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COOLOCE-12 debris bed coolability experiment: Cone on a cylindrical base

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VTT Technical Research Centre of Finland

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Abstract

The COOLOCE-12 experiment addressed a debris bed geometry that has a conical heap on top of a cylindrical base, i.e. part of the debris is distributed against the walls of the spreading area but the top part of the debris has the conical (heap-like) shape. The height of the conical part was half of the total height. The dryout power for this configuration was 17–26 kW (1929–2897 kW/m^3) for the pressure range of 1–4 bar. Comparisons to other debris bed geometry variations, namely, the fully conical bed and the top-flooded cylindrical bed, have been made. The results suggest that the cone on a base geometry has a comparatively high dryout power and coolability. In general, the results clarify the effect of the multi-dimensional flooding and the flow mode in relation to the effects of test bed height and the overall geometry and will be utilized in the validation and development of simulation models and codes.

Key words

severe accident, core debris, coolability, dryout heat flux, COOLOCE test facility

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RESEARCH REPORT

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Summary

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Contents

1. Introduction

A debris bed (particle bed) that consists of fragmented and solidified corium may be formed as a result of a core melt accident in a nuclear power reactor. Depending on the design of the reactor, such a debris bed may be formed in the containment (ex-vessel) or inside the pressure vessel. Ensuring the debris bed coolability is of high importance in the severe accident management strategy of the Nordic type boiling water reactors, two of which are located in Olkiluoto, Finland. The issue of corium coolability has also received considerable attention since the accident at Fukushima in March 2011 which apparently resulted in various degrees of core melting in Units 1–3.

The debris bed formation (solidification and settlement of particles) is a stochastic process whose outcome cannot be fully predicted. The debris bed may be highly complex in terms of particle size, morphology and the spatial distribution of particles. Therefore, the research work on debris coolability has been limited to certain geometries and two-phase flow modes that can be considered representative in a realistic severe accident scenario.

The COOLOCE test facility is a laboratory-scale facility at VTT designed to investigate the coolability of porous particle beds of different geometries. In the experiments, the dryout power which gives the limit for coolable steady-state is measured. The experiments were started in 2010-2011 with the main objective of comparing the dryout power of a conical (heap-like) particle bed configuration to that of a cylindrical (evenly distributed) configuration [1-5]. In 2012, the experiments were extended to include irregular gravel as a simulant material (COOLOCE-8) and initially subcooled pool (COOLOCE-9) [6]. After this, the focus was again on the effect of different flow modes and geometries on coolability. A cylindrical bed with lateral and top flooding was investigated in COOLOCE-10 [7] and a cylindrical bed with lateral flooding only in COOLOCE-11. In the former of the test series, all surfaces except bottom were open to flooding and, in the latter, an agglomerate simulant was placed on top of the test bed so that only lateral flooding was allowed.

This report describes the COOLOCE-12 test series which examined a geometry variation approximating a reactor scenario in which the debris bed has partially settled against the wall of the spreading area, with a conical heap of debris on the top. The geometry is a cone on a cylindrical base, flooded through the surface of the conical part and with impermeable sidewall in the cylindrical part. Simulations suggest that this type of debris bed may be formed as a result of spreading of the debris particles by natural circulation flows in the pool [8].

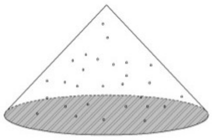
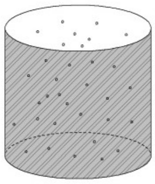
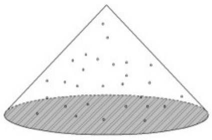
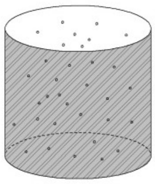
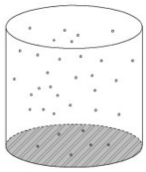
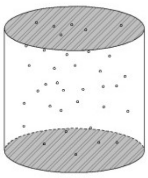
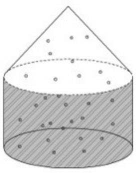
The validation of simulation codes against the experiments is a crucial part of the coolability research which aims at verifying that the codes are capable of producing reliable results in power plant scenarios. The experimental results will be used in the validation of the MEWA code (developed by IKE at Stuttgart University [9]) in use at VTT, the DECOSIM code developed by KTH (Royal Institute of Technology, Sweden) and the 3D CFD type approach developed by VTT (PORFLO and Fluent). These codes can be categorized as two-phase flow solvers with at least 2D modelling capability.

In addition, the results of COOLOCE-12 will be utilized in validating a separate, simplified model that describes the relative coolability of the conical and cylindrical geometries and the combinations of these geometries (the variations of the ratio of the heights of the conical and cylindrical parts). This model is used by KTH in the risk-informed approach to the coolability issue which aims to calculate the probability of non-coolable conditions by Monte Carlo simulations of dryout heat flux [10]. The joint efforts by KTH and VTT are performed in the frame of the NKS project DECOSE (Debris Coolability and Steam Explosions). One of the main objectives of these efforts is collecting the experiences gained during the work into best practice guidelines for debris coolability simulations.

2. Test matrix

The COOLOCE experiments starting in 2010 until August 2013 are summarized in *Table 1*. The experimental series are numbered according to their chronological order. In the reporting, the test runs for each pressure level are named in alphabetical order (of increasing pressure), e.g. COOLOCE-11a denotes 1.0 bar (abs.) pressure and COOLOCE-11f indicates 7.0 bar.

Table 1. The COOLOCE experiments 2010-2013.

Experiment	**Flow configuration**	**Test bed**	**Particle material**	**Pressure range [bar]**
COOLOCE-1 – 2	Conical, multi-dimensional			1.6-2.0
COOLOCE-3 – 5	Cylindrical, top flooding		Spherical beads	1.0-7.0
COOLOCE-6 – 7	Conical, multi-dimensional			1.0-3.0
COOLOCE-8	Cylindrical, top flooding		Irregular gravel	1.0-7.0
COOLOCE-9	Cylindrical, top flooding*			1.0
COOLOCE-10	Cylindrical, lateral and top flooding		Spherical beads	1.3-3.0
COOLOCE-11	Cylindrical, lateral flooding			1.0-7.0
COOLOCE-12	Cone on a cylindrical base, flooding through conical part		Spherical beads	1.0-4.0

** Initially subcooled water pool, saturated pool in all other experiments.*

The basis of pressure range selection in the experiments is “as high as possible”: The upper limit is either the maximum available power (if dryout power exceeds it) or the design pressure of the test vessel (if the dryout power is below maximum available). An exception to this is COOLOCE-9, the experiments with subcooled pool, in which pressure variation was not done due to the type of the experiment [6]. The pressure range given in the table is nominal (approximate), the average pressures for each dryout point and pressure histories are presented in the descriptions of the experiments in the Results Chapter of each technical report.

