HOT CELL FACILITY IN RESEARCH CENTER REZ SHIELDING PART READY

O. SRBA, A. PETRICKOVA, M. MIKLOS
Structural and System Diagnostics, Research Centre Rez Ltd., Rez, Czech Republic

P. SVOBODA, J. KOSINA
Design department, Research Centre Rez Ltd., Rez, Czech Republic

D. MERHOUT
Operation management, Research Centre Rez Ltd., Rez, Czech Republic

ABSTRACT

Paper presents concept of new hot cell facility within the project SUSEN (Sustainable Energy) at CVR (Research centre Rez). The cells will be used for preparation and testing of irradiated structural materials. The project uses existing building converted for the purpose of placement of new hot cells. New design is used – heavy shielding with airtight steel box.
Paper is focused on a construction of shielding parts of cells and airtight boxes. Constructional process and all tests that were performed will be presented. Interconnection between shielding parts and removable boxes will be discussed. Reality will be compare with models and ideas.
The project SUSEN is fully funded by the European Union. Most components must be purchased on the basis of competitive tendering or competitive dialogue.

1. Introduction

Within this project a new complex of 10 hot cells and one semi-hot cell will be build. Hot-cells are divided to 8 gamma hot cells and 2 alpha hot cells. The hot cells and semi hot cell will be equipped with experimental devices for diagnostics as well as set of devices for admittance of radioactive samples entering the hot cells (measuring of activity, dimensions, weight), technologies for a complex sample processing (cutting, welding, machining) and set of equipment for carrying out mechanical tests (stress testing machine, fatigue machine, creep, etc.) as well as to study material microstructure (microhardness and nanohardness tester, scanning electron microscope). Our facility allows work with radioactive samples with activity up to 300 TBq Co^{60} and with dimension of samples up to 2CT.

2. Shielding

Unique design of hot-cells allowed dividing hot-cell shielding in two main groups: shielding part and hermetic part. Inside shielding part (walls, windows) is placed hermetic steel box. Purpose of this box is to seal all radioactive aerosols within. This box is also removable and that allows to change instrumentation inside very quickly.

2.1 Shielding part - walls

All shielding (fig. 1) is made from a stainless steel, the outer wall shielding has thickness of 500 mm, internal wall between hot cells 300 mm with the possibility to make it wider up to 500 mm. The ceiling shielding has thickness of 400 mm and the floor shielding of hot cells is 300 mm wide. The detail design of the shielding has been decided by the supplier of the shielding. All modules are made from steel plates (100 mm wide), outer wall have 5 steps to prevent the gamma ray shots through the shielding (fig 2).

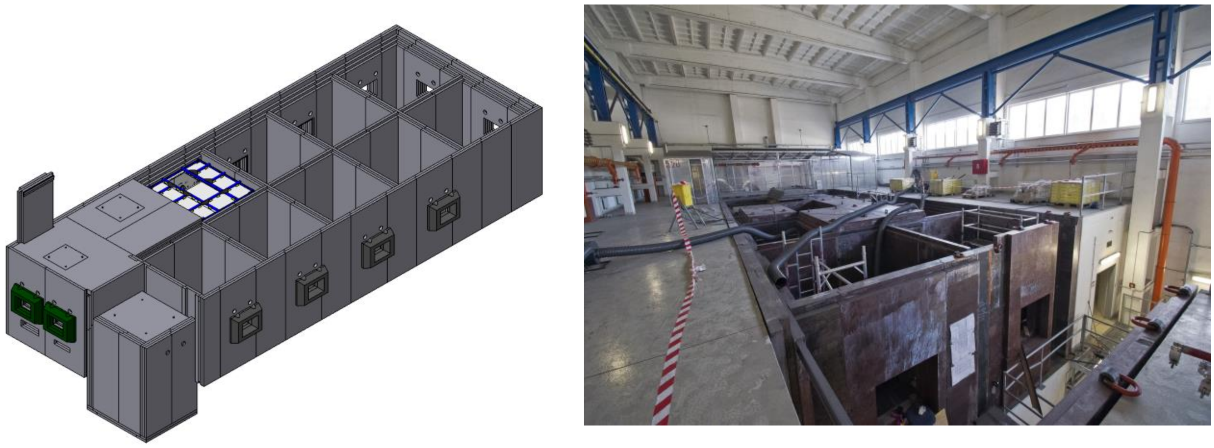


Fig. 1 Layout of the hot cells, left models – model (left), reality (right)

