Response to

Request for Additional Information No. 194 (598), Revision 0

03/24/2009

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 04.04 - Thermal and Hydraulic Design
Application Section: 4.4

QUESTIONS for Reactor System, Nuclear Performance and Code Review (SRSB)

Question 04.04-1:

Containment isolation valve of the N2 supply to the AMS is a manually operated valve, located outside of the containment, which is open whenever there is a need to replenish the accumulators to the AMS. Describe the containment isolation capability for this system. Confirm that there are isolation valves inside the containment which will automatically close upon receiving an isolation signal.

Response to Question 04.04-1:

Nitrogen supply to the Reactor Building users is provided by the Central Gas Supply System. The Central Gas Supply System has two, separate, supply headers to the Reactor Building, each entering the building through a containment penetration and having an inner and an outer containment isolation valve. The containment isolation valves are motor-operated globe valves that close automatically upon receipt of a Stage 1 Containment Isolation signal from the Protection System.

See the U.S. EPRFSAR Tier 2, Section 6.2.4 regarding the containment isolation.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 04.04-2:

Please provide information/data in regard to the AMS guide tube deformation and the impact it would have operationally and neutronically. How would the signal measurement be affected and what compensation is performed in POWERTRAX program?

Response to Question 04.04-2:

Aeroball measurement system (AMS) guide tubes are physically separated from the self powered neutron detectors (SPND). In the event it should become necessary, an individual AMS tube may be deactivated by an operator, thereby isolating that particular tube from the rest of the system. Due to the physical layout of the instrumentation lances, any deformation of an AMS guidetube would have no neutronic impact on an SPND measurement.

For additional information on POWRTRAX/E, see Section 3 of ANP10282P, “POWERTRAX/E Online Core Monitoring Software for the U.S. EPR Technical Report”.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 04.04-4:

1) Please provide P&IDs, related schematics and detail design information of the Aeroball monitoring system (AMS) and power density detector system (PDDS) to supplement and enhance the information contained in the DC FSAR. Provide a more detailed description of the AMS operation including a discussion of a complete calibration cycle with opening and closing times of the system valves. Also please provide information/data in regards to the AMS transport time correction and the effect it may have on the flux measurements. Explain how compensation is performed in POWERTRAX/E program to account for the transport time of the Aeroballs.
2) What are the design criteria for the Aeroball finger tubing? Can the tubing system withstand the RCS nominal system pressure of 2250 psi if the carrying gas supply is cut off? Describe the isolation systems that will actuate in case an AMS tube ruptures inside the vessel.
3) Please identify any reports of excessive residual moisture in the Aeroball tubing at operating plants employing the Aeroball monitoring system (AMS). Please provide a detail description of the event(s) and the root cause of excessive residual moisture. If excessive residual moisture had been detected, can one assume a single failure resulting in the leakage of the primary loop coolant through the tubing to the counting room or N2 supply room?
4) Where are the Aeroball monitoring system (AMS) counting room and the N2 supply line source located? What are the dose limits in these areas? Can the leakage of a tube cause significant dose in the upper containment?
5) Please identify the primary nitrogen source for the Aeroball monitoring system (AMS) during normal plant operation. In the event of a nitrogen gas pressure drop in the main supply nitrogen source, describe the process sequence of events to isolate the primary nitrogen source from the AMS. If the primary nitrogen source is isolated, identify the backup nitrogen source to the AMS that ensures continue Aeroball transport operation. In detail, describe the backup source functions and interface with the primary source and AMS. If applicable, show the relevant containment isolation valves on the P&IDs. What is the pressure setpoint at which the solenoid valve isolates the supply line to the main supply system? What is the nominal nitrogen pressure during normal operation? If there is a tube failure within the containment, what is the impact of the leakage on the containment pressure?
6) What is the allowable moisture content in the N2 line? Is the allowable limit controlled by the Technical Specifications? Please provide detail information to clarify how the moisture content is measured and controlled below the limit. There are 40 Aeroball tubes which are grouped into four subsystems representing the symmetrical core quadrants. If the moisture level in any of the subsystems is too high, is there a moisture sensor and controlling mechanism that will shut down and isolate the affected subsystem. If so, describe the operation in detail. Also, provide a detail description of the mechanism which controls the routing of the 10 Aeroballs strings per quadrant onto the counting table. If there is a moisture buildup within a tube, explain in detail how does this affect the following: (1) the flux readings of the Aeroball stack, (2) thermal limits calculations, and (3) the neutronics of the fuel assembly in the vicinity of the tube?

7) Twelve Siemens nuclear plants have used the PDDS and Aeroball monitoring system (AMS) systems for core monitoring. What are the major differences between the EPR™ core monitoring system and those used in Siemens plants? What are the advantages and disadvantages?

8) Please discuss in detail the self powered neutron detector (SPND) failure events reported at operating plants including additional details on the performance and maintenance history of this type of detector?

9) What is the lifetime of the Aeroballs? Is there an age-based correction factor in the calibration calculations?

10) [Question intentionally deleted].

11) The cables and tubes are routed out of the reactor through a penetration into the Aeroball monitoring system (AMS) room housing the instrumentation measuring cabinet and table. Is this penetration pressure tight? If so, please explain the reason for this pressure tight penetration since the AMS is located within the containment.

12) [Question intentionally deleted].

13) Describe in detail the Power Density Detector System (PDDS) and provide a list of references.

14) Considering any sensitivity deviations to core instrumentation calibration to potential shuffling of the Aeroballs allowed by the mechanical design of the system and manufacturing tolerances, please provide detail information of manufacturing tolerances to the measurement uncertainty.

    How does the Aeroball monitoring system (AMS) system compensate for the difference in the time of the flux measurements between each quadrant while the ball stacks are in the waiting position?

15) There are 40 ball stacks with 36 flux measuring detectors per ball stack. Please discuss in detail how the detectors are inter-calibrated to compensate for individual detector signal sensitivity loss? Is this performed in the Aeroball monitoring system (AMS) or POWERTRAX/E?

16) Please discuss in detail the following questions. How does the Aeroball monitoring system (AMS) compensate for a bad measuring detector? How many bad measuring detectors are permitted per ball stack before the ball stack is declared inoperable? If a ball stack is declared inoperable, how would the flux profile for that location be determine and what effect would there be on the thermal limit calibrations? What is the maximum number of inoperable ball stacks permitted per quadrant and full core? Are these limits regulated by the technical specifications? Is there a limit for the combination of failed in-core detectors and measuring detectors (ball stacks)?

17) The Aeroball has a diameter of 0.067inch (1.7mm). What is the inner diameter of the Aeroball tubing? What are the temperature coefficients of expansion for the Aeroball and tubing? Due to expansion, how is the gap between the tube and ball affected at normal operational temperature conditions? Does this affect the ball travelling through the tube? Also, how is the ball travelling through the tubing affected by growth and deformation of the Aeroball tube at operating temperature and high flux fields?

18) Describe in detail the quality control process for fabrication of Aeroballs. How are individual balls tested? What is the tolerance on the ball composition?

Response to Question 04.04-4, Part 1:

AMS Overview:

The Aeroball measurement system (AMS) is an electromechanical computer-controlled, fully automated, online flux mapping measurement system based on movable activation probes. Moveable probes are Aeroball stacks, in columns that span the active core height, that are used to determine the relative neutron flux density in the core. The AMS is used as a calibration tool for the SPNDs. POWERTRAX/E receives signals from the Aeroball measurement system to perform the three dimensional flux reconstructed power distribution. The three dimensional power distribution is used to calibrate the SPNDs. Power distribution is compared to a core model for trending analysis. The results of the power reconstruction calculation are verified and checked by engineering. Changes to the SPND calibration values are updated manually.

A nitrogen gas driving medium system located outside of the reactor vessel transports the Aeroball stacks to the core where they become irradiated. After irradiation, the balls leave the core through magnetic stops, described in the Response to Question 04.04-4, Part 6, and pass into the measuring table in the AMS room inside the containment. The mechanical design of the AMS fingers consists of two concentric steel tubes (i.e., the pressure tube and the Aeroball tube) surrounded by an outer protective steel tube. The magnetic stops of this response are part of the AMS outside the reactor pressure vessel (RPV) and are mounted on the lower level of the RPV closure head equipment. When closed, the magnetic stops retain the Aeroball stacks in a holding position above the reactor. When open, the magnetic stops permit the Aeroballs free passage to the reactor core or to the measuring table.

AMS tubes are routed from the top of the lances over RPV closure head equipment cable bridges through the reactor building to the AMS rooms. These tubes are the transportation device for the Aeroball stacks and propulsion gas. Because the AMS tubes are brazed pressure-tight, the cables are provided with a detachable sealed entry piece that permits the entire finger to be replaced.

The movable activation probes, or “Aeroballs”, are steel balls, composed of carbon, chromium, iron and vanadium. The useful neutron sensitive material is the vanadium isotope V^{51} which undergoes the following nuclear reactions:

$$V^{51} + n_0^1 \rightarrow V^{52} + \beta + \gamma \rightarrow Cr^{52}$$

The vanadium utilized in the balls produces a gamma decay signature readily discernable by the measurement software. When exposed to a neutron flux, the V^{51} used in the balls absorbs a neutron and reaches a higher energy state to become isotope V^{52}. With a half life of 3.75 minutes, V^{52} undergoes β- decay to Cr^{52}. Gamma radiation that is given off during this decay is measured by the AMS and the energy of the emitted γ used in the activity determination process is approximately 1.43 MeV.

The activity distribution along the Aeroball measurement table stacks is proportional to the neutron flux density, and thus, to the power density. If subsequent measurements are performed immediately following one another, the AMS software factors residual decay energy from previous measurements into the calculations. The balls are designed to be used for the life of the plant without the need for replacement since there is negligible depletion of V^{51} during each measurement; however, the balls can be replaced if Aeroball transport problems occur.

- See the Response to Question 04.04-4, Part 5 for nitrogen source information.
- See the Response to Question 04.04-4, Part 14 for AMS flux measurement timing sequence information.
- See the Response to Question 04.04-4, Part 15 for AMS calibration information.

Opening and closing times for system valves will be determined later in the design process for the U.S. EPR.

Figure 04.04-4-1, Figure 04.04-4-2 and Figure 04.04-4-3 display where the various parts of the incore equipment are located within the RPV.

