October 29, 1982

Ivan W. Smith, Chairman
Administrative Judge
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dr. A. Dixon Callihan
Administrative Judge
Union Carbide Corporation
P.O. Box Y
Oak Ridge, Tennessee 37830

Dr. Richard F. Cole
Administrative Judge
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Washington, D. C. 20555

In the Matter of
COMMONWEALTH EDISON COMPANY
(Byron Station, Units 1 and 2)
Docket Nos. 50-454 and 50-455

Dear Administrative Judges:

Enclosed for the information of the Board and parties is a copy of the final report of the International Atomic Energy Agency Advisory Mission regarding KRSKO steam generator modifications which, in draft form, was the subject of NRC memoranda attached to DAARE/SAFE's October 8, 1982 response to the Applicant's motion for clarification of the Board's summary disposition ruling.

Sincerely,

Steven C. Goldberg
Counsel for NRC Staff

Enclosure as stated

cc: (w/ encl.) Service List

DSOnpl

OFC	:OELD	:OELD	:Internatnl Programs	:	:	:	:
NAME	:SGoldberg:pl:	J Gray	:J LaFleur	:	:	:	:
DATE	:10/27/82	:10/29/82	:10/28/82	:	:	:	

INTERNATIONAL ATOMIC ENERGY AGENCY

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NUCLEAR POWER SAFETY

REPORT TO THE GOVERNMENT OF YUGOSLAVIA

TA REPORT No. 1937

Nuclear Power Safety

Advisory Services
Steam Generator Vibration Problems

(YUG/9/010)

Report to the Government of Yugoslavia

7 - 12 June 1982

ADVISORY MISSION TO YUGOSLAVIA

7 - 12 June, 1982

J.M. Izquierdo	Junta de Energia Nuclear Spain
I. Jung	Consultant, Sweden
L.G. Larsson	Nuclear Power Inspectorate, Sweden
R.L. Tedesco	Nuclear Regulatory Commission, USA
L.I. Tirén	IAEA

PREAMBLE

The Director General of the IAEA would like to place on record his understanding that, upon completion of its work, the Mission may make to the Yugoslav authorities and to the organization responsible for the operation of the nuclear power plant such recommendations as the Mission considers desirable regarding the measures that should be taken for ensuring the safe operation of the plant. The Mission's recommendations will be made on its own expertise and will not engage the IAEA in any way or imply any commitment on the part of the IAEA.

1982-07-07

SUMMARY

At the request of the Permanent Mission of Yugoslavia to the IAEA an advisory mission including five persons was sent to Yugoslavia during the period 7-12 June, 1982. The purpose was to discuss steam generator vibration problems at the Krško nuclear power plant with the licensing authority and plant management and to give advice on associated plant modifications.

After a few months' of initial operation at power the Krško plant has recently been shut down. Modifications are under way to permit further operation up to 100% power with a limitation on feedwater flow through the main steam generator nozzle. The aim of the flow limitation is to reduce steam generator tube vibration to acceptable levels at full power.

During the Mission's stay in Yugoslavia they formulated a set of recommendations to the Krško authorities. This includes recommending that the basis for the flow limitation be better developed in quantitative terms ; independent design review of plant modifications be completed on a timely basis ; operating programme be established to specify permissible operating modes during a pre-established limited operating time period ; comprehensive start-up testing programme be established and operator training be conducted prior to resumed operation ; and adherence to quality assurance requirements be ensured with regard to proper design verification and construction adequacy prior to operation of the plant as modified. The basis for these and other recommendations are discussed in the present report.

Advisory Mission to Yugoslavia

7 - 12 June, 1982

CONTENTS

1. INTRODUCTION

In a letter dated 27 April 1982 the Permanent Mission of the Socialist Federal Republic of Yugoslavia to the IAEA requested the assistance of an Agency team of experts to discuss steam generator vibration problems in the Krško nuclear power plant.

In response to the request, the Agency sent a mission to Yugoslavia during the period 7 - 12 June, 1982, consisting of the following four experts :-

J.M. Izquierdo	PWR Startup Group Leader Evaluation Division, Junta de Energia Nuclear, Spain
I. Jung	Professor Emeritus Steam Technology, Royal Institute of Technology, Stockolm, Sweden Consultant to the Swedish State Power Board
L.G. Larsson,	Director, Office of Inspection Nuclear Power Inspectorate, Sweden
R. L. Tedesco	Assistant Director for Licensing Division of Licensing, US Nuclear Regulatory Commission Washington, USA

Mr. L.I. Tirén from the Nuclear Safety Division of the IAEA also participated as the Scientific Secretary for the Mission.

During its stay in Yugoslavia the Mission mainly interacted with staff of the following organizations :-

- Republic Committee of Energy of the Socialist Republic of Slovenia, RKE SRS (acting as the regulatory body for the Krško nuclear power plant).
- Institute "Jožef Stefan", IJS (technical advisory body to the Republic Committee)
- Nuklearna Elektrarna Krško, NEK (Krsko nuclear power plant utility)
- Westinghouse Electric Corporation (vendor of Krško nuclear power plant)

The present report gives a summary of the work including recommendations of the IAEA Mission.

The Agency is obliged to the Governments of Spain, Sweden and the United States for their prompt response to the Agency's request for consultation. The effective arrangements made by the Yugoslavian authorities for the Mission are also gratefully acknowledged.

2. MISSION OBJECTIVES

Steam generator tube vibration is a concern in the operation of recent Westinghouse designed nuclear power plants, including the Krško plant. This concern has led to a proposal at Krško to modify the feedwater system before continuation of the start-up programme. The purpose of the Mission was to discuss the current situation, particularly with regard to safety, with members of authorities and Krško plant staff. In particular, the Mission was asked to give comments and advice on :

- proposed feedwater system modification, including changes in the control system
- resumed operation of Krško with regard to the steam generator tube vibration problem
- necessary documentation, evaluation and review to accept further operation of the plant as modified.

