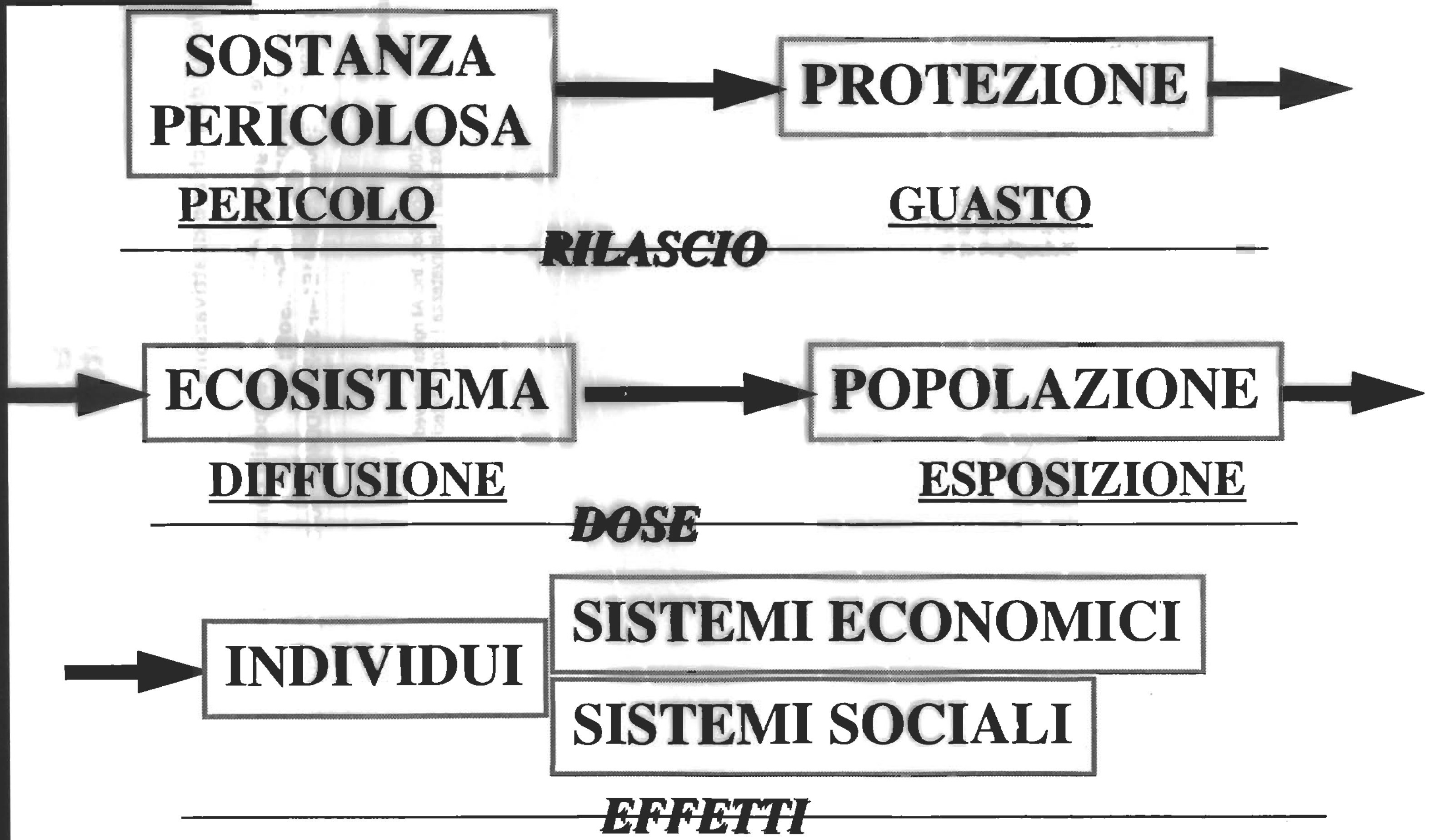
CONSEGUENZE-generalità



PERICOLO

SOSTANZE PERICOLOSE	CONSEGUENZE FISICHE	
■ TOSSICHE	CONCENTRAZIONE	ppm mg/M3
■ INFIAMMABILI	INTENSITA' DI IRRAGGIAMENTO	kW/M2
■ ESPLOSIVE	SOVRAPRESSIONE	kPa

