Full Scale Oil Fires in the HDR Containment

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1. ABSTRACT

Since 1982 fire hazard assessment is done in different fire experiments and fire code development for nuclear power plants in FR-Germany. Real fire experiments were done in the HDR-containment simulating fires near the dome of a German pre-convoy plant. The experiments were initiated and performed by the HDR Safety Program, Kernforschungszentrum Karlsruhe, FRG, and the Institute for Building Materials, Concrete Structures and Fire Protection, Technical University Braunschweig, FRG, sponsored by the Ministry of Research and Technology, FRG.

Fires with an average energy output up to 4000 kW were performed with temperatures of 1200 °C in the fire room influencing the dome directly. Because of mixing effects the temperatures decreased to a non dangerous level at a short distance. In the whole containment different types of physical parameters like temperature, velocity, gasconcentration, smoke density and pressure were measured. These real fire experiments were done to generate a new data base about fire behaviour in nuclear containments. In comparison with these datas different types of fire codes were evaluated and tested, which makes calculations transferable from experiment to real plant behaviour. During the last SMIRT-meeting first results were introduced.

2. INTRODUCTION

In 1987 real fire experiments were performed in the HDR-containment at a high level near the containment dome. The experiments before were done to test the containment behaviour under different ventilation conditions and to enlarge the measurement experience. The aim of this experiments was to simulate fires of cable trays near the dome in a German pre convoy plant and to verify fire codes calculating the main physical parameters only knowing the burning rate of the fire. As cable fires produce a lot of corrosive gases oil fires were performed protecting the HDR containment. During the experiments an energy output from 2000, 3000 and 4000 kW in average was measured by a balance in the fire room (Fig. 1). Figure 2 shows a fire level 1900 and the whole geometry of the containment with a height of 60 m, a diameter of 20 m and a volume of 11000 m³. Only results of one experiment are discussed in this paper. The datas of this experiment were used to compare results of different fire codes which are shown in a further contribution at SMIRT 10.

3. FIRE EXPERIMENTS

In the fire room a pan of 2 m² size was filled with 40 kg of oil. Seven minutes after ignition, fire began to decrease than oil (5,6 l/min) were pumped into the pan. After 30 minutes fire duration the oil supply was stopped. By the calculat-

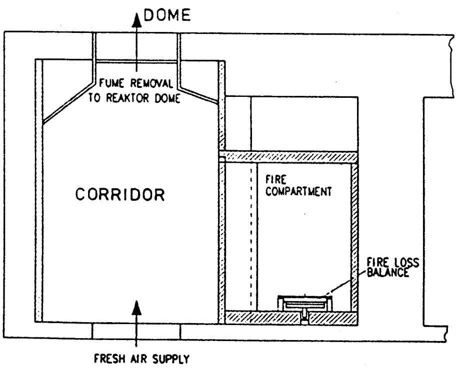

Fig. 1: Fire Room with Balance and Corridor on Level 1900

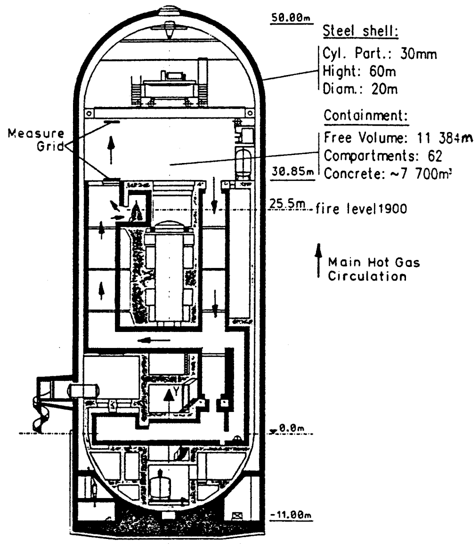

Fig. 2: Containment Geometry, Fire Level, Way of Gascirculation

ed burning rate found from the measured weight loss (Fig. 3) the maximum of energy output was 5000 kW in the beginning of the fire and decreased to 2850 kW, when oil was pumped into the pan.

During the fire by 300 different measure points temperatures in the fire room, temperatures, velocity and gasconcentration like O_2, CO_2, CO in the ventilation opening of the fire room and the 19 m height plume in the dome and convection pattern in the whole containment were measured (Valencia, 1987).

