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ETE Road Map

According to Chapter IV and V of the "Conclusions of the Melk Process and Follow-Up"

Item 1
High Energy Pipe Lines at 28,8 m Level

Final Monitoring Report

Report to the Federal Ministry of Agriculture, Forestry, Environment and Water Management of Austria

Vienna, June 2005

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Quality Assurance was assigned to all partners as an integral part of the document review during its development!

The organisations and individuals listed below "Technical Project Management" have provided computing support, technical analyses, and technical support to the Technical Project Managers during the course of the project, and their valuable contributions are acknowledged.

IRR-ARCS share jointly the responsibility for the Final Monitoring Report (FMR), including its contents and conclusions. No attribution of responsibility for the contents and conclusions of the FMR to the above-listed organisations and individuals is intended or implied.

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EXECUTIVE SUMMARY

I. Basis and background of the project

The Republic of Austria and the Czech Republic, using the good offices of Commissioner Verheugen, had reached an accord on the *"Conclusions of the Melk Process and Follow-up"* on 29 November 2001. In order to enable an effective use of the "Melk Process" achievements in the area of nuclear safety, the ANNEX I of this *"Brussels Agreement"* contains details on specific actions to be taken as a follow-up to the "trialogue" of the "Melk Process" in the framework of the pertinent Czech-Austrian Bilateral Agreement.

Furthermore, the Commission on the Assessment of Environmental Impact of the Temelín NPP – set up based on a resolution of the Government of the Czech Republic – had presented a report and recommended in its Position the implementation of twenty-one concrete measures (ANNEX II of the *"Brussels Agreement"*).

The signatories agreed, that implementation of the said measures would also be regularly monitored jointly by Czech and Austrian experts within the Czech-Austrian Bilateral Agreement.

A "Roadmap" regarding the monitoring on the technical level in the framework of the pertinent Czech-Austrian Bilateral Agreement as foreseen in the "Brussels Agreement" had been elaborated and agreed by the Deputy Prime Minister and the Minister of Foreign Affairs of the Czech Republic and the Minister of Agriculture and Forestry, Environment and Water Management of the Republic of Austria on 10 December 2001.

The Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management has entrusted the Umweltbundesamt (Federal Environment Agency) with the general management of the implementation of the "Roadmap". Each entry to the "Roadmap" corresponds to a specific technical project.

Item No.1 "High Energy Pipe Lines at the 28,8 m Level" of ANNEX I of the "Brussels Agreement" covers the integrity of the main steam and feed water piping at the +28,8 meter level of the Temelín reactor buildings, where this piping transits from the respective containment penetrations to the turbine hall. This issue is frequently referred to as "High Energy Line Breaks" or HELBs.

The objective of the Roadmap process covered by this item as stated in ANNEX I of the "Brussels Agreement" is:

> To *"ensure that the safety case demonstrating appropriate protection against high energy pipe breaks and consequential failures of the steam and feed water lines, complies with requirements and practices widely applied within the EU and that an appropriate combination of measures are in place."*

On behalf of the Austrian Government the Umweltbundesamt (Federal Environment Agency) has committed an Austrian Experts' Team composed of national and international experts to provide technical support for the monitoring of the implementation on the technical level of the +28,8 meter level Issue as listed in ANNEX I of the "Brussels Agreement". This specific technical project is referred to as project PN2 comprising altogether seven predefined "project milestones" (PMs).

The technical support for the monitoring on the technical level of the implementation of the "Conclusions of the Melk Process and Follow-up" regarding the item High Energy Pipe Lines at the 28,8 m Level Issues was aimed at focussing on the evaluation of how the Czech Side (operator as well as regulatory body) has dealt with the issue in a methodological way for implementation. In particular, it was intended to focus on HELB assessment and consequential failures mitigation, comprehensive PSA analyses and the implementation of ISI programmes, all to be checked against requirements and practices governed by valid interpretations of the

ALARA principle and widely applied within the EU and of new developments in WWER-reactor specific knowledge, both on the technical and regulatory level.

II. The approach and objectives of the Czech side

The Temelín NPP, originally of Soviet design, and later upgraded to include elements of western safety concepts and western equipment, has addressed integrity of the High Energy Lines at the 28,8 m Level late in the construction phase. During the Specialists' meetings in the frame of the Melk process it appeared that the process of a Comprehensive Safety Case Revisit of this topic at Temelín was not adequately completed. The availability of information on the details of the approach adopted at the Temelín NPP was insufficient. Therefore, HELs integrity on the 28,8 m level remained one of the items to be addressed during the follow up to the Melk process. This established the basis and defined the scope of the proposed project.

The NPP Temelín has to be considered as a very specific case: Design and construction were performed in the former Soviet Union, the manufacture occurred at least partially in the former Czechoslovakia under Russian supervision. After the political re-organisation of Eastern Europe the construction was completed including Western technology from Westinghouse under the responsibility of the plant owner. Licensing happened within the legal frame of the Czech Republic.

The key element in the monitoring process was a Specialists' Workshop on the "Roadmap" item No. 1 "HELB" and "Roadmap" item No. 2 "qualification of valves" (PN3) conducted in Prague on 7 and 8 November 2002 in the framework of an additional expert meeting according to Article 7 (4) of the Bilateral Agreement of the Exchange of Information on Nuclear Safety. In view of the interrelation of the two issues, the Czech hosts deemed it useful to treat both items at the same workshop. The workshop was the key element in the monitoring process for the analysis by the Austrian Experts' Team before and after the Specialists' Workshop. Additional information has been collected at the two Bilateral Meetings following the Specialists' Workshop. The analysis of the information made available at the three occasions is the basis for the present Final Monitoring Report of the Austrian Experts' Team.

In a series of presentations the outline of the solution for the HELB item was described by Czech experts at the Specialists' Workshop, along with the way the Licensing Authority had accepted these solutions.

The areas presented by the Czech side in a number of presentations at the Specialists' Workshop were related to the broad scope of the "Comprehensive Safety Case Revisit" (CSCR) initiated by SÚJB and accepted as endorsing the original decisions of the regulatory authority. Information about the following areas was presented and discussed:

- Design
  - Codes, Standards, Rules and Regulations applied and compared to those in the EU
  - Load Definition: Steam-Water Mixture of BRU-A and SGSV Qualification
  - Pipe Break Probability, Probabilistic Fracture Mechanics Overview
  - "Superpipe" Concept Application on Steam and Feed Water Lines Overview
- Thermal Hydraulics
  - Thermal-Hydraulics Analysis and Dynamic Calculations Overview,
Steam Water Hammer and Water Overfill.
  - Pressurised Thermal Shock Overview

- Materials
  - Material Properties
  - Flow Accelerated Material Corrosion Overview
- In-Service Inspection
  - Measurement of Operational Displacement (of piping sections)
  - Ultrasonic Testing,
    Non-Destructive-Evaluation Modifications, Qualification, Procedures and Results.

The approach of ČEZ a.s. to resolve the safety issue "Consequences of Secondary Piping Failure at the 28,8 m Level" of the Temelín Nuclear Power Plant (as approved by SÚJB) is to rely on break exclusion for the main steam and feed water piping extending over up to 30m each, including elbows from the containment penetration to the isolation valves.

The descriptions at the Specialists´ Workshop did provide information about the approach taken. However, due to the overview type of the presentations only limited insight was possible into the results and how these were obtained. Several questions remained open. As a consequence, both sides agreed that the pertinent Czech-Austrian Bilateral Agreement is the appropriate framework giving the opportunity for further discussion and sharing additional information on these issues.

The presentations at the Specialists´ Workshop in Prague provided an insight into the extensive work accomplished by the plant operator and its technical support organisations in trying to consolidate the safety case in the framework of the "Comprehensive Safety Case Revisit" (CSCR) for judgement by the licensing authority.

III. The approach by the Austrian Experts' Team

An Austrian Experts' Team of 15 national and international experts was committed by the Umweltbundesamt on behalf of the Government of Austria to give technical support for the monitoring on the technical level of the implementation of the HELB Issue as listed in Annex I of the "Brussels Agreement".

The project PN2 is composed of two complementary segments (horizontal and vertical), the horizontal segment depicting an assessment of principles, standards and practices, the vertical segment providing an analysis of HELB bounding cases and of the materials database established and used for the Temelín NPP.

The monitoring process conducted by the Austrian Experts' Team was concentrated on the engineering approach taken by ČEZ to have the Temelín HELs licensed by the SÚJB (State Office for Nuclear Safety).

In applying current safety philosophy, the consideration of HELB usually includes the precautions taken to identify HEL material and integrity degradation in time and sequences, which are likely to cause excessive loads on the HEL.

Both segments – the horizontal and vertical one – were related to the collection of information on the Temelín HEL behaviour during transients and over service life, as well as the HEL material history and usage and their vulnerability.

This specific technical project comprises altogether seven predefined "project milestones" (PM). The PMs requested by the contracting party, the Austrian Umweltbundesamt, represented the main tasks to be accomplished by the Austrian Experts' Team. Several preparatory tasks had to be performed to support and accomplish the main tasks. These preparatory tasks are also addressed in this report.

For the different tasks within the HELB assessment the state of science and technology was reviewed for comparison with the findings of the evaluation of the Czech approach and the Comprehensive Safety Case Revisit, which included the following issues:

- HEL quality with respect to design, construction/manufacture
- HEL analysis
- HEL surveillance
- ISI programme
- HELB related modifications
- HELB related EOPs and SAMGs

At the time of the NPP Temelín construction the actual HEL concept did not take into consideration the need for secondary coolant circuit failures mitigation to the extent needed. Therefore the WWER-1000 analyses were only conducted under the assumption, that subsequent failure of the secondary main coolant piping is too unlikely to occur.

With better knowledge of the materials behaviour and ISI results from a number of installations indicating ageing effects important to integrity, the secondary failure as a consequence of a rupture of one of the secondary main steam or feedwater lines outside the containment became subject of extensive investigations. The widely accepted practice to provide for physical protection of endangered components, structures and equipment introduced against common cause failure was not applied at the Temelín plant. Instead, an extensive program was started to demonstrate sustainable integrity of the secondary HEL in the first place and limitations to the consequential failures of HELs also.

To focus preparatory work of the Austrian Experts' Team and to guide the Austrian Delegation through the Specialists' Workshop, but also to enable proper preparation of the Specialists' Workshop on the bilateral level, in a **first step, Project Milestone 1 (PM1)**, the safety objective was broken down to Verifiable Line Items (VLIs). They were based on the Defense-in-Depth principle applied to qualify Temelín NPP's safety features consistency.

In a **second step** the Austrian Experts' Team prepared a list of documents **(PM2)** the **Specific Information Request – SIR**, considered to contain the kind of information required to provide profound answers to the VLIs (see ANNEX G).

The **third step (PM3)** in the **preparatory work for the Workshop** also included identification of standards and practices applied within the European Union Member States France and Germany, as well as in the US, for the HELB issue. Special focus was placed on the practice in France and the US, since the operator of ETE applied the codes, rules and regulations of these countries. In the Briefing to the Austrian Delegation these elements of the monitoring were presented to the mission participants.

The principles of HELB analyses requirements and the related work conducted within the Comprehensive Safety Case Revisit, the implementation at the plant including known modifications compared to former WWER-1000 related HEL programmes, the compliance and differences with the state of science and technology and currently accepted practices as identified were described and commented in the Briefing Material with respect to their safety significance.

At the Specialists' Workshop on HELB and Valve Qualification in Prague on 7 and 8 November 2002, experts from the plant operator, technical support organisations, and the licensing authority made fifteen well-prepared slide beamer presentations, characterised by one presenter as being of an overview nature.

The Workshop in Prague 2002 concentrated on the performance of the HELB analyses and HEL related operational precautions. Other topics related to HELB were not treated in detail at the Workshop, such as, multiple line failures, line penetration failures, the 28,8 m level support structure load bearing, HELB consequences to the primary coolant system and core cooling as well as reactivity control.

Within the limitations spelled out above, questions from the Austrian Experts' Team were mostly answered during the workshop.

Following the Specialists´ Workshop in this **fourth step (PM4)**, the Austrian Experts' Team reviewed the Specialists' Workshop presentations and the Austrian Experts' Team members provided contributions to the later issued **Preliminary Monitoring Report (PMR)**. Based on information available at the time, the Austrian Experts' Team had characterised several results in the PMR.

The evaluations in the PMR addressed four different levels of the process by commenting:

- on the adequacy of the information available from the presentations in view of the monitoring task and
- on the adequacy of the technical approach as such
- on the state of science and technology in Western Europe and its compliance with the situation identified at Temelín NPP
- on issues directed towards a resolution of the safety issue addressed and on its interrelation to the items of projects PN3: "Qualification of Valves" and PN4 "Qualification of Safety Classified Components."

As one of the results of the PMR the Austrian Experts' Team performed analyses for three issues identified as open in order, to assess the Czech statements related to those issues for this Final Monitoring Report (FMR).

These issues are:

- Recriticality of the reactor initiated by a HELB,
- Design loads for the HELs at the 28,8 m level and
- The material database.

The PMR focused on the application of the French Tronçons Protégés concept in the HEL case. The concept standard application requires short, weld-free pipe segments. The Temelín break exclusion application however comprises lengthy pipes with many welds. Further considerations should focus in some detail on the acceptance process of this novel approach and its endorsement requirements in a case-by-case licensing procedure.

In addition, contemporary practice in German and French licensing approaches foresees break exclusion demonstration acceptance only in addition to physical separation (e.g. with each steam-line or feedwater-line in its own compartment or with spatial separation up to the main isolation valves).

During the presentation at the Specialists' Workshop the Czech side reported the results of their evaluation on a separation wall splitting the +28,8 m level into two halves. While the construction was considered to be technically feasible, concerns arose due to the adverse influence of such a wall on maintenance and in-service inspections of near-by located components and equipment. According to the information presented, the implementation of other forms of physical separations also seems to be difficult with the given Temelín design. At the present time the plant operator does not plan to build such a separation wall.

The Austrian Experts' Team stated already in the PMR, that it would be interested in receiving information about the bases on which the Regulatory Authority accepted this unique approach for the break exclusion. The following items are of specific interest in this context:

- Given the existing piping layout in place at Temelín, break exclusion application, without considering the consequences of the postulated HELBs on the equipment related to safety, does not seem to conform to contemporary practice in German and French licensing.

- Break exclusion requires 100% surface and volumetric inspection of all welds in the break exclusion area (US NRC requirements in this regard do not permit any exceptions).
- The NDT (Non Destructive Testing) approach described by the operator's experts at the Specialists´ Workshop is currently not qualified for all difficulties encountered during inspections of the welds at the steam and feed water lines.
- **Break exclusion applications** (e.g., German KTA and French Tronçons Protégés) require post-weld heat treatment and post-weld surface treatment. The Austrian Experts' Team was told at the Specialists´ Workshop that neither of these treatments has been performed for welds in the break exclusion area at Temelín until now. Therefore consideration should be given that the state of the welds conforms to break exclusion requirements.
- **Material tensile properties** data used to demonstrate the stress criteria fulfilment are neither the code-based nominal values nor the minimum values certified from the manufacturer of the piping material actually installed. If either of these values were used, the break exclusion stress criteria would not be met. Instead, the properties values used are derived from available samples, yet evidence of representativity for the original piping material has not been provided. Close examination, should be considered for the available sources of material data. If available, their qualification to enhance the materials properties' database should be verified.
- Based on the information presented at the Specialists´ Workshop, the full functionality of the pipe whip restraints cannot be considered demonstrated up to now. This concerns in particular the weldment of the collar ring to the containment penetration.
- This is mainly because those events, which have been presented as initiators considered for **loads to the pipelines** are not yet complete. Events of potential importance, such as large leakage from the primary to the secondary circuit or the reference aircraft impact, have apparently not been included up to now.
- Taking into consideration the limitations identified above, the full assessment of the **behaviour of the primary coolant system and the reactor core** under the conditions of multiple steam line breaks in the compartment at the 28,8 m level would be of particular importance.

In the PMR the Austrian Experts' Team had grouped already its major findings, in view of the indicated progress regarding the plants safety and the information, expected from other, future Roadmap Workshops to complete the view obtained from the Comprehensive Safety Case Revisit.

In a **fifth step (PM5)** the Austrian side presented a **summary of the HELB issue monitoring** and the related main findings at the Bilateral Meeting on December 18, 2003. The discussion provided no new facts at this stage.

At the Bilateral Meeting November 28 and 29, 2004 two short lists of questions were delivered to the Czech partners resulting in valuable information to the Austrian Experts´ Team additional analyses which were finished in December 2004.

The **sixth and final step (PM6)** in the monitoring process of PN2 'High Energy Line Breaks' was to set up the **Final Monitoring Report (FMR), which is presented herewith**.

As suggested by the Austrian Experts' Team the Technical Project Management ordered additional analyses for the FMR (PM6) related to the three selected topics addressed above in context of the PMR issues list. For these three issues additional substantial work has been performed in the frame of PM6 to support the final assessments. The three issues are:

(1) The **behaviour of the primary coolant system and the reactor core** under the conditions of multiple steam line breaks in the compartment at the 28,8 m level and the suspected recriticality of the reactor,

(2) **Design loads for the HELs at the 28,8 m level** according to European practice (e.g. water hammer caused) compared with design seismic loads applied declared bounding by the Czech side

(3) **Qualification of the material properties data for the database** to be used in the break exclusion attempt, the HEL design verification and operational wear and ageing evaluation.

The main findings of these additional Austrian Experts' analyses are denoted in Chapter IV.

Since the results and the recent additional information presented by the Czech side were valuable but not sufficient to clarify these three issues, (1., 2. and 3.), it is recommended to follow also these issues beyond the end of the current Monitoring Process.

IV. Summary of Main findings

The evaluation of the presentations held at the Specialists´ Workshop by Czech experts is discussed in the FMR in relation to the international practice and the Czech requirements including the legal framework.

The results of the bounding case calculations performed in support of the monitoring effort are respected implicitly in the argumentation [**ANNEX F**].

All additional information collected during the work on the other Items, which have lasted from 2002 until late 2004, after the Bilateral Meeting on November 29 /30, 2004, has been duly taken into consideration, when transforming the original Preliminary Monitoring Report (created and issued as the result of PM4 in early 2003) into this Final Monitoring Report.

IV.1 Findings about the CSCR:

About the interaction of the operator, the manufacturer, the technical support organisations and the licensing authority with respect to HELBs solution implementation:

The presentations and comments during the Specialists´ Workshop suggest that the determination of requirements and the subsequent compliance verification should play the dominant role in the living safety culture for the realisation of the Defense-in-Depth concept established.

IV.2 Findings about the 28,8 m Level

The Monitoring regarding the HELBs technology evaluation adhered to the 18 defined Verifiable Line Items (see Chapter 4) presented below, each followed by the monitoring result compiled from the findings:

- **With respect to the piping design approach and piping stress analysis methodology, considering piping and components qualifications, service levels, load combinations:** (including expected and unexpected steam/water hammer effects)

  For the Comprehensive Safety Case Review: the logic of the design criteria, the design process and conclusive statements of compliance were discussed only in brief in the Czech experts' presentations at the Specialists´ Workshop. Similarly, the introduced so-called "Superpipe Concept" was not demonstrated embedded into the original design criteria, without evidence of code compatibility examination for the various codes, standards, rules and regulations.

An integrated approach of prevention, protection, qualification and mitigation measures was followed only partially, thus deviating in part from the Defense-in-Depth concept.

Justification for excluding large portions of the HEL piping from the "Superpipe Concept" re-qualification was also not included in the presentations.

Accessibility of related documentation to fill in gaps in the presentations would be a substantial asset.

- **Regarding the criteria used to select pipe break locations and orientations:**

  Only some indications were received on how pipe break locations candidates were selected and on how the breaks' orientations have been accepted or eliminated.

- **Regarding the postulated "aggressive" HELB points assumed in the analysis:**

  From the provided information "aggressive" HELB points identification of the subsequently postulated, and analysed breaks up to possible consequences could not be followed. It is not certain that loadings induced to the break exclusion zone from breaks outside this zone (i.e. in the containment or in the turbine hall) have been considered for maximum stress field determination. Consequential failure induced effects would provide also information about the investigated occurrences severity. Issues of this kind would deserve more in-depth attention.

  - Results of explorative work by experts of the Austrian Experts´ Team for a generic WWER 1000 set-up for the Design Loads for the HELs at the 28,8 m Level:

    Experts of the Austrian Experts' Team performed calculations according to state of science and technology. The results indicate that the extent to which "aggressive" HELB points were identified and considered for the Temelín NPP in the design review fell short at least with regard to the so-called Bubliks.

- **With respect to pipe internal dynamic fluid forces effects as a consequence of the postulated HELB (including geometry effects and blowdown characteristics):**

  Water Hammer load cases, supposed to be examined for both, the steam lines and the water lines and for various operational and accident transient conditions would have to be performed. Evidence that the Operation Base Earthquake loading consequences would be bounding to all other dynamic loadings fell short in the demonstration.

  - Results of explorative work by experts of the Austrian Experts´ Team for a generic WWER 1000 set-up for the Design Loads for the HELs at the 28,8 m Level:

    The results indicate that design loads for the HELs at Temelín NPP appear not to be enveloped by the seismic loads, an assumption made and confirmed by the Czech side.

  Investigations of dynamic loads are also indicated in all cases of operational loads when combined with degraded piping components.

- **The non-linear mechanical analysis to determine the whipping pipes dynamic response indicated:**

  Non-linear mechanical analyses were phased out due to the restrictions applied to the assumed break locations. Jet forces and reaction forces on the pipe whip restraints were briefly presented at the Specialists' Workshop

  - Results of explorative work by experts of the Austrian Experts´ Team Team for a generic WWER 1000 set-up for the Design Loads for the HELs at the 28,8 m Level:

    The results indicate that design loads for the HELs resulting from jet forces and reaction forces considered together with the dynamic response of whipping pipes require non-linear mechanical analyses.

- **About the evaluation of jet impingement shapes, temperatures, pressures, directions and loads, insofar as to find out whether jet forces impulse to HEL or walls or components are likely to cause consequential failures:**

  The restrictions applied to the assumed break locations resulted in no need for estimates of dynamic pipe whip response. Simulation results used for the preliminary design of a separation wall were not made available.

- **With respect to the proposed measures to protect safety related equipment from pipe whip, blowdown jets and reaction forces and separation of redundant features (requirements, material properties & sizing of pipe whip restraints and separating shields)**

  The provisions made to protect safety-related equipment as part of Defense-in-Depth concept's application were not presented. Even for those protective features that are in place (separation wall, supports etc.), no technological information was made available to the Austrian Experts' Team.

- **In the context of methodology and analyses of compartment pressurisation and environmental conditions following a postulated HELB:**

  The environmental conditions specification is a prerequisite for project PN4 "Qualification of Safety Classified Components". Specific Information made available can be found in the related FMR.

  On the context of structural design loads including pressure & temperature transients and dynamic reactions as consequences from HELB:

  In the presentations, the design loads required to be quantified for protection of safety related equipment as part of Defense-in-Depth concept application were identified for single events only and, for these cases, only qualitatively. Pipeline dynamics were treated based on a very theoretical simulation only.

- **In treating the methodology for evaluation of structural adequacy of Seismic Category I structures (those civil structures required to fulfil safety functions):**

  The provisions made to protect safety-related equipment from failure due to consequences from seismic loadings should be part of Defense-in-Depth concept's application; information about such provisions was not presented. Nothing was reported on this subject. The seismicity issue was treated in project PN6."Site Seismicity".

  The Austrian Experts' Team, when monitoring the actual status of the "Bubliks" sections evaluation for compliance with Defense-in-Depth requirements in the Specialists´ Workshop follow-up, had to find out that a conclusive solution to the water hammer loading has not been presented. The Czech Technical Support organization has indicated in a statement provided recently, that analyses to this open issue has been started already and is supposed to be conducted during 2005.

  To some extent, pipe whip consequential damage has been analyzed evidently by the Czech experts. At the Specialists' Workshop, the assumptions about the pipes' supporting structure, and in particular of the pipe supports intended to limit the movement of broken pipes, have been only mentioned qualitatively.

  - Results of explorative work by experts of the Austrian Experts´ Team for a generic WWER 1000 setup has lead to questions about the applicability of the results presented for Temelin to describe rupture events and pipe whip, that could damage the adjacent wall and impair the integrity of the HELs at the 28,8 m level.

- **As regards the structural analysis evaluation, including local loads on the concrete Category I structures and non-safety structures whose damage may impair the safety of the plant:**

  The load bearing capacity of the 28,8 m steel girder support and concrete structures to protect safety related equipment from indirect damage is part of the Defense-in-Depth concept application. Results to this need were not presented.

  - Results of explorative work by experts of the Austrian Experts´ Team for a generic WWER 1000 setup for the Design Loads for the HELs at the 28,8 m Level:

    Steam or feedwater line pipe whip in the vertical section after the 28,8 m level might endanger not only the adjacent turbine hall wall and the HELs in this area but also the HELs at the 28,8 m level in case the fix point near by at the turbine hall wall is not capable to take the resulting loads.

- **With respect to the structural failures, environmental conditions and potential flooding that might result in loss of safety functions and habitability of the main control room:**

  The provisions made to preserve vital safety functions as well as safety equipment, part of the Defense-in-Depth concept application, have not been presented.

- **Treating the aspect of adequacy of the safety class components environmental qualification – candidate equipment selection:**

  The aspect addressed was generally part of the project PN 4 "Qualification of Safety Classified Components". However no specific listing became available of candidate components at the 28,8 m level requiring environmental qualification.

- **Regarding the analyses methodologies to evaluate the plant response to MS & MFW HELB outside containment:**

  The elements necessary to monitor analyses and evaluations of plant response to High Energy Lines Breaks in order to provide for the safety of plant and the proper safety systems functions as part of Defense-in-Depth concept application were presented as overview information.

  - Results of explorative work by experts of the Austrian Experts´ Team for a generic WWER 1000 set-up lead to question, whether in case of a stuck rod scenario connected with a MSLB the Temelín NSSS remains in a controlled non-critical condition.

  The monitoring related to the Pressurised Thermal Shock vulnerability has taken place in the context of project PN9."Reactor Pressure Vessel Integrity and Pressurised Thermal Shock".

- **With respect to plant safety analysis, for performances of mitigating systems, radiological consequences calculations and Monitoring of adequacy of emergency procedures to mitigate MS & MFW HELB outside containment and their extension into SAMGs:**

  Those elements of the safety analyses providing the basis for consequences mitigation options and evaluations of plant response and the adequate safety systems functions as part of Defense-in-Depth concept application were presented as an overview information. This is also the context for events related to project PN9."Reactor Pressure Vessel Integrity and Pressurised Thermal Shock".

  - Results of explorative work by experts of the Austrian Team for a generic WWER 1000 set-up lead to questions about the behaviour of the Primary Coolant System and the Reactor Core:

    In a pilot study by experts of the Austrian Experts' Team the behaviour of the reactor core after a multiple lines break of the main steam piping has been analysed. According to the results, a WWER 1000 reactor like Temelín is likely to become critical after the scram with the most effective rod stuck in top position after a multiple steam line break.

    The results from calculations accomplished show that the effectiveness of the scram system is reduced by 20% if the most effective CRA is stuck in top position. The relative power contribution of individual assemblies in the surroundings of the stuck CRA is by a factor of two to three orders of magnitude higher when comparing it with the assemblies from the diametric opposite region of the core. Results for the end of the first cycle show that reactor will be critical again if the temperature drops below 200 to 197 °C.

  Based on these results the Austrian Experts´ Team concludes that re-criticality in case of a stuck rod scenario connected with a MSLB remains still an open question, very important for clarification. For answers to be fully satisfying the required comprehensive analyses would have to be performed.

  Fuel Elements' Integrity in relation to bounding accident sequences was not discussed quantitatively, but in some instances qualitatively.

- **With regard to the adequacy of in-service inspections programs of MS & MFW piping outside containment:**

  In Service Inspection was addressed in the context of periodic wall thickness history evaluation and Non-destructive Testing and Evaluation procedures implementation descriptions. The need was identified for more detailed description of the procedures as set up and implementation as well as of quality assurance.

  The general introduction into NDE practice at the TSO in Řež provided valuable indications about this topic.

- **In identifying the event frequency evaluation of HELB and of consequential failures:**

  Break exclusion applicability demonstration for very extended High-Energy Pipe ducts was accomplished with assuming the low leak and break frequency estimates supplied in the Specialists´ Workshop presentations, which do not relate well to European and worldwide industry experience and are therefore questioned.

- **Regarding requirements for the materials used and material properties degradation to be taken into account:**
  - Results of explorative work by experts of the Austrian Team for Materials Databases used as the basis for NPP's component materials and manufacturing specifications::

    The Austrian Experts´ Team performed a review of the information available about the material database used to support the evaluation regarding the Superpipe Concept applied by the Czech side for the HELs integrity verification at the 28,8 m level. The outcome of this review gives reason in several contexts to raise doubts whether the material database is adequately consolidated for break exclusion confirmation of the HELs at the 28,8 m level.

  The Materials Database development and materials properties definition process leads to the identification of several areas for clarification: the selection procedures of "comparable" material for test specimen manufacturing allowed no conclusion. The material properties used for qualification of the stress analysis results and the requirements imposed by the codes, standards, rules and regulations defined to be applicable could not be seen as in line.

  The materials properties requirements for the two pipe materials used could not be interrelated, as applicable for the "Superpipe Concept's" break exclusion re-qualification. The materials properties requirements defined for the High-Energy Lines at the design stage do not correspond with the properties of the material "in place". Therefore the acceptance criteria for the appropriate material properties would be of interest and the compliance demonstration documentation as well.

  Furthermore, the material properties as defined at the design stage of the HEL could not be related to the material properties of the pipe sections installed.

IV.3 SÚJB position

The SÚJB has acknowledged, accepted and approved the ETE approach for the 28,8 m-level HEL integrity demonstration and the associated accident scenario evaluation, including the consequential failure arguments, in particular also those conclusions drawn as a consequence of the Comprehensive Safety Case Revisit. The SÚJB has not asked for additional proof and did not impose additional requirements, besides a discussion of the ISI frequency that has not been closed yet.

V. Conclusions

The global approach as indicated in the presentations at the Specialists' Workshop provided for the following conclusions, which have been determined by the Austrian Experts' Team:

Since the identification of the HELBs issue several years ago, improvements are addressed in a comprehensive manner. The actions taken range from detailed examinations up to the measures implemented in the context of the "Comprehensive Safety Case Revisit" demonstrate a comprehensive process directed towards improvement. When considering the concerns expressed in the Austrian Technical Position Paper [ATPP 2000], the comparison with the current state also indicates a number of areas where improvements have been achieved and implemented.

The Austrian Experts' Team denotes, that it did not find reason to follow the views and expectations, expressed as a result of the Comprehensive Safety Case Revisit, upheld by the Czech side on the applicability of the break exclusion concept.

In this respect the following consolidated results were determined:

- **With regard to the materials used for the secondary High Energy Lines:**

  The comprehensive specification of the materials properties – as used and applied for the stress analyses results acceptance, for the break exclusion verification and for crack propagation to break at the pipe whip restraints' locations – should be an issue of in-depth exchange of information and expert discussion. The databases used for the materials properties' definition and the standards, rules and regulations applicable for defining the materials properties should be included therewith.

  Checking should be focused on the way material characteristics according to mandatory standards, rules and regulations are used and what is the significance of such characteristics in the licensing of components and assembled sections.

  The materials properties' requirements and verification of adequate properties of the materials used for the High-Energy Lines at the 28,8 m elevation should be supported by sufficiently qualified evidence.

- **With regard to the break exclusion concept verification:**

  The results of probabilistic analyses should also be an issue of in-depth exchange of information and expert discussion. Probabilistic analyses should include the failure probabilities of the entire piping ducts up to the first isolation valves. Moreover results from probabilistic fracture mechanics analyses for the duct exposed to maximum loadings should also be discussed.

  With regard to the special piping arrangement at the 28,8 m level concrete breaks' incidence rate assumptions are usually applied and certain In-Service-Inspection procedures are introduced. Comparisons for both issues with general industrial practice should be performed.

  The specific extensive use of the break exclusion assumptions and the associated deterministic break location definition should be supported by conclusive probabilistic acceptability results.

- **With regard to the break consequences:**

  The loads resulting from water hammer effects can be compared with regard to nature and consequences only in a limited way with earthquake loads as estimated.

  Due to water hammer, the pipes may experience loads significantly higher than those acting on them as a consequence of the earthquake specified.

  The pipe whip after rupture of the vertical section of a HEL must be assumed to act on the HEL at the 28,8 m level in such a way, that the pipe whip loading to the turbine hall wall is likely to have an effect on the HELs integrity at the 28,8 m level also, let alone secondary effects on the piping there.

- **With regard to accident consequences:**

  Exemplary severe High Energy Line Breaks' accident scenarios should be investigated with the following key elements: High Energy Line Break with the reactor at full power and control rods remaining stuck in top position, inhibiting a successful shut-down.
  The treatment should focus on the extent, to which accidents with consequences to the reactor core could evolve into events where releases of radioactive effluents are likely to take place.

  The nuclear power plant behaviour under severe accident conditions caused by High-Energy Line Breaks still requires extensive analyses of various severe accident sequences to understand options for the mitigation of consequences.

VI. 28,8 m Level Issues for future information exhange and expert discussions

The Austrian Experts' Team recommends pursuing further the issue of HELB as a major priority in the framework of the pertinent bilateral Agreement between the Federal Republic of Austria and the Czech Republic. This recommendation concerns the implementation and results from the HEL In-Service-Inspection programs as well as revisiting the major findings enumerated above. It is recommeded in particular to continue work on the mitigation of breaks of the HEL.

Items with high priority, where expert discussions based on additional and new information would be most valuable, are:

1.) With regard to the materials used for the secondary High Energy Lines:

Identification of the procedures used to determine material properties characterisation and their use in the component acceptance process according to mandatory standards, rules and regulations.

2.) With regard to the break exclusion concept verification:

Comparison with industry experience of break frequencies' assumptions specific to the particular arrangement of pipelines, and comparison with industry experience of the In-Service-Inspection adapted to the pipe ducts at the 28,8 m level.

The state of science and technology in codes and standards as followed in terms of consistency requirements in Western European practice.

3.) With regard to accident consequences:

Analysis of immediate accident consequences with regard to bounding cases determined for maximum dynamic loadings. Precautionary consequences should be drawn from confirmed bounding conditions only.

The intermediate accident consequences' analyses should focus on identifying the extent to which consequences to the reactor core, arising from accidents, are likely to evolve into events causing radioactive releases.

It appears to be essential for both accident aspects to know the magnitudes and the frequencies of related accident scenarios.

ZUSAMMENFASSUNG

I. Grundlage und Hintergrund des Projektes

Die Republik Österreich und die Tschechische Republik haben mit Unterstützung des Mitglieds der Kommission Verheugen am 29. November 2001 eine Übereinstimmung über die "Schlussfolgerungen des Melker Prozesses und das Follow-up" erzielt. Um eine wirksame Umsetzung der Ergebnisse des „Melker Prozesses“ im Bereich der nuklearen Sicherheit zu ermöglichen, enthält der Anhang I dieses „Brüsseler Abkommens" Details zu spezifischen Maßnahmen, die als Follow-up zum „Trialog" des „Melker Prozesses“ im Rahmen des betreffenden bilateralen tschechisch-österreichischen Abkommens durchzuführen sind.

Weiters legte die Kommission zur Prüfung der Umweltverträglichkeit des KKW Temelín – die auf Grund einer Resolution der Regierung der Tschechischen Republik eingesetzt wurde – einen Bericht vor und schlug in ihrer Stellungnahme die Umsetzung einundzwanzig konkreter Maßnahmen vor (Anhang II des „Brüsseler Abkommens").

Die Unterzeichneten kamen überein, dass die Einführung der beschriebenen Maßnahmen auch in regelmäßigen Abständen von österreichischen und tschechischen Experten im Rahmen des Bilateralen Tschechisch–Österreichischen Abkommens untersucht werden würde.

Zur Überwachung auf technischer Ebene im Rahmen des diesbezüglichen tschechisch-österreichischen bilateralen Abkommens wurde, wie im „Brüsseler Abkommen" vorgesehen, eine „Roadmap" („Fahrplan") ausgearbeitet und am 10. Dezember 2001 vom stellvertretenden Premierminister und Außenminister der Tschechischen Republik, sowie vom Bundesminister für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft der Republik Österreich vereinbart.

Das österreichische Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft beauftragte das Umweltbundesamt mit der Gesamtkoordination der Umsetzung der „Roadmap". Jeder Eintrag in der „Roadmap" entspricht einem spezifischen technischen Projekt.

Punkt Nr. 1 „Hochenergetische Rohrleitungen auf der 28,8 m Bühne" im Anhang I des „Brüsseler Abkommens" behandelt die Integrität der Frischdampf- und Speisewasserleitungen auf der 28,8 m Bühne des Reaktorgebäudes von Temelín – wo die Leitungen von den jeweiligen Durchdringungen im Containment (Sicherheitshülle) in die Turbinenhalle geführt werden. Dieser Themenbereich wird üblicherweise als „High Energy Line Breaks" (HELBs = Brüche von Hochenergieführenden Rohrleitungen) bezeichnet.

Wie im Anhang I des Brüsseler Abkommens aufgezeigt, lautet das unter diesem Punkt aufgeführte Ziel:

> *„Sicherzustellen, dass der Sicherheitsnachweis, der einen adäquaten Schutz gegen den Bruch hochenergetischer Leitungen und daraus resultierende Versagen der Dampf- und Speisewasserleitungen zeigt, den Anforderungen und der Praxis, wie sie innerhalb der EU breit angewendet werden, entspricht und eine adäquate Kombination von Maßnahmen besteht."*

Im Auftrag der Österreichischen Bundesregierung hat das Umweltbundesamt ein Österreichisches Experten-Team bestellt, das aus nationalen und internationalen Experten zusammengesetzt war, um die technische Unterstützung für den Monitoring Prozess bezüglich der Einführung von Maßnahmen auf technischer Ebene zum Problem auf der 28,8 m Bühne zu leisten, wie dieses im Annex I des „Brüsseler Abkommens“ und von dessen Folgeaktivitäten dargestellt ist. Auf das spezifische technische Projekt wird mit der Bezeichnung PN2 Bezug genommen, – es umfasst insgesamt sieben vordefinierte Projektmeilensteine“ (PMs).

Die technische Unterstützung für den Monitoring Prozess bezüglich der Einführung der „Schlussfolgerungen aus dem Melk Prozess und das Follow-up“ auf technischer Ebene, in Bezug auf das Problem der Hochenergetischen Rohrleitungen auf der 28,8 m Bühne, war darauf abgestellt, sich auf das Nachvollziehen zu konzentrieren, wie die tschechische Seite (der Anlagenbetreiber und die Aufsichtsbehörde) mit diesem Problemkreis in methodischer Weise bei der Einführung von Lösungen umgegangen sind. Insbesondere war beabsichtigt, sich auf die Bewertung von Bruchereignissen an Hochenergetischen Rohrleitungen und die Minderung von deren Folgewirkungen zu konzentrieren, wie auch auf umfassende Wahrscheinlichkeitsanalysen (PSA) zu den Sicherheitsaspekten und der Einführung von Wiederholungsprüfprogrammen (ISI). Alle diese Aktivitäten waren hinsichtlich Vorschriften und Anwendungen in der Praxis in Verbindung mit erprobten Auslegungen des ALARA Prinzips zu überprüfen, wie sie vielfach in der EU angewendet werden und auch hinsichtlich neuerer Entwicklungen mit WWER-Reaktor-spezifischen Kenntnissen auf der technischen, wie auf der Genehmigungsebene.

