SBEP-V2 DESCRIPTION

SBEP-V2: Fh-ICT Balloon Test

Deflagration of large-scale stoichiometric hydrogen-air mixture in open atmosphere
20-m diameter hemisphere

Experiment description

The experiment was performed by HySafe partner Fraunhofer Institut Chemische Technologie (FhG-ICT), Germany, in 1983 and described in two references[1,2]. In the experiment a 20 meters diameter polyethylene hemispheric balloon (total volume 2094 m^3) was placed on the ground and filled in with a homogeneous stoichiometric hydrogen-air mixture. The hemispherical balloon, used in the experiment, is shown in Figure 1(a). The balloon was fixed to the ground by weights placed inside, where the balloon wall met the floor. These weights alone did not compensate the upward buoyancy thrust and an additional rhombus-shaped wire net was laid over the balloon and fastened to the ground at 16 points, see Figure 1(b).

The filling process of the gases was closely observed in order to produce a homogeneous mixture to avoid an enrichment of the hydrogen in the upper areas of the balloon. The required air was provided from the atmosphere using a fan and introduced into the balloon via a tube fitted with a flutter valve. The hydrogen was supplied from several bottles connected in parallel, where the required quantity was ascertained using the known bottles volume and pressure. The air fans created an effective mixing of the gas in the balloon. Gas samples were taken at different heights inside the balloon and analysed using gas chromatography in order to check the hydrogen-air mixture homogeneity.

The initial pressure was equal 98.9 kPa and initial temperature was equal 283 K. The combustion was initiated by ignition pills of 150 Joules at the centre of the hemisphere basement. After ignition, the wrinkled flame was propagating in almost hemispherical form. At the same time, the balloon stretches slightly outwards until it bursts at the seams bordering the ground and along longitudinal welds. This occurs at the moment when the flame has reached about half of the radius of the balloon, i.e. about 5 meters. In the further course of the flame propagation, the balloon segments expand. Flow must be disturbed when the remaining unburned gas is flowing between segments of the balloon shell and is burning after that.

Pressure dynamics were recorded using 11 transducers, installed on the ground level in a radial direction at distances from 2 to 80 meters away from the centre of the hemisphere basement at radii: R = 2.0, 3.5, 5.0, 6.5, 8.0, 18.0, 25.0, 35.0, 60.0 and 80.0 meters). In addition one “a-head” pressure transducer installed along an axis running at right angle and mounted on a vertical timber wall of 1×1 m^2 placed on the ground at 25 meters far away from the ignition point.