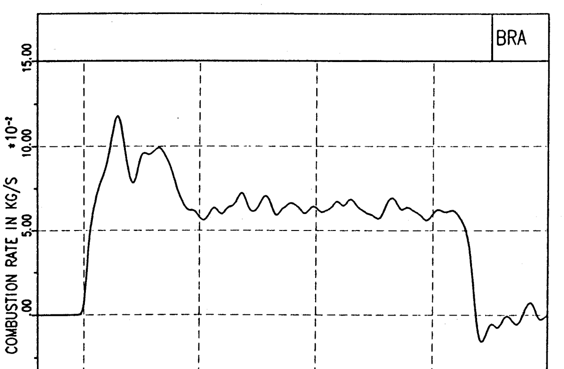

Fig. 3: Burning Rate in a 2 m² Pan

4. RESULTS OF EXPERIMENTS

Discussing results the containment will be divided into three different areas:

- zone of the fire room inclusive the ventilation opening,
- zone close to the fire is the near field area. This means the corridor near to the fire foom and the hot gas plume influencing the steel shell directly,
- zone away from fire called far field. It is the rest of the containment, especially the areas were the circulating gas is flowing like in stair cases (Fig. 2).

In general all fire room temperatures are quasi-stationary after 10 minutes fire duration because of the constant oil supply. During the time when 40 kg oil in the pan was burning the fire is influenced by the surface of the pan and the amount of oil in the pan (Fig. 4). The decrease of the oil level is 3,5 mm/min in the pan. Maximum temperatures of 1500 °C are found in top of the fire room. During the quasy-stationary phase temperatures of 1000 °C were measured.

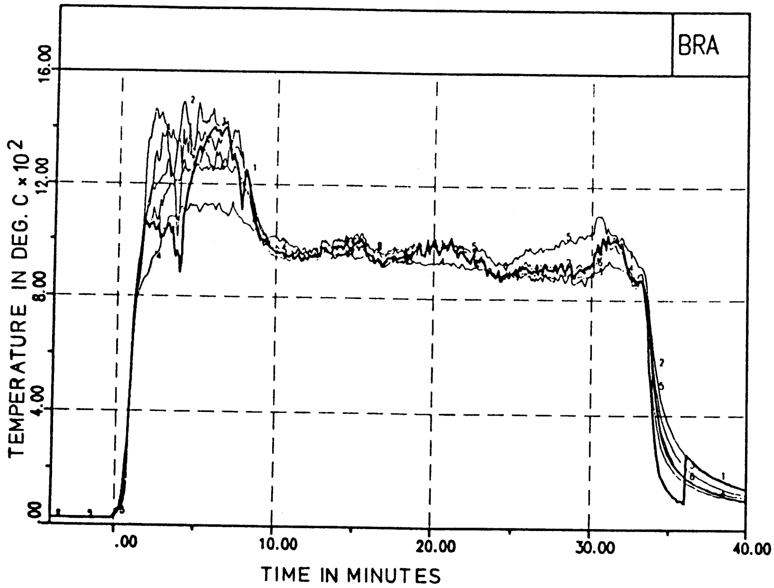

Fig 4.:

Hot Gas Temperature in the Fire Room near Ceiling

The temperatures near the floor of the fire room are influenced by incomming cold air. As the door opening is more on the right side of the fire room the gastemperatures were deminished by cold air on the right side and the back side of the oil pan. Fig. 5 shows the position of the pan in the fire room and the ventilation opening influencing the gas temperatures.

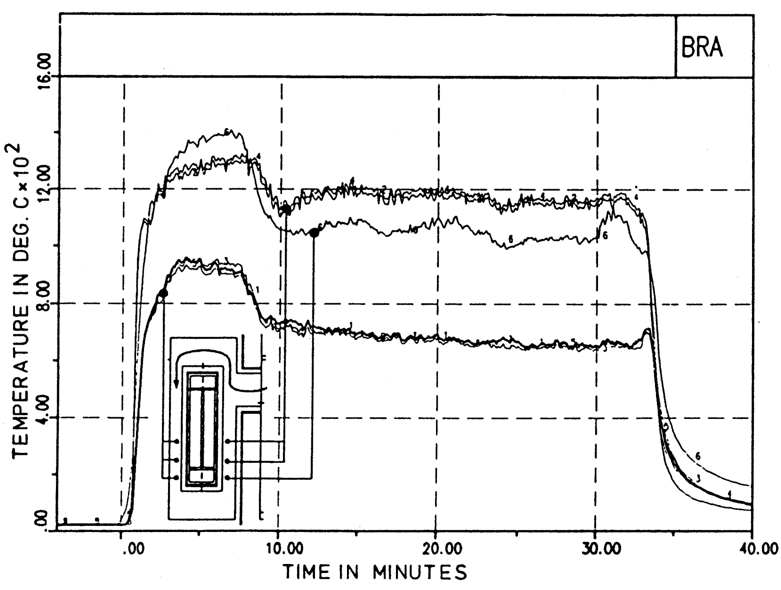

Fig. 5:

Gas Temperature Distribution near Floor, influenced by Air

In the door opening temperatures of 900 - 1300 °C were measured in the hot gas layer which is 1,2 m high, estimated by the temperature profile of the door height (Fig. 6). The fire turned from a fuel controlled to a ventilation controlled fire after 2 minutes fire duration. The oxygen concentration dropped to zero. CO_2 and CO got their maximum. Knowing the velocity distribution in the door opening one can determine mass- and energy flow into the containment. This datas are important, when test results are compared with calculated results of different fire codes and when the physical consistence of codes will be discussed.

