ZWV2	Dousing interruption time in vault	30 sec
18	WPSV2	Second dousing rate in vault	0 kg/sec
19	ZWH2	Dousing interruption time in hall	30 sec
20	WPSH2	Second dousing rate in hall	0 kg/sec

Some of these parameters may need some extraplanation :

The time delay in dousing is counted in seconds from the moment that the leakage starts. The dousing in the vault and the hall may start at different times. The sprinklers in the hall will not start before the pressure cap is opened. Thus, if the dousing time delay for the hall is smaller than the time at which the rupture disk opens, the sprinklers in the hall start immediately afterthe opening of the disk. The program has also an option for changing the dousing rates, respectively in the vault and in the hall, after a certain time (parameters 16, 17, 18 and 19). The leak may be shut-off after a certain time, according to the exponential function :

$$L_T = L_i \ast [0.5]^{\frac{T-T1}{t}} \qquad [T > T_1]$$

in which L_T = leak rate at time T

L_i = initial leak rate

T_1 = leak interrupt time

t = half time of leak shut-off

A second accident might be introduced by the specification of a negative half time.

The values of a number of physical constants are defined at the beginning of the program, one may change these constants by changing the concerning statements. The present value are given in the next table.

Symbol	FORTRAN Name	Physical constant	Value
ρ_{li}	RHOIN	Initial density of the air	1.2 kg/m^3
C_{vl}	CAIR	Heat capacity of air	720 J/g °C
C_o	CORG	Heat capacity of organic	2500 J/g °C
C_w	CWAT	Heat capacity of water	2100 J/g °C
r_m	RW	Specific evaporation heat of water	$2.5*10^6$ j/kg
R_m	GASW	Gas constant of steam	469.4 J/kg °K
R_l	GASA	Gas constant of air	297.5 J/kg °K
R_o	GASO	Gas constant fo diphenyl	36.8 J/kg °K
K_1	COMPRO	Compressibility of organic	2
C_1	C1	Critical pressure	0.577 bar
n	EN	Exponent of adiabatic expansion	1.135.

The initial values of some physical variables are defined in the program-paragraph "INITIAL CONDITIONS". These values are reset for each new case.

Symbol	FORTRAN Name	Physical variable	Initial value
	ZT	TIME	0 SEC
t_i	TEMPV	Temperature in vault	20 °C
ρ_{li}	RHO	Density of air in vault	1.2 kg/m^3
t_i	TEMPH	Temperature in hall	20 °C
ρ_{li}	RHOH	Density of air in hall	1.2 kg/m^3
M_{oi}	QORGV	Organic in vault	0 kg
M_{wi}	QWATV	Water in vault	0 kg
M_{hoi}	QORGH	Organic in hall	0 kg
M_{hwi}	QWATH	Water in hall	0 kg

2.2 Description of the input for CROOC

The input for CROOC consists of a combination of fixed point-, floating point-4 and alphameric information. Each element of information is limited in its actual size by the length of its field. A field exists out of a certain number of columns in a punch card. The length of the fields is defined by the format statement in the program.
A fixed point number is written without a decimal point in the utmost right part of the field.
A floating point number is written with a decimal point and eventually with an exponent. The place within the field is not important, only the exponent must be written to the utmost right.
Alphamerical information might contain all the currently used symbols.

Type	Example	Value	Format symbol
Fixed point	3	3	I
Fixed point	3	30	I *)
Floating point	3.	3	E
Floating point	3. E+1	30	E
Alphamerical	*P = 2.0	-	A

*) The blanks after the first significant digit are assumed to be zeros.

The input for the program CROOC consists of two main parts :

1. - The non-standard specifications for the cases to be calculated
2. - The specifications for the graphs to be drawn, including titles etc.

The program performs first all the calculations, prints and stores the results and continues with the drawing of the graphs for which a choice may be made out of all the previously calculated data.

One case to be calculated is represented by one or more cards, of which the last one has an asterisk in the first column. In each of these cards are up to 4 parameters defined which do not have standard values as mentioned in the table. The format of these cards is : [A2, I4, E12.4, 3(I6, E12.4)]. The program stops the actual calculations and moves to the second part if it meets a card with two asterisks in the first column. In this card the total number of graphs to be drawn is mentioned also.

There must be two or more cards for each graph, of which the last one has an asterisk in the first columns. The first introductory card of a graph-set contains the number of calculated variable which has to be plotted versus time. The columns 7-72 of this card may contain alphamerical information which will be written underneath the graph. The numbers of the variables are :

2 Partial pressure of organic in the vault
3 Partial pressure of water in the vault
4 Partial pressure of air in the vault
5 Total pressure in the vault
6 Temperature in the vault
7 Organic material in the vault
8 Partial pressure of organic in the hall
9 Partial pressure of water in the hall
10 Partial pressure of air in the hall
11 Total pressure in the hall
12 Temperature in the hall
13 Organic material in the hall

A specific card, following the first introductory card of a graph-set, must be given for each curve to be drawn. Such a card contains the number of the calculation case out of which the values for the already specified variable must be taken, to be plotted versus time.

The columns 7-72 may contain alphamerical information which will be written at the last point of the curve. It is advisable to keep these texts rather short so the graphs will not be extended too much and might be reproduced on normal report format.
All the cards of a graph-set are read by CROOC with the format (A2, I4, 16A4).
The input example will illustrate the description of the data deck. The example exists out of 3 calculations and 2 graphs.
The first calculation uses the standard values of the input parameters, as given on page 23, except :

1. The leak rate is 750 kg/sec in place of 7500 kg/sec
2. The rupture disk opens at 4 bar in place of 2 bar
3. The total time of interest is only 10 sec.

The second and the third case performs the calculations at different leak rates.
The first graph will contain 3 pressure curves because the number 5 means the calculated total pressure in the vault according to page 27 , completed with a caption [CARD 6] and curve description.
The second graph will only use the 12 th variable, i.c. the temperature in the hall, out of the second and the third case.

2.3 The output of CROOC

The output of CROOC consists of :

1. The values of the input parameters [page 23]. The non-standard values are marked with an asterisk.
2. The tables with the calculated variables as mentioned on page 27 ., completed with time and quantities of organic, respectively in the vault and in the hall.
3. A printed message after properly finishing the preparation of the calcomp tape.
4. A magnetic tape which is used as intermediary between the I.B.M. 360/65 and the calcomp equipment.

2.4 A shortened version of CROOC

As the presented version of CROOC can be used only by a very special equipment as available at CETIS-EURATOM, CROOC may easily be altered for use on other FORTRAN adapted computers. The second part of the program, i.e. the drawing of the graphs, has to be removed. In this case, the preparing of the shortened version is performed as follows :

1. Remove the last part of the program which starts with :
   ```
   300 NG = II(1)
   ```
2. Replace this part by :
   ```
   300 continue
         stop
         end
   ```
3. Remove out of the dimension statement the matrix amatr(10,14,200)
4. Remove the two parts of the program where this matrix is filled.

Input example for CROOC

CETIS/CADI (EURATOM)

PROBLEM | DATE | PAGE | OF

```
CASE 1     1       2   750.          8      4.
           2 *   10    10.
CASE 2     3 *    2    5000.
CASE 3     4 *    2     5.   E+2
           5 **   2
           6      5 FIG. 1      PRESSURE CURVES FOR THE VAULT AT SOME LEAK RATES.
GRAPH 1    7      1750 KG/SEC LEAK RATE
           8      35000 KG/SEC LEAK RATE
           9 *    2500 KG/SEC LEAK RATE
          10      6 FIG. 2      TEMPERATURE CURVES FOR THE HALL
GRAPH 2   11      25000 KG/SEC LEAK RATE
          12 *    3 500 KG/SEC LEAK RATE
```