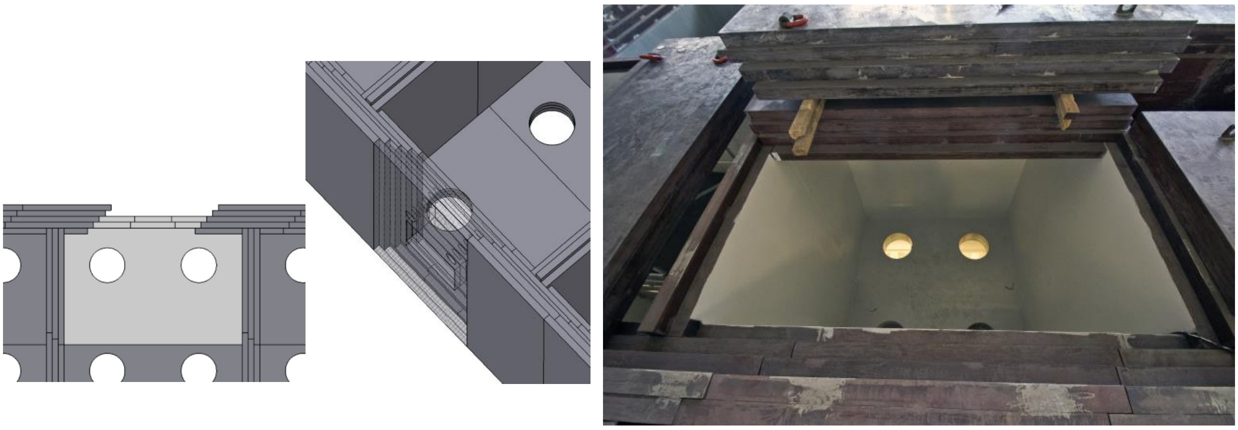


Fig. 2 Detail of the design of outer wall – model (left), reality (right)

Fig. 3 final treatment

All work (design, welding, assembly) was carried out by company Chemconex a.s [3]. in very short time. Approximately three months for design and all details, three months for production of all modules (welded steel plates) and three months for whole assembly with final treatment (painting, fig. 3). At the end of this year final test with radioactive source will proof shielding properties.

2.2 Shielding part - window

Shielded windows allow direct view inside of the hot cell. High demands are placed to transparency of glass and large viewing angle. Shielded windows also protect the operator from the effects of ionizing radiation. Their shielding effect is equivalent to 500 mm of steel. Dimension of window in control room is 800 mm x 600 mm. Thickness of window is 900 mm.

Producer of windows is company Saint-Gobain SOVIS, supplier is company Envinet a.s. [4]. Shielded windows are composed of several layers stabilized lead glasses (fig. 4).