The core instrumentation lance is the basic mechanical unit of the incore neutron-flux measuring system. A typical lance is shown on Figure 04.04-4-4. Instrumentation lances hold and guide the measuring devices for the SPND. There are four different types of instrumentation lances corresponding to specific core locations. The guide tube and protective tubes (fingers), housing either one ball probe (AMS finger) or several power density detectors (PDD) (PDD finger, Figure 4.4-1-2), are suspended from a yoke that rests on the top plate of the upper core structure between the control rod shroud tubes. At the lower end of the finger, the ball transport tube in the lance finger end in a gas permeable ball stop. Concentric to the ball support tube, a gas supply pipe is arranged that is sealed pressure-tight from the environment and connected to the ball transport tube via the ball stop, thus allowing a counter pressure to be applied to eject the ball stacks.

During operational conditions the lance yoke rests upon the top plate of the core structure. The outside diameter of the lance probes are dimensioned to fit into free control rod guide tubes of the fuel assemblies. The shafts extend upwards to the seal nozzles, where they penetrate the reactor pressure vessel closure head, Figure 04.04-4-2. The pressure-tight connection between the lance shafts and the instrumentation nozzle is given by an easily detachable double seal ring system which permits leak tightness tests after assembling each nozzle.

Aeroballs are spheres of 0.067 inch (1.7 mm) diameter with approximately 2500 balls per ball stack. When at the rest position, the ball stacks are above the solenoid ball stops, described in the response to Question 04.04-4, Part 6, which are located inside containment above the reactor vessel at the level of the cable bridge.

There are be 40 columns of ball stacks, divided into four subsystems, (Figures 04.04-4-3 and 04.04-4-25), with length approximately equal to active core height, further described in the Response to Question 04.04-4, Part 14. When the ball stops of a subsystem are opened, the ball stacks move pneumatically (by means of nitrogen gas, described in the Response to Question 04.04-4, Part 2), through the instrumentation lance (Figure 04.04-4-4) through the Incore Instrumentation nozzle closure (Figure 04.04-4-6) through the in-lance yolk (Figure 04.04-4-7) to their activation positions in the reactor core inside the Aeroball Measuring Probe (Figure 04.04-4-5) where the balls will be activated by neutrons. The activity distribution along the stacks is proportional to the neutron flux density and thus to the power density at the place of activation. The positioning of the Aeroballs at this point is displayed in Figure 04.04-4-8 and Figure 04.04-4-2.

After defined irradiation time of approximately 3 minutes, the ball stacks are transported from the core via nitrogen gas by passing through the path described above to the waiting position outside the core below the magnetic stops. After waiting approximately 3.7 minutes, the ball stops open, allowing the ball stacks to be transported, using nitrogen gas, to the measuring table, Figure 04.04-4-10.

In the measuring compartment the ball transport tubes are connected to a measuring table (Figure 04.04-4-9) comprised of 10 detector bars, each bar containing 36 tapering ports, for a total of 360 activation detectors. All detector bars are arranged on the measuring table with four ball transport tubes grouped together in parallel under each detector bar to form four subsystems. Refer to the Response to Question 04.04-4, Part 15 for more detailed information and figures. The vanadium utilized in the balls produces a gamma decay signature readily discernable by the measurement software. When exposed to a neutron flux, the V^{51} used in the balls absorbs a neutron and reaches a higher energy state to become isotope V^{52}. With a half life of 3.75 minutes, V^{52} undergoes β- decay to Cr^{52}. Gamma radiation that is given off during this decay is measured by the AMS and the energy of the emitted γ used in the activity determination process is approximately 1.43 MeV. Individual activation detectors are connected to a charge-sensitive amplifier and a pulse counter via coaxial relay units with a defined measuring period. Pulse counts acquired for the individual measuring channels are transferred to the AMS computer for further data processing.

The ball stacks of one subsystem are measured simultaneously with the measurements being performed individually for each stack. During the measurements, the activated ball stacks of the other three subsystems are in the rest position which is located inside containment.

Following the measurement, the ball stacks are transported, using nitrogen gas, to the rest position above the magnetic stops. Afterward, the procedure repeats for the remaining 3 subsystems.

An overview is provided in Figure 04.04-4-10.

This procedure is further detail in the Response to Question 04.04-4, Part 14.

Figure 04.04-4-11 provides a typical U.S. EPR SPND finger. Further information concerning SPNDs is provided in ANP-10282P, POWERTRAX/E Online Core Monitoring Software for the U.S. EPR Technical Report.

P&ID of Incore Instrumentation AMS:

An example P&ID of a typical AMS is shown in Figure 04.04-4-12. This figure is provided for informational purposes as the level of design detail shown will be finalized later in the design process.

FSAR Impact

The U.S. EPR FSAR will not be changed as a result of this question.

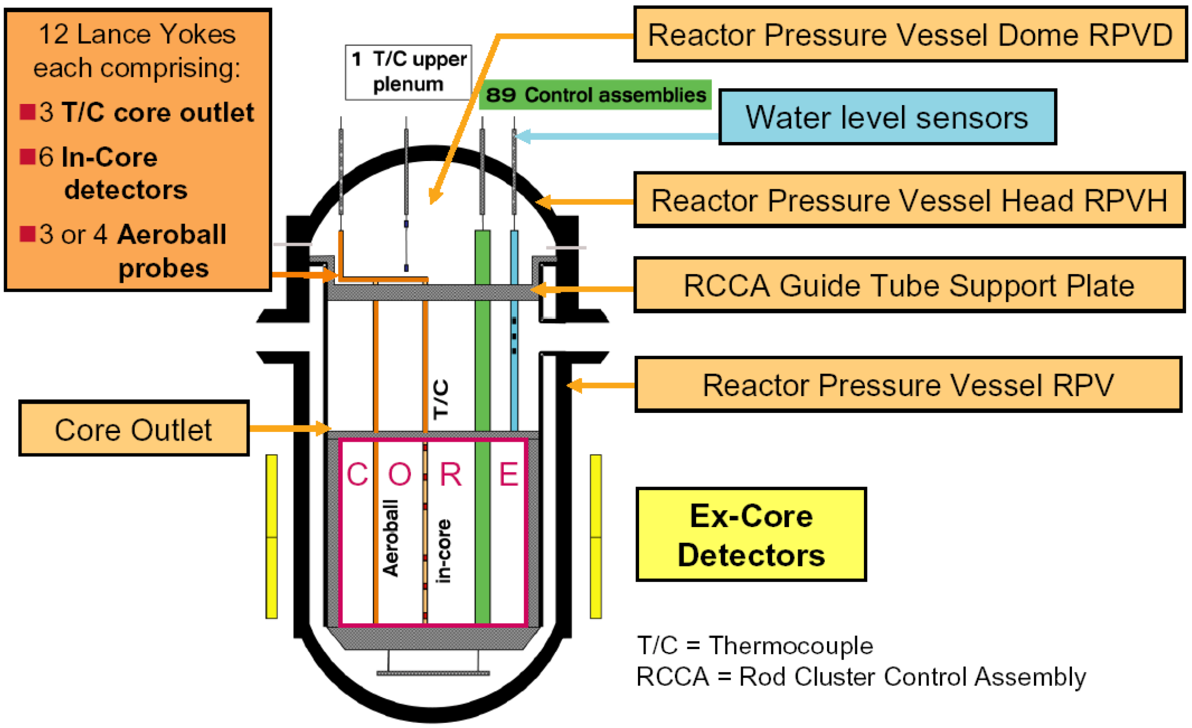
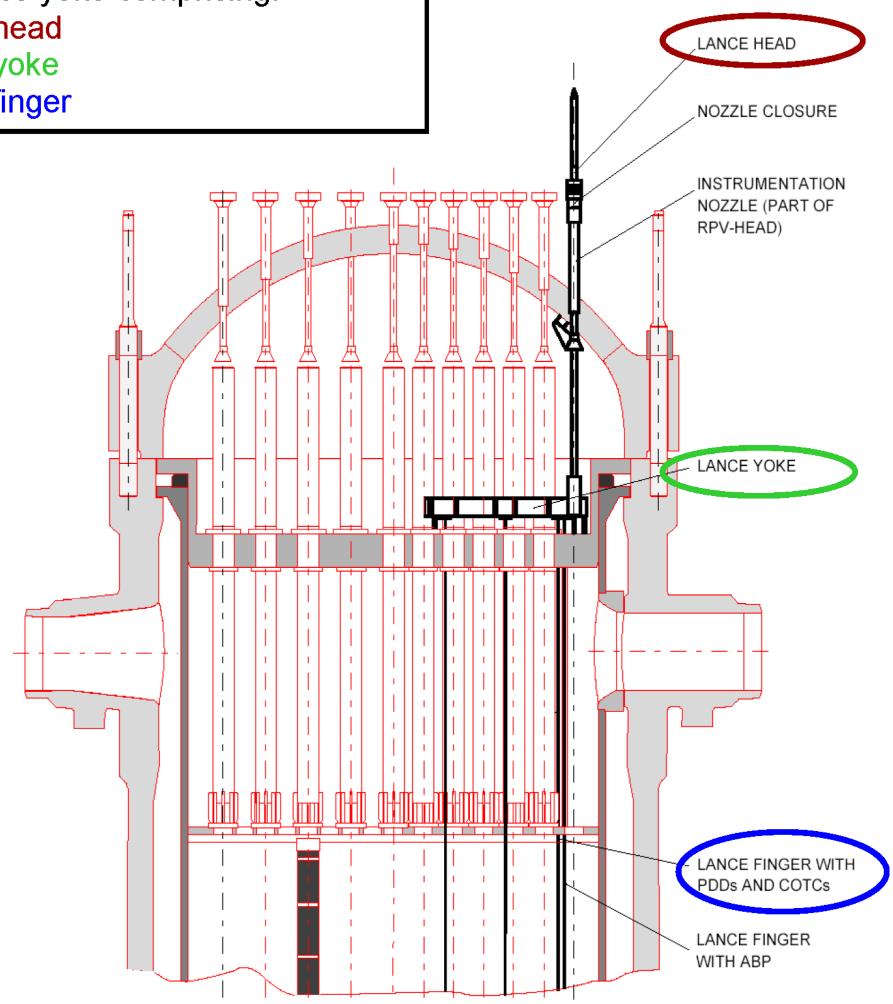


Figure 04.04-4-1: Incore Instrumentation Location Overview

- Each lance yoke comprising:
  - -) Lance head
  - -) Lance yoke
  - -) Lance finger



LANCE, INSTRUMENTATION NOZZLE AND COOLANT NOZZLE ARRANGEMENT DRAWN ROTATED
SOME CONTROL ROD GUIDE ASSEMBLIES AND NOZZLES NOT DRAWN