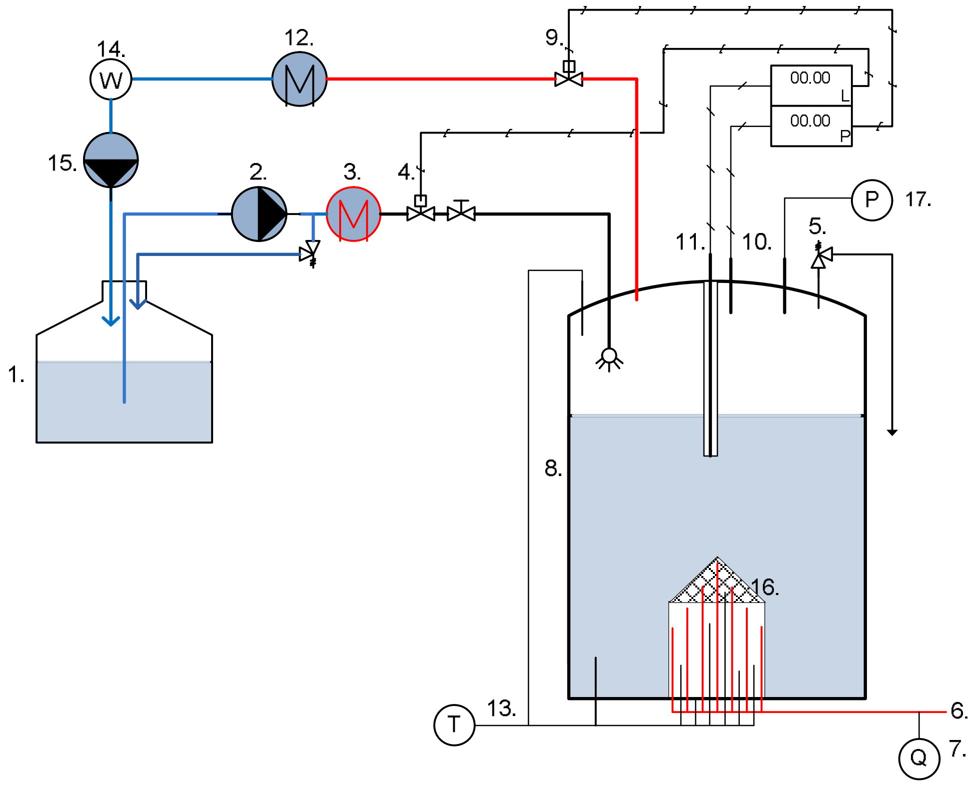
3. Experimental set-up

The main components of the COOLOCE test facility are the pressure vessel which houses the test particle bed, the feed water and steam removal systems and instrumentation. The custom-designed pressure vessel has a volume of 270 dm^3 and design pressure of 7 bar (overpressure). The schematic of the arrangement is presented in Fig. 1. The COOLOCE-12 test bed consists of a cone on a cylindrical base, shown in Fig. 2.

The cylindrical part is 250 mm in diameter (half the radius of the full-sized conical test bed) and 135 mm in height. The height of the conical part is also 135 mm yielding the total volume of 8.84 dm^3. This is about half the volume of the conical test bed. The arrangement was made by extracting a suitable geometry from the conical test bed of COOLOCE-6 – 7 as illustrated in Fig. 3. The modifications included the removal of the outermost heaters and temperature sensors, sealing their connections through the pressure vessel bottom plate with plugs and installing a new cylindrical wall.

The test bed is heated by ∅ 6.3 mm vertically installed cartridge heaters distributed in such a way that the power generation per unit volume of the test bed is as uniform as possible. There is a 50 mm layer of unheated particles above the heaters. The maximum nominal power of the heaters, i.e. the maximum test bed heating power, is 30.6 kW. Three of the heaters are equipped with internal thermocouples at 110 mm height from the test bed bottom to monitor their temperature.

The detection of dryout is based on increased temperature which is monitored by K type thermocouples installed in a configuration that gives a good coverage of the porous bed volume between the heaters. The thermocouple and heater map (relative to the test bed bottom plate) is shown in Appendix A. The number of thermocouples in the set-up is 46, ten of which are included in one multi-point thermocouple near the test bed centre.



1) Feed water tank
2) Feed water pump
3) Feed water pre-heater
4) Feed water control valve
5) Safety valve
6) Resistance heaters of the test bed
7) Power input and measurement
8) Pressure vessel
9) Steam line control valve (pressure control)
10) Pressure measurement (control)
11) Water level measurement (feed water control)
12) Condenser
13) Test bed temperature measurements
14) Bench scale for condensate mass flow measurement
15) Water recycling pump
16) Test bed
17) Pressure measurement

Fig. 1. Schematic of the COOLOCE test facility.

Fig. 2. The cone on a cylindrical base test bed.

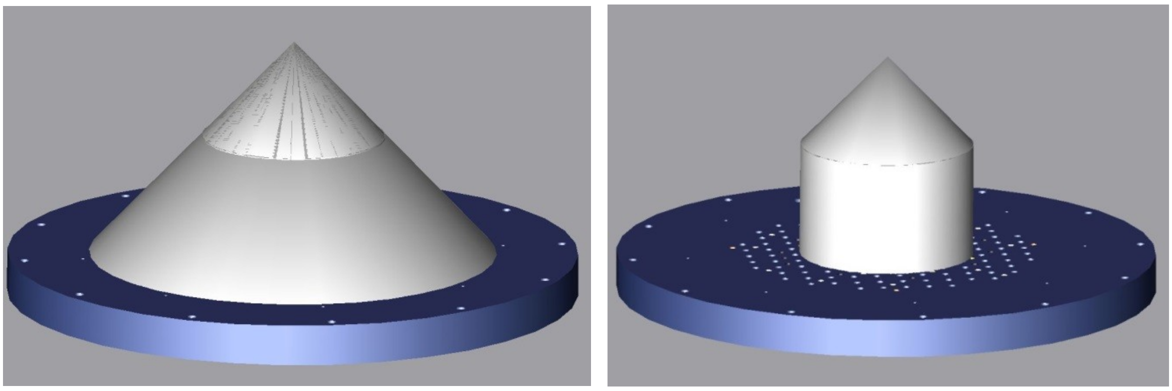


Fig. 3. Design sketches of the COOLOCE-12 test bed. The conical test bed (left) and the section to be extracted for COOLOCE-12 (right).

The debris simulant consists of zirconia/silica beads (ZrO_2 ≥ 65%, SiO_2 ≤ 35%). The size distribution has been measured with two methods: image processing and laser diffraction analyser. According to a sample of about 1000 beads that were photographed, the size range is 0.82-1.11 mm with the mean of 0.97 mm and standard deviation of 0.065 mm. The laser diffraction analysis (for different samples) showed that the volume-weighted average diameter is 0.975 mm and the surface mean is 0.960 mm which are very close to the image analysis results. In this analyses, small amounts (0.03-0.12%) of particles were even found to be smaller than 0.666 mm and larger than 1.430 mm but is seems likely that these extreme values are caused by occasional impurities in the sample, or the conglomeration of several particles.

According to separate measurements at KTH (Kungliga Tekniska Högskolan in Sweden), the effective particle diameter of the beads is 0.8 mm as measured for a bed porosity of 39.9% [11].This means that the representative diameter considering the flow resistance would be close to the smallest particles in the distribution, rather than the mean of 0.97 mm. The estimation was done by measuring the single-phase pressure drop and fitting the results to the prediction by the classical Ergun's equation [12]. It should be noted that this method of particle diameter estimation is not independent of porosity because both porosity and particle diameter have an effect on the pressure loss.

The density of the particle material is about 4200 kg/m^3 (4230 kg/m^3 according to a KTH measurement [11]). The particles are nominally spherical but the images of the particles reveal that some of them are not strictly spheres but slightly elliptical (spheres with some unknown tolerance for roundness). The test bed porosity is the particle volume divided by the volume of the space that can be filled with particles):

$$\varepsilon = 1 - \frac{m_{part} / \rho_{part}}{V_{tot} - V_{heater,TC}}$$

This yields the porosity of 0.375. Here, the volume of the heaters and thermocouples (which is 2.7% of the volume of the geometry) is subtracted from the total volume because the presence of these comparatively large structures would reduce the porosity and this would not be hydrodynamically well-grounded (especially for vertical structures).

3.1 The test procedure

The normal test procedure consists of a heat-up sequence and the main test sequence. Generally, these are similar in all the experiments with different geometrical configurations. Prior to the experiments, the test pressure vessel is filled with pre-heated demineralized water to a level of approximately 300 mm above the test bed surface. During the heat-up sequence the facility is heated up to the saturation temperature and steady-state boiling is reached. The power level of the heat-up sequence depends on e.g. the test pressure and the expected dryout power.

In the test sequence, a stepwise power increase is conducted until a dryout is indicated by one or more thermocouples within the test bed. Dryout is seen as a stable increase of the sensor temperature from the saturation temperature. A holding time of 20 to 30 minutes is applied for each power step. This is to allow enough time for the development of dryout (evaporation of liquid) inside the debris bed after the critical power level has been reached. An adequate holding time is especially important in top-flooded test configurations.