3. BACKGROUND AND CURRENT SITUATION

3.1 STEAM GENERATORS

The Krško nuclear power plant is a two-loop PWR plant of 664 MW gross electric power output. The main contractor is Westinghouse Electric Corporation. The plant has two main coolant loops each equipped with type D4 steam generators. It is the first plant with this type of steam generators to go into operation.

The D4 type includes a preheater section with cross-flow characteristics. The concern with regard to tube vibration stems from the fact that fluid induced vibrations have been experienced in preheat type steam generators used in PWR plants in Spain (Almaraz 1), Sweden (Ringhals 3) and the U.S.A (McGuire 1). As a result of these vibrations, significant tube wear in the tube-to-baffle plate intersections has been experienced in the Ringhals 3 and Almaraz 1 steam generators. These plants, however, have steam generators of somewhat different designs (Almaraz and Ringhals type D3, McGuire type D2) but are also preheater type. The most important difference is in the area of initial distribution of feedwater through the main nozzle. In the D2 and D3 types, the inlet flow is distributed upwards and downwards into the preheater tube area via an impingement plate. In the D4 type, on the other hand, all the incoming flow is directed downwards towards the bottom part of the preheater section. Common to all these steam generators, however, is the flow perpendicular to the tubes, directed by baffle plates in the preheater area (see figure 1 and 2).

MODEL D STEAM GENERATOR

FIGURE 1

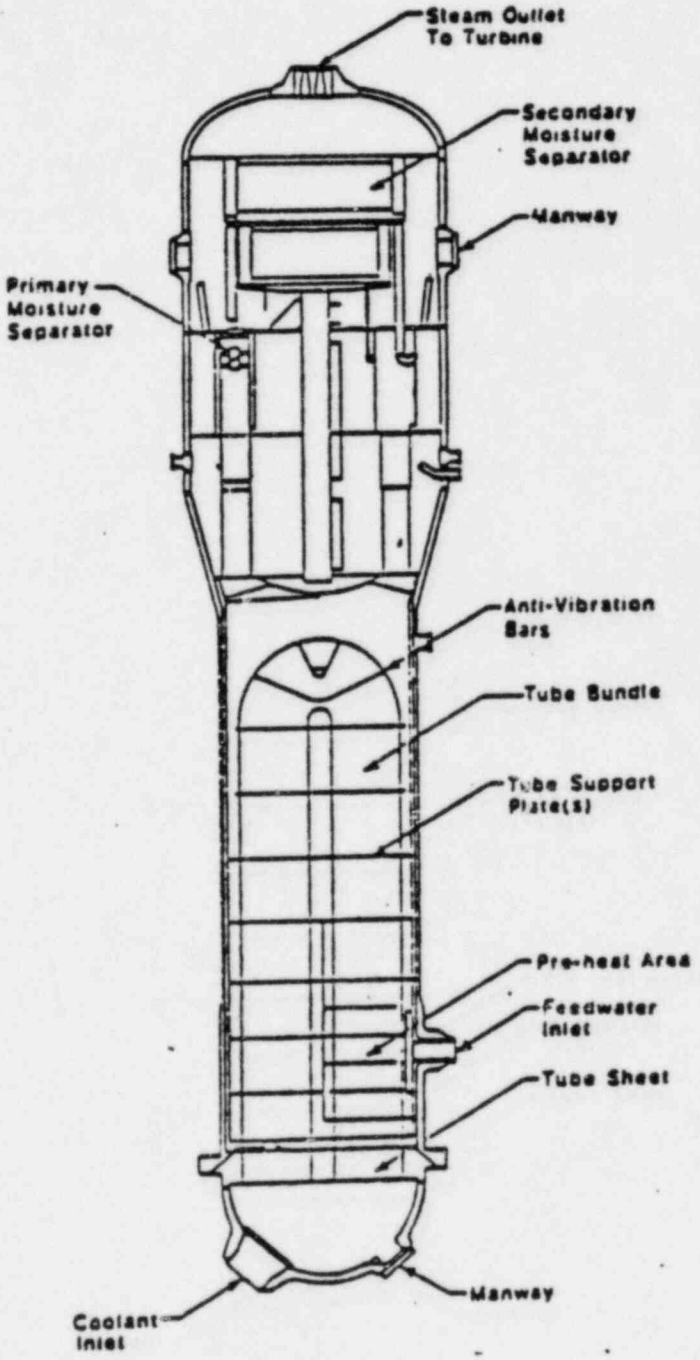
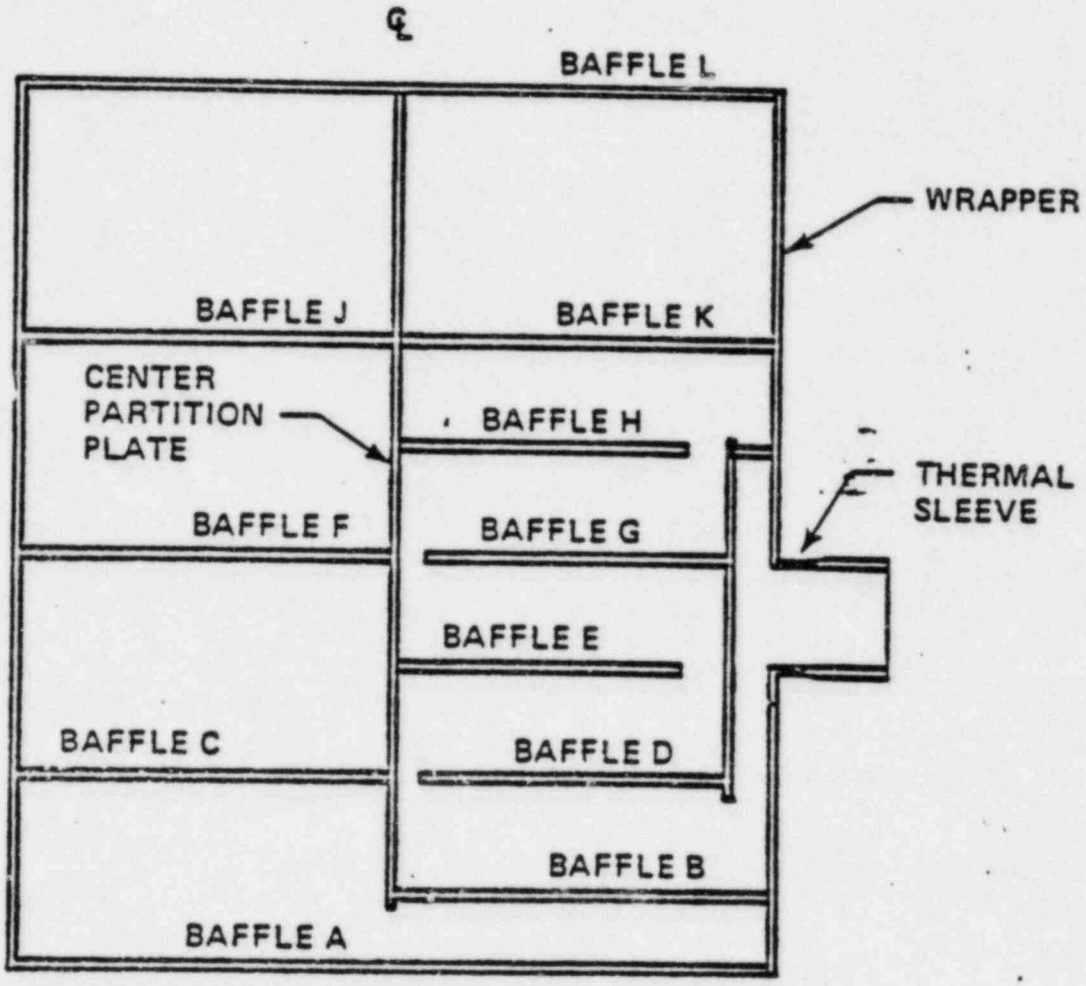