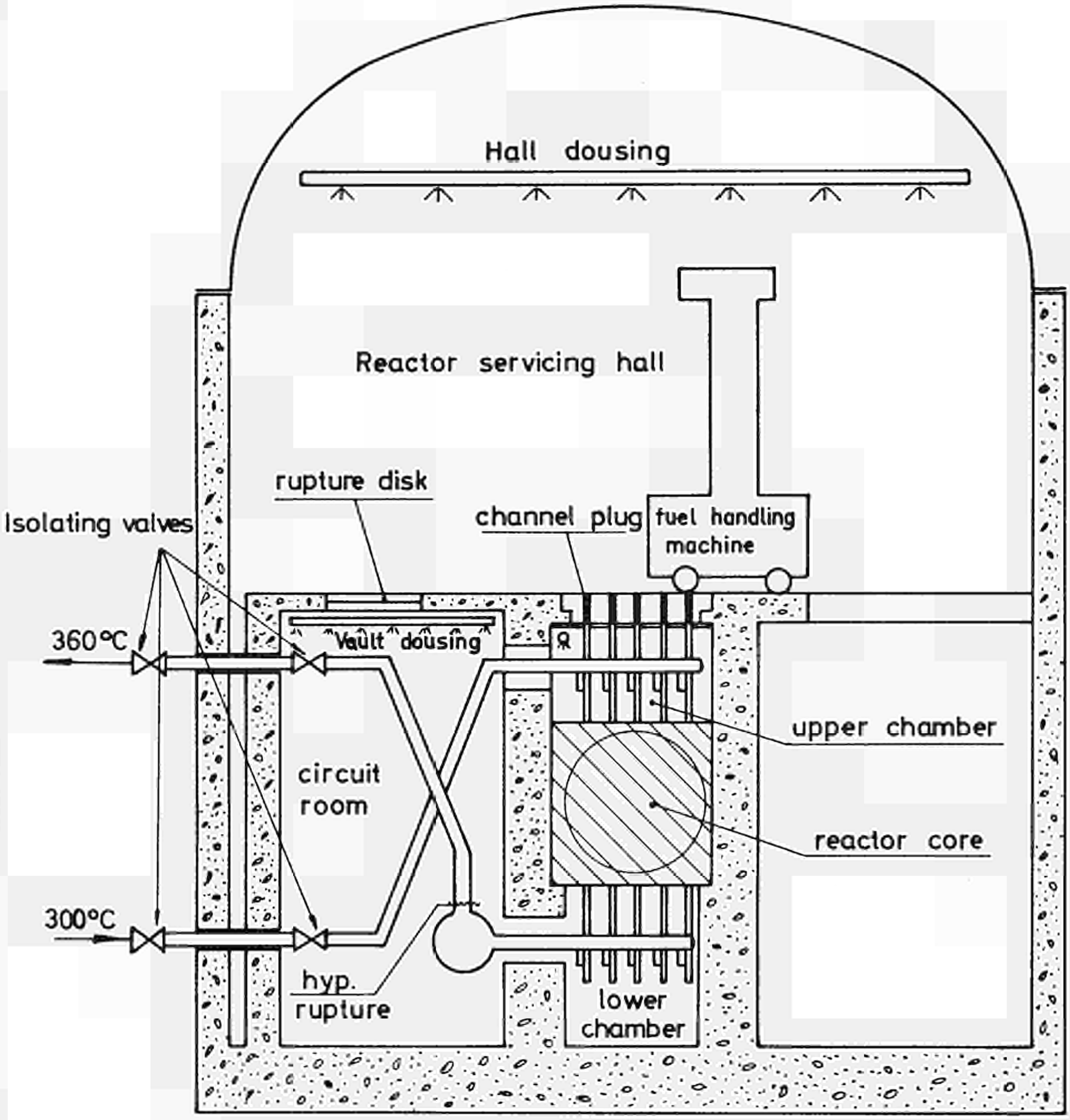

Fig.1 Containment system (schematic)

