ISTC Project «Scale experimental investigation of the thermal and structural integrity of the VVER Pressure Vessel Lower Head in severe accident» (#3635)

Participating Institutions:

- «Moscow Power Engineering Institute» (MPEI): Leading Institution
- Federal State Unitary Enterprise «Experimental and Design Organization “GIDROPRESS” (EDO «GP»)
- Lavrentyev Institute of Hydrodynamics of the Siberian Branch of the Russian Academy of Sciences (IGiL)

Start: Sept. 01, 2007

Duration: 36 months

Prolongation: 12 months (Sept.01, 2011)

Collaborators:

- Forschungszentrum Karlsruhe GmbH (Germany)
- CEA Saclay, DEN/DANS/DM2S/SEMT, Laboratoire de Mecanique Systeme et Simulation (France)
- Material and Components Safety Department, Institut fur Sicherheitsforschung, Forschungszentrum Rossendorf (Germany)
- EC JRC, Institute for Transuranium Elements (Karlsruhe), Hot Cell Technology (Germany)
- Division of Nuclear Power Safety, Department of Physics, Royal Institute of Technology (Sweden)

- Department of Engineering Physics, College of Engineering, University of Wisconsin (USA)
- Institute of Nuclear Technology, Institute of Nuclear Safety System, Incorporated (Japan)
- Mechanical & Nuclear Engineering, The Pennsylvania State University (USA)

The project efforts are focused on the following problems:

- - the designing and construction of the test facility for test examinations of the VVER-440 vessel scale models on the conditions which correspond to SA in the VVER;
- - manufacturing of the VVER-440 reactor vessel scale models (scale 1:5) . Material and technology, as well as thermal treatment have to correspond the same conditions of the regular VVER vessels manufacturing;
- - pursuance of the material creep test experiments with samples from the VVER vessel steel on the time range 2-50 h and temperature range 700 - 1200 C to receive the creep data for refinement of the constitutive creep model and ordinary mechanical characteristics of this steel;
- **-** the carrying out the scale experiments with VVER vessel models on the high-temperature heat-up and creep deformation of the vessel;
- - the mathematical treatment and analysis of scale experiments, carrying out the numerical pre- and post-test structural analyses of scale experiments with vessel models

2. Task "B": The preparation of the scale experiment (0)

ISTC project # 3635 was suspended for one year till September 2011.

Shift of the dates was due to the necessity to recover and repair electric pathways of the vessel heater and consequentially to hold a large-scale experiment on VVER vessel scale model.