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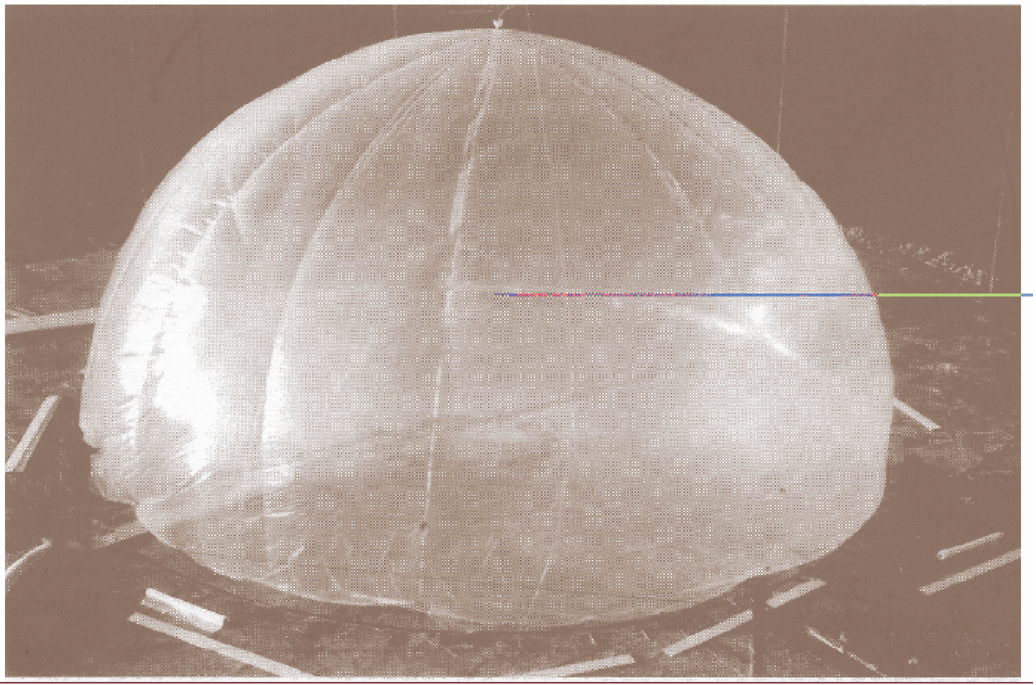
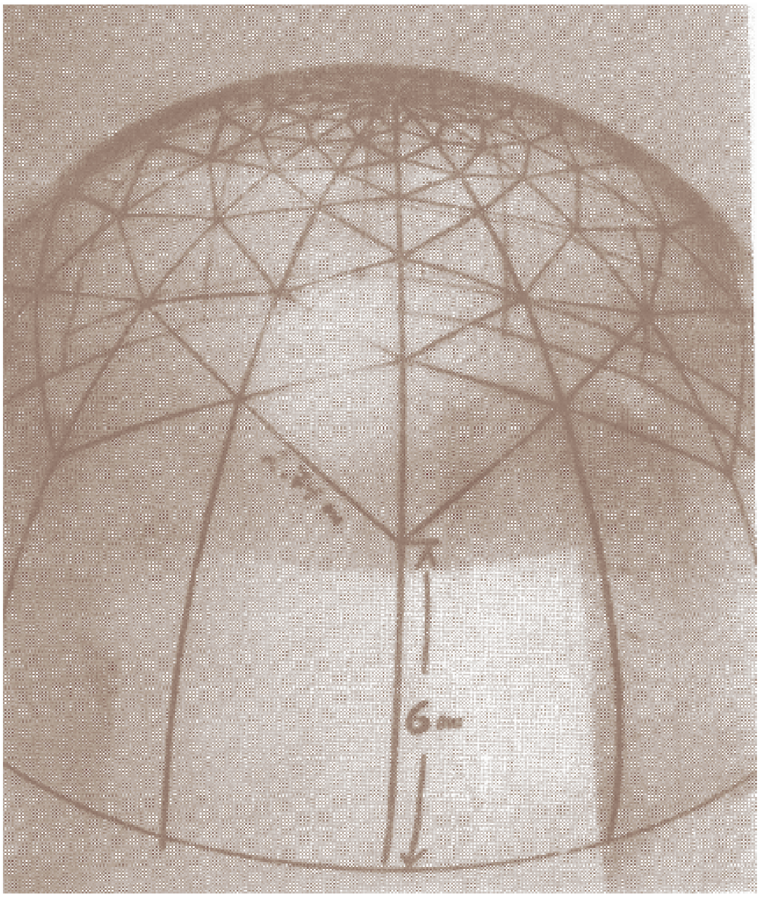
[1] Schneider H., Pförtner H. PNP-Sichcrheitssofortprogramm, Prozebgasfreisetzung-Explosion in der gasfabrik und auswirkungen von Druckwellen auf das Containment. Dezember 1983.

[2] Becker T., Ebert F., Vergleich zwischen experiment und theorie der explosion grober, freier gaswolken. Chem.-Ing.-Tech., V.57, N.1, pp.42-45, 1985.



(a)



(b)

Figure 1. 20-m radius hemispherical balloon (a) and wire net (b).