PROTEZIONE

- SERBATOI/TUBAZIONI

GUASTO

- ROTTURA CATASTROFICA
- PERDITA/FORO

RILASCIO

TERMINE SORGENTE

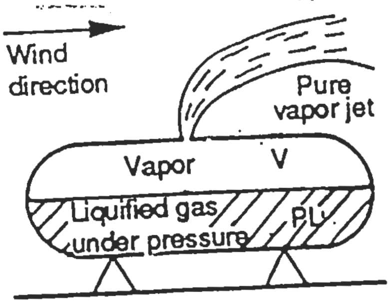
- TIPO DI SOSTANZA E MODALITA' DI STOCCAGGIO
- CAUSE E DIMENSIONI DELLA ROTTURA

MODELLI

- ANDAMENTO E TIPOLOGIA DELLA PORTATA DI RILASCIO
- ENERGIA CONTENUTA NEI FRAMMENTI
- AMPIEZZA DELL'ONDA DI PRESSIONE

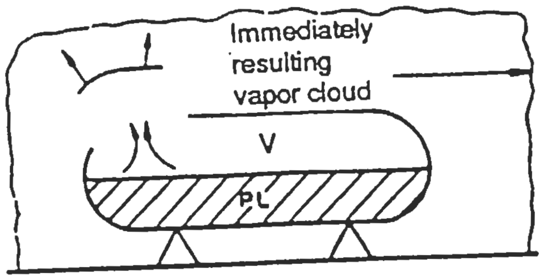
some conceivable release mechanisms

A



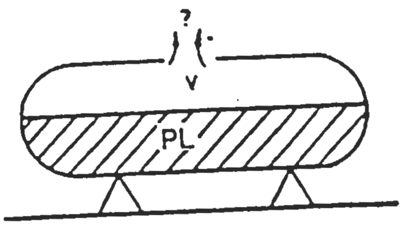
Small hole in vapor space-pressurized tank

B



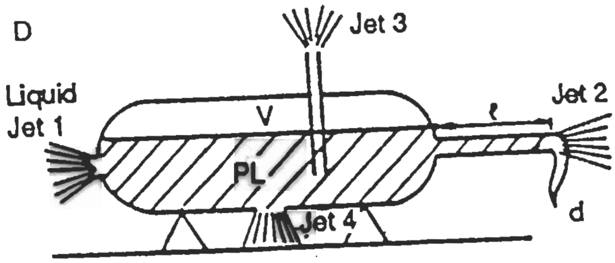
Catastrophic failure of pressurized tank

C



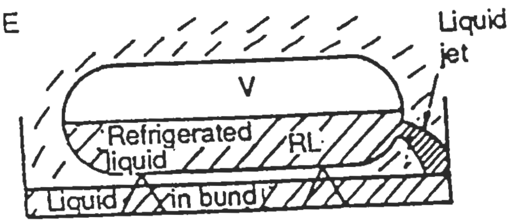
Intermediate hole in vapor space-pressurized tank

D



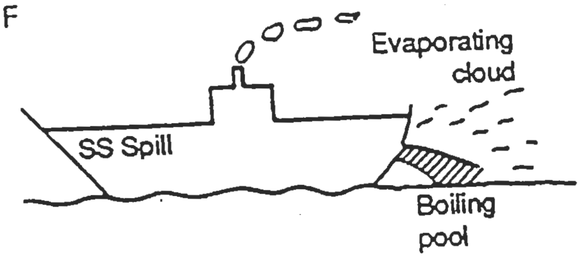
Escape of liquified gas from a pressurized tank