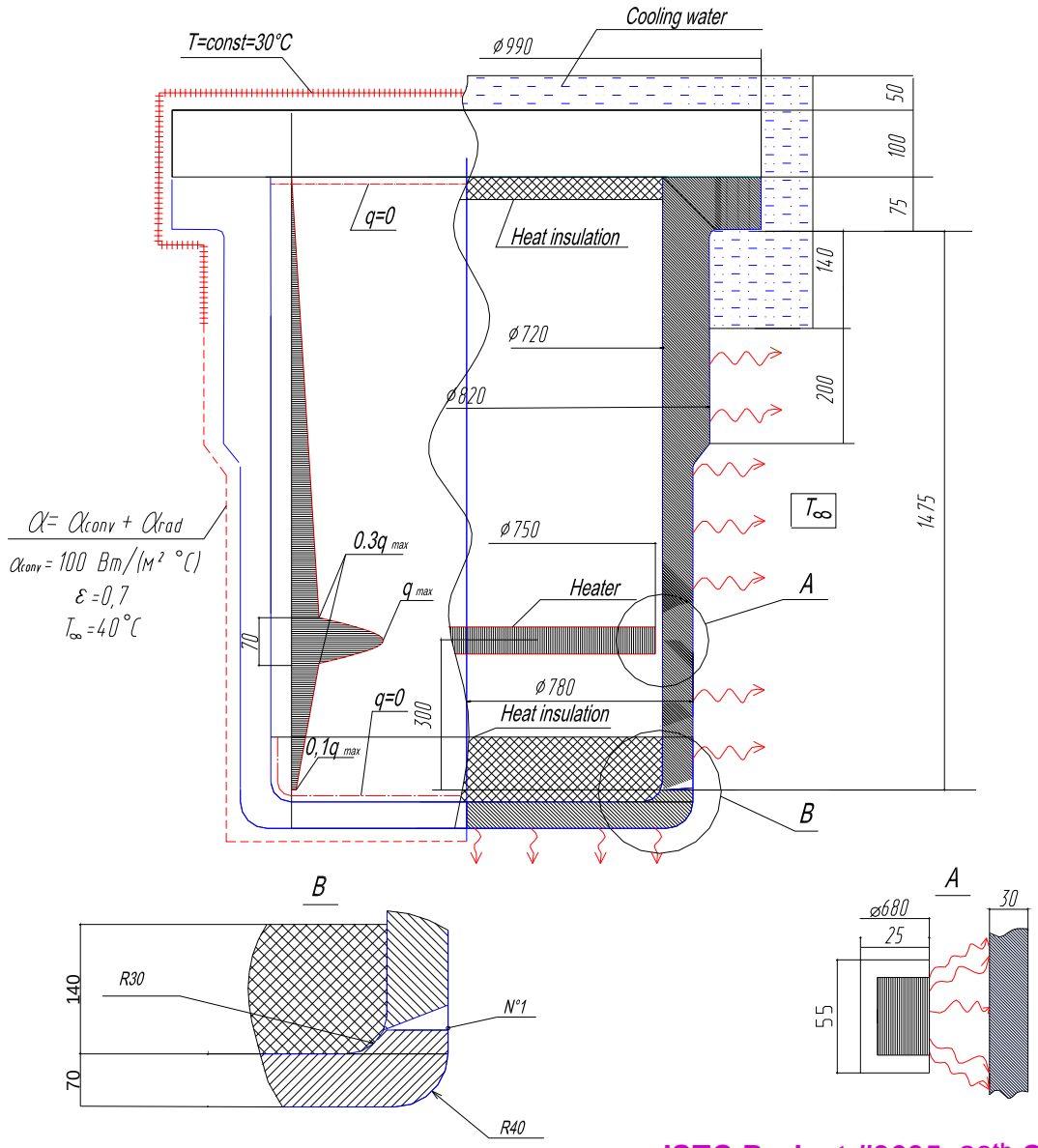
Unfortunately, we have not YET succeeded in holding the planned experiment on the vessel model.

However, I assure all the concerned participants of this project, and first of all those from EU who collaborate with us and provide financial support that after the planned experiment takes place all the results of it will be presented to the European participants in full scope in accordance with the terms of the contract.

Moreover, if we succeed in preparing an additional vessel model with elliptic bottom and holding an experiment on breakdown of such a construction we will also provide all the information and the results of the testing.

Below are the major results received by our team for the period from March 2011.

