# Determination of Thermal Hydraulics Parameters for Equipment Qualification

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Equipment Qualification in Nuclear Installations
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- Thermal-hydraulics (TH) parameters for Equipment Qualification (EQ)
- TH parameters in the mild conditions
- Determination of TH parameters for EQ in the harsh conditions

# TH parametrs for Equipment Qualification

- **TH environmental parameters for EQ should be determined for**
  - **mild conditions** - generally include normal plant conditions, and abnormal conditions (DBC1 and DBC2),
  - **accident conditions**
    - **harsh conditions** - during design basic accidents (DBC3 and DBC4)
    - **severe conditions** - during severe accidents (DEC A and DEC B)
- **Important thermal-hydraulics parameters:**
  - pressure,
  - temperature,
  - humidity,
  - submergence – water level, water spraying.

# TH parametrs for Equipment Qualification

- **Environmental parameters used for the EQ generally**
  - shall  be considered in the location, where the qualified equipment is actually installed
  - if the equipment is located in the larger area (e.g. a cable), it is necessary to take into account the location with the worst parameters
  - source of values:
    - mild conditions: measurement, project and design values
    - accident conditions: calculations

- **TH parameters in the mild conditions**
  - There are necessary to determine mean values of the pressure, temperature and relative humidity in the selected areas
    - pressure – not a problem, in the most areas of the NPP there is an atmospheric pressure with exception of the containment, where is small underpressure
    - temperature – may differ significantly in the different locations of the NPP, even in the range of one room; moreover, the temperature may vary in time, e.g. in dependence on the external temperature or on the unit operational modes
    - relative humidity - the steam content in the air may be a variable value, is directly connected with an air temperature

# TH parameters in the mild conditions

- To determine some typical or average value for the relevant location is usually possible on the basis of the long-term monitoring only.
- It is recommended not to trust too much the design values and prefer the measured values.
- It is further recommended long-term monitoring of TH parameters so that they caught also variations caused by the power or season fluctuations.
- If some modifications of the NPP will be made that could affect normal conditions (power uprate) , monitoring should be repeated.

# TH parameters in the harsh conditions

- **Harsh conditions – during design basis accidents**
  - Usually LOCA or HELB type with large releases of high-energy media (coolant)
  - It is assumed that if an equipment withstands the conditions of some event, then it withstands conditions of the similar, less serious event as well
- **TH parameters for the harsh conditions**
  - It is necessary to determine mean values of the total pressure, temperature, relative humidity and to determine possibility and extent of the submergence (i.e. maximum of water level) and water spraying for each areas in that qualified equipments are located

# TH parameters in the harsh conditions

- **Basement for qualification of the equipments is a <u>qualification envelope curve</u> with a constant or linear time response of the monitored parameters**
  - is a simple representation of the „worst case“ from all considered responses of the relevant parameter for the monitored time period
  - includes values that were reached during the particular accident analyses; the available results of environment analyses in the SAR shall be taken into account too
  - includes as well a qualified estimate of the accident behavior in the later phases, which may not be covered by the computing analyses
  - it is created usually for absolute pressure and atmosphere temperature
  - typically one or two qualification profile for the full pressure containment

# TH parameters in the harsh conditions

- For the given parameter X, the general shape of the qualification envelope curve $X_O^{EQ}(t)$ is then:

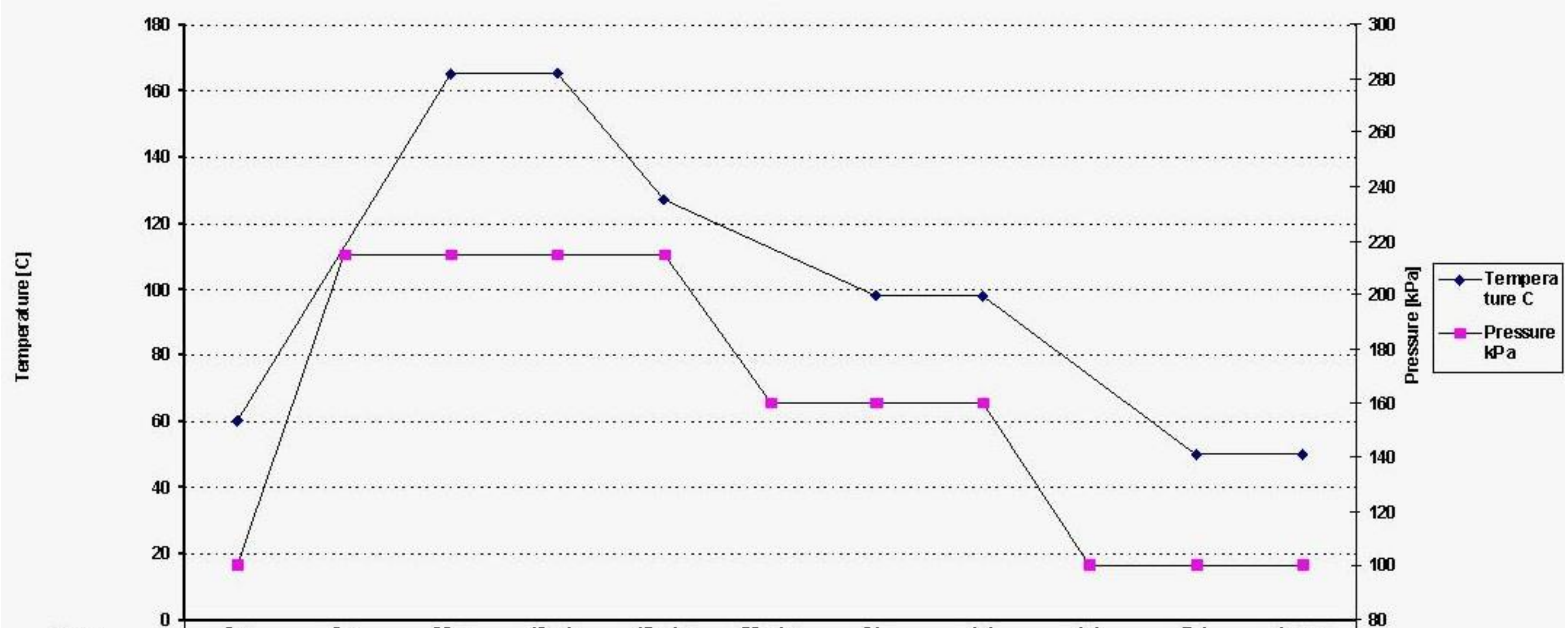
| | | |
|---|---|---|
| $\mathbf{X_O^{EQ}(t)}$ | $= K_1 \cdot t + A_1$ | for $t \in < 0 , t_1 )$ |
| | ... | |
| | $= K_m \cdot t + A_m$ | for $t \in < t_{m-1} , t_m )$ |
| | ... | |
| | $= K_M \cdot t + A_M$ | for $t \in < t_{M-1} , t_M >$ |

where:

| | | |
|---|---|---|
| where: | t | is a time |
| | m | is a time segment |
| | $K_m$ , $A_m$ | are a real constants which characterize behavior of the curve in the time segment **m**, |
| | M | is a total number of time segments for the qualification envelope curve of the parameter X. |

- The time segment $< 0, t_M >$, for which the qualification envelope curve shall be constructed, is called the **qualification interval**.

# Example of qualification envelope curve




| Time | 0 s | 2 s | 20 s | 10 min | 15 min | 50 min | 3 h | 1 d | 4 d | 7 d | 1 year |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature C | 60 | | 165 | 165 | 127 | | 98 | 98 | | 50 | 50 |
| Pressure kPa | 100 | 215 | 215 | 215 | 215 | 160 | 160 | 160 | 100 | 100 | 100 |

# TH parameters in the harsh conditions

- **Qualification interval (time range of the parameter determination) is depend on required endurance of equipment.**
- **For each qualification curve, there will be as well determined a recommended minimum safety margin – it is a value by which the condition level during the qualification process exceeds the conditions during the expected design basis accidents.**
  - to ensure covering of uncertainties in the all processes of environmental parameters determination
  - for pressure: +10 %
  - for temperature: + 8 °C

## Methodology steps of TH parameters determination in the harsh environment

1. Determination of type and scope of accidents and affected areas (rooms).
2. Determination of a response (course) of the TH parameters during accidents based on its calculations during required time period.
3. Creating of the qualification parameters - qualification envelope curves or maximal values including application of the safety margins.