II. Der Ansatz und die Zielvorstellungen der tschechischen Seite

Das Kernkraftwerk Temelín, ursprünglich Sowjetischer Bauart, später mit westlichen Sicherheitskonzepten und westlicher Technik aufgerüstet, hat erst spät in der Konstruktionsphase die Integrität der Hochenergetischen Rohrleitungen auf der 28,8 m Bühne aufgegriffen. Während der Experten-Treffen im Rahmen des Melker Abkommens schien es, dass der Prozess einer Umfassenden Neubewertung des Sicherheitsfragenkomplexes (Comprehensive Safety Case Revisit, CSCR) für diesen Bereich nicht angemessen zu Ende geführt worden war. Die Informationslage über Details des Konzeptes bezüglich des KKW Temelín war nicht ausreichend. Daher blieb die Integrität der Hochenergetischen Rohrleitungen auf der 28,8 m Bühne einer der Punkte für den Nachfolgeprozess zum Melker Abkommen („Follow-up“). Diese Tatsache hat Grundlage und Zielrichtung des vorgeschlagenen Projekts vorgegeben.

Das Kernkraftwerk Temelín muss als Spezialfall angesehen werden: Auslegung und Konstruktion wurden in der früheren Sowjetunion durchgeführt, die Herstellung erfolgte zumindest teilweise in der früheren Tschechoslowakei unter Russischer Aufsicht. Nach der politischen Reorganisation Osteuropas wurde der Bau unter Einbeziehung westlicher Technologie von Westinghouse unter der Verantwortung des Besitzers der Anlage fertiggestellt. Die Genehmigung erfolgte im legistischen Rahmen der Tschechischen Republik.

Das wesentliche Ereignis im Überprüfungsprozess („Monitoring Process") war das Experten-Treffen (Workshop) zu den Punkten Nr. 1 („HELB") und Nr. 2 („Qualifikation der Ventile" (PN3)) der „Roadmap", der am 7. und 8. November 2002 in Prag, im Rahmen eines zusätzlichen Experten-Treffens gemäß Artikel 7 (4), des Bilateralen Abkommens über den Austausch von Informationen über die nukleare Sicherheit abgehalten wurde. Angesichts des Zusammenhangs zwischen den beiden Themenbereichen hielten es die tschechischen Gastgeber für angebracht, beide Punkte in ein- und demselben Experten-Treffen zu behandeln. Das Experten-Treffen war das Schlüsselereignis für den Monitoring Prozess für die A-nalyse durch das Österreichische Experten-Team vor und nach diesem Ereignis. Zusätzliche Information ergab sich aus zwei weiteren Bilateralen Treffen, die auf das Experten-Treffen folgten. Die Auswertung der anläßlich dieser drei Gelegenheiten zur Verfügung gestellten Informationen, diente als Grundlage für den vorliegenden endgültigen Überprüfungsbericht (Final Monitoring Report) des österreichischen Experten-Teams.

Anhand einer Reihe von Präsentationen wurden auf dem Experten-Treffen Lösungsansätze für den HELB-Themenkreis von den tschechischen Experten beschrieben, sowie die Art und Weise, wie die Genehmigungsbehörde solche Lösungen akzeptiert hatte.

Die Bereiche, die von tschechischer Seite anhand der Präsentationen anlässlich des Experten-Treffens erläutert wurden, bezogen sich auf den breiten Ansatz des „Comprehensive Safety Case Revisit" (Umfassende Neubewertung des Sicherheitsfragenkomplexes), der von SÚJB initiiert und, als die ursprüngliche Entscheidung der Aufsichtsbehörde bestätigend, angenommen wurde. Es wurden Informationen zu folgenden Bereichen vorgebracht und erörtert:

- Auslegung
  - Angewandte Codes, Standards, Vorschriften und Regelungen sowie deren Vergleich mit jenen in der EU
  - Belastungsdefinition: Qualifizierung der Entlastungsventile BRU-A und Sicherheitsventile SGSV für Wasserdampfgemisch
  - Rohrbruchwahrscheinlichkeit, Übersicht über probabilistische Bruchmechanik
  - Anwendung des „Superpipe"-Konzepts auf Dampf- und Speisewasserleitungen
- Thermohydraulik
  - Übersicht über die thermohydraulische Analyse und dynamische Berechnungen, Wasserschlag und Wasserüberfüllung.
  - Übersicht über Schockbelastung unter Temperatur und Druck.
- Werkstoffe
  - Werkstoffeigenschaften
  - Übersicht über durchflussbeschleunigte Korrosion
- Wiederholungsprüfungen (ISI)
  - Messungen der betrieblichen Verschiebungen (von Rohrleitungsabschnitten)
  - Ultraschallprüfung, Modifikationen Zerstörungsfreier Prüfungen, Qualifikation, Abläufe und Ergebnisse.

Der Ansatz von ČEZ a.s. zur Lösung des Sicherheitsproblems „Folgen sekundären Rohrversagens auf der 28,8 m Bühne" des KKWs Temelín (wie von SÚJB akzeptiert) besteht darin, jeden Bruch der Frischdampf- oder Speisewasserleitungen (jeweils für einen Abschnitt mit einer Länge von bis zu 30 m und eingebauten Rohrbögen, der sich von den Durchdringungen durch das Containment bis zu den Isolationsventilen erstreckt) auszuschließen.

Die Ausführungen auf dem Experten-Treffen gaben zwar Aufschluss über den verwendeten Ansatz, erlaubten jedoch auf Grund der überblicksartigen Darstellung nur einen begrenzten Einblick in die Ergebnisse und wie diese erzielt wurden. Eine Reihe von Fragen blieb offen. Demzufolge kamen beide Seiten überein, dass das dafür vorgesehene bilaterale Abkommen zwischen Tschechien und Österreich den geeigneten Rahmen für weitere Diskussionen und einen weiteren Informationsaustausch zu diesen Themenbereichen darstellt.

Die Präsentationen auf dem Experten-Treffen gewährten einen Einblick in die umfangreichen Arbeiten, die der Betreiber der Anlage und seine Technischen Support Organisationen als Konsolidierungsversuch hinsichtlich der Sicherheitsfragen im Rahmen des „Comprehensive Safety Case Revisit" (CSCR) durchgeführt hatten und die von der Genehmigungsbehörde zu beurteilen waren.

III. Der Ansatz des österreichischen Experten-Teams

Ein Experten-Team von 15 internationalen Experten wurde vom Umweltbundesamt – im Auftrag der österreichischen Regierung – mit der technischen Unterstützung zur Überwachung der Abwicklung der HELB-Thematik auf der technischen Ebene beauftragt (wie im Anhang I des „Brüssler Abkommens“ aufgelistet).

Das Projekt, auf das mit der Bezeichnung PN2 Bezug genommen wird setzt sich aus zwei einander ergänzenden Segmenten (horizontal und vertikal), zusammen, wobei das horizontale Segment eine Zusammenschau von Vorgaben, Normen und Praktiken umreißt, das vertikale Segment Analysen von Grenzfällen für die Bruchereignisse von Hochenergetischen Rohrleitungen und der Werkstoff-Datenbasis, so wie sie für das KKW Temelín zur Verwendung kam, geliefert hat.

Das Monitoring durch das Österreichische Experten-Team hat sich auf dem ingenieursmäßigen Ansatz konzentriert, den ČEZ gewählt hat um die Hochenergetischen Rohrleitungen vom SÚJB (Staatsamt für Nukleare Sicherheit) genehmigt zu bekommen.

Unter Anwendung der zur Zeit geltenden Sicherheitsphilosophie schließt die Betrachtung von Bruchereignissen an Hochenergetischen Rohrleitungen die Vorkehrungen ein, die getroffen werden um Verschlechterung der Werkstoffe und der Integrität von Hochenergetischen Rohrleitungen mit der Betriebszeit zu erfassen und auch Betriebsabläufe, die höchstwahrscheinlich übermäßige Belastungen für die Hochenergetischen Rohrleitungen mit sich bringen.

Beide Segmente – das horizontale und das vertikale – betrafen beim KKW Temelín sowohl ein Sammeln von Informationen über das Verhalten der Hochenergetischen Rohrleitungen während Transienten und im Laufe ihrer Einsatzdauer, als auch die Befassung mit der Werkstoffgeschichte, der Werkstoffausnutzung und der Verletzbarkeit der Rohrleitungen selbst.

Dieses spezifische, technische Projekt umfasst insgesamt sieben vorgegebene „Projektmeilensteine" (PMs): Die PMs, die vom Auftraggeber, dem Umweltbundesamt, angeordnet worden waren, stellten die Hauptaufgabestellungen dar, die vom Österreichische Experten-Team zu erfüllen waren. Eine Reihe von vorbereitenden Arbeiten musste zur Unterstützung und Ausführung der Hauptaufgaben durchgeführt werden. Diese vorbereitenden Arbeiten werden in diesem Bericht ebenfalls behandelt.

Für die unterschiedlichen Aufgaben bei der Bewertung der Hochenergetischen Rohrleitungen wurde der Stand von Wissenschaft und Technik erfasst und zum Vergleich mit den Erkenntnissen aus der Auswertung der tschechischen Vorgangsweise herangezogen, ebenso für den Vergleich des „Comprehensive Safety Case Revisit" (Umfassende Neubewertung des Sicherheitsfragenkomplexes), der folgende Themenkreise beinhaltete:

- Die Qualität der Hochenergieführenden Rohrleitungen in Bezug auf Auslegung, Zusammenbau/Herstellung
- Die Analysen zu den Hochenergieführender Rohrleitungen
- Die betriebliche Überwachung der Hochenergieführenden Rohrleitungen
- Das Wiederholungsprüfprogramm
- Modifikationen mit Auswirkungen auf die Bruchereignisse an den Hochenergieführenden Rohrleitungen
- EOPs and SAMGs in Zusammenhang mit Bruchereignissen an Hochenergieführenden Rohrleitungen

Zu dem Zeitpunkt, als das KKW Temelín gebaut wurde, hat das tatsächlich vorhandene Konzept für die Hochenergieführenden Rohrleitungen die Notwendigkeit zur Abminderung der Auswirkung des Versagens des Sekundärkühlkreislaufes nicht in ausreichendem Maß mit in Betracht gezogen. Deswegen wurden die WWER-1000 Analysen unter der Annahme durchgeführt, dass das Versagen der sekundären Hauptkühlmittelleitungen zu unwahrscheinlich sein würde, um aufzutreten

Mit verbesserter Kenntnis der Werkstoffeigenschaften und den Wiederholungsprüfergebnissen von einer Reihe von Anlagen, die Alterungseffekte mit Einfluss auf die Integrität aufgezeigt haben, wurde das Sekundärkreisversagen, auf Grund eines Bruches einer Hochenergieführenden Rohrleitung, Gegenstand weitreichender Untersuchungen. Die vielfach akzeptierte Praxis, für den physischen Schutz von gefährdeten Komponenten, Strukturen und Einrichtungen gegen common-cause Versagen zu sorgen, kam in der Anlage in Temelín nicht zur Anwendung. Statt dessen wurde ein umfassendes Programm begonnen, um zu beweisen, dass in erster Linie die Integrität der sekundären Hochenergieführenden Rohrleitungen aufrechthaltbar ist und weiterhin eine Einschränkung des Folgeversagens von Hochenergieführenden Rohrleitungen möglich ist.

Um vorbereitenden Arbeiten des Österreichischen Experten-Teams eine Ausrichtung zu geben und die österreichische Delegation durch das Experten-Treffen zu führen, aber auch um eine geeignete Vorbereitung des Experten-Treffens auf bilateraler Ebene zu ermöglichen, wurde als **erster Schritt Projektmeilenstein 1 (PM1)** das Sicherheitsziel in **„Überprüfbare Teilaspekte"** („Verifiable Line Items", VLIs) aufgegliedert. Diese wurden auf der Grundlage des „Defence-in-Depth-Prinzips" erstellt, das zur Qualifikation der Sicherheitsmerkmale des KKW Temelín angewendet worden war.

In einem **zweiten Schritt (PM2)** wurde vom österreichischen Experten-Team eine Dokumentenliste (PM2) **„Specific Information Request – SIR"** erstellt, die eine Auflistung jener Informationen darstellt, die zur ausführlichen Beantwortung der in den VLIs enthaltenen Fragen erforderlich ist (siehe ANNEX G).

Zum **dritten Schritt (PM3)** der **vorbereitenden Arbeiten für das Experten-Treffen** gehörte auch eine Erhebung der innerhalb der EU-Mitgliedstaaten Frankreich und Deutschland sowie auch in den USA bezüglich der HELB-Thematik zugrunde gelegten Normen und Praktiken. Die Praxis in Frankreich und in den USA stellte einen besonderen Schwerpunkt dar, da sich der Betreiber von ETE auf deren Regelwerke, Richtlinien und Vorschriften beruft. Im Briefing der österreichischen Delegation wurden den Teilnehmerinnen und Teilnehmern der Mission diese Elemente des Monitoring vorgestellt.

In den Briefing Unterlagen wurden folgende Themen – nach deren Bedeutung für die Sicherheit – beschrieben und kommentiert: Die Grundzüge der Anforderungen an die Analysen zu den Bruchereignissen an den Hochenergieführenden Leitungen, die im Rahmen des „Comprehensive Safety Case Revisit" (der Umfassenden Neubewertung des Sicherheitsfragenkomplexes) durchgeführt wurden; die Anpassung der Anlage gemeinsam mit bekannten Modifikationen im Vergleich mit früheren, auf WWER-1000 ausgerichteten Programmen für die Hochenergieführenden Rohrleitungen; Übereinstimmungen mit und Unterschiede zum Stand von Wissenschaft und Technik und die zur Zeit anerkannten Praktiken.

Im Rahmen des am 7. und 8. November 2002 in Prag abgehaltenen Experten-Treffens über HELB und Ventilqualifikation gaben Experten der Betreibergesellschaft der Anlage, Experten von Organisationen zu deren technischer Unterstützung (Technische Support-Organisationen, TSO) und Experten der Genehmigungsbehörde 15 gut aufbereitete Videoprojektor-Präsentationen, die nach Aussage eines tschechischen Präsentators Überblickscharakter besaßen.

Das Experten-Treffen in Prag 2002 hat sich auf die Durchführung der HELB Analysen konzentriert und auf betriebliche Vorkehrungen bei den Hochenergieführenden Rohrleitungen. Weitere Themen im Zusammenhang mit HELB wurden beim Experten-Treffen nicht im Detail angesprochen, wie mehrfaches Rohrleitungsversagen, Durchdringungsversagen, die Belastbarkeit der Unterstützungskonstruktion auf der 28,8 m Bühne, HELB Folgewirkungen auf das Primärkühlsystem und die Kernkühlung, wie auch auf die Reaktivitätsregelung.

Bis auf einige – wie oben erläuterte – Einschränkungen wurden die Fragen des Experten-Teams während des Experten-Treffens größtenteils beantwortet.

Nach dem Experten-Treffen nahm das österreichische Experten-Team als **vierten Schritt (PM4)** eine genaue Durchsicht der Experten-Treffen-Präsentationen vor. Die Mitglieder des österreichischen Experten-Teams lieferten Beiträge für den später erstellten **„Preliminary Monitoring Report" PMR**. Auf der Basis der damals zur Verfügung stehenden Informationen hatte das österreichische Experten-Team etliche Ergebnisse im PMR festgehalten.

Die Ausführungen im PMR zielten auf folgende vier unterschiedliche Ebenen des Vorganges ab und lieferten dazu Kommentare. Die vier Ebenen betreffen:

- die Angemessenheit der aus den Vorträgen verfügbaren Informationen im Hinblick auf die Überwachungsaufgabestellung
- die Angemessenheit der technischen Herangehensweise als solcher,
- den Stand von Wissenschaft und Technik in Westeuropa und dessen Übereinstimmung mit den Gegebenheiten, wie sie im KKW Temelín erhoben wurden
- die Themenkreise, welche auf die Lösung des bekannten Sicherheitsproblems ausgerichtet waren, und deren Verbindung zu jenen Punkten, die in den Projekten PN3: „Qualifizierung von Ventilen“ und PN4: „Qualifikation von sicherheitsrelevanten Komponenten“ behandelt werden.

Eines der Ergebnisse des PMR war, dass österreichische Spezialisten zu drei als offen identifizierten Fragestellungen Untersuchungen durchführten, um die tschechischen Feststellungen zu diesen Fragestellungen für diesen Final Monitoring Report (FMR) zu untersuchen.

Die Fragestellungen waren folgende:

- Rekritikalität des Reaktors, initiiert durch ein Bruchereignis an den Hochenergieführenden Leitungen,
- Auslegungslasten für die Hochenergieführenden Leitungen auf der 28,8 m Bühne und
- Werkstoffe-Datenbank.

Der PMR konzentrierte sich auf die Anwendung des französischen Tronçons-Protégés Konzepts (Konzept für geschützte Rohrdurchdringungsabschnitte). Die Standardanwendung des Konzepts erfordert kurze Rohrleitungsabschnitte ohne Schweißnähte. Das in Temelín angewandte Bruchausschluss-Konzept betrifft jedoch lange Rohrleitungsabschnitte mit vielen Schweißnähten. Eine weitere Befassung sollte sich daher näher mit dem Weg zur Akzeptanz für diese neue Vorgangsweise und den Anforderungen an die Nachweise befassen, die dazu in einem Einzelgenehmigungsverfahren zu erbringen sind.

Darüber hinaus ist festzustellen, dass die gegenwärtig üblichen deutschen und französischen Genehmigungsansätze die Akzeptanz eines Bruchausschlussnachweises nur dann vorsehen, wenn zusätzlich eine räumliche Trennung gegeben ist (jede einzelne Dampf- oder Speisewasserleitung wird bis zur ersten Durchdringungsarmatur in ihrem eigenen Einschluss oder räumlich getrennt geführt).

In den Vorträgen beim Experten-Treffen berichtete die Tschechische Seite über Ergebnisse ihrer Bewertung einer Trennwand, die den Bereich auf der 28,8 m-Bühne in zwei Hälften teilen würde. Während die Errichtung als technisch machbar eingeschätzt worden war, erwuchsen Bedenken hinsichtlich der nachteiligen Auswirkungen, die eine derartige Trennwand auf die Instandhaltung und die Wiederholungsprüfungen der in unmittelbarer Nähe befindlichen Komponenten und Ausrüstungsgegenstände hätte. Den übermittelten Informationen zufolge scheint auch die Errichtung anderer Ausbildungsformen physischer Trennung bei der in Temelín vorgegebenen Anordnung schwierig zu sein. Die Errichtung einer solchen Trennwand ist seitens des Anlagenbetreibers derzeit nicht geplant.

Das Österreichische Experten-Team hat schon im PMR festgestellt, dass es daran interessiert wäre, jene Grundlagen zu erfahren, auf denen die Genehmigungsbehörde diesen einzigartigen Lösungsansatz – „Bruchausschluss“ – akzeptiert hat. In diesem Zusammenhang sind folgende Punkte von besonderem Interesse:

- Hinsichtlich der im Falle von Temelín vorliegenden Leitungsführung scheint die Anwendung des Bruchausschluss-Konzeptes, ohne die Auswirkungen anzunehmender Brucherreignisse von Hochenergetischen Rohrleitungen auf sicherheitsrelevante Anlagekomponenten zu berücksichtigen, jedenfalls nicht mit der gegenwärtigen Genehmigungspraxis in Deutschland oder Frankreich in Einklang zu stehen.
- Bruchausschluss erfordert eine 100%ige Prüfung, welche die Oberfläche und das Volumen aller Schweißnähte in der Bruchausschlusszone erfasst (die Anforderungen der amerikanischen Genehmigungsbehörde (US Nuclear Regulatory Commission, US-NRC, lassen in dieser Hinsicht keinerlei Ausnahmen zu).
- Der Ansatz zur zerstörungsfreien Werkstoffprüfung ist in der Form, wie er von den Experten der Betreibergesellschaft beim Experten-Treffen dargestellt worden ist, derzeit nicht geeignet, allen im Zuge der Prüfungen der Schweißnähte an den Dampf- und Speisewasserleitungen auftretenden Schwierigkeiten zu begegnen.
- Die **Anwendungen des Bruchausschlusses** (z. B. entsprechend den Regeln des deutschen Kerntechnischen Ausschusses (KTA) und den Anforderungen des französischen Tronçons-Protégés-Konzepts) erfordern nach Schweißnahtlegung eine Wärmenachbehandlung und ein Nachbearbeiten der Schweißnahtoberfläche. Das österreichische Experten-Team wurde beim Experten-Treffen darüber informiert, dass bis dato keine der beiden Behandlungsformen an den Schweißnähten der Bruchausschlusszone in **Temelín** durchgeführt worden ist. Es sollte daher in Zukunft besonders Bedacht darauf genommen werden, dass der Behandlungszustand der Schweißnähte den Bruchausschluss-Anforderungen entspricht.
- Die Werkstoffdaten hinsichtlich **Zugfestigkeitseigenschaften**, die zum Nachweis der Erfüllung mechanischer Spannungskriterien herangezogen werden, sind weder die der Auslegungsvorschrift zugrunde liegenden Nennwerte, noch die vom Hersteller für den tatsächlich eingesetzten Rohrleitungswerkstoff gewährleisteten Minimalwerte. Würde einer dieser beiden Werkstoffkennwerte herangezogen, so wären die Bruchausschlusskriterien nicht erfüllt. Stattdessen werden die Kennwerte für die Werkstoffeigenschaften von Proben abgeleitet, deren Übereinstimmung mit dem tatsächlich zum Einsatz gekommenen Rohrleitungswerkstoff allerdings nicht nachgewiesen wurde. Eine genaue Untersuchung der zur Verfügung stehenden Quellen für Werkstoffdaten sollte in Betracht gezogen werden. Sobald weitere Daten verfügbar werden, sollte deren Tauglichkeit zur Verbreiterung der Datenbasis betreffend die Werkstoffeigenschaften geprüft werden.
- Auf der Grundlage der, beim Experten-Treffen vorgestellten Informationen, kann die vollständige Funktionstüchtigkeit der Ausschlagsicherungen noch nicht als nachgewiesen angesehen werden. Dies trifft insbesondere auf die Schweißnähte für die Ringbefestigung an den Durchdringungen des Sicherheitseinschlusses zu.
- Das ist hauptsächlich darauf zurückzuführen, dass jene Ereignisse, die als Auslöser für **Belastungen der Rohrleitungen** präsentiert worden sind, nicht komplett sind. Ereignisse von potenzieller Bedeutung, wie große Leckage vom Primär- zum Sekundärkreislauf oder der Referenz-Flugzeugaufprall, sind augenscheinlich bis dato noch nicht einbezogen worden.
- Unter Berücksichtigung der oben festgestellten Einschränkungen wäre die gesamthafte Einschätzung der **Verhaltensweise des Primärkühlkreislaufes und des Reaktorkerns** unter jenen Bedingungen von besonderer Bedeutung, welche auf mehrfache Dampfleitungsabrisse innerhalb des Gebäudeabschnittes auf der 28,8 m Bühne folgen würden.

Im PMR hatte das Österreichische Experten-Team seine wesentlichen Erkenntnisse schon hinsichtlich der Hinweise auf Fortschritte bei der Anlagensicherheit geordnet und im Hinblick auf die von anderen Experten-Treffen in der Zukunft erwarteten Informationen, die geeignet gewesen wären die vom „Comprehensive Safety Case Revisit" (der Umfassenden Neubewertung des Sicherheitsfragenkomplexes) gewonnene Sicht zu vervollständigen.

In einem **fünften Schritt (PM5)** hatte die österreichische Seite eine **zusammenfassende Darstellung vom Monitoring des HELB Fragenkomplexes** und den damit in Verbindung stehenden wesentlichen Erkenntnissen beim Bilateralen Treffen am 18. Dezember 2003 vermittelt. Die Diskussion brachte in diesem Stadium keine neuen Erkenntnisse.

Beim Bilateralen Treffen am 28. und 29. November 2004 wurden zwei kurzen Fragelisten an die tschechischen Partner übergeben, die für die zusätzlichen Analysen des österreichischen Experten-Teams wertvolle Informationen ergeben haben. Diese Analysen wurden im Dezember 2004 fertig gestellt.

Der **sechste und letzte Schritt (PM6)** im Monitoring Prozess für PN2 „Bruchereignisse an Hochenergieführenden Rohrleitungen“ betraf die Erstellung des **Final Monitoring Reports (FMR)**, welcher hiermit vorgestellt wird.

Wie vom Österreichischen Experten-Team vorgeschlagen, beauftragte das Technische Projekt Management zusätzliche Analysen für den Final Monitoring Report (PM6), welche, mit den drei Fragen in Verbindung stehen, die oben in der Liste der PMR Fragestellungen erwähnt werden. Für diese drei Fragen wurde im Zusammenhang mit PM6 nicht unerhebliche zusätzliche Arbeit geleistet, um die Endbewertung zu stützen. Die drei Fragestellungen sind:

(1) Die **Verhaltensweise des Primärkühlsystems und des Rektorkerns** bei Bedingungen nach einem mehrfachen Frischdampfleitungsbruch im Bereich der 28,8 m Ebene und die zu vermutende Rekritikalität des Reaktors.

(2) **Auslegungslasten für die Hochenergieführenden Rohrleitungen auf der 28,8 m Bühne** entsprechend der Europäischen Praxis (z.B. vom Wasserschlag hervorgerufene), im Vergleich zu den Auslegungserdbebenlasten, die verwendet und von tschechischer Seite als einhüllende Lasten definiert worden sind.

(3) Die **Qualifikation der Werkstoffeigenschaften für die Werkstoff-Datenbank**, die für den versuchten Bruchausschlussnachweis, den Auslegungsnachweis für die Hochenergieführenden Rohrleitungen, sowie die Auswertung von betrieblichen Abnutzungs- und Alterungserscheinungen benutzt worden ist.

Die Haupterkenntnisse aus diesen zusätzlichen Analysen durch das österreichische Experten-Team sind im Kapitel IV aufgeführt.

Weil die Ergebnisse und die letzten Zusatzinformationen von tschechischer Seite zwar wertvoll, aber nicht ausreichend waren, die drei Fragen (1., 2. und 3.) zu klären, wird empfohlen diese Fragen über das Ende dieses Monitoring Prozesses hinaus zu verfolgen.

IV. Zusammenfassung der wesentliche Feststellungen

Die Auswertung der Präsentationen tschechischer Experten anlässlich des Experten-Treffens wird im Final Monitoring Report in Relation zur internationalen Praxis und zu den tschechischen Anforderungen einschließlich der rechtlichen Rahmenbedingungen diskutiert.

Die Ergebnisse der abdeckenden Rechnungen, die zur Unterstützung der Monitoring Bemühungen durchgeführt worden sind, werden implizit in der Argumentation berücksichtigt [**ANNEX F**].

Die gesamten Informationen, die zu anderen Punkten gesammelt wurden – während der Arbeiten, die von 2002 bis 2004 angedauert haben, auch noch nach dem Bilateralen Treffen am 29. und 30. November 2004 – wurden ordnungsgemäß in Betracht gezogen, als der ursprüngliche Preliminary Monitoring Report (er war Anfang 2003 als Resultat des PM4 geschaffen und herausgegeben worden) in dem vorliegenden FMR umgearbeitet wurde.

IV.1 Erkenntnisse bezüglich des CSCR (Umfassende Neubewertung des Sicherheitsfragenkomplexes)

Hinsichtlich des Zusammenwirkens des Anlagenbetreibers, des Herstellers, der technischen Support-Organisationen und der Genehmigungsbehörde im Zusammenhang bei der Einführung der Lösung für die Bruchereignisse an Hochenergieführenden Rohrleitungen:

Die Präsentationen und Kommentare während des Experten-Treffens legen nahe, dass die Festlegung von Anforderungen und die anschließende Verifikation der Erfüllung derselben in der vorliegenden Sicherheitskultur die Schlüsselfunktionen für die Verwirklichung des dargelegten Defence-in-Depth Konzepts spielen sollten.

IV.2 Erkenntnisse zur 28,8 m Bühne

Das Monitoring hinsichtlich der HELBs Technologieauswertung hat sich an den 18 festgeschriebenen VLIs orientiert (siehe Kapitel 4), die weiter unten angeführt sind und denen jeweils das Monitoring Resultat folgt, wie es aus den Erkenntnissen zusammengestellt worden ist:

- **Hinsichtlich des Rohrleitungsauslegungsvorganges, der Spannungsanalyse-Methode für die Rohrleitungen, unter Bedachtnahme auf die Rohrleitungs- und Komponenten-Qualifikation, die Einsatzbedingungen, die Belastungskombinationen:** (einschließlich erwarteter und unvorhersehbarer Folgen von Dampf- und Wasserschlägen)

  Für den „Comprehensive Safety Case Revisit" (der Umfassenden Neubewertung des Sicherheitsfragenkomplexes): die Logik hinter den Auslegungskriterien, der Auslegungsvorgang und schlüssige Aussagen zur Erfüllung der Anforderungen wurden in den Präsentationen der tschechischen Experten beim Experten-Treffen nur berührt. In ähnlicher Weise wurde das eingeführte so genannte „Superpipe-Konzept“ nicht als in die ursprünglichen Auslegungskriterien eingefügt vorgeführt, ohne erkennbare Prüfung auf Verträglichkeit der Vorschriften für die unterschiedlichen Regelwerke, Normen, Regeln und Vorschriften.

  Ein zusammenhängender Ansatz für Maßnahmen zur Vermeidung, Schutzfunktion, Qualifikation und Folgenminderung wurde nur teilweise verfolgt, somit wurden Abweichungen vom Defence-in-Depth Konzept aufgefunden.

  Eine Rechtfertigung dafür, dass weite Bereiche der HEL aus der Qualifikation nach dem Superpipe-Konzept ausgeschlossen wurden, war in den Präsentationen ebenfalls nicht eingeschlossen.

Zugangsmöglichkeiten zu entsprechender Dokumentation zur Beseitigung von Lücken in den Präsentationen wäre ein grundlegender Vorteil.

- **Hinsichtlich der Kriterien bei der Auswahl der Lage und Ausrichtung von Rohrleitungsbrüchen:**

  Nur einige Hinweise wurden über die Art erhalten, wie Kandidaten für Lagen von Rohrleitungsbrüchen ausgewählt worden sind und auf welche Art und Weise die Ausrichtungen von Rohrleitungsbrüchen akzeptiert oder verworfen worden sind.

- **Hinsichtlich der geforderten „aggressiven" HELB Bruchstellen, welche für die Analyse angenommen wurden:**

  Aus den zur Verfügung gestellten Informationen konnte die Ermittlung von „aggressiven" Bruchstellen für die in weiterer Folge postulierten und ausgewerteten Brüchen bis zu den möglichen Folgen nicht nachvollzogen werden. Es ist nicht sichergestellt, dass die Lasteinträge in die Bruchausschlusszone, die aus Brüchen außerhalb dieser Zone folgen (d. h. im Sicherheitseinschluss oder im Maschinenhaus), zur Ermittlung der maximalen Spannungsfelder herangezogen worden sind. Die Auswirkungen von Folgeversagen würden ebenfalls Hinweise auf die Schwere der untersuchten Ereignisabläufe geben. Derartige Problemkreise würden eine tiefer gehende Beachtung verdienen.

  - Ergebnisse der klärenden Arbeiten von Experten des österreichischen Experten-Teams zu einer generischen WWER 1000-Anlage in Bezug auf Auslegungsbelastungen für Hochenergieführende Rohrleitungen auf der 28,8 m Bühne:

    Experten des österreichischen Experten-Teams haben Berechnungen nach dem Stand von Wissenschaft und Technik durchgeführt. Die Ergebnisse weisen darauf hin, dass der Umfang, in dem aggressive Annahmen zu den Bruchstellen an den Hochenergieführenden Rohrleitungen für das KKW Temelín bei der Auslegungsüberprüfung getroffen worden sind, zumindest für die sog. Bubliks, zu kurz gegriffen haben.

- **Hinsichtlich der Auswirkungen von dynamischen Strömungskräften in Rohrleitungen als Folge von postulierten HELB (einschließlich geometrischer Auswirkungen und Abblase-Charakteristiken):**

  Lastfälle mit Wasserschlag, die für die Dampf- und die Wasserleitungen untersucht werden sollten, ebenso wie für unterschiedliche Betriebs- und Störfallbedingungen, verlangen offensichtlich nach Durchführung. Die Bestätigung, dass Belastungen, die aus dem betrieblichen Erdbeben folgen für alle anderen dynamischen Belastungen abdeckend wären, hat im Nachweisverfahren zu kurz gegriffen.

  - Ergebnisse der klärenden Arbeiten von Experten des österreichischen Experten-Teams zu einer generischen WWER 1000 Anlage in Bezug auf Auslegungsbelastungen für Hochenergieführende Rohrleitungen auf der 28,8 m Bühne:

    Die Ergebnisse legen nahe, dass die Auslegungslastfälle für die Hochenergetischen Leitungen durch die Erdbebenlastfälle nicht abgedeckt sind, eine Annahme, die jedoch von der tschechischen Seite getroffen und bestätigt wurde.

  Untersuchungen der dynamischen Belastungen sind auch für alle Fälle angezeigt, in denen es um betriebliche Belastungen geht, die in Gemeinschaft mit vermindert tragfähigen Rohrleitungskomponenten auftreten.

- **Die nicht-linearen Strukturanalysen zur Ermittlung von dynamischen Reaktionen von Rohrleitungsausschlägen zeigten:**

  Nicht-lineare Strukturanalysen wurden, wegen der Einschränkungen aufgegeben, welche für die angenommenen Bruchlagen zur Anwendung gekommen sind. Die Strahlkräfte und die Reaktionskräfte auf die Rohrausschlagsicherungen wurden beim Experten-Treffen nur kurz gestreift.

  - Ergebnisse der klärenden Arbeiten von Experten des österreichischen Experten-Team zu einer generischen WWER 1000 Anordnung in Bezug auf Auslegungsbelastungen für Hochenergieführende Rohrleitungen auf der 28,8 m Bühne:

Die Ergebnisse enthalten Hinweise darauf, dass die Auslegungsbelastungen für die Hochenergetischen Rohrleitungen aus den Strahlkräften und den Reaktionslasten zusammen genommen mit den dynamischen Reaktionen schlagender Leitungen den Einsatz nichtlinearer Analysemethoden erfordern würden.

- **Hinsichtlich der Bewertung der Auftreffeinwirkung von Strahlkräften nach deren Form, Temperatur, Druck, Richtung und Belastungen, um festzustellen, ob der Bewegungsimpuls von Strahlkräften auf HELs oder Wände oder Komponenten eine wahrscheinliche Ursache für Folgeversagen darstellen:**

  Die Einschränkungen, welche auf die angenommenen Bruchlagen angewandt wurden, hatten zur Folge, dass keine Notwendigkeit zur Abschätzung von dynamischen Rohrleitungsausschlagwirkungen gegeben war. Die Simulationsergebnisse, welche für die vorläufige Auslegung einer Trennwand gedient haben, wurden nicht zugänglich gemacht.

- **Hinsichtlich der vorgeschlagenen Maßnahmen, um sicherheitsrelevante Einrichtungen vor Rohrleitungsausschlagwirkung, Abblasestrahlen und Reaktionskraftwirkungen zu schützen und die gegenseitige Trennung von redundanten Funktionseinheiten (Anforderungen, Werkstoffeigenschaften und Dimensionierung von Ausschlagsicherungen und Trennabschirmungen):**

  Die Vorkehrungen, welche zum Schutz von sicherheitsrelevanten Einrichtungen, als Teil der Verwirklichung des Defence-in-Depth Konzepts, getroffen worden sind, wurden nicht vorgestellt. Sogar für diejenigen Schutzeinrichtungen, die angebracht wurden (Trennwand, Rohrhalterungen etc.), wurden dem österreichischen Experten-Team keine Informationen geliefert.

- **Im Zusammenhang mit der Vorgangsweise und den Untersuchungen zum Druckaufbau im abgeschlossenen Umraum bei Umgebungsbedingungen, die aus einem postulierten Bruch einer hochenergieführenden Rohrleitung folgen:**

  Die Spezifikation von Umgebungsbedingungen ist eine Voraussetzung für das Projekt PN4 “Qualification of Safety Classified Components” (Qualifikation sicherheitsrelevanter Komponenten). Spezifische Informationen, die verfügbar wurden, können in dem entsprechenden FMR eingesehen werden.

- **Im Zusammenhang mit den Auslegungsbelastungen für die Tragstrukturen, einschließlich Druck- und Temperaturtransienten und auch dynamischen Folgewirkungen aus Brüchen von hochenergieführenden Rohrleitungen:**

  In den Präsentationen wurden die erforderlichen Auslegungsbelastungen, die zum Schutz von sicherheitsrelevanten Einrichtungen als Teile der Defence-in-Depth Konzeptanwendung quantifiziert werden müssen, nur für vereinzelte Ereignisse benannt, und in diesen Fällen auch nur der Größenordnung nach. Die Rohrleitungsdynamik wurde nur in einer sehr theoretischen Simulation abgehandelt.

- **Zur Auswertemethodik für die Angemessenheit der Tragstrukturen für Erdbebenklasse I (es handelt sich dabei um solche baulichen Strukturen, die Sicherheitsfunktionen zu erfüllen haben):**

  Die Vorkehrungen, welche getroffen worden sind, um sicherheitsrelevante Einrichtungen vor den Folgewirkungen von Erdbebenbelastungen zu schützen, sollten Teil der Defence-in-Depth Konzeptanwendung sein; Informationen über derartige Vorkehrungen wurden nicht vermittelt. Über dieses Thema wurde nichts berichtet. Der gesamte “Site Seismicity” (Erdbebengefährdung am Standort) Fragenkomplex wurde in PN6 abgehandelt.

  Das österreichische Experten-Team hat beim Monitoring des gegenwärtigen Zustandes der Auswertung der “Bubliks” im Zuge der Nachbereitung des Experten-Treffens festgestellt, dass im Zusammenhang mit der Vereinbarkeit mit den Defence-in-Depth- Anforderungen eine schlüssige Lösung für den Wasserschlag nicht vorgestellt wurde. Die tschechische

TSO hat in einer kürzlich zur Verfügung gestellten Feststellung darauf hingewiesen, dass Analysen zu diesem offenen Punkt schon begonnen wurden und die Durchführung für 2005 vorgesehen sind.

Die Folgeschäden aus Rohrleitungsausschlägen wurden offensichtlich bis zu einem gewissen Ausmaß von den tschechischen Experten ausgewertet. Beim Experten-Treffen wurden die Annahmen zu den Unterstützungskonstruktionen der Rohrleitungen, und insbesondere auch die Annahmen zu den Rohrleitungsaufhängungen, welche vorgesehen sind, um die Bewegungsfreiheit der gebrochenen Rohrleitung einzuschränken, nur qualitativ erwähnt.

- Eine klärende Arbeit, die von Experten aus dem österreichischen Experten-Team ausgeführt wurde und Aufschluss über einen „generischen" WWER 1000 geben sollte, ergab Fragen hinsichtlich der Eignung der für Temelín präsentierten Ergebnisse zur Beschreibung von Bruchereignissen und Rohrleitungsausschlag, welche die anliegende Wand beschädigen und die Integrität der Hochenergieführende Rohrleitungen auf der 28,8 m Bühne beeinträchtigen könnten.

- **Betreffend die Bewertung der Strukturanalyse, einschließlich der örtlich an den Betonstrukturen der Klasse I und an den nicht sicherheitsrelevanten Strukturen auftretenden Belastungen, deren Beschädigung die Sicherheit der Anlage gefährden könnte:**

  Die Belastbarkeit der 28,8 m Stahlgerüstunterstützungskonstruktion und der Betonstrukturen, die sicherheitsrelevante Einrichtungen vor indirekter Beschädigung schützen, ist Teil der Defence-in-Depth Konzeptanwendung. Ergebnisse zu diesem Punkt wurden nicht vorgelegt.