The size of the power increments in COOLOCE-12 was 1 kW. The power increase scheme for each test sequence is documented in the power and temperature figures in Chapter 4. During the test sequence, the water level and pressure in the test vessel are controlled by the feed water and steam line control valves according to given set points. These process variables are shown in Chapter 4 for the purpose of documenting the events leading to dryout in the test runs. The heating power is manually controlled by adjusting the output voltage of a purpose-tailored power transformer. Three of the heaters are equipped with temperature sensors which help to detect possible overheating (“heater dryout”).

The condensate mass flow that exits from the facility can be estimated by a bench scale connected to the condenser outlet. This can be used to verify the power level of the experiments and to estimate the heat losses assuming that the water which is collected to the scale per unit of time is equal to the mass flux evaporated by the heated test bed. The difference between the power calculated from the measurements of mass (*calculated power*) and the *control power* gives an estimate of the heat losses and uncertainty in the recorded control power. Typically, this difference is 10-20% and increases with increasing power and pressure when the difference to the ambient temperature is greater.

Since the power generation by the test bed heaters has to compensate for the heat losses, in addition to being able to boil the water, the control power is greater than the calculated power. Based on the estimates of condensate accumulation at the dryout power steps, the difference is similar to the one observed in the previous COOLOCE experiments. Due to the unknown (and possible pressure-dependent) effect of direct contact condensation in the test vessel and other uncertainties in the condensate mass flow rate, we consider only the control power in Chapter 4.

4. COOLOCE-12 results

Dryout was measured for pressure levels 1 – 4 bar (abs). The results are collected in *Table 2*. The dryout power and the reported pressure are the averages of the power step leading to dryout. The test sequences are described in the following sections.

Table 2. COOLOCE-12 results.

Experiment	Gauge pressure [bar]	Dryout power [kW]	Dryout power density [kW/m^3]
12a	0.085	17.05	1929
12b	0.98	19.65	2224
12c	1.95	22.95	2597
12d	2.81	25.59	2897

4.1 COOLOCE-12a

The experiment at nominally atmospheric pressure required several attempts to reach dryout because, at first, only the heater sensors showed increased temperatures. As a result, this test run was the second last to be performed in COOLOCE-12.

The heater temperatures started to increase rather quickly at 15 kW before any indication of dryout in the test bed sensors. After that, the power steps were reduced to about 0.5 kW and they were made in rapid succession for the purpose of reaching dryout but reducing the amount of time the heaters would be exposed to high temperatures. This resulted in dryout at 17.1 kW. Dryout was indicated by the sensors 112-135 and 115-135, two points in the multi-point TC at 120 mm and 150 mm height from the test bed bottom. After dryout had been confirmed, the heater temperatures (according to the three sensor points at 110 mm) had reached 550-600°C and the power was switched off.

The power and temperature histories of the sensors that indicated dryout are illustrated in Fig. 4. The power peak seen in the figure after the test run at 60s is a test of the maximum power output with the present configuration, done to scope for which pressure levels dryout would be attainable. The process parameters of the test run, pressure, feed water temperature and the water level in the pressure vessel, are shown in Fig. 5. The temperature evolution of the heater sensors are presented in Appendix B.

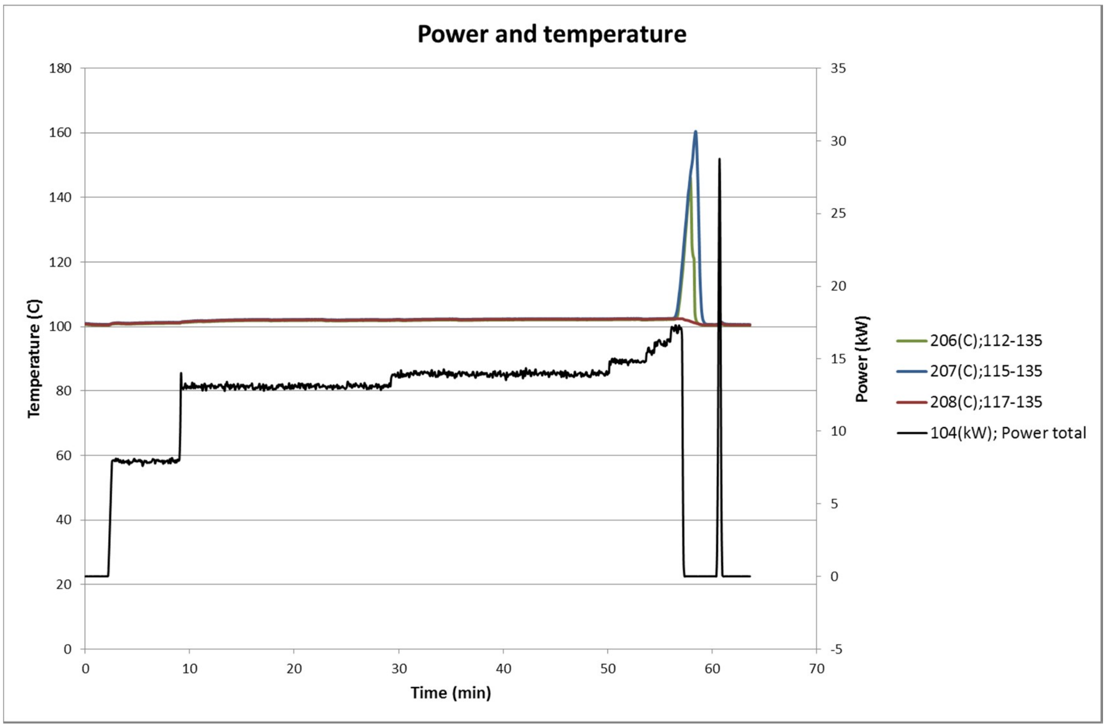


Fig. 4. Control power and the temperature of the sensor(s) indicating dryout in COOLOCE-12a.

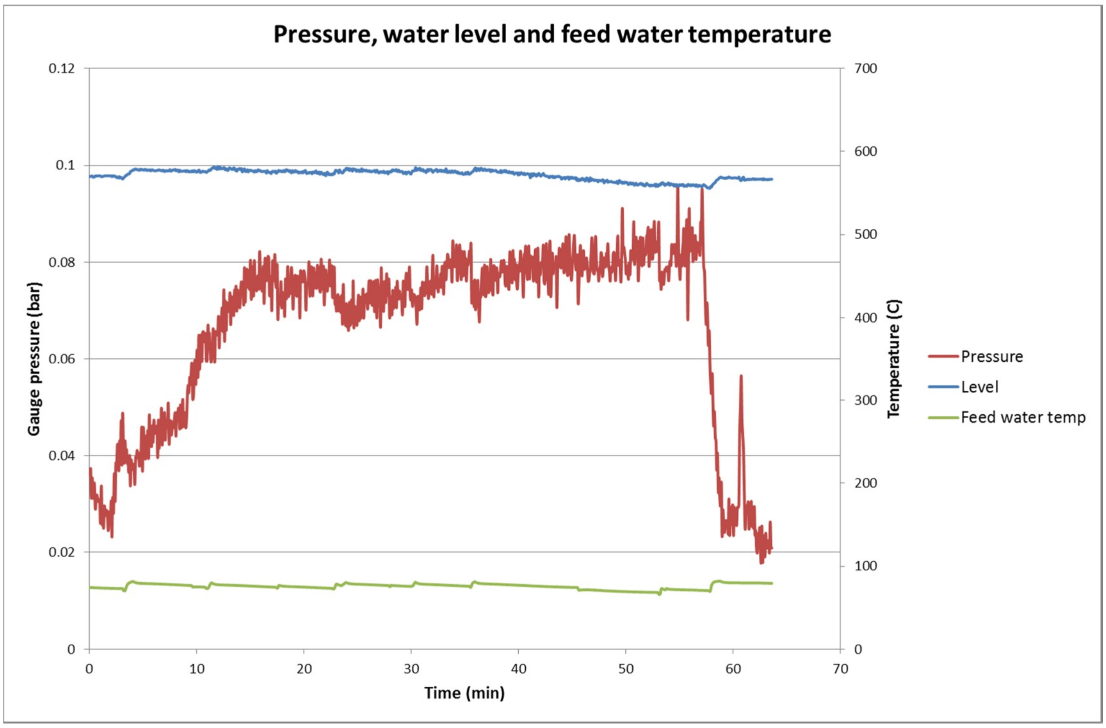


Fig. 5. Pressure and water level in the test vessel and feed water temperature in COOLOCE-12a.

