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Allgemeine Wirtschaftsberatungsgesellschaft m.b.H.

D-8183 Rottach-Egern

On the Influences of Safety Mesh
- as a Filling Material for Tanks -
for the Development of Propane Gas Explosions

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2. Tests and Evaluation of the Behaviour of Gases

2.1. SOME REMARKS

For safe handling of combustible gas-air mixtures, it is necessary to know the properties which make them dangerous. The most reliable way to ascertain how dangerous such gas-air or vapour-air mixtures are is to test samples and describe these properties with characteristic safety technical data.

In the following the dependences of the characteristic values for an explosion of combustible gases and vapours will be briefly described.

2.2. EXPLOSION LIMITS

The limits of explosion include a range of concentrations of inflammable gas mixed with air, where with a given ignitor, an independently propagating reaction can be triggered. The explosion range is limited by E_L as the lowest and E_U as the highest point. This region is also called the ignition range and is the decisive criterion for determining whether or not gas-air or vapour-air mixtures are explosive. As can be seen from figure 1, the limits of explosion are influenced by the ignition energy E and the initial pressure P_V .

1. Order

As ordered by the *Allgemeine Wirtschaftsberatung m.b.H.*, Rottach-Egern a study was performed by the expert group on explosions working for the central security division of *CIBA-GEIGY AG*, Basel. The aim of these informative tests was to ascertain the influence of safety mesh on the development of propane gas explosions. Safety mesh is used as a filling material for fuel containers in order to prevent explosions.

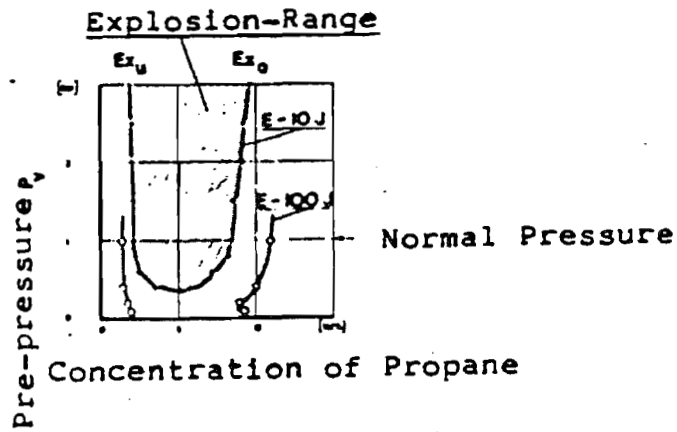


figure 1: Limits of an Explosion for Propane (7l Container)
at Room Temperature.

Especially the upper limit for an explosion E_U is influenced by these criteria.

The initial temperature also influences the limits of an explosion. This is the temperature which is measured just before ignition. The effect of higher initial temperatures is a linear widening of the explosion range.

2.3. MAXIMAL EXPLOSION PRESSURE, MAXIMAL VELOCITY OF PRESSURE INCREASE AND CHARACTERISTIC VALUE OF K_G

The explosion pressure P_{ex} and the velocity of pressure increase measured in time dp/dt describe the power of the reaction for a gas-air or vapour-air mixture in any given concentration after an ignition. (figure 2).

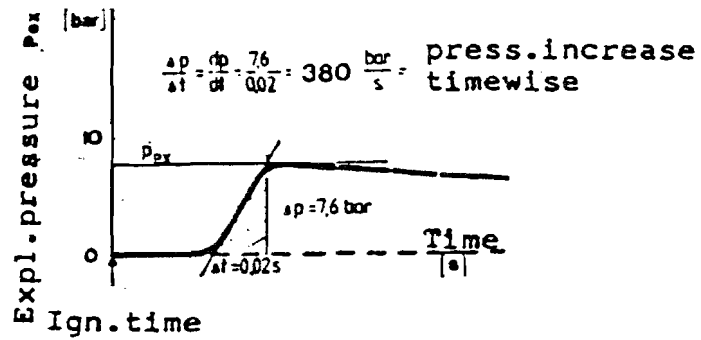


figure 2: Determination of Pressure Increase in Time dp/dt for an Explosion of a Combustible Gas.