  - Ergebnisse der klärenden Arbeiten von Experten des österreichischen Experten-Teams für einen generischen WWER 1000 zu den Auslegungsbelastungen für Hochenergieführende Rohrleitungen auf der 28,8 m Bühne:

    Ausschlagen der Dampf- und Speisewasserleitungsabschnitte im vertikalen Bereich (nach der 28,8 m Bühne) kann möglicherweise nicht nur die angrenzende Wand der Turbinenhalle und die daneben liegenden Hochenergieführenden Rohrleitungen gefährden, sondern auch die Hochenergieführenden Rohrleitungen auf der 28,8 m Bühne in Fällen, in denen der Festpunkt an der Wand zur Turbinenhalle nicht imstande ist, alle resultierenden Belastungen abzutragen.

- **Mit Bezug auf Strukturversagen, Umgebungsbedingungen und mögliche Überflutungen, die zu einem Verlust von Sicherheitsfunktionen führen könnten, sowie zur Unbenutzbarkeit der Reaktorwarte:**

  Die getroffenen Vorkehrungen zum Aufrechterhalten der wesentlichen Sicherheitsfunktionen, als auch der Sicherheitseinrichtungen, Teil der Defense-in-Depth Konzeptanwendung, wurden nicht vorgestellt.

- **Die Behandlung der Angemessenheit der Sicherheitsklassifizierung der Umgebungsbedingungen für Komponenten – Auswahl der Ausrüstung:**

  Der hier behandelte Aspekt war grundsätzlich Teil des Projektes PN4 „Qualifikation von sicherheitsrelevanten Komponenten". Es war jedoch keine spezielle Auflistung von in Frage kommenden Komponenten auf der 28,8 Meter Bühne, die eine Qualifikation für die Umgebungsbedingungen benötigen, verfügbar.

- **Hinsichtlich der Analysemethodik zur Auswertung der Anlagenauswirkungen von Frischdampf- und Speisewasser-HEL-Bruchszenarien außerhalb des Sicherheitsbehälters:**

  Die Einzelheiten, die erforderlich sind, um die Analysen und Auswertungen der Anlagenauswirkungen von HELBs zu erfassen, damit die Anlagensicherheit und die richtige Funktion der Sicherheitssysteme als Teil der Defence-in-Depth Konzeptanwendung gewährleistet sind, wurden als Überblicksinformation geliefert.

- Ergebnisse der klärenden Arbeiten von Experten des österreichischen Experten-Teams für einen generischen WWER 1000 stellen in Frage, ob im Fall eines steckengebliebenen Steuerstabes in Gemeinschaft mit einem Frischdampfleitungsbruch das nukleare Dampferzeugungssystem in Temelín in kontrollierbarem, unterkritischen Zustand bleibt.

Das Monitoring in Bezug auf die Gefährdung durch Thermoschock bei Druck (Pressurised Thermal Shock) hat im Rahmen des Projektes PN9 "Reactor Pressure Vessel Integrity and Pressurized Thermal Shock" (Reaktordruckbehälterintegrität und Schockbelastung unter Temperatur und Druck) stattgefunden.

- **In Bezug auf die Sicherheitsanalyse der Anlagen, auf die Leistungsfähigkeit von Systemen zur Folgenabminderung, auf Berechnungen zu den radiologischen Folgen und der Erhebung der Angemessenheit von Notmaßnahmen zur Minderung der Folgen von Frischdampf- und Speisewasserleitungsbrüchen außerhalb des Sicherheitsbehälters und von deren Erweiterung zu Richtlinien für das Management schwerer Unfälle (SAMGs):**

Diejenigen Elemente der Sicherheitsanalysen, welche die Grundlage für Abminderungsmöglichkeiten und für Bewertungen der Reaktionen der Anlage liefern, und die adäquaten Funktionen der Sicherheitseinrichtungen als Teil der Defence-in-Depth Konzeptanwendung, wurden im Überblick vermittelt. Das trifft auch auf den Zusammenhang von Ereignissen zu, die mit Projekt PN9 "Reactor Pressure Vessel Integrity and Pressurised Thermal Shock" verbunden sind.

- Ergebnisse der klärenden Arbeiten von Experten des österreichischen Experten-Teams für einen generischen WWER 1000 führt zu Fragen bezüglich des Verhaltens des Primärkühlkreislaufs und des Reaktorkerns:

  In einer Pilotstudie von Experten des österreichischen Experten-Teams ist das Verhalten des Reaktorkerns nach einem gleichzeitigen Bruch mehrerer Frischdampfleitungen untersucht worden. Den Ergebnissen zufolge, wird ein WWER-1000 Reaktor wie in Temelín nach erfolgter Reaktorschnellabschaltung, wobei der wirksamste Regelstab in der obersten Position blockiert bleibt, wahrscheinlich kritisch.

  Die Ergebnisse der Rechnungen zeigen, dass die Wirksamkeit des Schnellabschaltsystems um 20% gemindert wird, wenn das wirksamste Regelelement in der obersten Position stecken bleibt ist. Der relative Leistungsbeitrag von einzelnen Elementen in der Umgebung des festgefahrenen Steuerelements ist um einen Faktor von 2 bis 3 Größenordnungen höher, wenn man ihn mit Elementen im direkt gegenüber liegenden Core-Sektor vergleicht. Ergebnisse für das Ende der ersten Brennstoffkampagne zeigen, dass der Reaktor wieder kritisch wird, wenn die Hauptkühlmitteltemperatur unter den Temperturbereich von 200 bis 197 °C fällt.

Auf Grundlage dieser Ergebnisse hat das österreichische Experten-Team festgestellt, dass für die Rekritikalität im Fall eines Szenarios mit steckengebliebenem Regelstab, in Verbindung mit einem Bruchereignis an einer hochenergieführenden Rohrleitung, weiterhin eine offene Frage darstellt, für die eine Klärung sehr wichtig ist. Um zu zufrieden stellenden Antworten zu kommen, müssten die erforderlichen umfassenden Analysen durchgeführt werden.

Die Integrität der Brennelemente im Zusammenhang mit Störfallsequenzen, die Grenzfälle abdecken, wurde nicht quantitativ diskutiert, wohl aber für Einzelfälle qualitativ.

- **In Hinblick auf die Angemessenheit der Wiederholungsprüfungsprogramme der Frischdampf- und Speiswasserleitungen außerhalb des Sicherheitsbehälters:**

Wiederholungsprüfungen wurden im Zusammenhang mit der Auswertung der zeitabhängigen Entwicklung der zu wiederholenden Wandstärkenmessung erörtert und anhand von Beschreibungen der Einführung der zerstörungsfreien Prüfungen und Prüfanweisungen zur Bewertungen der Ergebnisse. Es wurde die Notwendigkeit für eine detaillierte Beschreibung der aufgestellten Anweisungen, deren Anwendung und auch der zugehörigen Qualitätssicherung festgestellt.

Die generelle Einführung in die NDE Praxis durch die TSO in Řež hat wertvolle Hinweise für diesen Sachbereich geliefert.

- **Zur Erhebung der Eintrittswahrscheinlichkeit von HELB und von Folgeversagen:**

  Der Nachweis für die Anwendbarkeit des Bruchausschlusses für äußerst weitreichende Hochenergieführende Rohrleitungssysteme wurde mit niedrigen Leck- und Bruchhäufigkeits-Annahmen ausgeführt, die in den Präsentationen des Experten-Treffens vorgestellt wurden. Diese Annahmen korrelieren nicht gut mit den Europäischen und Industrie-Erfahrungen weltweit und werden daher in Frage gestellt.

- **Im Zusammenhang mit den Anforderungen an die verwendeten Werkstoffe und der Verschlechterung der Werkstoffeigenschaften, die berücksichtigt werden müssen:**
  - Ergebnisse der klärenden Arbeiten von Experten des österreichischen Experten-Teams zu Werkstoff-Datenbanken, die als Grundlage für die Werkstoffe von KKWs sowie zur Herstellungs-Spezifikationen dienen:

    Experten des österreichischen Experten-Teams haben eine Untersuchung bezüglich Informationen zur Werkstoff-Datenbasis vorgenommen, die von der tschechischen Seite zur Absicherung der Bewertung hinsichtlich des Superpipe Konzepts für die HELs auf der 28,8 m Bühne verwendet wurde. Das Ergebnis dieser Untersuchung gibt in mehrfacher Hinsicht Anlass zu Zweifeln, ob die Datenbasis zur Rechtfertigung des Bruchausschlusses der Hochenergieführenden Rohrleitungen auf der 28,8 m Bühne hinreichend konsolidiert ist.

  Die Entwicklung der Datenbasis für die verwendeten Werkstoffe und der Vorgang zur Festlegung der Werkstoffeigenschaften führen zur Identifikation von mehreren Bereichen mit Klarstellungsbedarf: Die Auswahlvorgänge für „vergleichbare“ Werkstoffe zur Herstellung von Versuchsproben hat keine schlüssige Beurteilung zugelassen. Hinsichtlich der Werkstoffeigenschaften, die zur Abnahme der Spannungsanalyseresultate verwendet worden sind, ist nicht erkennbar, dass diese im Einklang mit den Anforderungen wären, die durch Regelwerke, Normen und Vorschriften, als verbindlich festgelegt worden sind.

  Die Anforderungen an die Werkstoffeigenschaften für die zwei zum Einsatz gekommenen Rohrleitungswerkstoffe konnten nicht in der Form, wie dies vom „Superpipe Konzept“ zur Requalifikation durch Bruchausschluss verlangt wird, zueinander in Beziehung gebracht werden. Weiters entsprechen die Werkstoffeigenschaften, welche bei der Auslegung für die hochenergieführenden Rohrleitungen festgelegt worden sind, nicht den Werkstoffeigenschaften der ausgeführten Rohrleitungen. Deswegen wären die Abnahmekriterien für die geeigneten Werkstoffeigenschaften von Interesse und die Dokumentation des Erfüllungsnachweises ebenfalls.

IV.2 Position des SÚJB

Das SÚJB hat den ETE Ansatz für den Nachweis der Integrität der HEL auf der 28,8 m Bühne, gutgeheißen, angenommen und bestätigt, ebenso die damit in Verbindung stehende Unfallszenarienauswertung, einschließlich der Folgeschadenargumentation, und hier im Speziellen auch hinsichtlich der Schlussfolgerungen, die von den Folgerungen aus dem „Comprehensive Safety Case Revisit" (der Umfassenden Neubewertung des Sicherheitsfragenkomplexes) abgeleitet worden sind. Das SÚJB hat keine zusätzlichen Nachweise gefordert und hat auch keine zusätzlichen Anforderungen gestellt, außer einer Diskussion über die Häufigkeit von Wiederholungsprüfungen, die noch nicht abgeschlossenen wurde.

V. Schlussfolgerungen

Der umfassende Ansatz, auf den in den Vorträgen beim Experten-Treffen hingewiesen wurde, hat zu folgenden Schlussfolgerungen durch das österreichische Experten-Team geführt:

Seit der Problemkreis um die Bruchereignisse von Hochenergieführenden Rohrleitungen vor einigen Jahren erkannt wurde, wird in umfassender Weise auf Verbesserungen hingearbeitet. Die vorgenommenen Arbeiten, die detaillierte Überprüfungen bis hin zu den Maßnahmen umfassen, die im Zusammenhang mit dem "Comprehensive Safety Case Revisit" ergriffen wurden, demonstrieren einen umfassenden Prozess mit Ausrichtung auf Verbesserung. Bezugnehmend auf die im Austrian Technical Position Paper [ATPP 2001] festgehaltenen Bedenken ergibt der Vergleich mit dem heutigen Stand, dass in einigen Bereichen Verbesserungen erzielt worden sind.

Das Österreichische Experten-Team hält fest, dass es keine Begründung gefunden hat, der Sichtweise und den Erwartungen zu folgen, die als Ergebnis des "Comprehensive Safety Case Revisit" (der Umfassenden Neubewertung des Sicherheitsfragenkomplexes) dargestellt wurden und von tschechischer Seite für das Bruchausschlusskonzept aufrechterhalten werden.

In diesem Zusammenhang sind folgende gesicherte Ergebnisse festgestellt worden:

- **Zu den Werkstoffen, die sekundärseitig für die Hochenergieführenden Rohrleitungen verwendet wurden:**

  Die umfassende Spezifikation der Werkstoffeigenschaften – wie diese verwendet und wie sie zur Erlangung einer Akzeptanz der Ergebnisse der Spannungsanalyse herangezogen wurde – sollte zum Gegenstand eines tiefer gehenden Informationsaustausches, mit Expertendiskussionen, gemacht werden, ebenso auch die Werkstoffeigenschaften für den Bruchausschlussnachweis und die Ermittlung der Rissausbreitung bis zum Bruch an jenen Stellen, wo Ausschlagsicherungen angebracht sind. Es sollten ebenfalls die für die Festlegung der Werkstoffeigenschaften herangezogene Datenbasis, sowie angewandte Normen, Regeln und Vorschriften hierin eingeschlossen werden.

  Die Einsichtnahme sollte sich darauf konzentrieren, inwieweit nach zwingenden Normen, Regeln und Vorschriften Kennwerte für die Werkstoffeigenschaften verwendet werden und welche Bedeutung diesen Kennwerten beim Zulassungsvorgang für Bauteile und Baugruppen zukommt.

  Die Anforderungen an die Werkstoffeigenschaften und die Prüfung der entsprechenden Eigenschaften der für die Hochenergieführenden Leitungen auf der 28,8 m-Bühne verwendeten Werkstoffe sollten durch hinreichend qualifizierte Nachweise belegt werden.

- **Zur Gültigkeit des Bruchausschlusskonzeptes:**

  Die Ergebnisse der Wahrscheinlichkeitsanalysen sollten ebenfalls zum Gegenstand eines tiefer gehenden Informationsaustausches, mit Expertendiskussionen, gemacht werden. Wahrscheinlichkeitsanalysen sollten die Versagenswahrscheinlichkeiten der gesamten Leitungsführung bis zu den ersten Durchdringungsarmaturen einbeziehen. Darüber hinaus sollten auch Ergebnisse aus bruchmechanischen Wahrscheinlichkeitsanalysen für jene Leitungsführung, die den maximalen Belastungen ausgesetzt ist, besprochen werden.

  Für die besondere Anordnung der Leitungsführung auf der 28,8 m-Bühne werden bestimmte Bruchhäufigkeitsannahmen üblicherweise angewandt, sowie bestimmte Wiederholungsprüfungen vorgesehen. Für beide Themenkreise sollten Vergleiche mit der allgemein üblichen Industriepraxis gemacht werden.

Die Zulässigkeit der besonderen Anwendung von Bruchausschlussannahmen und deren großzügigen Auslegung, sowie der damit verbundenen deterministischen Bestimmung der Bruchlagen sollte durch schlüssige Belege für die Annehmbarkeit aus Wahrscheinlichkeitsüberlegungen unterstützt werden.

- **Hinsichtlich der Folgewirkungen von Brüchen:**

  Die Belastungen durch Wasserschlag können nach deren Art und Folgewirkungen nur eingeschränkt mit den abgeschätzten Erdbebenbelastungen verglichen werden.

  Durch Wasserschlag können die Rohrleitungen bedeutend höhere Belastungen erfahren als solche, die in der Folge des spezifizierten Erdbebens auf sie einwirken.

  Vom Ausschlagen der Hochenergieführenden Rohrleitung nach dem Bruch des vertikalen Abschnittes ist anzunehmen, dass dieses sich auf die Hochenergieführende Rohrleitung auf der 28,8 m Bühne derart auswirkt, dass die Ausschlagbelastungswirkung auf die Wand der Turbinenhalle wahrscheinlich auch Auswirkungen auf die Unversehrtheit der Hochenergieführenden Rohrleitung auf der 28,8 m Bühne haben wird, ganz abgesehen von den sekundär auftretenden Auswirkungen auf die anderen Rohrleitungen dort.

- **Zu den Unfallfolgen:**

  Exemplarische Unfallszenarios sollten für das KKW Temelín mit folgenden Schlüsselrandbedingungen untersucht werden: Unter Volllast treten Brüche an Hochenergetischen Rohreitungen auf und Regelstäbe bleiben in der höchsten Position stecken und verhindern derart eine erfolgreiche Reaktorschnellabschaltung.

  Die Untersuchungen sollten sich darauf konzentrieren, in welchem Ausmaß sich Unfälle mit Folgewirkung auf den Reaktorkern zu Ereignissen entwickeln, bei denen Freisetzungen von Radioaktivität wahrscheinlich sind.

  Das Verhalten des Kernkraftwerkes unter Unfallbedingungen, die durch Brüche Hochenergieführender Rohreitungen hervorgerufen würden, erfordert noch umfangreiche Analysen verschiedenartiger Unfallverläufe, um Möglichkeiten der Verminderung von Unfallfolgen verstehen zu können.

VI. Punkte zur 28,8 m Bühne – für künftigen Informationsaustausch und künftige Expertengespräche

Das Österreichische Experten-Team empfiehlt, die mit der Integrität der Hochenergetischen Rohrleitungen auf der 28,8 m Bühne in Zusammenhang stehenden Sachverhalte mit hoher Priorität, im Rahmen des laufenden bilateralen Abkommens geschlossen zwischen der Republik Tschechien und der Bundesrepublik Österreich, weiterzuverfolgen. Diese Empfehlung betreffen die Verwirklichung und die Resultate des Programms für Wiederholungsprüfungen für die Hochenergetischen Rohrleitungen ebenso wie die wesentlichen Ergebnisse, die oben dargestellt wurden. Insbesondere wird empfohlen, hinsichtlich der Folgenabminderung von Bruchereignissen an den Hochenergetischen Leitungen weiterzuarbeiten.

Punkte mit hoher Priorität, bei denen Experten-Gespräche auf der Grundlage von zusätzlichen und neuen Informationen besonders wertvoll wären, sind die folgenden:

1.) Mit Bezug auf die Werkstoffe, welche für die sekundären Rohrleitungen mit hohem Energieinhalt verwendet werden:

Ermittlung derjenigen Prozeduren, die verwendet worden sind um die Werkstoffcharakteristiken festzulegen und deren Verwendung bei der Freigabe der Komponenten nach verpflichtend einzuhaltenden Normen, Regeln und Vorschriften.

2.) Im Hinblick auf das Absichern des Bruchausschlusskonzeptes:

Vergleich der Häufigkeitsannahmen von Brüchen mit den Häufigkeitsannahmen, die für diese speziellen Rohrleitungsanordnungen in der Industrie gelten. Ebenso soll die, an die tatsächliche Rohrleitungsführung auf der 28, m Bühne angepasste Wiederholungsprüfanweisung mit den Erfahrungen der Industrie verglichen werden.

Der Stand von Wissenschaft und Technik bezüglich Regelwerke und Normen, wie dieser in der europäischen Praxis in Hinblick auf die Forderung nach innerem Zusammenhang gehandhabt wird.

3.) In Hinsicht auf die Unfallfolgen:

Unmittelbar wirksam werdende Unfallfolgen sollten zur Erhebung abdeckender Unfälle untersucht werden, welche für maximale dynamische Belastungen anzusetzen sind. Schlüsse im Hinblick auf Vorsorgemaßnahmen sollten nur auf der Basis von bestätigten, abdeckenden Randbedingungen gezogen werden.

Die Analysen von mittelbaren Unfallfolgewirkungen sollte sich auf die Ermittlung des Ausmaßes konzentrieren, in welchem Folgewirkungen auf den Reaktorkern, die aus Unfällen entstehen können, wahrscheinlich zu radioaktiven Freisetzungen führen würden.

Für beide Aspekte der Unfallfolgen ist es erforderlich, sowohl Eintrittswahrscheinlichkeiten, als auch die Folgen zu kennen.

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1 INTRODUCTION

1.1 Background of the project

The Republic of Austria and the Czech Republic have, using the good offices of Commissioner Verheugen, reached an accord on the "Conclusions of the Melk Process and Follow up" on 29 November 2001. In order to enable an effective use of the "Melk Process" achievements in the area of nuclear safety, the ANNEX I of this "Brussels Agreement" contains details on specific actions to be taken as a follow-up to the "trialogue" of the "Melk Process" in the framework of the pertinent Czech-Austrian Bilateral Agreement.

To enable an effective "trialogue" follow-up in the framework of the pertinent Czech-Austrian Bilateral Agreement, a seven-item structure given in ANNEX I of the "Brussels Agreement" has been adopted. Individual items are linked to:

- Specific objectives set in licensing case for NPP Temelín units;
- Description of present status and future actions foreseen by the licensee and SÚJB respectively.

Each item under discussion will be pursued according to the work plan agreed at the Annual Meeting organised under the pertinent Czech-Austrian Bilateral Agreement.

Furthermore, the Commission on the Assessment of Environmental Impact of the Temelín NPP – set up based on a resolution of the Government of the Czech Republic – presented a report and recommended in its Position the implementation of twenty-one concrete measures (ANNEX II of the "Brussels Agreement).

The signatories agreed that within the Czech-Austrian Bilateral Agreement Czech and Austrian experts would also regularly monitor jointly the implementation of the said measures.

A "Roadmap" regarding the monitoring on the technical level in the framework of the pertinent Czech-Austrian Bilateral Agreement as foreseen in the "Brussels Agreement" has been elaborated and agreed by the Deputy Prime Minister and Minister of Foreign Affairs of the Czech Republic and the Minister of Agriculture and Forestry, Environment and Water Management of the Republic of Austria on 10 December 2001.

This „Roadmap" is based on the following principles:

- *The implementation of activities enumerated in ANNEX I and II of the "Brussels Agreement" will be continued to ensure that comprehensive material is available for the monitoring activities set out below.*
- *Having in mind the peer review procedure foreseen by the EU to monitor the implementation of the recommendations of the AQG/WPNS Report on Nuclear Safety in the Context of Enlargement, the Czech and Austrian sides agree that this peer review should serve as another important tool to handle remaining nuclear safety issues.*
- *As a general rule the regular annual meetings according to Art. 7(1) of the bilateral Agreement between the Government of Austria and the Government of the Czech Republic on Issues of Common Interest in the Field of Nuclear Safety and Radiation Protection will serve to monitor the implementation of those measures referred to in Chapter V of the Conclusions and to address questions regarding nuclear safety in general, in particular those issues which – according to Chapter IV of the Conclusions – have been found, due to the nature of the respective topics, suitable to be followed-up in the framework of this – Bilateral Agreement.*
- *In addition, specialists' workshops and topical meetings will take place, organised as additional meetings according to Art. 7(4) of the bilateral Agreement between the Government of Austria and the Government of the Czech Republic on Issues of Common Interest in the Field of Nuclear Safety and Radiation Protection, as set out in the "Roadmap".*

The Federal Ministry of Agriculture, Forestry, Environment and Water Management entrusted the Umweltbundesamt (Federal Environment Agency Ltd. with the general management of the implementation of the "Roadmap". Each entry to the "Roadmap" corresponds to a specific technical project. [see ANNEX C].

The objective of the Roadmap process covered by the Item No.1 "High Energy Pipe Lines at the 28,8 m Level" of ANNEX 1 of the "Brussels Agreement" covers the integrity of the main steam and feed water piping at the +28,8 meter level of the Temelín reactor buildings, where this piping transits from the respective containment penetrations to the turbine hall.

This issue is frequently referred to as "High Energy Line Breaks" or HELBs. The objective regarding this item as stated in ANNEX I of the "Brussels Agreement" is to *"ensure that the safety case demonstrating appropriate protection against high energy pipe breaks and consequential failures of the steam and feed water lines, complies with requirements and practices widely applied within the EU and that an appropriate combination of measures are in place."*

With the associate objective:

ANNEX I provides the following statements regarding the **"Present Status and specific Actions Planned"**:

"The issue of protection against high energy pipe breaks and consequential failures of the steam and feed water lines is included in the existing licensing case of Temelín unit No.1. To solve the difference in opinions of experts with regard to this issue, the Regulatory Authority initiated revisit of the safety case documentation in order to re-evaluate its compliance with requirements and practices widely applied in the EU. Alternative methods of assessment are being applied for this purpose as well as data collected during unit No. 1 commissioning tests. The result of these efforts will be made available to the Regulatory Authority till the end of September 2002 for final decision. Depending on the result, schedule for implementation of additional safety measures may be included into the above – mentioned regulatory submittal[1]. The signatories understand that additional safety measures for both units will be considered by the Regulatory Authority and if needed included into the above mentioned regulatory decision in order to meet the objective of this item."

The "Roadmap" specified that a Specialists' Workshop would be held in Prague in the 2nd half of 2002 to discuss this issue. This workshop on the "Roadmap Item No. 3" was conducted in Prague on 24 and 25 November 2002 according to Article 7 (4) of the Bilateral Agreement of the Exchange of Information on Nuclear Safety. This workshop was the key element in the monitoring process. In a series of presentations the outline of the technical approach to the 28,8 m Level Item and the Comprehensive Safety Case Revisit [CSCR] was described by Czech experts, including the legal framework for the issue and the information provided to the Licensing Authority about the technical approach.

On behalf of the Austrian Government the Umweltbundesamt (Federal Environment Agency) committed a Austrian Experts' Team composed of national and international experts to provide technical support for the monitoring of the implementation on the technical level of the RPVI/PTS Issue as listed in ANNEX I of the Conclusions of the Melk Process and Follow-up. This specific technical project is referred to as project PN2 comprising altogether seven predefined "project milestones" (PMs).

To focus preparatory work of the Austrian Austrian Experts' Team and to guide the Austrian Delegation through the Specialists' Workshop but also to enable proper preparation of the Specialists' Workshop on the bilateral level, in a **first step** Project Milestone 1 (PM1) the safety objective was broken down to Verifiable Line Items (VLIs) (see the related tabular en-

[1] For details see Sixth Additional Information to the Position Paper on Chapter 14 "Energy" submitted to the EC in September 2001

tries on top of the individual chapther and pargraphs). They were based on the Defence in Depth principle applied to qualify Temelín NPP's engineered safety features consistency for accident operation.

In a **second step** the Austrian Experts' Team prepared a list of documents (PM2) the Specific Information Request – SIR, considered to contain the kind of information required to provide for profound answers to the VLIs (see ANNEX G)[2].

The **third step** in the preparatory work for the Workshop also included identification of standards and practices applied within the European Union Member States for the HELB issue (France and Germany). The focus was placed on practices in Belgium, Finland, France, Germany, Spain and Sweden (since these EU Member States have several operating pressurised water reactors), with less emphasis on practices in the Netherlands and the United Kingdom (since each of these EU Member States have only one operating PWR). In addition, practice in the US has been considered extensively, since the operator of ETE applied US-codes, rules and regulations. In the Briefing to the Austrian Delegation (PM3) these elements of the monitoring were presented to the mission participants.

Prior to the week before the Specialists Workshop, little new information had become available since July 2001 the delivery date of the Austrian Technical Position Paper [ATPP 2001], containing the Austrian conclusions at the end of the tripartite process.

The Temelín Roadmap Specialists' Workshop on HELB and Valve Qualification (another issue defined by the Roadmap that is closely interrelated with the HELB issue PN3."Qualification of Valves") took place in Prague on 7 – 8 November 2002.

Electronic copies of most of the presentations (as listed in Specialists' Workshop (PM3)) were made available a few days prior to the Workshop, and the representative of the Czech licensing authority provided copies of his presentation at the workshop.

Experts from ČEZ a.s., the Nuclear Research Institute Řež plc, the Institute of Applied Mechanics Brno, Ltd., and from the SÚJB made fifteen well-prepared slide beamer presentations, characterised by one presenter as being of an overview nature. Following the presentations, time was provided for questions from the Specialists' Team.

A number of questions posed by the Austrian Experts' Team were considered to exceed the level of detail or the scope of the Roadmap Workshop activities by the Czech side. Discussion on these questions was limited to side conversations. However, no essential background documents were supplied to the Austrian Experts' Team in these contexts.

Following the Workshop in this **fourth step** (PM4), the Austrian Experts' Team reviewed the Specialists' Workshop and the Austrian Experts' Team members provided contributions to the Preliminary Monitoring Report (PMR). Based on information currently available, the Austrian Experts' Team has compiled several results that have become evident.

This Preliminary Monitoring Report is based on evaluations by the Austrian Experts' Team of the presentations and discussions during the Specialists' Workshop: the findings of the Austrian Experts' Team were exchanged and discussed after the workshop and the Preliminary Monitoring Report (PMR) was reviewed in an internal workshop of the Austrian Experts' Team held on 8 and 9 December 2002 in Vienna.

The evaluations in the PMR address three different levels of the process by commenting

(1) On the adequacy of the information available in view of the monitoring task (i.e. the presentations) and
(2) On the adequacy of the technical approach as such

[2] The SIR, as updated after the Prague Specialists' Workshop is listed in ANNEX G

(3) On issues directed towards a resolution of the safety issue addressed and on its interrelation to the projects PN3.“Qualification of Valves” and PN4.“Qualification of Safety Classified Components” Items.

Note that the assessment of technical adequacy is closely related to a number of other “Roadmap” items. Consequently, a final evaluation will only be possible by the end of the Monitoring process on the technical level, as set out in the Roadmap, taking into account the results of other Roadmap events as well as additional information which might be available, inter alia in the framework of the pertinent Czech-Austrian Information Agreement.

The analysis of information made available there played a significant role in the development of the basis for the Preliminary Monitoring Report. The Czech presentations at the Specialists’ Workshop covered a broad scope of aspects related to the development and implementation of RPVI/PTS avoidance and mitigation measures. [For the individual presentation titles see under Specialists’ Workshop (PM3) on page 40 below].

These Workshop presentations referred to almost all topics and items, which were of interest to the Austrian Experts’ Team with the exception of details regarding the three topics.

In a **fifth step (PM5)** the Austrian side presented a summary of the HELB issue monitoring and the related main findings at the Bilateral Meeting on December 18, 2003. The discussion with the Czech partner resulted in no essential information transfer, which would have had to be considered and would have added to the evaluation.

At the Bilateral Meeting November 28 and 29, 2004 the good quality of discussion enabled delivery of two short lists of questions to the Czech partners resulting in valuable information to the Austrian Experts´ Team additional analyses which were finished in December 2004 only.

The **sixth step (PM6)** in the monitoring process of PN2 ‘High Energy Line Breaks’ was to set up the Final Monitoring Report (FMR), which is presented herewith.

As suggested by the Austrian Experts’ Team the Technical Project Management ordered additional analyses for the FMR (PM6) related to the three selected topics of the above PMR issues list. For these three issues additional substantial work has been performed in the frame of PM6 to support the final assessments. The three issues are:

(1) The **behaviour of the primary coolant system and the reactor core** under the conditions of multiple steam line breaks in the compartment at the 28,8 m level and its suspected recriticality of the reactor,

(2) **Design loads for the HELs at the 28,8 m level** according European practice (e.g. water hammer caused) compared with design seismic loads applied declared bounding by the Czech side

(3) Qualification of the **material properties data for the database** to be used in the break exclusion attempt, the HEL design verification and operational wear and ageing evaluation.

Results provided for conclusions as mentioned in ANNEX K and cited in the Executive Summary. The final evaluation on the HELB issue took into account the results of the related PMR and if relevant other Roadmap events as well as additional information which were available, inter alia in the framework of the pertinent Czech-Austrian Information Agreement.

1.2 Scope of the project

The project PN2 „High Energy Pipe Lines at the 28,8 m Level“ deals with the topic of HEL integrity and breaks damage as a consequence of rupturing one of the MSL or MFWL and other subsequent damage in that area as well, including secondary pipeline failures of HEL adjacent to the failed one. In all the cases the most critical accident sequences and resulting transients to the primary circuit under high pressure are of interest. This is one of the main concerns within the Temelín reactor safety analysis since the HEL integrity function at least up to the first isolation valves are relevant to basic safety of the plant. A rupture of these components could threaten even safe shutdown conditions of the core.

The IAEA requirements for the analyses as denoted in ANNEX F, Austrian PN2 Benchmark Exercise cover some of the accident scenarios' aspects to be managed. At the same time all avoidance and mitigation measures as well as the related design precautions have to be monitored and the Comprehensive Safety Case Revisit (CSCR) and SUPERPIPE as well.

1.3 HELB Technical Background

The Temelín nuclear power plant (NPP) is a two-unit facility designed as WWER-1000/320 pressurised water reactors originally according to the standards of the former Soviet Union. Following the political changes, the plant design was upgraded (including redesign of fuel and instrumentation & control equipment delivered by Westinghouse) and put into operation beginning with Unit 1, which had its startup testing in 2001. In the plant safety analyses reports (SARs), the plants' response to "design basis accidents" (DBAs) are evaluated assuming a single active failure in the safety system response, and the performance of the plant is evaluated to ensure that basic safety criteria are met. Such SAR assessments are performed more recently also for cases with possible impact on RPVI resulting from PTS events. RPVI issues pertaining to eventual failure under SA conditions however are treated together with SAM considerations and as such the consequences of these accidents – results of international research and development programs – and the issue of accident management (AM) gained prominence in the 1990s. The SA related measures are not discussed within the scope of the PN2 and PN9 monitoring.

The overall objective is to further reduce the risks of HELs' failure. In this context accident management plays an important role in the Defense-in-Depth concept. Design verification as well as components and system functions assurance have been performed, also for all items, which have been added to the design of the plant in order to enable it to cope with, to prevent or to mitigate HELB events and their adverse effects on other HELs and equipment as well as systems located in this area and the consequences, which could be even severe accidents. When the Czech Republic and the Republic of Austria jointly issued the Melk Concluding Statement and the Road Map, the HELB issue and its management were specified for further technical monitoring.

1.4 General description of the project concept

To appreciate this development, a team under the Technical Project Management of IRR-ARCS performed the monitoring work on this project. The team addressed in a broad ''horizontal segment' the specific defense in depth concept requirements for the Temelín Nuclear Steam Supply System (NSSS) based on underlying analyses and principles ("vertical segment").

Horizontal segment

The assessment of principles, standards and practices is aimed to discuss:

- The Czech regulations and guidelines used for HEL integrity demonstration in the context of Code requirements under which the secondary circuit high-energy piping has been design and constructed, and
- The IAEA Guidelines that were elaborated especially for WWER reactors PRISE assessment.

The comparison with Western state-of-the-art is included for the HEL integrity specific issues in order to provide an insight into Western safety philosophy and practice and to judge whether the Czech approach and measures taken can be considered comparable to Western practice.

This procedure allows the treatment of individual safety problems as so called "Safety Cases". In the HEL case the Czech side has taken up a procedure similar to the "Safety Case" handling by implementing the "Comprehensive Safety Case Revisit" much in a way this is done there. In addition a combination of the so called "SUPERPIPE" qualification concept with Code requirements taken from the French Règlements Code du Construction (RCC), the US NRC and ASME Codes and from Czech indigenous requirements. Some of these safety principles are included into the description of Western state-of-the-art to demonstrate the different practice.

Some of the specifics of this combination of approaches were presented at the workshop, some have been found in open literature as well. Monitoring was therefore also relying on the pilot studies already introduced with the vertical segment.

Vertical segment

A team of Austrian TSOs looked after possible vulnerability of the HELs and in a very limited manner of their support structures in a set of peer review like spot-check analyses in a 'vertical evaluation'. The technical work was managed in parallel by providing transfer of information and joint discussion of important issues. The FMR is the responsibility of IRR-ARCS and gives credit to the findings from both, the 'horizontal' and the 'vertical' evaluations.

Modern analytical techniques have provided tools to analyze thermal hydraulic transients from the onset (e.g. water hammer events) and the resulting mechanical loads on the "free" ends of ruptured pipes, allowing simulation also of pipe-whip and its consequences to adjacent structures. Fluid dynamics and stress analyses codes and fracture mechanics tools have been used in the design verification process. The monitoring process was concentrated on the engineering approach taken by ČEZ to have the HELs licensed by the SÚJB (State Office for Nuclear Safety).

Most Western countries are bound to the U.S. ASME Code or at least adopted main parts into their National Codes (Germany, France). In contrast to this proceeding the United Kingdom has a non-prescriptive Code that is based on demonstration of compliance with basic safety principles.

1.5 Specialists' Workshop (PM3)

Several tasks had to be performed by the Austrian Experts' Team for the preparation of the Specialists' Workshop:

- Identification of the requirements for HEL in accordance with the state of the science and technology and industrial practice.
- Identification of information available on HEL and Superpipe activities at the Temelín NPP.
- Identification and evaluation of results published on WWER-1000 HEL material properties and behaviour with respect to conservative assessment.
- Provision of the Verifiable Line Items.
- Provision of the Specific Information Request.
- Preparation of the Briefing Material, Briefing Session
- Preparation of HELB analyses for selected bounding cases and for consequences.

The results of all tasks performed have served for monitoring the actual state of the Temelín NPP, the preparation of the Workshop and the introduction into the various disciplines for the Austrian delegation.

The Specialists' Workshop scheduled in the frame of the "Conclusions of the Melk Process and follow-up" for the second half of 2002 took place at SÚJB in Prague during November 8th and 9th, 2002.

The Agenda of this PN2 Workshop covered the following presentations:

P. Krs (SÚJB)	Workshop opening.
G. Polte (Head Austrian Delegation)	Welcome and Introduction of Meeting Participants
M. Holán (ETE)	Temelín NPP position on high energy piping at 28,8 m level
J. Žďárek (NRI)	Comprehensive safety case overview.
Pečínka (NRI)	Dynamic calculations results due to the steam water hammer and water overfill overview.
Pečínka (NRI)	Flow accelerated corrosion assessment.
V. Pištora (NRI)	PTS methodology/harmonisation with EU practice.
M. Ondrouch	Material Database Summary.
Fridrich (NRI)	Qualification Dossiers for S-W Mixture of BRU-A and SGSV including EQ of BRU-A actuator.
Horáček (NRI)	Qualification of UT NDE
Junek (ÚAM)	Displacement measurement results.
Pečínka (NRI)	Pipe break probability calculation overview
L. Horáček (NRI)	UT NDE testing and results
Maček (NRI)	Summary of TH analysis.
J. Žďárek (NRI)	Superpipe concept application on steam and feed water lines
M. Holán (ETE)	Time schedule and modifications required for 100% UT NDE.
P. Krs (SÚJB)	SÚJB preliminary asessment of the Safety Case results.

The monitoring evaluation of the Czech contributions is integrated into the following chapters of the Final Monitoring Report.

Late in the process some additional statements were delivered to the Austrian Experts' Team intended to reconfirm the approval bases of the HEL at the 28,8 m level.

In a final statement related to these presentations concerning the PN2 topics the Austrian delegation welcomed the additional information provided, as well as the opportunity to obtain answers to further questions.

1.6 Structure of this report

The Sections 2 to 4. of the FMR[3] provide a comprehensive evaluation of relevant aspects relating to the two units of the Temelín NPP. The material presented in these sections is arranged into several subsections corresponding to the selected evaluation factors or aspects. With some exceptions, each of these subsections comprises of three parts:

- *"Description of the issue and fundamentals"* and "*The current state-of-the-art requirements and practices"*: provides an informative introduction to the specific issue; the next part defines the 'assessment criteria' specific to the evaluation area/factor i.e. the basis to be used for the assessment.
- *"Current plant status"* includes a brief comment on the related plant status with references to other sources of information, and
- *"Evaluation"*: summarises the results of the assessment against specific assessment criteria.

Deficiencies or safety concerns as well as the recommended issues for further monitoring are identified in this report. All these conclusions and issues of further monitoring are summarised in Chapter 5 and 6 and in the Executive Summary as well.

The FMR also contains 12 ANNEXES with PN2 relevant and general monitoring information.

The present report reviews all evaluated information on the topics in question and represents an evaluation of the knowledge accumulated and acquired during the Melk Process about HELB and HEL integrity at the 28,8 m level.

[3] This report considers the results of the projects PN2, PN4, PN6, PN9 and PN10 wherever required.

2 ISSUE SPECIFICATION AND CZECH RESPONSE

2.1 Specification

In the VVER-1000 design adopted at the Temelín 28,8 m level (see Figure 2), there are four main steam pipes and four main feed water pipes.