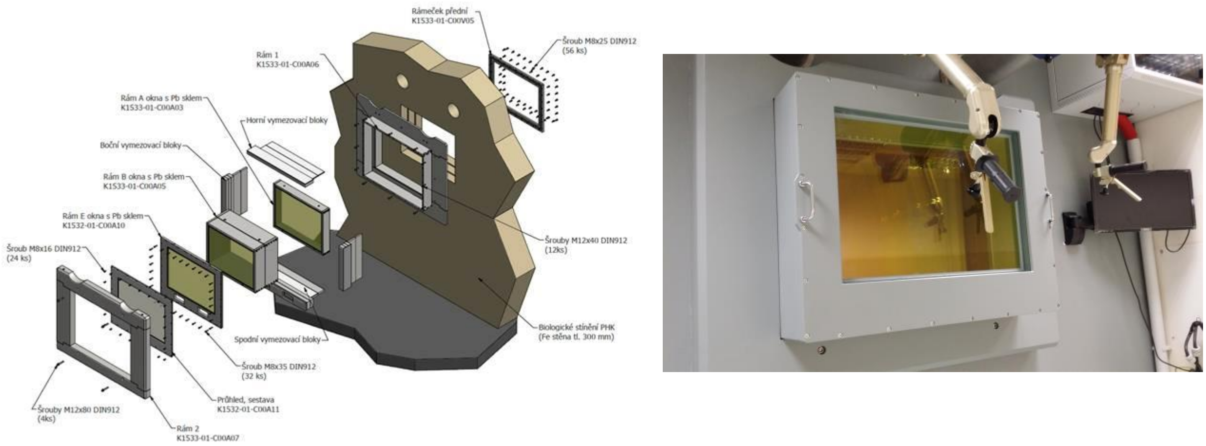


Fig. 4 Composition of shielded window – model (left), reality (right)

2.3 Shielding part - manipulators

Manipulators are an important element of the hot cells (fig. 5). Each hot cell is equipped with two Master/Slave manual manipulators. Manipulators are used for remote and precise work in hot-cell. Manipulators could lift up to 5kg and their range is almost the whole work place in hot cell Producer of manipulators is company Wälischmiller Engineering, supplier is company Envinet a.s. [4].

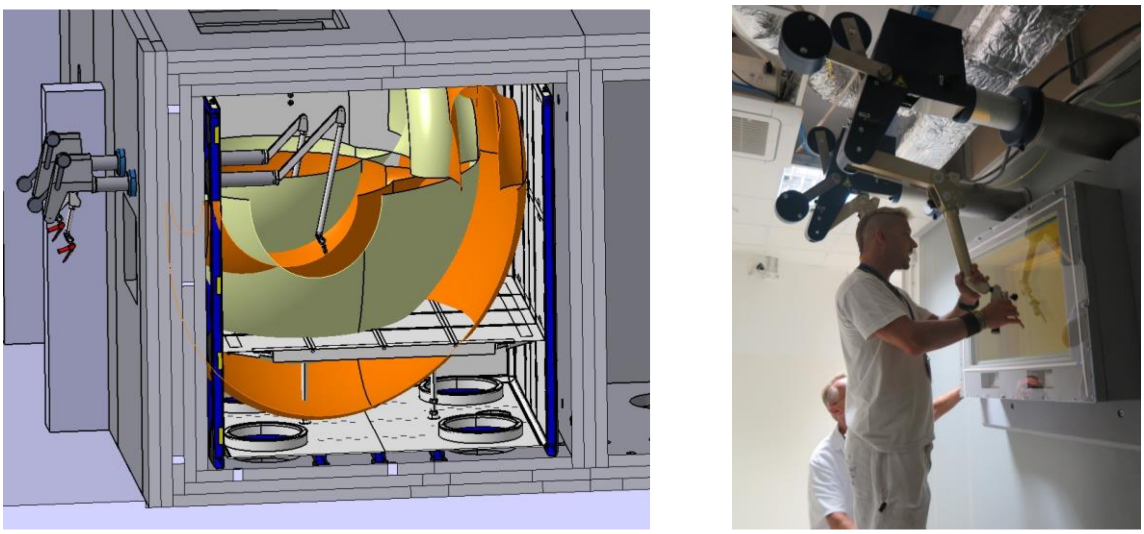


Fig. 5 Manipulators – model (left), reality (right)

2.4 Hermetic part - steel box

In each hot-cell will be a hermetic removable box from stainless steel (fig. 6). Hermetic steel Box is first and only barrier for radioactive aerosols. Some leaking will solve under-pressure in the Box, in the gamma-cells -150 Pa and in alpha-cells -500 Pa. Alpha-cells demand high airtightness and in case of accident all system will be set in state of emergency. That means that inside of alpha box will be under-pressure -3500 Pa. This stat was tested on prototype of the boxes (fig. 7). During the test leaking and structural stability was observed. No leaking and structural instability were found. Another test was focused on maximal internal load (static and dynamic). Box was designed to hold weight 7 ton (3,5t box and 3,5t equipment). Box was loaded to a total weight 8 ton. Then 50 cycles of lifting to a height of 4 meters by crane was performed. Once again no structural instability or plastic deformations were found.