4.2 COOLOCE-12b

Similarly to COOLOCE-12a, the heater temperatures started to increase prior to dryout in the test bed sensors with the power being 19 kW. The dryout spread to the test bed sensors when the power was marginally increased, and the final dryout power was 19.7 kW. The holding time at this power was only about 1.5 minutes during which the temperature of the sensor 115-135 at 150 mm from the test bed bottom increased about 15°C from the saturation temperature before power was decreased to zero. The hottest heater (T69) had reached 450°C. The power and temperature histories of the sensors that indicated dryout are illustrated in Fig. 6. The process parameters of the test run, pressure, feed water temperature and the water level in the pressure vessel, are shown in Fig. 7.

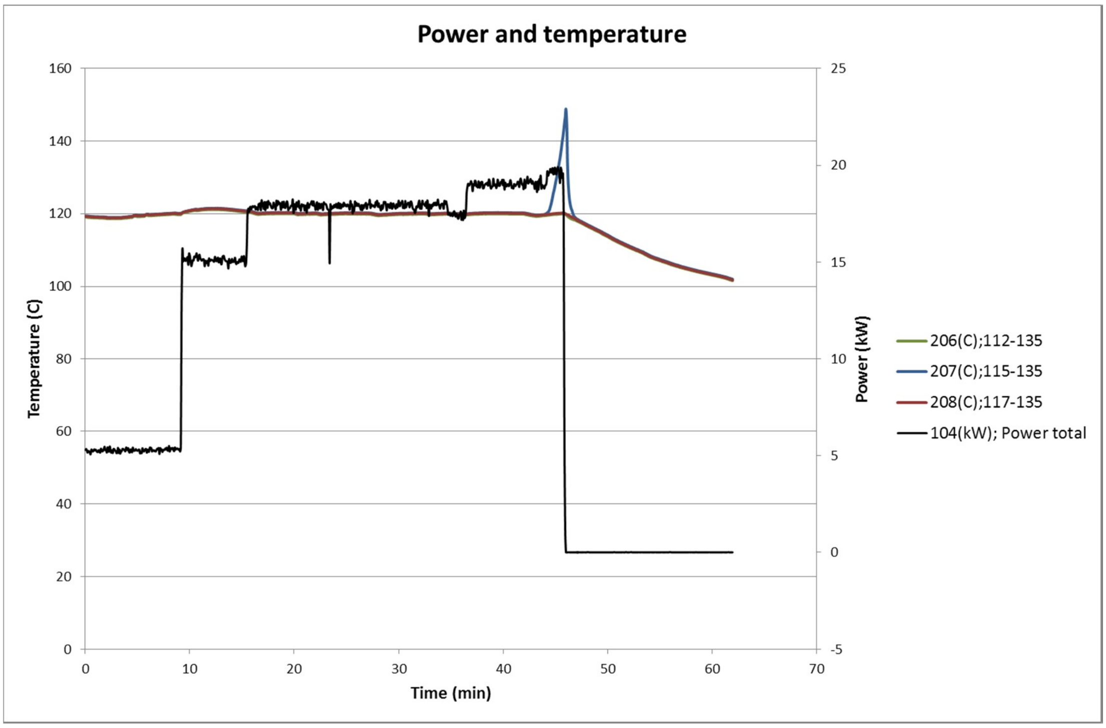


Fig. 6. Control power and the temperature of the sensor(s) indicating dryout in COOLOCE-12b.

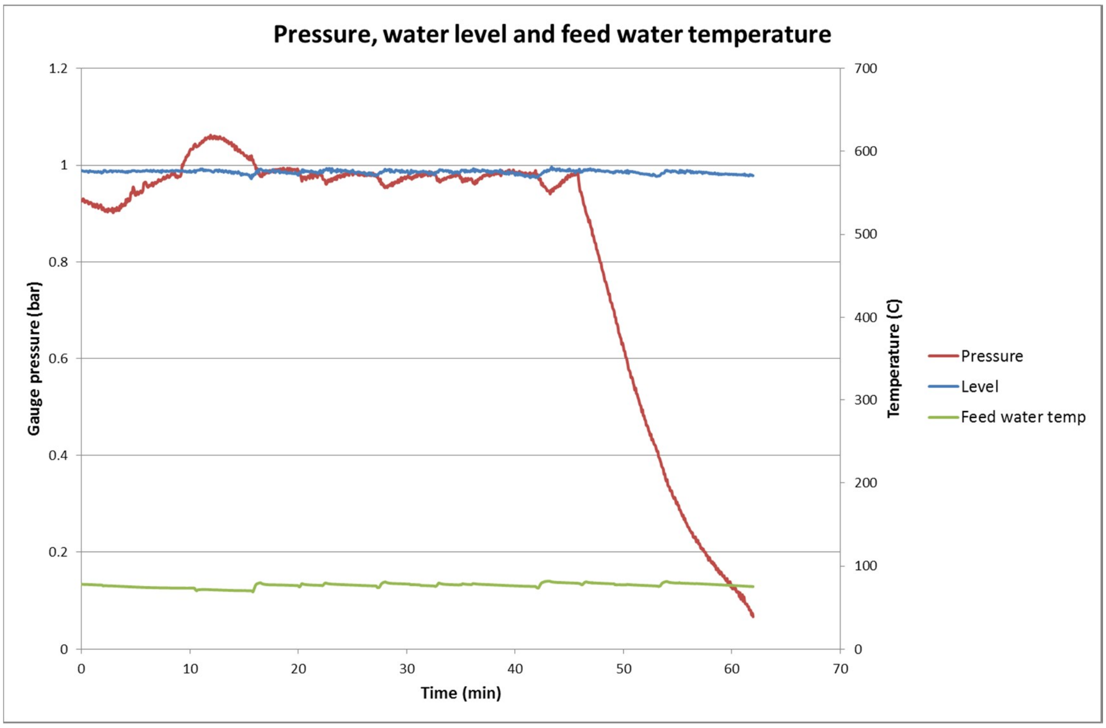


Fig. 7. Pressure and water level in the test vessel and feed water temperature in COOLOCE-12b.

4.3 COOLOCE-12c

In the COOLOCE12-c test sequence, dryout was found at the same power level than the heater temperature excursion, at 23 kW. The test bed dryout was indicated by the sensor 115-135 at 150 mm from the bottom at about the same time when all the heater sensors started to show a clear increase. The maximum test bed temperature was 195°C and the maximum heater temperature 415°C before the power was switched off. The power and temperature histories of the sensors that indicated dryout are illustrated in Fig. 8. The process parameters of the test run, pressure, feed water temperature and the water level in the pressure vessel, are shown in Fig. 9.