The deflagration front propagation was filmed using high-speed cameras. Dynamics of the flame shape profiles with time, filmed by cameras, positioned along to the pressure measurements axis and normal to it, is available for comparison and shown in Figure 2. The flame propagation was evaluated along the radial paths between 45° and 135° from the point of ignition and the average values of the flame front radius and flame front velocity were derived. The error, arising from indistinctness of the flame contour and fluctuations in picture frequency, was estimated by the authors[1] as ±5% without taking into account certain asymmetries in flame propagation.

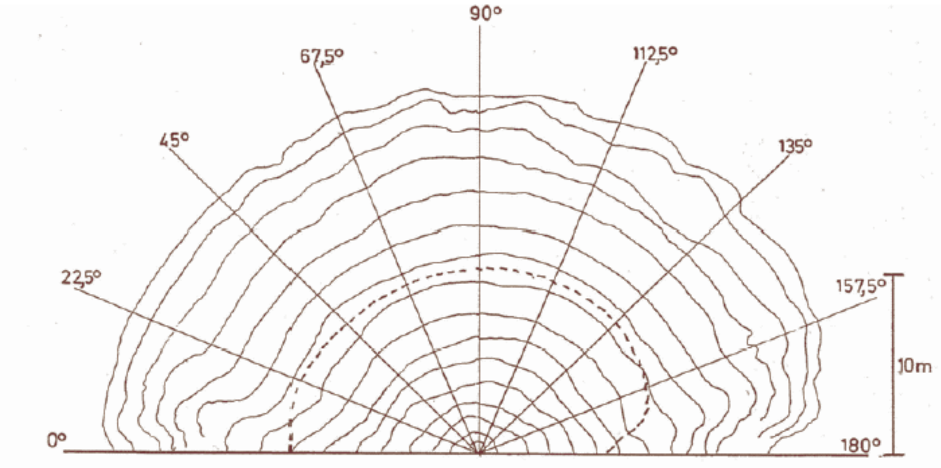


Figure 2. Flame front contours with time

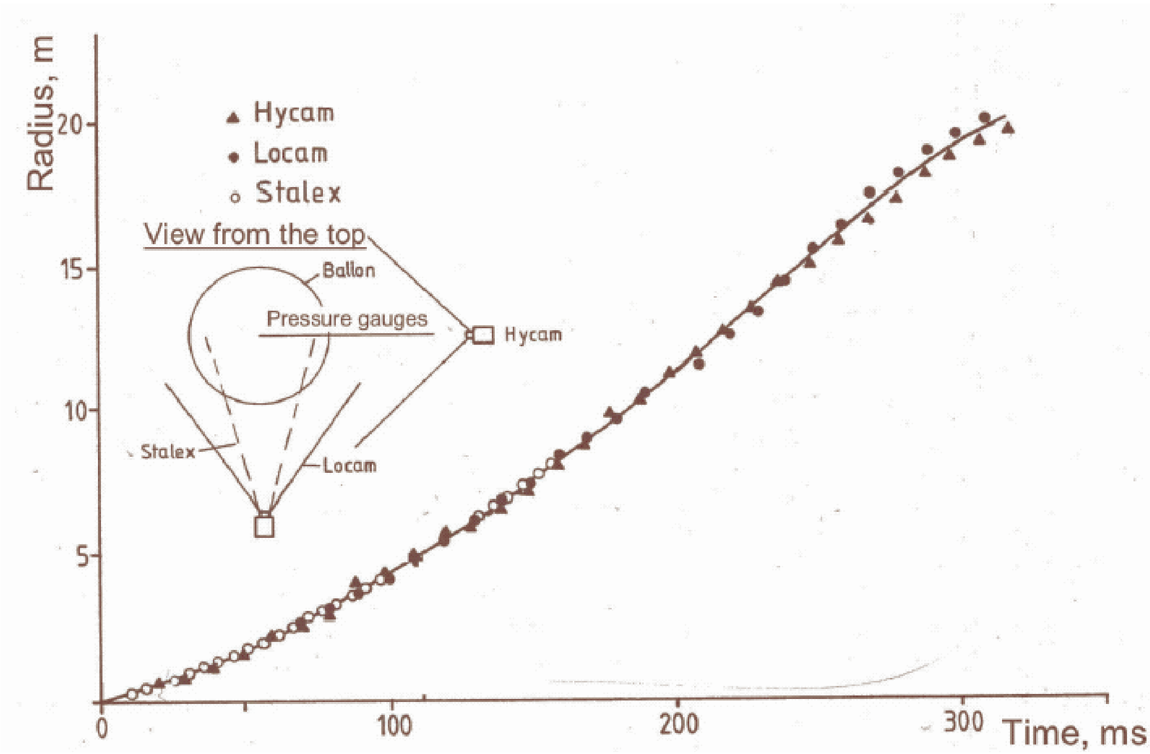


Figure 3. The flame front radius, obtained from post-processing of films from different cameras, and the averaged flame front radius.

Experimental data for comparison with simulations

Dynamics of the flame front radius with time, obtained from post-processing of films from different cameras, is shown in Figure 3 together with the averaged one.

Pressure dynamics, obtained at distances 2, 5, 8, 18, 35 and 80 meters from the centre of the hemisphere are shown in Figures 4-8 correspondingly.

Initial conditions

At initial moment the hemispherical balloon is filled with quiescent air, T_i=283 K, p_i=98.9 kPa.

Results to be reported by participants

The following list contains the specification of results requested from the participants. These results were included in different files, which were uploaded to the HySafe web page at a reserved section only accessible by partners (HySafe→ Work packages → WP3 → SBEPS).

V2.1 Description of the model, including governing equations, initial and boundary conditions for simulations, numerical details (solution method, discretisation schemes, etc); what model parameters if any were adjusted to match the experimental data.

Used code and its version.