E

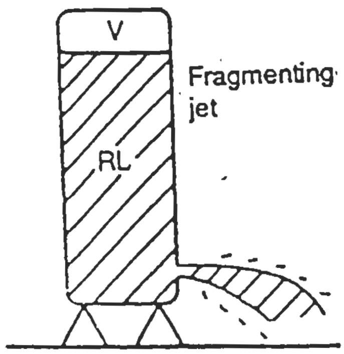


Spillage of refrigerated liquid into bund

F



Spillage of refrigerated liquid onto water

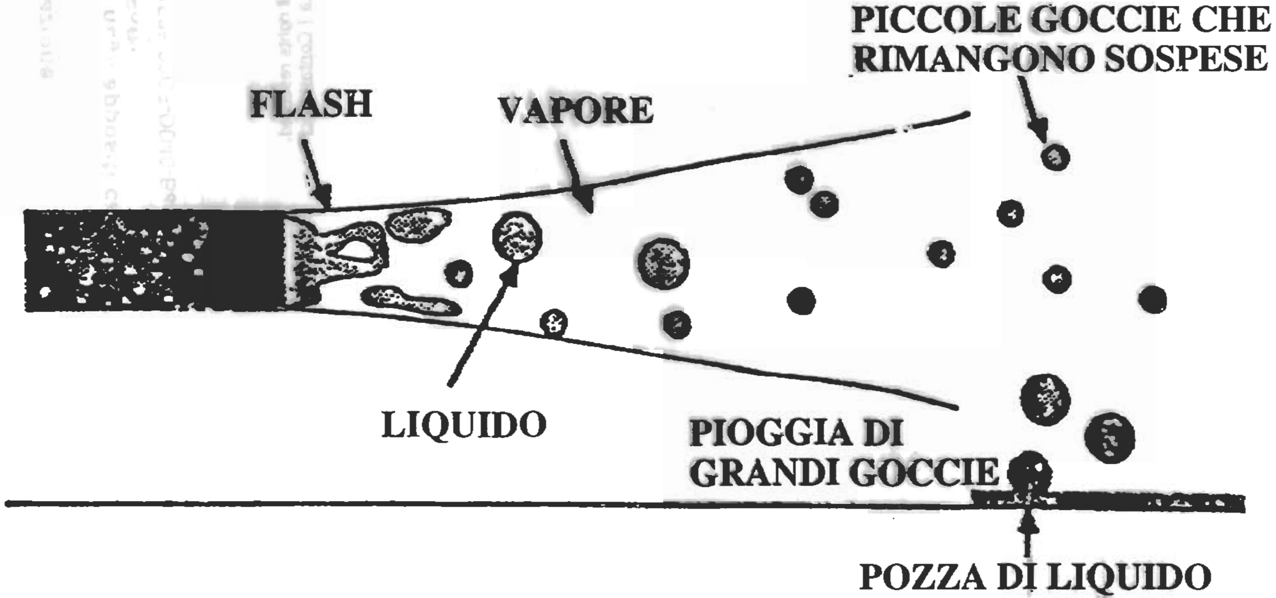


High-velocity fragmenting jet from refrigerated containment

PORTATA DEL RILASCIO

- LIQUIDA
- GAS
- BIFASE

→ MODELLI



Appendix B of the Flammable and Combustible Liquids Code Handbook (NFPA, 1987c). API RP520 (API, 1976) recommends a similar formula applicable to pressurized storage of liquids at or near their boiling point where the liquids have a higher molecular weight than that of butane.

All of the recommended heat flux equations in API 520 and NFPA Codes that are used to design relief valves assume that the liquids are not self-reactive or subject to runaway reaction. If this situation arises, it will be necessary to take the heat of reaction and the rate of the reaction into account in sizing the relief device.

Liquid Discharges. Discharge of pure (i.e., nonflashing) liquids through a sharp-edged orifice are well described by the classical work of Bernoulli and Torricelli (see Perry and Green, 1984) and can be expressed as

$$G_L = C_d A \rho \left(\frac{2(p - p_a)}{\rho} + 2gh \right)^{1/2} \tag{2.1.7}$$

where G_L = liquid mass emission rate (kg/s)
C_d = discharge coefficient (dimensionless)
A = discharge hole area (m^2)
ρ = liquid density (kg/m^3)
p = liquid storage pressure (N/m^2 absolute)
p_a = downstream (ambient) pressure (N/m^2 absolute)
g = acceleration of gravity (9.81 m/s^2)
h = height of liquid above hole (m)

The discharge coefficient for fully turbulent discharges from small sharp edged orifices is 0.6–0.64. Fauske (1985) suggests a value of 0.61. Crane Co. (1981) provides values for smooth nozzles and gives a good description of how to account for pipe fittings and other obstructions when calculating discharge rates.

Two-Phase Discharge. The significance of two-phase flow through restrictions and piping has been recognized for some time (Benjamin and Miller, 1941). Beginning in the mid-1970s the AIChE-DIERS has studied two-phase flow during runaway reaction venting. DIERS researchers have emphasized that this two-phase flow usually requires a larger relief area compared to all-vapor venting (Fauske et al., 1986). Leung (1985) provides comparisons of these areas over a range of overpressure. Research supported by the nuclear industries has contributed much to our understanding of two-phase flow, as have a large number of studies undertaken by universities and other independent organizations.

