3.9. ECO - Experiments on energy COnversion during a steam explosion

Objective of the facility

In case of a steam explosion, e.g. as a consequence of a severe reactor accident, part of the thermal energy of the melt is transferred into mechanical energy. At Forschungszentrum Karlsruhe, the ECO experiments are being directed to measure the conversion factor under well-defined conditions. The programme was launched in 2000. Alumina from a thermite reaction is used as a simulating material instead of corium. Dimensions of the test facility as well as major test conditions, e.g. temperature and release mode of the melt, water inventory and test procedure, are based on the former PREMIX experiments (from 1994 to 1999).

Parameters of the facility

The ECO facility, housed inside the large FAUNA steel vessel, was designed for investigating energy conversion ratios up to 20 %, related to 10 kg of melt. In principle, it consists of a piston/cylinder system having 4 m in the total height. The melt generator providing the melt (≈ 2600 K) is part of the cylinder. The water pool has 0.6 m in diameter, and up to 1.3 m in depth. The steam explosion is triggered by two explosion capsules located in the centre and at the edge of the bottom of the pool. The test vessel (”piston”), under the pressure forces developing due to the steam explosion, moves downwards against the resistance of the underlying crushing material.

Instrumentation and measurements

The instrumentation was especially designed to evaluate the energy transferred, using pressure transducers, void probes, thermocouples, strain gauges, and displacement transducers. The void probes, forming a grid of 8 axial and 8 radial positions, give good information about the axial and radial growth of the mixing zone.

The deformation of the crushing material is an important integral measurement of the transferred mechanical energy. In ECO-01 and ECO-02, this deformation was of the order of 2 mm only, i.e. at the lower limit of the design. In ECO-03, less than 1 kg of melt were released due to malfunction of a valve, and the deformation was practically zero.

Important changes were made in the test conditions of ECO-04 and ECO-05 to reach a larger conversion rate. In ECO-04, two changes were made: (1) To reduce the amount of water involved in the condensation processes during the premixing and explosion phases, a concentric steel cylinder having about half of the pool diameter was mounted in the vessel. Holes drilled into the cylinder wall allowed the transfer of pressure waves from the mixing region to the vessel wall where the pressure transducers were located. (2)The melt release from the crucible through the nozzle was started with the aid of another fast slide valve mounted in the nozzle a short distance below the crucible. When the chemical reaction of the thermite was finished, this (upper) slide valve opened. This valve was to guarantee a fairly compact melt jet with full diameter immediately from the beginning.

In fact, the conversion of thermal into mechanical energy was much more effective in ECO-04 than in the three tests before. The piston moved downward by 65 mm, corresponding to a conversion factor of about 0.5 percent.

In ECO-05, additionally, a “melt jet divider” was mounted at the nozzle exit to enhance mixing and to reduce the penetration speed. The device, consisting of four ribs forming a cross, divided the compact jet, principally into four parts. One effect of this supplement was decisive for the good result: the melt was prevented from penetrating downward at a high rate. At the instant of triggering, as scheduled, a melt mass of 16.4 kg had been released. This was significantly larger compared to the previous tests. After firing the trigger capsule, the strongest explosion of the test series occurred. The piston moved downward by 319 mm, which corresponds to an efficiency of about 2.3 percent.

Table 9.1 ECO test matrix

Exp. ID	Date	Type (characteristics)
ECO-01	25.04.00	- melt discharged: 5.76 kg, - pool: d=0.6 m, h= 1.1 m, T= 293 K, - initial system pressure 0.1 MPa - triggered explosion.
ECO-02	12.12.00	- melt discharged: 2.87 kg - pool: d=0.6 m, h=1.05 m, T= 293 K - initial system pressure 0.1 MPa, - open system, self-triggered explosion.
ECO-03	10.04.01	- melt discharged: 0.9 kg - pool: d=0.6 m, h=1.05 m, T= 323 … 363 K - initial system pressure 0.25 MPa, - triggered explosion, but malfunction of a valve
ECO-04	14.11.01	- melt discharged: 9.6 kg - pool: d=0.3 m, h=1.05 m, T= 336 … 369 K - initial system pressure 0.25 MPa, - inner cylinder to reduce active volume, - triggered explosion
ECO-05	19.06.02	- melt discharged: 16.4 kg - pool: d=0.3 m, h=1.05 m, T= 329 … 355 K - initial system pressure 0.23 MPa, - melt jet divider at nozzle exit, - triggered explosion