FIGURE 2

MODEL D4 LOWER SHELL INTERNALS



3.2 KRSKO OPERATING EXPERIENCE

The plant was synchronized to the external grid for the first time on 2 October 1981, and load testing at 75% power was successfully completed on 23 December. In order to study possible tube vibration, accelerometers were installed on four steam generator tubes in the preheater area in January 1982. The plant was subsequently operated at varying power levels from February to May, 1982. The operation included approximately 1500 hours at 70% and short intervals at 100% power. In the earlier full power runs, all the feedwater was introduced through the main nozzle. However, in the April and May runs at 100% power the main feedwater line was throttled to 70% flow and the additional 30% flow was fed through the auxiliary nozzle. This mode of operation was achieved by operating all three main feedwater pumps to overcome the increased flow resistance.

Accelerometer recordings made by the vendor during operation indicated steam generator tube vibrations increasing with feedwater flow. The measurements were compared with similar observations at Almaraz and Ringhals. As a result, the vendor determined that some modification to the Krško plant was necessary to permit the plant to be operated at full power. The plant was shut down on May 14, 1982, and eddy current tests (ECT) were performed on steam generator tubes. The Mission was informed that no significant indication of tube wear had been found as a result of these tests.

At the time of the Mission's stay in Yugoslavia, one of the accessible instrumented steam generator tubes was cut and pulled out for further examination. The tube location was row 49, column 56, which was considered a critical location with respect to vibrations. The Mission experts were also given the opportunity to inspect the tube visually. There were some marks visible on the tube, at the locations of tube-to-baffle plate intersections, but any depth of wear appeared to be far below the level detectable with ECT.