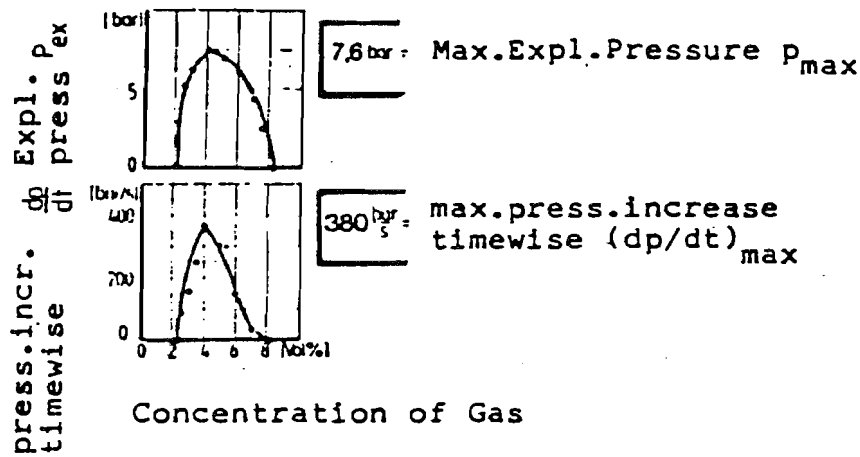


figure 3: Dependence of the Charateristic Value of an Explosion upon the Concentration of a Combustible Gas.

Maximal values (maximal explosion pressure P_{max} , maximal velocity of pressure increase measured in time $(dp/dt)_{max}$) are determined by measuring over a wide spectrum of concentrations (figure 3).

The above mentioned characteristic values for an explosion – and also the limits of an explosion – are determined in a spherical container of sufficient size ($V \geq 1l$) with an ignition device placed in the center. Usually a continuous spark gap is used as an ignition device with an energy E of about 10J. Of course, as the characteristic values for an explosion depend on other factors, the measured values – unless otherwise stated – relate to room temperature, standard pressure and mixtures ignited in a static state.

The maximal pressure of an explosion P_{max} is not dependent on the volume of a container ($V \geq 1l$) if it is a closed sphere and the ignition device is placed at its center.

On the other hand the maximal velocity of pressure increase measured in time $(dp/dt)_{max}$ is dependent on the volume. It will decrease with increasing volumes according to the "cubic law".

$$\left(\frac{dp}{dt}\right)_{max_1} * V_1^{\frac{1}{3}} = \left(\frac{dp}{dt}\right)_{max_2} * V_2^{\frac{1}{3}} = const. = K_G$$

The value K_G ($\text{bar}\cdot\text{m}\cdot\text{s}^{-1}$) is a characteristic value which is specific for each combustible gas and is relevant for the testing method. The characteristic value K_G is independent of the container size. The validity of the "cubic law" has been proved to be valid for volumes $V \geq 1l$.

One quantity which does influence the characteristic value of an explosion is the initial pressure P_v . As can be seen from figure 4 an increase of the initial pressure above standard pressure (1 bar absolute) results in a proportional increase of the maximal explosion pressure as well as the maximal velocity of pressure increase measured in time. Thus the characteristic value K_G also increases.

A decrease in the pressure below standard pressure will result in a proportional decrease of the characteristic values, until for a certain minimal pressure (which is gas dependent) the independently propagating reaction of an explosion ceases. However, the characteristic values for an explosion are independent of the ignition energy if the initial pressure is sufficiently low.

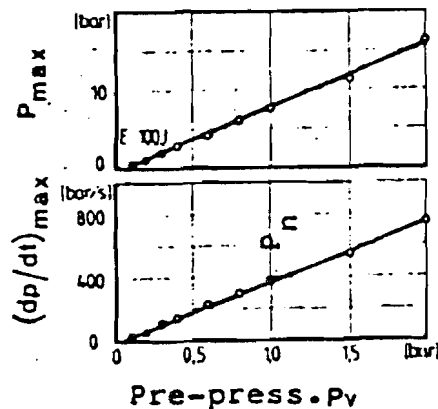


figure 4: Dependence of Pressure on the Charateristic Values for an Explosion (Propane, 7l Container; $E \simeq 10$ J).

The explanations given so far were under the assumption that the explosive gas-air mixtures are static at the moment of ignition. However, in many cases the state of the gas is non-static, i.e. turbulent. Figure 5 uses methane as an example to show the influence of "turbulences" on the characteristic values of an explosion. In contrast to the explosion pressure, the explosion power increases nearly ten-fold. In general, explosions of gases with normally low burning velocity are much more greatly influenced by turbulences than gases with high burning velocities or high velocities of pressure increase. The turbulence of a gas mixture only slightly expands the range of an explosion.