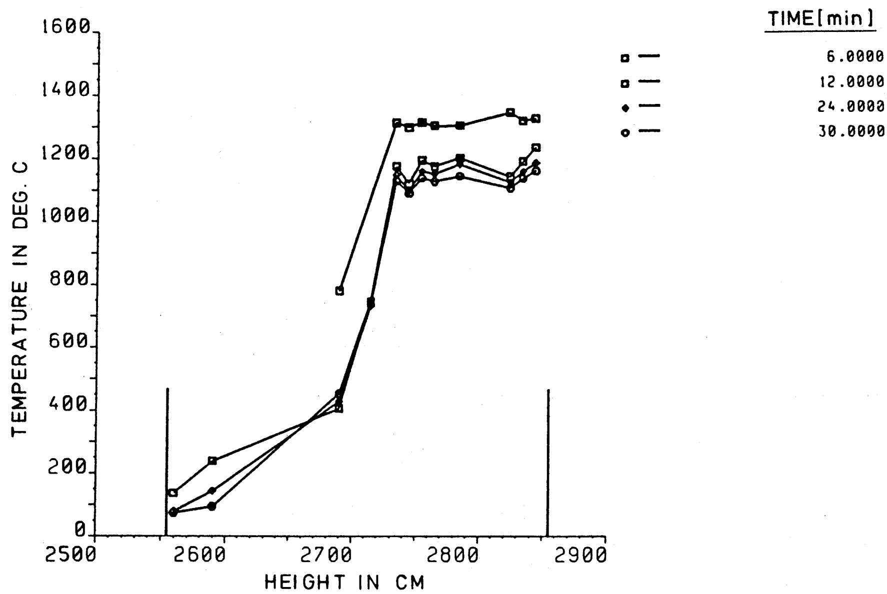

Fig. 6: Temperature Profile in the Door Opening (3 m Height)

A short distance after the fire room the hot gas reached the dome and a 19 m high plume influenced the steel. Two measure grids (Fig. 2) and a lot of single measurement points were installed in the plume area. So we have a lot of datas about temperature-, velocity- and gas concentration profiles. The temperature distribution in two measure grids near the fire room (31 m) and on a higher level (39 m) after 6 minutes fire duration show the influence of mixing effects between hot gas flowing up and the air surrounding. The temperature decreased and got an uniform level in the upper grid (Fig. 7). The cooling of the hot gas is very strong in a distance of 6 m on its 19 m way towards the steel shell (Fig. 8). This fire did not reach the design temperature of 165 °C of the steel shell after a 30 min fire duration.

Short after ignition a thermal induced gas circulation caused an uniform distribution of gas concentration and soot in the whole containment. The vent air filter and the recirculating air filter were used for clearing the containment air. After a short time they lost their function. Visibility than drop to zero, so that even personnel knowing the plant layout will be hardly able to identify and fight the fire source. The soot spread over the whole plant, even in closed rooms deposition of soot was found on all horizontal surfaces (5 - 10 mm tick). As the CO_2-concentration increased to values of 3 % after a 30 min fire duration, no fire will stop in want of oxygen in a real nuclear power plant for a long time. We got a lot of datas for the containment behaviour under fire. This

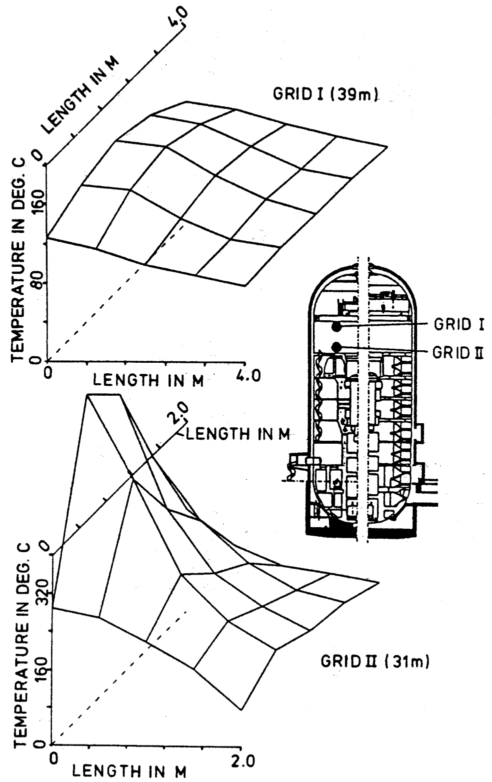

Fig. 7: Temperature Profile in different Measure Grids (6 min Fire Duration)