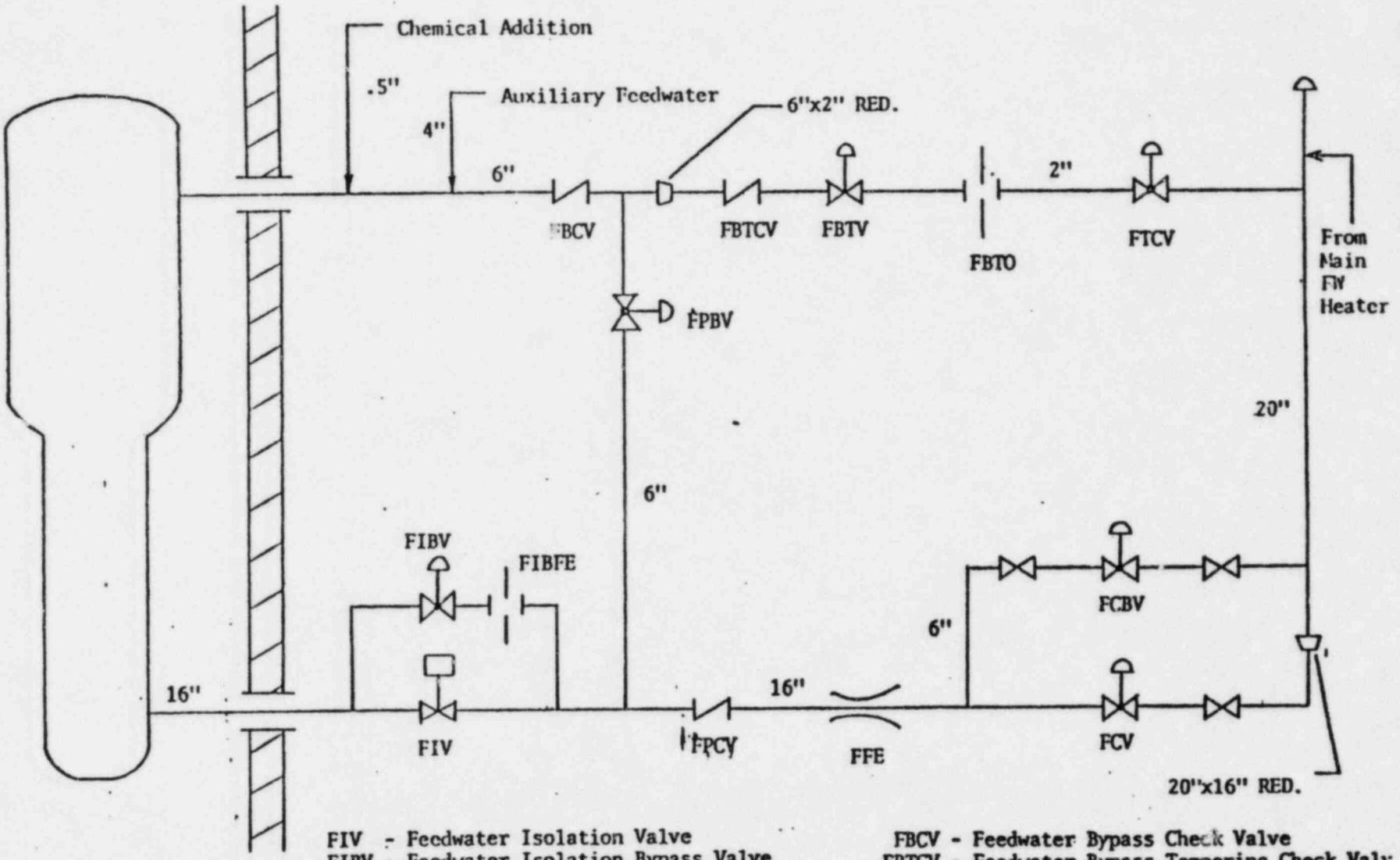
3.3. PROPOSED MODIFICATION AND PLANS FOR RESUMED OPERATION

Based on the experience of observed tube vibrations in Krško and comparison with similar data from other plants the vendor concluded that steady state feedwater flow through the main nozzle should be limited to 70% of nominal flow at full power. The vendor then developed a proposal to modify the plant to keep within this flow limit while retaining the possibility to reach 100% power. The basic change is to redirect 30% of the feedwater flow at full power from the main nozzle to the top auxiliary nozzle of the steam generators. This entails a substantial modification of the feedwater system, including new piping and valving (see figures 3 and 4) as well as major changes of the feedwater and steam generator control systems.

The proposed modification is being implemented and the necessary hardware changes are now under way. Operation of the plant as modified is planned to be resumed in July 1982.

KRSKO FEEDWATER BYPASS SYSTEM: PRESENT ARRANGEMENT

Issue: 4/1/82



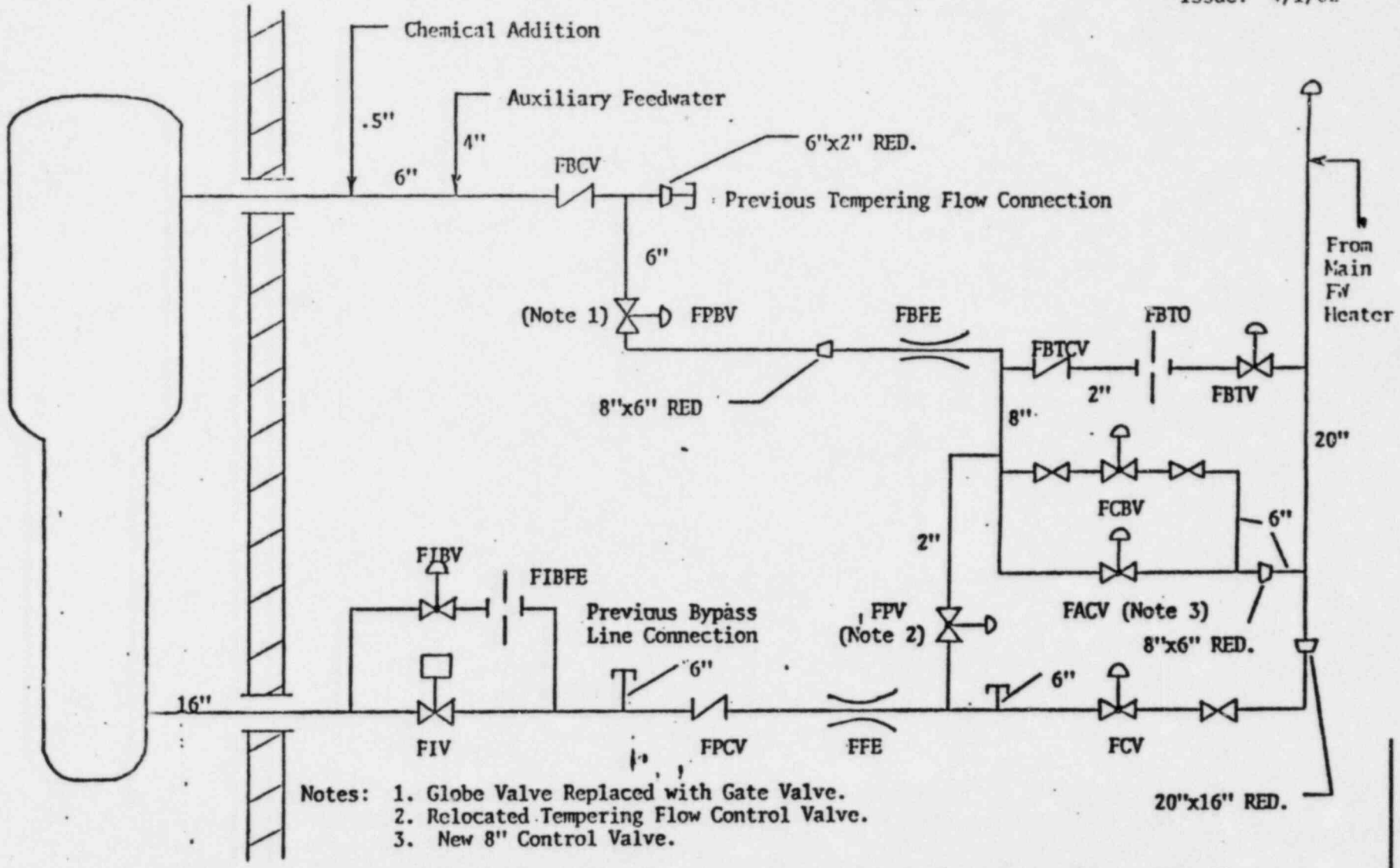
FIV - Feedwater Isolation Valve
FIBV - Feedwater Isolation Bypass Valve
FIBFE - Feedwater Isolation Bypass Flow Element
FPCV - Feedwater Preheater Check Valve
FCV - Feedwater Control Valve
FCBV - Feedwater Control Bypass Valve