The steam pipes travel in pairs on opposite sides of the containment, penetrating the containment wall, and following a number of bends until they reach the main steam isolation valves (MSIVs) in pairs on opposite sides of the front of the +28,8 meter elevation of the reactor building. The steam pipes are arranged such that in case rupture of one pipe occurs, the consequential failure of any second adjacent line is not precluded. However, due to the geometric location of the MSIVs, the coinciding rupture of three or four steam pipes between the containment penetration and the isolation valves is very unlikely. (External events are not within the scope of this report).

Three piping loops, referred to as "bubliks" (Figure 3), are connected to each main steam pipe, each with a T-joint and a valve. One of the valves is a main steam relief valve (BRU-A), and two of the valves are main steam safety valves (MSSVs).

The feed water pipes are likewise arranged in pairs on opposite sides of the containment, underneath the steam lines. The feed water lines travel from the containment penetrations, and follow a number of bends until they reach the feed water isolation valves. The feed water isolation valves are located in a row at the very front of the +28,8 meter level, and in this area it is in principle possible to rupture more than two feed water pipes.

In the Technical Position Paper issued near the conclusion of the Melk Process, the Austrian position on the HELB issue was set forth as follows [ATPP 2001] :

> *In case of a rupture of one or more of these lines damage of adjacent lines as well as other safety-relevant equipment cannot be excluded as a consequence of pipe whip and/or jet impingement effects by discharged material. This could trigger an accident sequence causing large radioactive releases. This issue has not been sufficiently addressed.*
>
> *The main objective of adequate re-assessment and reconstruction of the +28,8 m level must be to physically exclude multiple steam line breaks and consequential component and equipment failures that cannot be compensated by the safety systems and thus could result in severe accidents with potential large release of radioactivity.*

As part of the accession process of the Czech Republic to the European Union, the Atomic Questions Group (AQG) of the Council of the European Union and its ad-hoc Working Party on Nuclear Safety (WPNS) were mandated to examine the nuclear safety status, inter alia, of the Temelín NPP in the Czech Republic. In a country-specific recommendation, the AQG/WPNS recommended [WPNS 2001].

> *Ensure that the safety case demonstrating appropriate protection against high energy pipe breaks and consequential failures of the steam and feed water lines, complies with requirements and practices widely applied within the EU and that an appropriate combination of measures are in place.*

The safety issue of concern therefore is, that a rupture of a high energy line (HEL) at the 28,8 m level (see [ATPP 2001]) can induce consequential failures. These failures can cause the event to exceed Design Basis Accident conditions, as assumed for the accident analyses of the Pre-Operational Safety Analysis Report [POSAR] and the accident consequences can eventually lead to unacceptable environmental effects.

2.2 Response to the HELB issue

How to deal with this safety issue is clearly indicated, as an example, in the U.S. NRC Standard Review Plan [NUREG 0800], Section 3.6.1, where guidance is given to the regulator on how to review the plant design for protection against piping failures outside containment. European requirements and practices are very similar and sometimes even more stringent.

*The plant design is reviewed "to assure that such failures would not cause the loss of needed functions of safety related systems and to assure that the plant could be safely shut down in the event of such failures" [*NUREG 0800*] and subsequently kept in stable and safe shut down condition.*

The acceptability of the plant design against these postulated pipe breaks is based on the U.S. General Design Criterion 4 of [10 CFR 50] Appendix A, requesting structures, systems and components "important to safety" to be designed to accommodate the dynamic effects of a postulated pipe rupture, including the effects of pipe whip and discharging fluids. Rupture locations and dynamic effects associated with the postulated rupture are determined in Section 3.6.2 of the Standard Review Plan and in the associated Branch Technical Positions.

In finally assessing the Safety Issue the State Office for Nuclear Safety initiated, what it refers to as a "Comprehensive Safety Case Revisit" (CSCR) of the HELB issue by requesting ČEZ, a.s. to "produce safety documentation enabling SÚJB to settle the discrepancy in opinions of experts on above mentioned issues in a way standard for regulatory practices – by reassessment of existing safety case taking into account newly available information and technical arguments" [WPNS 2001].

The bases for SÚJB approval of the main steam and feed water piping design at the ETE +28,8 m elevation in the initial licensing stage were as follows (as cited in the presentation by the representative of the licensing authority):

- Implementation of a quality assurance system (including non-destructive testing plan) for design, manufacture and installation of the high-energy pipes in order to decrease the possibility of any sudden pipe break
- Postulation of locations where a break is possible in reality (according to the US Nuclear Regulatory Commission's Standard Review Plan [USNRC SRP] Section 3.6.2) and subsequent installation of whip restraints at these locations to eliminate the possibility of consequential failures of the main steam lines and main feed water lines
- Re-routing of the emergency feed water system piping out of the critical area at the +28,8 meter elevation

In the CSCR, ČEZ a.s. has settled on an approach known as "break exclusion" — that is to exclude the possibility of a break of the piping between the containment wall and the first isolation valves in the main steam and main feed water system (see ANNEX C, Figure 3). by reducing break likelihood to such a low value that pipe rupture consequences need not be subject to further design measures.

As part of the CSCR, ČEZ, a.s. has identified a combination of three out of four investigated steps, when applying break exclusion to the main steam and feed water piping at ETE in order to resolve the HELBs issue [SWSPR 2002]:

- Confirmation of correct location and design of pipe whip restraints, with circumferential welds covered by the pipe whip restraints inspected by qualified ultrasonic testing (UT) procedures in accordance with the European Network on Inspection Qualification (ENIQ).
- Application of the break exclusion principle to the pipelines from the containment penetration to the first isolation valves outside containment, including a requirement for 100% volumetric qualified UT examinations for all welds in the high energy piping system from the containment penetrations to the first isolation valves (see ANNEX C, Figure 3).

- Implementation of main steam and feed water line monitoring (pipe wall thinning predictive calculations with follow-up wall thickness measurements), management of chemical composition of feed water, and pipe displacement measurements during commissioning tests and refuelling outages (as needed).
- After considering the positive and negative aspects of a possible separation wall (which was found to be feasible to be installed between the two pairs of main steam lines and main feed water lines), the SÚJB decided not to require installation of the separation wall. This decision was based on negative influences of the wall on in-service inspections of the main steam and feed water piping, and on benefits of the combination of pipe whip restraints, application of break exclusion, and periodic piping system monitoring.

The essentially new element to be considered was introduced by the plant operator, ČEZ a.s., under the acronym "Superpipe Concept" as a sound demonstration of the break exclusion based upon European Code (in this case French) requirements. For this purpose the requirements imposed according to the French rules [ANNEX D, RCC-P and RCC-M] had to be adapted to the licensing requirements environment of Temelín NPP (e.g. by rules and/or regulations adopted by the Czech Association of Mechanical Engineers (AME)).
The licensing authority SÚJB has approved the above approach, and the Council of the European Union has been informed of this decision by a note submitted by the Czech Government in October 2002 [AQG CZ 2002].

In the Prague Workshop on 7 and 8 November 2002 the approach to cope with this safety issue has been explained to the Austrian Experts' Team in a series of presentations: it is mainly based on the HEL break exclusion approach and relies on improved in-service inspection procedures. A variety of interrelated problems, such as material quality, erosion-corrosion effects, Non Destructive Evaluation and pipe break probability quantification were also addressed in the presentations.

3 EVALUATION OF THE WORKSHOP PRESENTATIONS AND IDENTIFICATION OF OPEN ISSUES BY THE AUSTRIAN EXPERTS' TEAM

Areas of Monitoring

No	VLI/VLI group description
1	**OVERALL EVALUATION OF THE APPROACH**
1	Monitoring of piping design rules and recommendations, exceptions, analysis methodology, qualifications, service levels, load combinations (steam/water hammer effects included) in European, international and when compared with Czech practice
2	**SPECIFIC TECHNICAL EVALUATIONS**
1	Monitoring of piping design approach and piping stress analysis methodology, considering piping and components qualifications, service levels, load combinations (including expected and unexpected steam/water hammer effects)
2	Monitoring of the criteria used to select pipe break locations and orientations
3	Monitoring of the postulated "aggressive" HELB points assumed in the analysis ("aggressive" means: "which can damage structures, systems or components important to safety sufficiently to impair safety functions to an unacceptable level")
4	Monitoring of pipe internal dynamic fluid forces effects as a consequence of the postulated HELB (including geometry effects and blowdown characteristics)
5	Monitoring of the non-linear mechanical analysis to determine the whipping pipes dynamic response
6	Monitoring of the evaluation of jet impingement shapes, temperatures, pressures, directions and loads, insofar as to find out whether jet forces impulse to HEL or walls or components are likely to cause consequential failures
7	Monitoring of the proposed measures to protect safety related equipment from pipe whip, blowdown jets and reaction forces, and separation of redundant features (requirements, material properties & sizing of pipe whip restraints and separating shields)
8	Monitoring of the methodology and analyses of compartment pressurisation and environ-mental conditions following a postulated HELB
9	Monitoring of the structural design loads including pressure & temperature transients and dynamic reactions as consequences from HELB
10	Monitoring of the methodology for evaluation of structural adequacy of Seismic Category I structures (those civil structures required to fulfil safety functions)
11	Monitoring of the structural analysis evaluation including local loads on the concrete Category I structures and non-safety structures whose damage may impair the safety of the plant.
12	Monitoring of the structural failures, environmental conditions and potential flooding that might result in loss of safety functions including Monitoring of main control room habitability
13	Monitoring of the adequacy of the safety class components environmental qualification. This should be addressed in PN4. Only identification of candidate components requested
14	Monitoring of the analysis methodologies to evaluate the plant response to MS & MFW HELB outside containment
15	Monitoring, based on plant safety analysis, for performances of mitigating systems, radiological consequences calculations and Monitoring of adequacy of emergency procedures to mitigate MS & MFW HELB outside containment and their extension into SAMGs
16	Monitoring of adequacy of MS & MFW piping outside containment in-service inspections programs

No	VLI/VLI group description
17	Monitoring of event frequency evaluation of HELB and of consequential failures
18	Monitoring of requirements for materials used and for material degradation to be taken into account. Verification of design, adequate maintenance and ageing effects.
3	**SÚJB's Position**
1	RULES & REGULATIONS
1.2	COMPARISON OF NATIONAL, RUSSIAN, EU AND US CODES AND PRACTICE
1.2.1	RPVI and PTSA comparison with Russian, and Western European State-of-the-Art

This evaluation by Austrian Experts' Team was made following the presentations during the Workshop. It groups the Monitoring results, comments, observations and annotations according to technological categories they might be attributed to, in order to provide more insight into the topics treated.

The results presented here (Chapter 3) are used to obtain Monitoring results regarding the VLIs (Chapter 4) as well as summary conclusions (Chapter 5).

3.1 Overall evaluation of the approach in resolving the issue

The overall monitoring process preparation followed the "Defense-in-Depth"[4] principle of preventive, protective and mitigative safety measures on which the plant design is based. The application of this principle is reviewed.

The Austrian Experts' Team broke the safety objectives down into a set of 18 "monitoring items" that are logically interrelated[5], but manageable separately as VLIs, derived from Section 3.6.1 of the Standard Review Plan and plant design experience.

Monitoring is done to verify whether the operator's response to the HELB issue can be interpreted as a consistent, comprehensive and sustainable application of the "Defense in Depth" concept (DID) according to the 18 Verifiable Line Items (VLIs).

For this verification all of the following 18 "monitoring items" need to be carefully pursued for comprehensive and thorough monitoring of the implementation of the solution to the HELB safety issue.

In essence, the results of the Workshop should have provided answers related to all these VLIs. Note that the presentations during this workshop did not explicitly follow the 18 "monitoring items" or the DID concept applied.

[4] The DID concept has been confirmed by the operator to be one of the governing principles of the nuclear safety concepts' implementation at ETE. [NRNSC2001under 13.1.3 p. 100]

[5] see the Workshop Programme, ANNEX A, for the MONITORING scope of the project PN2

3.1.1 Adequacy of the information in view of the monitoring task

There is a clear consensus amongst the Austrian Experts' Team that the presentations by ČEZ a.s. and SÚJB were informative, but at a very general level. The full report versions of the Comprehensive Safety Case Revisit (CSCR) as submitted by ČEZ a.s. to the SÚJB, and of the formal SÚJB decision on the CSCR could have been made available to the Austrian Experts' Team. This fact limits conclusions that can be drawn in this report directed to the Austrian government. The Specific Information Request (SIR) indicates the areas where additional information would have been an asset to the monitoring results.

3.1.2 Adequacy of the technical solutions presented

The demonstrated applicability of a break exclusion concept requires that a comprehensive combination of preventive, protective and mitigative measures be developed, implemented and sustained during operation of the Temelín NPP. The Austrian Experts' Teaminvestigated how the DID concept is upheld under the prevailing special conditions, and monitored the quality of this process based on the information provided by the Czech side. In doing so the Austrian Experts' Team arrived at the following views:

- Correct positioning and design of pipe whip restraints, comprehensive NDT, and extensive periodic pipe monitoring (e.g., wall thickness measurements) are part and parcel of the break exclusion concept as intended by properly applying the provisions of the code chosen [STD-MATL]. These factors are generally not considered "independent" levels of protection or "safety layers" as asserted by the experts of the plant operator, the licensing authority and the representative of the TSO. Indeed, these factors are safety related precautionary measures and part and parcel of whatever approach is taken to secondary piping integrity, and are not unique to break exclusion. Furthermore, application of break exclusion without fully qualified application of pipe whip restraints, comprehensive NDT and extensive periodic pipe monitoring would not be acceptable according to up-to-date European codes of practice.
- The protection implemented against HELB at Temelín is based on the application of a break exclusion assumption. In contrast with Defense-in-Depth (which recognises the supporting and integrated roles of prevention, protection, qualification, and mitigation), the approach employs prevention and mitigation only. The presenters from the plant operator, the licensing authority and the TSO confirmed this fact.
- The basis for changing the Defense-in-Depth (DID) concept in this specific instance was not put forward by the Czech side. The break exclusion approach applied can only be considered as being part of the solution to the item of concern.
- Another part, the analyses and evaluation of the consequences of breaks on structures, systems and components relevant to safety, that in any case must be postulated (e.g. at the terminal ends or along the "bubliks"), has not been addressed in the Specialists' Workshop nor in other documentation accessible by the Austrian Experts' Team up to now.
- The proposed solution is a "first of its kind" solution to the best knowledge of the Austrian Experts' Team. While this does not mean that the licensing authority cannot accept the solution, once in possession of the complete evidence provided by the operator, the Austrian Experts' Team finds it difficult to discuss licensability in EU countries or in the US based on the information currently available. Application of the break exclusion approach to piping of such an extent requires adequate justification and applicability demonstration, which has to be backed up by consistently qualifying the approach to the highest standards' requirements and should be supported properly with adequate technological evidence. Demonstrated admissibility of multiple HELBs implies acceptance of CCF/CMF and must be argued in the licensing process.

- From the presentations, it was unclear to what extent the accepted HELB solution follows either the USNRC Standard Review Plan or the ANSI/ANS requirements for postulation of high energy line break locations. The Austrian Experts' Team considers it unlikely that the solution complies either with the US-NRC Standard Review Plan (to which the Czech side pointed, both ČEZ a.s. and the SÚJB) or with the ANSI/ANS requirements. AME[6] requirements were not presented and documentation about the standards applied, which could justify this extended scope of application was not available.
- The codes, standards, rules and regulations applied could not be identified from the available presentations. No evidence was given on how the gaps between the original design code, standard, rules and regulations and those used for HELB solution, qualification and requalification have been bridged by the plant operators' approach. The procedures adopted to mingle different code and standards requirements while introducing the so-called Superpipe Concept were only mentioned on several occasions in the presentations.
- Given the existing piping layout in place at Temelín, break exclusion application, without considering the consequences of the postulated HELBs on the equipment related to safety, would not conform to current French and German practice. There was no evidence that the so-called "aggressive" break points were identified as required by the applied French codes. Analyses of consequential failures due to dynamic effects, jet impingement, pipe whip, etc. were not performed taking into account the break exclusion concept as applied here. This might be the reason why the protection of safety-related structures, systems and components located in the area was not addressed at all by the presentations.
- A proposal of physical separation of Main Steam and Main Feed Water lines with a wall at 28,8 m level, in accordance with Western recommendations, was made and submitted by the plant operator as a protective safety feature. It was disregarded by SÚJB because of the "significant restriction of maintenance and in-service inspection" caused by its presence in the area. A comparison with the break exclusion approach as defined by the U.S. Standard Review Plan (see ANNEX B), indicates that such a position could not be successfully advocated in a licensing process under the US licensing regime.
- Prevention and – if applicable – protection measures are not clearly distinguished, and therefore defence in depth principles are not realised to the full extent in the solution as adopted. The operator should remain vigilant about the potential implications on safety culture.

[6] The Czech Association of Mechanical Engineers was cited to have played a key role in the "Superpipe" Concept development. The definition of and obligations related to this work were not explained.

3.2 Specific technical evaluations

No.	VLI title/description
5	Monitoring of the non-linear mechanical analysis to determine the whipping pipes dynamic response
6	Monitoring of the evaluation of jet impingement shapes, temperatures, pressures, directions and loads, insofar as to find out whether jet forces impulse to HEL or walls or components are likely to cause consequential failures
7	Monitoring of the proposed measures to protect safety related equipment from pipe whip, blowdown jets and reaction forces, and separation of redundant features (requirements, material properties & sizing of pipe whip restraints and separating shields)
8	Monitoring of the methodology and analyses of compartment pressurisation and environmental conditions following a postulated HELB
11	Monitoring of the structural analysis evaluation including local loads on the concrete Category I structures and non-safety structures whose damage may impair the safety of the plant
12	Monitoring of the structural failures, environmental conditions and potential flooding that might result in loss of safety functions, including Monitoring of main control room habitability.

In the following chapters, ten specific technical monitoring areas are addressed by the Austrian Experts' Team; these relate to the:

- Break exclusion concept for the high-energy lines at the 28,8 m level,
- Water hammer loadings to the high-energy lines during transient and accident conditions,
- Pipe wall thickness measurements to monitor erosion/corrosion,
- PTS Methodology & Harmonisation with EU Practice in the context of multiple steam line breaks,
- Materials Database extension due to lack of abundant archive original material,
- Qualification of UT NDE for the welds of the high energy line piping,
- Operational Displacement Measurements for high energy lines structure,
- High energy lines Pipe Break Probability Calculations,
- Thermal Hydraulic Analysis (TH) of the reactor system in response to a multiple steam line break,
- Comprehensive Safety Case Revisit (SÚJB Position).

History and background of the break exclusion approach as adopted by ČEZ:

Exclusion of any break along large portions of the HELs was the original and first approach of the operator to cope with the problem of the adjacent high energy lines at the 28,8 m level. The erosion/corrosion degradation effects during operation are considered to be the prime cause for failure. A more adequate water chemistry operation regime in the feed water lines was one of the justifications to support this original approach.

The operator replaced this original approach after non-applicability was determined by a second approach, one, which considered breaks but only at selected locations of the pipelines. These breaks were postulated according USNRC rules only for pipe sections where calculated stresses exceed the maximum allowable stress applicable for the individual pipe sections (at the containment penetrations and at the pipe whip restraints located close to the turbine hall separation wall).

This second approach turned out to be unsatisfactory as well. This is clearly documented by the WPNS country report [WPNS 2001] for the Czech Republic and the response by the Czech authority indicating a revisit of the "safety case" at the 28,8 m level.

The result of this revisit is the ex-post demonstration of compliance with the so-called Superpipe Concept performed by the operator and accepted by the licensing authority. The "Superpipe Concept" as applied here is an extension of the original Tronçons Protégés, according to e.g. RCC-P 1400 Troisieme Partie Regles d'Interface 3.1 Régles d'Installation ref. 3.13.6.3 [RCC-P] in combination with the material usage limits applicable according to [RCC-M], paragraph C 3650 etc. [see RCC-P]. The French concept is one European variant of the original US-NRC break exclusion design concept, defining the application conditions with respect to special design requirements, material quality, manufacturing quality, in service inspection, operation conditions monitoring, etc.

This concept can be applied for portions of straight pipes and bends in case all associated requirements are fulfilled.

However, after reviewing the related presentations of the Czech side, the Austrian Experts' Team has reservations concerning the fulfilment of these requirements. The following items address the roots of these reservations.

3.2.1 Break Exclusion ("Superpipe")

No.	VLI title/description
1	Monitoring of piping design approach and piping stress analysis methodology, considering piping and components qualifications, service levels, load combinations (including expected and unexpected steam/water hammer effects)
9	Monitoring of the structural design loads including pressure & temperature transients and dynamic reactions as consequences from HELB
10	Monitoring of the methodology for evaluation of structural adequacy of Seismic Category I structures (those civil structures required to fulfil safety functions)

The "Superpipe" Concept as developed for the Temelín case has not been presented to the full extent, perhaps because it is said to have been derived from the French Tronçons Protégés RCC code provisions [RCC-P] and [RCC-M]. Nevertheless, it is important to note that the "Superpipe" Concept as such is a novel approach going far beyond previous applications. Therefore, it needs to be coherently composed as a comprehensive concept. In particular, the verification of its integration into the codes, rules and regulations originally applied to ETE before implementation would have deserved special attention. Furthermore, compliance with the requirements imposed by two specifications derived from two different codes has not been presented.

- The EU as well as the US licensing practice in applying the break exclusion concept to secondary piping is to demonstrate exclusion of breaks only for short straight pipe sections. In the case of the main steam and feed water Temelín piping layout ETE applies break exclusion for the first time in Europe for a layout with several welds over a distance of tens of meters (see ANNEX C, Figure 3) including 90 degree bends. At the same time the "bubliks" piping loops connected via T-joints to the main steam and feed water lines and leading to the relief valves and safety valves are excluded from this break exclusion demonstration, although the piping diameter is close to the main piping these loops are connected to. Considering rules and regulations and widely accepted requirements in the EU the design features as implemented represent a deviation from standard practice. The Austrian Experts' Team is therefore of the opinion that the standard justification is not sufficient and that more extensive evidence (see ANNEX A, Workshop Programme) would be required.

- The operator has strictly limited the application of the break exclusion concept to the main steam and feed water piping.

  The main steam piping in each of the four main steam lines has three branch sections "bubliks" connected via T-joints (see ANNEX C, Figure 3), which are piping segments from the main steam line to the BRU-A and MSSVs. These “bubliks”, as stated by the presenters, are not part of the break exclusion concept and have not undergone structure analysis.

  This should have been done for the following reasons:

  The “bubliks” and the piping connecting the “bubliks” to the main steam line are – in case of primary to secondary leak – part of the containment boundary, the ultimate radioactive effluents retention boundary. It is EU practice (in Germany, for example [KTA 3211]), to fully consider integrity of the piping from the T-joint to the relief or safety valve.

  The operator’s approach does not comply with this practice, and does not in the view of the Austrian Experts’ Teamrecognise adequately the significance of the “bubliks” as parts of the containment boundary.

  Without performing required stress analyses and postulating ruptures in the “bubliks”, the Austrian Experts’ Team considers this approach as not being in compliance with the HELB requirements designed to prevent consequences on equipment relevant to safety in the proximity of the lines.

- Considering the components, some aspects of the presentation on the “Superpipe Concept” do not appear to be strict applications of the NUREG-Standard Review Plan [NUREG 0800] or French Code [RCC-P] concepts, e.g., the use of actual material properties for break exclusion area piping stress verification.

  With this approach the allowable safety margins of piping load-bearing capabilities are changed. (The piping analyses are usually performed by checking the maximum stress encountered against the nominal material properties values multiplied by a safety factor according to the Code applied, in order to keep the additional margin against the actual material properties as a nominally not consumed safety asset).

Findings about the „SUPERPIPE concept“ application

The „SUPERPIPE concept“ was developed as simple design tool with respect to the integrity of pipelines that experience high operational loads due to unavoidable design requirements. For such pipeline segments special limiting criteria are defined for a sufficient safety margin between the load-induced stresses and the strength of the materials.

The SUPERPIPE concept as applied for the main steam line and the feed water lines in the NPP Temelín, units 1 and 2, has been analysed, showing that the approach is reduced to the comparison of the materials’ tensile strength characteristics and the stresses resulting from operational loads multiplied by defined safety coefficients.

The demonstration of the fulfilment of the SUPERPIPE concept criteria for the main steam line system (steel 16GS) is not possible using the normative specified minimum values from the Russian Codes: For at least two sections the allowable stress values are exceeded.

The Czech experts have made a statement contradicting that: *“All sections of the main steam line system meet the SUPERPIPE concept criteria.”* This statement is based on the replacement of the materials’ properties specifications according to the applicable standard by data from experiments taken from the so called “materials’ data base” (for piping material used for WWER-440 piping, and only a few values for the materials’ tensile strength available). These values must be considered non-representative for the design qualification for at least three reasons:

- The number of values from the so called “materials’ data base” is not significant enough to construct a statistically reasonable set
- The material specimen neither originate from the material used for production, nor is it from the same heat – it has not even an established comparability certificate
- The steam line materials’ strength must be expected to further decrease with increasing service time, based on the experimentally observed ageing effects.

Therefore the Austrian Experts’ Team recommends to the Austrian Government to continue monitoring maintenance and applicability of the database used for the SUPERPIPE concept.

3.2.2 Water Hammer

No.	VLI title/description
4	Monitoring of pipe internal dynamic fluid forces effects as a consequence of the postulated HELB (including geometry effects and blowdown characteristics)

- Several water hammer load cases for transient and accident conditions must be considered for the HELs at the 28,8 m level. The related presentation and the discussion did not reveal whether important load cases have received sufficient attention. These include:
  - Opening and closing of one or both MSSVs,
  - Blow down of steam water mixture followed by water,
  - Closing of the turbine stop valve in the turbine hall followed by closing of the main steam isolation valve,
  - Pipe break at the "bublik" T-joint, feed water line break in the turbine hall,
  - Feed water pump failure with closing of the isolation valve, and
  - Switching of the feed water pumps.
- The suitability of the Operation Base Earthquake (OBE) loading consequences – Service level B event – to envelope all water/steam hammer effects, as repeatedly stated, is questioned by the Austrian Experts’ Team. In fact, based on the low magnitude of the seismic event apparently assumed for ETE (deduced from the fact that no special seismic supports or shock absorbers have been installed), it seems to be difficult to demonstrate that the OBE event could envelope dynamic loading effects. There are usually quite significant water hammer effects especially on the FW lines, which can serve as an example. More evidence should therefore be presented to substantiate the above assumption. (According to US SRP [NUREG 0800] only the Normal and Abnormal Events (Service Levels A, B) shall be considered in order to obtain the piping state of stress for setting up the baseline for postulated HELBs).

Topical investigation on Generic Water Hammer Effects

The considerations put forward by the Czech side in accomplishing the CSCR have been communicated during the Specialists’ Workshop. As a result from this, several independent analytical investigations have been performed by the Austrian Experts’ Team as a complement to the above-mentioned bilateral exchange and critical investigation of information:

When monitoring the actual status of the “Bubliks” sections evaluation for compliance with Defense-in-Depth requirements in the Workshop follow-up, it was found that a conclusive solution to the water hammer loading has not been presented. The Czech Technical Support organization has indicated in a statement provided recently, that analyses to this open issue has been started already and will be continued in 2005.

In order to better understand the load histories resulting from Water Hammer and Pipe whip a dedicated investigation was conducted, making use of data correspondingly close to WWER 1000. Because the available data were not comprehensive enough for analyses perfectly representing such a plant, the Austrian Experts' Team determined the missing information from

- Data of similar plants
- Typical characteristics taken from several comparable NPPs' investigated by the Austrian Experts' Team.

That is why this is a "generic investigation", being valid for a plant behaviour similar to NPP Temelín. Recent information from UJD Řež confirmed that some assumptions made for the generic analyses are indeed Temelín specific. Other generic assumptions made were specified for Temelín but did not result in a big influence on the results already available.

For the analyses the Feed Water and the Main Steam Lines in room 820 outside the containment on level 28,8 m are not supposed to fail under any circumstances. It was assumed that the integrity of the containment and the wall between reactor building and machine hall must not be put at risk.

Loads which might in principle damage the Feed Water Lines and the Main Steam Lines result from the so called "water hammer", i.e. forces acting on the pipe line as a consequence of pressure waves and fast moving liquid masses in the pipe line.

Four cases producing significant pressure waves have been investigated:

(1) Break of a HEL's vertical pipeline section at the turbine hall wall with or without subsequent closing of a check valve or a (non-return) flap.

(2) Break of a "bublik" connecting the Main Steam Line to a Main Steam Safety Valve (MSSV) or to a Main Steam Relief Valve (BRU-A).

(3) Opening and closing the BRU-A and the MSSV's

(4) Steam is relieved after opening of the BRU-A and the MSSV's. In case the water level rises later on in the Steam Generator, water will flow suddenly and accelerated into the Main Steam Lines and then be stopped rather abruptly at the smaller cross sections of the valves (choking).

The loads resulting from these water hammer effects have been compared with estimated earthquake loads derived from seismic inputs for the Temelín NPP presented by the Czech partner in the frame of PN8 "Seismic Design". This was done in order to evaluate the relative significance of the water hammer load for the design.

Findings from a Generic Investigation on Pipe Whip Effects

Also a consequence of a rupture of the Main Steam Line or Feed Water Line in the turbine hall is the so-called "pipe whip". It results from acceleration of the broken pipe-end. An investigation of the Austrian Experts' Team, using a generic piping/support structure model, demonstrated that the pipe whip of the vertical pipe section outside the reactor building wall – leading into the turbine building, might damage the turbine hall separation wall and the support structures there. The other steam and waterlines running in parallel are of course put at risk as well. Consequences to the HELs containment penetrations and the containment itself depend on the stiffness of the HELs fixpoint at the wall separating the intermediate building from the turbine hall house.

Pipe whip consequential damage has been analyzed evidently for the Temelín NPP to some extent. At the Workshop, the assumptions about the supporting structure, and in particular of the pipe supports intended to limit the broken pipe movement, have been presented qualitatively only. The "generic" analyses leads to question the results applicability to rupture events at the vertical pipe ducts leading to the machine hall. The 28,8 m-Level support as well as the vertical pipe ducts surrounding areas might be at risk from pipe ruptures there. These rupture locations were not considered aggressive break points to be associated to eventually massive consequences. The brief information provided by ETE does not answer the questions about defense in depth being suitably addressed in this context. [UJD 2004]

Main Conclusions from the "generic" investigations

The loads resulting from water hammer effects can be compared with regard to nature and consequences only in a limited way with estimated earthquake loads. To evaluate the relative significance of the water hammer, the related result is:

Due to water hammer, the HELs at the 28,8 m level may experience loads significantly higher than those acting on them as a consequence of the earthquake specified for Temelín. The Czech statement that the earthquake loads could be considered bounding for the water hammer loads is in contradiction to this.

In the most severe case – (4) in the above – one reason for the rather high water hammer loads is the huge pipe length between the steam generators and the relief valves.

The pipe whip after rupture of a HEL must be assumed to act on the HEL at the 28,8 m level also in case one of the vertical pipes leading to the turbine building fails. In such a case the pipe whip loading that results for the containment penetration is likely to have an effect also on containment integrity, in case the fix point at the turbine hall wall cannot take the pipe whip loads.

Recommendations from the "generic" investigations

The Austrian Experts' Team's spot checks applied to key considerations put forward by the Czech side in accomplishing the CSCR – as communicated during the Workshop – has led to remarkable results:

Even though the results of the pipe loading investigations as performed by the Austrian Experts' Team cannot be applied exactly to Temelín NPP due to the generic character of the investigations, the trend shown should be seriously taken into consideration, i.e.:

- It should be investigated,
  - Whether there are significant differences between the information the Austrian Experts' Team used and the factual situation at the NPP Temelín,
  - What are the correct results and the correct conclusions to be drawn from the investigations made by the Austrian Experts' Team for the NPP Temelín.
- The immediate accident consequences should be analyzed with regard to bounding cases determined for dynamic loadings. Precautionary consequences should be drawn from confirmed bounding conditions only.
- The consequences of Austrian Experts' Team's results should be checked and transformed to consequences deemed applicable to the NPP Temelín.
- The intermediate accident consequences' analyses should focus on identifing the extent to which consequences to the reactor core, arising from accidents, are likely to evolve into events causing radioactive releases.
- It appears to be essential for both accident aspects to know the magnitutes and the frequencies of related accident scenarios.
- The Austrian Experts' Team therefore recommends to the Austrian Government to consider including these issues into future monitoring.

3.2.3 Pipe Wall Thickness (Flow-Accelerated Corrosion, Erosion/Corrosion)

No.	VLI title/description
13	Monitoring of the adequacy of the safety class components environmental qualification. This should be addressed in PN4. Only identification of candidate components requested
16	Monitoring of adequacy of MS & MFW piping outside containment in-service inspections programs

As far as known to the Austrian Experts' Team, Feedwater-lines operate, usually, at a significant state of stress and have experienced serious troubles in the past, both in conventional and nuclear power plants. At the same time the degradation effects of erosion/corrosion on FW lines are well known all over the world. The repeated statement that the stress-state of FW lines is very low and that huge safety margins exist was not supported with sufficient evidence.

- The flow-accelerated corrosion, which in general affects the inner surface layers of pipes resulting from the water/steam-water fluid specific chemistry operation regime (FAC, or erosion/corrosion) causes wall thickness reduction. This might induce risk of pipe leak or rupture. Continuous wall thickness monitoring is therefore a mandatory in-service inspection procedure. The presentation on this topic shows feed water system piping wall thickness dimensions that are at or close to the critical dimensions. Further reduction to below the critical wall thickness due to FAC results in failure of the pipe.

  Pipe wall thickness dimensions from some of the actual measurements are at or less than the minimum design value required.
- There was insufficient explanation by the operators experts why the new definition of the "nominal thickness" versus the actual measured values is acceptable in suggested compliance with the specification of the original Russian project of the Temelín VVER 1000.
- From the presentations it appears that pre-operational wall thickness measurement, as required by the Russian Code [RUS-ISI] (and European practice), was not performed. The information available to the Austrian Experts' Team is that the first measurements were performed only after start of the test operation. The pipe wall thickness verification has not been conducted before plant operation as required by the break exclusion approach.
- Insufficient detail was presented concerning the periodicity of planned wall thickness measurements for the main feed water system, and concerning the number and locations of thickness measurements planned and the basis for their selection.
- The implementation of wall thickness measurement procedures into the ISI program cannot be considered an "independent safety layer" (as declared by the representative of the licensing authority).
- Frequent outages during the plant start-up and test operation phases as well as non-steady state operation conditions do not allow the secondary side water chemistry to be kept within the narrow pH-levels bandwidth required for proper corrosion control and limitation.
- Despite the already redefined "nominal" wall thickness, the related presentations reported CHECWORKS™ lifetime predictions for only 16 years. Note that predictions of the widely used CHECMATE™/CHECWORKS™ program can considerably under-estimate the wear rate if the pipeline is not properly modelled – as happened in connection with several accidents reported in [NRC-Bulletins]. Thus the existence of "huge safety margins" on FW lines as seen by the presenters was not plausible to the Austrian Experts' Team.
- Characterisation of the current status, evolving changes prediction and therefore well-documented histories of all the elements of the HEL is mandatory for confirming the bases of re-qualification of the HEL according to break exclusion requirements. The procedures adopted have not been described or presented and monitoring of their adequacy was therefore not performed.

3.2.4 PTS[7] Methodology & Harmonisation with EU Practice

No.	VLI title/description
2	Monitoring of the criteria used to select pipe break locations and orientations
3	Monitoring of the postulated "aggressive" HELB points assumed in the analysis ("aggressive" means: "which can damage structures, systems or components important to safety sufficiently to impair safety functions to an unacceptable level")
14	Monitoring of the analysis methodologies to evaluate the plant response to MS & MFW HELB outside containment

The PTS analysis presented by the Czech side for the Temelín VVER 1000 (presentation by an expert of the plant operator) consisted of only a general approach. Even the PTS analysis for rupture of two main steam lines is indicated as "practically done" but not yet complete or presented in detail. PTS analyses for other events (small LOCA, opening of the pressurizer relief or safety valve, primary to secondary leaks and other events) are not set for completion until 2003-2004. The PTS issue was subject of the PN9 Specialists' Workshop in 2004 according to the Roadmap.

Accordingly, no conclusions can be drawn at this time on the adequacy of the approach or on the adequacy of implementation of the PTS calculations, despite the fact that rupture of two main steam lines could result in vessel overcooling and potentially result in PTS conditions.

3.2.5 Materials Database

No.	VLI title/description
18	Monitoring of requirements for materials used and for material degradation to be taken into account

The adequacy of the Materials Database compilation process as well as the uses made of the materials properties to demonstrate fulfilment of various requirements within the "Safety Case" are discussed below.

- It should be clarified which sections of the MFW and MS lines are made of heat resistant steel material ST 20 and which of 16GS.
- The Materials Database as presented seems to be insufficient: some evidence was given, but the results are not consistent because the test results used were produced using three categories of materials:
  1) "archival material" (eds. rem. [archive]) (here consisting of samples for the weldment properties documentation),
  2) "plant specific material" (from experimental welds made in Russia) and

[7] **P**ressurized **T**hermal **S**hock (PTS) can be the most serious intermediate consequence of – in between other initiating events – main secondary coolant pipe failure events. This type of event is likely to activate emergency core cooling. As a consequence cold emergency core cooling water enters the **R**eactor **P**ressure **V**essel (RPV) at certain flow rates over time. The PTS sequence results from cold water "tongues" when formed from the RPV inlet down the RPV wall causing a rapid temperature drop in this wall. These temperatures drop causes deformation stresses due to temperature differences in the RPV wall. Deficiencies originally of negligible influence on the load-bearing capacity of the RPV can result in stress concentrations with crack stress relief areas, relieving unbearable loads via crack propagation and eventually causing catastrophic failure of the RPV. PTS occurs also when the reactor vessel has been severely overcooled, and then subjected to re-pressurisation (for example, due to actuation of high pressure injection or even the higher pressure pumps in the emergency boration system). If the vessel is cooled below its nil ductility transition temperature and then re-pressurised, the resulting stresses from pressure and temperature gradients can cause brittle fracture of the vessel.

3) "industry base material" (specific for VVER 440 – and said to have been selected as material equivalent to the one used)

It was not demonstrated that differences in the results amongst the three categories were insignificant. The test results could also be interpreted to suggest that the three materials tested do not exhibit comparable properties (e.g. in terms of ductility or fracture toughness). In addition, the reported small number of validated results from experiments is not suitable to derive consolidated material properties for pipes, elbows and welds.

- According to applicable standards, more work must be performed to provide evidence, that the MFW and MS lines actual material properties are better than the minimum allowable properties according to the code applicable and applied. The Austrian Experts' Team could not find any justification to exclude the certified material characteristics (component passport data) from the database used.
- The tensile characteristics used within the "Superpipe Concept" do not appear to be representative because the origin of the material used for the specimen is not known, the number of experimental results is too low, and the certified values from the component passports are not taken into account.
- Some areas of evidence about establishing material properties quantification were provided, but results are not consistent. The claim, that the minimum material properties values required were met with a probability of 97,75%, was not demonstrated.
- The "as used" material properties derived from the database are not admissible, because in the "Superpipe" application case, the use of materials minimum properties values is required by the Standards applied [STD-MATL]. (The stress criteria of the "Superpipe" concept are not met for the main steam line system, if – as required by the code applicable – the minimum material properties values for yield strength and ultimate strength are used. The stress criteria are also not met if the certified material properties values from the component passports are used.)
- Regarding steel type ST20 properties, there appears to be a lack of experimental data for the lower temperature range and the weld material as well. The use of the piping material 12022.1 specimens' results to add additional information to the ST20 properties database raises questions about these data sets being representative for this database. (Using material from Dukovany NPP also raises questions about differences in material properties because the raw material has undergone different transformation processes to serve the substantially different design and operation conditions.)

  Additional technical information – like the reports mentioned in the references of presentation number 2 (as listed in ANNEX A)– would be essential to fully identify the activity performed and the results validation.