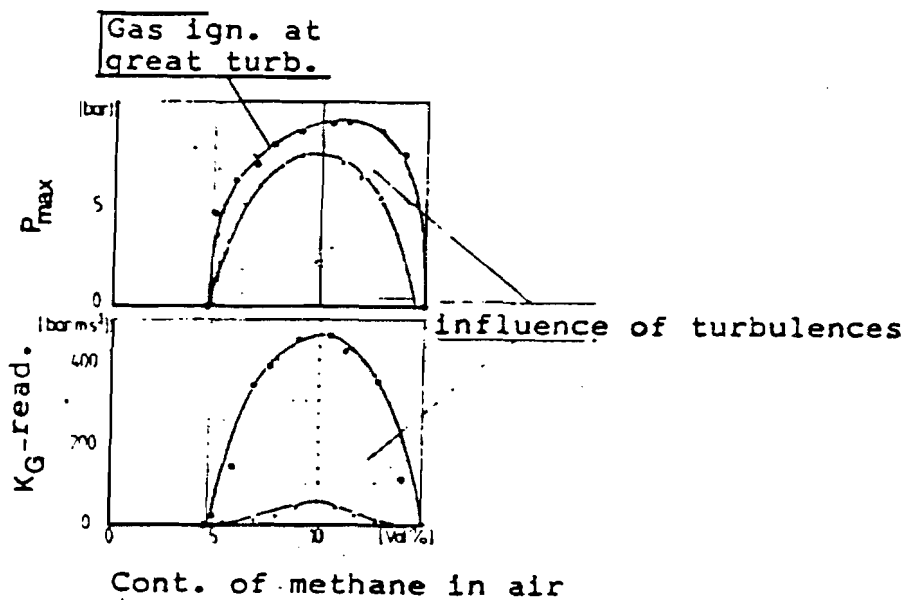


figure 5: Influence of Turbulence on the Characteristic Value of an Explosion (Methane, $E = 10 \text{ J}$).

3. Description of the Safety Mesh

The safety mesh that is to be tested consists of a special alloy of aluminium and magnesium. The thickness of the mesh is about 2 mm and the material is resistant to corrosion (see figure 6).