After these two tests the design of boxes were approved and our manufacture department has started production of 12 boxes (10 gamma, 2 alpha)

Fig. 6 Hermetic Box – model (left), reality (middle, right)

Fig. 7 Testing of the prototype Box

Due to airtight feature all connections to the box are very problematic. Each Box has 4 plates full of airtight interconnection which will support everything in the Box (fig. 8) – electricity, sensors, control wires, gases, cooling systems, radioactive ventilation and liquid waste. This problem was solved thanks to radioactive-resistant glue which will seal all interconnection.

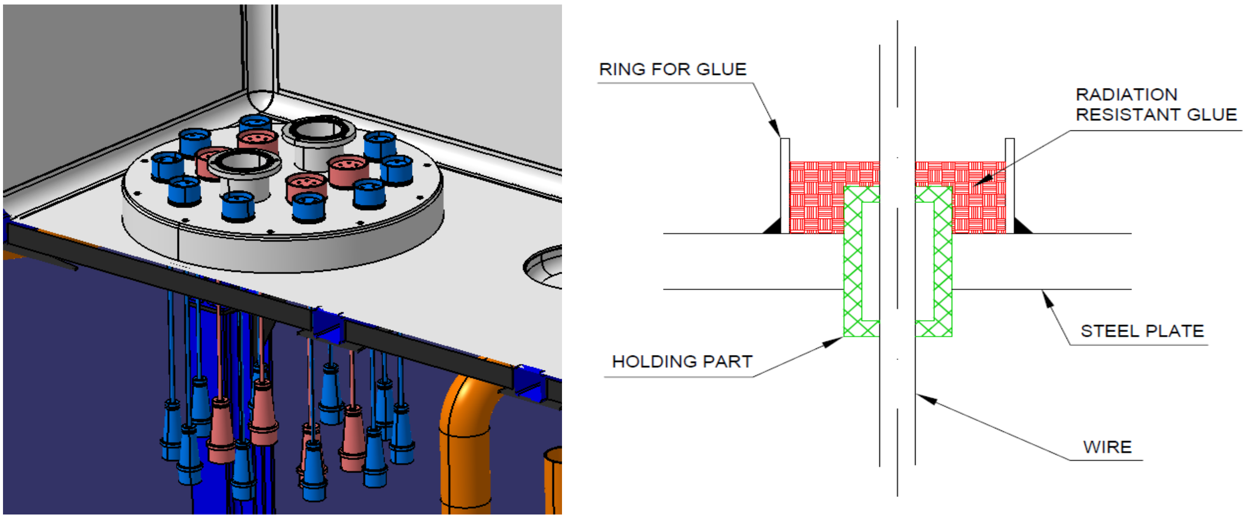


Fig. 8 Airtight connection – model (left), detail (right

Removable feature is very useful if instrumentation inside hot-cell has to be changed. Docking bay could simulate a chamber with manipulators, cameras and all connection (fig. 9). Box with equipment inside could be prepared and tested on non-active samples for a long time and then quickly move to the chamber. Action “remove and insert box” takes 3 hours. Reconnection and revival of equipment depends on type of equipment but approximately 8 hours. That means two days for changing instrumentation in the chamber.