ABP AEROBALL PROBE
PDD POWER DENSITY DETECTOR
COTC CORE OUTLET THERMOCOUPLE

Figure 04.04-4-2: Incore Instrumentation Location Overview

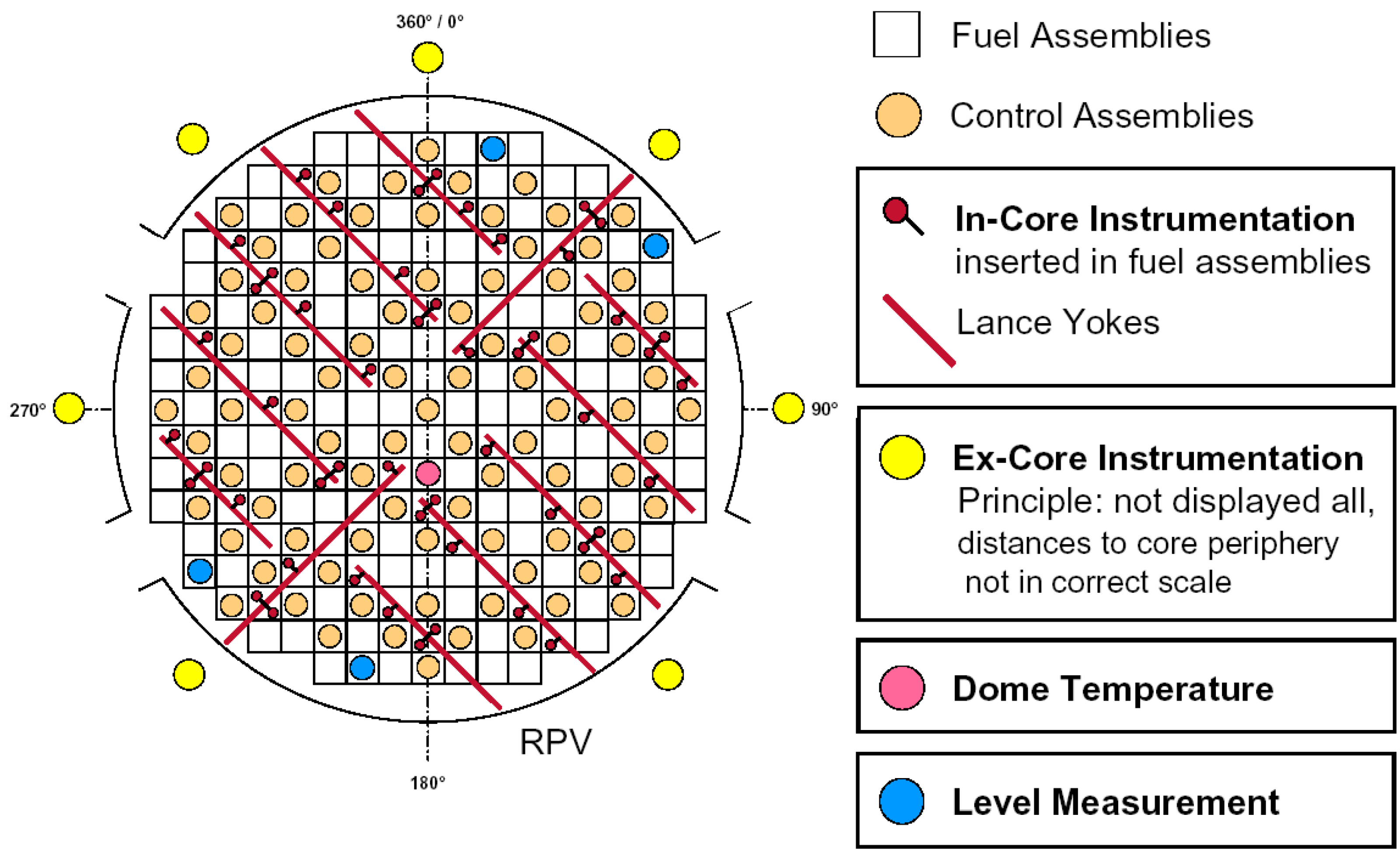


Figure 04.04-4-3: AMS / SPND Lance Configuration - Radial Position of the 12 Lance Yokes

Figure 04.04-4-4: Typical Instrumentation Lance

Figure 04.04-4-5: Typical Aeroball Measuring Probe (AMP)

Figure 04.04-4-6: Typical EPR Incore Instrumentation Nozzle Closure

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Figure 04.04-4-7: Typical EPR Incore Instrumentation Lance Yoke

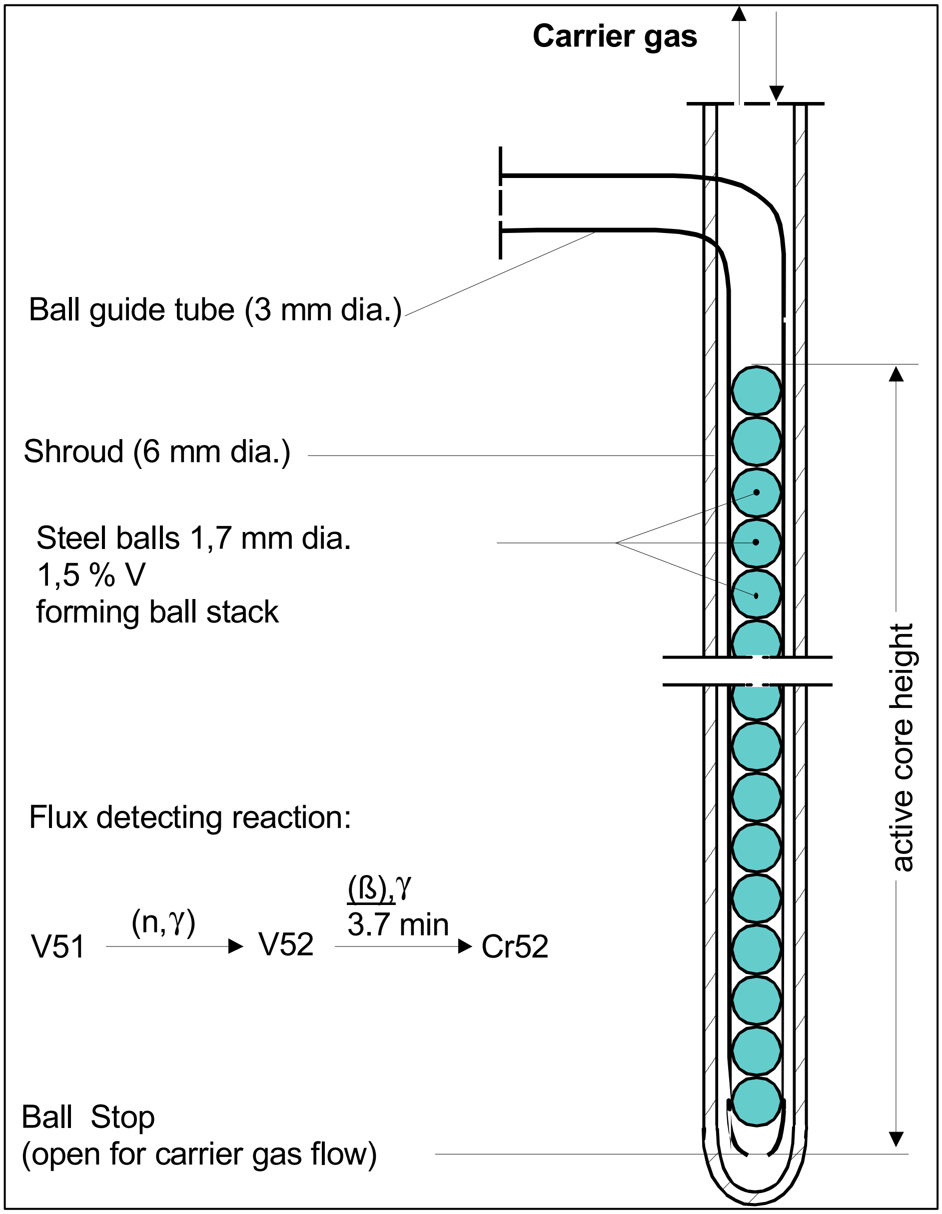

Figure 04.04-4-8: Aeroball Probe (Schematic)

