Code assessment and code verification for containment fires

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1 INTRODUCTION

Using theoretical models (so called zone models) for to describe the development and effects of fire requires experience in the field of preventive protection against fire as well as reliable experimental data, which may be compared with the theoretical results obtained. This is the only way to evaluate on the safe side the diverse possible situation of fire development on the basis of appropriate calculations.

For years the institute for Baustoffe, Massivbau und Brandschutz, University of Braunschweig, is concerned with problems of preventive protection against fire based on experiments and theoretical calculations in the field of industry constructions as well as nuclear power plants (Dobbernack & Wesche 1986; GRS & ABK, 1985). At present we discuss fire scenarios in real power plants in Germany, therefore we have a research program with large scale experiments in a containment to receive basis data and to verify the used codes in a complex realistic environment.

2 EXPERIMENTS

The experiments were carried out in an old containment of 11.000 m^3. Up to now three series of 14 experiments with forced and natural ventilated fires were performed. Figure 1 shows the level of fire which is situated 50 m beneath the containment dome and includes fire room, corridor, staircase and airchannel (more details of the experiments are shown in the contribution of K. Müller, Kernforschungsanlage Karlsruhe: Containment behaviour under fire conditions and its calculatibility).

For code assessment we need an improved understanding of the physical processes occuring during fire. Therefore different measuring systems were installed in the fire room, fire room opening, corridor, stair cases, ventilation openings and the whole containment for the following parameters: temperature, velocity, pressure, heattransfer, gas analysis and smoke density. Thus it is possible to dertermine physical values like energy- and mass transport.

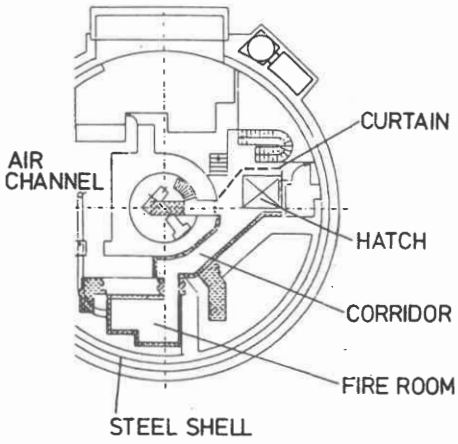

Fig. 1. Fire comparment level

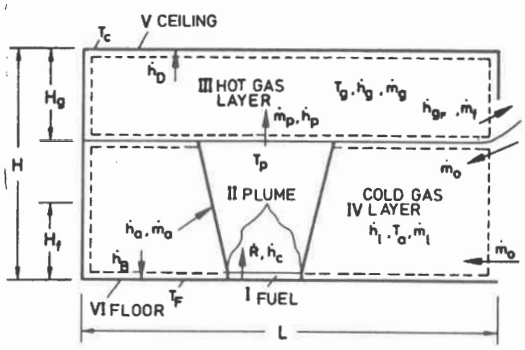

Fig. 2. Zone model segments, schematic

3 USED CODES

In the beginning of our studies only codes for industrial fire protection were available for theoretical calculations. This codes are suitable for describing effects of fire in single rooms or defined areas directly influenced by fire when varying fire room dimension, fire load and ventilation. This codes are mainly used to calculate data about time dependent temperatures and energy flux into structures which enables a classification of structures adequate to German standard DIN 4102, DIN 18 230 and DIN 18 232.

Figure 2 shows the scheme of a zone model for a fire room, which is divided in the following six segments:

I Place of heat release from the burning materials (burning rate).
II Plume: Area above the burning fuel in which the rising hot gases are mixed with cold air.
III Hot gas layer: The hot gas accumulates under the ceiling, forming the hot gas layer, which varies depending on ventilation opening.
IV Cold gas layer: Area beneath the hot gas layer filled with air.
V Ceiling: Area behind the hot gas layer.
VI Floor: Area behind the cold gas layer, heating it by convection

The calculated values of the segments represent means respectively.

Another type of code (system code) up to now was used for describing the hydrogen propagation for nuclear safety research. The geometry of fire room may be divided in any number of segments at all. The calculation procedures for the segments are similar to those used for zone models.

4 CODE REQUIREMENTS

The used codes can only be availuated if the requirements of the quality of results are defined. The codes should determine as many physical parameters as possible which influence the development of fire or re-

sult from it, considering multi fire room scenarios and a closed containment. A code which describes not only the relevant effects of fire in the near by surroundings but also safety aspects of the whole containment in areas far away from fire would be the most attractive one. As the development of fire is influenced by many parameters like room geometry, kind and arrangement of fire load and ventilation a mathematical model solving the whole problem is up to now not available. Therefore a catalogoue of criterions was worked out for classification of the codes which contains primary and secondary criterions for areas close to or far away from fire.

Pressure and temperature are considered as primary criterions for areas close to fire. They should be within an accuracy of 10 - 20 %. The burning function of the fire load, height of the gas layer, energy- and massflux and velocity are considered as secondary criterions. They may only be within an accuracy of 30 % because these parameters are determined in an indirect way. But they are useful to test the physical consistance of the codes. For areas far away from fire primary criterions are not only temperature and pressure but also gas concentrations as well as the behaviour of aerosoles because aspects of escape routes and filter pollution are of great importance. The accuracy should be within 10 - 20 %. For the secondary criterions an accuracy of 50 % is acceptable.