# TH parameters in the harsh conditions

## 1. Determination of type and scope of accidents and affected areas (rooms):

- **Accident selection is depend on location of the qualified equipments**
  - mainly rooms and areas inside the containment
  - areas outside containment passed by pipes with high energy medium (steam, feedwater)
- **Basically there are considered a loss of coolant accidents (LOCA) inside the containment and the high energy line break (HELB) accidents inside and outside the containment**
  - it shall be demonstrated that the analysed cases causes the bounding environmental conditions

# TH parameters in the harsh conditions

## 1. Determination of type and scope of accidents and affected areas (rooms):

- **Time period of the analyses**
  - every accident should be analysed until the parameters are stabilized
  - usually several hours
- **Examples of spectrum of the analysed postulated initiating events (accidents) for VVER-440 / V-213**
  - inside containment (hermetic area): LB LOCA, SLB, SB LOCA, control rod bundle drive case break and I&C line break
  - outside containment in the intermediate building: MSLB, MSHR or combination of the both, MFWLB

## 2. Calculations of the selected accidents and determination of the TH parameters courses:

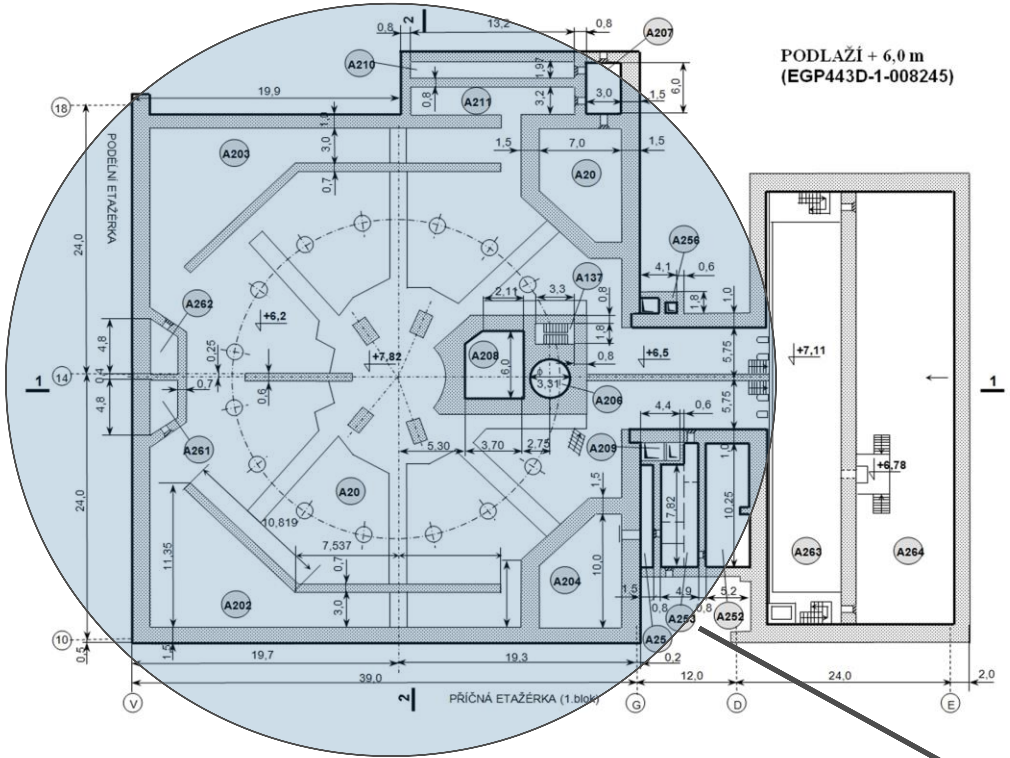
- **Using the thermal hydraulics computer codes that are utilized to determine released mass and energy (MER) from primary or secondary circuit and the resulting changes of environmental parameters in the rooms.**
  - both conservative licensing and the best estimate models have been used for accident analyses
- **1st step – determination of the mass and energy release (MER) from primary or secondary circuit into the each considered areas for each selected accident scenario**
  - usually using the system code (RELAP, ATHLET, etc.)
  - detailed model of primary and secondary circuit