2. Task “B”: Experimental VVER-440 vessel scale model (1)

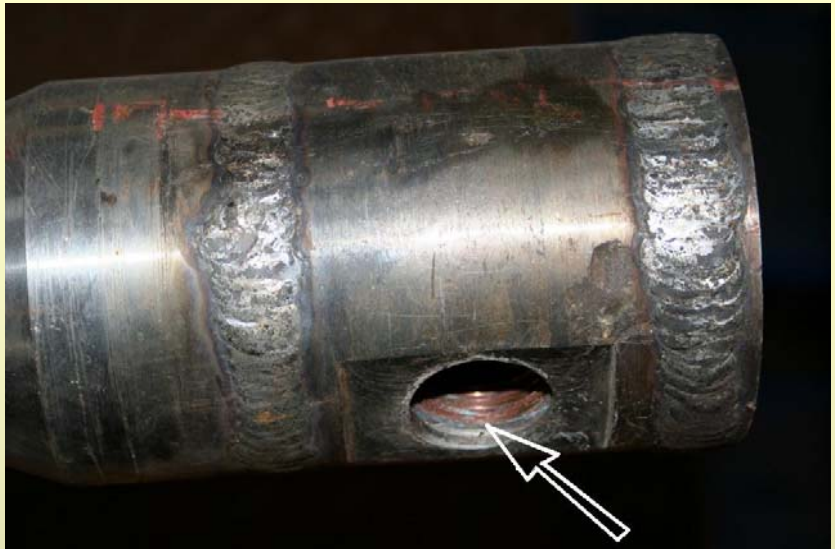


- In the vessel model the VVER steel (15Kh2NMFA) is used for the cylindrical course of the vessel. The bottom of model is made of the Steel 20.

it is planned in the scheduled experiment to study heating and deformation of the model cylindrical part.

Fig.2.1 – the vessel scale model design

●3. Task “C”: The preparation of the scale experiment (2)



The loss of the integrity occurred because of an internal engineering flaw of the welded seam connecting the two parts of the electrical conductor made of copper and the stainless steel

The main problem we had to deal with was repairing of the heater’s electric pathways. When the first tests on the leak integrity of the vessel model were held, the leak integrity of the electric pathways was disrupted and it became necessary either to repair the electric pathway or to make a new one.

It was resolved to take efforts to repair the damaged part of the heater and to test it for leak integrity.

●3. Task “C”: The preparation of the scale experiment on the high-temperature heat-up and creep deformation of the vessel model (3)

Test for leak integrity of the scale model and auxiliary systems of the IVRSA facility

In the course of the test the assembled vessel model with a lid and a heater was filled with water.

The overpressure in the model was due to the gas pressurization.

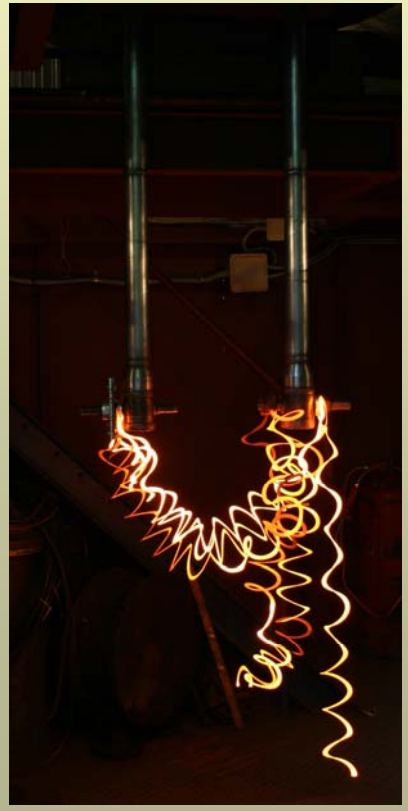
After the repairing works the electric pathway was tested for integrity, which proved that it was not disrupted.

●3. Task “C”: The preparation of the scale experiment on the high-temperature heat-up and creep deformation of the vessel model (4)

As far as the electric pathway is cooled from the inside with water and its breakdown in the process of the main scale experiment on the vessel may cause irreparable damages it was decided to have additional tests of the electric pathway construction at higher temperatures.

These tests included those with imitators of heating elements. As such elements from chrome-nickel (nichrome) alloy were used.