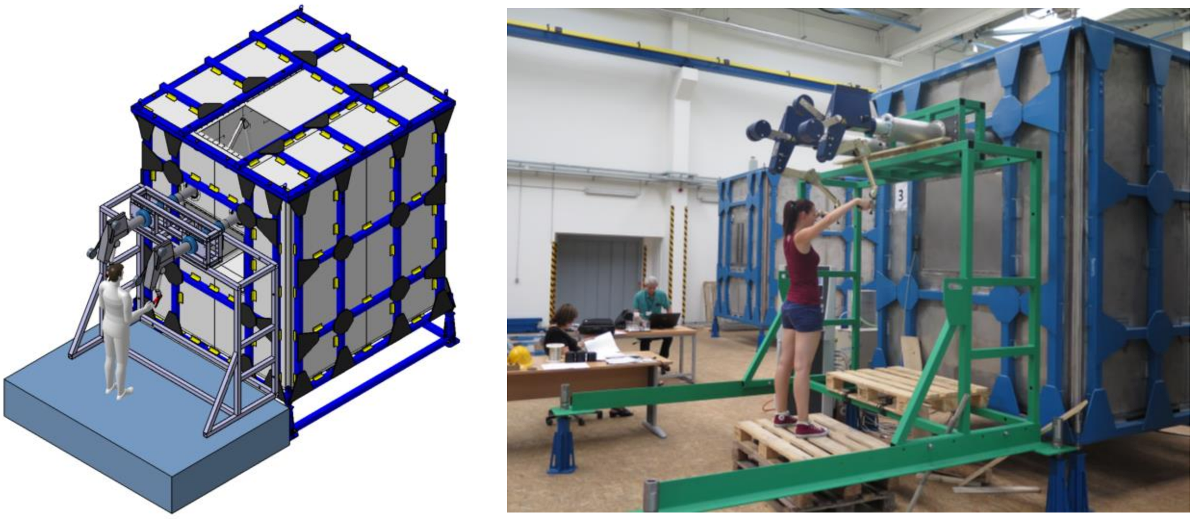


Fig. 9 Docking bay – model (left), reality (right)

3. Semi-hot cell and Scanning electron microscope

Semi-hot cell is dedicated to a microstructural study of radioactive materials (fig 10). For that purpose scanning electron microscope (SEM) and nanoindentation device will be installed. Scanning microscope will be equipped with field electron gun (FEG) which could operate for very long time without service intervention. If FEG has to be replaced, exchange with focusing and adjustment took whole month. For this reason semi-hot cell is equipped with a door which serves for quick removal of microscope (fig 11). Microscope will be on antivibration platform which will also serve as a moving device based on rails. Once microscope (active part) is outside, the door will be closed and the work inside will be resumed. Microscope will be then reconnected and brought back to life. This could be done in one hour. Microscope could work with all its parts inside and outside too.

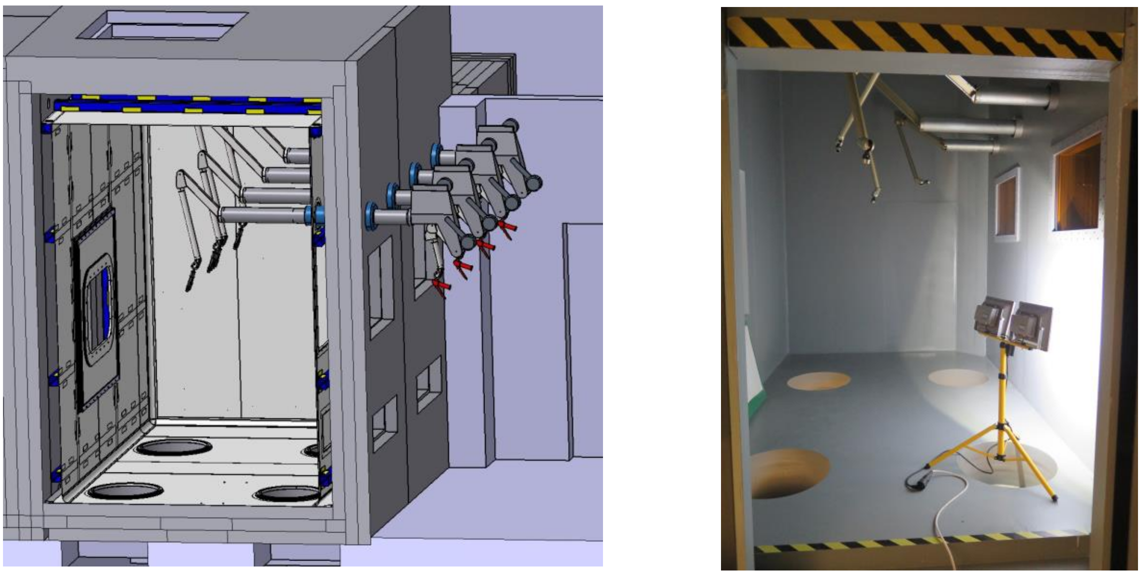


Fig. 10 Semi-hot cell – model (left), reality (right)