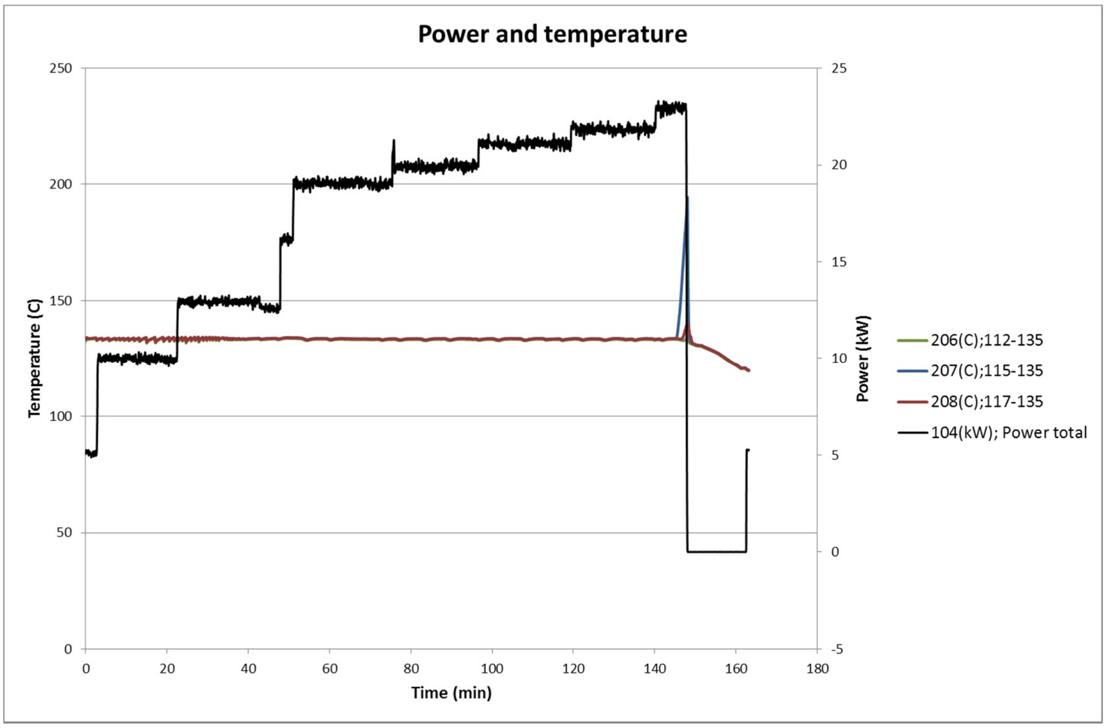


Fig. 8. Control power and the temperature of the sensor indicating dryout in COOLOCE-12c.

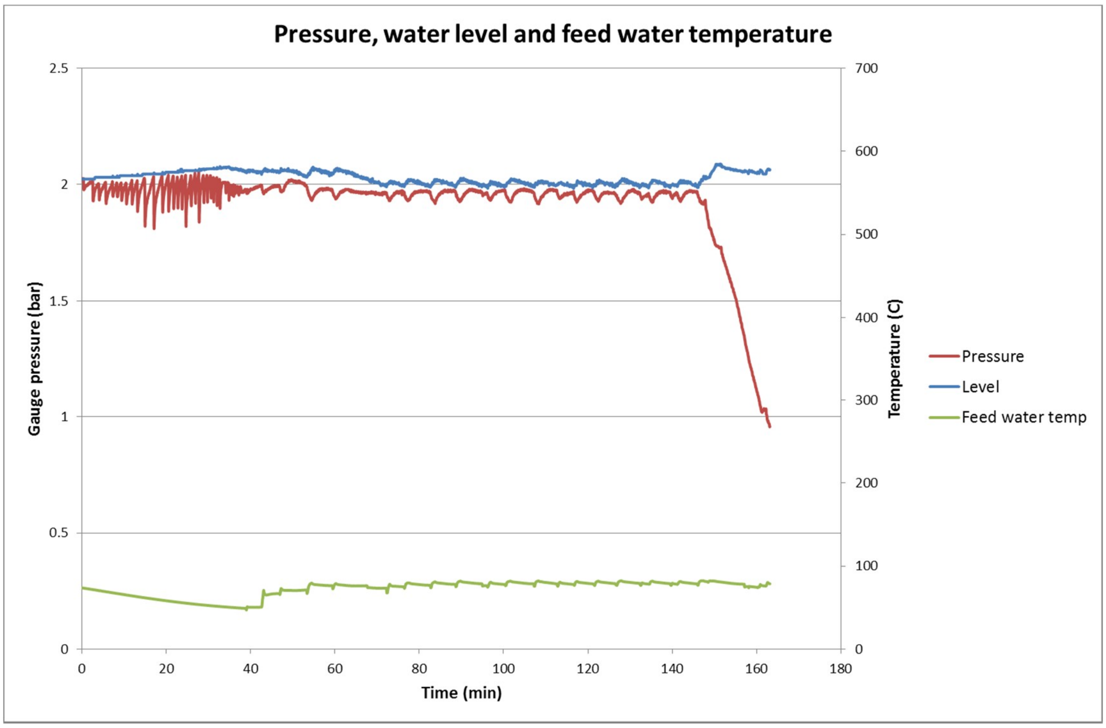


Fig. 9. Pressure and water level in the test vessel and feed water temperature in COOLOCE-12c.

4.4 COOLOCE-12d

The highest pressure level attained in COOLOCE-12 was 4 bar with the dryout power of 25.6 kW. The dryout location was the same as in the other experiments of the series, 150-170 mm from the test bed bottom. The power and temperature histories of the sensors that indicated dryout are illustrated in Fig. 10. The maximum test bed temperature was about 190°C and the central heater reached 320°C after which the heater apparently failed and its temperature quickly returned to saturation temperature. The heater failure is also seen in Fig. 10 in the last power step before the power is decreased to zero, where the power drops from 25.6 kW to about 24 kW before the termination of the test.

The pressure, feed water temperature and the water level in the pressure vessel are shown in Fig. 11. Towards the end of the test sequence, the pressure started to fluctuate somewhat and the pressure at the time of dryout was slightly lower than intended, about 3.8 bar abs. No attempt to correct the pressure level was made, however, since this would have disturbed the measurement by further fluctuations. The pressure drop to zero after dryout marks the end of the experiment.

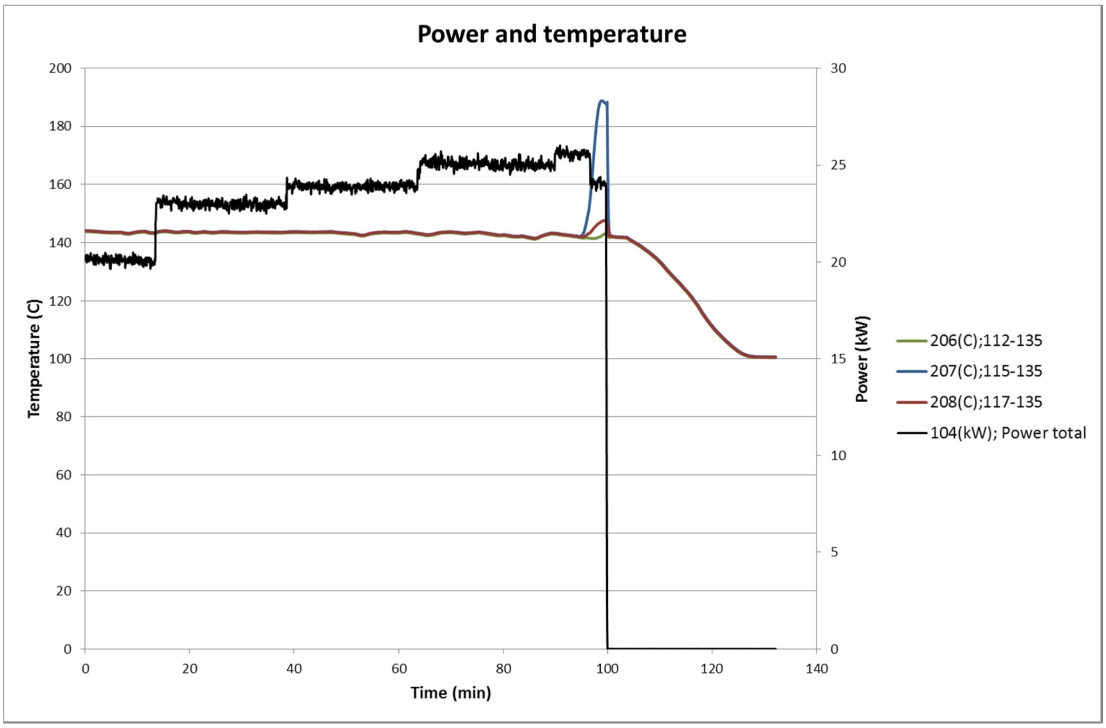


Fig. 10. Control power and the temperature of the sensor indicating dryout in COOLOCE-12d.