FBCV - Feedwater Bypass Check Valve
FBTCV - Feedwater Bypass Tempering Check Valv
FBTV - Feedwater Bypass Tempering Valve
FBTO - Feedwater Bypass Tempering Orifice
FTCV - Feedwater Tempering Control Valve

FIGURE 3

KRSKO FEEDWATER BYPASS SYSTEM : PROPOSED ARRANGEMENT

Issue: 4/1/82



Notes:
1. Globe Valve Replaced with Gate Valve.
2. Relocated Tempering Flow Control Valve.
3. New 8" Control Valve.

FPCV - FW Preheater Check Valve
FIV - FW Isolation Valve
FIBV - FW Isolation Bypass Valve
FCV - FW Control Valve
FCBV - FW Control Bypass Valve

FBFE - FW Bypass Flow Element
FFE - FW Flow Element
FBTV - FW Bypass Tempering Valve
FBCV - FW Bypass Check Valve
FPBV - FW Preheater Bypass Valve

FIBFE - FW Isolation Bypass Flow Element
FBTO - FW Bypass Tempering Orifice
FBTCV - FW Bypass Tempering Check Valve
FPV - FW Purge Valve
FACV - FW Aux. Control Valve

FIGURE 4

The authorities and Krško plant management recognize that operation of the plant as modified will be on a trial basis. While there is hope that the modification now being undertaken will be adequate as a final solution to the problem, proof to this effect has still to be awaited. Renewed start-up tests, operating experience with the modified control system and, in particular, future ECT, will have to be evaluated carefully as a basis for future conclusions in this respect.

The Mission received no detailed operating plan, and no definite limit was given on operating time before the next ECT. However, the plant technical director indicated that new ECT is envisaged to be performed in the autumn of 1982.

3.4 ASSISTANCE GIVEN TO KRSKO AUTHORITIES

The Republic Committee of Energy of the Slovenian Republic is advised by the Institute Jožef Stefan and the Engineering Bureau Electroproject in safety matters for the Krško plant. Other institutions also give advice to the authorities of the Republic of Croatia. In addition, the IAEA has, through the years, provided frequent assistance to the Yugoslav authorities on many different aspects of the Krško project. Other organizations are involved in specific areas of consultation. For example, the Krško utility, NEK, employs the NUS Corporation, USA, as a consultant.

The Yugoslav authorities have recently requested assistance by the US NRC in evaluating safety aspects of the steam generator related modification to the plant. During the Mission's stay in Yugoslavia, interim comments from the US NRC were received. The comments were based on documents provided by a Yugoslav delegation at a 25 May 1982 visit to the NRC. The Mission was given the opportunity to read the NRC comments and found them reflecting an in-depth approach taken by the US NRC in reviewing the matter. This development, in conjunction with the reviews made by the other organizations, gives assurance that the Yugoslav authorities will continue to receive adequate guidance in safety matters related to the current steam generator problem.

4. RECOMMENDATIONS AND DISCUSSION

The present section of the report is a revised version of draft recommendations and discussion handed over to the Yugoslav authorities during the Mission's stay in Yugoslavia.

The Mission had the benefit of reviewing various design studies covering the proposed modification to the D-4 Krško steam generators. In addition, the Mission met with representatives of the licensing authority, the utility and the vendor to further discuss the proposed design modifications. On the basis of its study, the Mission developed a

number of recommendations that are set forth in this section of the report. It believes that due consideration should be given to these recommendations and appropriate actions taken prior to plant start-up following modifications that will be made in the feedwater system. It is to be noted that the recommendations presented relate to the Krško plant and do not necessarily apply to other similar plants without further evaluation.

Recommendation No. 1

The Mission recommends that the basis used to establish the 70% main feedwater flow through the steam generator preheater section should be better developed in more quantitative terms, i.e. relating feedwater flow rates to vibration frequencies, amplitudes and, in particular, wear rates.

Discussion

Westinghouse representatives at the meeting held on June 8, 1982, at the Krško site discussed some recent test results obtained from internal instrumentation installed on the D-4 Krško steam generators.

The data presented to the Mission showed minor vibration effects at a power level of 50%. The acceleration spectrum broadened and amplitudes increased with increased power and feedwater flow rates. The data extended to the case of 100% power and flow rate. These measurements, correlated with similar data from other plants, form the basis for the assumption that no damaging tubes vibrations will occur in the Krško steam generators operating with a feedwater flow through the main nozzle in the 70% range. This is also the basis for the proposed feedwater system modifications. However, the vendor has not yet determined whether a correlation of tube wear with the Krško test data can be made.