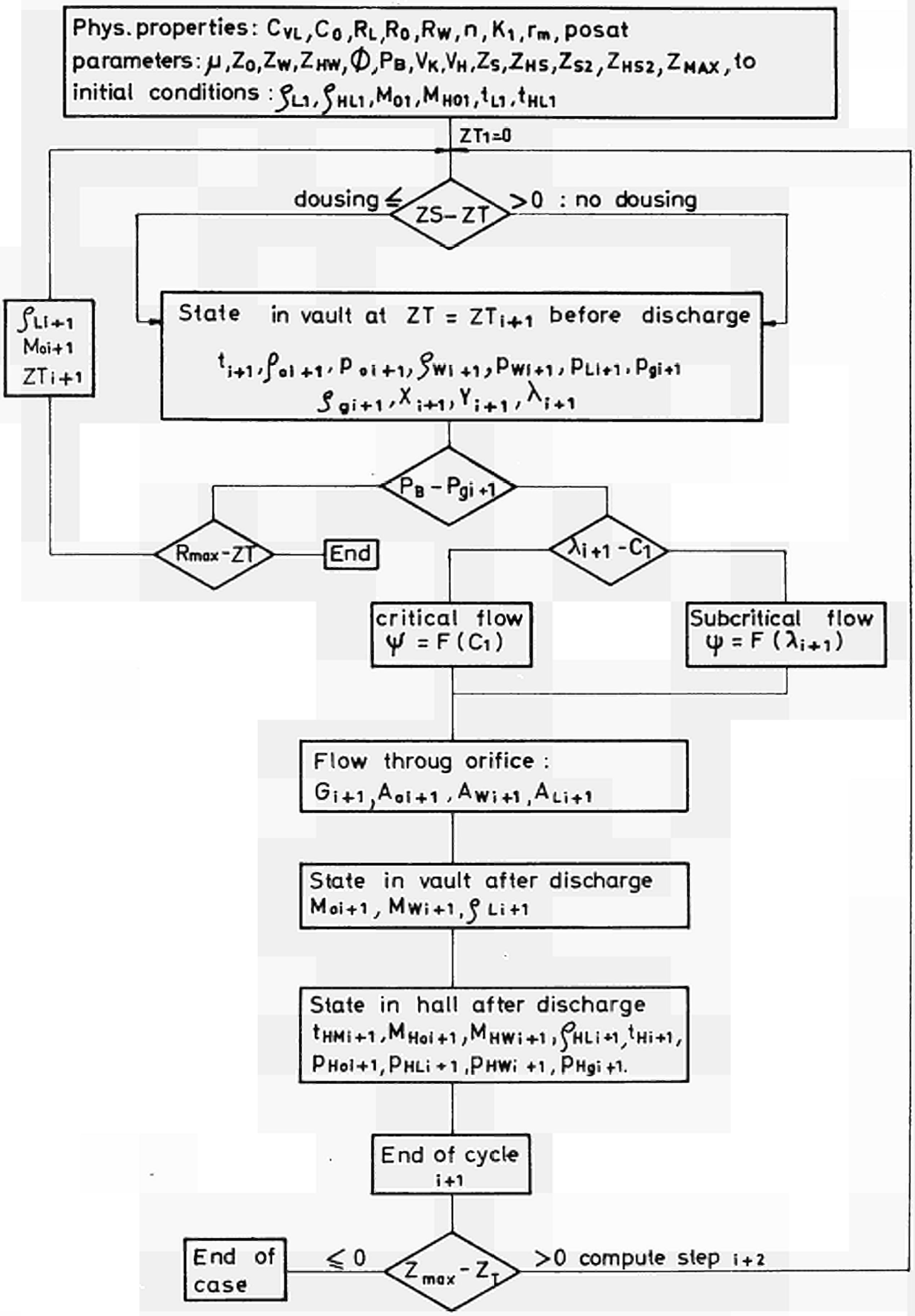

Fig. 2. General scheme of calculation

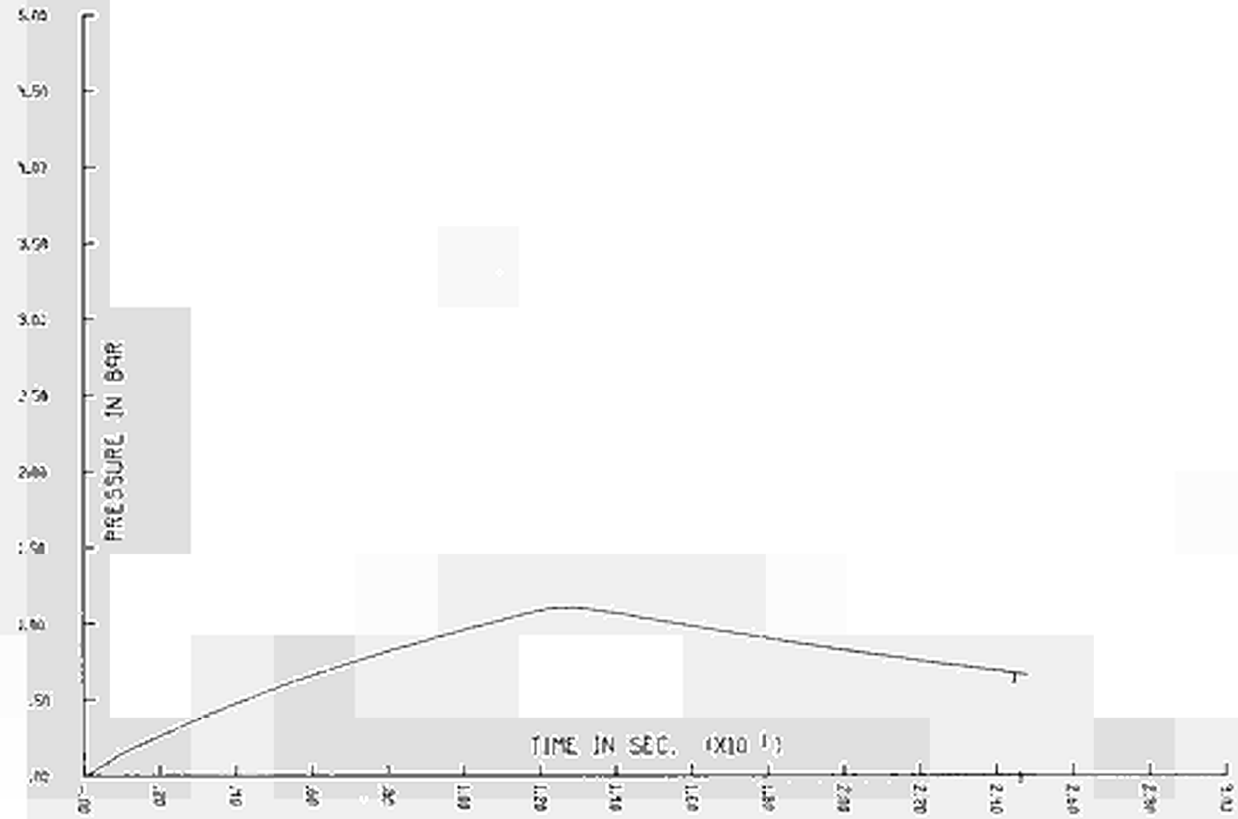

FIG. 3 PARTIAL COOLANT PRESSURE IN VAULT

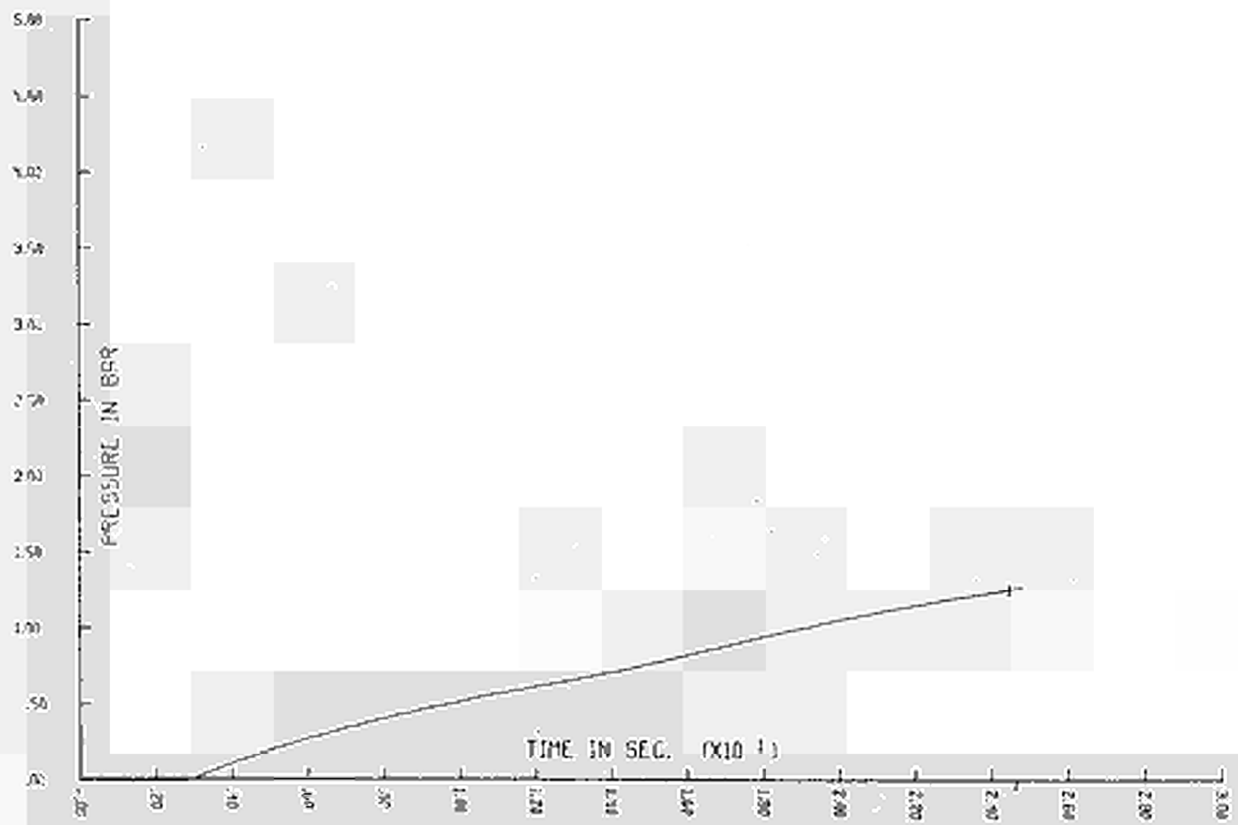

FIG. 4 PARTIAL WATER PRESSURE IN VAULT

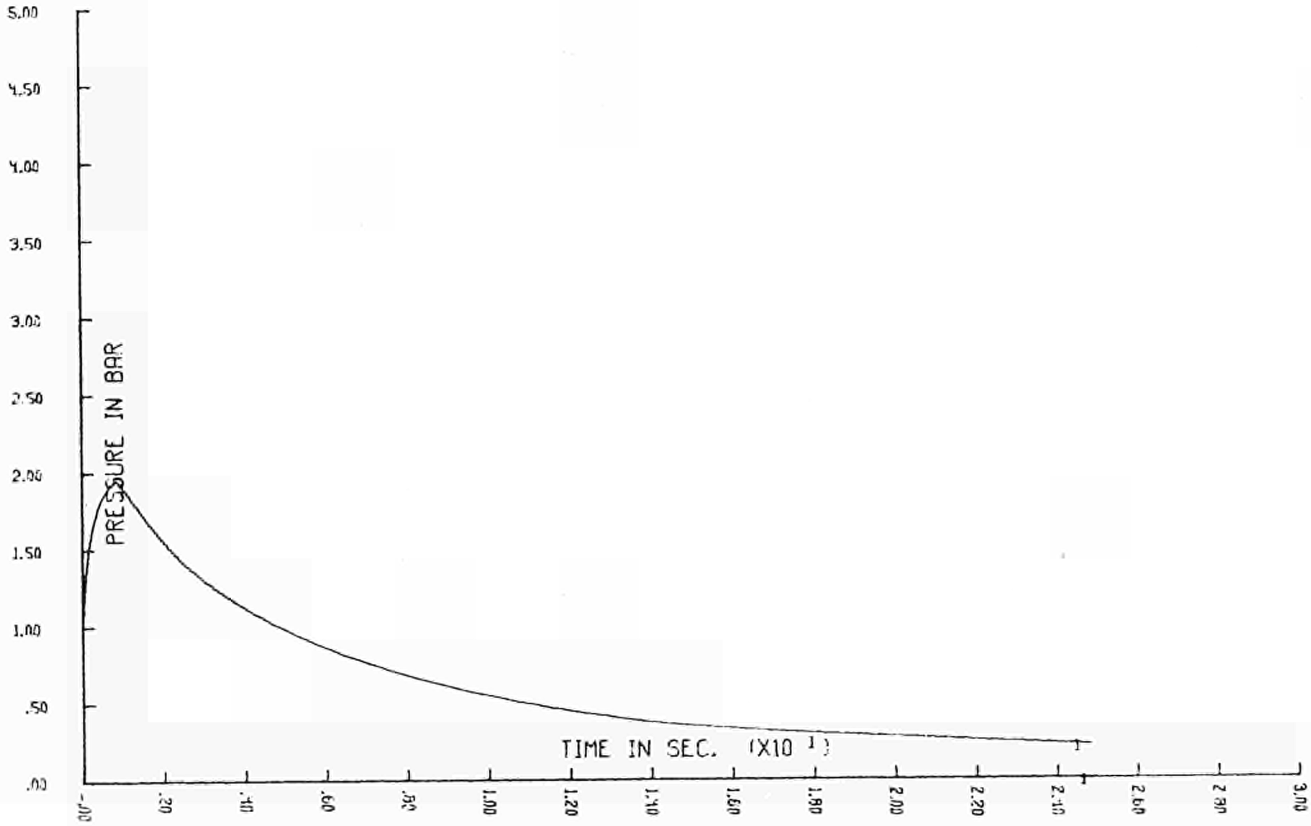

FIG. 5 PARTIAL NITROGEN PRESSURE IN VAULT

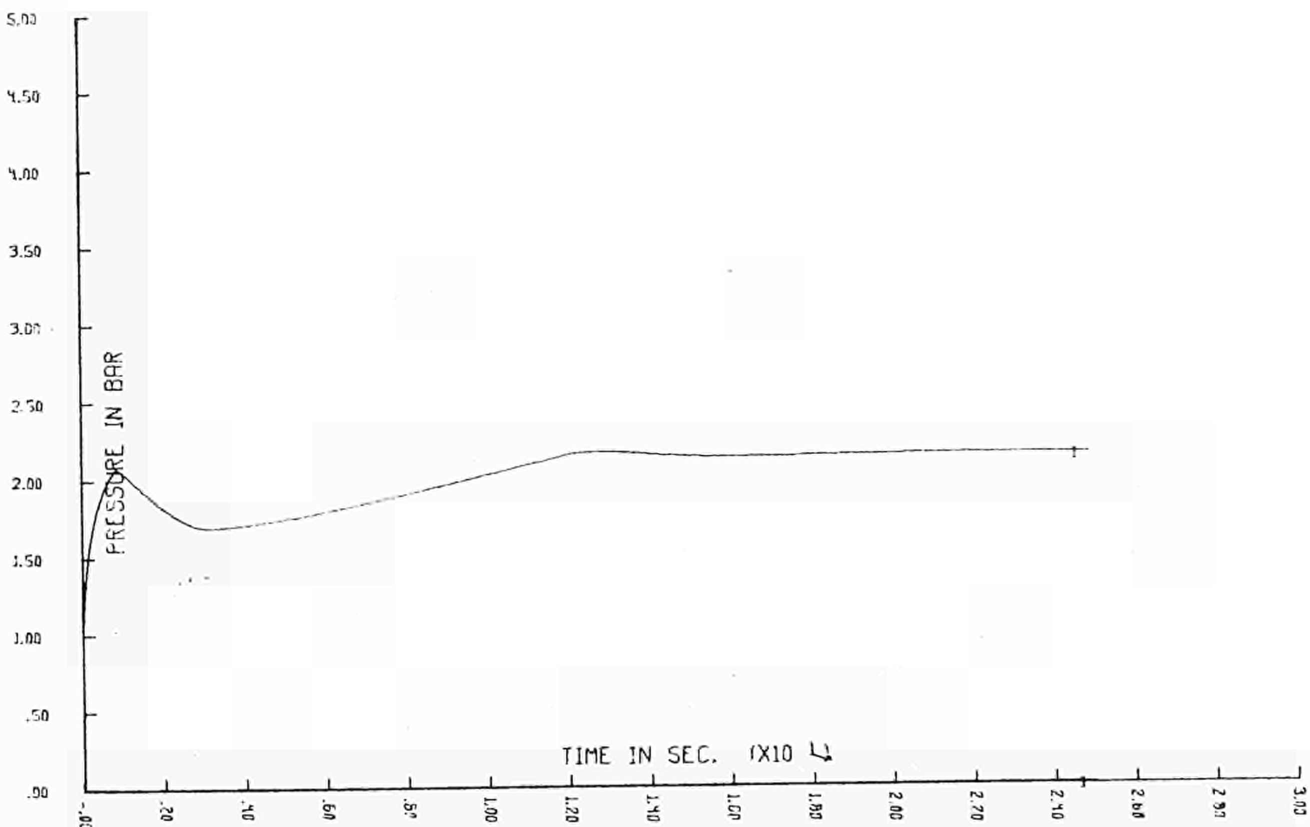

FIG. 6 TOTAL VAULT PRESSURE

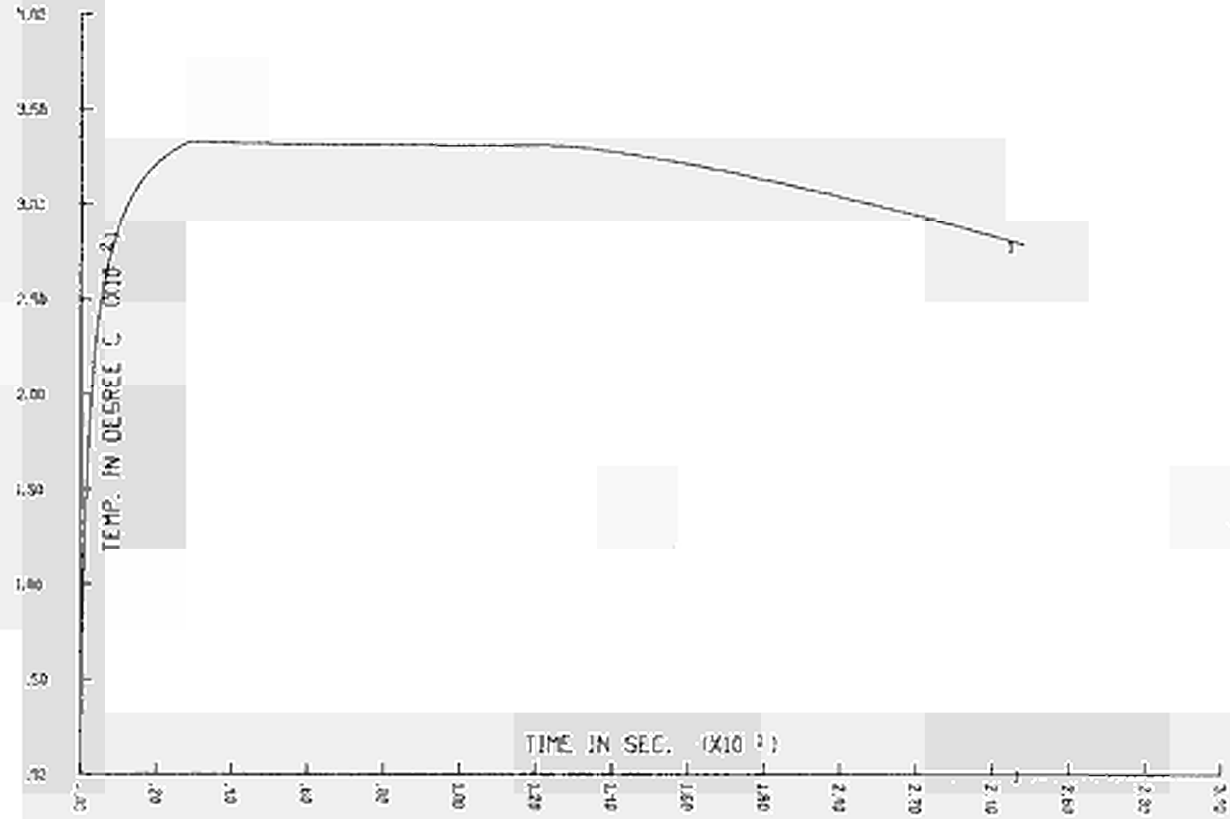

FIG. 7 TEMPERATURE IN THE VAULT

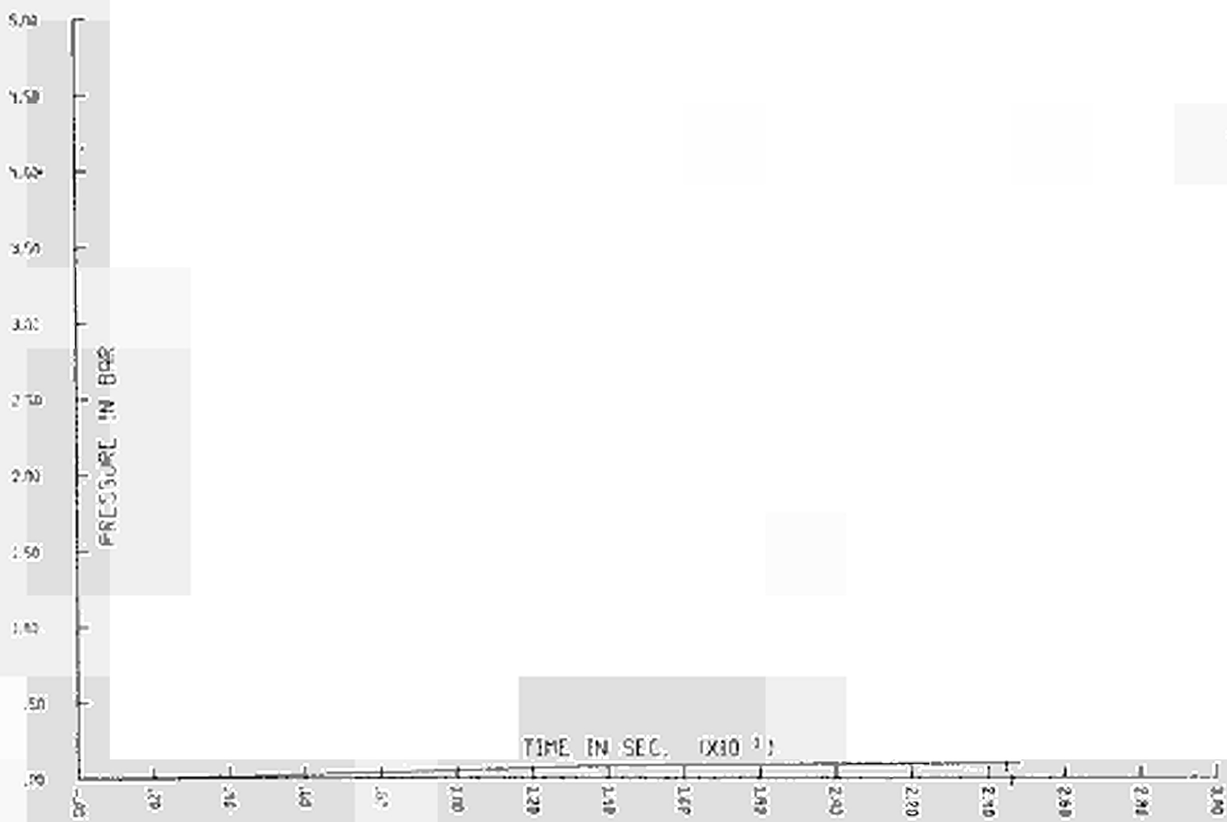

FIG. 8 PARTIAL COOLANT PRESSURE IN HALL

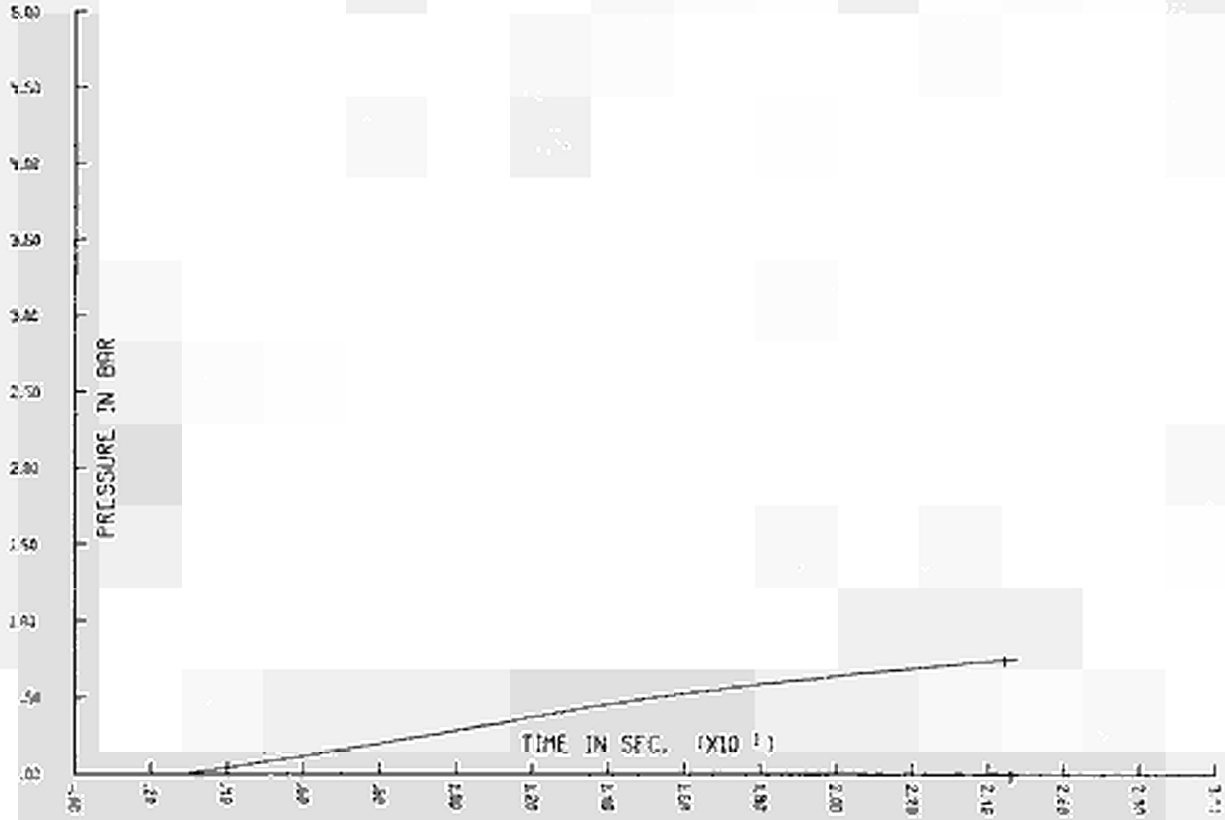

FIG. 9 PARTIAL WATER PRESSURE IN HALL

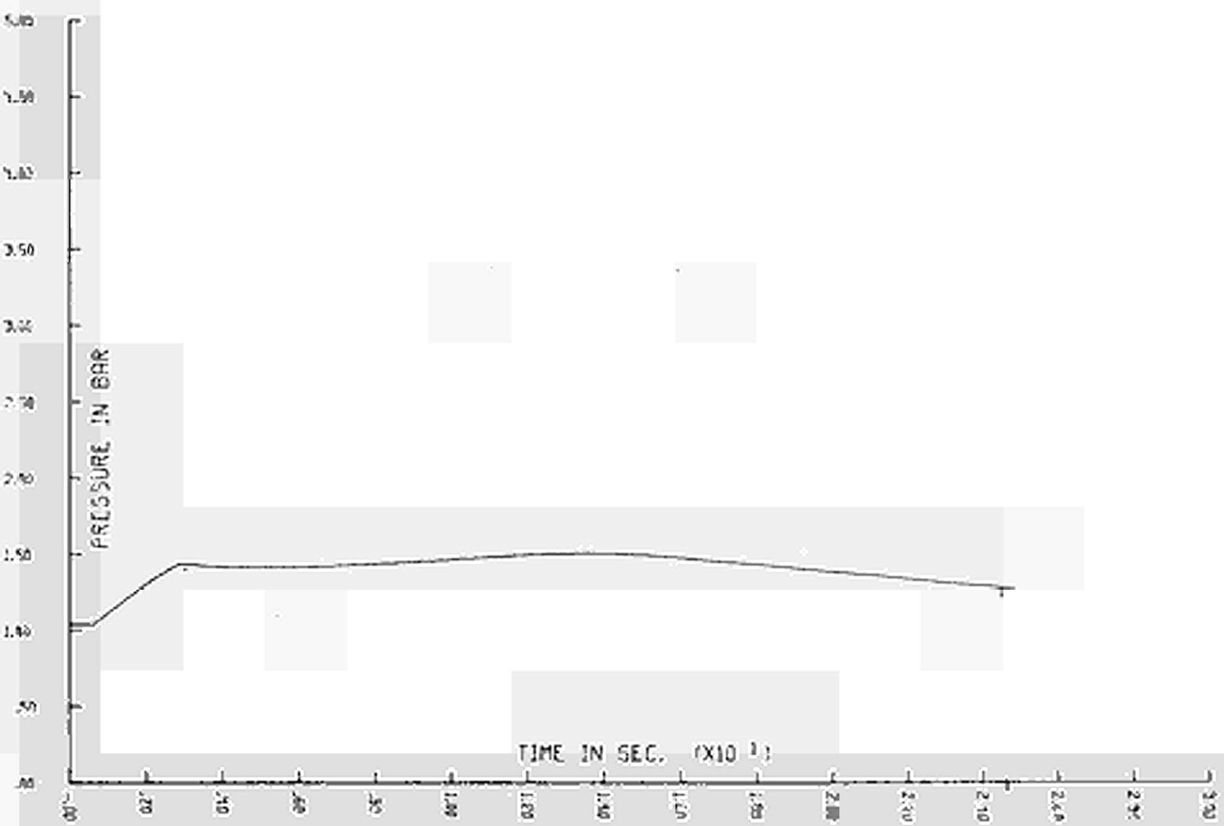

FIG. 10 PARTIAL AIR PRESSURE IN HALL

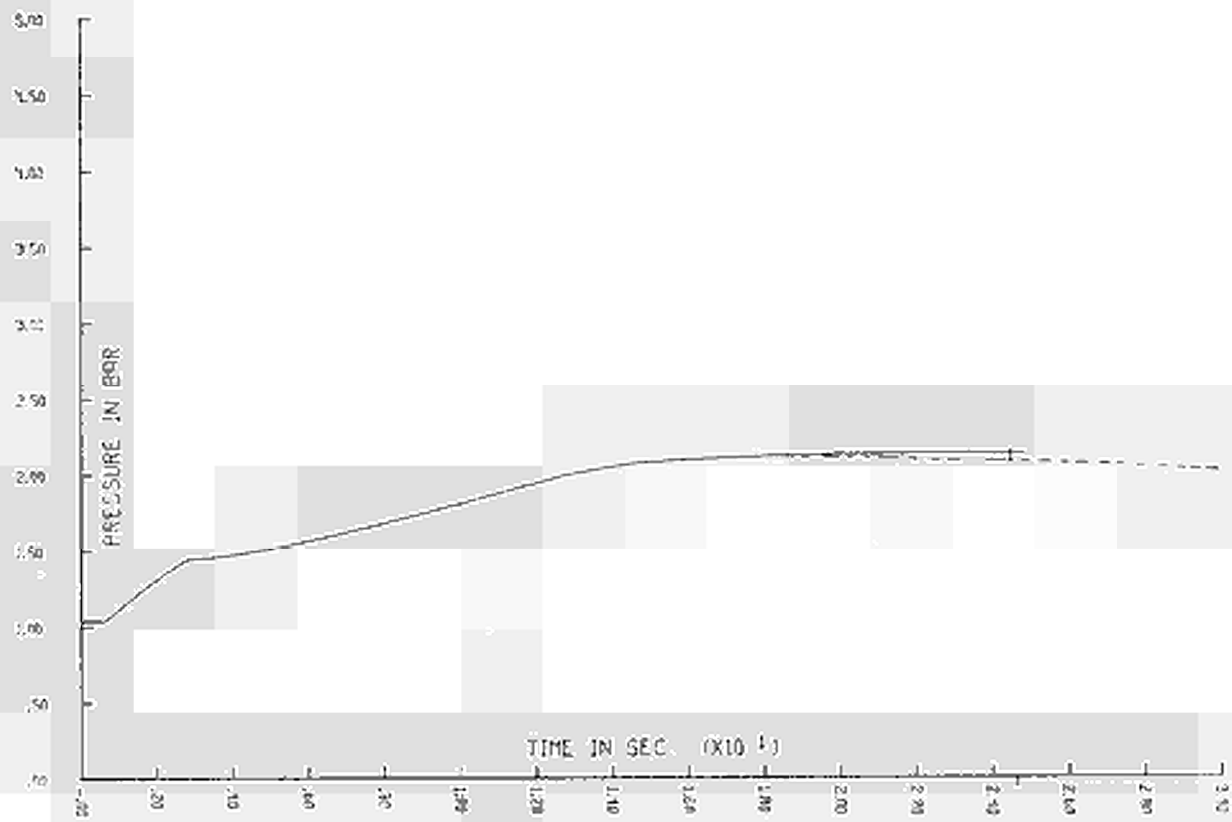

FIG. 11 TOTAL PRESSURE IN HALL

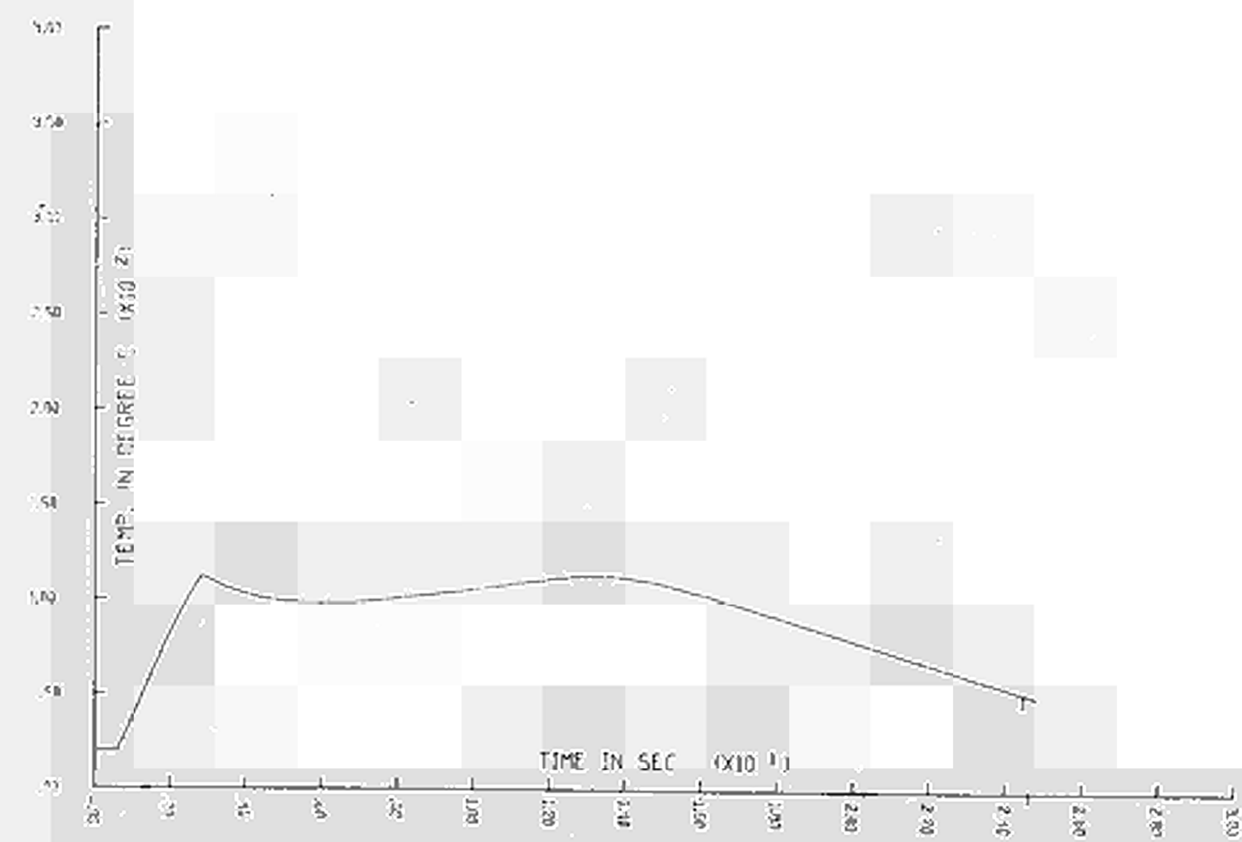

FIG.12 TEMPERATURE IN HALL

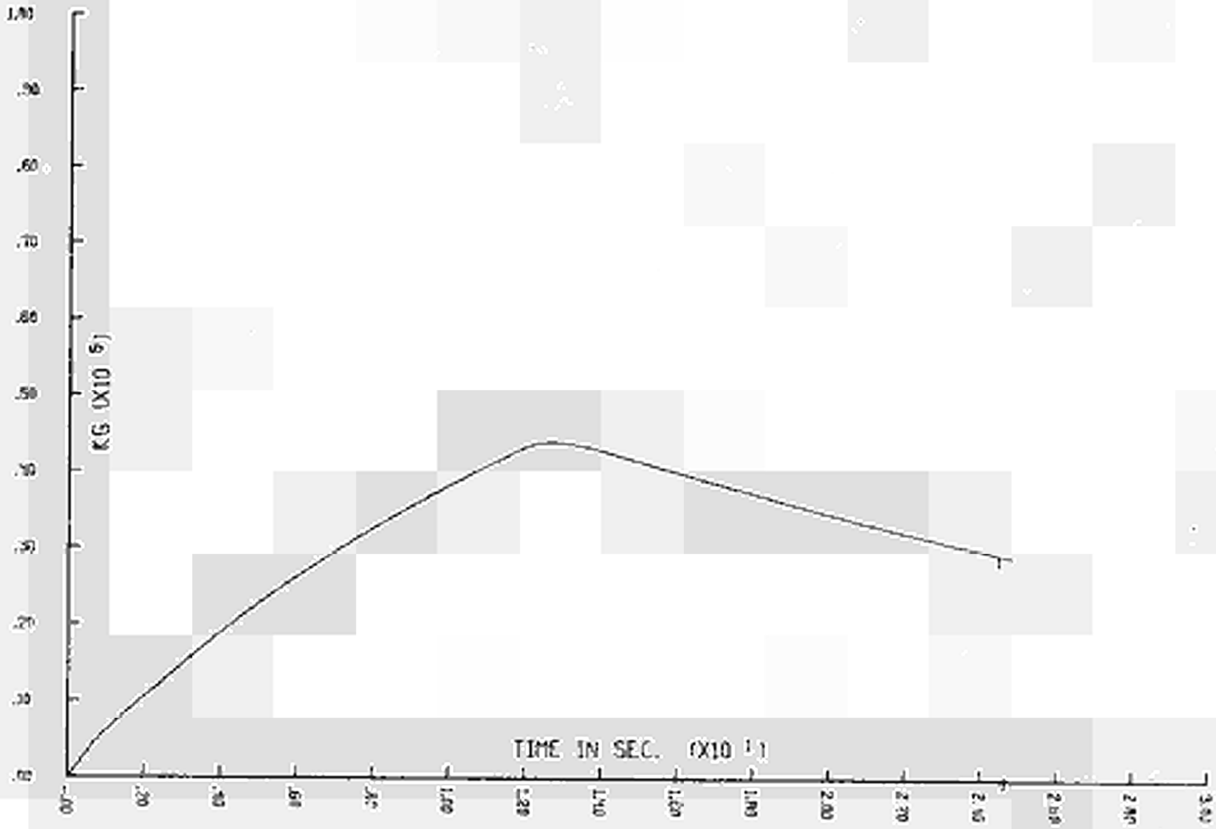

FIG.13 MASS OF COOLANT IN VAULT

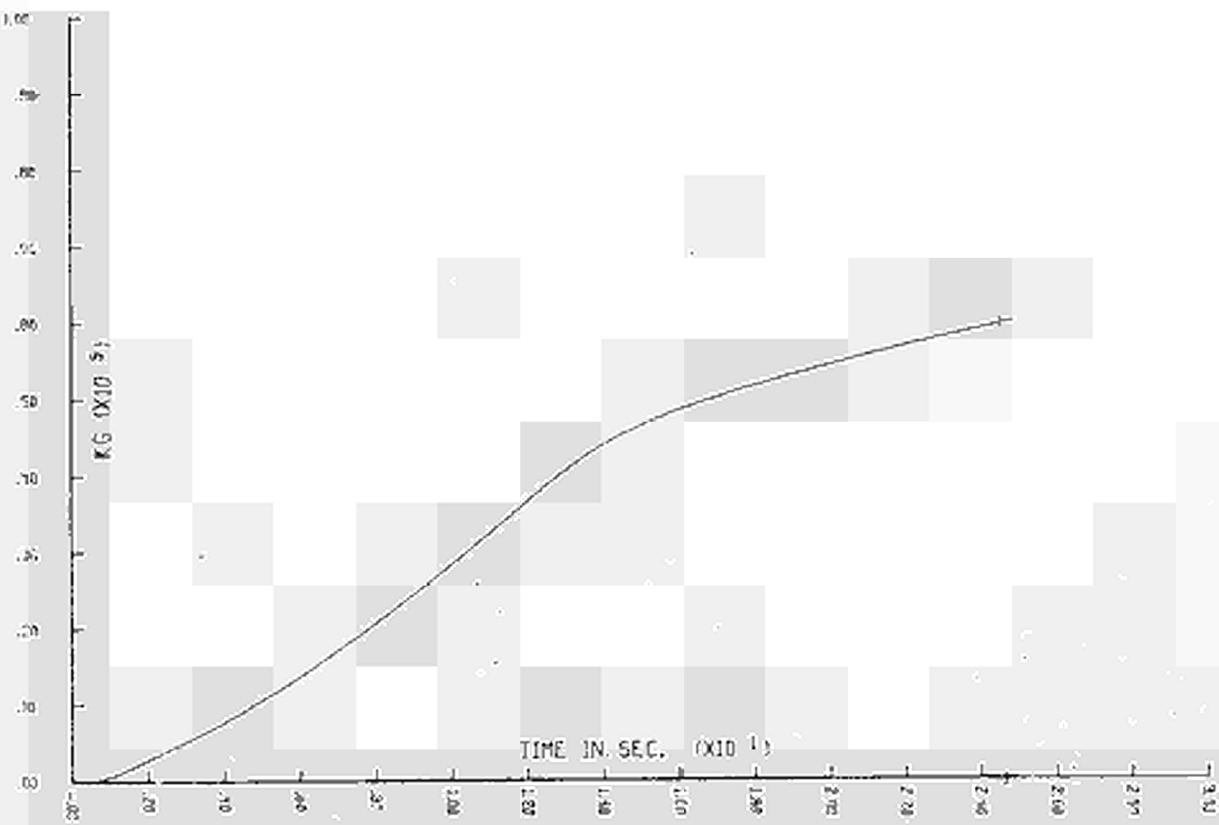

FIG.14 MASS OF COOLANT IN HALL

```
C------PROGRAM CROOC BY HERMAN I. DE WOLDE AND R. SIMON-----------------
C       DATE JULY 1968.
C
C       CROOC CALCULATES THE BUILD-UP OF CONTAIMENT PRESSURE AFTER SEVERE
C      1PIPING FAILURE
C
C
C
        DIMENSION TIME(200),ATR(200),IC(10),ALFAB(16)
        DIMENSION AMATR(10,14,200),TT(3),PP(3),TTP(3),AMASS(3),ALFA(10,16)
       1,AL(16)
        DIMENSION PAR(20),ST(20),II(4),PARM(4),NCY(10),ZMC(10)
        EQUIVALENCE (PAR(1),VOLV),(PAR(2),OPSEC),(PAR(3),TEMORG),(PAR(4),H
       1U),(PAR(5),WPSECV),(PAR(6),ZS),(PAR(7),DELZ),(PAR(8),PB),(PAR(9),D
       2ELZA),(PAR(10),ZMAX),(PAR(11),OSURF),(PAR(12),VOLH),(PAR(13),WPSEC
       3H),(PAR(14),ZSH)
        EQUIVALENCE (PAR(2),OPSECV)
        EQUIVALENCE (PAR(15),ZO2),(PAR(16),ZOHALF),(PAR(17),ZWV2),(PAR(18)
       1,WPSV2),(PAR(19),ZWH2),(PAR(20),WPSH2)
        DATA STAR,STAR,DSTAR,BLNK/'*','*','**',' '/
        DATA TT,PP,TTP,AMASS/0.0,0.00001,10.0,5.0,0.0,0.0,400.0,0.0,0.0,1.