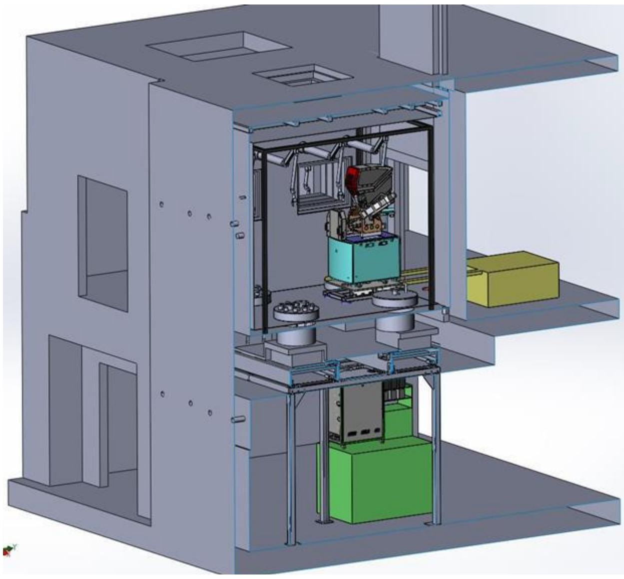
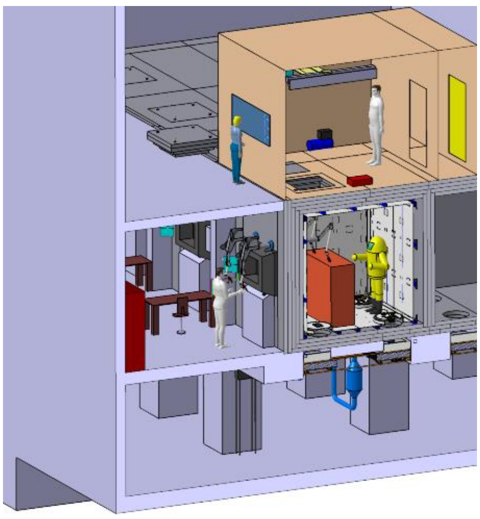


Fig. 11 SEM inside chamber

4. Pre-chamber

Limited space in the building did not allow to create a pre-chambers, therefore was a mobile pre-chamber developed. The pre-chamber has its own electrical circuit, ventilation, connector for the fresh air (for the protective suits) and entrance doors (fig 9, left). The door in the floor is for access to a hot cell. Pre-chamber will be equipped with shelves for tools and overhead crane for minor repairs. Protective suits (pressurised, Tyvek) and place dedicated to decontamination should cover all necessary operation for the day-to-day running. Pre-chamber will be moved by the indoor crane and it has its swap space on the ceiling of operator halls. During operation inside hot-cell (fig. 9, left) all communication of all workers will be carried out by open communication channel. Visual control of workers and work will be done by shielded window in hot-cell, pre-chamber and set of cameras. Pre-chamber will be made from stainless steel, interior walls will be from polycarbonate plates. This design was chosen because polycarbonate has high radiation resistance, it is non-conductive and could be easily replaced. Non-conductivity is very important for safety reason and it affectsall enabled processes inside pre-chamber.