The Mission believes that a more deterministic correlation should be made to better ensure the acceptability of the proposed 70% flow limit. In addition, estimates of margin should be developed to establish conservative permissible upper limits for the proposed initial operating programme. Additional test results are necessary to qualify the acceptance of extended operation at the proposed 70% main feedwater flow limit. Such results would also be useful in developing future tube plugging limits in accordance with US NRC Regulatory Guide 1.121.

A review should be made to ensure that the tubes chosen for vibration measurements constitute a conservative sample so that no detrimental vibration exists in other tubes. In addition, consideration should be given to the completness of the model tests performed with D-4 type steam generators.

Regardless of the lack of criteria, it is, however, the opinion of the Mission that the Krško plant, from steam generator tube wear point of view, can be safely operated for limited periods, pending further confirmatory studies and ECT at the proposed operating conditions.

Recommendation No. 2

The proposed modification of the feedwater system is extensive. The Mission recommends that the independent design reviews of this modification be completed on a timely basis. The review should include mechanical and thermo-hydraulic aspects as well as those relating to control and protection system modifications.

Discussion

The Mission notes that, in addition to the design review made by the Institut Jožef Stefan, the authorities now receive assistance by the US NRC in this matter. The independent review should deal with selected design aspects to provide added assurance of the overall adequacy of the proposed modifications.

With regard to the steam generators, the Mission identified the concern of vibration of the intermediate deck plate due to the increased auxiliary nozzle flow injection.

Reduced flow through the preheater section (from 100% to 70% flow) may lead to increased steam formation at the bottom part of the preheater. The Mission was informed that the vendor did not expect any water hammer hazard to develop as a result of increased steam generation. A criterion was quoted under which no net steam formation should occur in the four first passes of the preheater. This criterion would also be met at the reduced flow operation.

The reduced flow could also result in sludge deposition at steam generator tube-to-baffle plate intersections. Again, the vendor's evaluation showed that sufficient flow velocities are maintained to prevent sludge deposition.

However, it is the Mission's opinion that these concerns justify careful monitoring during intitial start-up and subsequent plant operation.

Results from model tests in Sweden have shown extremely high and instable flow velocities after the main feedwater restrictor nozzle in the D-3 type steam generator. For this reason, the Mission would recommend for future possible action that the exchange of this restrictor by a multi-venturi nozzle restrictor be considered for Krško as a means to reduce the velocities and to provide a more uniform flow distribution into the downcomer channel. This should ensure a steady flow entrance to the preheater tube-bank.

It is the Mission's view that the design review may be made in conjunction with initial plant operation but should be completed as a prerequisite for acceptance of the modification as a permanent solution.

Recommendation no. 3

The Mission recommends that careful consideration be given to ensure that there would be no adverse interactions between the control and safety features of the feedwater system.

Discussion

The proposed modifications include changes to the reactor protection system, the feedwater control system and the auxiliary control system. The effects of such changes with regard to possible adverse system interactions should be fully understood, especially under transient and accident modes and at various flow conditions. Of particular concern would be the effect of the proposed changes on overcooling transients, transients involving switch-overs (e.g.load rejections), and other such events included in Chapter 15 FSAR analyses. Further, no adverse failures in the control system should preclude the operation of any required safety function.

The set-point study should be revised to take into account control system modifications.

The proposed modification includes deletion of the steam/feedwater flow mismatch trip. Westinghouse informed the Mission that no credit has been taken for this trip in the safety analysis of the plant. The Mission was also informed by telephone on June 10, 1982, that the US NRC has accepted the deletion of this trip as a generic change.

Recommendation no. 4

The Mission recommends that an operating program be established to specify permissible operating modes at various main feedwater flow rates through the main nozzle and allowed short term operation at rates above 70%. The initial operating program should include a definite operating time limit at 70% flow until the next ECT is to be performed.

Discussion

At the meeting held on June 8, 1982, it was not apparent that operating limits had been fully evaluated. Permissible operation at 70% flow for a specified time period prior to the next ECT inspection should be established prior to plant restart. In addition, off-normal conditions wherein flow in the preheater could exceed 70% should be evaluated. This includes consideration of a maximum limit, and permissible times for anyone event or number of events where 70% flow would be exceeded.

The merits of a passive device versus the present flow alarm for limiting the flow should be evaluated especially with regard to excess feedwater transients.

Recommendation no. 5

The Mission recommends that, prior to operation in the proposed mode, a comprehensive start-up testing programme should be established. Test during the start-up phase should be performed to confirm predictions. In addition, operator training should be conducted prior to operation in the proposed mode, to account properly for the modified operating procedures.

Discussion

Clearly the proposed changes to the operation of Krško involve new demands on the part of the operator to properly respond to plant changes. This is especially true in the ranges where flow changes and flow-split occurs. Westinghouse should provide technical bases for system operations to establish the start-up test programme. The results of previous tests should be re-evaluated. Subsequently, proper detailed operating procedures should be prepared, reviewed and approved prior to plant start-up for the new operating modes. In addition, control system stability and the possible change in the potential for adverse water hammer in the preheater and auxiliary piping of the feedwater system should be investigated and procedures verified to deal with such events.

Recommendation no. 6

The Mission recommends that the new operating characteristics in the preheater secion with the revised flow-split be evaluated to assure that no adverse changes will occur in thermal and hydraulic design basis for the D-4 steam generator.

Discussion

Further studies are needed regarding the flow distribution in the D-4 steam generator. Better understanding appears to be needed about the flow through the auxiliary feedwater nozzle and how it may affect main feedwater flow at various power levels. The consequences of using the auxiliary feedwater piping and nozzle should be evaluated using conservative assumptions of auxiliary feedwater flow and temperatures considering critical system malfunction.