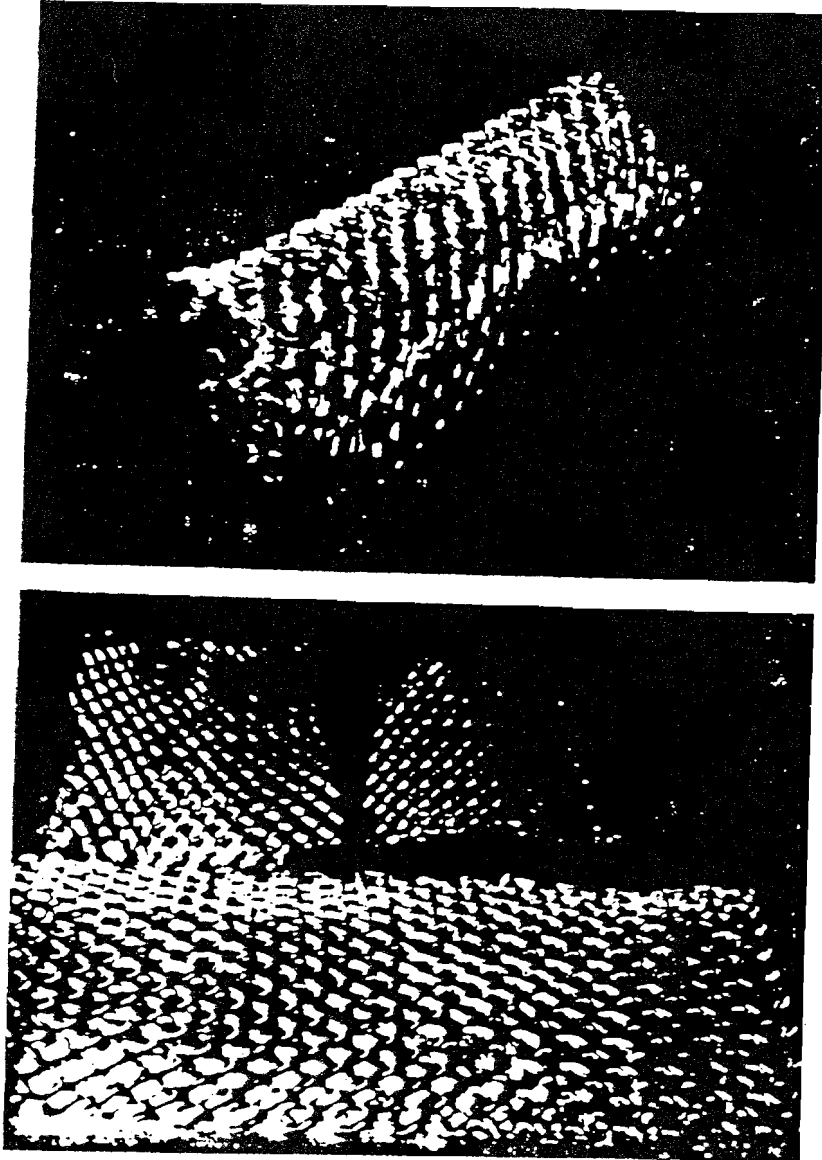


figure 6: Safety Mesh

The safety mesh is a filling material which can either be used for gas containers or for containers with combustible liquids. The purpose of the safety mesh is to prevent explosions through heat conduction (dissipation).

Because the structure of the safety mesh is relatively complicated, the test results described in the following will relate, in principle, to the total surface area.

4. Method of Testing

4.1. TESTING APPARATUS

The explosion tests were carried out in a thermostatically controlled spherical container with a contents of 20l (see figure 7).

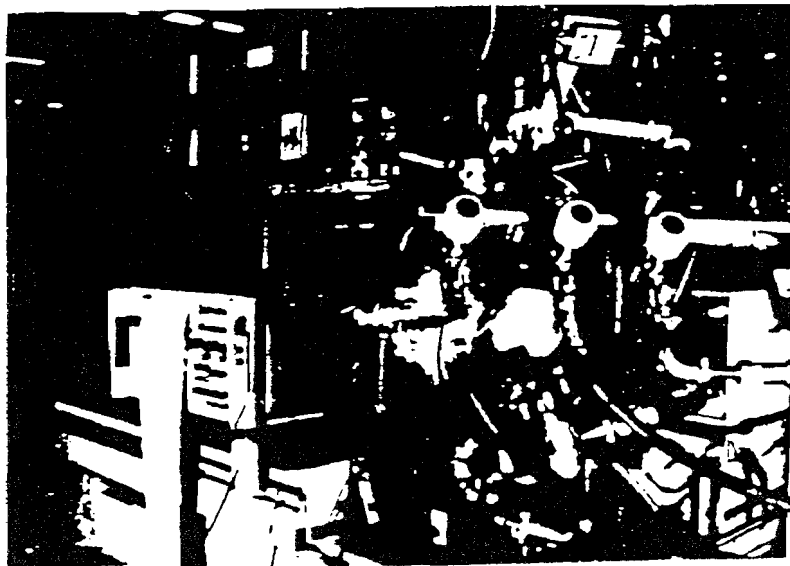


figure 7: Laboratory Apparatus: 20l Container for Determining the Characteristic Values of Combustible Gases and Vapours.

The different mixtures were produced by mixing the gas components of known partial pressures. This method was chosen as no extra work need be performed in order to determine the exact values of the gas concentrations. The ignitions of the different mixtures were always initialized from the center of the sphere. In all experiments a commonly used AC continuous spark gap was employed as the ignitor whose energy was $E = 10 J$.

The time dependence of the explosion pressure was measured with interlinked piezoelectric manometers connected to a light spot line printer.

4.2. TESTING METHODS

The tests were carried out with propane. If the maximal explosion pressure P_{max} is 7.5 bar, the characteristic value K_G is $75 \text{ bar}\cdot\text{m}\cdot\text{s}^{-1}$ for a cylindrical container; for a spherical container K_G is $100 \text{ bar}\cdot\text{m}\cdot\text{s}^{-1}$. This value is similar to that of most known solvent vapours.

For the experiments the container was filled with increasing amounts of safety mesh corresponding to larger surface areas of the mesh (figure 8).

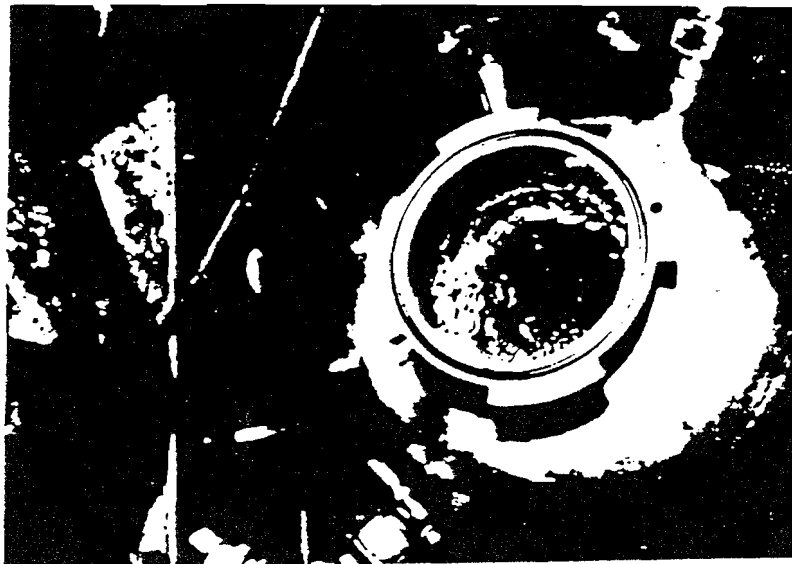


figure 8: 20l Container Filled with Safety Mesh.