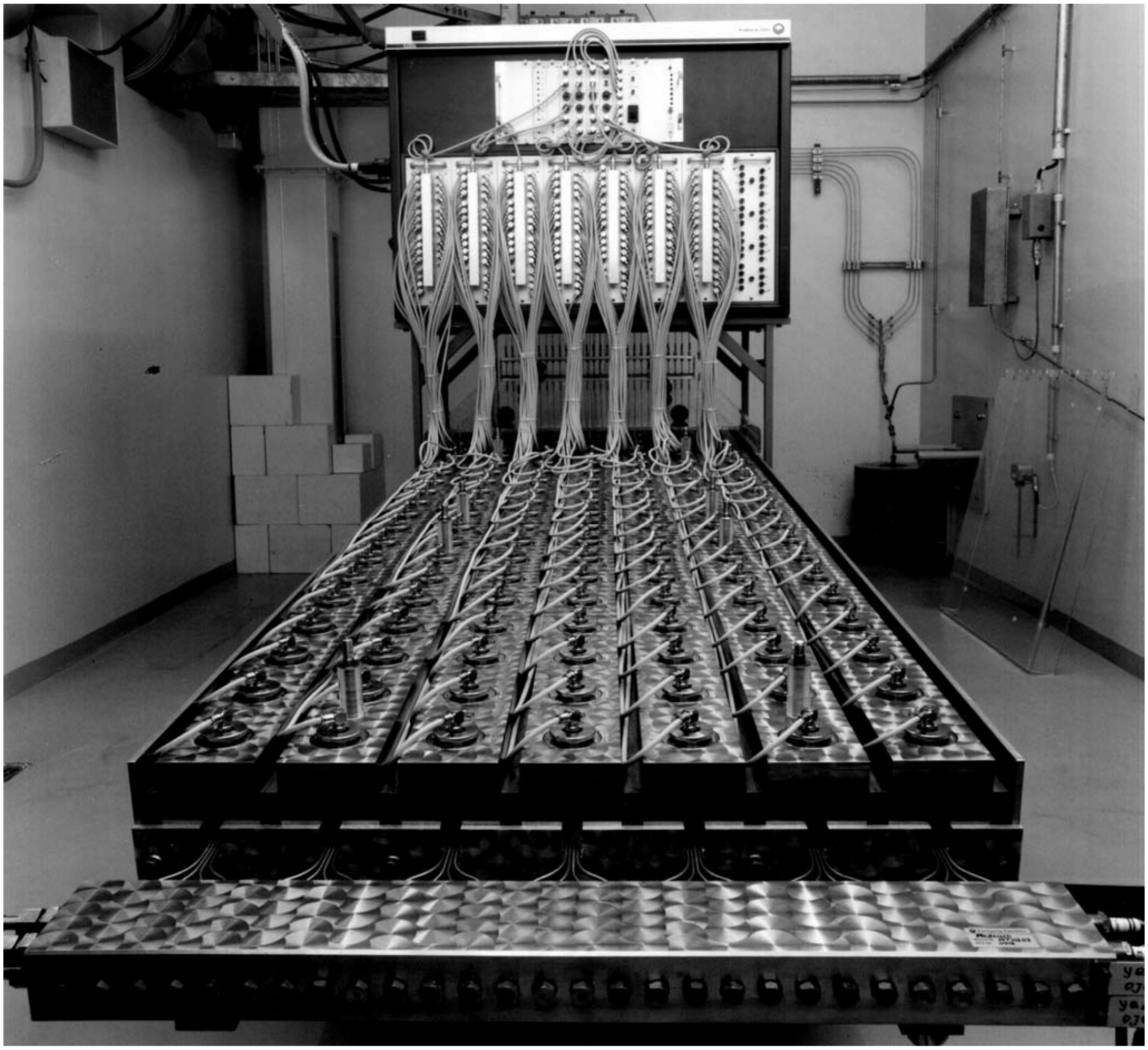

Figure 04.04-4-9: Aeroball System Measuring Table (KONVOI Plant)

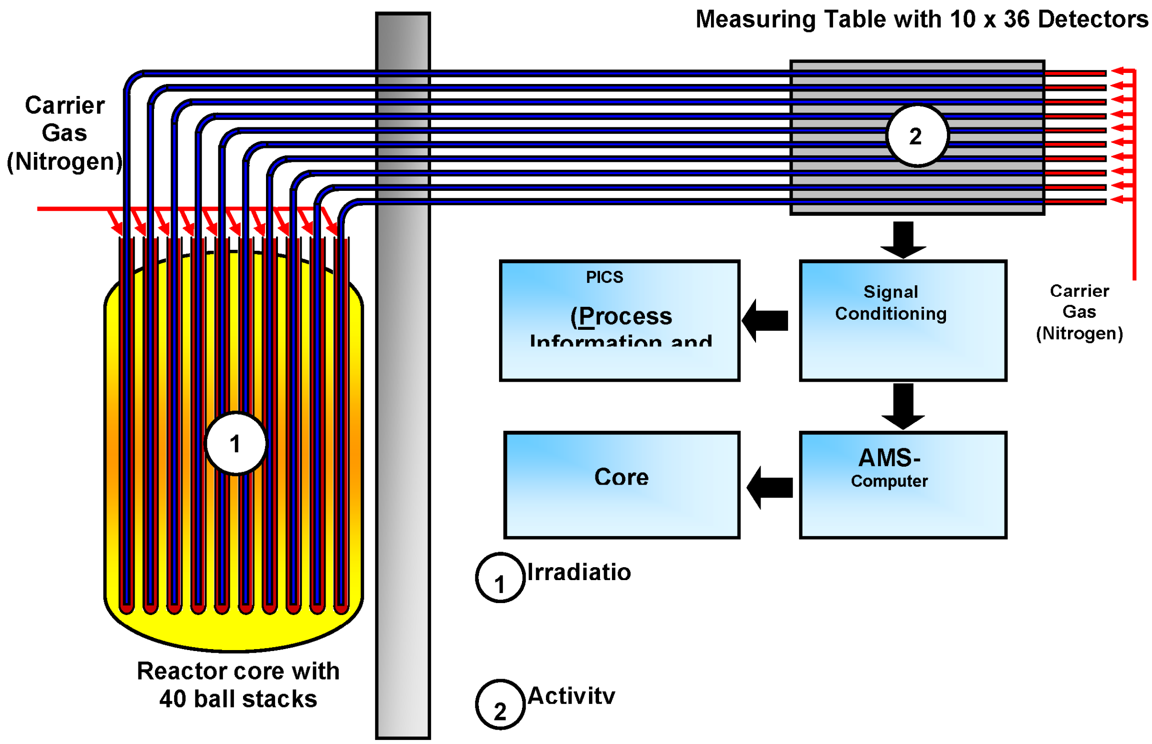

Figure 04.04-4-10: Overview of Aeroball System

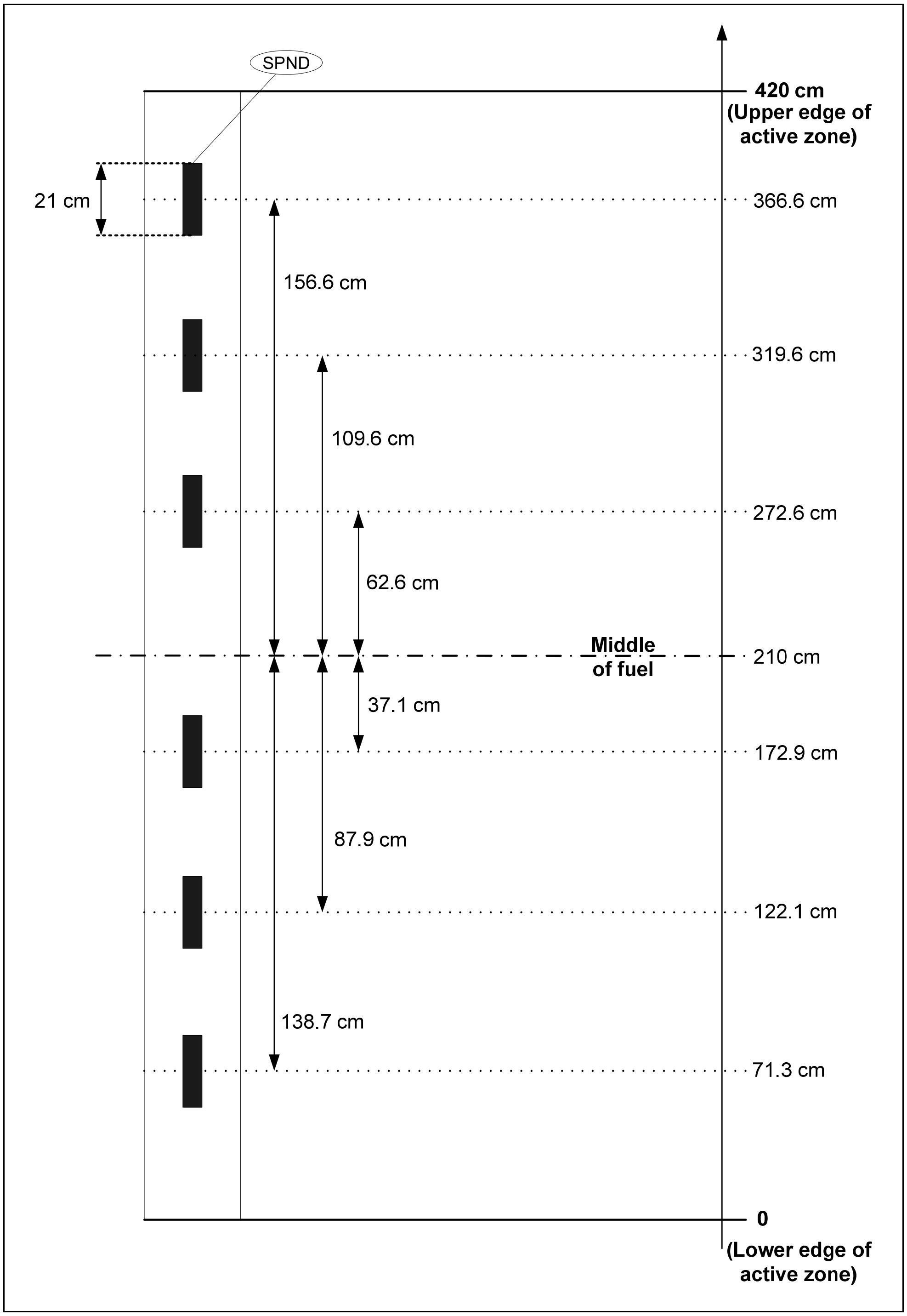

Figure 04.04-4-11: Typical U.S. EPR SPND Finger

Figure 04.04-4-12: Example P&ID of a Typical AMS

Response to Question 04.04-4, Part 2:

The design pressure of the AMS tubes, which are part of the reactor coolant pressure boundary (RCPB), is 2535 psig. The Aeroball lance fingers comprise two concentric stainless steel tubes (refer to Figure 04.04-4-14), which include the pressure tube and the ball tube that are surrounded by an outer protective stainless steel tube. The 0.067 inch (1.7 mm) diameter AMS balls are pneumatically propelled through the 0.079 inch (2 mm) inner diameter ball tube (which has a wall thickness of 0.020 inch, 0.5 mm) to their activation positions in the reactor core (Table 4.04-4-1). The AMS balls are then activated by the neutron flux in the core. Inside the Aeroball finger the ball tube ends at the bottom in a ball stop designed to hold back the Aeroballs but let the gas flow pass through. The ball tube is concentrically surrounded by the gas-tight pressure tube. Openings in the ball stop allow nitrogen to flow between the ball tube and pressure tube. This allows gas to be injected under pressure into the ball tube from one end or the other to propel the stack of Aeroballs either into, or out of, the core. A protection tube encases the ball tube and pressure tube. The protection tube is designed to withstand the temperature and pressure of the reactor coolant system. Small perforations in the both ends of the protection tube allow reactor coolant to flow inside and contact the pressure tube. The 0.157 inch (4 mm) diameter pressure tube (wall thickness 0.039 inch, 1 mm) is subject to nitrogen gas pressure on the inside (approximately 150 psi) and is subject to reactor coolant system pressure on the outside.

Refer to Response Number 12 in Response to Request for Additional Information – ANP 10287P, “Incore Trip Setpoint and Transient Methodology for U.S. EPR Topical Report” (TAC No. Q00013, ML082261522) for more information regarding failure of the AMS pressure boundary.