Those portions of the transient and accident analysis, contained in Chapter 15 of FSAR, which are affected by the modifications should be identified. The safety analysis should be revised as necessary and should then be reviewed independently.

It must be understood that the modifications will result in a small decrease in plant thermal efficiency. In this context, the Mission was informed about plans to increase primary coolant average temperature by approximately 1.5°F in order to improve thermal efficiency. The Mission is concerned that such a change may have implications which have not been clarified in the area of safety margins and should therefore not be attempted until consequences of other modifications have been reviewed, and operation of the plant as modified has progressed satisfactorily.

Recommendation No. 7

The Mission recommends that, as additional information becomes available from the Krško and other ongoing related programmes, the proposed modification and operating program should be reevaluated and programatic changes be made as appropriate.

Discussion

As in any program of the type being investigated at Krško, due attention must be given to the utilization of any new understanding or information that may become available. Apparently, the vendor will be in a position to provide additional information, due to his involvement with other similar plants. This information would serve to help the utility to better assess the full impact of steam generator vibration problems on the operation of the Krško nuclear power plant. Every effort should be made to provide such information as it becomes available.

In addition, the licensing authority is encouraged to continue establishing good contacts with the authorities in the countries with D-2, D-3 and D-4 steam generators.

Recommendation No. 8

The Mission recognizes the wide-spread impact of the modifications on the Krško plant. Accordingly, careful attention must be given to the quality assurance (QA) aspects associated with all the changes being made to ensure that the modifications have been carried out in accordance with the stated objectives for plant operation.

Discussion

Recent experience at other nuclear facilities involving plant design and construction activities have shown the need for establishing an adequate Quality Assurance programe to ensure that proper desgin verification and plant modifications are carried out according to stated objectives in the FSAR as amended. Similar concern is applicable to the modifications being proposed at the Krško plant for the feedwater system. The utility should ensure the adequacy of their QA programme so that the proposed changes are implemented in the intended manner. This involves such activities as design control and plant walk-down to ensure proper implementation of the required changes prior to operation. In addition, QA for operation should be included to cover appropriate operation aspects.

APPENDIX I

SUMMARY OF MISSION ACTIVITIES

Sunday, 6.6

The Scientific Secretary for the Mission met with Dr. Milan Copič of the Republic Committee of Energy of the SR of Slovenia. The objectives of the Mission were discussed and major items for the agenda were identified.

Monday, 7.6

Initial presentations and discussions were held at the Krško plant with the Mission and representatives of the Republic Committee of Energy, the Institut Jožef Stefan, and the Krško utility, NEK. The present situation at the plant was explained and the major problems of the steam generators and plant modification were outlined by the NEK Technical Director. A flexible agenda for the Mission's work was agreed upon.

Information material in the form of the FSAR with amendments and other documents was provided to the Mission.

A short tour of the plant was made.

Tuesday, 8.6

Additional documents were provided to the Mission, including a series of questions raised by the Krško utility and vendor responses regarding the steam generator vibration problem and the proposed feedwater system modification. Written comments made by the Institute Jožef Stefan were also given to the Mission for information.

The day was mainly spent by the Mission in examining the documents received as a basis for their findings and conclusions.

The Mission made a visual inspection of a steam generator tube pulled out for further detailed examination by vendor and utility experts.

Wednesday, 9.6

In the morning, presentations were given by representatives of the vendor. The presentations included an account of steam generator tube vibration measurements, a description of the feedwater system modification, and a more detailed presentation of proposed changes to the control and protection system. The Misson was given ample time to put questions to the vendor experts.

Based on the information given, the Mission members discussed among themselves their views on the current problems. These discussions continued for the remaining part of the day. A set of Mission findings and responses to the concerns expressed by the licensing authority and the Krško utility was drafted.

Thursday, 10.6

The initial Mission draft findings were handed over to the licensing authority and Krško utility representatives for their comments. A discussion on the draft was held, with participation from the Republic Committee of Energy, the Institut Jožef Stefan, the Krško utility and the NUS consultant firm.

The Mission then spent the remaining part of the day in formulating and supplementing their draft recommendations. The new draft was given to the Republic Committee of Energy representative at the end of the day.

Friday, 11.6

In the morning, a presentation was given by Professor Ingvar Jung. This was made on the request of the Republic Committee of Energy and dealt with the current steam generator tube wear problem at the Ringhals 3 plant as well as related research, tests and development in Sweden. The Swedish State Power Board (Ringhals utility) and Westinghouse are conducting tests on a full scale model of a section of a Ringhals steam generator (see Appendix II of this report).

The new Mission draft recommendations were then discussed with the Yugoslav representatives, including additional explanations by the Mission.

Three of the Mission members left Yugoslavia on this day.

Saturday, 12.6

The remaining Mission members continued discussing the draft recommendations, mostly with regard to editing items, and also the structure of the final report to the Government of Yugoslavia.

APPENDIX II

SWEDISH EXPERIENCE OF STEAM GENERATOR TUBE VIBRATIONS AND TESTING PROGRAMME

by

I. Jung

The following Appendix is a summary of a presentation given at Krsko on 11 June, 1982. The views expressed here are those of the author, Professor Ingvar Jung.

1. DIFFERENCE BETWEEN D3 AND D4 TYPE GENERATORS

The situation at Ringhals 3 and 4 (R3 and R4) steam generators of D3 type is much more complicated and grave than at the two D4 generators at Krsko. In the D3 type generators the flow from the restrictor nozzles goes straight into the tube bank between baffle plates 6 and 7 and the tubes are only unsufficiently protected by two holed circular impingement plates. At R3, there are indications of vibrations of dangerous amplitudes already at 40% feed of the 600 Kg/s nominal full load value.