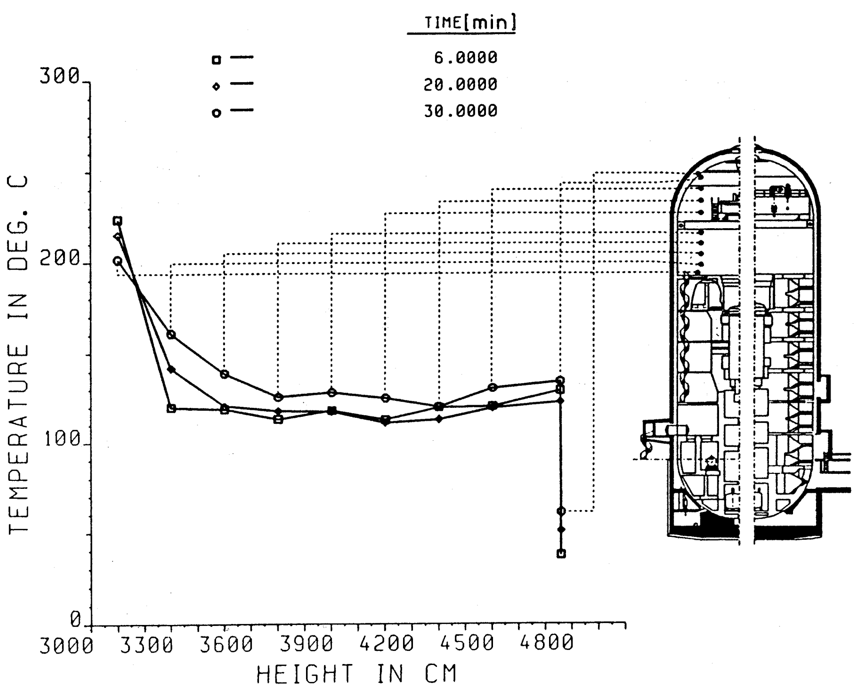

Fig. 8: Temperature Profile of Plume (19 m Height) and Steel Shell Temperature

will be a help to transfer results from the HDR-dimensions to real plant behaviour. As example from all the datas the temperature behaviour of the downward flowing hot gas in the staircase opposite the fire room is shown in Fig. 9. The bottom area of the containment is involved but the main gas flow is circulating back to the fire room described in Fig. 2.

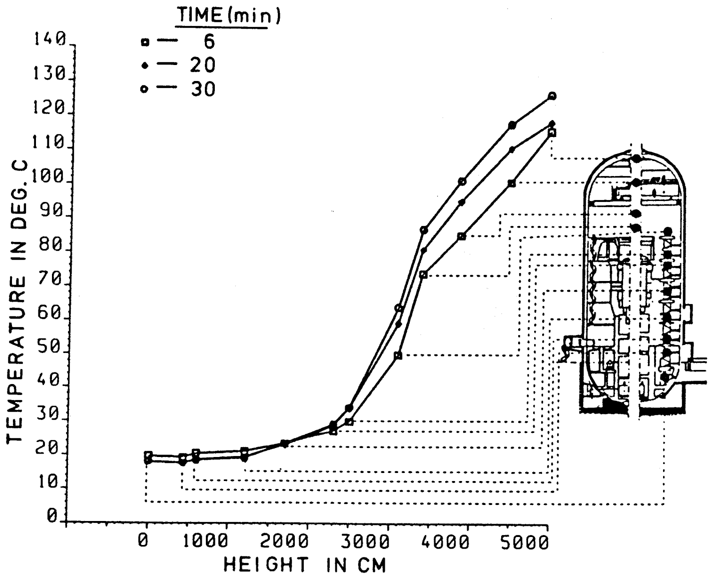

Fig. 9: Temperature Profile of downward flowing Gas

5. CONCLUSION

In an experimental series oil pool fires near the dome of the containment were performed. By these fires a real fire situation in a German pre convoy plant was simulated. The effects of a fire with an energy output between 2800 and 5000 kW were described for the near field and far field area of the containment. A lot of measured datas (300 different measure points) will be helpful for describing real plant behaviour and are offered to fire code user to calibrate their codes by datas found in semi realistic experiments.

REFERENCES

Valencia, L. Große Ölbrandversuche im HDR-Containment; Versuchsergebnisse und erste Beurteilung, 11. Statusbericht des HDR-Projektes, Kernforschungszentrum Karlsruhe, 1987.