       10E+5,0.0,0.0/
C
C------CONSTANTS--------------------------------------------------------
C
        RHOIN=1.2
        CAIR=720.
        CORG=2500.
        CWAT=2100.
        RW=2.5E+6
        GASW=469.4
        GASA=297.5
        GASO=36.8
        COMPRO=2.0
        C1=0.577
        EN=1.135
        ICASE=0
C
C------FIXED VALUES FOR THE VARIABLE INPUT PARAMETERS ------------------
C
     80 CONTINUE
      1 VOLV=3300.
      2 OPSECV=7500.
      3 TEMORG=360.
      4 HU=1.
      5 WPSECV=167.
      6 ZS=3.
      7 DELZ=0.02
      8 PB=2.
```

```
   11 OSURF= 7.
   12 VOLH=38000.
   13 WPSECH=149.
   14 ZSH=3.
   15 ZO2=10.
   16 ZOHALF=1.
   17 ZWV2=30.
   18 WPSV2=0.
   19 ZWH2=30.
   20 WPSH2=0.
      DO 89 I=1,20
   89 ST(I)=BLNK
C
C-----READ INPUT-----------------------------------------------------
C
   90 READ(5,92)TAR,(II(I),PARM(I),I=1,4)
   92 FORMAT(A2,I4,E12.4,3(I6,E12.4))
      DO 96 I=1,4
      IF(II(I))96,96,94
   94 IA=II(I)
      ST(IA)=STAR
      PAR(IA)=PARM(I)
   96 CONTINUE
      IF(TAR.EQ.STAR)GO TO 98
      IF(TAR.NE.DSTAR)GO TO 90
      GO TO 300
   98 CONTINUE
C
C-----INITIAL CONDITIONS---------------------------------------------
C
      ZT=0.
      TEMPV=20.
      QORGV=0.
      NCYCL=0
      NWAY=1
      RHO=RHOIN
      WSWIT=0.
      QWATV=0.
      PH=1.
      WSWITH=0.
      RHOH=1.2
      QORGH=0.
      TEMPH=20.
      QWATH=0.
      DZ=DELZ
      PHO=0.
      PHW=0.
      PHA=RHOH*GASA*(TEMPH+273.)*1.E-5
      PH=PHO+PHW+PHA
      G=0.
```

```
      TT(3)=ZMAX
      ICASE=ICASE+1
C
C
C-----WRITE INPUT------------------------------------------------------
C
      OPSA=OPSECV
      TAU=ALOG(0.5)/(-ZOHALF)
      WRITE(6,101)
  101 FORMAT (1H1/' *****  INPUT DATA  *****'///)
      WRITE(6,102) VOLV,ST(1),OPSECV,ST(2),TEMORG,ST(3),HU,ST(4),WPSECV,
     1ST(5),ZS,ST(6),DELZ,ST(7),PB,ST(8),DELZA,ST(9),ZMAX,ST(10),OSURF,S
     2T(11),VOLH,ST(12),WPSECH,ST(13),ZSH,ST(14)
  102 FORMAT (