  In addition, the specific probabilistic model chosen to fit the data merely on the basis of a Chi-square-test is not justified unless further substantiated.

The related topical investigation performed by the Austrian Experts´ Team concludes in its Summary Statement (see ANNEX A) from the materials data base point of view:

These data (of the Materials Data Base) must be considered non-representative for the design qualification for at least three reasons:

- The number of values from the so called "materials' data base" is not significant enough to construct a statistically reasonable set
- At least the specimen of the basematerial do not originate from the material used for production of ETE piping, for the weld specimens it is not proven that they were manufactured from the same heat – there is not even an established comparability certificate
- With increasing service time a further decrease of the steam line materials' strength has to be expected, based on the experimentally observed ageing effect.

Therefore the Austrian Experts' Team recommends to the Austrian Government to continue monitoring maintenance and applicability of the database used for the SUPERPIPE concept.

- Regarding Charpy-V-Notch test results reported by the Czech side, indicating the materials ductility properties (used e.g.- for LBB demonstration cases), the following is evidently applicable for ETE:

  The requirements to be fulfilled were not specified. Fracture toughness properties of the steels used are rather low (properties in some cases considerably lower than k_{CV} = 51 J/cm^2 would be unacceptable if one applies KTA Rules as an exemplary European standard [KTA 3211]).

- The ageing results presented at the Specialists' Workshop have not been obtained by testing VVER-1000 secondary piping material as used for the MFWL and MSL (ST20, 16GS). This means that the information available on the ageing behaviour is not VVER-1000 specific and therefore not applicable for ETE.
- European practice regarding break exclusion applications (e.g., German KTA and French Tronçons Protégés) require post-weld heat treatment and post-weld surface treatment. The Czech experts told the Austrian Experts' Team at the Workshop that neither of these treatments was performed for welds in the break exclusion zone at Temelín. Therefore it is recommended to demonstrate that the state of the welds does conform to break exclusion requirements as they have been widely adopted in Europe.

3.2.6 Qualification of UT NDE

No.	VLI title/description
18	Verification of design, adequate maintenance and ageing effects

The adequacy of the UT-NDE procedures as well as the uses made of the NDT methods to demonstrate applicability of the break exclusion concept's various requirements within the "Safety Case" are discussed:

- To qualify ultrasonic testing (UT) methods in the context of ISI of the HELs at the 28,8 m level, the plant operator applied ensembles of weld shapes and defect orientations which do not represent worst case defects.

  It was not presented how the "false calls" problem due to geometrical indications can be dealt with (i.e., misinterpreting a weld defect as a non-defect geometry indication). The few examples of obtained defect images as presented indicate a kind of ultrasonic probe movement that makes it nearly impossible to discriminate between geometry and root defects.

  There seems to be no proof that the test block defects are representative and provide for readings comparable to those causing the real difficulties encountered in interpreting UT NDT indications and comparable to real defect in the weld root, the most critical case.

- The inspections of the circumferential welds of the HELs need to be performed with a probe movement parallel to the weld axis. In addition, X-ray frames' evaluation should be available to the UT inspectors to enhance decision making in the case of geometric indications.
- While the Czech side acknowledges the importance of NDT, the practical implementation has been delayed. This may be true also for the inspection intervals and the last finger print inspections on the welds foreseen for 2006; the Austrian Experts' Team would consider an earlier date much more preferable. According to the French code Tronçons Protégés document (termed "Superpipe" here) intensified 100% volumetric inspection is required for all welds. The expert from ETE indicated a remarkably reduced NDT application for ISI. An explanation by the Czech side on how the reduced programme is justified would be helpful.

- During the workshop differences in the interpretation between ČEZ a.s. and Nuclear Research Institute Řež were voiced about the inspection frequency and whether 100% in-service inspection (ISI) of all welds is required. To completely rely on break exclusion, as adopted by the Czech side, 100% surface and volumetric inspection of all welds in the break exclusion area is required.
- The inspection procedures for the “Superpipe” break exclusion strategy include their application frequency for material integrity and/or material degradation verification. This has not been described in the comprehensiveness required for monitoring. The 100% in-service inspection (ISI) requirement is evidently still at stake. USNRC requirements are also set up for 100% volumetric ISI inspection for the entire break exclusion area, without any exceptions. Unfortunately, the time schedule for NDE measures could not be discussed due to time restrictions at the Specialists‘ Workshop.

Nonetheless, some comments can be made:

- The related slides presented by the plant operator indicate a considerable reduction of the in-service inspection scope.
- The Specialtists’ Team recommends the use of state of the art detection probabilities below 100% for weld flaws, since possible misperception bears high-risk consequences potential.

3.2.7 Displacement Measurements at the 28,8 m level

- The displacement measurements – as described by the operator in detail when presenting the instrumentation installed – are an interesting start-up exercise detail. The testing and results, if they confirm acceptable movements, are a precondition for operation under normal conditions. In that these measurements are said to have confirmed PIPESTRESS simulation results for both units, they provide for confidence about the stress calculations for normal operation and can serve as good bases for stress calculations under adverse conditions.
- No indication was given on how these operational displacement measurements will be used for load cycles and furthermore for cyclic load pattern identification, accumulation quantification and effects verification as usually applied in the LBB application context. The more stringent break exclusion concept’s requirements could make use of it as an additional source of information.

3.2.8 Pipe Break Probability Calculations

No.	VLI title/description
17	Monitoring of event frequency evaluation of HELB and of consequential failures

- The probabilistic analysis considers only the welds between the containment penetration and the isolation valves. Neither failure of the piping itself, nor failure of the valves was considered. As such, the analysis appears to be incomplete. The results were put forward without considering the uncertainties of the estimates.
- The probabilistic analysis based on the PRAISE code was performed without specific relation to actual data obtained from the plant, e.g. to the results of the NDE qualification. A description of the input data, the assumptions, and the modelling approach were not included in the presentation. An update on the results is required to gain more insight into the real situation.

- The proper choice of probabilistic models for the input data was not argued in the presentation (evidence should not only be based upon assumptions, since e.g. the present technology application does not provide for 100% flaw detectability). An assessment of some parameters' statistical behaviour is considered necessary in order to avoid misinterpretations (e.g. application of the normal distribution might not be justified in some instances).
- Probabilistic analysis of pipe break frequency should take into account all contributors and all uncertainties involved. Not all information on statistical uncertainties concerning material properties, geometry, loading, corrosion, reliability of non-destructive testing and examination, initial cracks (location, orientation, size, depth), in-service inspection strategy, environmental conditions, etc. has been addressed in the analysis yet.
- The overall results with a small leak frequency for normal operating conditions (NOC) of 10^{-5} [events/y], a large leak frequency for NOC of 10^{-6} to 10^{-8} [events/y], and a rupture frequency (Double Ended Guillotine Breaks) of less than 10^{-10} [events/y] are not in line with industry experience (8,000 reactor-years of commercial NPP experience), which indicates corresponding values of $2{,}25\times10^{-3}$ [events/y] for small leaks, $2{,}7\times10^{-2}$ [events/y] for large leaks, and $9{,}5\times10^{-3}$ [events/y] for ruptures [LYDELL 2000]. In the absence of a more detailed presentation and of the opportunity to review the underlying detailed report(s), the results cannot be considered to be plausible.
- The presentation included an estimate of the failure frequency of the piping resulting from design basis earthquakes. Accordingly, the design basis earthquake has an assumed frequency of 10^{-4} [events/y], and the conditional probability of failure of the piping at the conditions of the design basis earthquake is 10^{-4} [events/y], yielding a failure frequency of 10^{-8} [events/y]. However, this is not the piping failure frequency comprising all earthquakes. Much larger earthquakes are possible below 10^{-4} [events/y], which have larger conditional probabilities of failure, for which the absolute frequency of failure contribution could exceed 10^{-8} [events/y]. The 10^{-8} [events/y] value cited in the presentation by the expert of the plant operator is not a summation of **all** earthquake-caused contributions to failure, but rather only a point estimate for one ground acceleration value. (Frequencies of 10^{-8} [events/y] are encountered with extraordinary ground acceleration patterns from events such as comet and asteroid impacts. This comparison may serve to illustrate that such extremely low estimated frequencies of pipe failure as the 10^{-10} result estimated appear problematic.)
- No seismic hazard analysis was presented. The basis for the adopted frequency of 0,1 g peak ground-acceleration is not clarified. Although the seismic analysis will be the subject of another workshop, at least some basis for the value presented would have been helpful (e.g., presentation of the seismic hazard curve).
- SÚJB, in its submission to the EC in October 2002 [CR 2002], cites the extraordinarily low frequency numbers denoted in the report cited. Even though frequencies below 10^{-8} [events/y] can only be supported with difficulty by current PSA methods, they generally lack plausibility compared with the industry experience that numerous steam line and feed water line ruptures have actually occurred. (This is in contrast to the situation with primary system piping, for which in more than 8 000 reactor-years of experience there have been zero large pipe ruptures, and for which regulatory acceptance of failure frequencies of 10^{-6} [events/y] and lower is relatively common.)

3.2.9 Thermal Hydraulic Analysis (TH)

No.	VLI title/description
15	Monitoring, based on plant safety analysis, for performances of mitigating systems, radiological consequences calculations and Monitoring of adequacy of emergency procedures to mitigate MS & MFW HELB outside containment and their extension into SAMGs

The purpose of TH analyses is to demonstrate that the safety principles of the Temelín NPP will be respected in case of multiple steamlines breaks at the 28,8 m level. In this context the reactivity transients caused by steamlines' breaks, which result in considerable rapid cool down of the primary coolant system are of particular interest. The duration and magnitude of the associated reactivity disturbances determine the resulting primary system pressure/temperature transients.

Application specification

Four different topics are covered in the Thermal Hydraulics (TH) presentation:

(1) Fuel integrity

(2) Maximum primary circuit pressure

(3) PTS-analysis input data

(4) Radioactive effluents release.

Evidence and demonstration

The Czech side gave an overview of their efforts related to the four topics named above. However, the calculations carried out and the results obtained need to be described in more detail to form a sound judgement on them. Without information about the input data decks, representation, boundary conditions and assumptions, the results presented cannot be monitored to the contrary the introduction into the topics (2) – (4) as presented implies comprehensiveness of the analyses. A full power analysis as input for the discussion of topic (1) was not made available. The thermohydraulic results presented for topic (3) are only part of the input deck for simulating the PTS issue. Local thermohydraulic information including heat transfer behaviour would be needed for appropriate monitoring of potential HELB related PTS events. The results of topic (4) are input for radioactivity release calculations, but no radioactivity source term has been disclosed.

Fuel integrity

- The SIR (Specific Information Request) describes the kind and amount of information, which would be necessary to adequately assess the calculations made and the results obtained. Based on the information provided, such an assessment cannot be made. While the applicability requirements for the codes DYN3D, ATHLET and VIPRE are well known to the Austrian Experts' Team, information on the calculation procedures themselves (e.g. DNBR analyses and code coupling) was not made accessible.
- The code DYN3D-ATHLET itself contains several correlations for the determination of DNBR behaviour (Departure from Nucleate Boiling Ratio, an indicator for rapid transition to reduced fuel cooling) developed especially for VVER-fuel elements. The use of such correlations would further simplify the evaluation.
- Information about important parameters during the analyses (especially the reactivity status in the core, the power behaviour, the core inlet temperatures and mass flow rates and the primary circuit pressure) would be necessary to fully appreciate the presentations provided by the operator.

Primary circuit integrity

The following information would be needed to monitor the effects of HELBs on the primary system:

- Full set of initial and boundary conditions
- Deviations from the Input deck used in Fuel Integrity (1)
- Time dependencies of important parameters

- Details about the modelling of the secondary side
- Information about the reactivity status of the core
- Reactor core damage assessment.

3.2.10 Comprehensive Safety Case Revisit (SÚJB Position)

The presentations during the workshop yielded only limited information on the interaction between the licensee, the regulatory authority and the management of the safety issues by SÚJB in regulating the safety of Temelín NPP. There was little evidence about such licensing process elements as:

- Evaluation of proposals from the licensee,
- Identification of all related safety aspects,
- Compliance with requirements and practices widely applied within the EU,
- Definition of requirements and conditions, findings, comments and requests set up by SÚJB and replies from the operator,
- Independent review from sources contracted by the regulator,
- Inspection activities performed by SÚJB staff.

The reasoning and the position of the Czech Safety Authority SÚJB therefore remain unclear.

- The presentation about SÚJB activities provided no evidence about the licensing strategies followed within the "Licensing Case" approval merely stated: "licensed according to Standard Review Plans" – and no evidence about the conformance of the Comprehensive Safety Case Revisit (CSCR) activities with it. A more detailed presentation would be needed to understand, for instance, the safety argumentation concerning the absence of PTS relevant cracks is not closed at the present time.

3.2.11 Reactivity Control and Safe Shutdown Requirement

The behavior of the Temelín WWER-1000 NSSS under severe accident conditions resulting from Main Steam Line guillotine breaks requires extensive analyses of various accident-scenarios in order to verify the solutions according to design and to understand options for the mitigation of consequences.

Results from calculations accomplished by the Austrian Experts' Team show that the effectiveness of the scram system is reduced by 20% if the most effective CRA is stuck in top position. The relative power contribution of individual assemblies in the surroundings of the stuck CRA is by a factor of two to three orders of magnitude higher when comparing it with the assemblies from the diametric opposite region of the core. Results show that reactor will be critical again if the temperature drops below 200 .. 197 °C.

Based on these results the Austrian Experts´ Team concludes that re-criticality in case of a stuck rod scenario connected with a MSLB remains still an open question, very important for clarification. For answers to be fully satisfying the required comprehensive analyses would have to be performed.

Since the results presented by the Czech side were not suitable to clarify the issue, the Austrian Experts´ Team recommends to the Austrian Government to monitor this re-criticality issue beyond the end of the current Monitoring Process.

4 EVALUATION OF THE MONITORING PROCESS ACCORDING TO THE VLIS

The Monitoring results reported here are the mere outcome of the analyses performed by all the specialists of the Austrian Experts' Team conduction the Monitoring and providing the results. The generic evaluation of WWER 1000 design features comparable to the Temelín was used to confirm or adjust the conclusions drawn to reflect the actual state of the units.

The demonstrated applicability of a break exclusion concept requires a comprehensive combination of preventive, protective and mitigative measures to be developed implemented and sustained during operation of a NPP. The Austrian Experts' Team monitors how the DID concept is upheld under the special boundary conditions imposed by the existing HELs and their environment. Furthermore, the team monitors the adequacy of the requalification process based on the information provided by the Czech side.

The Austrian Experts' Team arrived at the following views about attributing its findings to the Verifiable Line Items defined for the monitoring process.

The contribution to the individual VLIs – after being weighed against the verification scope – is summarised as the conclusive Preliminary Monitoring results.

In addition, the following broader context of Safety Culture implications was defined by the Austrian Experts' Team to collect the Monitoring findings on the interaction in the licensing process.

VLI title/description
Monitoring of the interaction of the operator, the manufacturer, the technical support organisations and the licensing authority with respect to HELBs solution implementation.
The Austrian Experts' Team deplored the limitations in evidence about the respective roles and the interaction of the operator, the manufacturer, the technical support organisations and the licensing authority in the qualification process, in the requalification process, in the Comprehensive Safety Case Revisit and subsequently during the persisting operational verification procedures. The presentations and comments during the workshop suggest that requirements and compliance determination play a dominant role in the living safety culture established. The monitoring process' progress and result could be enhanced considerably by providing evidence about the related procedures and specifications.

The Monitoring regarding the HELBs technology evaluation adhered to the 18 defined Verifiable Line Items presented below (see chapter 3.1), each followed by the preliminary monitoring result compiled from the Austrian Experts' Team's Monitoring findings:

No.	VLI title/description
1	**Monitoring of piping design approach and piping stress analysis methodology, considering piping and components qualifications, service levels, load combinations (including expected and unexpected steam/water hammer effects)** The Austrian Experts' Team welcomed the overview provided for the Comprehensive Safety Case Review: the logic of the design criteria, the design process and conclusive statements of compliance, however, were not provided. Similarly, the introduced so-called "Superpipe Concept" was not demonstrated to be embedded into the original design criteria, and evidence of code compatibility examination for the various codes, standards, rules and regulations was not provided. The Austrian Experts' Team observed deviations from the defense-in-depth concept: an integrated approach of prevention, protection, qualification and mitigation measures was followed only partially. Justification was not evident for these deviations from the defense-in-depth concept and from comprehensive application of standards chosen like ANSI/ANS or the US-Nuclear Regulatory Commissions Standard Review plan. Justification for excluding large portions of the HEL piping from the "Superpipe Concept" re-qualification was also not included in the presentations. The Austrian Experts' Team would appreciate obtaining a listing of the various codes, standards, rules and regulations applied in the HELB issue in order to properly monitor the compliance with the requirements. The Austrian Experts' Team is prepared to monitor in particular the "Superpipe Concept" specification for HEL piping and components and how its application relates to the French RCC code requirements. A presentation of the logic of the design process and criteria – starting with the premises and ending with conclusions formulated as clear statements of compliance with specific rules – would be helpful. Accessibility of related documentation to fill in gaps in the presentations would be a substantial asset.
2	**Monitoring of the criteria used to select pipe break locations and orientations** The Austrian Experts' Team received only some indications on how candidate selections of pipe break locations and the break's orientation have been accepted or eliminated. The selection procedure document would render the process transparent for also monitoring the decisions' basis to disregard break locations or larger pipe sections eligible, like the "bubliks". For the Austrian Experts' Team a thorough structure analysis of the entire piping up to the first valves after the containment penetration would provide for the necessary insight to determine breaks and secondary failure Defense-in-Depth requirements.
3	**Monitoring of the postulated "aggressive" HELB points assumed in the analysis ("aggressive" means: "which can damage structures, systems or components important to safety sufficiently to impair safety functions to an unacceptable level")** The evidence that "aggressive" HELB points were identified, subsequently postulated and analysed up to possible consequences could not be extracted by the Austrian Experts' Team from the information provided. It has not been made certain by the models used that loadings induced to the break exclusion zone from breaks outside this zone (i.e. in the containment or in the turbine hall) have been considered for maximum stress determination. Consequential failure induced effects would provide also information about the investigated occurrences severity. Information of this kind was not available for monitoring.

No.	VLI title/description
4	**Monitoring of pipe internal dynamic fluid forces effects as a consequence of the postulated HELB (including geometry effects and blowdown characteristics)** The Austrian Experts' Team was interested in Water Hammer load cases that were supposed to be examined for both the steam lines and the water lines and for various operational and accident transient conditions. The Austrian Experts' Team could not detect evidence that the Operation Base Earthquake loading consequences exceed all other dynamic loadings and would therefore be bounding load cases. Austrian Experts' team generic WWER 1000 analyses result in higher loads for water hammer than for earth quake conditions. Investigations of dynamic loads are also indicated in all cases of operational loads in combination with degraded piping components.
5	**Monitoring of the non-linear mechanical analysis to determine the whipping pipes dynamic response** The restrictions applied to the assumed break locations resulted in no recognised need for non-linear mechanical analyses. Jet forces and reaction forces on the pipe whip restraints were briefly described at the Workshop. The Austrian Experts' Team determined that any reconsideration of the Verifiable Line Item #1 will also add to the knowledge required here.
6	**Monitoring of the evaluation of jet impingement shapes, temperatures, pressures, directions and loads, insofar as to find out whether jet forces impulse to HEL or walls or components are likely to cause consequential failures** The restrictions applied to the assumed break locations resulted in no need for estimates of dynamic pipe whip response. Jet forces and reaction forces on the pipe whip restraints were briefly mentioned at the Workshop. Any reconsideration of the Verifiable Line Item #1 will also add to the knowledge required here. Simulation results used for the preliminary design of a separation wall were not made available. The Austrian Experts' Team obtained rather limited information on this subject.
7	**Monitoring of the proposed measures to protect safety related equipment from pipe whip, blowdown jets and reaction forces and separation of redundant features (requirements, material properties & sizing of pipe whip restraints and separating shields)** The provisions made to protect safety-related equipment as part of defence in depth concept application were not presented. Even for those protective features that are in place (separation wall, supports etc.), no technological information was made available to the Austrian Experts' Team. The current status of the line item could not be verified.
8	**Monitoring of the methodology and analyses of compartment pressurisation and environmental conditions following a postulated HELB** The Austrian Experts' Team recognises the environmental conditions specification as being a prerequisite for project PN4 "Qualification of Safety Classified Components". Within the scope of this project PN2 the Austrian Experts' Team learned, that secondary failure and the resulting environmental conditions should serve to determine how the components could stand these loadings. Additional information might be important for the Monitoring of environmental conditions at the 28,8 m level, including also information that is not available from project PN4.

No.	VLI title/description
9	**Monitoring of the structural design loads including pressure & temperature transients and dynamic reactions as consequences from HELB** In the presentations, the design loads required to be quantified for protection of safety related equipment as part of defence in depth concept application were identified for single events only and, for these cases, only qualitatively. Pipeline dynamics were treated based on a very theoretical simulation only. There is no need to intensify information exchange about theoretical aspects of this topic. The thermal-hydraulic simulations also performed for the POSAR support the Austrian Experts' Team's view on accident management questions. Further information would be desirable on the plant behaviour analyses results.
10	**Monitoring of the methodology for evaluation of structural adequacy of Seismic Category I structures (those civil structures required to fulfil safety functions)** The provisions made to protect safety-related equipment from failure due to consequences from seismic loadings should be part of defence in depth concept application; information about such provisions was not presented. Nothing was reported on this subject. The seismicity issue will be treated in project PN6."Site Seismicity".
11	**Monitoring of the structural analysis evaluation including local loads on the concrete Category I structures and non-safety structures whose damage may impair the safety of the plant** The load bearing capacity of 28,8 m steel girder support and concrete structures to protect safety related equipment from indirect damage is part of the defence in depth concept application. Results to this need were not presented. In the presentations at the Specialists' Workshop this topic was not addressed at all!
12	**Monitoring of the structural failures, environmental conditions and potential flooding that might result in loss of safety functions including Monitoring of main control room habitability** The provisions made to preserve vital safety functions and safety equipment as part of defence in depth concept application was not presented. The environmental qualification of electrical equipment should be examined in PN4. "Qualification of Safety Classified Components"
13	**Monitoring of the adequacy of the safety class components environmental qualification. This should be addressed in PN4 (monitored in PN4."Qualification of Safety Classified Components"). Only identification of candidate components requested** The listing of candidate components requiring environmental qualification (monitored in PN4."Qualification of Safety Classified Components") as part of the defence in depth concept application was not yet available. To the knowledge of the Austrian Experts' Team the identification and exemplary verification was not yet performed during project PN4.
14	**Monitoring of the analyses methodologies to evaluate the plant response to MS & MFW HELB outside containment** The elements necessary to monitor analyses and evaluations of plant response to High Energy Lines Breaks in order to provide for the safety of plant and the proper safety systems functions as part of defence in depth concept application were presented as overview information. The monitoring related to the Pressurised Thermal Shock vulnerability would take place in the context of project PN9."Reactor Pressure Vessel Integrity and Pressurised Thermal Shock". More detail would be required to enable the Austrian Experts' Team to consolidate a positive monitoring result.

No.	VLI title/description
15	**Monitoring, based on plant safety analysis, for performances of mitigating systems, radiological consequences calculations and Monitoring of adequacy of emergency procedures to mitigate MS & MFW HELB outside containment and their extension into SAMGs** Those elements of the safety analyses providing the basis for consequences mitigation options and evaluations of plant response and the adequate safety systems functions as part of defence in depth concept application were presented in an overview information. The monitoring of the Pressurised Thermal Shock mitigation procedures was declared completed in 2004 and has been treated in the context of project PN9."Reactor Pressure Vessel Integrity and Pressurised Thermal Shock". Fuel Integrity during bounding accident sequences was not discussed quantitatively but in some instances qualitatively. More detail would be required to enable the Austrian Experts' Team to consolidate a positive monitoring result.
16	**Monitoring of adequacy of MS & MFW piping outside containment in-service inspections programs** In Service Inspection to establish and sustain protection against High Energy Lines Breaks as part of defence in depth concept application was addressed in the context of periodic wall thickness history evaluation and Non-destructive Testing and Evaluation procedures implementation descriptions.The Austrian Experts' Team identified areas of improvement and at the same time the need for more detailed description of the procedures set up and implementation as well as of quality assurance. The 100% volumetric examination requirement should be followed. The Austrian Experts' Team could not conclude whether the Czech side has reached a defined position on this matter.
17	**Monitoring of event frequency evaluation of HELB and of consequential failures** The Austrian Experts' Team concluded that break exclusion applicability demonstration for very extended High-Energy Pipe ducts with large diameters could not be justified based solely on deterministic break location selection. Probabilistic fracture mechanics evaluation, in combination with probabilistic evaluation of NDE based flaw detectability, should provide break incidence frequency estimates regarding the defined break exclusion areas. The small leak and break frequency estimates supplied in the Workshop presentations do not relate well to industry experience and are therefore questioned by the Austrian Experts' Team. Additional evidence should be produced and provided in order to promote the monitoring on this Verifiable Line Item.
18	**Monitoring of requirements for materials used and for material degradation to be taken into account**
	The Austrian Experts' Team in monitoring the Materials Database development and materials properties definition process identified several areas for clarification: the selection procedures of "comparable" material for test specimen manufacturing could not be monitored conclusively. Its has not become evident to the Austrian Experts' Team that the material properties used for qualification of the stress analysis results are in line with the requirements imposed by the codes standards rules and regulation defined to be applicable. The Austrian Experts' Team could not interrelate the materials properties requirements for the two pipe materials used, as applicable for the "Superpipe Concept's" break exclusion requalification and the materials properties requirements defined for the High-Energy Lines in the design process, with the properties of the material "in place". Additional evidence about comparable and acceptable properties is required.

The VLIs Preliminary Monitoring result indicates a considerable number of distinct areas where sufficient information has been gained enabling conclusions to be drawn.

These results can be regrouped and associated to areas needing further investigation and provide an outline for the future Monitoring focus.

5 SUMMARY OF THE MAIN FINDINGS

The evaluation of the presentations held at the Specialists´ Workshop by Czech experts is discussed in the FMR in relation to the international practice and the Czech requirements including the legal framework.

The results of the bounding case calculations performed in support of the monitoring effort are respected implicitly in the argumentation. [**ANNEX F**]

All additional information collected during the work on the other Items, which have lasted from 2002 until late 2004, after the Bilateral Meeting on November 29 /30, 2004, has been duly taken into consideration, when transforming the original Preliminary Monitoring Report (created and issued as the result of PM4 in early 2003) into this Final Monitoring Report.

5.1 Findings about the CSCR

About the interaction of the operator, the manufacturer, the technical support organisations and the licensing authority with respect to HELBs solution implementation:

The presentations and comments during the Specialists´ Workshop suggest that the determination of requirements and the subsequent compliance verification should play the dominant role in the living safety culture for the realisation of the Defense-in-Depth concept established.

5.2 Findings about the 28,8 m Level

The Monitoring regarding the HELBs technology evaluation adhered to the 18 defined Verifiable Line Items (see Chapter 4) presented below, each followed by the monitoring result compiled from the findings:

- **With respect to the piping design approach and piping stress analysis methodology, considering piping and components qualifications, service levels, load combinations** (including expected and unexpected steam/water hammer effects):

  For the Comprehensive Safety Case Review: the logic of the design criteria, the design process and conclusive statements of compliance were discussed only in brief in the Czech experts' presentations at the Specialists´ Workshop. Similarly, the introduced so-called "Superpipe Concept" was not demonstrated embedded into the original design criteria, without evidence of code compatibility examination for the various codes, standards, rules and regulations.

  An integrated approach of prevention, protection, qualification and mitigation measures was followed only partially, thus deviating in part from the Defense-in-Depth concept.

  Justification for excluding large portions of the HEL piping from the "Superpipe Concept" re-qualification was also not included in the presentations.

  Accessibility of related documentation to fill in gaps in the presentations would be a substantial asset.

- **Regarding the criteria used to select pipe break locations and orientations:**

  Only some indications were received on how pipe break locations candidates were selected and on how the breaks' orientations have been accepted or eliminated.

- **Regarding the postulated "aggressive" HELB points assumed in the analysis:**

  From the provided information "aggressive" HELB points identification of the subsequently postulated, and analysed breaks up to possible consequences could not be followed. It is not certain that loadings induced to the break exclusion zone from breaks outside this zone (i.e. in the containment or in the turbine hall) have been considered for maximum stress field determination. Consequential failure induced effects would provide also information about the investigated occurrences severity. Issues of this kind would deserve more in-depth attention.

  - Results of explorative work by experts of the Austrian Experts´ Team for a generic WWER 1000 set-up for the Design Loads for the HELs at the 28,8 m Level:

    Experts of the Austrian Experts' Team performed calculations according to state of science and technology. The results indicate that the extent to which "aggressive" HELB points were identified and considered for the Temelín NPP in the design review fell short at least with regard to the so-called Bubliks.

- **With respect to pipe internal dynamic fluid forces effects as a consequence of the postulated HELB (including geometry effects and blowdown characteristics):**

  Water Hammer load cases, supposed to be examined for both, the steam lines and the water lines and for various operational and accident transient conditions would have to be performed. Evidence that the Operation Base Earthquake loading consequences would be bounding to all other dynamic loadings fell short in the demonstration.

  - Results of explorative work by experts of the Austrian Experts´ Team for a generic WWER 1000 set-up for the Design Loads for the HELs at the 28,8 m Level:

    The results indicate that design loads for the HELs at Temelín NPP appear not to be enveloped by the seismic loads, an assumption made and confirmed by the Czech side.

  Investigations of dynamic loads are also indicated in all cases of operational loads when combined with degraded piping components.

- **The non-linear mechanical analysis to determine the whipping pipes dynamic response indicated:**

  Non-linear mechanical analyses were phased out due to the restrictions applied to the assumed break locations. Jet forces and reaction forces on the pipe whip restraints were briefly presented at the Specialists' Workshop

  - Results of explorative work by experts of the Austrian Experts´ Team Team for a generic WWER 1000 set-up for the Design Loads for the HELs at the 28,8 m Level:

    The results indicate that design loads for the HELs resulting from jet forces and reaction forces considered together with the dynamic response of whipping pipes require non-linear mechanical analyses.

- **About the evaluation of jet impingement shapes, temperatures, pressures, directions and loads, insofar as to find out whether jet forces impulse to HEL or walls or components are likely to cause consequential failures:**

  The restrictions applied to the assumed break locations resulted in no need for estimates of dynamic pipe whip response. Simulation results used for the preliminary design of a separation wall were not made available.

- **With respect to the proposed measures to protect safety related equipment from pipe whip, blowdown jets and reaction forces and separation of redundant features (requirements, material properties & sizing of pipe whip restraints and separating shields)**

  The provisions made to protect safety-related equipment as part of Defense-in-Depth concept's application were not presented. Even for those protective features that are in place (separation wall, supports etc.), no technological information was made available to the Austrian Experts' Team.

- **In the context of methodology and analyses of compartment pressurisation and environmental conditions following a postulated HELB:**

  The environmental conditions specification is a prerequisite for project PN4 "Qualification of Safety Classified Components". Specific Information made available can be found in the related FMR.

- **On the context of structural design loads including pressure & temperature transients and dynamic reactions as consequences from HELB:**

  In the presentations, the design loads required to be quantified for protection of safety related equipment as part of Defense-in-Depth concept application were identified for single events only and, for these cases, only qualitatively. Pipeline dynamics were treated based on a very theoretical simulation only.

- **In treating the methodology for evaluation of structural adequacy of Seismic Category I structures (those civil structures required to fulfil safety functions):**

  The provisions made to protect safety-related equipment from failure due to consequences from seismic loadings should be part of Defense-in-Depth concept's application; information about such provisions was not presented. Nothing was reported on this subject. The seismicity issue was treated in project PN6."Site Seismicity".

  The Austrian Experts' Team, when monitoring the actual status of the "Bubliks" sections evaluation for compliance with Defense-in-Depth requirements in the Specialists´ Workshop follow-up, had to find out that a conclusive solution to the water hammer loading has not been presented. The Czech Technical Support organization has indicated in a statement provided recently, that analyses to this open issue has been started already and is supposed to be conducted during 2005.

  To some extent, pipe whip consequential damage has been analyzed evidently by the Czech experts. At the Specialists' Workshop, the assumptions about the pipes' supporting structure, and in particular of the pipe supports intended to limit the movement of broken pipes, have been only mentioned qualitatively.

  - Results of explorative work by experts of the Austrian Experts´ Team for a generic WWER 1000 set-up has lead to questions about the applicability of the results presented for Temelin to describe rupture events and pipe whip, that could damage the adjacent wall and impair the integrity of the HELs at the 28,8 m level.

- **As regards the structural analysis evaluation, including local loads on the concrete Category I structures and non-safety structures whose damage may impair the safety of the plant:**

  The load bearing capacity of the 28,8 m steel girder support and concrete structures to protect safety related equipment from indirect damage is part of the Defense-in-Depth concept application. Results to this need were not presented.

  - Results of explorative work by experts of the Austrian Experts´ Team for a generic WWER 1000 set-up for the Design Loads for the HELs at the 28,8 m Level:

    Steam or feedwater line pipe whip in the vertical section after the 28,8 m level might endanger not only the adjacent turbine hall wall and the HELs in this area but also the HELs at the 28,8 m level in case the fix point near by at the turbine hall wall is not capable to take the resulting loads.

- **With respect to the structural failures, environmental conditions and potential flooding that might result in loss of safety functions and habitability of the main control room:**

  The provisions made to preserve vital safety functions as well as safety equipment, part of the Defense-in-Depth concept application, have not been presented.

- **Treating the aspect of adequacy of the safety class components environmental qualification – candidate equipment selection:**

  There was no listing available of candidate components requiring environmental qualification, which could have been in PN4."Qualification of Safety Classified Components" as part of the defence in depth concept.

- **Regarding the analyses methodologies to evaluate the plant response to MS & MFW HELB outside containment:**

The elements necessary to monitor analyses and evaluations of plant response to High Energy Lines Breaks in order to provide for the safety of plant and the proper safety systems functions as part of Defense-in-Depth concept application were presented as overview information.

  - Results of explorative work by experts of the Austrian Experts´ Team for a generic WWER 1000 set-up lead to question, whether in case of a stuck rod scenario connected with a MSLB the Temelín NSSS remains in a controlled non-critical condition.

    The monitoring related to the Pressurised Thermal Shock vulnerability has taken place in the context of project PN9."Reactor Pressure Vessel Integrity and Pressurised Thermal Shock".

- **With respect to plant safety analysis, for performances of mitigating systems, radiological consequences calculations and Monitoring of adequacy of emergency procedures to mitigate MS & MFW HELB outside containment and their extension into SAMGs:**

  Those elements of the safety analyses providing the basis for consequences mitigation options and evaluations of plant response and the adequate safety systems functions as part of Defense-in-Depth concept application were presented as an overview information. This is also the context for events related to project PN9."Reactor Pressure Vessel Integrity and Pressurised Thermal Shock".

  - Results of explorative work by experts of the Austrian Team for a generic WWER 1000 set-up lead to questions about the behaviour of the Primary Coolant System and the Reactor Core:

    In a pilot study by experts of the Austrian Experts' Team the behaviour of the reactor core after a multiple lines break of the main steam piping has been analysed. According to the results, a WWER 1000 reactor like Temelín is likely to become critical after the scram with the most effective rod stuck in top position after a multiple steam line break.

    The results from calculations accomplished show that the effectiveness of the scram system is reduced by 20% if the most effective CRA is stuck in top position. The relative power contribution of individual assemblies in the surroundings of the stuck CRA is by a factor of two to three orders of magnitude higher when comparing it with the assemblies from the diametric opposite region of the core. Results for the end of the first cycle show that reactor will be critical again if the temperature drops below 200 to 197 °C.

  Based on these results the Austrian Experts´ Team concludes that re-criticality in case of a stuck rod scenario connected with a MSLB remains still an open question, very important for clarification. For answers to be fully satisfying the required comprehensive analyses would have to be performed.

  Fuel Elements' Integrity in relation to bounding accident sequences was not discussed quantitatively, but in some instances qualitatively.

- **With regard to the adequacy of in-service inspections programs of MS & MFW piping outside containment:**

  In Service Inspection was addressed in the context of periodic wall thickness history evaluation and Non-destructive Testing and Evaluation procedures implementation descriptions. The need was identified for more detailed description of the procedures as set up and implementation as well as of quality assurance.

  The general introduction into NDE practice at the TSO in Řež provided valuable indications about this topic.

- **In identifying the event frequency evaluation of HELB and of consequential failures:**
  Break exclusion applicability demonstration for very extended High-Energy Pipe ducts was accomplished with assuming the low leak and break frequency estimates supplied in the Specialists´ Workshop presentations, which do not relate well to European and worldwide industry experience and are therefore questioned.

- **Regarding requirements for the materials used and material properties degradation to be taken into account:**
  - Results of explorative work by experts of the Austrian Team for Materials Databases used as the basis for NPP's component materials and manufacturing specifications::

    The Austrian Experts´ Team performed a review of the information available about the material database used to support the evaluation regarding the Superpipe Concept applied by the Czech side for the HELs integrity verification at the 28,.8 m level. The outcome of this review gives reason in several contexts to raise doubts whether the material database is adequately consolidated for break exclusion confirmation of the HELs at the 28,8 m level.

  The Materials Database development and materials properties definition process leads to the identification of several areas for clarification: the selection procedures of "comparable" material for test specimen manufacturing allowed no conclusion. The material properties used for qualification of the stress analysis results and the requirements imposed by the codes, standards, rules and regulations defined to be applicable could not be seen as in line.

  The materials properties requirements for the two pipe materials used could not be interrelated, as applicable for the "Superpipe Concept's" break exclusion re-qualification. The materials properties requirements defined for the High-Energy Lines at the design stage do not correspond with the properties of the material "in place". Therefore the acceptance criteria for the appropriate material properties would be of interest and the compliance demonstration documentation as well.

  Furthermore, the material properties as defined at the design stage of the HEL could not be related to the material properties of the pipe sections installed.

5.3 SÚJB position

The SÚJB has acknowledged, accepted and approved the ETE approach for the 28,8 m-level HEL integrity demonstration and the associated accident scenario evaluation, including the consequential failure arguments, in particular also those conclusions drawn as a consequence of the Comprehensive Safety Case Revisit. The SÚJB has not asked for additional proof and did not impose additional requirements, besides a discussion of the ISI frequency that has not been closed yet.

6 CONCLUSIONS

6.1 Global Approach

The global approach as indicated in the presentations at the Specialists' Workshop provided for the following conclusions, which have been determined by the Austrian Experts' Team:

Since the identification of the HELBs issue several years ago, improvements are addressed in a comprehensive manner. The actions taken range from detailed examinations up to the measures implemented in the context of the "Comprehensive Safety Case Revisit" demonstrate a comprehensive process directed towards improvement. When considering the concerns expressed in the Austrian Technical Position Paper [ATPP 2000], the comparison with the current state also indicates a number of areas where improvements have been achieved and implemented.

The Austrian Experts' Team denotes, that it did not find reason to follow the views and expectations, expressed as a result of the Comprehensive Safety Case Revisit, upheld by the Czech side on the applicability of the break exclusion concept.

In this respect the following consolidated results were determined:

- **With regard to the materials used for the secondary High Energy Lines:**

  The comprehensive specification of the materials properties – as used and applied for the stress analyses results acceptance, for the break exclusion verification and for crack propagation to break at the pipe whip restraints' locations – should be an issue of in-depth exchange of information and expert discussion. The databases used for the materials properties' definition and the standards, rules and regulations applicable for defining the materials properties should be included therewith.

  Checking should be focused on the way material characteristics according to mandatory standards, rules and regulations are used and what is the significance of such characteristics in the licensing of components and assembled sections.

  The materials properties' requirements and verification of adequate properties of the materials used for the High-Energy Lines at the 28,8 m elevation should be supported by sufficiently qualified evidence.