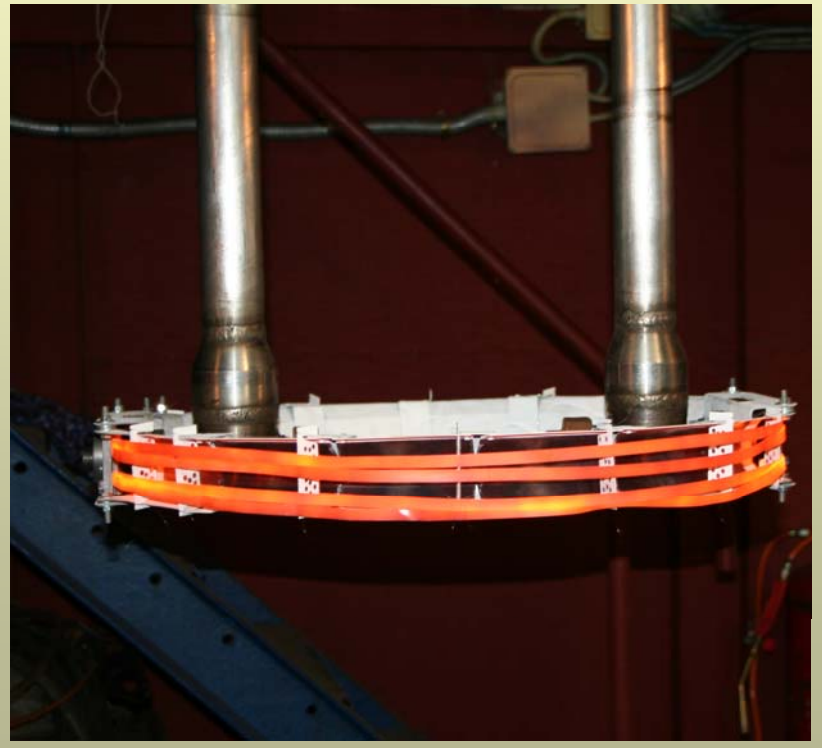
These series of tests with the air of above 750 C proved that the construction of the electric pathway is fully operating.



●3. Task “C”: The preparation of the scale experiment on the high-temperature heat-up and creep deformation of the vessel model (5)

Moreover, tests of the heater of the model assembled were held, when as heating elements of the Nickel-chrome alloy were used.

This construction was also tested with the air of above 750 C, and proved that it is fully operating.



●3. Task “C”: The preparation of the scale experiment on the high-temperature heat-up and creep deformation of the vessel model (6)

For the purpose of eliminating the possibility of unplanned breakdown of the construction of the heater it was decided to test the heater additionally using tungsten heating elements in argon atmosphere with a temperature above 1,100 C for longer than 20 hours.

The tests will be carried out with the use of a hermetical vessel of stainless steel.

The preparation to the experiment is being done at present and it will be carried out in the end of October 2011.

●3. Task “C”: The preparation of the scale experiment on the high-temperature heat-up and creep deformation of the vessel model (7)

1) If the result of the test will be negative a heater of a new construction (without water cooling) will be used.

The construction of such a heater has been developed and its making has been started in correspondence to the plans of using it in further experiments.

2) If the result is positive the heater will be placed at the scale model of the vessel and the experiment will be held using it.

3) In such a case the experiment on the scale model of the vessel is planned to be carried out in November 2011