The AMS has the ability to isolate a leak in an AMS probe by closing two magnetic valves on a pressure and/or humidity signal. Figure 04.04-4-13 shows the location of the magnetic valves for each subsystem. If an event occurs affecting all 40 probes, the magnetic valves close to isolate the entire system.

Monitoring and the automated isolation valve response preserve the reactor coolant system pressure boundary under abnormal plant conditions.

During more than 30 years of AMS operation in reactor plants, primary coolant has never been detected in the Aeroball tubes and an AMS tube rupture of this nature has never occurred. See RAI 170, response to Question 03.05.01.02-2 for additional information.

FSAR Impact

The U.S. EPR FSAR will not be changed as a result of this question.

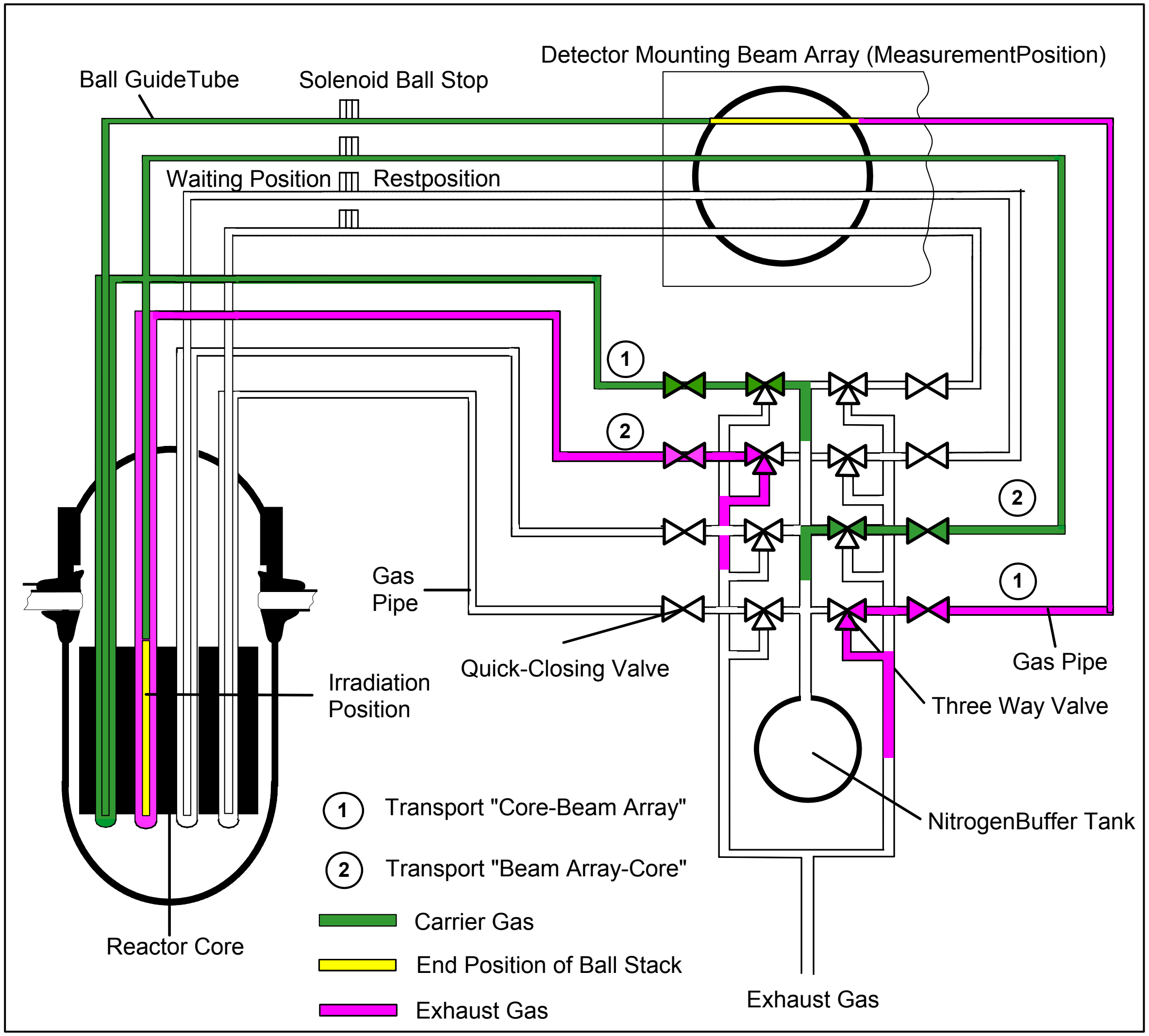

Figure 04.04-4-13: Aeroball Pneumatic Transport System

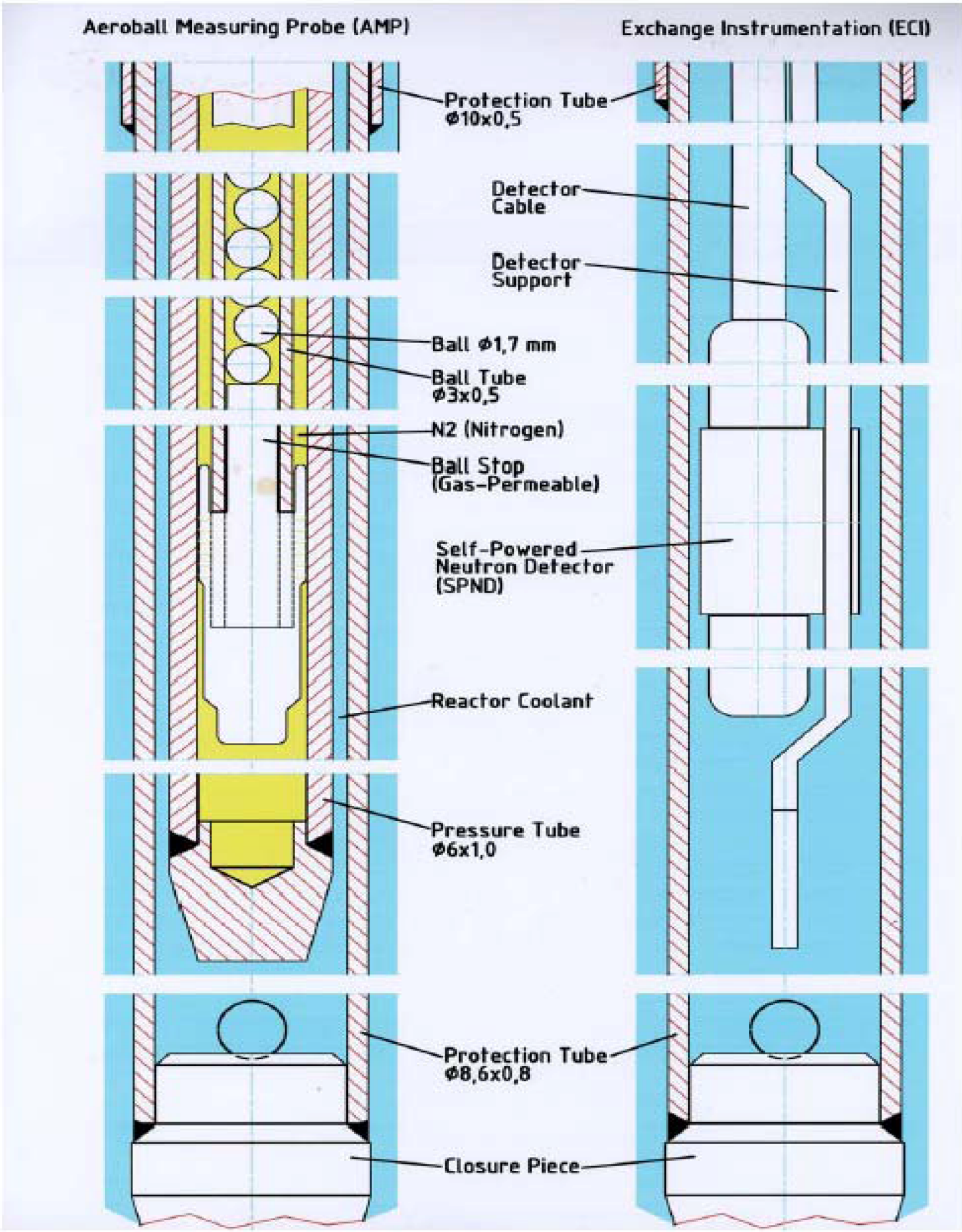

Figure 04.04-4-14: Aeroball System / SPND Lance Configuration

Table 04.04-4-1: Data for a Typical U.S. EPR Aeroball Probe Lance

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Notes Regarding Question 04.04-4, Part 2, Table 1:

(1) Other potential Stainless Steel (SS) types that could be used are 14550 =347 SS or 14571 =316 SS Ti.
(2) See Response to Question 04.04-4, Part 18 of this question set concerning the alloy composition of Aeroballs.

Response to Question 04.04-4, Part 3:

The Response to Question 04.04-4, Part 2 provides more detailed information concerning the arrangement of the Aeroball tubes within the lance finger. Primary coolant has never been detected in the Aeroball tubes. The Aeroball tubes are not in contact with the coolant itself; therefore, the primary pressure barrier is the lance finger. If the lance finger breaks and in addition the Aeroball tube is leaking, the primary coolant could theoretically flow to the measuring table. The design pressure of the AMS tubes, which are part of the RCPB, is 2535 psig. The Aeroball tube itself can sustain this pressure; and it is tested to an internal pressure of 2785 psig. In such an event, the moisture sensors detect the presence of coolant in the tube and immediately close the quick-closing valves (fast closing valves), which safely isolate the Aeroball tubes (at the valve rack side and at the core side of the measuring table). However, even if the quick-closing valves did not immediately close, the tubes can withstand the pressure. Such an accident has not occurred in any Aeroball installation.

The data of failed Aeroball probes, which was obtained over approximately 30 years of operation for 220 fuel cycles of 12 plants, typically with 28 Aeroball probes in each cycle, shows that the last significant degradation of AMS occurred over 17 years ago, in 1991.

The root cause of excessive residual moisture that was observed after nitrogen tank hydrostatic test for KKP2 was not due to RCS leakage but was due to the hydrostatic testing maintenance procedure. During Cycle 5 of the KKP2 plant, 1989/1990, a hydrostatic test maintenance procedure was performed on the nitrogen tanks but all the residual moisture was not removed from the tanks. The residual moisture content caused excessive humidity in the nitrogen transport lines, which resulted in the observed failure of 21 of 28 Aeroball probes. Upon restoration and progression into Cycle 6 of the KKP2 plant, 1990/1991, the same event occurred. Maintenance procedures were improved to preclude another such occurrence. This was the last observed failure of any Aeroball system world-wide to date.