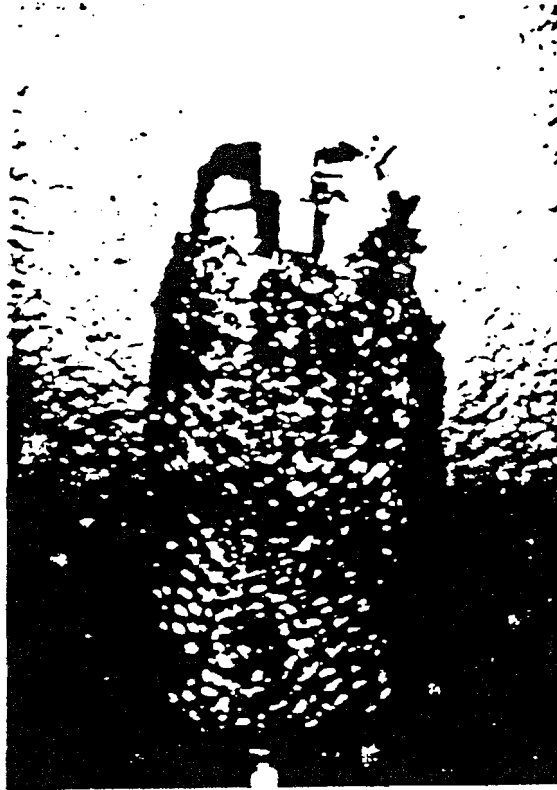


figure 9: Electrodes Insulated with Asbestos
and Covered by Safety Mesh.

In order to avoid a short circuit caused by spark discharge between the spark gap electrodes and the safety mesh the electrodes were insulated with asbestos and covered by safety mesh (figure 9). Therefore the safety mesh could be packed densely.

5. Test Results

The explosion tests were performed throughout the entire explosion range of propane in air i.e. 2% by volume – 9% by volume. This was done for different surface areas of filling mesh. The optimal characteristic values for an explosion as determined by experiment are summarized in Table 1.

Table 1: Influence of Safety Mesh on the Characteristic Values for an Explosion of Propane in Air

— 20l Spherical Container, STP

— AC Continuous Spark Gap, Ignition Energy $E = 10 \text{ J}$

— Partial Pressure Method

Safety Mesh	E_L	E_U	Explosion Domain	P_{max}	K_G
(m^2)	(% by vol.)	(% by vol.)	(% by vol.)	(bar)	($\text{bar}\cdot\text{m}\cdot\text{sec}^{-1}$)
0.0	2.0	9.5	7.5	8.5	112
0.8	2.25	9.5	7.25	6.6	93
1.2	2.5	9.0	6.5	5.4	91
3.2	2.5	7.5	5.0	2.9	73
5.6	1.5	5.5	4.0	0.7	14

The influence of the propane gas concentration on the characteristic values for an explosion is portrayed in figure 10.