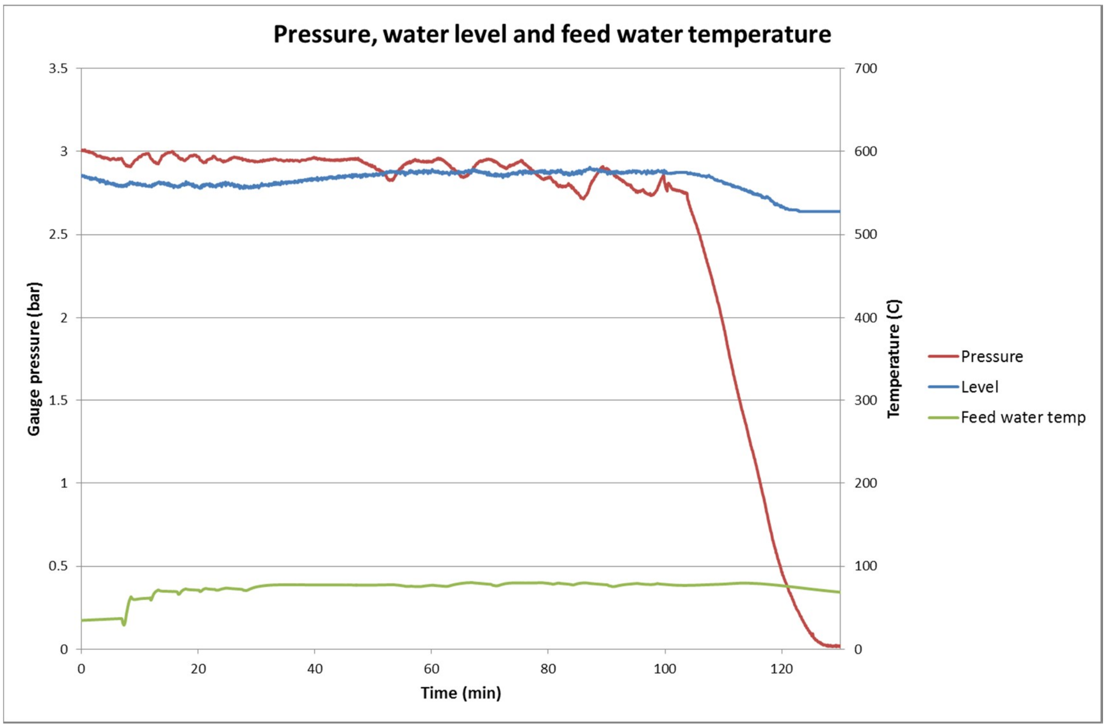


Fig. 11. Pressure and water level in the test vessel and feed water temperature in COOLOCE-12d.

4.5 Discussion

Dryout was successfully measured for the pressure levels of 1-4 bar indicated by clear temperature increases in all the test sequences. However, the test set-up was more vulnerable to high heater temperatures compared to the other set-ups, including the fully conical test bed of COOLOCE-6 and -7. Significantly increased heater temperatures were measured in connection with all the dryout points, and some of the central heaters failed during the last test sequence. This might suggest that the present type of geometry has the highest steam content in the locations of the heater sensors (we have data only from one axial point in the heater) but the reason to why this occurred only in COOLOCE-12 and not in the experiments with the fully conical bed is unclear.

As before, only the temperature excursions in the test bed sensors are interpreted as dryout even if increased heater temperatures occurred at lower power. The dryout location was in the test bed centre, axially between 120-170 mm, and clearly the hottest point was at 150 mm. This is just above the junction of the conical and cylindrical parts.

5. Coolability in relation to flat-shaped and conical beds

The dryout heat fluxes (DHFs) measured for a top-flooded cylindrical bed with the ceramic particles at 1.1 bar pressure were 252 kW/m^2 and 270 kW/m^2 (COOLOCE-3 and the repeatability experiment COOLOCE-3R). The 1-D DHF can be converted to dryout power for a top-flooded flat-shaped debris bed of known dimensions, making it possible to compare the results of the cone on a base experiments to the basic 1D cylinder even though the flow modes are different.

The dryout power for an "imaginary" cylindrical bed (comparison cylinder) with the same radius and volume than the cone on a base is shown in Fig. 12 with the experimental results. The dryout power is calculated as

$$P = \frac{DHF \times V}{h}$$

where *DHF* is the measured heat flux for the flat-shaped cylindrical bed (W/m^2), *P* is power (W), *V* is volume (m^3) and *h* is the height of the cylinder (m).

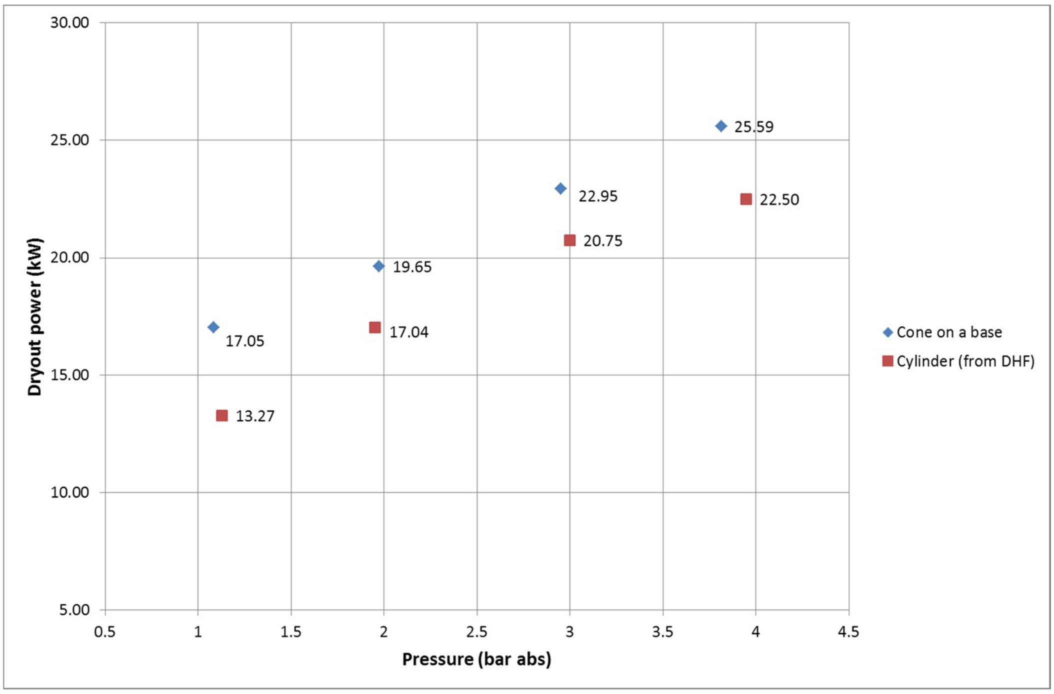


Fig. 12. Dryout power of the cone on a base in COOLOCE-12 and a flat-shaped cylinder with the same size and radius as the cone on a base. The latter is based on an earlier measurement of DHF in flat-shaped cylinder (COOLOCE3-5).

The height of the comparison cylinder in this case is 180 mm, i.e. the cylinder is 90 mm lower than the tip of the cone in COOLOCE-12. The comparison shows that the cone on a base has improved coolability: the dryout power of the cone on a base is 10-15% greater than that of the flat-shaped cylinder of equal radius at 2-4 bar. At 1.1 bar, the increase is as much as 28%. However, the 17.2 kW point is more uncertain than the other measured powers as the heater dryout started already at 15 kW which means that the actual dryout power is between 15-17.2 kW. In the other experiments, bed dryout was seen 0-0.7 kW after the heater temperature increase.