5 CODE ASSESSMENT

Starting out from the zone model for one room the codes had to be extended for their application to multi fire rooms. The model should allow calculations for the area close to fire (Fig. 1: Fire room, corridor up to the hatch) and describe influences of fire in the containment.

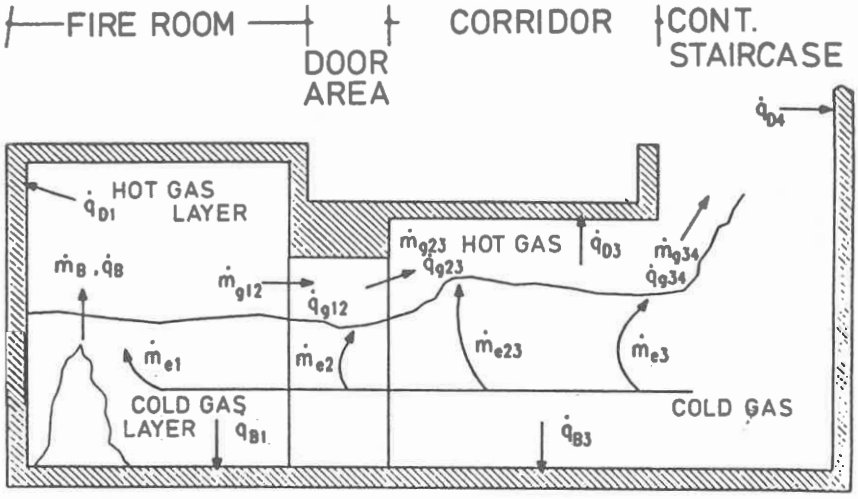

Fig. 3. Multiroom Zonemodel with local energy- and massflux (schematic)

Fig. 3 shows a scheme of the fire level with energy ($\dot{q}$) and mass fluxes ($\dot{m}$) obtained with the model developed. As hot gases escape on top of the burning area and colder air flows to the lower part of the

burning area mixing effects between the gas layers occur. These mixing effects have a great influence on the decrease of temperature along the way of hot gases. In the beginning of our studies the zone model did not consider these effects. After having observed the mixing effects in further experiments using more measuring points (like temperature, velocity and composition of gases) the codes were developed to include these aspects.

To be able to assign calculated values to experimental data a reference catalogue was elaborated including all physical parameters for each part of the rooms. For an assessment of different codes a series of experiments was performed among others using gas fires with forced ventilation. The corresponding theoretical data were calculated on the basis of given values for input energy and excess air of the burner.

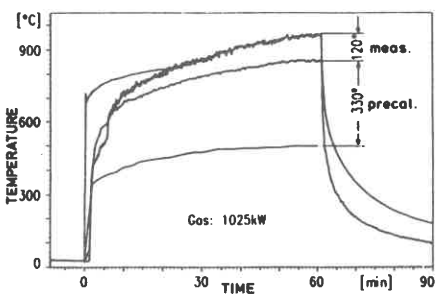

Figure 4. Precalculation of different codes compared with measurements for the fire room

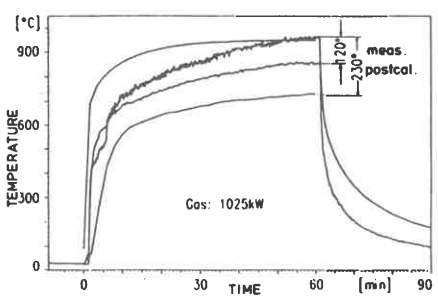

Figure 5. Postcalculation of different codes compared with measurements for the fire room

Fig. 4 shows the range of results obtained with different codes for the hot gas temperatures of the fire room which differ to a far greater extent than the measured values. Considering that the experiments were not performed with the given value of excess air of 10 - 20 % but under a slight deficiency of air boundary conditions obviously have a strong effect on the results of the codes because based on the correct value of air supply post calculations with the same models agreed much better with the experimental data (Fig. 5). Therefore the codes meet nearly all demands of accuracy which are necessary in this field.

Similar results for the fire room were obtained using material ventilated fires. Provided that the burning rate e.g. the release of energy in the fire room is known, the codes allow calculations of temperatures with sufficient accuracy. Postcalculations of the hot gas temperatures in the corridor differed to a much greater extend (Fig. 6). Especially one code with far reaching higher temperatures obviously did not consider mixing effects.

Leaving the fire room level through the hatch, the hot gases spread themselves over the whole containment. Therefore this ventilation opening represents the bounds between the close and the distant areas of the fire room. According to the German regulations for protection against fire these bounds have to obey corresponding safety levels.

Calculations of temperatures and velocities as well as energy and mass fluxes of the hot gases escaping from the hatch at the end of the corridor were performed with some of the codes and gave results of different quality, comparing for example the velocity of the escaping hot gases (Figure 7). Especially one code produced velocities (pre- and post calculation), which were much lower than measured values.