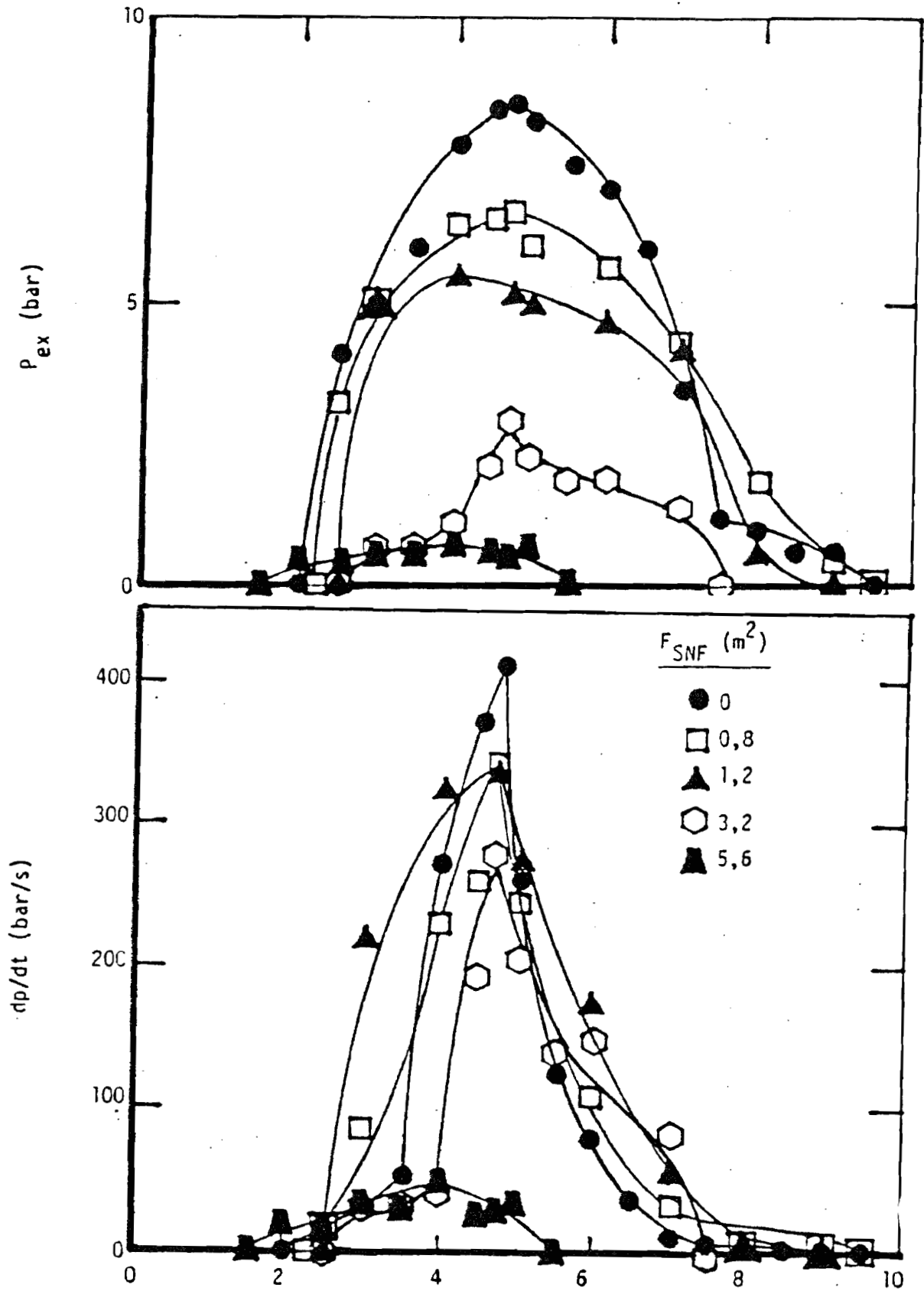


figure 10: Influence of Propane Gas Concentration on the Characteristic Values for an Explosion of Propane-Air Mixtures. (20l container, $E \approx 10$ J, STP)

6. Discussion of Test Results

6.1. EXPLOSION LIMITS, EXPLOSION RANGE

The surface area of the safety mesh inserted into the 20l sphere affects the upper and lower limits for an explosion. This effect is portrayed in figure 11.

The lower limit for an explosion E_L is not affected by the additional surface area of the safety mesh within the accuracy of this measurement. On the other hand for large values of safety mesh area the upper explosion limit E_U approaches the lower limit for an explosion E_L . Both limits meet at a point where the surface area of the safety mesh $F = 8 \text{ m}^2$.

In other words, for a 20l container with a safety mesh area of 8 m^2 no explosion of propane is to be expected for the given ignition device.