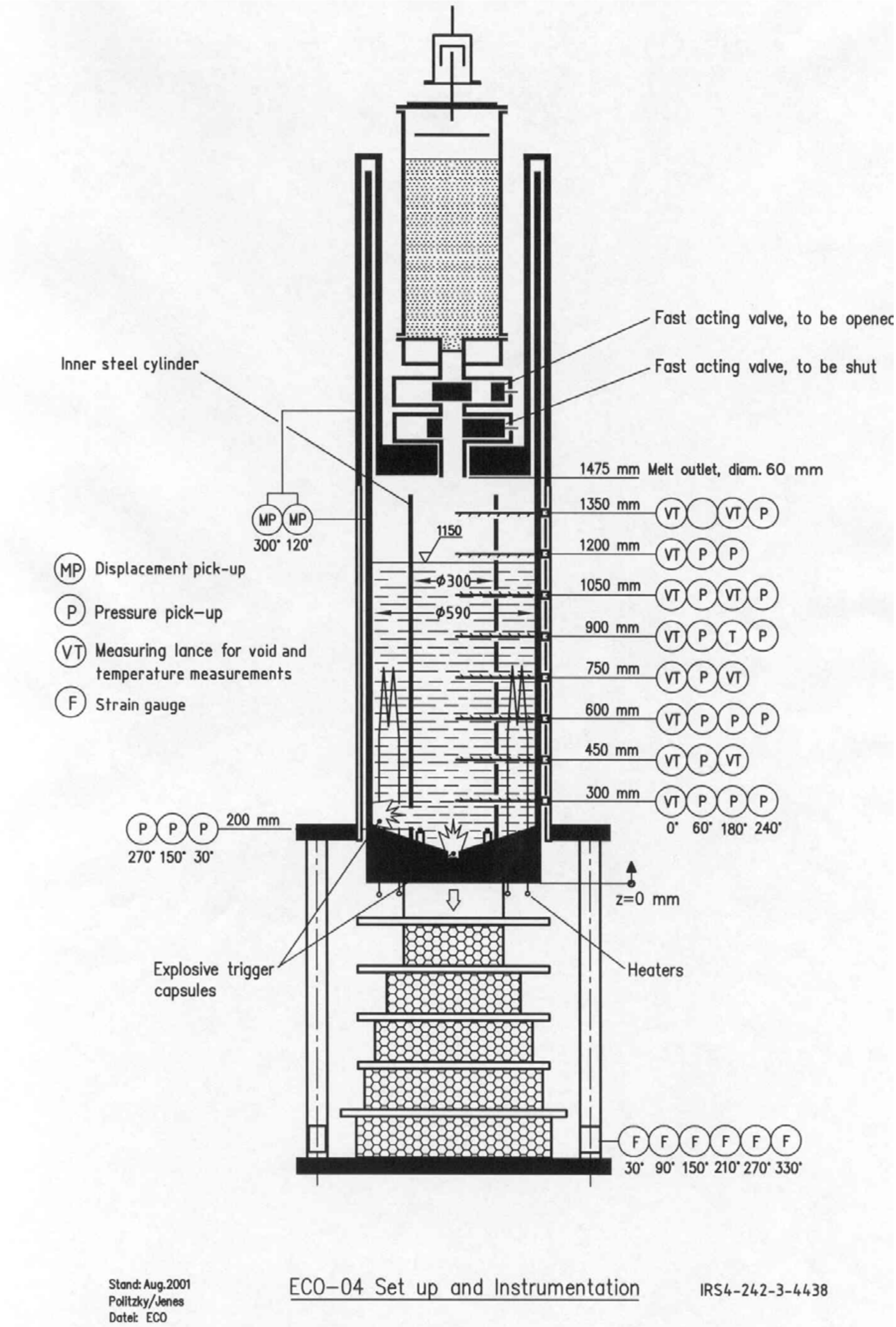

Fig. 9-1 Scheme of the ECO facility