Description of the grid and/or picture of the grid cross section in a vertical plane crossing the vertical axis of the hemisphere; characteristic mesh sizes; total number of control volumes in the grid(s); effect of the grid size on simulation results;

Computer equipment used (operating system, CPU number, type and clock speed, RAM) and CPU time, required for simulations (for each different grid used).

V2.2 A graph with simulated dynamics of the averaged flame front radius with time compared to experimental flame front propagation dynamics given.

V2.3 A graph with the simulated pressure histories obtained at the location of the first pressure gauge (distance R=2 m from the centre of the hemisphere).

V2.4 A graph with the simulated pressure dynamics obtained at the location of the second pressure gauge (distance R=5 m from the centre of the hemisphere)

V2.5 A graph with the simulated pressure dynamics obtained at the location of the third pressure gauge (distance R=8 m from the centre of the hemisphere)

V2.6 A graph with the simulated pressure dynamics obtained at the location of the fourth pressure gauge (distance R=18 m from the centre of the hemisphere)

V2.7 A graph with the simulated pressure dynamics obtained at the location of the fifth pressure gauge (distance R=35 m from the centre of the hemisphere)

V2.8 A graph with the simulated pressure dynamics obtained at the location of the sixth pressure gauge (distance R=80 m from the centre of the hemisphere)

V2.9 Simulated flame front surface profiles at time corresponding to experimental t=60 ms

V2.10 Simulated flame front surface profiles at time corresponding to experimental t=120 ms

V2.11 Simulated flame front surface profiles at time corresponding to experimental t=180 ms

V2.12 Simulated flame front surface profiles at time corresponding to experimental t=240 ms

V2.13 Simulated flame front surface profiles at time corresponding to experimental t=300 ms

V2.14 Video animation of the deflagration front propagation (2D or 3D). Arbitrary scene and point of view (optional)