- **With regard to the break exclusion concept verification:**

  The results of probabilistic analyses should also be an issue of in-depth exchange of information and expert discussion. Probabilistic analyses should include the failure probabilities of the entire piping ducts up to the first isolation valves. Moreover results from probabilistic fracture mechanics analyses for the duct exposed to maximum loadings should also be discussed.

  With regard to the special piping arrangement at the 28,8 m level concrete breaks' incidence rate assumptions are usually applied and certain In-Service-Inspection procedures are introduced. Comparisons for both issues with general industrial practice should be performed.

  The specific extensive use of the break exclusion assumptions and the associated deterministic break location definition should be supported by conclusive probabilistic acceptability results.

- **With regard to the break consequences:**

  The loads resulting from water hammer effects can be compared with regard to nature and consequences only in a limited way with earthquake loads as estimated.

Due to water hammer, the pipes may experience loads significantly higher than those acting on them as a consequence of the earthquake specified.

The pipe whip after rupture of the vertical section of a HEL must be assumed to act on the HEL at the 28,8 m level in such a way, that the pipe whip loading to the turbine hall wall is likely to have an effect on the HELs integrity at the 28,8 m level also, let alone secondary effects on the piping there.

- **With regard to accident consequences:**

  Exemplary severe High Energy Line Breaks' accident scenarios should be investigated with the following key elements: High Energy Line Break with the reactor at full power and control rods remaining stuck in top position, inhibiting a successful shut-down.
  The treatment should focus on the extent, to which accidents with consequences to the reactor core could evolve into events where releases of radioactive effluents are likely to take place.

  The nuclear power plant behaviour under severe accident conditions caused by High-Energy Line Breaks still requires extensive analyses of various severe accident sequences to understand options for the mitigation of consequences.

6.2 28,8 m Level Issues for future information exhange and expert discussions

The Austrian Experts' Team recommends pursuing further the issue of HELB as a major priority in the framework of the pertinent bilateral Agreement between the Federal Republic of Austria and the Czech Republic. This recommendation concerns the implementation and results from the HEL In-Service-Inspection programs as well as revisiting the major findings enumerated above. It is recommeded in particular to continue work on the mitigation of breaks of the HEL.

Items with high priority, where expert discussions based on additional and new information would be most valuable, are:

1.) **With regard to the materials used for the secondary High Energy Lines:**

Identification of the procedures used to determine material properties characterisation and their use in the component acceptance process according to mandatory standards, rules and regulations.

2.) **With regard to the break exclusion concept verification:**

Comparison with industry experience of break frequencies' assumptions specific to the particular arrangement of pipelines, and comparison with industry experience of the In-Service-Inspection adapted to the pipe ducts at the 28,8 m level.

The state of science and technology in codes and standards as followed in terms of consistency requirements in Western European practice.

3.) **With regard to accident consequences:**

Analysis of immediate accident consequences with regard to bounding cases determined for maximum dynamic loadings. Precautionary consequences should be drawn from confirmed bounding conditions only.

The intermediate accident consequences' analyses should focus on identifying the extent to which consequences to the reactor core, arising from accidents, are likely to evolve into events causing radioactive releases.

It appears to be essential for both accident aspects to know the magnitudes and the frequencies of related accident scenarios.

7 REFERENCES

10 CFR 50	U.S. Code of Federal Regulations [Code of Federal Regulations] TITLE 10 ENERGY PART 50 DOMESTIC LICENSING OF PRODUCTION AND UTILIZATION FACILITIES, US Government Printing Office, Washington D.C.
AQG CZ 2002	SÚJB approval decision as submitted by the Czech Government in a note to the Council of the European in October 2002 http://www.sujb.cz/soubory/AQGrevrec.pdf/.
ASME 1986	Section III, Nuclear Power Plant Component, Division I, ASME Boiler and Pressure Vessel Code, American Society of Mechanical Engineers, New York 1986
ATPP 2001	Austrian Technical Position Paper, http://www.umweltbundesamt.at/fileadmin/site/umweltthemen/kernenergie/temelin/Melk/Trialog/positionpaper/etetrialogreport_gesamt.pdf.
CHECKMATE™ CHECWORKS™	software packages focus on corrosion-related issues in the balance of plant portions of nuclear power plants, and to support the development and implementation of tools and software to assist nuclear operators in addressing corrosion issues throughout a plant's piping, vessels and the components of other systems. EPRI solutions Business Development, Headquarters, 3412 Hillview Avenue, Palo Alto, California 94304, U.S.A.
CR 2002	Safety Evaluation Summary NPP Temelín Comprehensive Safety Case Revisit subjected to High-Energy Steam and Feed Water Pipelines At the 28,8 m Level and Safety and Relieve Valves Qualification. Revision adapted for purpose of informing the European Council in frame of the EU enlargement process, SÚJB, Prague, October 2002
KTA 3211	KTA 3211.1 Druck- und aktivitätsführende Komponenten von Systemen außerhalb des Primärkreises Teil 1: Werkstoffe 4.2 Sicherheitstechnische Regel des KTA
KTA 3211. 1 to 4	Druck- und aktivitätsführende Komponenten von Systemen außerhalb des Primärkreises, Sicherheitstechnische Regel des KTA, Juni 1991
LYDELL 2000	B. Lydell, Pipe Failure Probability – the Thomas Paper Revisited, in Reliability Engineering and System Safety 68 (2000) 207-21)
Melk 2001	Conclusions of the Melk Process ad Follow-up, ANNEX I, Brussels, 29.11.2001
NRC-Bulletins	Nuclear Regulatory Commission Bulletin – Bulletin Board System, United States Office of Nuclear Reactor Regulation, Washington, D.C. 20555-0001
NRNSC 2001	National Report for the purpose of the Nuclear Safety Convention, Ref. 10366/2.0/2001, http://www.sujb.cz/docs/NationalReport.pdf.
NUREG 0800	NUREG-0800, USNRC Standard Review Plan U.S. Nuclear Regulatory Commission Office of Nuclear Reactor Regulation, Washington, DC 20555

ONDROUCH 2002	Ondrouch: Material Database Summary; Workshop at SÚJB, Prague, Czech Republic 7-8 November, 2002
PIPESTRESS™	(formerly called PS+CAEPIPE) is a library of interrelated software modules for static and dynamic analyses of nuclear and non-nuclear piping systems. It provides unmatched dynamic analysis power to handle complicated problems. SST Systems, Inc. U.S.A.
PMR-PN3	PRELIMINARY MONITORING REPORT PN3: BRU-A AND MAIN STEAM SAFETY VALVE QUALIFICATION FOR WATER AND TWO-PHASE FLOW, Institute of Risk Research – Austrian Research Centers Seibersdorf,Vienna, Austria, 10 February 2003
PNAE-G-7-002-86	Strength Analysis Standards for Equipment and Piping at Nuclear Power Plants; Energoatomizdat: Moskva 1989
POSAR	Pre-operation Safety Analysis Report, (declared confidential in 2002 by ETE)
PRAISE™	Computer code PRAISE-C for Double-Ended Guillotine Break (DEGB) Breaks from Weld Cracks in Light-Water Reactor Piping Systems, OECD-NEA NESC Databank
RCC-M	RÈGLES FONDAMENTALES DE SÛRETÉ RELATIVES AUX RÉACTEURS À EAU SOUS PRESSION, Règles générales applicables à la réalisation des matériels mécaniques (réf.: code RCC-M), (8 avril 1981); révision 1 (12 juin 1986).
RCC-P	RÈGLES FONDAMENTALES DE SÛRETÉ RELATIVES AUX RÉACTEURS À EAU SOUS PRESSION : Règles de conception et de construction des centrales nucléaires PWR. Recueil de règles relatives aux procédés tranches de 900 MWe (réf.: code RCC-P) ranches de 1400 MWe (réf.: code RCC-P) RÈGLE SIN N°3130/84 du 13 juin 1984
RCODE Pipes	GOST 8731-74, 8732-78, 1050-88 (close to API 5L, grade B, ASTM A106/A53)
RUS-ISI	Standard program of in-service inspection of the material state for base materials and welds for components and piping in NPPs of the type VVER-1000, ATPE-9-96, Moscow 1997.
STD-MATL	RÈGLES FONDAMENTALES DE SÛRETÉ RELATIVES AUX RÉACTEURS À EAU SOUS PRESSION, RFS-V.2.c. Règles générales applicables à la réalisation des matériels mécaniques (réf.: code RCC-M), (8 avril 1981); révision 1 (12 juin 1986).
SWSPR 2002	Specialists' Workshop Presentation made by the Czech side, Prague, November 7th and 8th, 2002.
USNRC SRP	U.S. Nuclear Regulatory Commission Standard Review Plan, (here especially USNRC SRP 3.6.2, BTP MEB 3-1), U.S. Nuclear Regulatory Commission, Washington, DC 20555 (equiv. to NUREG 0800).

WPNS 2001 — Contribution of the Commission services to question n° 1 of the questionnaire submitted on 13 September 2000 by the Presidency to the Atomic Questions Group in the framework of the mandate given to it by the Coreper on 26 July 2000, NON-PAPER (29/09/2000) EU, Brussels, 2000.

Report on Nuclear Safety in the Context of Enlargement, "I" Item, 13789/00 ATO 74 ELAR 210, General Secretariat of the Council, ATO 36 ELARG 118, Brussels 27 May 2001.

Report on Nuclear Safety in the Context of Enlargement, ADDENDUM TO THE "I" Item, 13789/00 ATO 74 ELAR 210, General Secretariat of the Council, ATO 36 ELARG 118, Brussels 27 May 2001.

Report on Nuclear Safety in the Context of Enlargement, CORRIGENDUM TO THE "I" Item, 13789/00 ATO 74 ELAR 210, General Secretariat of the Council, ATO 36 ELARG 118, Brussels, 5 June 2001.

Report on Nuclear Safety in the Context of Enlargement, "I" ITEM NOTE, 5034/02 ATO 1 ELAR 1, General Secretariat of the Council, ATO 1 ELARG 1, Brussels 5 June 2002.

ZDAREK 1997 — J. Zdarek, L. Pecinka, P. Kadecka & J. Dotrel: HIGH ENERGY PIPE LINE BREAK POSTULATIONS AND THEIR MITIGATION – EXAMPLES FOR WWER NUCLEAR POWER PLANTS; Nuclear Research Institute Řež, plc, Division of Integrity and Materials Řež ‘ near Prague Czech Republic, 23rd MPA-Seminar, Stuttgart, October 1 and 2, 1997.

ZDAREK 2002 — J. Zdarek, L. Pecinka, P. Kadecka, J. Rydlova, J. Andel: Superpipe concept application on steam and feed water lines; Workshop at SÚJB, Prague, Czech Republic 7.-8. November 2002.

ABBREVIATIONS

[Item No.1]	Identification chosen by the AQG/WPNS for the RPVI/PTSA issue
3D	Three-Dimensional
3SGT	3 Steam Generator Tube rupture
10CFR50	Section of the US Code of Federal Regulations on Nuclear Safety
16GS	Pipelines mild steel type
A	
A820 and 826/1	28,8 m level
aggressive	Most threadening (conditions)
ALARA	Safety concept: "As Low As Reasonably Achievable"
AM	Accident Management
ANNEX	Annex to the document
ANOC	Abnormal Operation Condition
Ansaldo	Consultant/Designer/manufacturer, Italy
ANSI/ANS	American National Standards Institute/American Nuclear Society
API	American Petrol Institute
APP	Application
APPENDIX	Appendix to the document
AQG	Atomic Questions Group
AQG/WPNS	Atomic Questions Group/Working Party on Nuclear Safety of the EU
archival	archive (material stored away for later use)
ARCS	Consultant: Austrian Research Centers seibersdorf research
ASME	American Society of Mechanical Engineers
ASME Code QME	American Society of Mechanical Engineers Code for Qualification of Active Mechanical Equipment Used in Nuclear Power Plants
ASME QME-1-1994	American Society of Mechanical Engineers, Qualification of Active Mechanical Equipment Used in Nuclear Power Plants, 1994
ASTM	American Society of Testing Materials
ATHLET	Advanced Thermal Hydraulics Code developed by GRS
ATPP	Austrian Technical Position Paper
austenitic	Alloyed, corrosion resistant, ductile steel
B	
BAM	Bundesanstalt für Materialprüfung (Germany)
BMI	Bundesministerium des Inneren
BRU	Steam Dump Station
BRU-A	Steam Dump Station/Valve to the Atmosphere
BTP	

C	
C3650	RCC-M Code Provisions
C3656	RCC-M Code Provisions
CC	Common Cause
CCF	Common Cause Failure
CCF/CMF	Combined Common Cause/Common Mode Failure deliberations
CEA	Commissariat à l'Energie Atomique
CERVUS	Working Group CERVUS
České Budějovice	City close to Temelín
ČEZ	České energetické závody – the Czech Electricity Generating Company
ČEZ a.s	ČEZ-Elektrarne Temelín – the portion of ČEZ, a.s. Operator of ETE: Energetická společnost ČEZ, as
ČEZ/ETE	ČEZ-Elektrarne Temelín – the portion of ČEZ, a.s. Operator of ETE
CFR	Code of Federal Regulations (USA)
Charpy	Designer of the embrittlement test procedure
Charpy-V-Notch Test	fracture toughness test using special specimen
CHECMATE™/	Corrosion wear prediction software developed by EPRI
CHECMATE™/ CHECWORKS™	Corrosion wear prediction software developed by EPRI
CHECWORKS™	Corrosion wear prediction software developed by EPRI
Chekhov	Checkov Company (joint venture with Siemens) producer of valves
chi square	Uncertainty quantification method
CHOOZ	Nuclear Power Plant where the conception adoptées pour les tranches du palier N4
cladding	Metal skin of nuclear fuel or the RPV inner surface
CMF	Common Mode Failure
Code	Consistent package of rules and regulations
Code-Case	Individually treated application of a Code setting requirements
Commissioning	Licensing Process
CONF	Czech Conference Paper Series (documentation)
Coreper	Every Member State has a Permanent Representative in the EU with the rank of ambassador. The fifteen Permanent Representatives together form the Committee of Permanent Representatives, better known as COREPER (Comité des Représentants Permanents)
CR	Control Rod
CRA	Control Rod Assembly
CRASH	PAM-CRASH an impact analysis code f
CSCR	Comprehensive Safety Case Revisit
CSCR	Comprehensive Safety Case Revisit
CUMULUS	valves test facility of EdF
ČZ	Czech Republic

D	
DBAs	Design Basis Accident
DC	Direct Current
DEGB	Double Ended Guillotine Break of main coolant piping
DID	Defense in Depth
DIMNP	Dipartimento di Ingegneria Meccanica, Nucleare e della Produzione, University of Pisa (Italy)
DITI	Publication Series source not identifiable
diversity	identical function provided by applying different means
DN	Nominal Diameter (of Pipes)
DNB	Departure from Nucleate Boiling
DNBR	Departure from Nucleate Boiling Rate
Doket	Document
ductility	Material property providing for deformation capability before rupture
duplicate	Reproduce test
DYN3D	3D Code
E	
EBP	IAEA-EBP: IAEA Extrabudgetary Program
EC	European Community
ECCS	Emergency Core Cooling System
EdF	Électricité de France
EE	External Event
ELAR	Enlargement of the European Union (documentation)
ELARG	Enlargement of the European Union (documentation)
ENIQ	European Network for Inspection Qualification
EOPs	Emergency Operation Procedures
EPRI	Electrical Power Research Institute
EQ	Environmental Qualification
esp	especially
ETE	Temelín NPP: Nuklearna Elektrarna Temelín (Czech abbreviation)
ETE1	Electrarna Temelín NPP Unit 1
ETE2	Electrarna Temelín NPP Unit 2
EU	European Union
Exec	Executable
F	
FAC	Flow-Accelerated Corrosion
Final Report	Final Monitoring Report
FMR	Final Monitoring Report
Framatome	Framatome, Designer/Supplier, France
FW	Feed-water

G	
GbR	Consultant: Innovativer Werkstoffeinsatz GbR
GOST	Code of Standards, Russia
GRS	Gesellschaft für Reaktorsicherheit –und Anlagen mbH (Germany)
Guidelines	Non-mandatory recommendations for an identified purpose
guillotine break	Break type perpendicular to the axis of the main component body
H	
Hanger	pipeline vertical support
Harmonisation	develop a coherent view or solution
HEL	High Energy Lines
HELB	High Energy Line Break
hexagonal	six edged cross-section shape of the ETE fuel element
I	
IAEA	International Atomic Energy Agency
IGCC	Intergranular Corrosion Cracking
Inc	Incorporated
IPU	SG Safety Valves (IPU-Valves)
IRF	Consultant: Institute of Risk Research, University of Vienna
IRR	Consultant: Institute of Risk Research, University of Vienna
IRR/ARCS	Monitoring Group of Consultants
ISI	In-service Inspection
Isometric	drawing projection method for engineering designs
J	
jacket	Here: equipment used for the prevention of jet impingement
jet	High speed flow (ejection)
JETE	Jaderna Electrarna Temelín
judgement	Result of factual and documented results assessed
K	
KED	Consultant: KED, Germany
KKW	Kernkraftwerk
KTA	Kerntechnischer Ausschuss – German Nuclear Standards Commission
L	
las	
LBB	Leak Before Break Method proving leak detectability before break
LBP	Low Break Probability Concept of SKI (Sweden)
LOCA	Loss of Coolant Accident
loop	Reactor Coolant Circut (piping, function)
Ltd	Limited

M	
MEB	Standard Break Requirements according to specification
MELCOR	Core degradation simulation code
Melk	City in Austria where the A – CZ "Melk Agreement" was signed
MFW	Main Feed-Water
MFWL	Main Feed-Water Line
Mochovce	EMO Nuclearna Electrarna Mochovce in Slovakia
mock-ups	physical representation of relevant component properties for testing
MONITORING	Austrian oversight process along the Temelín “Roadmap”
MS	Main Steam
MSIV	Main Steam Isolation Valve separating the steam generator from the turbine
MSL	Main Steam Line
MSLB	Main Steam Line Break
MSS	Main Steam System
MSSV	Main Steam Safety Valve
N	
N4	Usage classification for Pipin according to the French RCC code
NC	ASME-NC Section: ASME Code requirements
NDE	Non-Destructive Evaluation
NDT	Non Destructive Testing
NEA	Nuclear Energy Agency (OECD)
NESC	OECD Database
NOC	Normal Operation Condition
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission (USA)
NRI	Nuclear Research Institute (in Řež, Czech Republic)
NRI-Řež	Nuclear Research Institute in Řež
NSSS	Nuclear Steam Supply System
NUREG	Nuclear Code of Regulations of the NRC
O	
OBE	Operation Bases Earthquake
OC	Outside Containment
OECD	Organisation for Economic Cooperation and Development
OPB	Russian Code for Nuclear Installations
OST	Russian Code for Nuclear Installations (also GOST)
P	
P&ID	Piping and instrumentation diagrams
PAM-CRASH	Impact Analysis Computer Code
Passport	Certified materials properties document according to OPB requirements
PFM	Probabilistic Fracture Mechanics

PiNAE	Standards for eg. seismic design of nuclear power stations (Russia)
PIPESTRESS	stress evaluation code for pipelines
plc	Public Legal Company
PM	Project Milestone (PM1, PM2, PM3, PM4, PM5, PM6)
PMR	Preliminary Monitoring Report
PMs	Project Milestones
PN …	Project of the “Roadmap” (PN1 ... PN11)
PN2	Project Number 2 “High Energy Pipe Lines at the 28,8 m Level”
PN3	Project Number 3 “Qualification of Valves”
PNAEG	Standards for designing of nuclear power stations (Russia)
POSAR	Pre-Operational Safety Analysis Report
pp	... and the following pages
PRAISE	Probabilistic Fracture Mechanics Code
PRISE	Primary to Secondary Leak Event
Procedure	Qualified and approved sequence of actions serving a specified purpose
Project Milestone	subdivision of IRR/ARCS Project
PS+CAEPIPE	Original version of the now PIPESTRESS computer code
PSA	Probabilistic Safety Assessment/Analysis
PTS	Pressurised Thermal Shock (quenching shock of structures under high pressure and temperature)
PTSA	Pressurised Thermal Shock Analyses
PWR	Pressurised Water Reactor
Q	
QME	Quality of active Mechanical Equipment
QVC	Extension of Qualification from Parent to Candidate Valves
QVP	Qualification for Parent Valves
R	
RANKING	Importance of document requested
RCC	Règlements Code du Construction
redundancies	System portions providing for independent identical functions
Ref	Reference
Reference material	Material with well established properties
Řež	Here: Nuclear Research Center in Řež, Czech Republic
RFS	Règles générales applicables à la réalisation des matériels mécaniques
R_m	Ultimate strength from tensile test
Roadmap	Elaborated and agreed steps to be followed in the
$R_{p0,2}$	Yield strength from tensile test
RPV	Reactor Pressure Vessel
RPVI	Reactor Pressure Vessel Integrity
RPVI/PTS	Reactor Pressure Vessel Integrity/Pressurised Thermal Shock

RSK	Reaktor-Sicherheitskommission (Germany)
RUS	Russian
S	
S03, S04	Piping section identifiers
SA	Severe Accident
SAM	Severe Accident Management
SAMG	Severe Accident Management Guideline
SAR	Safety Analysis Report
sB	
Scenario	Sequence of events
scram	Emergency reactor shutdown
SG	Steam Generator
SGSV	Steam Generator Safety Valve
SHUTDOWN	Reactor out of operation
Similarity	Comparable operation properties of two components different in size
SIN	
SIR	Specific Information Request
SKI	Statens Kernenergi Inspectorate the Swedish Licensing Authority
sog	so called
spalling	
Specialists'	Experts Appointed for the Roadmap Process
SRP	Standard Review Plan of the US-NRC
ST 20	Piping mild steel type used at ETE
St20	Piping mild steel type used at ETE
STD	Standard
SÚJB	Státní Úřad Pro Jadernou Bezpečnost – Czech Licensing and Supervisory Body
SUPERPIPE	Indigenous "Safety Case" demonstration composed by the Czech partners
Surveillance	Properties development verification process
SV	Safety Valve
SWSPR	Service Water System Pressure Relief
T	
TH	Thermal-Hydraulic
TOR	Terms of Reference
toughness	Resistance to fracture, ductility of materials
Tronçons Protégés	Break exclusion procedure according to the French RCC
TSO	Technical Support Organisation
TX	system portions providing for independent identical functions

U	
ÚAM	Ústav Aplikované Mechaniky, BRNO, spol. s.r.o. Supplier SGs
UJD	Nuclear Regulatory Authority (UJD SR)
ÚJV	Ústav jaderného výzkumu Řež (ÚJV), Research Institute Řež
UONI	Welding procedure specification
US	United States of America
USA	United States of America
USNRC	United States Nuclear Regulatory Commission
US-NRC	United States Nuclear Regulatory Commission
UT	Ultrasonic Testing
V	
validated	Qualified for use in a validation procedure
VERLIFE	Unified Procedure for Lifetime Assessment of Components and Piping in WWER NPPs
VIPRE	Electric Power Research Institute's thermal-hydraulic licensing analysis code of the nuclear utilities
VLI	Verifiable Line Item
volumetric	Encompassing the entire material volume of interest
VVER	WWER synonym (Water-cooled Water-moderated Energetic Reactor = VVER is an acronym for Vodo-Vodyannoy Energeticheskiy Reactor)
W	
WORKSHOP	PM3 event in Prague
WPNS	Working Party on Nuclear Safety of the EU
WWER	PWR: Vodo-Vodyannoy Energeticheskiy Reactor–water-cooled, water-moderated, reactor; Soviet-design pressurised water reactor
WWER 1000/320	WWER 1000 [MW_e] Type 320

FORMULA ENTRIES

chi square .. ζ^2	Uncertainty quantification method
γ-heating	Heating due to Gamma-Irradiation
k_{CV}	Material fracture toughness quantification
M_B	Mechanical momentum
ø	Diameter (nominal) of piping
$R^{20°C}_{m}$	Ultimate strength from tensile test at 20°C
$R^{20°C}_{p0,2}$	Yield strength from tensile test at 20°C
R^{T}_{m}	Ultimate strength from tensile test at Temperature
$R^{T}_{p0,2}$	Yield strength from tensile test at Temperature
S_c	Allowable stress at cold system conditions
S_h	Allowable stress at hot system conditions
S_h+S_a	Allowable stress at hot system plus accident conditions
S_m	Maximum allowable stress
T_{test}	Test Temperature

SI-UNITS AND OTHER

Symbols

[°C]	Degrees centigrade = Temperature
[g]	gram
[J/cm^2]	Joule per centimetre square = specific cracking work
[J]	Joule = work
[K]	Degrees Kelvin = absolute temperature
[km]	Kilometer
[kN]	kilo Newton = force
[l]	liter = 0,001 [m^3] Volume
[m]	meter = length
[mm]	millimeter = length
[MN]	Mega Newton = force
[MPa]	Mega Pascal = specific force = pressure or stress
[MW$_e$]	Mega Watt electric = Nominal Power Output
[s]	second = time
[W]	Watt = power
pH [1]	pH has been more accurately defined as pH = -log aH$^+$ with the [pH] = [1] where aH$^+$ is the hydrogen ion activity. In solutions that contain other ions, activity and concentration are not the same. The acidity of basicity of a solution is related to the relative concentrations of H_3O^+ and OH^- : where log is a base-10 logarithm and [H$^+$] is the concentration of hydrogen ions in gram atoms or moles per liter of an aquatic solution, it provides a measure on a scale from 0 to 14 of the acidity or alkalinity of a solution (where 7 is neutral and greater than 7 is acidic and less than 7 is basic). In pH the "p" stands for the German word for "power", potenz, so pH is an abbreviation for "power of hydrogen".

ANNEX A

WORKSHOP PROGRAMME
ON HIGH ENERGY PIPING AT 28,8 m LEVEL

Revision 1, issued 2002 11 07

Workshop Programme on High Energy Piping at 28,8 m Level Date: 7-8 November, 2002 Place: SÚJB Prague

	Thursday November 7, 2002		
	Workshop opening.	Krs (SÚJB)	-----
1.	Temelín NPP position on high energy piping at 28,8 m level	Holán (ETE)	7.1
2.	Comprehensive safety case overview.	Žďárek (NRI)	7.2.1
3.	Dynamic calculations results due to the steam water hammer and water overfill overview.	Pečínka (NRI)	7.2.2
4.	Flow accelerated corrosion assessment.	Pečínka (NRI)	7.2.3
	Coffee Break (11^{15}-11^{45})		-----
5.	PTS methodology/harmonisation with EU practice.	Pištora (NRI)	7.2.4
	Lunch Break (12^{45} – 14^{00})		-----
6.	Material Database Summary.	Ondrouch	7.2.5
7.	**Qualification Dossiers for S-W Mixture of BRU-A and SGSV including EQ of BRU-A actuator.**	**Fridrich (NRI)**	**7.2.6**
	Coffee Break (15^{00}-15^{30})		-----
8.	Qualification of UT NDE	Horáček (NRI)	7.2.7
9.	Displacement measurement results.	Junek (ÚAM)	7.2.8
10.	Pipe break probability calculation overview	Pečínka (NRI)	7.2.9
	Friday November 8, 2002		
1.	UT NDE testing and results	Horáček (NRI)	7.2.7
2.	Summary of TH analysis.	Macek (NRI)	7.2.10
3.	Superpipe concept application on steam and feed water lines	Žďárek (NRI)	7.2.1
	Coffee Break (10^{30}-11^{00})		-----
4.	Time schedule and modifications required for 100% UT NDE.	Holan (ETE)	7.2.7
5.	SÚJB preliminary assessment of the Safety Case results.	Krs (SÚJB)	7.1
	Lunch Break (12^{00} – 13^{30})		
	Discussion on Safety Case Status (13^{30} – open end)	Included in comments	---------------------

ANNEX B

COMPARSION OF THE ETE SOLUTION WITH U.S. STANDARD REVIEW PLAN IN VIEW OF SÚJB'S REJECTION OF A PHYSICAL SEPARATION OF MAIN STEAM AND MAIN FEED WATER LINES

Comparsion of the ETE solution with U.S. Standard Review Plan in view of SÚJB'S rejection of a physical separation of main steam and main feed water lines.

The Regulatory Authority has shown satisfaction over the approach and the solution of the safety issue. The proposal of physical separation of Main Steam and Main Feed Water lines with a wall at 28,8 m level, in accordance with Western recommendations, was submitted as an additional safety feature by the plant operator. It was rejected because of the "significant restriction of maintenance and in-service inspection" caused by its presence in the area.

This position should be further examined for the following reasons:

The break exclusion approach as defined by the U.S. Standard Review Plan – Sect. 3.6.2 BTP MEB 3-1, B 1b (and by French [RCC-P]) – is an exception to break postulation, in the so-called "Containment Penetrations Areas" or "Break exclusion zones"[8]. only, provided that a set of specific requirements are met. This position is in agreement with General Design Criterion 4 of 10CFR50 Appendix A. The statement there is: *"dynamic effects with postulated pipe ruptures may be excluded from the design basis, when analyses demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis of the piping."*

Here in the following there are some excerpts on the criteria that must be met according to the above-mentioned SRP and the actual situation of the HEL at the 28,8 m elevation in the Temelín NPP:

Sect. B.1b (1): *"the following design stress and fatigue limits should not be exceed: for ASME Code Section III, Class 2 piping"* – the Temelín MS and MFW lines were produced to similar design requirements: *"The stress ranges calculated by the sum of equations (9) and (10) of § NC 3652 of ASME code, Section III, are smaller than 0.8 (1.2 S_h+S_a) for the normal or abnormal operation of the reactor; the maximum stress intensity calculated by equation (9) of § NC 3652 is below 1.8 Sh."* S_h and S_a are allowable stresses at maximum temperature, and allowable stress ranges for thermal expansion, *"as defined in article NC3600 of the ASME Code",* that means *"the minimum Code material properties."*

Material tensile properties data used at ETE for the demonstration of the fulfilment of the stress criteria are neither the code-based nominal values nor the minimum certified values from the manufacturer for the piping material as installed. If either one of these values were used, the break exclusion stress criteria would not have been met. Instead, values used are derived from test samples for which evidence of reliability for the original piping material has not been provided.

Sect. B.1b (2): *"Welded attachments, for pipe supports or other purposes, to these portions of piping should be avoided except where detailed stress analyses, or tests, are performed to demonstrate compliance with the limits of B.1 (1)."*

Along the HEL at 28,8 m level there are several weld-on attachments (e.g. pipe whip restraints reinforcing plates are welded to the main pipes). This solution is not allowed by German rules (KTA).

Sect. B.1b (3): *"The number of circumferential piping welds and branch connections should be minimised."*

Along the HEL at 28,8 m level there are several circumferential piping welds (elbows) and branch connections (three T joints connecting each steam line to the so-called "bubliks").

Sect. B.1b (4): *"The length of these portions of piping should be reduced to the minimum length practical."*

[8] The "break exclusion zone" is in Western NPPs the area of the piping between the Reactor Building containment penetration outboard weld and the upstream weld of Auxiliary Building anchor point beyond the isolation valves, including Main Steam safety valves and connecting branch piping.

The length of steam and feed water lines from the containment piping penetration to the isolation valves is in the order of tens of meters.

Sect. B.1b (5): *"The design of pipe anchors or restraints … should not require welding directly to the outer surface of the piping ..."*

This is the case with the pipe whip restraints fixtures (see also in the above).

The current ETE solution is not in full compliance with the principles of the above requirements and at the same time exceptions are adopted from each requirement.

ANNEX C

FIGURES AND SCHEMES

Revision 4, Issued 2003 01 12

Origin of the Figures

Figures	Title	Source
Figure 1	Scheme and Plant lay-out for a generic VVER	http://www.nucleartourist.com/type/vver.htm http://www.insc.anl.gov/sov_des/npfsubib.php
Figure 2	Temelín NPP mock-up in between other exhibiting the 28,8 m level area and two main secondary feedwater lines	http://www.insc.anl.gov/sov_des/
Figure 3	Temelín NPP – the main steam and feed water lines inside and outside the containment (at 28,8 m level)	WWER-1000 specific schematic

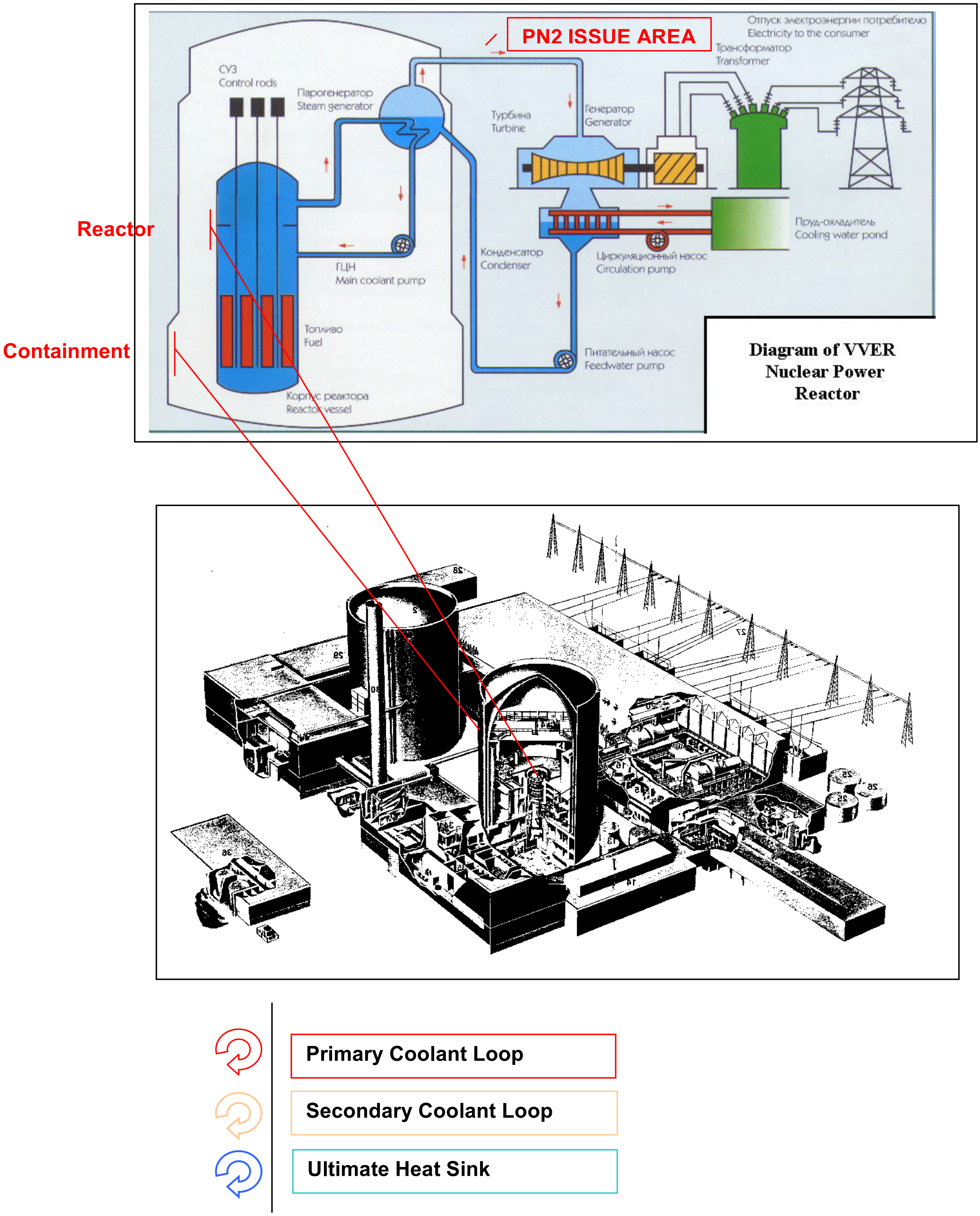

Figure 1: Scheme and Plant lay-out for a generic VVER

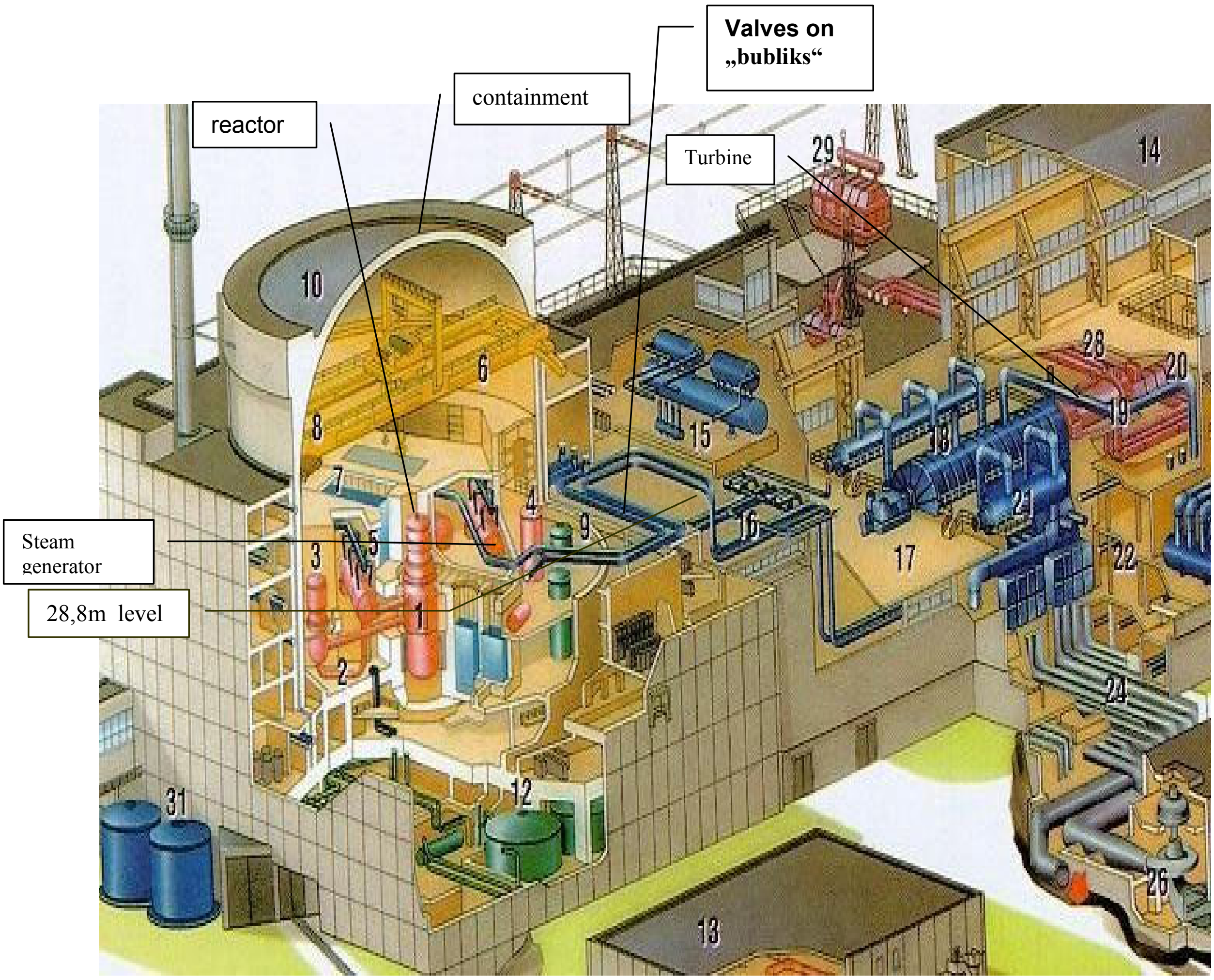

Figure 2: Temelín NPP – mock-up in between other exhibiting the 28,8 m level area and two main secondary feed water lines

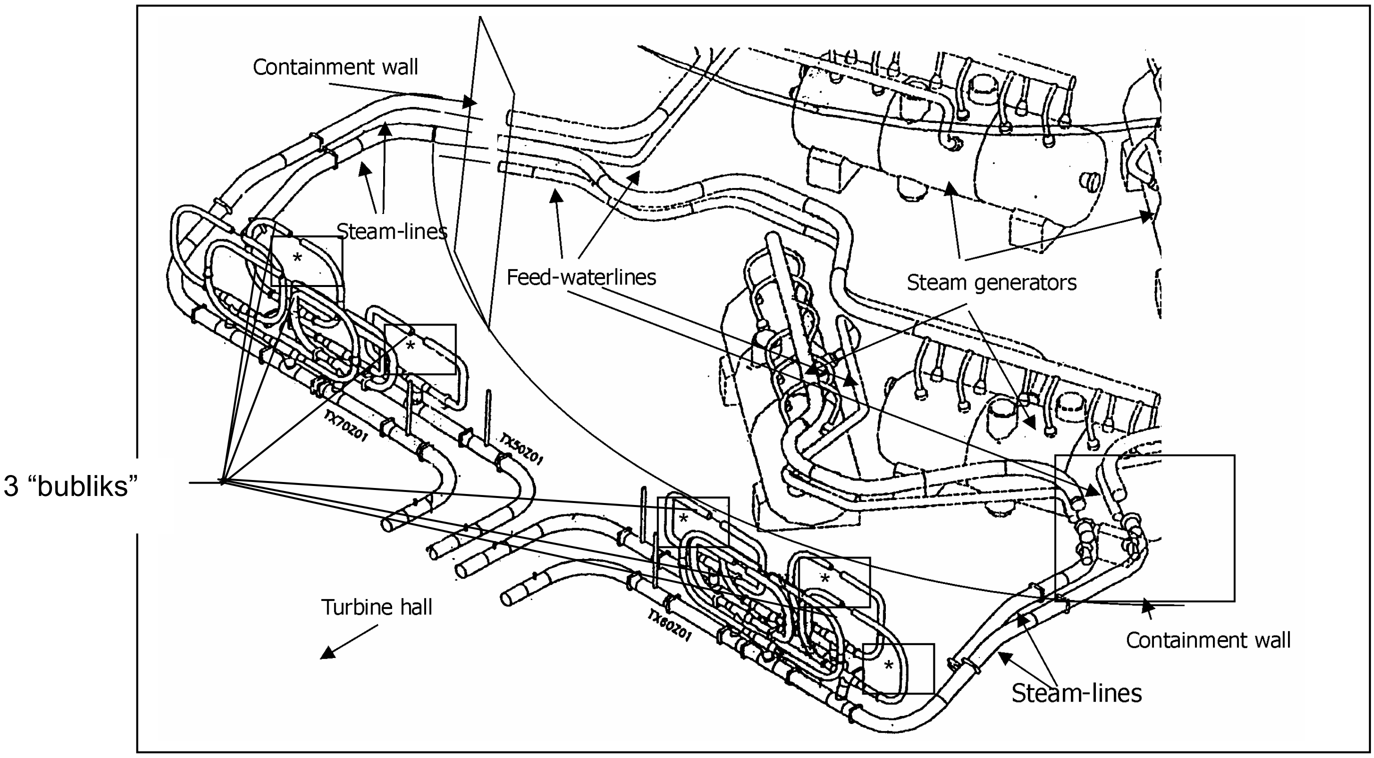

Figure 3: Temelín NPP – the main steam and feed water lines inside and outside the containment (at 28,8 m level)

ANNEX D

REGLES APPLICABLES AUX PROCEDES DES CENTRALES NUCLEAIRES A EAU LEGERE SOUS PRESSION DE 1400 MWE

(AUTHORS EDF AND FRAMATOME) FOR ORIENTATION ON THE “SUPERPIPE” IDEA.