# 2. Calculations of the selected accidents and determination of the TH parameters courses:

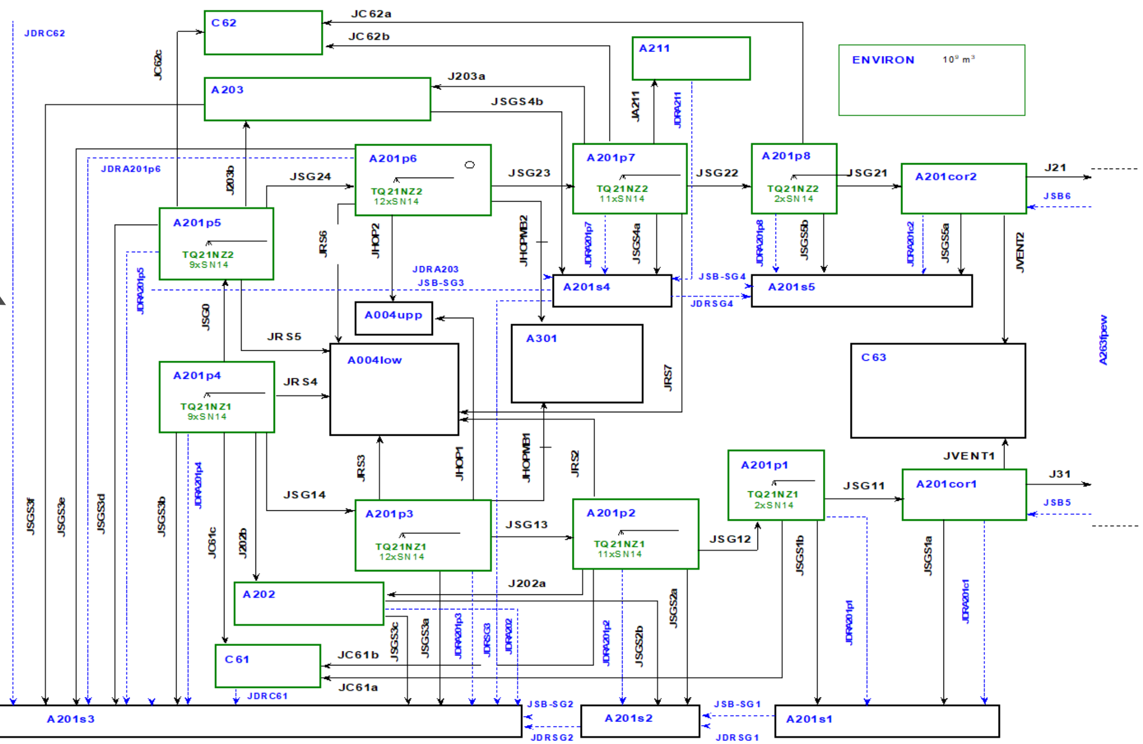
- **2nd step – determination of the course of the necessary TH parameters in each monitored areas during all selected accidents**
  - usually using the containment or integral code (for example MELCOR, COCOSYS, GOTHIC etc.) that uses lumped parameter approach
    - dividing calculated area into several zones (nodalisation), each zone is characterized by mean pressure, atmosphere temperature and water temperature
    - models of all relevant safety systems (spray systems, bubble condenser …)
  - parameters shall be calculated as mean values reached in the whole room or area
  - mass and energy releases into rooms as result of previous step is used as basic boundary condition for the calculations
    - for containment calculation of TH parameters for EQ can be use realistic initial condititions
  - for all parameters, there shall be found both maximum reached values and a time behaviour of these parameters