     A'  1',' VOLUME OF VAULT',14X,F12.3,' M3 ',A1//
     B'  2',' LEAK RATE',20X,F12.3,' KG/SEC ',A1//
     C'  3',' TEMPERATURE OF ORGANIC',7X,F12.3,' DEGREE C ',A1//
     D'  4',' MIST,FRACTION',16X,F12.3,' ',A1//
     E'  5',' DOUSING RATE IN VAULT',8X,F12.3,' KG/SEC ',A1//
     F'  6',' TIME DELAY DOUSING IN VAULT',2X,F12.3,' SEC ',A1//
     G'  7',' TIME STEP 1',18X,F12.3,' SEC ',A1//
     H'  8',' RUPTURE DISK OPENS AT',8X,F12.3,' BAR ',A1//
     I'  9',' TIME STEP 2',18X,F12.3,' SEC ',A1//
     J' 10',' TOTAL TIME ',18X,F12.3,' SEC ',A1//
     K' 11',' FREE SECTION OF RUPTURE DISK',1X,F12.3,' M2 ',A1//
     L' 12',' VOLUME OF HALL',15X,F12.3,' M3 ',A1//
     M' 13',' DOUSING RATE IN HALL',9X,F12.3,' KG/SEC ',A1//
     N' 14',' TIME DELAY DOUSING IN HALL',3X,F12.3,' SEC ',A1/ )
      WRITE(6,105)Z02,ST(15),ZOHALF,ST(16),ZWV2,ST(17),WPSV2,ST(18),ZWH2
     1,ST(19),WPSH2,ST(20)
  105 FORMAT (
     A' 15',' LEAK INTERRUPT TIME',10X,F12.3,' SEC ',A1//
     B' 16',' HALF TIME',20X,F12.3,' SEC ',A1//
     C' 17',' DOUSING IN VAULT INTERRUPTED',1X,F12.3,' SEC ',A1//
     D' 18',' SECOND DOUSING RATE IN VAULT',1X,F12.3,' KG/SEC ',A1//
     E' 19',' DOUSING IN HALL INTERRUPTED',2X,F12.3,' SEC ',A1//
     F' 20',' SECOND DOUSING RATE IN HALL',2X,F12.3,' KG/SEC ',A1//)
      WRITE(6,103)
  103 FORMAT (1H1/' STEP TIME  RELATIVE PRESSURES IN VAULT TEMP. ',
     1'  ORGANIC  ',10X,
     2' RELATIVE PRESSURES IN HALL  TEMP.  ORGANIC    MASS'/
     312X,' ORG.  WATER  AIR  TOTAL ',8X,' IN VAULT',10X,
     4'  ORG.  WATER  AIR  TOTAL ',8X,' IN HALL  DISCHARGE'//)
  104 FORMAT (I4,F6.2,4F7.3,F7.2,E11.3,10X,4F7.3,F7.2,2E11.3)
      PVA=RHO*GASA*(TEMPV+273.)*1.E-5
      PVO=0.
      PVW=0.
      PV=PVA
      GO TO 130
C
```

```
C-----CALCULATIONS FOR THE VAULT------------------------------------
C
  110 ARG1=RHO*VOLV*CAIR*TEMPV
      ZT=ZT+DELZ
      IF(ZO2.GT.ZT)GO TO 140
      OPSECV=OPSA*EXP(TAU*(ZO2-ZT))
  140 IF(ZWV2.GT.ZT)GO TO 142
      WPSECV=WPSV2