When released to atmospheric pressure, any pressurized liquid above its normal boiling point will start to flash and two-phase flow will result. Two-phase flow is also likely to occur from depressurization of the vapor space above a mass of a volatile liquid, especially if the liquid is viscous (e.g., greater than 500 cP) or has a tendency to foam.

The DIERS computer program, SAFIRE, is relatively complex to use and requires extensive physical properties. Fauske and Epstein (1987) have provided the following practical calculation guidelines for two-phase flashing flows. The

Gas Discharge Equations. There are two flow regimes corresponding to sonic (or choked) flow for higher pressure drops and subsonic flow for lower pressure drops. The transition between the two flow regimes occurs at the critical pressure ratio, r_{crit}, which is related to the gas heat capacity ratio γ via

$$r_{crit} = \left(\frac{p}{p_a}\right)_{crit} = \left(\frac{\gamma+1}{2}\right)^{\gamma/(\gamma-1)} \tag{2.1.1}$$

where p = absolute upstream pressure (N/m^2)
p_a = absolute downstream pressure (N/m^2)
γ = gas specific heat ratio (C_p/C_v, dimensionless)

Typical values of γ range from 1.1 to 1.67, which give r_{crit} values of 1.71 to 2.05. Thus for releases of most diatomic gases ($\gamma = 1.4$) to atmosphere, upstream pressures over 1.9 bar absolute will result in sonic flow. Gas flow through an orifice is given by

$$G_v = C_d \frac{Ap}{a_0}\psi \tag{2.1.2}$$

where G_v = gas discharge rate (kg/s)
C_d = discharge coefficient (dimensionless $\leq$ 1.0)
A = hole area (m^2)
a_0 = sonic velocity of gas at $T = (\gamma RT/M)^{1/2}$
M = gas molecular weight (kg-mol)
R = gas constant (8310 J/kg-mol/°K)
T = upstream temperature (°K)
ψ = flow factor, dimensionless

The flow factor, ψ, is dependent on the flow regime as follows:

For subsonic flows

$$\psi = \left\{\frac{2\gamma^2}{\gamma-1}\left(\frac{p_a}{p}\right)^{2/\gamma}\left[1-\left(\frac{p_a}{p}\right)^{(\gamma-1)/\gamma}\right]\right\}^{1/2} \quad \text{for } \frac{p}{p_a} \leq r_{crit} \tag{2.1.3}$$

For sonic (choked) flows

$$\psi = \gamma\left(\frac{2}{\gamma+1}\right)^{(\gamma+1)/2(\gamma-1)} \quad \text{for } \frac{p}{p_a} \geq r_{crit} \tag{2.1.4a}$$

or

$$\psi = \gamma\left(\frac{1}{r_{crit}}\right)^{(\gamma+1)/2\gamma} \tag{2.1.4b}$$

Relief Valve Discharge. An important case of gas discharge is the flow from pressure relief valves. Where relief is due to fire exposure in a nonreacting discharge of subcooled or saturated liquids is described by

$$G_{2p} = C_d\sqrt{G_{sub}^2 + G_{ERM}^2/N} \qquad (2.1.8a)$$

where G_{2p} is two phase mass flow rate (kg/m²/s). Discussion of each term will follow. The effect of subcooling is accounted for by

$$G_{sub} = \sqrt{2(p - p_v)\rho_f} \qquad (2.1.8b)$$

where p = storage pressure (N/m²)
p_v = vapor pressure at storage temperature (N/m²)
ρ_f = liquid density (kg/m³)

For saturated liquids, equilibrium is reached if the discharge pipe size is greater than 0.1 m (length greater than 10 diameters) and discharge rate is predicted by

$$G_{ERM} = \frac{h_{fg}}{v_{fg}(TC_p)^{1/2}} \qquad (2.1.8c)$$

where h_{fg} = latent heat of vaporization (kJ/kg)
v_{fg} = change in specific volume liquid to vapor (m³/kg)
T = storage temperature (°K)
C_p = liquid specific heat (kJ/kg/°K)