No abnormal operational occurrence of any AMS probes has been observed for any reactor plants other than those indicated in Table 04.04-4-2.

Table 04.04-4-2: Abnormal Operational Occurrences with AMS Probes

Plant:	Biblis A	KKP 2	KKP 2	Other Reactor Plants
Year:	1975/76	1989/90	1990/91	1975 to Present
Time Since Beginning of Cycle:	Cycle 1 245 EFPD	Cycle 5 70 EFPD	Cycle 6 6 EFPD	
Number of Failed Probes:	14 of 32	21 of 28	21 of 28	
Reason:	Wrong lubrication	Excessive residual moisture after N_2 tank hydro test	Subsequent failure of same probes in next cycle	

Additional observed failures of the AMS include the event of stuck balls. Problems with stuck balls arose in Biblis unit A during the first cycle after about 245 efpd (1975). Until the end of this cycle a total of 14 out of 32 probes failed. The reason was a wrong lubrication of the ball stacks but also a specific mechanical problem. Biblis unit A was the first Siemens plant with an active core height of 3.9 meters and correspondingly longer and heavier ball stacks. In this first plant the end position of the ball guide tubes was too weak with the consequence the last ball stuck in this position and constituted an impediment for the carrier gas used to drive out the ball stacks from the core. During the refuelling outage the instrumentation lances (unit consisting of at most four Aeroballs and one SPND finger) were replaced by new ones equipped with more resistant bottom ends. In all other plants and cycles (cumulative experience of approximately 190 cycles) ball transport did not pose significant problems.

A disturbance of the ball transport can be clearly identified by evaluating the Aeroball measurement results. The preferred method is a carefully measured amount of lubrication. If this was ineffective, replacement of the ball stack could be necessary. If necessary, it is possible to apply a higher carrier gas pressure (approximately 200 psi) to remove the balls. This operation can be performed with mounted Aeroball system using the installed Aeroball control equipment thus, the doses taken by the employees is negligible. The consequences of failed Aeroball probes are the loss of information regarding the flux distribution; the consequences are the same in the case of stuck balls.

FSAR Impact

The U.S. EPR FSAR will not be changed as a result of this question.

Response to Question 04.04-4, Part 4:

The nitrogen propulsion gas supply source is from the gas supply system of the plant and is cleaned, dried and supplied to the pressure reservoir.

There are four redundant nitrogen subsystems, located in room UJA23-042 (i.e., Instrumentation measuring cabinet room), for controlling / performing Aeroball transport.

The dose rate information provided by the U.S. EPR FSAR Tier 2,Section 12.3, states that the dose limit in these areas is to be less than 25 millirem per hour (i.e., <25 mrem/hr). An area dose rate radiation monitor in the Aeroball measuring room continually monitors the radiation level and provides a warning of sudden increased dose rate during operation of the system or of unexpected high dose rate.

Pressure and humidity sensors automatically isolate the system by the use of automatically actuated quick-closing valves. The setpoint for the isolation sensors has not yet been determined. Procedures will be established to minimize moisture content in the Aeroball and propulsion-gas tubes. Figures 04.04-4-15 and 04.04-4-16 display where the AMS rooms and system parts are located.

Leakage of reactor coolant through an Aeroball tube would be a small break loss of coolant accident (LOCA). The small break LOCA is described in U.S. EPR FSAR Tier 2, Section 15.6.5.2 and the radiological consequences are found in U.S. EPR FSAR Tier 2, Section 15.0.3.11. Refer to the Response to RAI 133, Supplement 3, Question 19-244(1) and 19-244(2).

FSAR Impact

The U.S. EPR FSAR will not be changed as a result of this question.

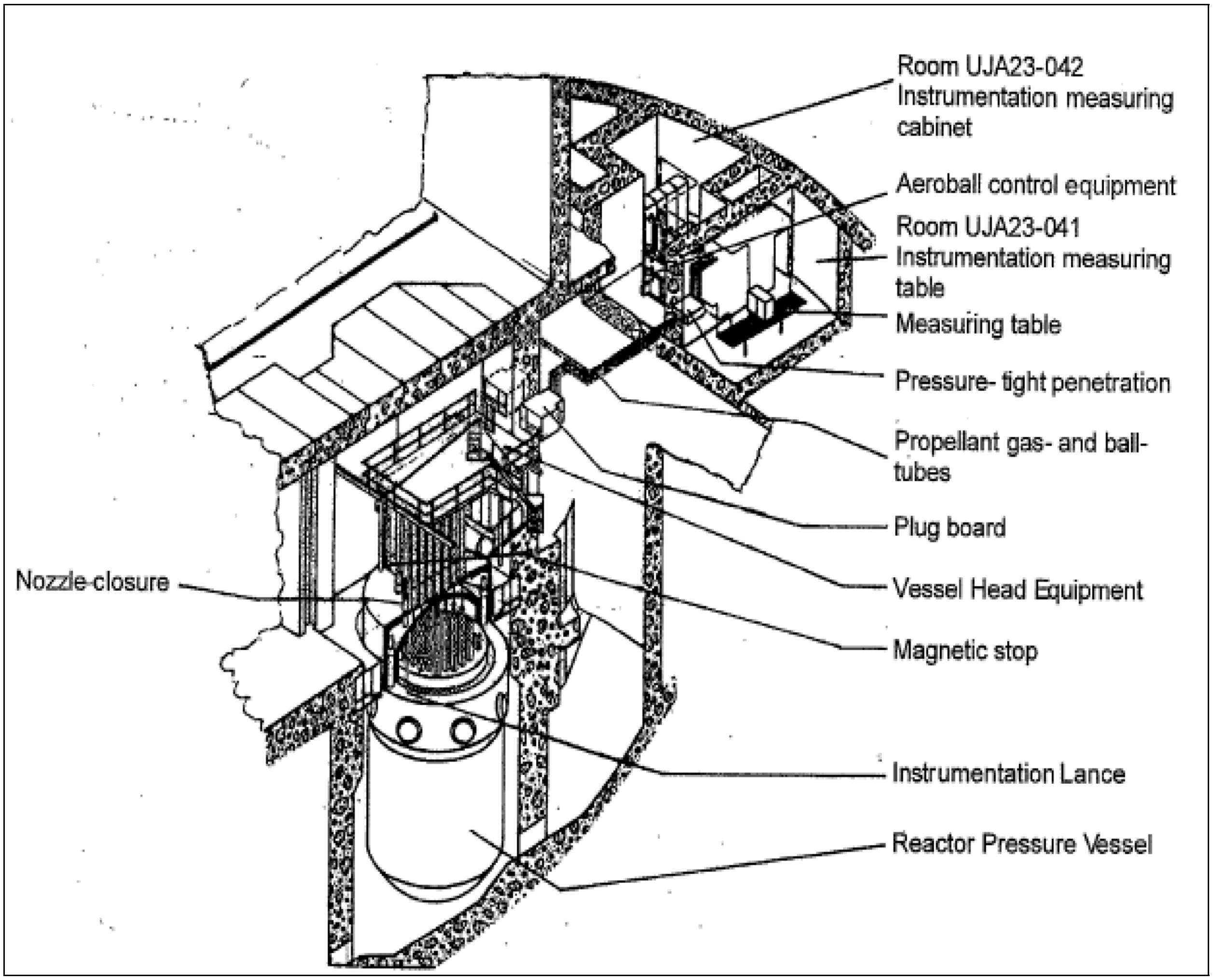

Figure 04.04-4-15: Aeroball Measurement System Instrumentation Location

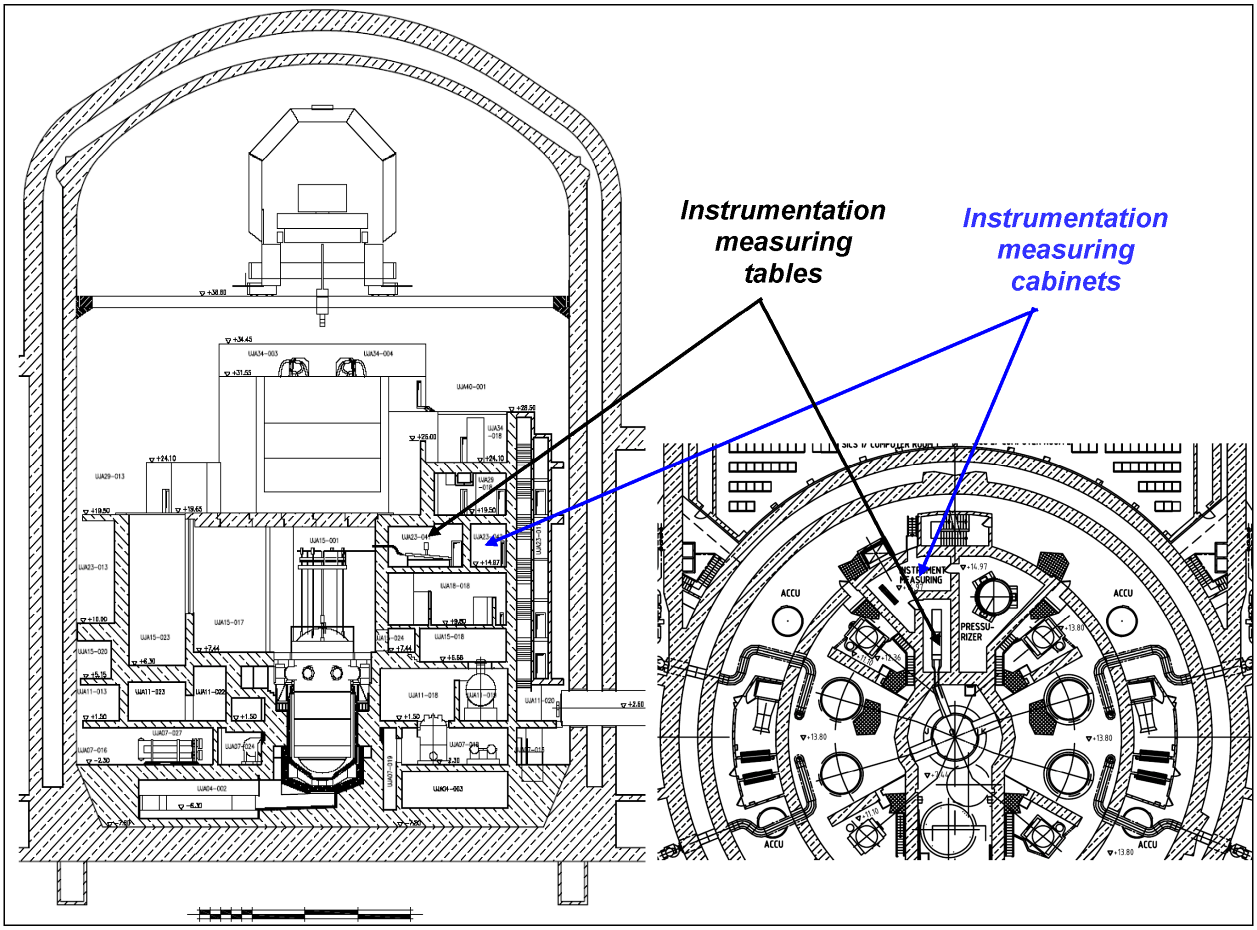

Figure 04.04-4-16: General (Overview) Location of the AMS System

Response to Question 04.04-4, Part 5:

Nitrogen propulsion gas supply source is from the gas supply system of the plant and is cleaned, dried and supplied to the pressure reservoir.