  142 IF(ZWH2.GT.ZT)GO TO 144
      WPSECH=WPSH2
  144 CONTINUE
      IF(ZS.GT.ZT) GO TO 125
      WSWIT=1.
  125 CONTINUE
      ARG2=QORGV*CORG*TEMPV
      ARG3=OPSECV*DELZ*TEMORG*CORG
      ARG4=WPSECV*DELZ*RW*WSWIT
      ARG5=RHO*VOLV*CAIR
      ARG6=(QORGV+OPSECV*DELZ)*CORG
      TEMPV=(ARG1+ARG2+ARG3-ARG4)/(ARG5+ARG6)
      NCYCL=NCYCL+1
      RHOVO=(QORGV+OPSECV*DELZ)/VOLV
  112 PVO=RHOVO*GASO*(TEMPV+273.15)*1.E-5/COMPRO
      PVOX=EXP(0.0118*(TEMPV-244.))
      IF(PVOX.GT.PVO)GO TO 113
      PVO=PVOX
  113 CONTINUE
      QWATV=(QWATV+WPSECV*DELZ)*WSWIT
      RHOVW=QWATV/VOLV
      PVW=RHOVW*GASW*(TEMPV+273.)*1.E-5
      PVA=RHO*GASA*(TEMPV+273.)*1.E-5
      PV=PVO+PVW+PVA
      RHOVG=HU*RHOVO+RHOVW+RHO
      X=(HU*RHOVO)/RHOVG
      Y=RHOVW/RHOVG
C
C
      GO TO (126,200),NWAY
  126 IF(PV-PB) 128,128,132
  128 IF(ZT-ZMAX)130,130,223
  130 RHO=RHOIN
      WRITE(6,104)NCYCL,ZT,PVO,PVW,PVA,PV,TEMPV,QORGV
C
C-----STORE THE CALCULATED RESULTS----------------------------------
C
      I=ICASE
      J=NCYCL+1
      AMATR(I,1,J)=ZT
      AMATR(I,2,J)=PVO
      AMATR(I,3,J)=PVW
```

```
      AMATR(I,4,J)=PVA
      AMATR(I,5,J)=PV
      AMATR(I,6,J)=TEMPV
      AMATR(I,7,J)=QORGV
      AMATR(I,8,J)=PHO
      AMATR(I,9,J)=PHW
      AMATR(I,10,J)=PHA
      AMATR(I,11,J)=PH
      AMATR(I,12,J)=TEMPH
      AMATR(I,13,J)=QORGH
      AMATR(I,14,J)=G
      QORGV=QORGV+DELZ*OPSECV
      GO TO 110
  132 NWAY=2
      GO TO 200
  134 STOP
C
C-----THE PRESSURE CAP IS OPEN---------------------------------------------
C
  200 AMDA=PH/PV
      IF(AMDA.LT.1.)GO TO 203
      WRITE(6,201)
  201 FORMAT (' END OF RUN BY P-VAULT IS LESS THAN P-HALL')
      ZMAX=ZT-DELZ
      GO TO 223
  203 CONTINUE
      IF(ZSH.GT.ZT) GO TO 202
      WSWITH=1.
  202 IF(AMDA-C1)204,204,206
  204 PSI=(C1**(1./EN))*SQRT(EN*(1.-C1**((EN-1.)/EN))/(EN-1.))
      GO TO 208
  206 PSI=AMDA**(1./EN)*SQRT(EN*(1.-AMDA**((EN-1.)/EN))/(EN-1.))
  208 CONTINUE