REGLES DE CONCEPTION ET DE CONSTRUCTION DES CENTRALES NUCLÉAIRES REP

REGLES APPLICABLES AUX PROCEDES DES CENTRALES NUCLÉAIRES A EAU LÉGÈRE SOUS PRESSION DE 1400 Mwe

RCC-P1400

Document préparé par EDF et FRAMATOME

Révision 1 – Octobre 1991

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Révision 1
Octobre 1991

AVERTISSEMENT

Le [RCC-P] est destiné aux organismes chargés de la conception et de l'installation de systèmes des centrales nucléaires à eau sous pression et peut être utilisé dans le cadre de relations contractuelles entre le client (propriétaire-exploitant de la centrale) et le constructeur de la chaudière ou de l'îlot nucléaire, ainsi que dans celui de relations avec des Autorités de Sûreté.

Il traduit les règles de conception adoptées pour les tranches du palier N4, dont la centrale tête de série est CHOOZ.

Il est susceptible d'évoluer pour suivre les progrès techniques réalisés.

Ce document est établi et édité conjointement par ELECTRICITE DE FRANCE et FRAMATOME. Il ne peut être diffusé sans leur accord écrit.

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SOMMAIRE GENERAL

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Révision 1
Octobre 1991

QUATRIEME PARTIE

REGLES APPLICABLES AUX ETUDES DE FONCTIONNEMENT

CINQUIEME PARTIE

REGLES APPLICABLES A LA PROTECTION DES PERSONNES CONTRE LES RAYONNEMENTS IONISANTS

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Dans les règles suivantes, les calculs des contraintes et du facteur d'usage sont effectués en considérant le chargement faisant intervenir le séisme correspondant au demi-spectre de dimensionnement (voir chapitre 4.2) et les situations correspondant aux conditions de fonctionnement normal ou aux incidents de fréquence modérée (conditions 1 et 2)

3.1.3.6.1 Tuyauteries haute énergie

a) Circuit primaire principal (niveau 1 du RCC-M)

On retient 11 types de ruptures sur le circuit primaire principal, définis comme suit :

- boucles
  - 6 ruptures guillotine (aux entrées et sorties des composants: cuve, générateur de vapeur, pompe) ;
  - 1 rupture guillotine au milieu de la branche intermédiaire reliant le générateur de vapeur à la pompe ;
  - 1 rupture longitudinale à l'intrados du coude situé à l'entrée du générateur de vapeur ;
- piquages
  - 3 ruptures guillotine aux piquages de plus grand diamètre: circuit de refroidissement du réacteur à l'arrêt, accumulateurs et ligne d'expansion du pressuriseur.

b) Tuyauteries auxiliaires étudiées suivant les règles de niveau 1 RCC-M

On fait l'hypothèse de rupture aux points suivants :

- aux extrémités de la tuyauterie ;
- aux points intermédiaires où l'on a, à la fois, le facteur d'usage supérieur à 0,1 et l'amplitude de variation de la somme des contraintes primaires et secondaires entre deux états du système (calculée par l'équation (10) du paragraphe B 3653 du RCC-M), supérieure à 2,4 S_m ;

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- aux points intermédiaires où l'on a, à la fois, le facteur d'usage inférieur à 0,1, l'amplitude de variation de la somme des contraintes primaires et secondaires définie précédemment supérieure à 3 S_m, et les amplitudes de variations pour les contraintes d'expansion thermique, d'une part, pour la somme des contraintes primaires plus secondaires de membrane et de flexion (hors flexion thermique et expansion thermique) d'autre part, (respectivement équations (12) et (13) du paragraphe B 3653 du RCC-M), supérieures à 2,4 S_m.

Si aucun point intermédiaire ne peut être retenu de cette façon (ou s'il n'y en a qu'un), il en est choisi deux, sur la base des contraintes les plus élevées, présentant entre eux un écart d'au moins 10 % sur le niveau des contraintes ou, si l'écart est inférieur à 10 %, séparés par au moins un coude. Il peut n'en être choisi qu'un seul, au point où les contraintes sont les plus élevées, si la tuyauterie est droite, sans singularité et si toutes les contraintes sont en-dessous du niveau admissible.

c) Tuyauteries de niveaux 2 et 3 RCC-M

On fait l'hypothèse de rupture aux points suivants

- aux extrémités de la tuyauterie ;
- aux points intermédiaires où le taux de contraintes calculé par la somme des équations (10) et (7) des paragraphes C ou D 3650 du RCC-M dépasse 0,8 (1,2 Sh+ Sa), si l'analyse de contrainte est disponible.

Si aucun point intermédiaire ne peut être retenu de cette façon (ou s'il n'y en a qu'un), il en est choisi deux, sur la base des contraintes les plus élevées, présentant entre eux un écart d'au moins 10% sur le niveau des contraintes ou, si l'écart est inférieur à 10%, séparés par au moins un coude. Il peut n'en être choisi qu'un seul, au point où les contraintes sont les plus élevées, si la tuyauterie est droite, sans singularité et si toutes les contraintes sont en-dessous du niveau admissible.

Si l'analyse de contrainte n'est pas disponible, on fait l'hypothèse de rupture aux singularités de la tuyauterie (emplacements où le coefficient d'amplification de contrainte défini au paragraphe C3680 du RCC-M est supérieur ou égal à 2).

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d) Tuyauteries non classées – RCC-M

On utilise les règles de l'alinéa précédent.

3.1.3.6.2 Tuyauterie à moyenne énergie

On fait l'hypothèse de fissure traversante aux points où le taux de contraintes, calculé selon les équations (10) et (7) des paragraphes C ou D 3650 du RCC-M, est supérieur ou égal à 0,4 (1,2 S_h+ S_A).

Si l'analyse des contraintes n'est pas disponible, la localisation des fissures traversantes s'effectue selon les critères définis à l'alinéa d précédent du paragraphe 3.1.3.6.1.c.

3.1.3.6.3 Tronçons protégés

On ne postule pas de rupture ni de fissure traversante sur les tuyauteries haute énergie étudiées suivant les règles de niveau 2 du RCC-M lorsque toutes les exigences suivantes sont réalisées (critères de conception des tronçons protégés) :

- la longueur de ces tronçons est réduite autant que possible ;
- le taux de contraintes calculé par la somme des équations (10) et (7) du paragraphe C 3650 du RCC-M n'excède pas 0,8 (1,2 Sh+ Sa) ;
- les contraintes maximales calculées par l'équation (10) paragraphe C 3650 du RCC-M, sous les chargements résultant de la rupture de tuyauterie au-delà de la zone de traversée, ne dépassent pas 1,8 Sh (les chargements considérés sont le poids, la pression et les conséquences de la rupture).
- aucune soudure n'est réalisée sur la surface externe de ces tuyauteries à moins qu'elle ne puisse être contrôlée en volume à 100% et qu'une analyse de contraintes détaillée ne montre que les contraintes ne dépassent pas les valeurs de l'alinéa 3.1.3.6.1 c ;

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- le nombre des soudures circulaires ou longitudinales est limité. Si des fourreaux sont utilisés, il n'y a aucune soudure longitudinale, sauf si des accès sont prévus pour permettre leur contrôle volumique périodique ; les tronçons droits de tuyauteries sont réalisés à partir de tubes sans soudures ;

- les discontinuités géométriques, telles que les changements de section aux raccords tuyauteries-vannes, aux noeuds de tuyauteries, aux changements d'épaisseur de tuyauterie, sont conçues pour que les concentrations de contraintes soient minimisées;

- l'ensemble des soudures est soumis à une inspection renforcée précisée dans le programme correspondant.

Ceci n'est mis en oeuvre que pour les tronçons de tuyauterie eau et vapeur compris entre la traversée proprement dite et le point fixe extérieur.

3.1.3.7 Ruptures ou fissures traversantes postulées

Cette sous-section ne s'applique qu'aux tuyauteries hors circuit primaire principal pour lequel le paragraphe 3.1.3.6.1 est d'application et hors tronçon protégé (voir paragraphe 3.1.3.6.3).

Pour les tuyauteries de diamètre nominal inférieur ou égal à 25mm, on nt considère aucune rupture ni fissure traversante de tuyauterie pour ce qui concerne les conséquences mécaniques (jet, fouettement).

Il convient toutefois de vérifier que la rupture d'une ligne d'instrumentation du système de protection raccordé au circuit primaire ne conduit pas à des agressions provoquant :

Remark:

In addition to this Code and Regulation the following rules should be consulted whether applicable or not for the “Superpipe” approach:

RCC-M	paragraph
	C 3650
	D 3650
	B 3653
	C 3680

ANNEX E

LIST OF AUSTRIA PROJECTS

Austrian Projects Identification

PN 1	Severe Accidents Related Issues	[Item No. 7a]*
PN 2	High Energy Pipe Lines at the 28,8 m Level (AQG/WPNS country specific recommendation)	[Item No. 1]*
PN 3	Qualification of Valves (AQG/WPNS country specific recommendation)	[Item No. 2]*
PN 4	Qualification of Safety Classified Components	[Item No. 5] *
PN 5	Chapter V – Environmental Impact Assessment	
PN 6	Site Seismicity	[Item No. 6]*
PN 7	Severe Accidents Related Issues	[Item No. 7b]*
PN 8	Seismic Design	
PN 9	Reactor Pressure Vessel Integrity and Pressurised Thermal Shock	[Item No. 3]*
PN 10	Integrity of Primary Loop Components – Non Destructive Testing (NDT)	[Item No. 4]*

** The Items are related to ANNEX I of the "Conclusions of the Melk Process and Follow-up"*

ANNEX F

AUSTRIAN PN2 BENCHMARK EXERCISE

WWER-1000/320: List of PTS Initiating Events

At present guidelines for plant-designers recommend the following list of initiating events (IEs) to be considered for WWER-1000 PTS analyses. These IEs were used to explore the PTS in relation to the WWER-1000 emergency operation procedures and the thermal load transients as indicated in the second column.

In the third column the transients as selected for the Austrian benchmark exercise are denoted addressing WWER-1000 PTS events consequences to the RPV wall. Most of the work accomplished for a generic WWER set-up compares well to the actual ETE situation.

IAEA-EBP-WWER-08, IAEA, Vienna, April 1997		**Austrian Benchmarks**
#	**Candidate Transient**	**IRR/ARCS treatment**
1.	Spectrum of postulated piping break within the reactor coolant pressure boundary.	performed DEGB, limited LOCA intermediate
2.	Rupture of the line connecting the pressurizer and a pressurizer safety valve.	performed
3.	Inadvertent opening of one pressurizer safety valve.	Performed considered with 8.
4.	Leaks from the primary to the secondary side of the steam generator: • SG tube rupture • Primary collector leaks up to cover lift-up.	omitted
5.	Inadvertent opening of one check or isolation valve separating reactor coolant boundary and low pressure part of the system.	omitted
6.	Inadvertent actuation of ECCS during power operation.	considered with 3.
7.	Chemical and volume control system malfunction that increases reactor coolant inventory.	omitted
8.	Inadvertent opening of one steam generator safety or relief valve or turbine bypass valve.	considered with 9 in PN2 and PN9
9.	Spectrum of steam system piping break inside *(rem. IC)* and outside of containment *(rem. OC)*	performed for *OC* considered with 8 in PN2 and PN9
10.	Feed-water piping break	omitted

(List according to: Guidelines on Pressurized Thermal Shock Analysis for WWER Nuclear Power Plants, IAEA-EBP-WWER-08, IAEA, Vienna, April 1997)

ANNEX G

EXTRACT FROM THE “SPECIFIC INFORMATION REQUEST BY THE AUSTRIAN EXPERTS’ TEAM”

Technical Support
for the monitoring on the technical level of the implementation of
ANNEX I and ANNEX II of the
Conclusions of the Melk process and follow-up

Project No. 2

Item No.1.High Energy Pipe Lines at the 28,8 m Level
(AQG/WPNS country specific recommendation)"
PM2

Specific Information Request

DOCUMENT NO: **IRR/ARCS**-520-PN2-02-08

TITLE: Temelín Road map, PN2 – PM2: Specific Information Request

TABLE OF CONTENTS

Specific Information Request (SIR) in the context of " Item No.1 – High Energy Pipe Lines at the 28,8 m Level (AQG/WPNS country specific recommendation)"

Information about the use of the following tables:

The SIR asks for documentation and information about all Activities undertaken to resolve the "Safety Case", which are treated in the Comprehensive Safety Case Revisit (CSCR).

1. These **Activities are denoted** in the " 6th Additional Information to the Decision Paper on Chapter 14 „Energy" " (Document CONF-CZ-50/01, Brussels, 2001 09 17, **hereinafter in the APPENDIX I document**). It contains only aspects linked to the HELB issue that need to be treated (according to Conf-CZ 50/01). The Activities have been numbered individually in columns **1 and 2** of the Table in APPENDIX I.
2. **The requested Specific Information** (see the following table) is organised according to areas of interest for monitoring. **In column 1 on page 132ff it indicates the Activities** the document requested is thought to be related to.
3. *The **WORKSHOP** has indicated some of the **documentation** available and these titles have been added*)*[*)]. These titles have been added also here and the Activities they are associated with in column 7 (on page 132ff).

Since most of the documentation is known neither by exact title and author, nor by document number or identification code, the expected content is outlined in the following tables by an English short title, indicating the main topic(s) of interest. Based on this information, the organisational technology units at ČEZ/ETE, the supplier(s) and/or the licensing authority should be able to identify the relevant documentation.

Information contained in the documentation is needed as one supplement to create answers to the Verifiable Line Items. A positive answer to the Verifiable Line Items supports assumptions about an adequate, consistent and sustainable implementation of the Defense in Depth concept.

The Ranking I to III (introduced in column 2,3,4) of the SIRs applied in the following tables is only intended to indicate priorities for access to the related information. It does not indicate that some of this information is not required for the monitoring process.

[*)] It is understood that key documentation as it is cited in the individual WORKSHOP documents can also be accessed in the MONITORING Process under way.

Area	I	II	III	No	High Energy Pipe Lines at the 28,8 m Level – Specific Information Request	Related Activities see col 1,2 ↓
1	**2**	**3**	**4**	**5**	**6**	**7**
Codes and Regulations	x			1	Czech Codes and other codes & rules that were applied in the primary and secondary systems. Special attention should be given to the:	
	x				− piping integrity requirements	2.
	x				− design loads	2.
	x				− load combinations and structural parts	2.
	x				− mechanical, structural and ISI requirements for break exclusion demonstration	2.
	x			2	Specification of rules and regulations governing the application procedures of the simulation codes (used in stress analyses, pipe break loads and impact, water hammer, corrosion, probabilistic fracture mechanics …)	2.
	x			3	Safety evaluation and plant start-up tests evaluation report(s) issued by the SÚJB concerning Temelín insofar as the report(s) address(es) HELB issues	2.6.
	x			4	Safety Analysis Report (Chapters related to the topic in question, most recent revision)	1.
Material and Coolant Fluid	x			5	Data base for Fractures and Mechanical Properties Including Corrosion for Temelín NPP, ÚJV, Report 10294, October 1994 (as well as subsequent updates and replacements for this report)	3.3.
		x		6	Documentation of erosion/corrosion verification and mitigation programs applicable to the main steam and main feed water lines	2.
	x			7	Report on the determination of mechanical and fracture mechanical characteristics for all materials of the main steam and main feed water lines (ETE-1 and ETE-2)	2.
		x		9	Chemical composition and material properties for all main steam & main feed water (including welds, piping restraints, penetrations, and valves)	2.
		x		10	System specification of water chemistry and water treatment for main coolant pipes and secondary pipes (MS & MFW) and diagnostic parameter evaluation procedures (such as pH-value control in various operation regimes, concentration of oxygen ammonia, etc)	2.
Design		x		11	Determination specification and design of pipe whip restraint requirements/material properties	2.1, 2.2.
	x			12	Specification of break exclusion requirements, including the design basis and in-service inspection provisions to ensure that the design basis continues to be met	2.5, 3.1.
	x			13	Specification of pipe whip restraints requirements, including the design basis and in-service inspection provisions to ensure that the design basis continues to be met	6., 2.

Area	I	II	III	No	High Energy Pipe Lines at the 28,8 m Level – Specific Information Request	Related Activities see col 1,2 ↓
1	2	3	4	5	6	7
	x			14	Static and seismic analysis specification document, results evaluation and validation for the secondary coolant loops	2.
	x			15	Seismic design parameters for Temelín and floor response spectra used for the piping stress analysis for the main steam and main feed water lines (including penetrations, pipes, valves, welds, and pipe restraints)	2.
Loads	x			16	Design loads (such as water-steam hammer, design transients, seismic level, etc.) and load combinations specification (as used for ETE1 and ETE2)	2.
	x			17	Water hammer analysis specification and results documentation for the main steam lines and main feed water lines	3.2.
	x			18	Local loads on concrete structures and integrity evaluation of floors and walls for the main steam lines and main feed water lines	2.
		x		19	Beyond design basis accidents and the related load definition for high energy line breaks	2.
	x			20	Comprehensive loads and damage mechanisms specification for feed water and main steam lines, for the entire plant life	2.
Safety Provisions	x			21	Specification and documentation of modifications to the current plant Emergency Operating Procedures (EOPs) and severe accident management guidance planned to assist the plant staff in responding to HELB initiating events and consequential failures (probabilistic aspect)	2.4.
	x			22	Emergency Operating Procedures (EOPs) related to HELB initiating events (and consequential failures) response and management (probabilistic aspect)	2.4.
	x			23	Guidelines for severe accident management of severe accidents involving high energy line break initiating events and consequential failures (probabilistic aspect)	2.4.
Stress and Failure Analysis	x			24	Specification of criteria and methodology used for main steam line and main feed water line piping stress analysis and pipe rupture approach	2.
	x			25	Piping stress analysis of main steam lines and main feed water lines (loops 1 through 4) including the containment penetration and the piping extending from the penetration to the turbine building wall	2.
	x			26	Sensitivity Study of Stress Response of Steam Piping & Feed water Line after Hanger Failures, ÚJV, 10238, June 1994 (as well as any subsequent updates and replacements for this document)	2.
	x			28	Report evaluating the pipe break locations postulated for the main steam lines and main feed water lines (loops 1 through 4)	2.

Area	I	II	III	No	High Energy Pipe Lines at the 28,8 m Level – Specific Information Request	Related Activities see col 1,2 ↓
1	2	3	4	5	6	7
Failure Consequences Analysis	x			29	Report by the Regulatory Authority SÚJB evaluating multiple consequential pipeline failures resulting from HELB initiating events	1.
	x			30	Multiple pipe breaks analyses specification documenting exclusion of multiple main steam line and main feed water line breaks for demonstration for internal events and external events	2.
				31	Specification and documentation for modifications planned to reduce the likelihood of consequences of HELB initiating events and consequential failures	2.4.
		x		32	Assessment documents quantifying the likelihood of steam generator tube leakage or rupture as a consequence of main steam line rupture	2.4.
		x		33	Core neutronics/return to power analysis documentation (which underlies the PSA's assessment of accident progression analysis for HELB initiating events and consequential failures). Calculations and assessment covering multiple steam line, multiple feed water line, and mixed cases involving steam and feed water line ruptures should be provided as available	4.1.
Preventive Measures and related Components	x			34	Layout of existing design solution and proposed design solution for main steam line and main feed water lines from the containment penetration to the turbine building wall, with supports and restraints locations (if any) – "as-built" documentation	2.
	x			35	Pipe whip restraint and containment penetration restraint drawings for the main steam lines and main feed water lines (loops 1 through 4)	2.1, 2.2.
	x			36	Pipe whip sizing assessment and related reports for the main steam line and main feed water lines	2.1, 2.2.
	x			37	Proposal for Design Changes for Feed water lines ETE, Unit 1, ÚJV 10245 T, July 1994 (as well as any subsequent updates and replacements for this report)	1., 2.
	x			38	Design and arrangement of the main steam safety valves, main steam relief valves (BRU-A), and main steam isolation valves, including opening and closure behaviour description in accident conditions (delay, characteristics)	1., 2., 7.
	x			39	Component passports (especially valve data) for the main steam lines and the feed water lines (ETE-1 and ETE-2, loops 1 through 4 in both units))	7., 2.
			x	40	LBB Handbook covering the main steam lines and main feed water lines (if LBB is applied for this case by Czech side)	3.
			x	41	Leak before break (LBB) concept specifications and LBB calculations reports for the main steam lines and main feed water lines (loops 1 through 4, ETE1 and ETE2)	3.

Area	I	II	III	No	High Energy Pipe Lines at the 28,8 m Level – Specific Information Request	Related Activities see col 1,2 ↓
1	**2**	**3**	**4**	**5**	**6**	**7**
			x	42	Specification of leak detection systems for feed water and main steam lines surveillance	3.4.
			x	43	Evaluation report of jet impingement including temperatures/pressures response for the main steam lines and main feed water lines	2.3.
			x	44	Evaluation report of jet impingement shape including jet direction and loads for the main steam lines and main feed water lines	2.3.
		x		45	Specification of equipment used for the prevention of jet impingement effects on safety related equipment (protective jacket)	2.3.
		x		46	Jet shields drawings and sizing report for the main steam lines and main feed water lines (loops 1 through 4, ETE1 and ETE2)	2.3.
		x		47	Evaluation document of the postulated pipe break locations in relation to safety related equipment in the vicinity of pipe breaks	1., 2.
PSA and PFM	x			48	Internal events (IE) probabilistic safety assessment (PSA) for Temelín (updated circa 2002) (including the main report, attachments, and appendices to the main report, computerised plant model, PSA-software specification)	2.4.
	x			49	Most recent external events (EE) probabilistic safety assessment (PSA) for Temelín for which HELB is possible as a result of the initiating event (most recent issue thereof); main report, attachments, appendices to the main report, computerised plant model, PSA-software specification. Relevant initiating events may include, for example, aircraft crash or seismic events. (main steam lines and main feed water lines from the isolation valves to containment wall)	2.4.
		x		50	Reports analysing accident progression using the MELCOR (or other severe accident progression codes) for accident sequences initiated by HELB of the main steam lines and feed water lines from the containment penetration to the turbine building wall (loops 1 through 4, ETE1 and ETE2)	4.3.
	x			51	Most recent level 2 PSA for Temelín which provides the containment event tree, accident progression analysis, and source term analysis relevant to severe accident sequences involving HELB initiators and consequential HELB sequences (including the main report, attachments, appendices to the main report, computerised plant model, PSA-software specification)	2.4.
	x			52	Quantification of the initiating event frequencies for HELB in the main steam lines and main feed water lines (loops 1 through 4, ETE1 and ETE2) which provides the basis for the values used in the revised internal events PSA	2.4.

Area	I	II	III	No	High Energy Pipe Lines at the 28,8 m Level – Specific Information Request	Related Activities see col 1,2 ↓
1	2	3	4	5	6	7
	x			53	Quantification of conditional probability of consequential high energy line break following a HELB initiating event in the main steam lines and main feed water lines (loops 1 through 4, ETE1 and ETE2)	2.4.
	x			54	Documentation of quantitative basis of top events which appear in PSA sequence cut sets for which HELB is an initiating event or a consequential failure (system notebooks, human reliability analysis, or documents of comparable content for the quantitative basis for the top event)	2.4.
		x		55	Report about failure cases considered in the assessment of secondary failures resulting from HELB in the main steam lines and main feed water lines (loops 1 through 4, ETE1 and ETE2)	2.4.
	x			56	Probabilistic fracture mechanics (PFM) analyses documentation for the main steam lines and main feed water lines at Temelín NPP	2.4.
		x		57	Documentation on piping and instrumentation diagrams (P&ID) for the main steam and main feed water systems, including the instrumentation and control systems used for HELB events response and management in the emergency operating procedures and severe accident management guidance	1., 2.
Integrity verification	x			58	Specifications of in-service inspection (ISI) program(s) and related procedures applicable to the main steam lines and feed water lines including the immediate containment wall vicinity	6.
	x			59	Specifications of non-destructive testing (NDT) program(s) and related procedures applicable to the main steam lines and feed water lines including the immediate containment wall vicinity	6.
	x			60	Specifications of the NDT program for the main steam lines and main feed water lines (loops 1 through 4, ETE1 and ETE2), including a description of the methodology and a summary of NDT results before start-up, and the ISI procedures and results	6.
	x			61	NDT of circumferential welds and fillet welds of fixation plates in the areas covered by the pipe whip restraints for main steam and feed water lines:	6.
	x				− as built drawings of the set-up	1., 2.
	x				− test specifications and procedures	6.
	x				− results of qualification tests on reference specimens	6.
		x			− NDT equipment specification	6.
		x			− NDT records	6.
Operation		x		62	Plant operation data (if comparable or generic) suitable to demonstrate that corrosion (IGCC, stress corrosion, etc.) is assumed to be not a problem for the secondary system of the VVER 1000 NPPs and Temelín units 1 and 2	3.3

Area	I	II	III	No	High Energy Pipe Lines at the 28,8 m Level – Specific Information Request	Related Activities see col 1,2 ↓
1	2	3	4	5	6	7
		x		63	Plant operation data (if comparable or generic) suitable to demonstrate that erosion (flow velocity layout components, etc.) is not a problem for the secondary system of the VVER 1000 NPPs	3.3
	x			64	Report or database of historical HELB events used or established as part of the process of estimating the initiating event frequency for HELB	2.4.
Accident Scenarios and Accident Analyses	x			65	Description of the code(s) used for the HELB thermohydraulic plant (including qualification for VVER type reactors, modelling of the horizontal steam generator, degree of modelling, numerical description applied, critical (discharge) flow models, entrainment model(s), coolant mixing models and assumptions)	4, 4.1, 4.2
	x			66	Description of the code(s) used for the HELB thermohydraulic core analyses (including verification and validation basis)	4, 4.1, 4.2
	x			67	Description of the code(s) used for the HELB neutron-kinetic core analyses (including neutron-kinetic core model with approximations for steady-state and transient neutron flux distribution, code-qualification for calculation of hexagonal fuel elements, code verification and validation basis)	4, 4.1, 4.2
	x			68	Description of the coupling of the core and the plant models (including coupling of different codes used, proof of non-affecting the results in case of de-coupled analysis)	4, 4.1, 4.2
	x			69	Information about the degree of modelling the core, modelling of single components and about imple-mentation of control and safety systems (including modelling of essential plant components like loops, steam-generator primary and secondary side, relevant primary and secondary side pumps, thermohy-draulic and neutron-kinetic axial/radial nodalisation, macroscopic cross section library for reactor core)	4, 4.1, 4.2
	x			70	Description of the HELB scenario selected (including break location, size and number of affected loops, neutron-physical and thermohydraulic initial and boundary conditions, stuck open control rod position, availability of control and safety systems and actions during the transient)	4, 4.1, 4.2
	x			71	Assessment of the HELB scenario selected (i.e. a bounding scenario regarding core cooling/heat removal, fuel rod integrity, return to power after scram, including models/assumptions for primary coolant mixing in down-comer, lower and upper plenum and in the core)	4, 4.1, 4.2
	x			72	Description of the HELB transient calculations (including description of analysis performed, time-history of sequence of events concerning activation/de-activation of relevant control and safety systems, transients of core inlet temperature and of steam generator water level)	4, 4.1, 4.2
	x			73	Results of steady-state and transient calculations concerning reactor core (including control rod move-ment, transients of reactor power, of reactivity, of fluid temperatures/pressures at core inlet and outlet, of core mass flow, maximum temperatures of fuel/cladding/coolant, of 3D power distribution at minimal DNB locations, DNBR analysis results)	4, 4.1, 4.2

Area	I	II	III	No	High Energy Pipe Lines at the 28,8 m Level – Specific Information Request	Related Activities see col 1,2 ↓
1	2	3	4	5	6	7
	x			74	Results of steady-state and transient calculations concerning primary circuit model (including time history of coolant temperatures in hot/cold legs and mass flow rates in loops, pressure in upper plenum and pressurizer, water level in pressurizer)	4, 4.1, 4.2
	x			75	Results of steady-state and transient calculations concerning secondary circuit model (total/liquid/steam discharge mass flow rate through break opening, discharge coefficients, steam generator pressure and water level, steam line and safety/relief valves mass flow rates, feed water mass flow rates and temperatures for normal, auxiliary and emergency feeding of every single steam generator)	4, 4.1, 4.2
	x			76	Discussion of the results of the HELB transient thermohydraulic calculations performed (including information about sensitivity of results to specific parameters and modelling features)	4, 4.1, 4.2
1	2	3	4		6	7
Area	I	II	III	No	High Energy Pipe Lines at the 28,8 m Level – Specific Information Request	Related Activities see Col 1,2 ↑

Additional WORKSHOP documents*)

RANKING	I	II	III		Documents	Related Activities see col 1,2 ↓
1	2	3	4		6	7
Procedure assessment	x				Comparative study on regulatory requirements of the US NRC, CEA (France) and RSK – BMI (Germany) on pipe break postulations. Report DITI, May 2002	3.1
	x				LBB concept modification based on comprehensive study with the Break Preclusion Concept. Report DITI, May 2002	3
	x				“Superpipe” concept application according to the RCC-P on the steam lines. Report DITI, June 2002	(3 new)
Pipe Whip restraints	x				Pipe whip restraint[s] design for steam feed water piping outside hermetic zone. Report UAM, March 2001	2.1
Stress and displacement measurements	x				Project for strain gage measurement on steam and feed water lines. Report UAM, July 2001	3.4
	x				Displacement measurement on steam and feed water lines at A820 for Units No. 1 and 2. Report UAM, July 2002	2.6
Thermal Hydraulic Assessment	x				Thermal-hydraulic analysis of 2 MSL breaks for Safety Case 28,8 m at NPP Temelín. Report DITI, July 2002	4
Dynamic Forces Assessment	x				Dynamic response of steam and feed water lines on steam and feed water hammer. Report DITI 300/113, June 2001	3.2
	x				Integrity Assessment of Steam Lines on Primary to Secondary leak. Report DITI, August 2002	2.3
	x				Probability calculation of steam and feed water lines failure for NOC, ANOC and seismic loading conditions. Report DITI June 2002	2.4
	x				Steam line response on opening and closing BRU-A. Report DITI August 2002	3.2
	x				Steam Generator relief valve (BRU-A) discharge piping assessment for NOC and ANOC loading conditions. Report DITI, September 2002	3.2
	x				Qualification of impulse line connecting steam lines, SG impulse safety and safety valves for two phase a[nd] water loads. Report DITI, September 2002	3.2
Separation Wall Study	x				Determination of maximum forces due to pipe breaks on steam and feed water lines acting on separation wall. Report DITI May 2002	5
Material Database	x				Refinement of the materials database-mechanical and fracture mechanics properties for secondary circuit materials. Report DITI, July 2002	2

Containment Pipe Penetrations	x				Pipe whip restraint[s] effect assessment on containment pipe penetrations hermetic sealing ability due to postulated pipe break on steam and feed water lines. Report DITI, December 2001	2.1
PTS Method-ology	x				Methodology of the structural Part of the PTS Assessment for the NPP Temelín. Report DITI, July 2002	4.2
	x				Initiation events summaries for the PTS assessment. Report DITI, February 2002	4.2
UT NDE Qualification	x				Inspection procedure for UT NDE of fillet welds with fixation plates for pipe whip restraints. Report DITI, June 2002	6
	x				Inspection procedure for mechanised UT NDE of circumferential steam and feed water welds. Report DITI, June 2002	6
1	**2**	**3**	**4**		**6**	**7**
RANKING	**I**	**II**	**III**		**Documents**	**Activities Col 1,2 ↑**

APPENDIX I

REFERENCES IN THE SIR

are related **to the following Activities** as announced in Document
"Sixth Additional Information to the Decision Paper on Chapter 14 'Energy'" (Document. CONF-CZ-50/01, Brussels, 2001 09 17)

Activity No. in SIR column 7	#		Activity description	Status	Time schedule
1	2	3	4	5	6
1.		1	Preparation of Comprehensive Safety Case on Temelín NPP high energy piping layout at 820 and 826/1 BRU-A and SGSV steam-water mixture qualification (the report will comprise results of steps 2 – 7)	Started 30.1.2001	30.09.2001 1st Progress 30.10.2001 2nd Progress Rep. 30.03.2002 3rd Progress Rep. 30.06.2002 Final Report 30.09.2002 Regulatory Submittal
2		2	Stress state calculation and measurement including:		
	1	3	pipe whip restraint reassessment	Finished	10.03.2001
	2	4	pipe penetrations reassessment	Finished	15.08.2001
	3	5	integrity reassessment of steam piping due to water overfill	Started	30.10.2001
	4	6	probability calculation according to PRISE methodology	Started	30.10.2001
	5	7	(US NRC) in comparison with LBP Pipe (SKI Methodology		
	6	8	stress state measurements projects	Started	till 2003
3		9	LBB concept application assessment including:		
	1	10	comparison with Break Preclusion Concept	Started	30.10.2001
	2	11	dynamic loading calculations due to steam water hammer	Finished	15.08.2001
	3	12	E-C assessment	Started	15.09.2001
	4	13	LBB concept application according to the US NRC SRP 3.6.3.	Started	30.04.2002
4		14	TH analysis of multiple steam and feed water lines breaks in respect:		
	1	15	core cooling and final performance	Started	15.10.2001
	2	16	PTS situation		15.10.2001
	3	17	radiological consequences		15.10.2001
5		18	Feasibility study on separation of steam and feed water lines by qualified separation walls design	Started	30.06.2002
6		19	UT Qualification of method, equipment and personnel according to ENIQ methodology for circumferential welds and pipe whip restraint fixation elements, UT testing and assessment of results	Started	30.11.2001 and during outage
7		20	Qualification file development for the BRU-A valve and the SG SV (IPU-Valves) for steam-water mixture performance	Started	30.06.2002

ANNEX H

EXTRACT FROM QUESTIONS RAISED FOR THE BILATERAL MEETING 28 AND 19 NOVEMBER 2004 BY AUSTRIAN EXPERTS' TEAM AND ANSWERS PROVIDED BY THE CZECH SIDE

Questions:

1. KEDs fluid dynamic calculations of pipe breaks outside the fix point of the 28,8 m level in the machine hall of the longest and shortest feed water lines and main steam lines resulted in water hammer forces:

   Max. fluid force acting on longest horizontal pipe section of

   - feed water line: ~ 500 kN
   - main steam line: ~ 820 kN

   That is much more (roughly factor 5) than the maximum acceleration force due to earthquake (using the floor response spectra of the document; "Maly_SeismicQualific_vienna_2003b.pdf"

   Mail from IRF 16.11.2004

   Contrary to that: During the meeting at Prague nov.2002 it was told, that the earthquake load covers all other loads, especially water hammer loads.

   We would be interested, how had been derived that comparison by Czech side?

2. KEDs Finite Element calculations of pipe breaks of the main steam lines in the machine hall at ~13 m show that the pipe whip and the following impact between pipe and reactor concrete wall would damage parts of the wall as long as there are no pipe whip restrains between ~13 m and ~15 m.

   - Are there pipe whip restrains for main steam and feed water lines in that region?

3. During the meeting at Prague nov.2002 it was told, that it is allowed that a bublik breaks.

   - Has it been investigated if the lateral jet force due the bublik break might cause a damage of the main steam line?

Enclosure

Question 1:

French “superpipe” concept according RCC-P Article 3.1.3.6.3 is based on the RCC-M Code, Article C3650, equations (7) and (10). In equation (1) the following requirement shall be met

$$S_a = \frac{P_{\max} D_0}{4 n_t} + 0.75 i \frac{M_A + M_B}{Z} \leq 1.2 S_n$$

where MB is the resultant moment due to occasional loads, such as thrust from relief and safety values loads, from pressure and flow transients and specified earthquake effects. Loads from pipe rupture beyond anker are not included. Of course it is possible to analyse this case but the level D criteria according Article C3656, i.e. $S_a \leq 2.4 S_h$ shall be taken into account.

Our statement from the 3rd Workshop, Nov. 2002 is thus correct.