4. The Task "D": Creep testing of the VVER vessel steel (1)

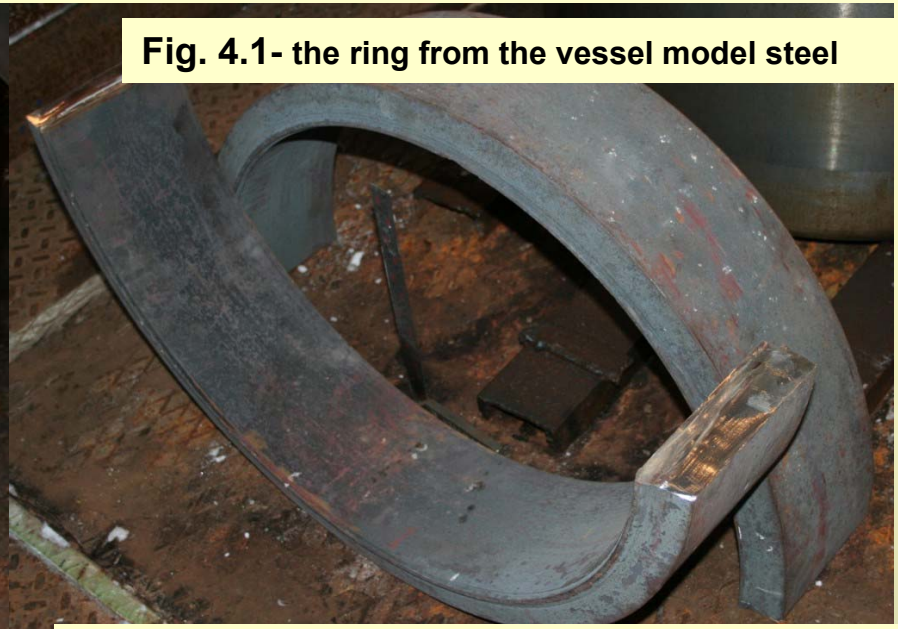


Fig. 4.1- the ring from the vessel model steel

With the purpose of identification of high-temperature mechanical characteristics of the steel the vessel scale model is made of it was decided to make a control batch of samples from the test and to conduct a creep test of this steel.

It is necessary to conduct such test because real mechanical characteristics of steel, the scale model is made of, are needed for numerical after-test calculations of the planned experiment.

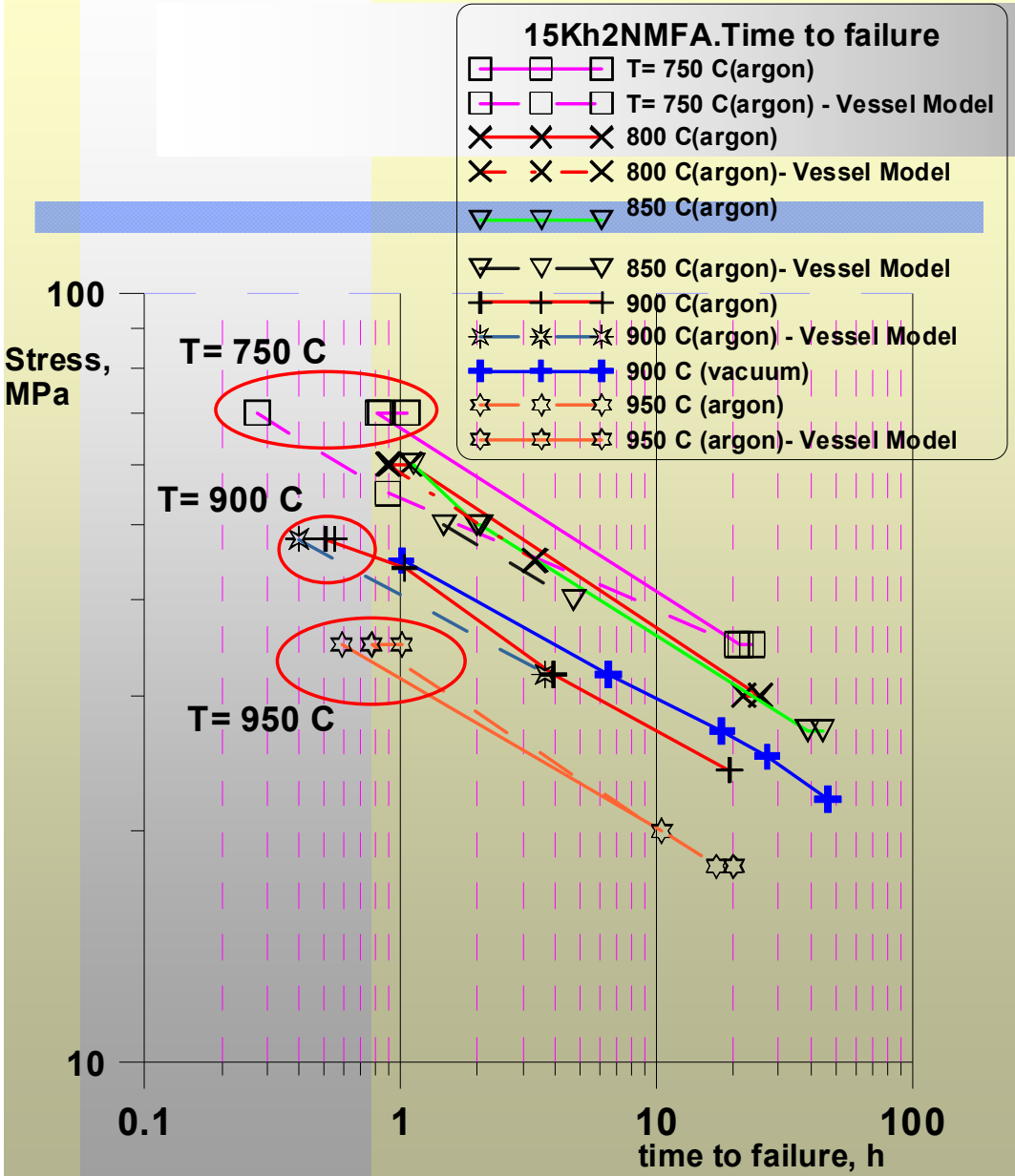
That is why after preliminary stages of the heat treatment of body frame model (before welding of the bottom) a ring was cut from it. This ring was used in the final stage of heat treatment with the assembled model (after the welding of the bottom).