      G=OSURF*PSI*SQRT(2.*PV*RHOVG*1.E+5)
      AO=X*G
      AW=Y*G
      AA=G-AO-AW
C
C-----QUANTITY OF ORGANIC AND LOSS OF WATER IN THE VAULT---------------
C
      QORGV=QORGV+DELZ*OPSECV-AO*DELZ
      QWATV=(QWATV-AW*DZ)*WSWITH
      RHO=RHO-AA*DZ/VOLV
      IF(ZSH.GT.ZT) GO TO 220
      WSWITH=1.
  220 ARG1=(RHOH*VOLH*CAIR+QORGH*CORG)*TEMPH
      QWATH=QWATH+AW*DZ*WSWIT+WPSECH*DZ*WSWITH
      ARG7=QWATH*CWAT*TEMPH
      ARG8=QWATH*CWAT
      ARG2=(AO*CORG+AA*CAIR)*DZ*TEMPV
```

```
      ARG3=(WPSECH*DZ*RW)*WSWITH
      ARG4=(RHOH*VOLH+AA*DZ)*CAIR
      ARG5=(QORGH+AO*DZ)*CORG
      TEMPH=(ARG1+ARG2-ARG3+ARG7)/(ARG4+ARG5+ARG8)
      QORGH=QORGH+AO*DZ
      RHOHA=RHOH+AA*DZ/VOLH
      TEMPH=(TEMPH+273.)*(RHOHA/RHOH)**0.4-273.
      RHOH=RHOHA
      PHA=RHOH*GASA*(TEMPH+273.)*1.E-5
      PHW=QWATH*GASW*(TEMPH+273.15)*1.E-5/VOLH
      PHO=EXP(0.0118*(TEMPH-244.))
      PHOX=(QORGH*GASO*(TEMPH+273.15)*1.E-5)/(VOLH*COMPRO)
      IF(PHOX.GT.PHO)GO TO 221
      PHO=PHOX
  221 CONTINUE
      PH=PHA+PHW+PHO
      DELZ=DELZA
      DZ=DELZ
      IF((NCYCL-(50*(NCYCL/50))).NE.0)GO TO 222
      WRITE(6,103)
  222 CONTINUE
      WRITE(6,104)NCYCL,ZT,PVO,PVW,PVA,PV,TEMPV,QORGV,
     1PHO,PHW,PHA,PH,TEMPH,QORGH,G
C
C-----STORE THE CALCULATED RESULTS--------------------------------------
C
      I=ICASE
      J=NCYCL+1
      AMATR(I,1,J)=ZT
      AMATR(I,2,J)=PVO
      AMATR(I,3,J)=PVW
      AMATR(I,4,J)=PVA
      AMATR(I,5,J)=PV
      AMATR(I,6,J)=TEMPV
      AMATR(I,7,J)=QORGV
      AMATR(I,8,J)=PHO
      AMATR(I,9,J)=PHW
      AMATR(I,10,J)=PHA
      AMATR(I,11,J)=PH
      AMATR(I,12,J)=TEMPH
      AMATR(I,13,J)=QORGH
      AMATR(I,14,J)=G
      IF(ZT.LT.ZMAX)GO TO 110
  223 NCY(ICASE)=NCYCL
      ZMC(ICASE)=ZMAX
      GO TO 80
C
C-----DESIGN THE GRAPHS-------------------------------------------------
C
  300 NG=II(1)
```

```
      ING=0
  302 ING=ING+1
      IF(ING-NG)306,306,380
  306 CONTINUE
  310 FORMAT (A2,I4,16A4)
  308 READ (5,310) AA,NV,(AL(I),I=1,16)