# TH parameters in the harsh conditions

## Dukovany NPP (VVER-440 / V-213)
## SG box for COCOSYS




## NPP




## Nodalisation
## used for COCOSYS code

# 3. Creating of the qualification parameters:

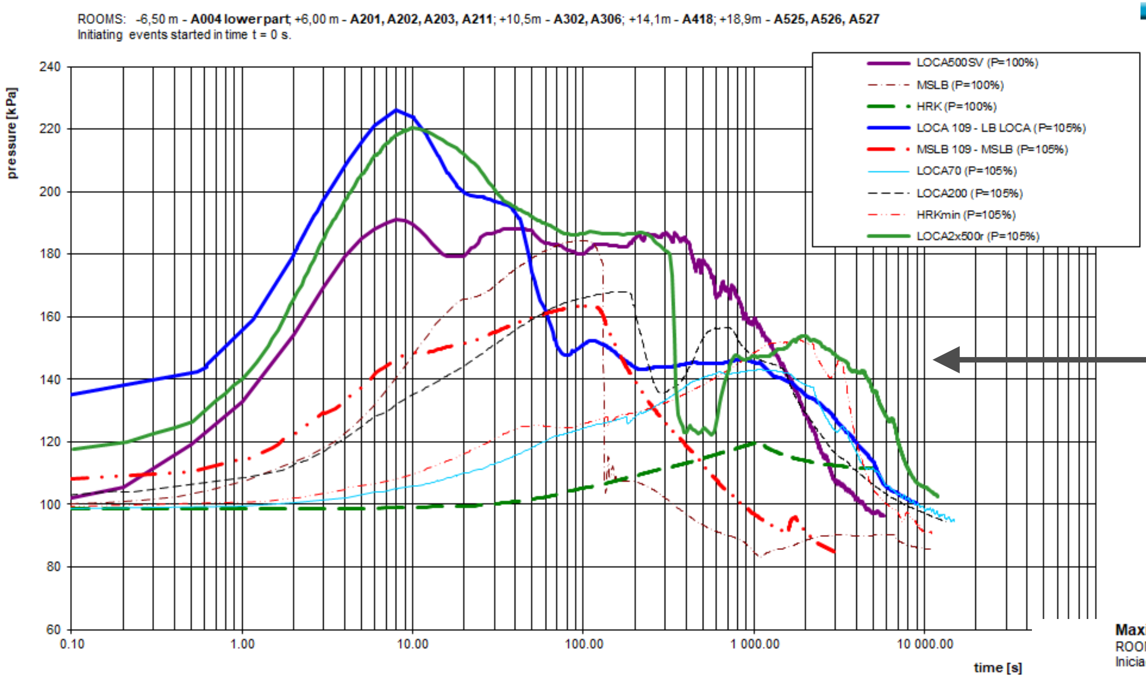
- **First, construction of the curve representing the worst possible time behaviour of the appropriate parameter from all analysed accidents in the each monitored area – so called *maximum course from all considered accidents***
  - The maximum time-response curve for the given **X** parameter, evaluated from all considered accidents **i**, is determined from the following relationship:

$$X_M(t) = \max [X_i(t)]_{i = 1, \ldots, N}$$

where:

**$X_M(t)$** is a maximum response of the X parameter
**$X_i(t)$** is a time-response of the X parameter for the **i** accident,
**N** is a number of accidents analysed in the relevant area