At that time only one zone model was able to describe the temperature development in the containment. The system code produced more detailed results for this area and therefore was superior to the other models presented. Figure 8 shows the temperature development which were calculated and measured on a level of the containment far away from the fire level. The codes are able to produce further physical parameters which are not discussed in this paper.

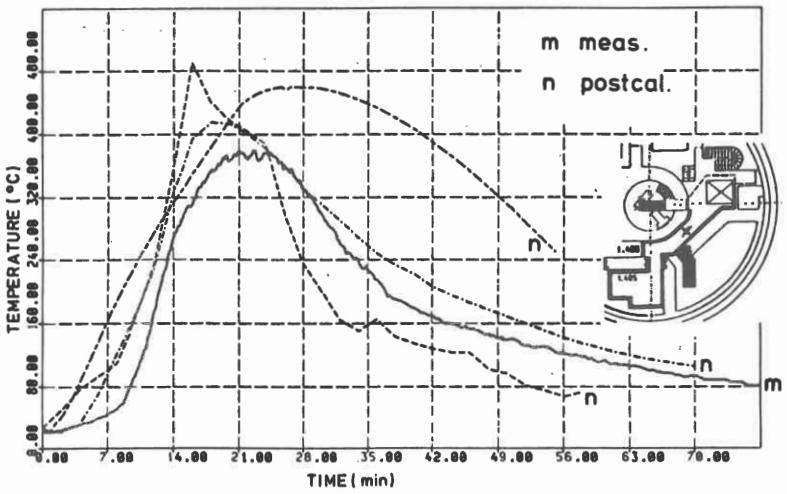

Fig. 6. Temperature development of hot gases in corridor, postcalculations

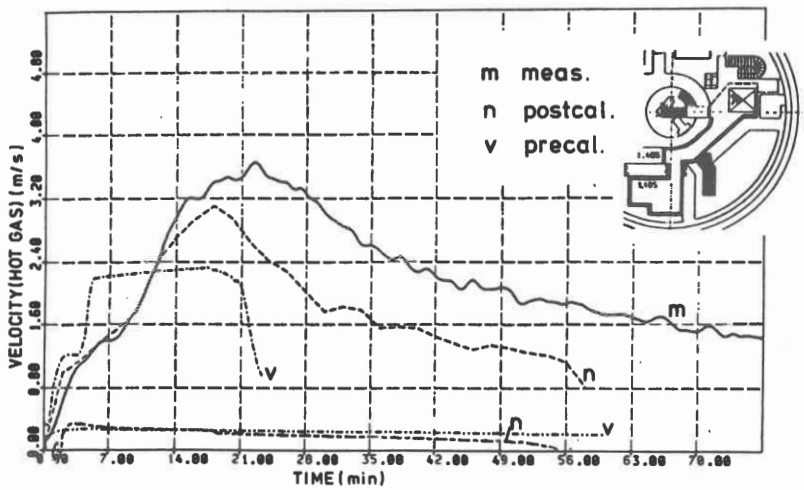

Fig. 7. Velocity of hot gases in the hatch, flowing into the containment, pre- and postcalculations

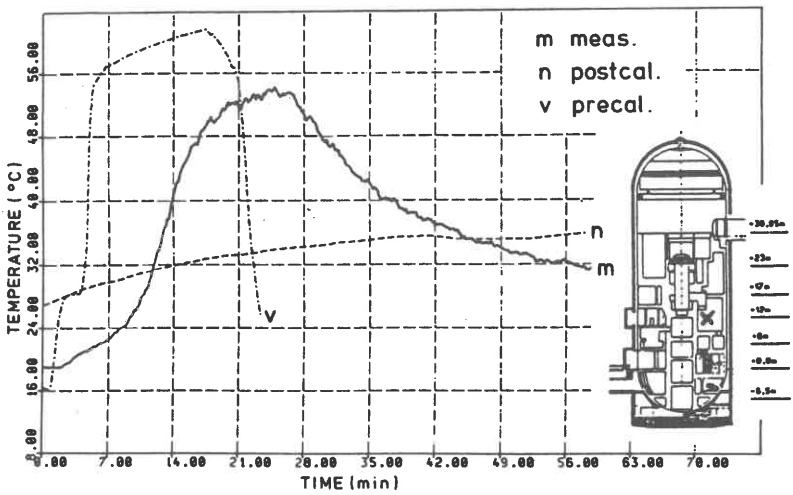

Fig. 8. Temperature in the containment, far away from fire room level, pre- and postcalculation

At present developments of the zone models are going on. Calculating the next experiments in the HDR the zone models will be able to describe local physical parameters in the containment.

6 SUMMARY

The codes originally used for fire in industrial constructions were developed for their application on multi fire room scenarios. They are able to describe fires in containments. Comparing the theoretical values of different models with experimental data obtained in a large scale containment the accuracy of the models were assessed. The codes showed rather good results in areas close to the fire room but must be improved for distant areas of the containment. These studies are in progress.

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