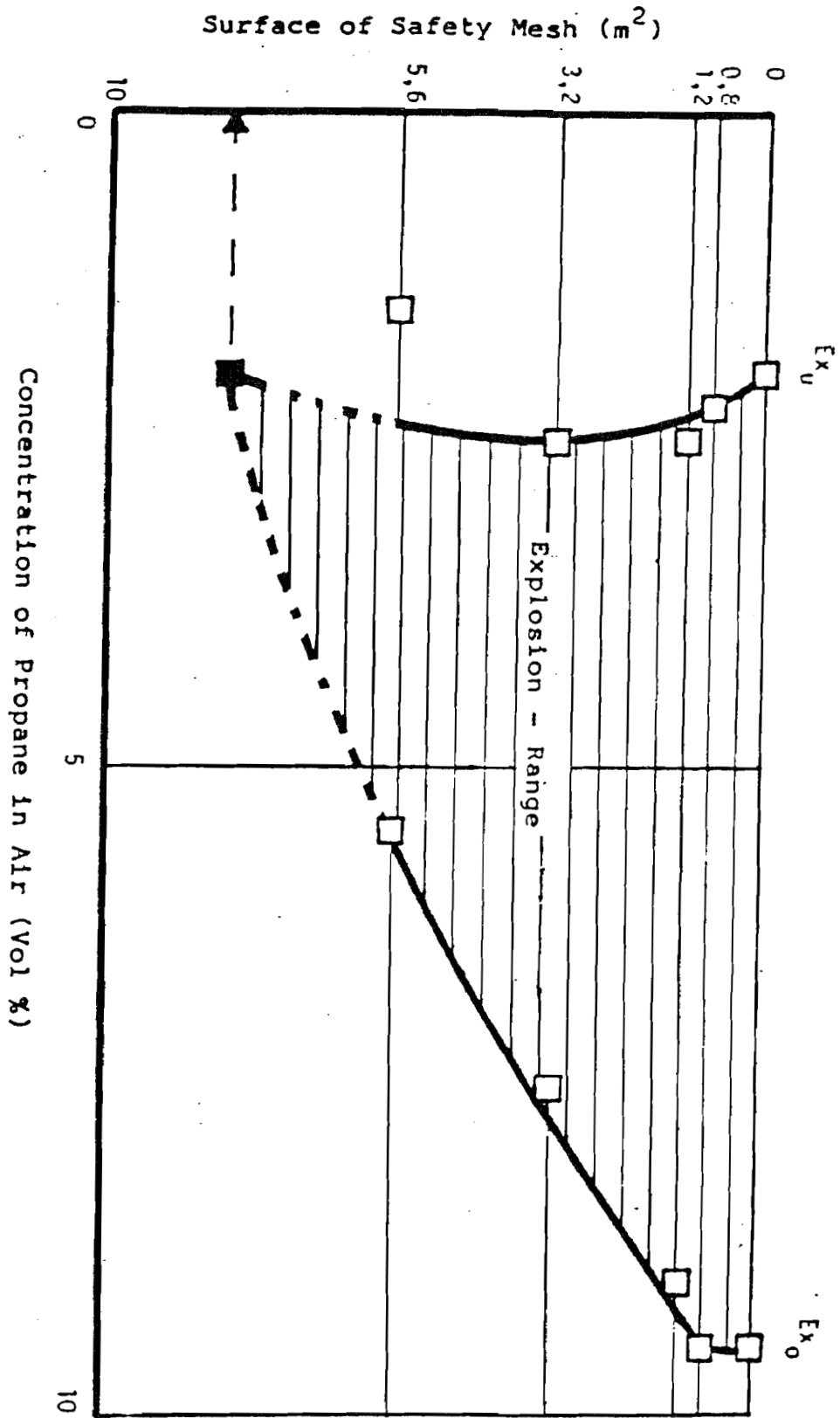


figure 11: Influence of Safety Mesh on the Limits of an Explosion for Propane-Air Mixtures.

(20l container, $E \approx 10$ J, STP)

6.2. OPTIMAL CHARACTERISTIC VALUES FOR AN EXPLOSION

The influence of the safety mesh's surface area on the optimal characteristic values for an explosion of propane is shown in figure 12. These characteristic values are the maximal explosion pressure P_{max} and K_G .

As can be seen in figure 12 the characteristic value K_G decreases linearly with respect to the inserted safety mesh surface area. The decrease of the maximal explosion pressure P_{max} is even stronger. In both cases the extrapolation of the curve yields a surface area of about 8 m^2 where no explosion of propane can be expected. This result is consistent with the value determined in section 6.1.