The results suggest that in this particular geometry, the effect of the multi-dimensional flooding (which increases coolability) is slightly greater than the effect of the increased height (which decreases coolability). Note that we could also select comparison cylinders of different heights based on the above “scaling equation”. In power plant scale, the slope angle of the conical part would be smaller (~15°) as well as the height to width ratio because of the greater width of the spreading area compared to the estimated debris volume. The small-scale experimental geometry is not directly scalable to the plant scale.

In general, the coolability of the cone on a base bed is high. This can be shown by a more direct comparison between the experimental geometries of the fully conical bed, the cylindrical bed and the cone on a base bed. The test beds are all equal in height which means that the power density difference is comparable to the difference of the local heat flux at the highest point of the geometry (heat flux is power density multiplied by height). The geometrical complexity or the flow mode variation is not considered. Instead, in the non-cylindrical geometries we examine only the highest point and the imaginary cylinder below this point with infinitesimally small diameter, i.e. the centre line of the geometry which is assumed to be analogous to a cylindrical, one-dimensionally flooded cylinder.

The top-flooded cylinder is the default geometry against which the two other geometries are compared under the above assumption. Fig. 13 shows the DHF ratio of the non-cylindrical and the cylindrical geometries (DHF/DHF_{cyl}) for the different geometry variations and pressure levels. The geometry variation is expressed as the ratio of the conical part height to the total height, i.e. 1 for cone, 0 for cylinder and 0.5 for the cone on a base.

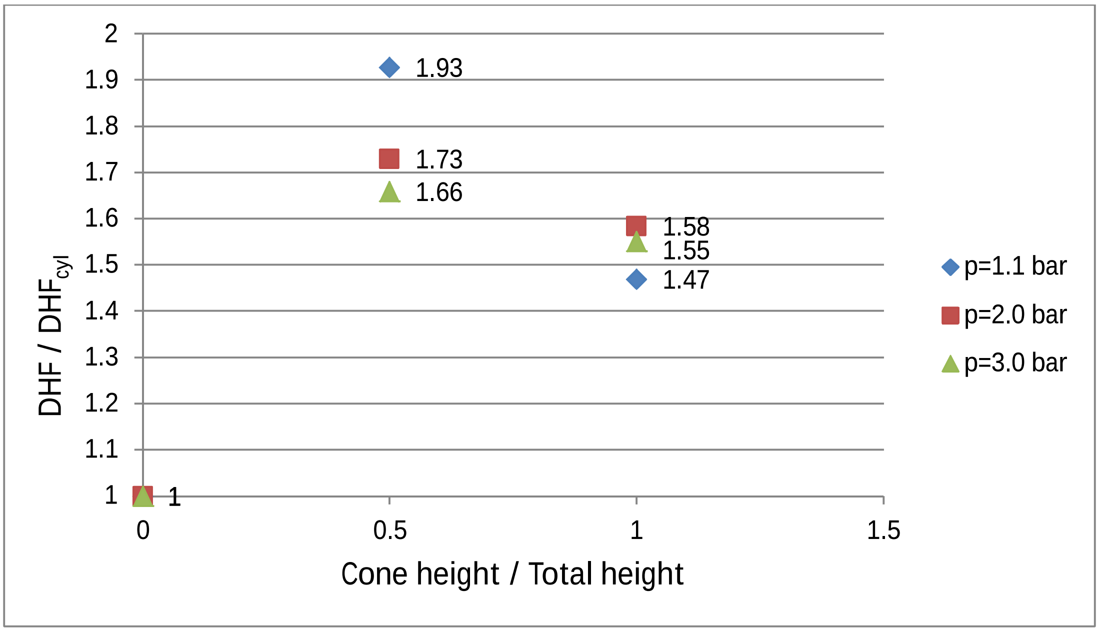


Fig. 13. The effect of debris bed geometry on local dryout heat flux (constant slope angle of 47° for the conical part).

The results suggest that the coolability of the cone on a base geometry is slightly better than that of the fully conical geometry. This is regardless of the fact that the geometry is only partially laterally flooded. For the conical bed, the DHF is about 1.6 times the DHF of a cylindrical bed. For the cone on a base test bed, this ratio is about 1.7 for pressures above atmospheric and 1.9 for the atmospheric pressure (which is the 17.2 kW point with a greater measurement uncertainty).

The result is somewhat surprising since the fully conical and the fully cylindrical geometries were assumed to be the easiest and the most difficult to cool, respectively. The explanation to this behaviour appears to be the two-phase flow mode. The main cause behind the dryout formation is the increase of the steam flux to a high enough level to entirely replace water in the bed at certain height. The mass flux of steam accumulated in the outer - and the lowest - region of the cone on a base test bed is small enough to allow water to infiltrate downwards through this region. Concerning the dryout zone, it is not important whether the bottom region of the test bed receives coolant thought the lateral flow through the inclined surface of the full cone, or through the flow down near the perimeter of the low cylindrical part. Both geometries are capable of providing water into the bottom region. Based on the present results, the cooling is marginally more effective when the radius is reduced to half of the original cone and the water flow at the outer region is directed downwards.

Preliminary simulations with the MEWA code predict similar relative DHFs as the experiments (DHF in the cone on a base is 5-7% greater than in the full cone). This does not confirm that the experimental behaviour is exactly reproduced in the simulations (due to e.g. model limitations) but it gives more confidence to the validity of the experimental observations. The comparison of the experimental and simulation results will be provided in a separate report.

6. Conclusions

The COOLOCE-12 experiment addressed a debris bed geometry that has a conical heap on top of a cylindrical base, i.e. part of the debris is distributed against the walls of the spreading area (due to e.g. spreading by steam flow) but the top part of the debris maintains the conical shape. The height of the conical part was half of the total height. The dryout power for this configuration was 17–26 kW (1929–2897 kW/m^3) for the pressure range of 1–4 bar.

Two types of comparisons to other debris bed geometry variations have been presented. Firstly, a DHF-based comparison to a cylindrical bed with the same volume and diameter indicates that the dryout power of the cone on a base geometry is slightly higher than the one in the top-flooded cylinder. Secondly, a direct comparison of the experimental results of the three geometry variations – the fully conical bed, the top-flooded cylindrical bed and the cone on a base bed – shows that the cone on a base has the greatest local DHF and, consequently, the best coolability (at least for the examined ratio of the conical and cylindrical part height and slope angle). The difference compared to the conical bed is not large, however, and the mechanism for the dryout development may be rather similar to that of the fully conical geometry.

The results clarify the effect of the multi-dimensional flooding and flow mode on coolability in relation to the effects of test bed height and overall geometry and will be utilized in simulation model and code validation.