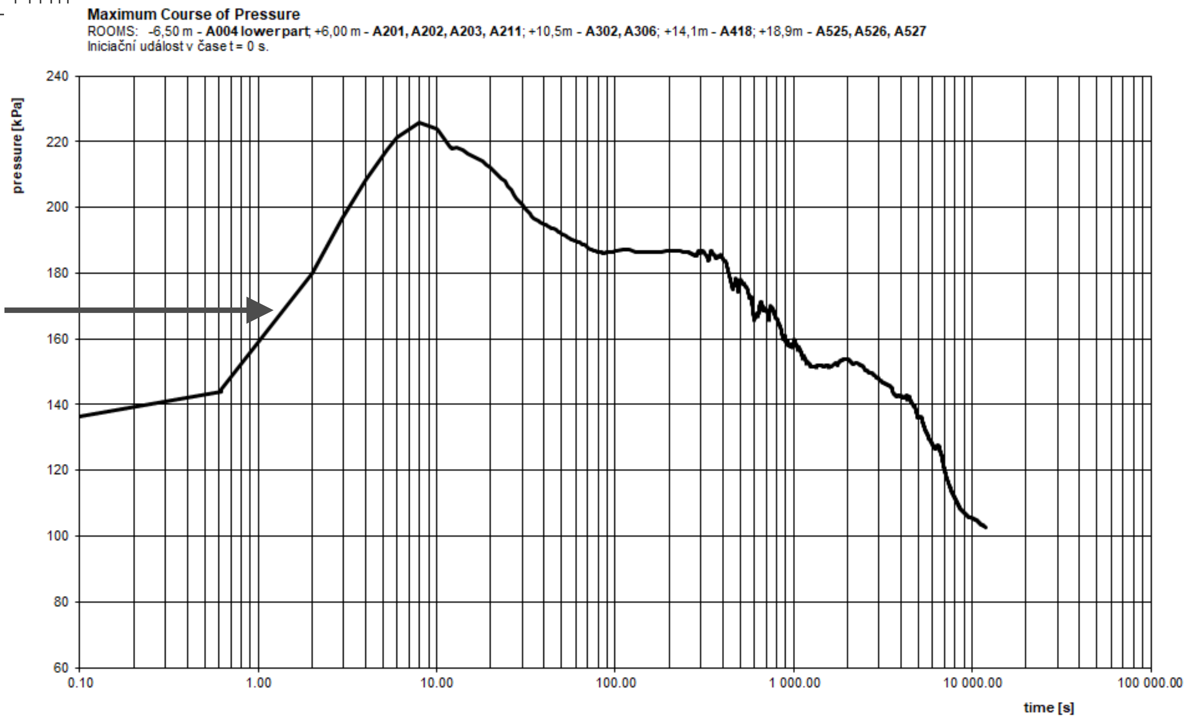
# TH parameters in the harsh conditions




## Dukovany NPP (VVER-440 / V-213) pressure, SG box

**Pressure courses during selected spectrum of accidents**

**Maximum course of pressure from all considered accidents**



# TH parameters in the harsh conditions

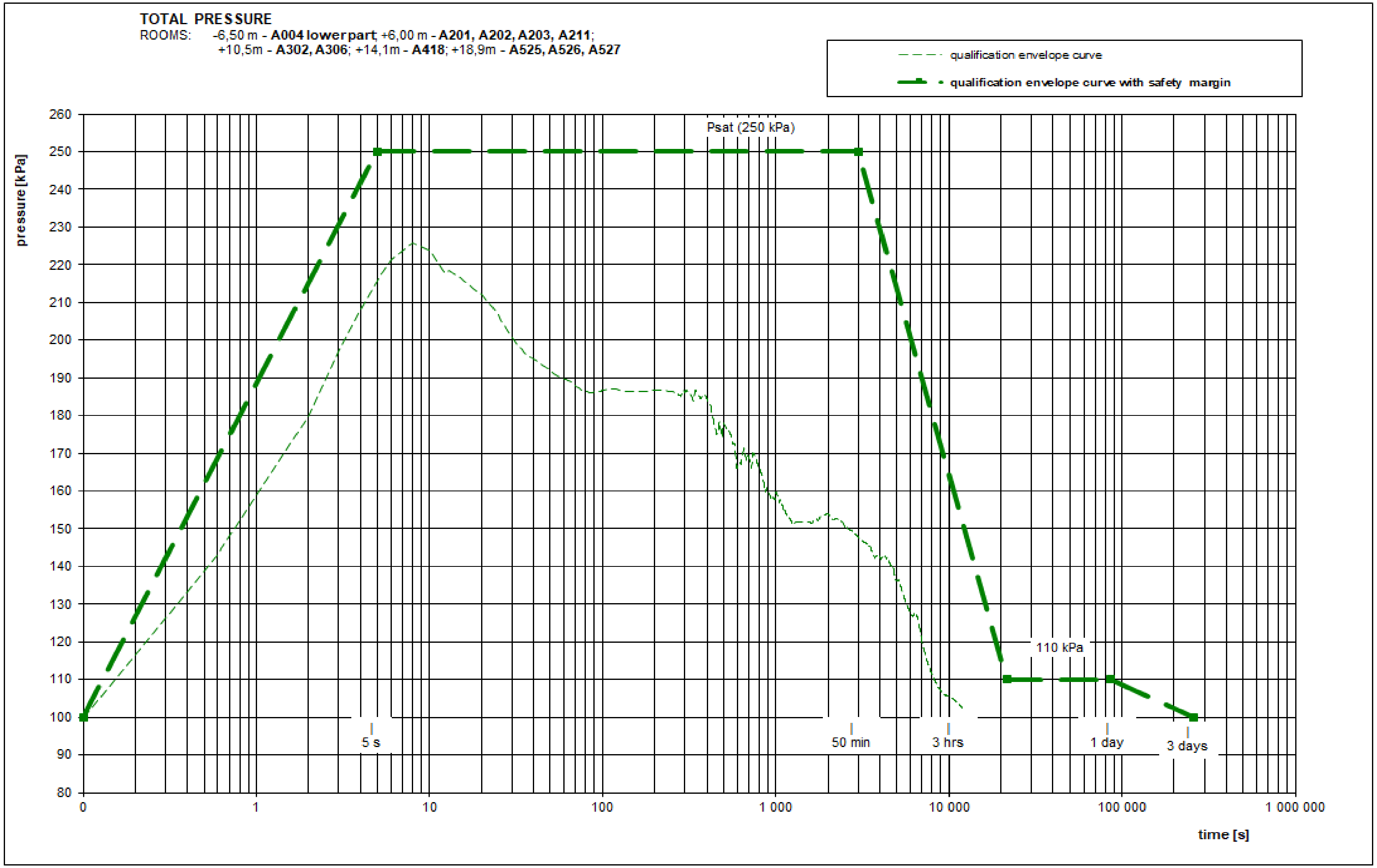
## 3. Creating of the qualification parameters:

- **Next, construction of a *qualification envelope curve* for selected parameters in selected areas for the monitored period**
  - based on maximum course from all considered accidents
  - it is necessary to take into account the relevant results from the actual Safety Analysis Report
  - envelope includes as well a qualified estimate of the accident behavior in the later phases, which may not be covered by the computing analyses
  - necessary safety margin is applied to the maximal values

# TH parameters in the harsh conditions

## Qualification envelope curve example

**Dukovany NPP (VVER-440 / V-213)**
**pressure, SG box**



# TH parameters in the harsh conditions

## 3. Creating of the qualification parameters:

- **Determination of the maximal values for other parameters (for example submergence: is essential to determine only the possibility and extent of the submergence).**
- **Last, preparation of a zone environmental data sheet for all monitored areas**
  - list contains all environmental condition for normal and harsh condition of appropriate area
    - radiation parameters
    - TH parameters including qualification envelope curves if exists

# TH parameters in the harsh conditions

| ENVIRONMENTAL CONDITIONS | | | | AREA: | SG BOX |
|---|---|---|---|---|---|
| | | | | CONDITIONS: | HARSH |
| | | | | | |
| AREA INCLUDES: | | | | REVISION: | 2 |
| rooms: A004/1 - lower part of the reactor shaft (-6,50 m); A201/1 except connecting corridors A202/1, A203/1, A211/1 (+6,00 m); A302/1, A306/1 (+10,50 m); A418/1 (+14,10 m); A525/1, A526/1, A527/1 (+18,90 m) | | | | DATE: | 11/96 |

| Parameter | Normal Environment | | Harsh Conditions: | LOCA, HELB |
|---|---|---|---|---|
| TEMPERATURE<br>[°C] | 23 - 55 | | Time<br>0 - 1 s<br>1 - 900 s<br>900 - 3600 s<br>1 - 24 Hr<br>1 Day - 3 Days | Temperature (1)<br>60 - 127<br>127<br>127 - 98<br>98<br>98 - 83 |
| | | | Envelope curve see Fig. B-25 | |
| TOTAL PRESSURE<br>[kPa] | Atmospheric | | Time<br>0 - 2 s<br>2 - 900 s<br>900 - 3000 s<br>3000 s - 1 Day<br>1 Day - 3 Days | Pressure (2)<br>100 - 215<br>215<br>215 - 160<br>160<br>160 - 120 |
| | | | Envelope curve see Fig. B-25 | |
| RELATIVE HUMIDITY<br>[%] | up to 90 | | Time<br>0 s - 3 Days | Relat. Humidity<br>100 |
| SPRAY | NO | | for A201/1 A004/1:<br>Time<br>0 s - 24 Hr<br><br>from 24 Hr<br><br>NO for other rooms | <br><br>$H_3BO_3$ (4) solution spraying<br><br>NO spray |
| RADIATION<br>[Gy] | 30 Year Dose<br>Gamma Radiation:<br>$3 \times 10^6$ | Neutron Radiation:<br>$3 \times 10^6$ | 30 Day Dose<br>Gamma Radiation:<br>$1{,}35 \times 10^5$ | |
| SUBMERGENCE (Flood Level)<br>[m] | NO | | For all rooms on the floor +6,00m:<br>1,62 m (3)<br>(Max. flood level +7,62 m, then overflow to A004/1)<br><br>NO for other rooms | |

LEGEND NOTES:
(1) With safety margin +8 °C
(2) With safety margin +20 kPa
(3) Related to the lowest point of the floor, which is at the elevation +6,20m.
(4) The mixture of: primary coolant (cca 250m3), contents of ECCS tanks - TQ (30m3, composition: (10g N2H4 . H2O + 98g KOH + 150g H3BO3) per 1 kg H2O), TH (811m3, composition: 12g $H_3BO_3$ per 1 kg $H_2O$), TJ (281 $m^3$, composition: 12g H3BO3 per 1 kg H2O), and contents of bubble condenser trays (cca 1300$m^3$, solution of 12 g $H_3BO_3$ and 0,1 g $N_2H_4$ per 1 kg $H_2O$)