For discharge pipes less than 0.1 m, the flashing flow increases strongly with decreasing length, approaching all liquid flow as the discharge pipe length approaches zero. This nonequilibrium effect is estimated by the parameter N (dimensionless) in Equation (2.1.8a) given by

$$N = \frac{h_{fg}^2}{2\Delta p \rho_f C_d^2 v_{fg} T C_p} + \frac{L}{L_c} \qquad \text{for } 0 \le L \le L_c \qquad (2.1.8d)$$

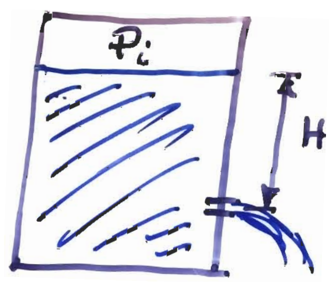
where L = pipe length to opening (m)
L_c = 0.1 m

For $L = 0$, Equations (2.1.8a) and (2.1.8d) reduce to (2.1.7) (neglecting the head of liquid). Equivalently, the discharge rate of flashing liquids from sharp-edged orifices at vessels can be estimated as though there were no flashing.

There are many equally valid techniques for estimating two-phase flow rates. The nuclear industry has undertaken substantial analysis of critical two-phase flow of steam–water mixtures. The Nuclear Energy Agency (1982) has published a review of four models and summarized available experimental data. Klein (1986) reviews the one-dimensional DEERS model for the design of relief systems for two-phase flashing flow. Three-dimensional models are also available although little published information on their use is available. Additional complexity does not guarantee improved accuracy and can unnecessarily complicate the task of risk analysis.

It is worth highlighting that design calculations for the sizing of relief

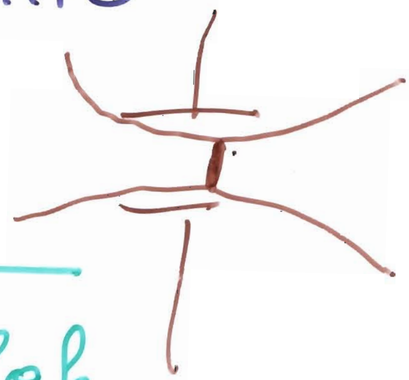
RILASCIO DI LIQUIDO



Dipende da

- pressione
- altezza liquido sopra rottura

Si utilizzano relazioni del tipo



$$Q_e = C_D A \rho_e \sqrt{2\frac{P_i - P_a}{\rho_L} + 2gh}$$

Il liquido fuoriuscito forma una pozza.

Se $T_b < T_a \Rightarrow$ FLASHING

La frazione di liquido che prende parte al flashing dipende da $\Delta T = T_b - T_a$, calore specifico, calore latente di evaporizzazione.

La restante frazione evapora lentamente prendendo energia da

- atmosfera
- suolo

$$1 - e^{-\frac{c_p}{\lambda}\Delta T}$$

RILASCIO VAPORE o GAS

POSSIAMO AVERE DUE CONDIZIONI

$$Q = C_D A p_s \sqrt{\frac{\gamma M}{R T_s}\left[\frac{2}{\gamma+1}\right]^{\frac{\gamma+1}{\gamma-1}}}$$ per FLUSSO CRITICO

$$Q = C_D A \sqrt{2 p_s \rho_g \left(\frac{\gamma}{\gamma+1}\right)\left[\left(\frac{P_a}{P_s}\right)^{\frac{2}{\gamma}} - \left(\frac{P_a}{P_s}\right)^{\frac{\gamma+1}{\gamma}}\right]}$$ per FLUSSO SUB-CRITICO

IL CALCOLO DEL TRANSITORIO SI PUÒ EFFETTUARE NELLE DUE CONDIZIONI ESTREME:

ISOTERMA $\quad P_i V = \text{cost.}$

ADIABATICA $\quad P \rho^{-\gamma} = \text{cost}$

NEL PRIMO CASO IL CALORE VIENE DALL'ESTERNO E IL CONTENITORE SI SVUOTA COMPLETAMENTE

NEL SECONDO CASO IL CALORE VIENE DAL LIQUIDO CHE SI RAFFREDDA FINO A RAGGIUNGERE LA TEMPERATURA DI EBOLLIZIONE

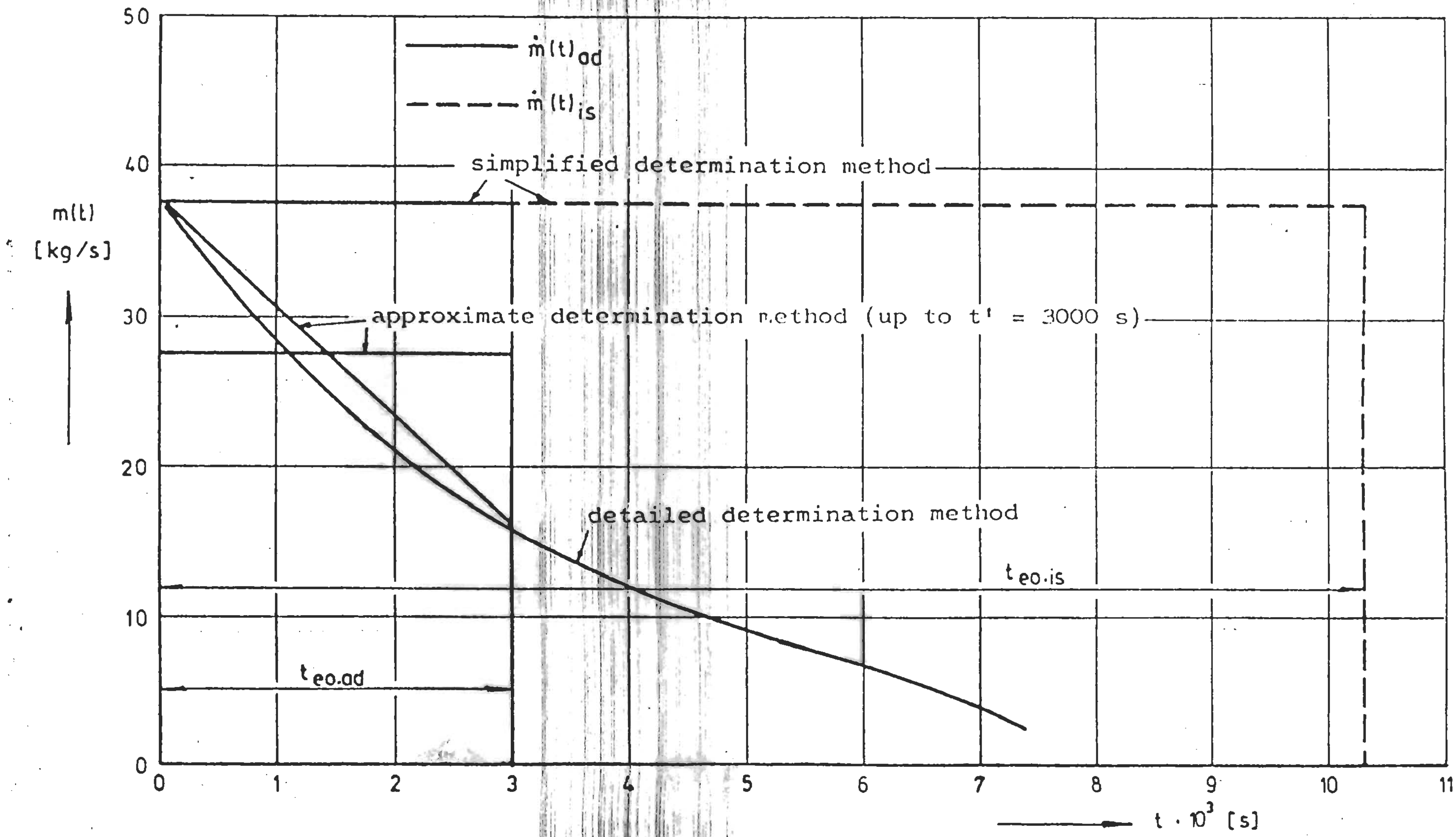


Fig. 5.2.2. CALCULATION RESULTS FOR VAPOUR OUTFLOW

MODELLI SORGENTE

SI IPOTIZZANO I SEGUENTI SCHEMI DI RILASCIO

① CONTENITORE PRESSURIZZATO

- PERDITA IN ZONA VAPORE
- PERDITA IN ZONA LIQUIDA

Si può avere

→ FUORIUSCITA DI VAPORE
→ FUORIUSCITA DI LIQUIDO (POZZA)
→ MISCELA BIFASE

② CONTENITORE CRIOGENICO

- PERDITA IN ZONA LIQUIDA

Si può avere

→ FUORIUSCITA DI LIQUIDO (POZZA)

③ CONTENITORE DI GAS

Si può avere

→ FUORIUSCITA DI GAS