4. The Task “D”: Testing of the VVER vessel steel (2)

- At present creep tests of steel from which the scale model of the vessel is constructed have been carried out.
- Creep tests were carried out in the protective argon environment;
- Creep tests were carried out with the temperature of 750- 950 C range with duration up to 25 hours.

The specimens fabricated for the tests had circular cross-section of 8 mm diameter and working length of 45-50 mm.

4. The Task "D": Testing of the VVER vessel steel (3)



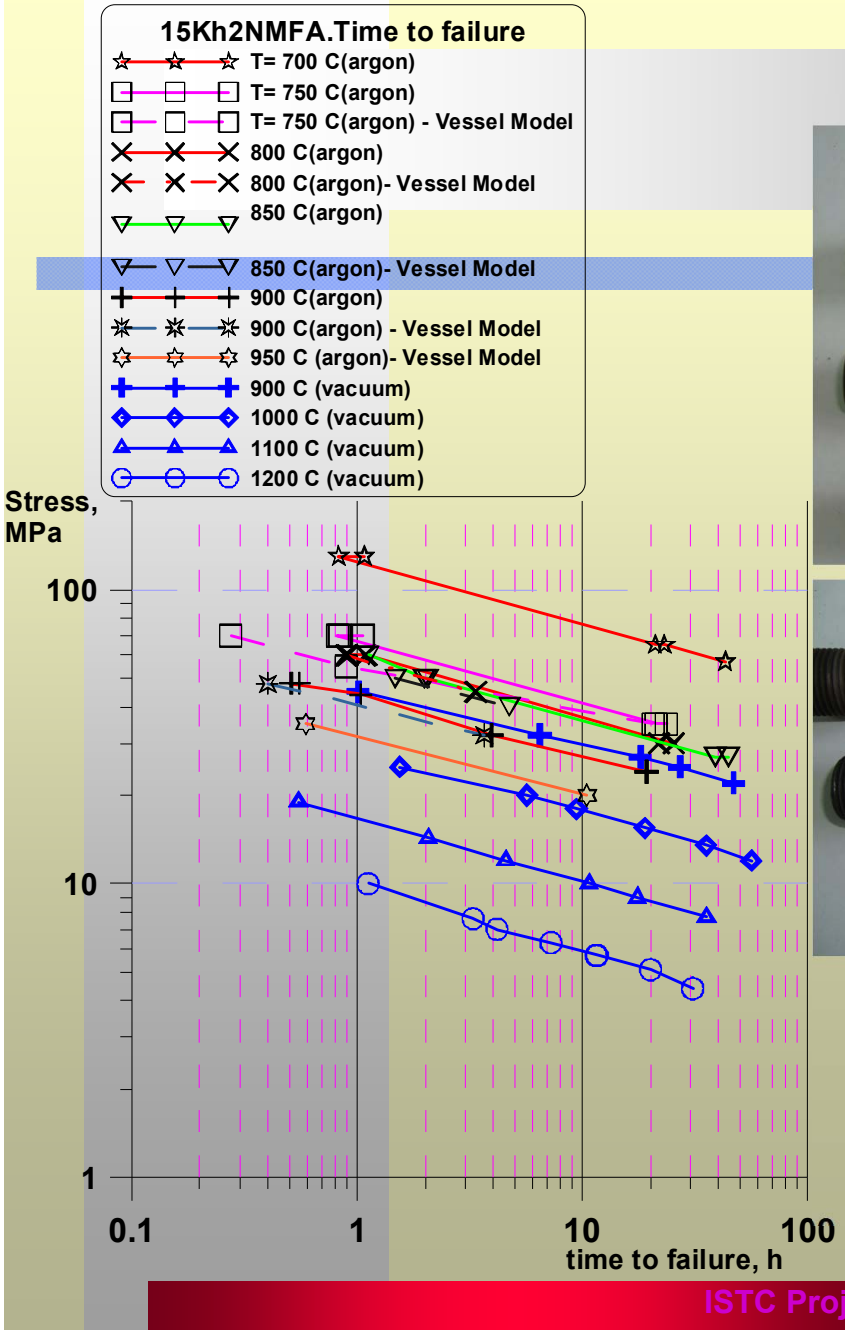
As a result of the carried out tests following characteristics of the steel from which the vessel is made have been determined:

1) in the range of 750-800 C, and in the range of 850-950 C the time to failure of the real VVER vessel steel is two-three times longer than in case of the vessel model steel failure.

It is most evident in case of higher load. If the load is less the difference of time to failure becomes insignificant;

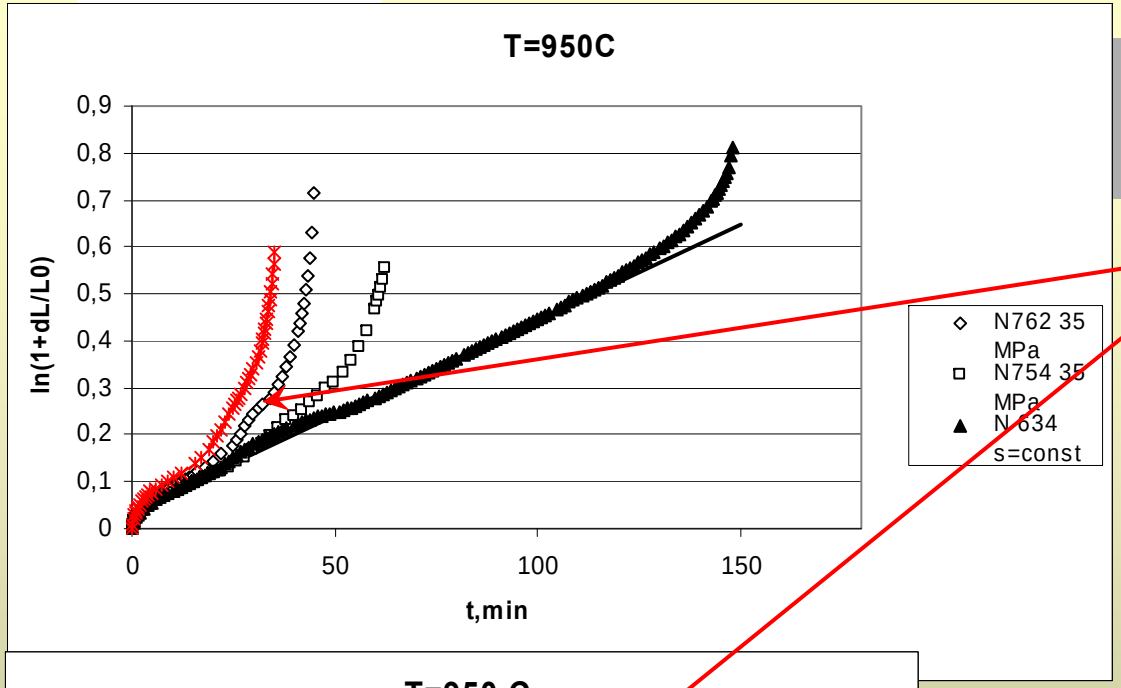
2) in the range of 800-850 C the types of steel in question (vessel steel of VVER and vessel model steel) have almost the same creep characteristics within all the range of loads.
The defined creep velocity of these steels was found to be almost the same within the whole range of loads in temperature range 800-850 C.