See U.S. EPR FSAR Tier 2, Section 6.2.4 regarding containment isolation.

Nominal nitrogen pressure during operation is approximately 150 psig.

Pressure setpoints for the solenoid valve isolation of the supply line to the main supply system will be deterimined later in the design process for the U.S. EPR, based main nitrogen supply pressure and the sizing of the AMS nitrogen system.

The nitrogen used to move the Aeroballs is directed to the four pneumatic subsystems via pressure reducers, buffer tanks with pressure indicators and switches, solenoid valves, filters, and branches. Each subsystem is equipped with a separate solenoid valve control system.

In the event of a nitrogen gas pressure drop in the main supply system, the supply line to the main supply system is automatically isolated by a solenoid valve.

Aeroball transport is provided by using reserve nitrogen from the buffer tanks. Gas supply piping leading to the individual subsystems branches into two three-way valves. One valve controls the nitrogen gas train leading to the instrumentation lance; the other valve controls the nitrogen gas train leading to the measuring table. The valves are also connected to the common discharge line via an aerosol filter. Each three-way valve has a solenoid-operated, quick-closing valve mounted upstream on the reactor side.

In the event of Aeroball transport system failure (i.e., humidity sensor or pressure switch response), the monitoring modules provide alarm signals to the process automation system and automatically close the solenoid-operated, quick-closing valve. This feature prevents Aeroball transport in the subsystems involved until the cause of failure has been identified and removed. Under normal operating conditions, the quick-closing valves are opened by the AMS computer for Aeroball transportation.

Leakage of reactor coolant through an Aeroball tube would be a small break LOCA. The small break LOCA is described in U.S. EPR FSAR Tier 2, Section 15.6.5.2. The radiological consequences are found in U.S. EPR FSAR Tier 2, Section 15.0.3.11. Refer to the Response to RAI 133, Supplement 3, Question 19-244(1) and 19-244(2).

The valve rack i in the AMS control cabinet room (UJA23-042) immediately next to the AMS measuring table in room (UJA23-041). It comprises the valves necessary for ball transport control. The nitrogen gas pipes leading to the measuring table are routed through this valve rack and laid parallel to the ball transport tubes in the neighboring AMS measuring table compartment.

The nitrogen used to move the balls is directed to the four pneumatic subsystems via pressure reducers, buffer tanks with pressure indicators and switches, solenoid valves, filters, and branches. Each of the four subsystems is equipped with a separate solenoid valve control system.

At the measuring table, the 40 ball tubes are grouped into four subsystems of 10 ball tubes each. Each of the four subsystems has its own valve control with redundant voltage supply for the nitrogen pneumatic transport system and is thus capable of being operated independently. Lead shielding strips are positioned between the mounting beams to shield the detectors from radiation from the ball stacks underneath adjacent mounting beams. The measuring table contains connections for the replacement of the ball stacks if required. The driving manifold at the lower end of the measuring table connects the individual ball tubes of the four subsystems of the Aeroball system. Each gas connection supplies the ball tubes of a single system via longitudinal and traverse openings. The end-stop for the ball stacks is be screwed into the driving medium manifold and protrude into the ball tubes. The balls are retained by the end stop while the driving medium is able to flow through unimpeded in both directions. A moisture sensor is mounted in the driving medium manifold that shuts down the associated system if the moisture level in the subsystem is too high

Figures 04.04-4-17 and 04.04-4-18 display typical Aeroball Control Equipment (auxiliary component outside RPV, which is not in contact with primary coolant) used to control the nitrogen flow for ball transport into, and out of, the RPV.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Figure 04.04-4-17: Picture of a Typical AMS Nitrogen System

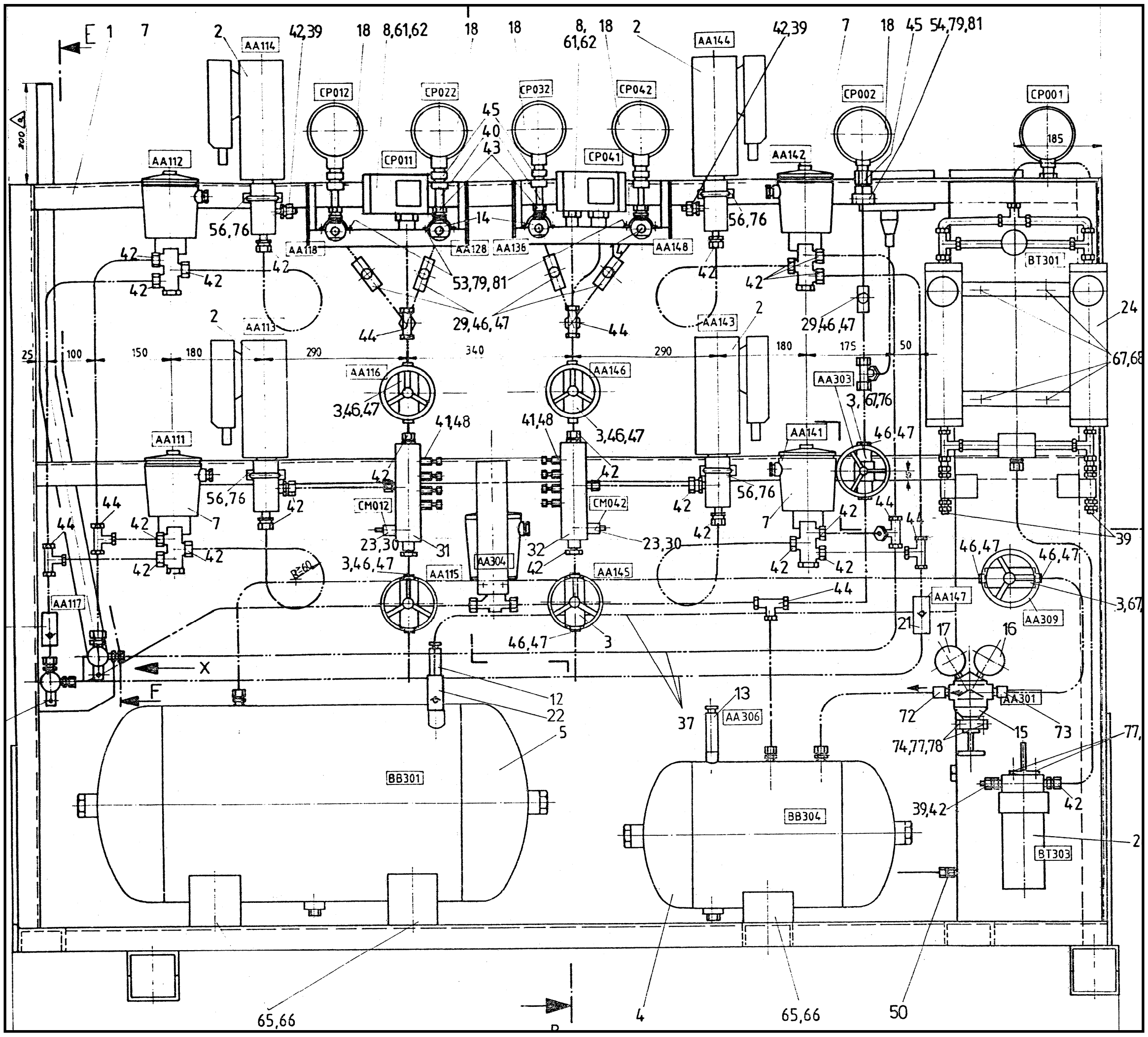

Figure 04.04-4-18: Diagram of a Typical AMS Nitrogen System

Response to Question 04.04-4, Part 6:

Moisture in the Aeroball tubes does not affect the flux measurement; it does influence the mechanical functionality of the system. The lubricant used in the tubes does not work properly when in contact with water or high moisture. To provide sufficient dryness, a nitrogen dryer is used. Based on operating experience, the system will work without the nitrogen dryer, because the industrial nitrogen of high purity used for the system is normally sufficiently dry for the function. See the Response to Question 04.04-4, Part 16 of this question set for information concerning flux readings, thermal limit calculation affects and neutronics information for an isolated Aeroball stack.

Procedures will be established to minimize moisture content in the Aeroball and propulsion-gas tubes. Pressure and humidity sensors automatically isolate the system by the use of automatically actuated quick-closing valves. If the moisture level in the subsystem is too high, a moisture sensor mounted in the driving medium manifold shuts down the associated system. The setpoint for the isolation sensors will be determined later in the design process, based on detection and isolation of a reactor coolant leak into an AMS tube. AMS N^2 system isolation operation is described in the response to Question 04.04-4, Part 5.