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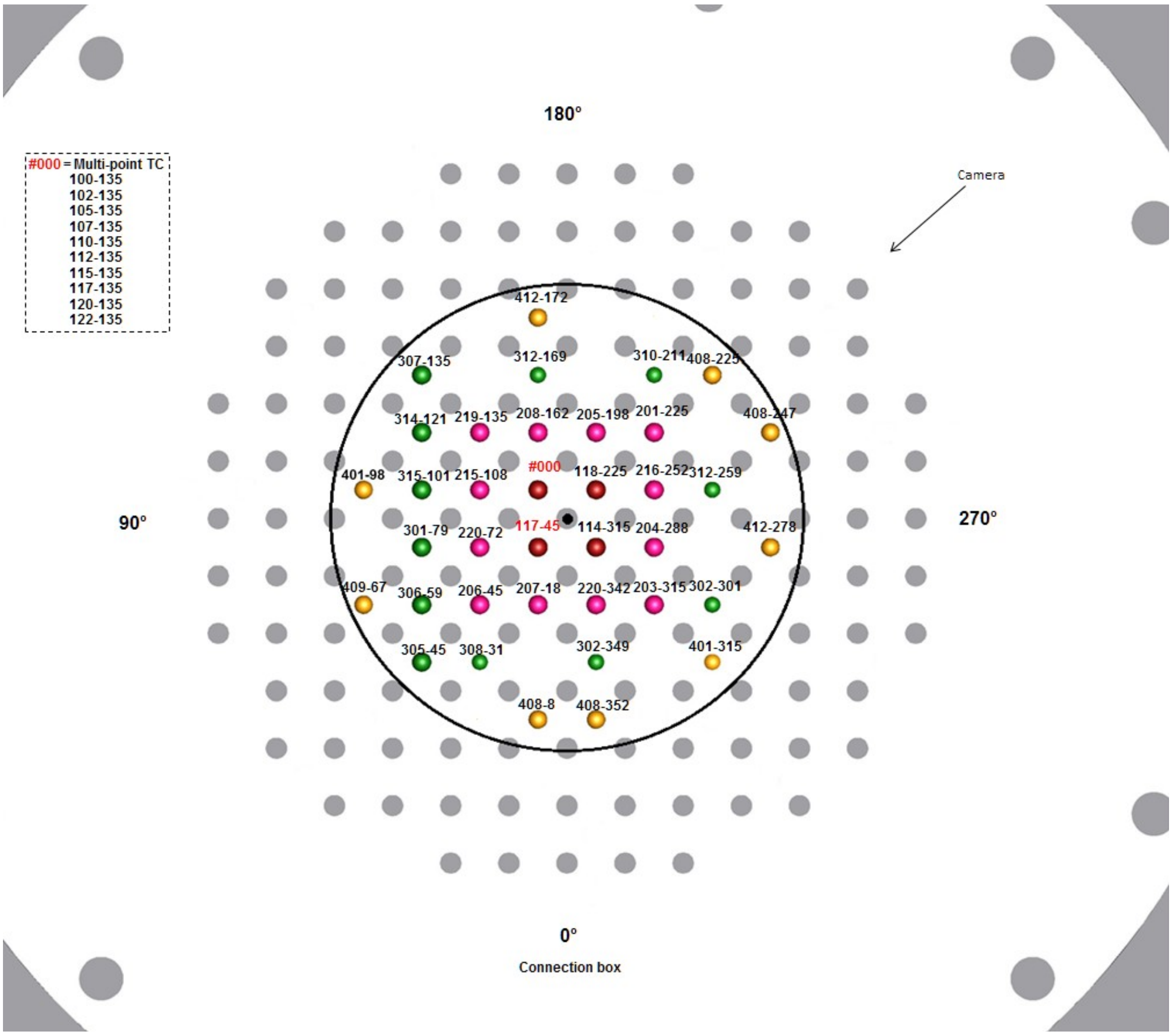
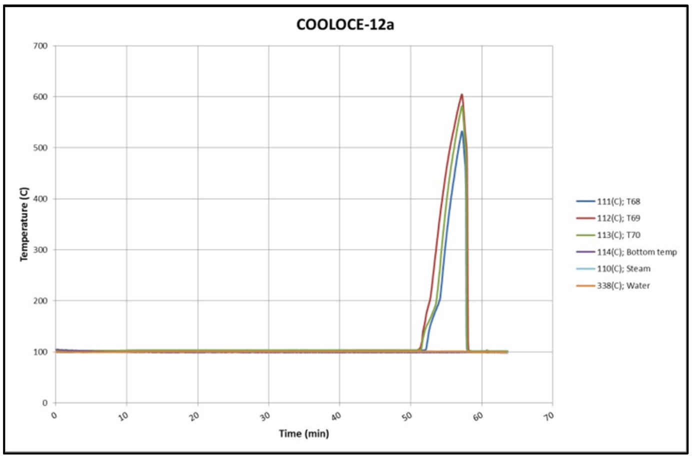
Appendix A. Thermocouple arrangement of the modified COOLOCE cone (cylindrical base)

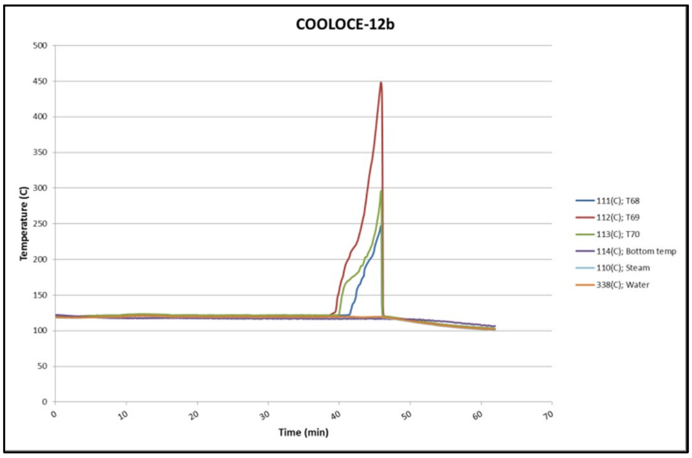


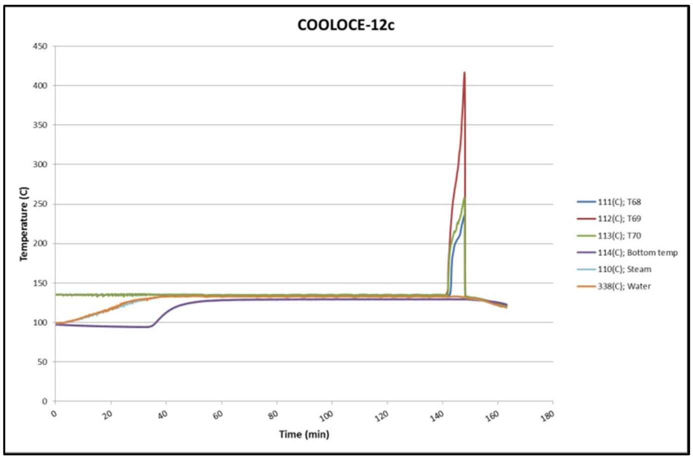
Example of how to read the map:

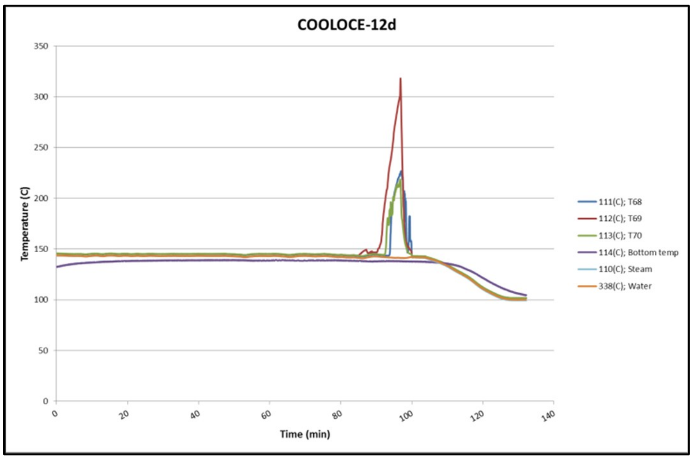
118-225
1 – number of the ring to which the thermocouple belongs to (1 indicates the central sensors, 5 the outermost)
18 – height of the thermocouple from the bottom in cm
225 – angle between the thermocouple location and 0°

Appendix B. Heater temperatures









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Abstract max. 2000 characters	The COOLOCE-12 experiment addressed a debris bed geometry that has a conical heap on top of a cylindrical base, i.e. part of the debris is distributed against the walls of the spreading area but the top part of the debris has the conical (heap-like) shape. The height of the conical part was half of the total height. The dryout power for this configuration was 17–26 kW (1929–2897 kW/m^3) for the pressure range of 1–4 bar. Comparisons to other debris bed geometry variations, namely, the fully conical bed and the top-flooded cylindrical bed, have been made. The results suggest that the cone on a base geometry has a comparatively high dryout power and coolability. In general, the results clarify the effect of the multi-dimensional flooding and the flow mode in relation to the effects of test bed height and the overall geometry and will be utilized in the validation and development of simulation models and codes.
Key words	severe accident, core debris, coolability, dryout heat flux, COOLOCE test facility

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