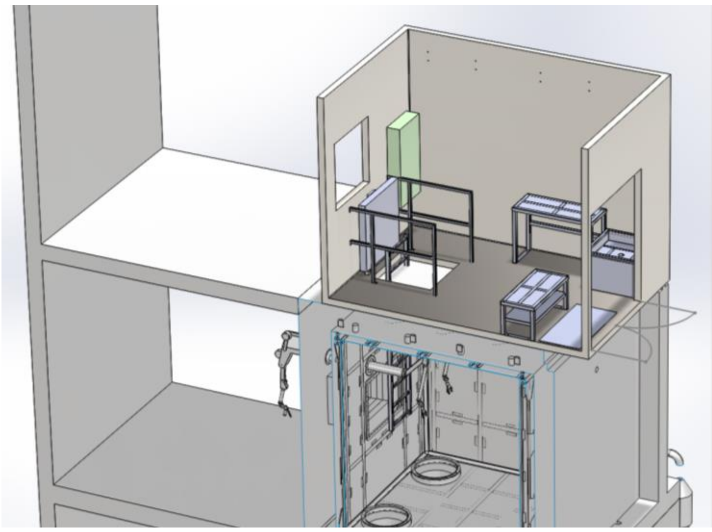


Fig. 9 Pre-chamber on the top of hot cell during operation (left), model from producer (right)

5. Control system of hot cells and Radiation protection system

All-important operating data are collected in the central control system for each hot cell. The system monitors under-pressure, temperature, radiation level, valves and position of material transfer device in each chamber. If necessary it could directly control the ventilation system and even start state of emergency. The system will have master overview console placed in a meeting room were all information from all chambers will be accessible. The system will communicate and exchange information with active ventilation, camera system, some technologies and radiation protection system.

Radiation protection system is separated and individual system with on-line monitoring and evaluation. Each hot cell is equipped with dose rate probes. One is directly inside the chamber; the second is located in control room. Other probes are installed in the building at potentially dangerous places (e.g. Storage of solid radioactive waste). These probes also measure and evaluate the volume activity of air in the building. Radiation protection system fully controls tanks for liquid radioactive waste. Probe for measuring the fluid volume activity is installed in each tank.

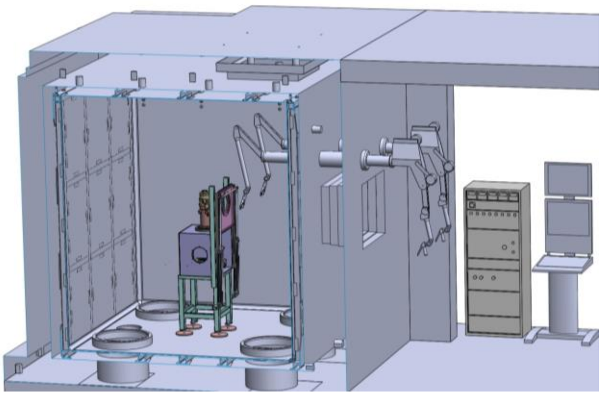
Thanks to both these systems, we have a constant overview of the safety situation throughout the building.

6. Instrumentation

6.1 Manufacturing instrumentation (cutting, welding, drilling, machining):

Electrical discharge machine (EDM)

uses electrical discharges (sparks) to manufacture desired shape without thermal and mechanical damage in the surrounding area of the cut.
Operation: Cutting and machining
Main parameters: Maximum weight of workpiece 30 kg; dimensions of traversing table: 600x400 mm.
Producer: Envinet a.s. (Emotek s.r.o.)



Electron beam welding machine (EBW)

Uses a beam of high-velocity electrons which melt and flow two materials together as the kinetic energy of the electrons is transformed into heat upon impact.
Operation: Welding
Main parameters: Vacuum chamber dimensions: 300x300x300 mm; Maximum dimensions of workpiece 170x170x230 mm; the accelerating voltage: 20-60 kV; vacuum conditions 10^{-5} Pa.
Producer: ÚJV Rez a.s.

Computer numerical control (CNC) machining centre

Is automatic of machine tools.
Operation: Grinding, machining and drilling
Main parameters: Maximum weight of workpiece 15 kg; maximum length of workpiece 200mm.
Producer: Mikronex s.r.o.