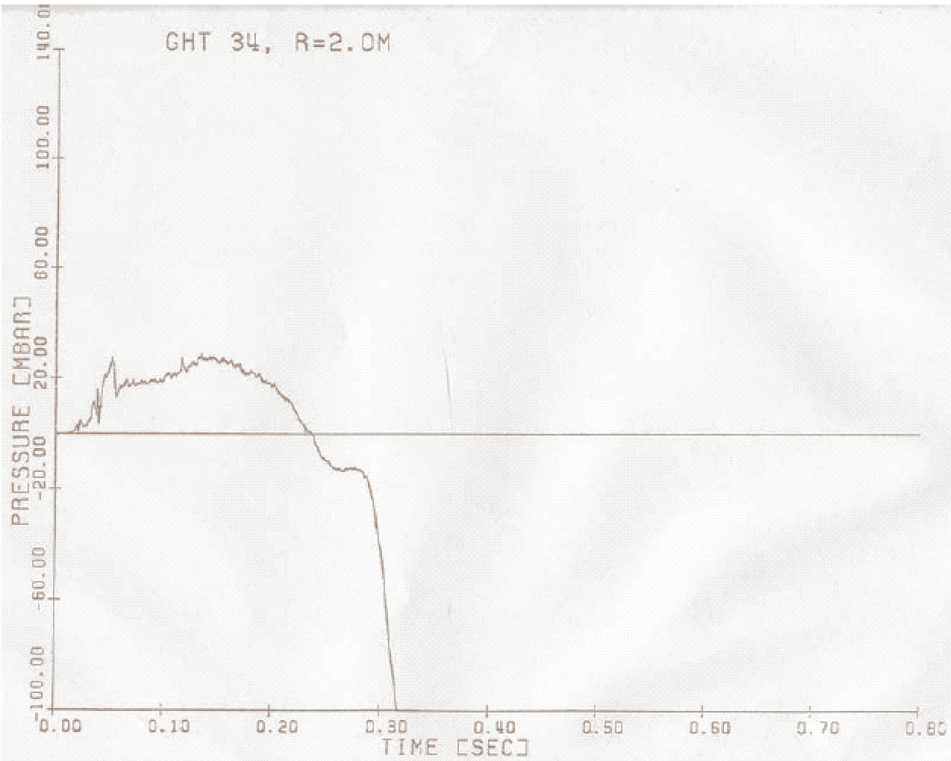


Figure 4. Pressure dynamics, registered at distance 2 meters from the centre of the hemisphere.