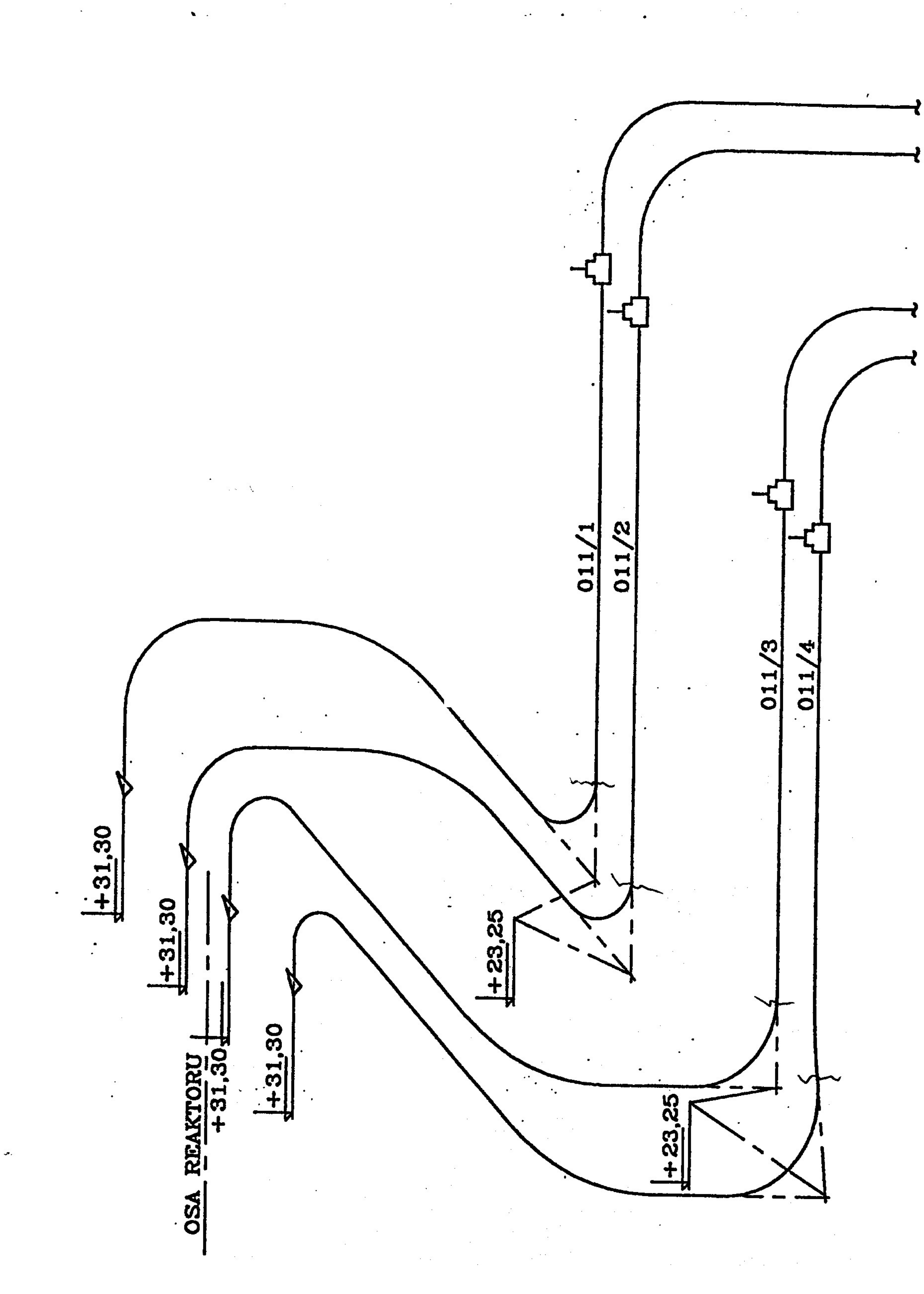
Question 2:

In the turbine hall the breaks shall be postulated according MEB 3-1, BTP.c (2) (b) (i), i.e. at each pipe fitting (e.g. elbow, tee, cross, flange and non-standard fitting) etc.

According our opinion, the worst case is the break postulation in the elbows on the floor +23,25 m, see Fig. 1 and 2. For the analysis of wall-piping impact using of such computer code as PAM-CRASH is advantage. Can you inform us about the methodology of KEDs Finite Element calculations ? Second question: what do you mean under word “damage”? Is it scabbing or spalling? According to our very simple calculations perforation is impossible.

Question 3:

The analysis of bubliks started and will continue next year.


011/1
011/2
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+31,30
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OSA REAKTORU

Fig. 1

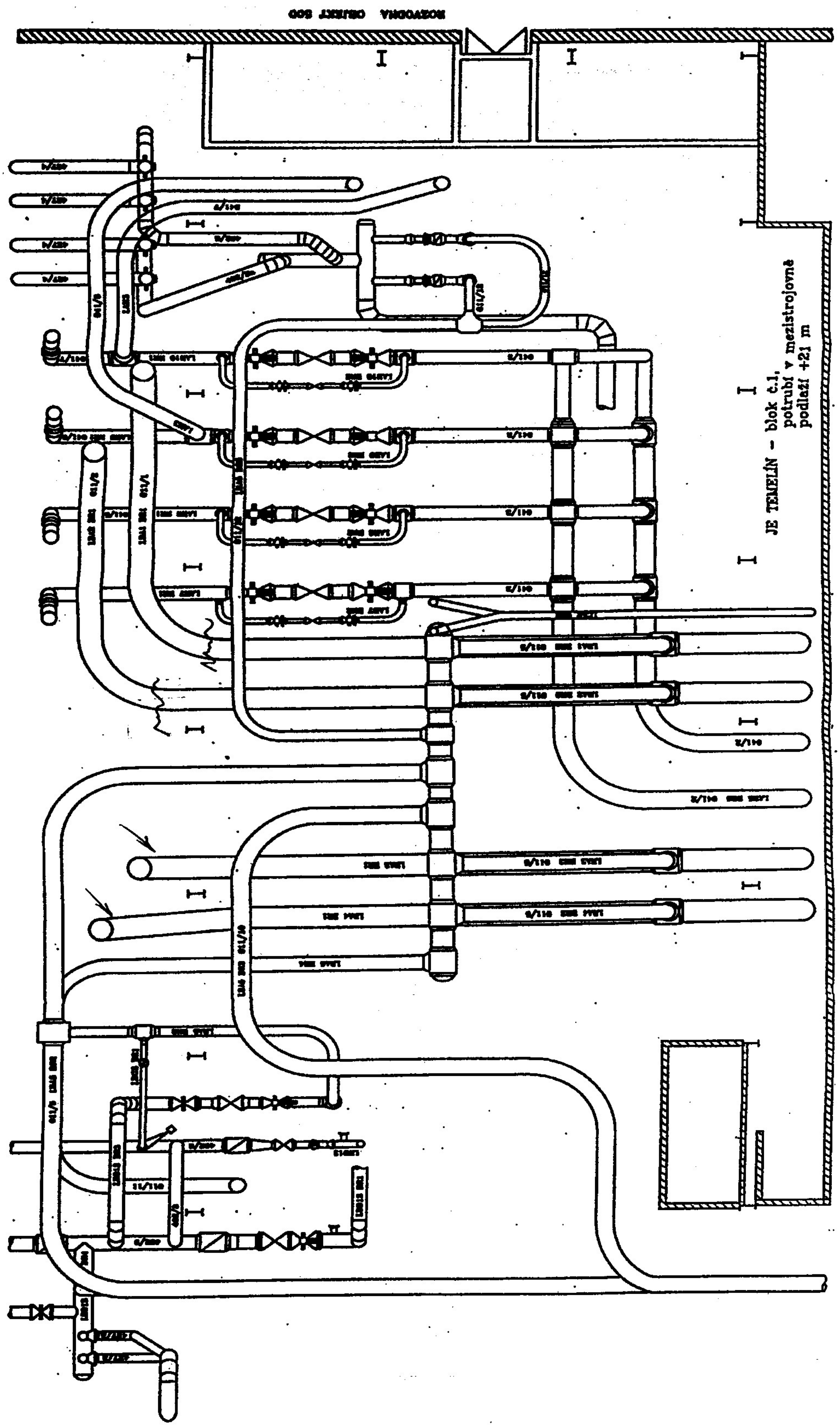


Fig. 2

Temelín Roadmap

Open Questions concerning Steam and Feed Water Lines of Temelín NPP.

Replies:

ad 1) In Fig. 1 are not indicated valves. It is only top view on the run ø 630 × 25 and the T joints to bubliks;

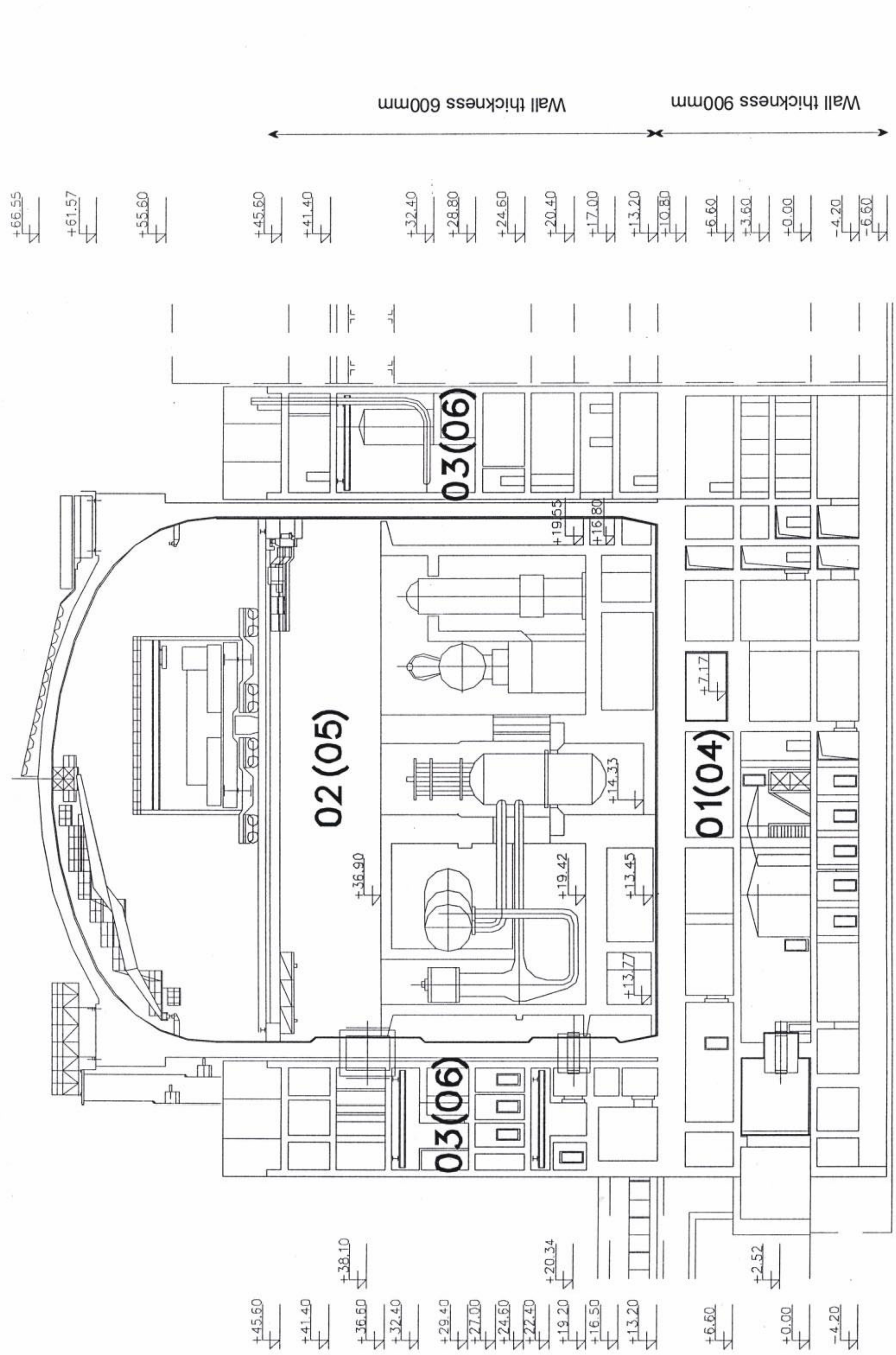
ad 2) In the steam lines between SG and machine hall are not flow limiters;

ad 3) Yes, we confirm this parameters. But have in mind that design parameters are higher;

ad 4) Swing check valves with disk position indicator DN 400 PN160, p_p – 8.6 MPa, type A 42 127 – 4160 – 400 minimal internal diameter 320 mm, welded into piping ø 426 × 24, too in series, body of austenitic steel (forged + welded). (TX 41, 42, 43, 44 S03, S04) – main feedwater piping L = 1010 mm;

ad 5) The wall thicknesses are illustrated in enclosed Figure;

ad 6) Inside machine hall on the vertical wall are not installed pipe whip restraints.


Wall thickness 600mm
Wall thickness 900mm
02 (05)
01(04)
03(06)
03(06)

ANNEX I

NPP TEMELÍN: CRITICAL DISCUSSION OF THE MATERIALS' DATABASE AS APPLIED FOR THE PIPE LINES AT THE 28,8 M LEVEL IN THE FRAME OF THE SUPERPIPE CONCEPT [MEYER 2004)

NPP Temelín: Critical discussion of the database as applied for the pipe lines at the 28,8 m level in the frame of the SUPERPIPE concept

Summary Statement

The „SUPERPIPE concept“ was developed as simple design tool with respect to the integrity of pipelines that experience high operational loads due to unavoidable design requirements. For such pipeline segments special limiting criteria are defined for a sufficient safety margin between the load-induced stresses and the strength of the materials.

The SUPERPIPE concept as applied for the main steam line and the feed water lines in the NPP Temelín, units 1 and 2, has been analysed, showing that the approach is reduced to the comparison of the materials' tensile strength characteristics and the stresses resulting from operational loads multiplied by defined safety coefficients.

The demonstration of the fulfilment of the SUPERPIPE concept criteria for the main steam line system (steel 16GS) is not possible using the normative specified minimum values from the Russian Codes: For at least two sections the allowable stress values are exceeded.

The Czech experts have made a statement contradicting that: *"All sections of the main steam line system meet the SUPERPIPE concept criteria"*. This statement is based on the replacement of the materials' properties specifications accoding to the applicable standard by data from experiments taken from the so called "Materials' Data Base" *(Archival data: production welding samples, Plant Specific Data: experimental welds made in Russia; Industry Data: base materials specific for WWER-440)*.These values must be considered non-representative for the design qualification for at least three reasons:

- The number of values from the so called "materials' data base" is not significant enough to construct a statistically reasonable set
- At least the specimen of the basematerial do not originate from the material used for production of ETE piping, for the weld specimens it is not proven that they were manufactured from the same heat – there is not even an established comparability certificate
- With increasing service time a further decrease of the steam line materials' strength has to be expected, based on the experimentally observed ageing effect.

Therefore the Austrian Experts' Team recommends to the Austrian Government to continue monitoring maintenance and applicability of the database used for the SUPERPIPE concept.

1. Introduction: SUPERPIPE concept

The „SUPERPIPE concept“ was developed as a code design rule for piping integrity for pipelines that experience high loading histories due to requirements to be met by their design. The short segment of the main steam line in the area of the containment penetration is an example for this, where the geometrical design does not allow non-destructive ISI from outside. For such pipeline segments special limiting criteria are defined to provide for a sufficient safety margin between the load-induced stresses and the strength of the materials.

Based on the **French Code RCC-P** and the **ASME Code Section III** the following limiting criteria for the allowable operational stresses sB have been defined for the SUPERPIPE concept:

$$\sigma^B \leq 0{,}8 \cdot (1{,}2\ S_h + S_A) \quad (1)$$

with

$$S_A = f \cdot (1{,}25\ S_c + 0{,}25\ S_h) \quad (2)$$

S_c .... limiting stress at minimum (cold) temperature

S_h .... limiting stress at maximum (hot) temperature

f.................... reduction factor form the cyclic loading

This factor f is selected form the following table 1:

Number of Equivalent Full Temperature Cycles N	f
7 000 and less	1,0
7 000 to 14 000	0,9
14 000 to 22 000	0,8
22 000 to 45 000	0,7
45 000 to 100 000	0,6
100 000 and more	0,5

In the main steam line case and for the feed water lines the number of cycles remains below 7 000 for full temperature cycles (Reactor Start-up and Shut-down) this way even in case of 40 years of operation the factor is f = 1.

This simplifies equation (1) to:

$$\sigma^B \leq 1{,}16\ S_h + S_c \quad (3)$$

According to ASME Code Section III for Class 2 and 3 piping:

$$[S_h \text{ v } S_c] = \min \{ R^{20°C}_{p0,2}/1{,}5\ ;\ R^{T}_{p0,2}/1{,}5\ ;\ R^{20°C}_{m}/3;\ R^{T}_{m}/4 \} \quad (4)$$

with:

$R_{p0,2}$ .... yield strength from tensile test at 20°C, or deviating temperature

R_m .... ultimate strength from tensile test at 20°C, or deviating temperature.

This comparison is the complete “SUPERPIPE concept”, in words: The maximum operational stresses are compared with the materials’ tensile characteristics according to the applicable standard: ultimate tensile strength (R_m) and yield strength ($R_{p0,2}$) at room temperature and operational temperature.

Two remarks to the procedure:

a) The constructor must meet structural integrity criteria for the specific pipe segments. Two options are there for matching design with defined operational parameters:
   - Constructive measures for the limitation of operational stresses (use of larger wall thickness, avoidance of geometrical stress concentration like elbows, T-sections, diameter reductions)
   - Material optimisation (use of optimised materials, avoidance of welds in the respective sections).

   Neither one of the measures are achievable or envisaged for application to the main steam lines and the feed water lines in the NPP Temelín in order to make them conform to the SUPERPIPE concept requirements, even though replacement of the piping of these systems' pipings is feasable in principle. In the NPP Temelín, the application of the SUPERPIPE concept is obviously an evaluation comparison applied to the complete non-optimised pipe system at the 28,8 m level – a procedure that one can assume certainly not aimed at by the authors of the codes used in this novel combination.

b) In modern fracture mechanics concepts steels optimised only with respect to strength would not be selected for this purpose, they require an **optimised relation between strength and toughness**. The SUPERPIPE concept is an outdated concept of the 70[ies] (ASME Code 1972). Based on modern strength analysis, these evaluations' comparisons contain the following hazard:

   For the SUPERPIPE concept compliace high-strength steel **independent of its toughness** would fulfil equations (3) and (4).

The SUPERPIPE concept application will be discussed in the following for the two pipeline systems. According to the concept the materials' tensile characteristics at room temperature and at operational temperature (see below 2. Materials characteristics of the pipelines at the 28,8 m level) multiplied with the respective safety factors (equations (3) and (4)) have to be compare with the stresses calculated from the operational loading conditions (see Stress values).

2. Materials characteristics of the pipelines at the 28,8 m level

2.1. Normative values and measured values from the component passports

The main steam line pipes were manufactured from the Si-Mn alloyed steel 16GS, the feed water lines in the area of the 28,8 m level from the carbon steel St20. Both steels are well known and described in the respective normative codes [PNAEG G-7-002-86]. Their production and specification is also standardized in within technological standards:

- 16GS
- TU-3-923-75
- St20
- TU-14-3-460-75

These steels are usually welded with welding electrodes UONI 13/55.

In relation to the SUPERPIPE concept, the characteristics specified for these materials are the following:

Table 2: normative strength characteristics [ONDROUCH 2002] and [ZDAREK 1997]

steel	$R_{p0,2}$ [MPa]	R_m [MPa]	$R_{p0,2}$ [MPa]	R_m [MPa]
16GS	294	491	226	450
St20	216	412 .. 549	177	410
UONI 13/55	334 .. 373	490 .. 539		
T_{test}	20 [°C]	20 [°C]	300 [°C]	300 [°C]

In relation to the presentation of the materials' data base [ONDROUCH 2002] (see: Experimental materials' characteristics from the database) so called "certified values" were presented – for temperature 20 [°C] – as average values and minimum values. According to the Czech expert's answer during the discussion at the Workshop these values are taken from the components' passports. Values for a test temperature of 300 [°C] were not given. The Austrian Experts' Team has available a summary of materials' characteristics from the passports.

Table 3: Minimum values from the component passports [ONDROUCH 2002]

steel	$R_{p0,2}$ [MPa]	R_m [MPa]
16GS	333,5	519,9
St20	235,4	441,5
T_{test}	20 [°C]	20 [°C]

These minimum values from the component passports are supposed to prove that the specified normative values were reached during manufacture.

2.2. Experimental materials' characteristics from the database

The presentation on the SUPERPIPE concept during the Workshop [ZDAREK 2002] was using the materials' database as presented in [ONDROUCH 2002]. Therefore it is necessary to discuss the bases of this database:

The samples for these destructive testing experiments were manufactured from residual materials of the steam and feed water pipes according to [ONDROUCH 2002]:

- *Archival data: production welding samples,* [i.e. data from tested archive Material]
- *Plant Specific Data: experimental welds made in Russia;*
- *Industry Data: base materials specific for WWER-440*

Therefore at least the used experimental values for the base material cannot be considered to be representative for the ETE piping material.

These materials' characteristics from destructive testing include tensile strength, Charpy impact toughness and fracture toughness data. Only the materials' characteristics relevant for the SUPERPIPE concept will be discussed here.

An evaluation of the presentation in [ONDROUCH 2002] shows that the relevant characteristics are based on a very limited number of samples only:

The existence of 2 to 5 single values cannot be considered sufficient set of test results for a consolidated database, especially in case of these values being used in safety analyses instead of the specified minimum values according to the applicable standard or instead of the “certified” values from the component passports. These minimum values derived from the experimental data are summarised or further discussion of the SUPERPIPE concept as applied:

Steel	Prop.	Stress	T	Temp.	Evaluated	Reference
16GS	$R_{p0,2}$	[MPa]	20	[°C]	3 samples	(slide 23 in [ONDROUCH 2002])
	R_m	[MPa]	20	[°C]	3 samples	(slide 23 in [ONDROUCH 2002])
	$R_{p0,2}$	[MPa]	300	[°C]	3 samples	(slide 23 in [ONDROUCH 2002])
	R_m	[MPa]	300	[°C]	samples	(slide 23 in [ONDROUCH 2002])
St20	$R_{p0,2}$	[MPa]	20	[°C]	5 samples	(slide 21 in [ONDROUCH 2002])
	R_m	[MPa]	20	[°C]	5 samples	(slide 21 in [ONDROUCH 2002])
	$R_{p0,2}$	[MPa]	300	[°C]	2 samples	(slide 21 in [ONDROUCH 2002])
	R_m	[MPa]	300	[°C]	2 samples	(slide 21 in [ONDROUCH 2002])

The existence of 2 to 5 single values cannot be considered as a sufficiently consolidated database, especially in case of using these values in safety analyses instead of the normative specified minimum values or instead of the “certified” values from the component passports. For the further discussion of the applied SUPERPIPE concept these minimum values derived from the experimental data are summarised:

Table 4: Minimum values of the data base

Steel	$R_{p0,2}$ [MPa]	R_m [MPa]	$R_{p0,2}$ [MPa]	R_m [MPa]
16GS	313,5	492,5	266,3*	468,9*
St20	223,2	469	238,5*	459*
Temp.	20 [°C]	20 [°C]	300 [°C]	300 [°C]

*(The values marked with * were not presented in [ONDROUCH 2002], but were found in [ZDAREK 2002], slide 33 and 56 with the reference to the data base. (These values can also be derived from the slides 21 and 23 in [ONDROUCH 2002])*

The presentation about the Materials’ database [ONDROUCH 2002] shows another interesting fact on the strength of the steels:

For the relevant materials’ ageing experiments were performed and evaluated with respect to strength characteristics.

The results (see slides 24 and 25 in [ONDROUCH 2002]) show that the strength characteristics (R_m and $R_{p0,2}$) for the steel of the main steam line pipe and its welds are lower after ageing than those for the virgin state (esp. for high temperatures). These results are confirmed by measured fracture toughness at high temperatures before and after ageing (see slides 26 and 27 in [ONDROUCH 2002]). Therefore a decrease in strength and toughness of this steel has to be expected with increasing the duration of operation.

Finally the following has to be stated:

In nuclear technology, the application of database values is necessary and permitted only in cases where at the time of manufacture of the components no specification for the minimum characteristics existed due to lack of a testing and evaluation methodology.

A typical example for this is the use of a limiting curve for the temperature dependence of fracture toughness derived as the lower-bound curve of all experimental data for a specific group of steels. The necessity of this procedure is based on the fact that at the time of projecting and manufacturing of the older reactors the fracture mechanics methodology was not yet developed for practice and the respective standards were not yet implemented. Nevertheless, such a database must include a large amount of experimental results as qualified data in order to be able to derive based on statistics the lower bound limiting characteristic with sufficient conservatism.

3. Stress values

According to the: SUPERPIPE concept explanation the materials' strength characteristics have to be compared with the stresses caused by the superimposed operational loads of the plant. It is not the aim of this contribution to evaluate the completeness and quality of the stress analyses of the main steam line and feed water line systems in the NPP Temelín, although the Workshop presentation has raised a number of questions (consideration of a complete set of coinciding load conditions; consideration of the real wall thicknesses – that are sometimes smaller than the code requirements as specified; consideration of the erosion thinning of the wall for strength calculations, etc.). Here, the values given in [ZDAREK 2002] are summarised in order to perform the comparison with the materials' characteristics:

Main steam line

The following maximum operational stress values are cited for the Sections as:

Segment TX50Z01	**[MPa]**
Section A17 X:	255,67
Section A17 S:	193,67
Section A1:	171,67
Segment TX70Z01	**[MPa]**
Section C17 X:	238,37
Section C17S:	178,72
Section C1:	191,49
Segment TX80Z01	**[MPa]**
Section D17X:	256,32
Section D17S:	194,08
Section D1:	n.k.

Feed water line

The following maximum operational stress values are cited for the Sections as:

Segment TX41Z01	**[MPa]**
Section A1:	154,99
Section A2:	107,58
Section A5:	103,87
Segment TX42Z01	**[MPa]**
Section B1:	178,37
Section B2:	119,26
Section B11X:	115,45
Segment TX44Z01	**[MPa]**
Section D1:	155,10
Section D2:	107,29
Section D5:	104,03

It is obvious that stress level in the feed water lines is lower than in the steam line.

4. The comparison according to the SUPERPIPE concept:

The summary of materials'characteristics and stress levels in the section 2.1. Normative values and measured values from the component passports **and 3. Stress values** allow the evaluation of the main steam and feed water systems' pipelines in the frame of the SUPERPIPE concept.

In accordance with the international standards (ASME, KTA, RCC) the specified minimum values for the respective steel group has to be used.

The Russian Code regulations [PNAE G-7-002-86] require also in 3.7:

"For the determination of the allowable nominal stresses the specified values of the mechanical properties (short-term and long-term strength) given in the governmental or industrial standards (GOST or OST) or in the technical specifications (TU) have to be used. In case of lacking values in these documents the values given in the tables P1.1 and P1.4 have to be used."

For the discussed case of the steels 16GS and St20 and the weld UONI 13/55 these normative values are given in section 2.1. Normative values and measured values from the component passports, table 2, and also reported in [ONDROUCH 2002] and [ZDAREK 2002]. With these values for the steel 16GS (main steam line system) follows:

S_c = min {$R^{20°C}_{p0,2}$/1,5 ; $R^{20°C}_{m}$/4 } = min { 294/1,5 ; 491/4} = min {196; 122,75} =
= 122,75 [MPa]

S_h = min {$R^{20°C}_{p0,2}$/1,5 ; $R^{T}_{p0,2}$/1,5 ; $R^{20°C}_{m}$/3 ; R^{T}_{m}/4 } = min {294/1,5; 226/1,5; 491/3; 450/4}
= min {196; 150,7; 163,7; 112,5} = 112,5 [MPa]

According equation (3) the maximum allowable operational stress σ^B is:

$$1{,}16\ S_h + S_c = 253{,}25\ [\text{MPa}].$$

For the feed water line the analogue limiting value is 221,9 [MPa].

These values based on the normative specified data in comparison with the stress levels summarised in 3. Stress values provide for the following findings:

- For the feed water line no problems result from the SUPERPIPE approach.
- For the main steam line systems there are two sections that do not meet the SUPERPIPE criteria.

The Czech experts have made a statement in [ZDAREK 2002] contradicting that: *"All sections of the main steam line system meet the SUPERPIPE concept criteria"*. This statement is based on the replacement of the materials' properties characteristics accoding to the applicable standard by data from experiments taken from the so called "materials' data base" that are higher than the characteristics according to the standard.

This approach cannot be considered to be correct, not only because of the extremely limited database (only 3 experimental data points for each value) but also because of the deviation from the codes' rules and regulations. Also in the case of the feed water line the "Materials' data base" values were used, so that the maximum allowable stress value is too high, but this has no consequences for the conclusions in principal.

Finally, also the problem of ageing should be considered: According to [ONDROUCH 2002] the materials' strength is decreasing with the time of operation. A quantitative evaluation of this effect is not possible due to lack of requirements for the resistance to fatigue of the steel 16GS. In any case the trend indicates that the ageing might aggravate the problem.

6. Findings

The SUPERPIPE concept applied for the main steam line and the feed water lines in the NPP Temelín, units 1 and 2, has been analysed, showing that the approach is reduced to the comparison of the materials' tensile strength characteristics and the operational loads including defined safety coefficients.

The specified minimum values for the used steels were compiled together with the certified values from the component passports and additional experimental values from the "materials' data base".

The demonstration of the fulfilment of the SUPERPIPE concept criteria for the main steam line system (steel 16GS) is not possible using the normative specified minimum values from the Russian Codes: for at least two sections the limiting stress values are surmounted.

The contradicting statement from the Czech experts that all sections of the main steam line system meet the SUPERPIPE concept criteria is based on the incorrect replacement of the normative specifications by non-representative experimental data of the "materials' data base".

With increasing service time a further decrease of the steam line materials' strength has to be expected, based on the experimentally observed ageing effect.

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ANNEX J

CONSEQUENCES FROM A MSLB TO BE EXPECTED FOR THE SHUTDOWN SYSTEM EFFECTIVITY

Consequences from a MSLB to be expected for the Shutdown System Effectivity

Summary

The behavior of the Temelín WWER-1000 NSSS under severe accident conditions resulting from Main Steam Line guillotine breaks requires extensive analyses of various accident scenarios in order to verify the solutions according to design and to understand options for the mitigation of consequences.

The Austrian Experts´ Team concluded from the information provided by the Czech partners at the PN2 Specialists´ Workshop that issues indicated above remained open. It is therefore of basic interest to Austria to obtain answers to these questions, because accident consequences of re-criticality of the Temelín WWER-1000 reactor might have consequences off site.

The issue in question here is to verify whether or not sub-criticality of the reactor core is maintained properly during the very fast cool-down transient of the primary system following a single break of the main steam line or even multiple steam lines breaks. Advanced reactor codes accepted in Western European countries for PWRs have been used to achieve this target. The calculations were performed after the codes were adapted for WWER reactors and verified especially for WWER-1000 applicability.

The extensive work included the generation of the macroscopic cross section and diffusion parameters library for the Temelín core during first operation cycle, based on the information about specific design of the reactor core, reflectors, fuel assemblies and absorbers. After accomplishing the necessary calculations, these library data were successfully verified by calculations of the most important reactivity parameters and coefficients and by comparing them with Czech results.

The library generated was used to calculate reactor core criticality after scram at full power level and assuming decreasing coolant temperatures. The iodine and xenon concentrations and distributions correspond to the full power status bearing in mind very fast accident development after the rupture of the MSL. Uniform coolant temperature is assumed in the core. A conservative approach was followed for defining assumptions, initial and boundary conditions for the calculations. The coolant temperature is assumed uniform in the core. When defining assumptions, initial and boundary conditions for calculations a conservative approach was followed. This means that all reactor parameters have to be still in the operational limits, but with the most negative value (from the point of view of the selected scenario). Thus, at the end of the first cycle and before the scram the initial conditions included:

- The reactor is at the end of the first cycle
- The reactor is operated at 102% and 106% of nominal power before scram
- The average hot leg coolant temperature is 2 K higher than nominal
- The CRA absorber control group #10 is at maximum insertion into the core
- The single failure principle is applied and this leads to the requirement of one of the most effective control rod assemblies (CRAs) to be stuck in the top insertion position.

The specific design of the reactor internals of a WWER-1000 doesn't allow to place movable absorbers at the periphery of the core and jamming one of the most effective CRA close to this zone leads to significant decrease of the effectiveness of the scram system. The present studies showed that the most effective CRA is out of the groups #3 or #4.

Results from accomplished calculations show that the effectiveness of the scram system is reduced by 20% if the most effective CRA is stuck in top position. The relative power contribution of individual assemblies in the surroundings of the stuck CRA is by a factor of two to three orders of magnitude higher when comparing it with the assemblies from the diametric opposite region of the core. Results show that reactor will be critical again if the temperature drops below 200 .. 197 °C.

Based on these results the Austrian Experts´ Team concludes that re-criticality in case of a stuck rod scenario connected with a MSLB remains still an open question, very important for clarification. For answers to be fully satisfying the required comprehensive analyses would have to be performed.

Since the results presented by the Czech side were not suitable to clarify the issue, the Austrian Experts´ Team recommends to the Austrian Government to monitor this re-criticality issue beyond the end of the current Monitoring Process.

ANNEX K

DESCRIPTION OF POST-PMR ANALYSES RESULTS OBTAINED BY THE AUSTRIAN EXPERTS' TEAM

Description of Post-PMR Analyses Results obtained by the Austrian Experts' Team

The Austrian Experts' Team proposed to and conducted later for the Technical Project Management additional analyses intended to serve the FMR (PM6) in providing additional information for conclusions to be achieved. Three selected topics were to be addressed in context of the PMR issues list.

For these three issues additional substantial work has been performed in the frame of PM6 to support the final assessments. The three issues are:

(1) The **behaviour of the primary coolant system and the reactor core** under the conditions of multiple steam line breaks in the compartment at the 28,8 m level and its suspected recriticality of the reactor,

(2) **Design loads for the HELs at the 28,8 m level** according European practice (e.g. water hammer caused) compared with design seismic loads applied declared bounding by the Czech side

(3) **Qualification of the material properties data for the database** to be used in the break exclusion attempt, the HEL design verification and operational wear and ageing evaluation.

The main findings of these additional Austrian Experts' analyses are denoted below.

Since the results and the recent additional information presented by the Czech side were valuable but not sufficient to clarify these three issues, (1., 2. and 3.), further work needs to be performed to definitely conclude the issues.

The 3 work topics have addressed a number of Verifiable Line Items providing indications the way it is described in the following paragraphs:

- **Regarding the postulated "aggressive" HELB points assumed in the analysis:**

  Results of explorative work on the Design Loads for the HELs at the 28,8 m Level:

  The Austrian Experts´ Team performed calculations according to state of science and technology. The results indicate that the extent to which "aggressive" HELB points were identified and considered in the design review fell short at least with regard to the so-called Bubliks.

- **With respect to pipe internal dynamic fluid forces effects as a consequence of the postulated HELB (including geometry effects and blowdown characteristics):**

  Results of explorative work on the Design Loads for the HELs at the 28,8 m Level:

  The results indicate that design loads for the HELs appear not to be enveloped by the seismic loads an assumption made and confirmed by the Czech side.

- **The non-linear mechanical analysis to determine the whipping pipes dynamic response indicated:**

  Results of explorative work on the Design Loads for the HELs at the 28,8 m Level:

  The results indicate that design loads for the HELs resulting from jet forces and reaction forces considered together with the dynamic response of whipping pipes require non-linear mechanical analyses.

- **As regards the structural analysis evaluation, including local loads on the concrete Category I structures and non-safety structures whose damage may impair the safety of the plant:**

  Results of explorative work performed by the Austrian Experts' Team on the Design Loads for the HELs at the 28,8 m Level:

The load bearing capacity of the 28,8 m steel girder support and concrete structures to protect safety related equipment from indirect damage is part of the Defense-in-Depth concept application. Results to this need were not presented. Therefore additional work was needed to gain insight into the background.

Steam or feedwater line pipe whip in the vertical section after the 28,8 m level might endanger not only the adjacent turbine hall wall and the HELs in this area but also the HELs at the 28,8 m level in case the fix point near by at the turbine hall wall is not capable to take the resulting loads.

- **With respect to plant safety analysis, for performances of mitigating systems, radiological consequences calculations and Monitoring of adequacy of emergency procedures to mitigate MS & MFW HELB outside containment and their extension into SAMGs:**

  Results of explorative work performed on the Behaviour of the Primary Coolant System and the Reactor Core:

  Those elements of the safety analyses providing the basis for consequences mitigation options and evaluations of plant response and the adequate safety systems functions as part of Defense-in-Depth concept application were presented as an overview information. This is also the context for events related to project PN9 “Reactor Pressure Vessel Integrity and Pressurised Thermal Shock”. Therefore additional work was needed to gain insight into the background.

  In a pilot study by the Austrian Experts’ Team the behaviour of the reactor core during multiple lines break of the main steam piping has been analysed. According to the results the WWER 1000 reactor at Temelín is likely to become critical after the scram with the most effective rod stuck in top position after a multiple steam line break.

  The results from calculations accomplished show that the effectiveness of the scram system is reduced by 20% if the most effective CRA is stuck in top position. The relative power contribution of individual assemblies in the surroundings of the stuck CRA is by a factor of two to three orders of magnitude higher when comparing it with the assemblies from the diametric opposite region of the core. Results for the end of the first cycle show that reactor will be critical again if the temperature drops below 200 to 197 °C.

- **Regarding requirements for the materials used and material degradation to be taken into account:**

  Results of explorative work on the Materials-Database:

  The Austrian Experts´ Team performed a review of the information available about the material database used to support the evaluation regarding the Superpipe Concept applied by the Czech side for the HELs integrity verification at the 28,8 m level. The outcome of this review gives reason in several contexts to raise doubts whether the material database is adequately consolidated for break exclusion confirmation of the HELs at the 28,8 m level.

  The materials properties requirements for the two pipe materials used could not be interrelated, as applicable for the “Superpipe Concept’s” break exclusion re-qualification. The materials properties requirements defined for the High-Energy Lines at the design stage do not correspond with the properties of the material “in place”. Therefore the acceptance criteria for the appropriate material properties would be of interest and the compliance demonstration documentation as well.

  The results obtained lead the Austrian Experts’ Team to the conclusion, that in the respective areas there is a well-established indication for needs for additional information. Appropriate measures should be taken in order to obtain this information in due time.

ANNEX L

MISSION STATEMENT

As adopted by the Austrian Experts' Team

Monitoring Mission Statement

The independent Austrian Experts' Team agreed on a "Mission Statement" to define the monitoring process co-ordinated by IRR/ARCS.

"Monitoring" is a process performed in a predefined frame addressing selected issues defined in the "Conclusions of the Melk Process" as well as in the "Roadmap" and the solutions to these issues adopted by the Czech side.

Issues and their solutions are monitored on the basis of reference safety criteria and requirements coherent with Safety Approaches accepted in Western Europe. The requirements are checked against the generally applied Defense in Depth Concept.

The Monitoring has the objective to obtain evidence that adequate solutions have been submitted by the licensee to the licensing authority and that these solutions have been appropriately evaluated and approved by the regulator. Monitoring aims at performing an evaluation of the quality and adequacy of an overall process and the implementation results.

The Czech side has offered documentation and discussion opportunities.

The Monitor, in order to form a consistent opinion should be provided with the opportunity to ask for additional information and evidence or request supporting assessments to understand the evidence presented.

Reports of the Austrian Experts' Team therefore include monitoring results of

- What has been done,
- How the applicable requirements have been addressed,
- How the safety objectives' and requirements' compliance was analysed and justified for the proposed solutions, and
- How were evaluated the solutions in the frame of the licensing process and considered in the related regulatory process

The Monitors were not tasked with performing a licensing review of Temelín NPP, and nothing in their reports may be construed to represent any such review. The responsibility for the safety and licensing of Temelín remains with ČEZ a.s. as the owner of the facility, and with the SÚJB, as the designated nuclear licensing and regulatory authority under Czech law.