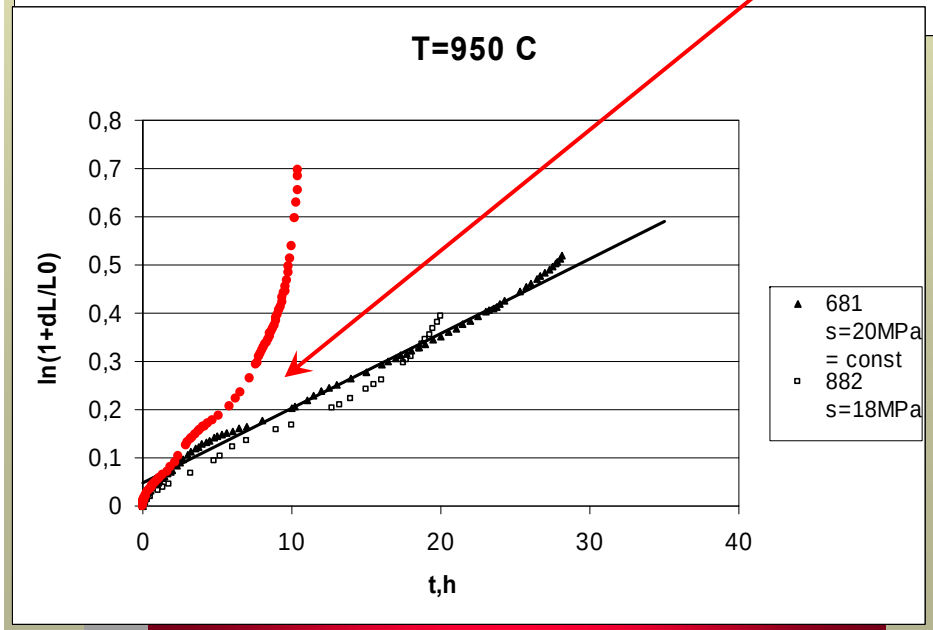
4. The Task "D": Testing of the VVER vessel steel (4)



Specimens from the vessel model steel after creep testing in argon. T= 750…950 C

4. The Task "D": Testing of the VVER vessel steel (5)





3) in the range of 900-950 C creep characteristics of the two types of steel is almost the same.

In fact we have the same "bump" on the creep graphs with the same level of deformation of the sample.

However, the "bump" appears at different time periods.

The defined creep velocity is almost the same for the two types of steel.

We believe that the differences in the manner of deformation of these types of steel are connected to the differences in heat treatment of the basic vessel of VVER and the vessel model.

The main difference is that the vessel model was treated with one temper drawing, when the vessel of VVER is treated likewise several times.

The influence of such temper drawing on the creep characteristics of VVER steel have not been taken into consideration before.

Conclusion

In the end, I would like to thank all the colleagues from CEG-SAM and the collaborators of the ISTC Project #3635 on the behalf of my team and me personally for their help during this project.

We feel sad, that our research cooperation within the frame work of International Science and Technology Center is coming to a conclusion, and I hope that we will have new opportunities for cooperation.

After the planned scale experiment takes place all the results of it will be presented to the European participants in full scope in accordance with the terms of the contract.

Thank You!