      ICC=0
  312 ICC=ICC+1
      READ (5,310) AA,IC(ICC),(ALFA(ICC,I),I=1,16)
      IF(AA.NE.STAR)GO TO 312
      NC=ICC
      TT(3)=0.
      DO 313 I=1,NC
      KK=IC(I)
      IF(TT(3).GT.ZMC(KK))GO TO 313
      TT(3)=ZMC(KK)
  313 CONTINUE
      CONVX=TT(3)/15.
      CALL FINIM(0.,0.)
      IF((ING-5*(ING/5)).NE.0)GO TO 314
      CALL FINIM(25.,-60.)
  314 CALL SYMBL4(0.0,1.0,0.3,0.0,AL,64)
      CALL FINIM(0.0,3.0)
      IF(NV.GT.5)GO TO 320
  318 CALL DESSIN(TT,PP,3,1,1,1,0,0,15.0,10.0,0,0,13H TIME IN SEC.,-13,1
     16H PRESSURE IN BAR,16,0)
      CONVY=PP(1)/10.
      GO TO 350
  320 IF(NV.GT.6)GO TO 324
  321 CALL DESSIN(TT,TTP,3,1,1,1,0,0,15.0,10.0,0,0,13H TIME IN SEC.,-13,
     118H TEMP. IN DEGREE C,18,0)
      CONVY=TTP(1)/10.
      GO TO 350
  324 IF(NV.GT.7)GO TO 326
  325 CALL DESSIN(TT,AMASS,3,1,1,1,0,0,15.0,10.0,0,0,13H TIME IN SEC.,-1
     13,3H KG,3,0)
      CONVY=AMASS(1)/10.
      GO TO 350
  326 IF(NV.GT.11)GO TO 330
      GO TO 318
  330 IF(NV.GT.12)GO TO 334
      GO TO 321
  334 IF(NV.GT.13)GO TO 340
      GO TO 325
  340 IF(NV.GT.14)GO TO 346
  342 CALL DESSIN(TT,AMASS,3,1,1,1,0,0,15.0,10.0,0,0,13H TIME IN SEC.,-1
     13,7H KG/SEC,7,0)
      CONVY=AMASS(1)/10.
      GO TO 350
  346 WRITE (6,348)
```

```
348 FORMAT (' ERROR EXIT  NV IS LARGER THAN 14')
    STOP
350 CONTINUE
    DO 364 INC=1,NC
    KC=IC(INC)
    NCYCL=NCY(KC)
    DO 360 I=1,NCYCL
    TIME(I)=AMATR(KC,1,I)
360 ATR(I)=AMATR(KC,NV,I)
    DO 362 I=1,16
362 ALFAB(I)=ALFA(INC,I)
    CALL DESSIN(TIME,ATR,NCYCL,1,1,1,0,0,15.0,-10.0,0,0,1H ,-1,1H ,1,0
   1)
    AM=TIME(NCYCL)
    AN=ATR(NCYCL)
    AM=AM/CONVX
    AN=AN/CONVY
    CALL SYMBL4(AM,AN,0.15,0.0,ALFAB,64)
364 CONTINUE
    CALL FINIM(0.0,12.0)
    GO TO 302
380 CALL FINTRA
    WRITE(6,382)NG
382 FORMAT (1H1/' CALCOMP HAS DRAWN',I4,'  GRAPHS.')
    STOP
    END
```

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Alfred Nobel

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