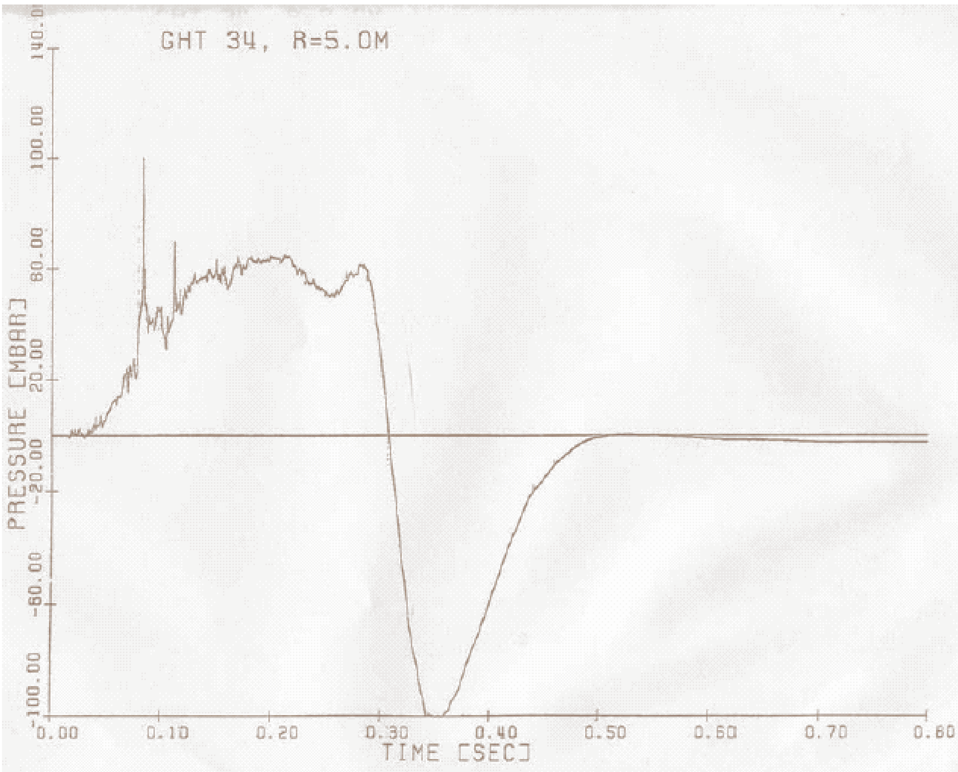


Figure 5. Pressure dynamics, registered at distance 5 meters from the centre of the hemisphere.

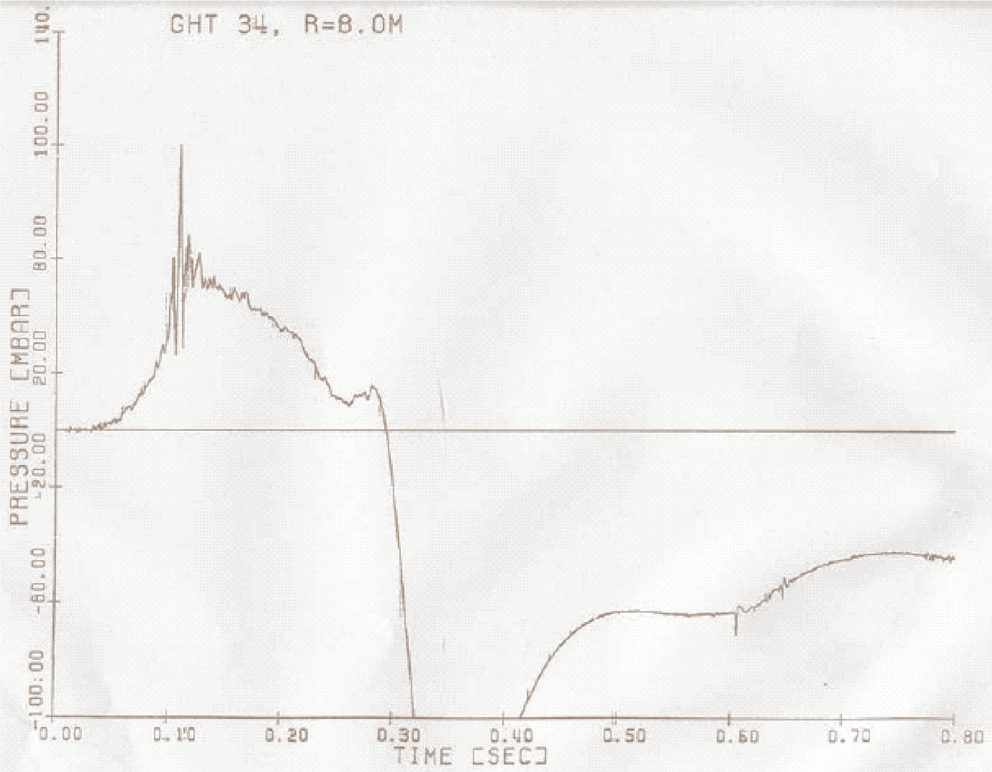


Figure 6. Pressure dynamics, registered at distance 8 meters from the centre of the hemisphere.