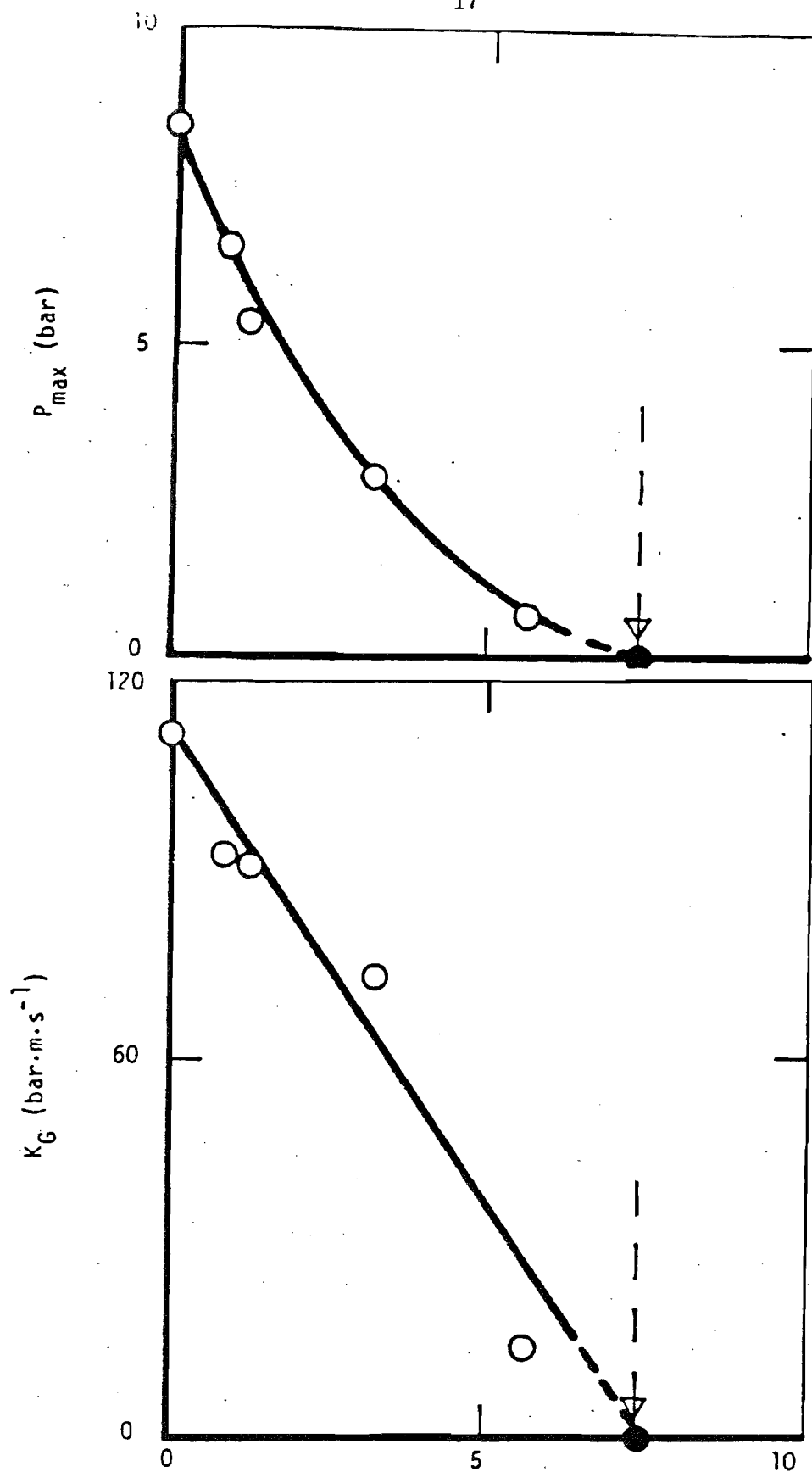


figure 12: Influence of Safety Mesh on the Characteristic Value for an Explosion of Propane-Air Mixtures. (20l Container, $E \approx 10$ J, STP)

6.3. CONCLUSIONS

As based on the results of the explosion experiments for propane measured with a 20l sphere filled with safety mesh, the following statement can be clearly made: The additional surface area of the safety mesh either hinders or possibly completely prevents the development of an explosion due to heat dissipation. For a 20l sphere 8 m² of surface area are needed.

However, the value of 400 m²/m³ surface area of safety mesh per unit volume is only valid for a sphere of 20l. In order to determine this value for larger containers (as used in everyday life) it is necessary to perform experiments with containers of e.g. one or even ten m³.

Such containers are available for the expert group on explosions. It should be considered whether safety mesh also can be used to attenuate or even completely prevent explosions of other gases reacting more violently than propane e.g. hydrogen.

7. Summary

As ordered by the *Allgemeine Wirtschaftsberatung m.b.H.*, Rottach-Egern a study was performed to determine whether the filling of a 20l sphere with safety mesh can hinder or even prevent the development of a propane gas explosion.

First a general overview concerning the development of explosions and characteristic values for an explosion is given. Then a description of the safety mesh, the testing apparatus and methods follows.

The results of the experiment show that the inclusion of 8 m^2 safety mesh surface area in a sphere of 20l ($= 400\text{ m}^2/\text{m}^3$) prevents a propane explosion. This result is valid for an ignitor (continuous spark gap) providing an ignition energy of 10J.

Additional experiments must be performed with larger containers in order to obtain results which are applicable for everyday use.