6.2 Testing instrumentation

Universal tensile testing machine

Is a device for testing of mechanical properties.
Main parameters: Tension and compression up to 250 kN; Combined axial-torsional loading; testing temperature: -150 to 1000 °C (air); maximum sample size: 1” CT
Test type: Tensile test, fracture toughness test, low cycle fatigue, combined loading test.
Producer: Igitur (Instron)

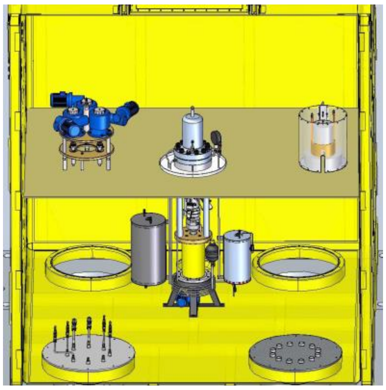
High frequency resonance pulsator

Is a device for testing of mechanical properties at high frequencies.
Main parameters: Combination of static and dynamic loading up to 50kN; frequencies up to 250Hz; testing temperatures: RT to 800 °C (air); maximum sample size: 1” CT
Test type: High cycle fatigue, pre-cracking of CTs.
Producer: Zwick Roell

Electromechanical creep machine

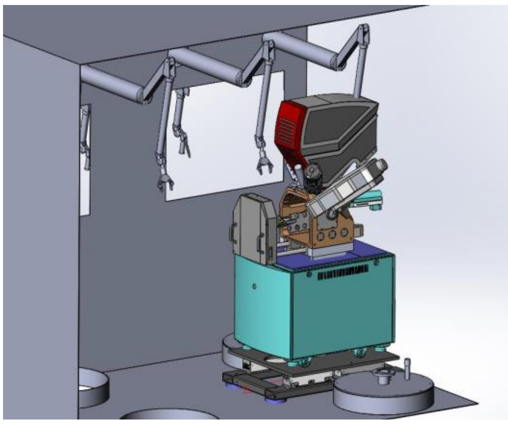
Is a device for testing of mechanical properties at elevated temperatures.
Main parameters: Loading up to 50 kN; Maximum temperature: 800 °C (air)
Test type: Thermal creep test, Creep-fatigue test.

Autoclave with water loop



Is a device for testing materials in control environment (water, high pressure, high temperature).
Main parameters: Loading up to 25kN; maximum testing temperatures: 350 °C (water with control chemical composition); maximum sample size: 0.5” CT
Test type: Tests of mechanical and corrosion resistance properties (Stress corrosion cracking, slow strain rate test, lubricant hydrolysis), crack growth rate test.
Producer: ÚJV Rez a.s.

Scanning electron microscope



is a device for microstructural and chemical analysis.
Main parameters: FEG, detectors (SE, in-lens SE, BSE), EDS, WDS system.
Test type: fracture surface, state of microstructure, chemical composition.
Producer: Elfast (TESCAN Brno, s.r.o.)

Nanoindenter with Nano Scratch Tester

is a device for nanoscale mechanical characterization of alloys, nanostructures, thin films.

Main parameters: load range from 70 nN up to 10 mN, quality optics and SPM imaging with resolution 10 nm.

Moduls: Nano Scratch Tester for scratch resistance evaluation, critical delamination forces, friction coefficient

Test type: static nanomechanical properties (nanohardness, Young's modulus, indentation creep), scratch resistance.

Producer: Hysitron (RMI s.r.o.)

7. Conclusions

New hot cells complex will be ready and operational in 2016. The whole system will cover all process: receiving of the material, samples preparing, mechanical testing and microstructure observation. New design of hot cells has some very interesting and useful features and difficulties too. Due to high shielding we will be prepared for material from decommission NPP as well as highly irradiated materials for fusion applications. Our hot cells are close to research nuclear reactor LVR-15 and new irradiation facility (high irradiation by cobalt source in high and low temperatures also vacuum) which will be built in project SUSEN. This allowed us to cover everything for R&D of materials for Gen II NPP, future NPP Gen IV, fusion reactors and space programs.

8. Acknowledgments

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9. Nomenclature

Hot cells, active samples testing, radiation protection.

10. References

[1] http://cvrez.cz

[2] http://susen2020.cz

[3] http://www.chemcomex.cz/

[4] http://www.envinet.cz/en