In the D4-generators the feedwater flow from the main inlet is passing down through a downcomer channel to the bottom baffle plates. The tube bank in the preheater section is shielded from the jet forces and the instable flow from the flow restrictor nozzles by a tight impingement plate. At Krsko, tests were presented to the Mission indicating that no vibrations of importance occur in the tubes at feed flows to the main inlet below 60-70% of the full continuous flow 550 Kg/s. With a top feed of 30% and with the 4-nozzle flow restrictors exchanged by a multi-nozzle restrictor with venturi diffusors of sensible design the tube bundles should then be outside vibration risk zones.

2. HISTORY OF R3 AND R4 D3-STEAM GENERATORS

R3 was started in the spring 1981 and had worked at power levels greater than 90% for about 3000 H when tube failures and tube leakages were found in October 1981. The unit was stopped and some 1750 tubes were eddy current tested. 230 tubes had indications of severe wear in the contact aeras with the baffle plates in the preheater section. 31 tubes had wear diminishing the tube wall thickness to less than 40% in the three first tube rows with maximum wear in the plates 6 and 7 but spread from plate 5 to plate 9. These 31 tubes were plugged and R3 was started up again with only 40% load. After 1500 hours the unit was stopped and the generators again inspected by ECT. In one generator signs of increased wear have been found in June 1982.

Findings

At full flow, the 4-nozzle flow restrictor exhibits flow velocities of 30 m/s in the throat section and 15 m/s at the outlet of the restrictor insert. Flow measurements show that the velocities after

the insert are very unstable with pressure fluctuations (total pressures) of approximately ± 0.7 bar. The two circular, holed impingement plates arranged before the tube banks between baffle plates 6 and 7 (intended to distribute the flow from the feed inlet) are completely insufficient to protect the tubes (with a free span of 550 mm) from the impact of the jets and to spread the flow uniformly. Velocities into the tube bank in the section between plates 6 and 7 are found to be very unstable and ununiform. Velocities from plus 10 m/s to minus 2 m/s were measured in the entrance space before the first tube row. With completely uniform flow into row 1, the horizontal velocity should be 0.7 m/s before the tubes, and about 2.3 m/s in the gap area. Even under stable flow conditions, these velocities are in the zone of vibration danger, according to Connel criteria, especially with regard to the first two to three tube rows.

Proposal for design changes and repair

The following design changes are under consideration and are tested at full scale experiments at Aelvkarleby as well as in model air and water tests at Aelvkarleby and in Finspaang, Sweden.

A. To exchange the 4-nozzle flow restrictors by a multi-nozzle design with venturi diffusors reducting and rectifying the outlet feed velocity to the minimum possible (corresponding to the feed inlet area).

B1. To introduce vane diffusers in the feed outlet between baffles 6 and 7 in order to distribute the flow uniformly to the tube bank ;

B2. To install hole plate restrictors and rectifiers in the feed outlet as in B1 ;

B3. To install internal manifolds (sprinklers) consisting of double hole plates made of sections covering most of the tube bank entrance area ;

B4. To take out the two first tube rows and insert solid bars in the preheater section in order to secure a stable and uniform flow to all rows from row no. 3 ;

B5. To install a five row dummy grid of solid bars through the feed inlet between plates 6 and 7. The tubes in the middle of row 1 have to be taken out to give place for the U-form restrictor-rectifier grid bundle.

C. To fasten the first two tube rows in the middle of the span between plates 6 and 7 by springs or fingers between the tubes.

D1. To introduce 30% top feed like the arrangement now installed at Krsko ;

D2. To open windows between the baffle plates to by-pass a portion of the feed flow through the preheater section, vertically upstream and downstream.

My personal opinion is that the solution will be a combination of measures A1, B3 or B5 and D1 for Ringhals 4 and A1, B4, B3 or B5 and D1 for Ringhals 3.

APPENDIX III

List of Participants in discussions with the IAEA Mission

J. Aralica	Technical Director, Operation	NEK
N. Bernot		IBE
P. Bilčar	Superintendent, Erections	NEK
V. Bradač	Manager, Quality Assurance	IE
J. Brguljan	Manager, Quality Assurance	NEK
M. Copič	Chairman, Advisory Board of Reactor Safety	RKE SRS
I. Durdek	Chief of QA/QC Engineering	NEK
A. Fabijančić	Planning and Scheduling Department	NEK
V. Fatur		RKE SRS
D. Feretić	Technical Director	NEK
L.G. Fitzgerald	Vice-President Intern.Operations	NUS

M. Gregorič		IJS
D. Horwat	QA Consultant	IMK
V. Janoschek		UNSD
M. Jeran		IBE
P.V. Judd	Consultant	NUS
B. Mavko	Coordinator, Nuclear Safety	IJS
Z. Pavlović	Manager, Licensing and design	NEK
D. Tankosić		NEK
P. Tomaš		IRB
J. Valčić		RKEIRZ SRH
B. Vojnović		IRB

Westinghouse attendees at presentation (1982-06-09)

J. Alba	Nuclear Technology Division - Systems Engineering
E.M. Burns	Nuclear Technology Division - Nuclear Safety & Licensing
D. Comoletti	

E. Heggeseth	
J. James	
J.V. McKeown	Project Director, Krsko Project
W. Revler	
N.R. Singleton	Nuclear Technology Division

Abbreviations used :

IBE	Engineering Bureau Electroproject, Ljubjana.
IJS	Institute Jožef Stefan, Ljubjana.
IE	Institute of Electric Utilities of the Republic of Croatia
IMK	Institute of Metal Constructions of the Republic Slovenia.
IRB	Institute Rudjer Bošković, Zagreb.
NEK	Nuklearna Elektrarna Krško, Krško Utility.
NUS	Nuclear Utility Services Corporation, USA.
RKE SRS	Republic Committee of Energy of the Socialist Republic of Slovenia.
RKEIRZ SRH	Republic Committee of Energy, Industry, Mining and Crafts of the Socialist Republic of Croatia.