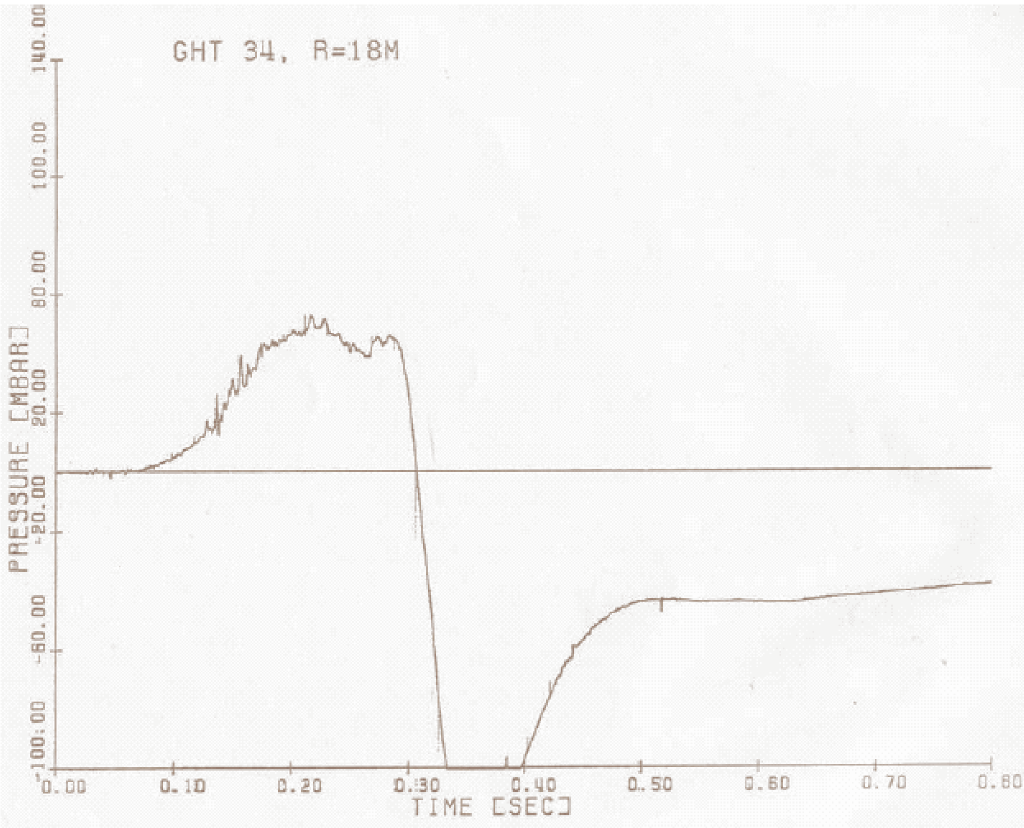


Figure 7. Pressure dynamics, registered at distance 18 meters from the centre of the hemisphere.