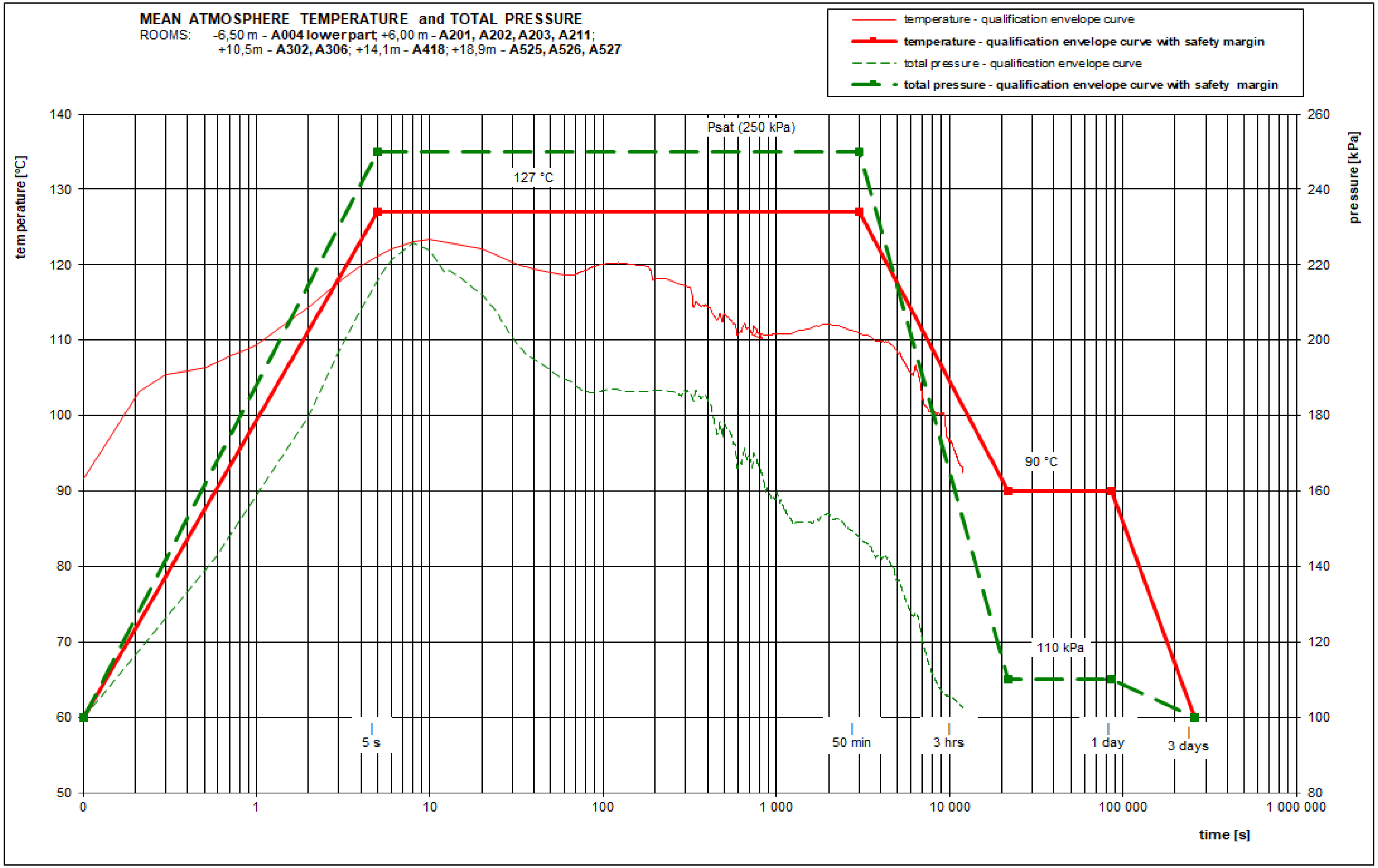
## Zone environmental data sheet example

### Dukovany NPP (VVER-440 / V-213)

# TH parameters in the harsh conditions

## Qualification envelope curves example

**Dukovany NPP (VVER-440 / V-213)**



**Thank you for your attention !**

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