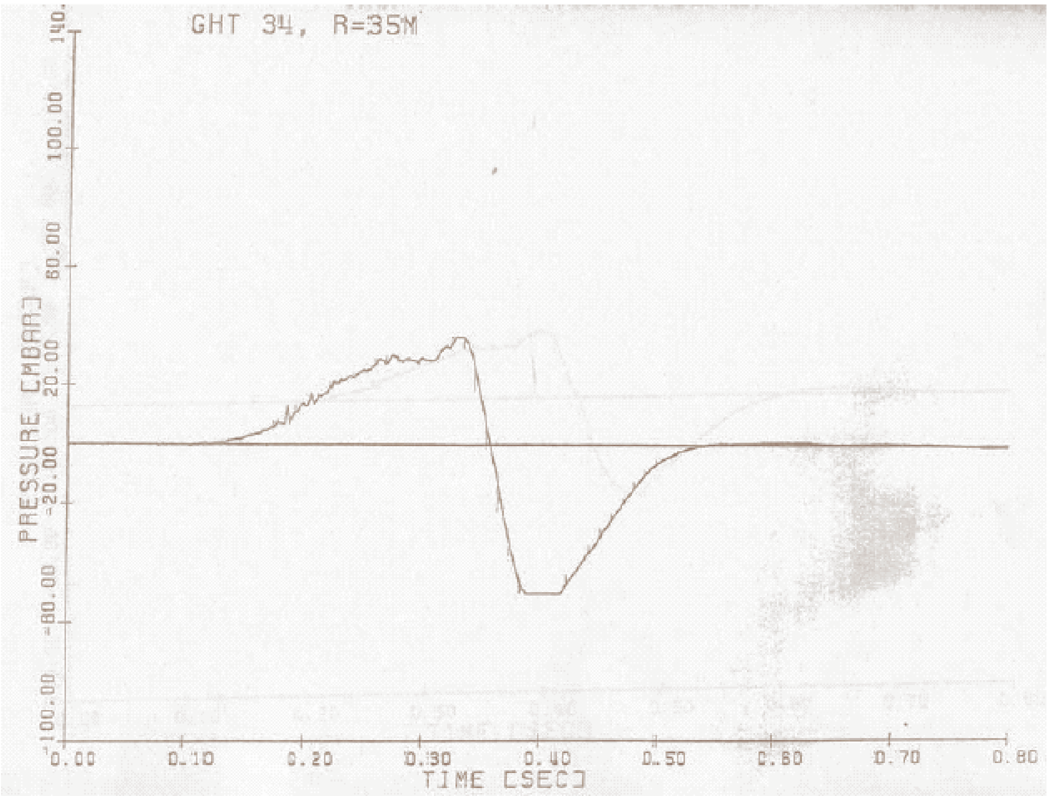


Figure 8. Pressure dynamics, registered at distance 35 meters from the centre of the hemisphere.

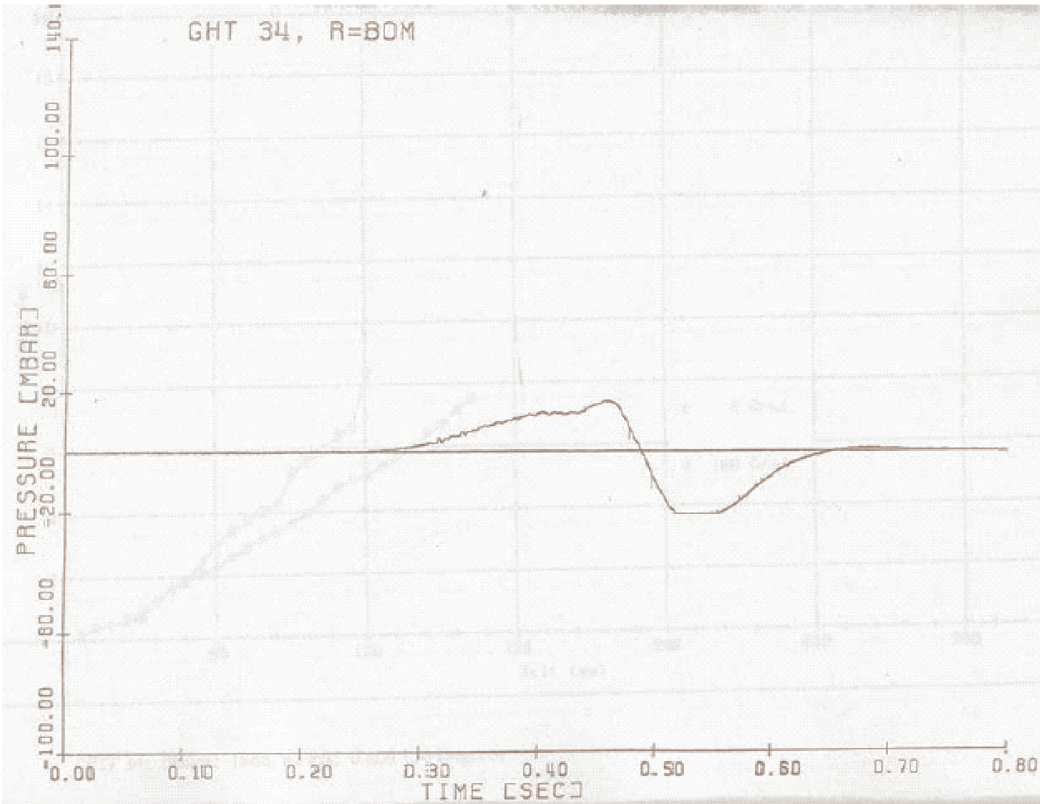


Figure 9. Pressure dynamics, registered at 80 meters from the centre of the hemisphere.