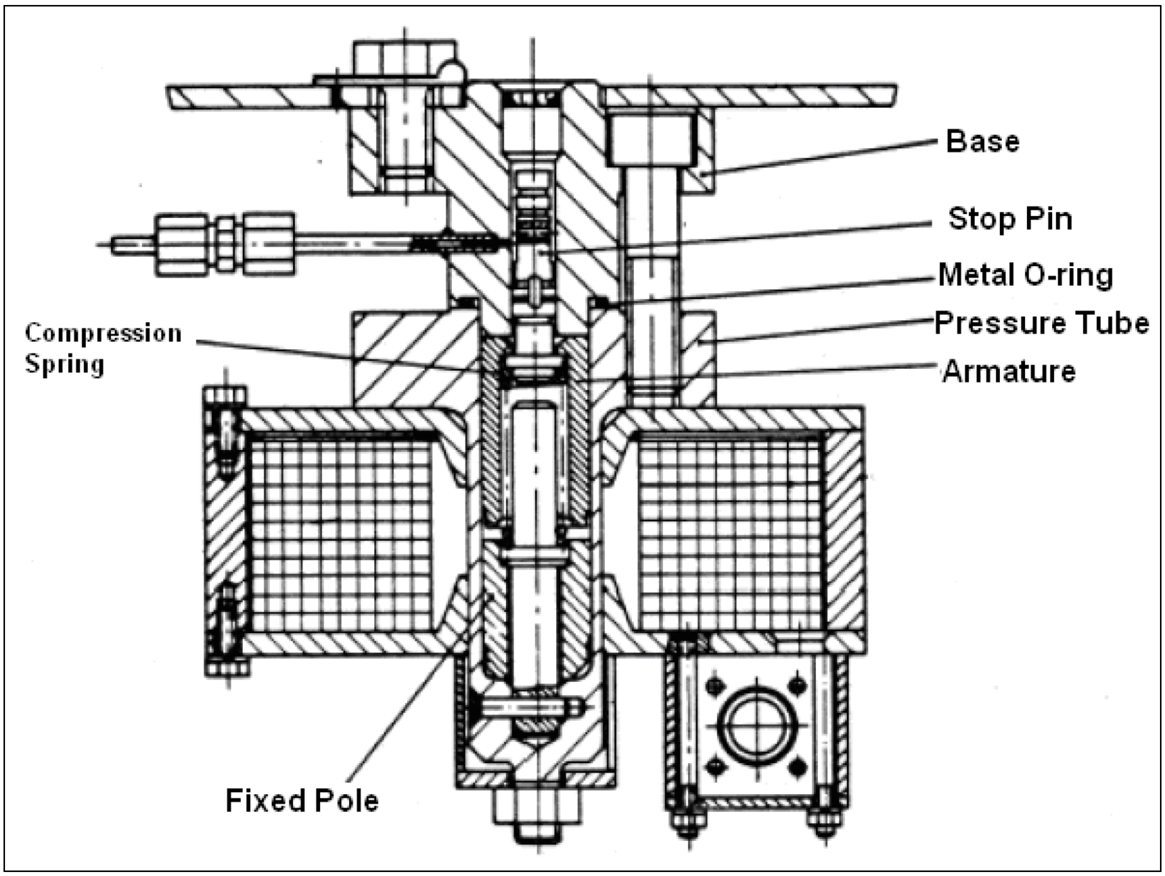

Figure 04.04-4-19: Typical Solenoid Aeroball Stop

Figure 04.04-4-19 is a typical solenoid Aeroball stop employed in the AMS. The solenoid ball stops, total of 40, are situated in the ball transport tubes between the lance and the measuring table with all ball stops located close to the lance. The solenoid Aeroball stop is closed with a piston mounted in a pressure-tight housing; but remains permeable to the nitrogen gas. The solenoid Aeroball stop forms a gateway which is opened or closed for the ball stack movement. When it is open, the balls are permitted to be transported in either direction (i.e. to the core or the measuring table). When the solenoid Aeroball stop is closed, a defined wait or rest position located inside containment is used for the ball stack. At the wait position which is located inside containment, the ball stack is located below the solenoid Aeroball stop (pressure applied in the direction measuring table) whereas at the rest position, also located inside containment, the ball stack is located above the ball stop (pressure applied in the direction lance or no pressure applied). Each ball stack is irradiated in one core position and is transported to the measuring table (and back) in an individual, closed tube that does not have any connections to the other tubes of other core positions. Due to the mechanical design of the system, including the tube and ball diameter, there is no shuffling of the Aeroballs. See response to Question 04.04-4, Part 18 for information pertaining to manufacturing tolerances. See Figure 04.04-4-23 for the tube arrangement of the four subsystems at the measurement table.

The AMS system is not explicitly included in the Technical Specifications. Refer to the Response No. 21 in Response to Request for Additional Information - ANP·10287P “Incore Trip Setpoint and Transient Methodology for U.S. EPR Topical Report” (TAC No. Q00013, ML082261522) for more information.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Response to Question 04.04-4, Part 7:

From a mechanical design perspective, the U.S. EPR and current plants with operating AMS reactor plant core monitoring systems are built the same. The U.S. EPR design is adapted to a larger core. Consequently, the AMS has an increased number of probe fingers and a larger measuring table. In contrast to current plants with AMS, the AMS used in the U.S. EPR has modernized electronics and is computer controlled. An advantage of digital electronics is increased electrical property stability, independent of temperature change or radiation.

For AMS plants, the SPNDs are not used in the Protection System (trip actuation) but for safety grade limitations (partial trip). The protection systems of AMS plants function in a similar way to typical U.S. PWR plants using an excore detector system. The U.S. EPR uses SPNDs for both partial trip and trip actuation functions.

The methodology for the U.S. EPR trip system is described in ANP-10287P, “Incore Trip Setpoint and Transient Methodology for U.S. EPR Topical Report”.

Table 04.04-4-2 provides a listing of nuclear power plants currently using the Aeroball Measurement System.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Table 04.04-4-2: Nuclear Power Plants Using the Aeroball Measurement System

	Plant Name	Plant Acronym	Capacity (MW)	First Power Generation	End of Power Generation
	Germany				
1	Biblis A	KWB A	1,225	8/25/1974	Still In Operation
2	Biblis B	KWB B	1,300	4/25/1976	Still In Operation
3	Brikdorf	KBR	1,440	10/14/1986	Still In Operation
4	Emsland	KKE	1,400	4/19/1988	Still In Operation
5	Grafenrheinfeld	KKG	1,345	12/18/1981	Still In Operation
6	Grohnde	KWG	1,430	9/4/1984	Still In Operation
7	Isar2	KKI 2	1,475	1/22/1988	Still In Operation
8	Neckarwestheim1	GKN 1	840	6/3/1976	Still In Operation
9	Neckarwestheim2	GKN 2	1,365	1/3/1989	Still In Operation
10	Obrigheim	KWO	357	10/29/1968	5/11/2005
11	Philppsburg 2	KKP 2	1,458	12/17/1984	Still In Operation
12	Unterweser	KKU	1,410	10/1/1978	Still In Operation
	Netherlands				
13	Borssele	KCB	480	7/4/1973	Still In Operation
	Spain				
14	Trillo 1	CNT	1,066	5/23/1988	Still In Operation
	Switzerland				
15	Gosegen	KKG	1,020	2/2/1979	Still In Operation
	Brasil				
16	Angra 2		1,350	7/21/2000	Still In Operation

Response to Question 04.04-4, Part 8:

[ ]

See ANP-10282P POWERTRAX/E Online Core Monitoring Software for the U.S. EPR Technical Report for additional information regarding SPNDs.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Table 04.04-4-3: Plants A, B, C - Failure of SPNDs

Response to Question 04.04-4, Part 9:

The lifetime of the Aeroballs is not limited by vanadium, V^{52}, depletion but by ball transport criteria. Because the depletion of detector nuclide V^{52} is negligible because of the short irradiation time, no age-based correction of the Aeroballs is necessary. Typically about 100 Aeroball measurements (AM) per operational cycle are performed. In some plants the same Aeroballs have been used for more than 500 measurements. For one plant, after 700 measurements the Aeroballs were replaced. A test of the Aeroballs was performed with an Aeroball measurement made immediately prior to their removal followed by another measurement with the fresh Aeroballs right after the replacement, while plant conditions were kept constant. The results showed no recognizable difference in the measured activation values between the removed and replacement Aeroballs.

The average service life of Aeroballs in currently operating plants is provided in Table 04.04-4-4 of this response.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Response to Question 04.04-4, Part 11:

This question is addressed in the Response to RAI 22, Supplement 1, Question 19-149, Part f and Part g.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Response to Question 04.04-4, Part 13:

Power Density Detector (PDD) and Self Powered Neutron Detector (SPND) are used interchangeably. Fixed incore Power Distribution Detectors (PDD) are comprised of SPNDs strategically distributed radially and axially throughout the core. The SPNDs allow for continuous core power distribution monitoring during normal and transient conditions. The PDD system is responsible for providing continuous power peaking signals to the reactor Protection System (PS).

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Response to Question 04.04-4, Part 14:

Each ball stack is irradiated in one core position and is transported to the measuring table (and back) in an individual, closed tube that does not have any connections to other tubes of other core positions. Due to the mechanical design of the system, including the tube and ball diameter, there is no shuffling of the Aeroballs. See the Response to Question 04.04-4, Part 18 for information pertaining to manufacturing tolerances.

The activation values are corrected in the AMS computer for:

- Run-time from the core (including the waiting time for the Aeroballs of the 2nd, 3rd and 4th subsystem).
- Detector dead time and sensitivity.
- Rest activity from vanadium and Mn due to previous Aeroball Measurement.
- The additional time the Aeroballs at the bottom of the probe are in the core, since they are in the core longer than those at the top.
- Stray gammas from neighboring segments (from axial neighbors in the same bar as well as neighboring bars).
- Geometrical positioning of the tube in the tapering port.

Neutron/gamma transport models or correlations:

Decrease in V^{52} activity between end of activation and start of activity measurement —The time correction factors $e^{\lambda V52 \Delta T}$ (λv^{52} decay constant of V^{52}, ΔT time interval between end of activation and start of measurement) for determination of activation values from the measured count rates are between 1.1 and 1.8 depending on the time of measurement.

Dead time corrections of measured count rates:

The dead time losses occurring during the measurement of detector pulses must be eliminated in the event of high count rates due to the finite time resolution of the instrumentation electronics. With an activation time of 3 minutes at rated power, the correction for the highest count rates is in the region of 1percent of the measured count rates. The only residual error is the difference in the dead time for the various instrumentation channels, which is a second-order error.

Figure 04.04-4-20 graphically details the duration period for each step of the Aeroball measurement. The following list provides detail of the event sequence, including the approximate time duration of each event, of an Aeroball measurement:

- Aeroballs are driven into the core using the carrier gas – Approximately 30 seconds.
- Activation of the steel spheres in the core – Approximately three minutes.
- Aeroballs removed from the core – Approximately one minute.
- Measurement of Activation Rates – Approximately three minutes.
- Processing in Aeroball Computer – Approximately four minutes.
- Transfer of Data to Plant Process Computer or POWERTRAXIS system – Approximately 12 minutes after the start of the Aeroball measurement.

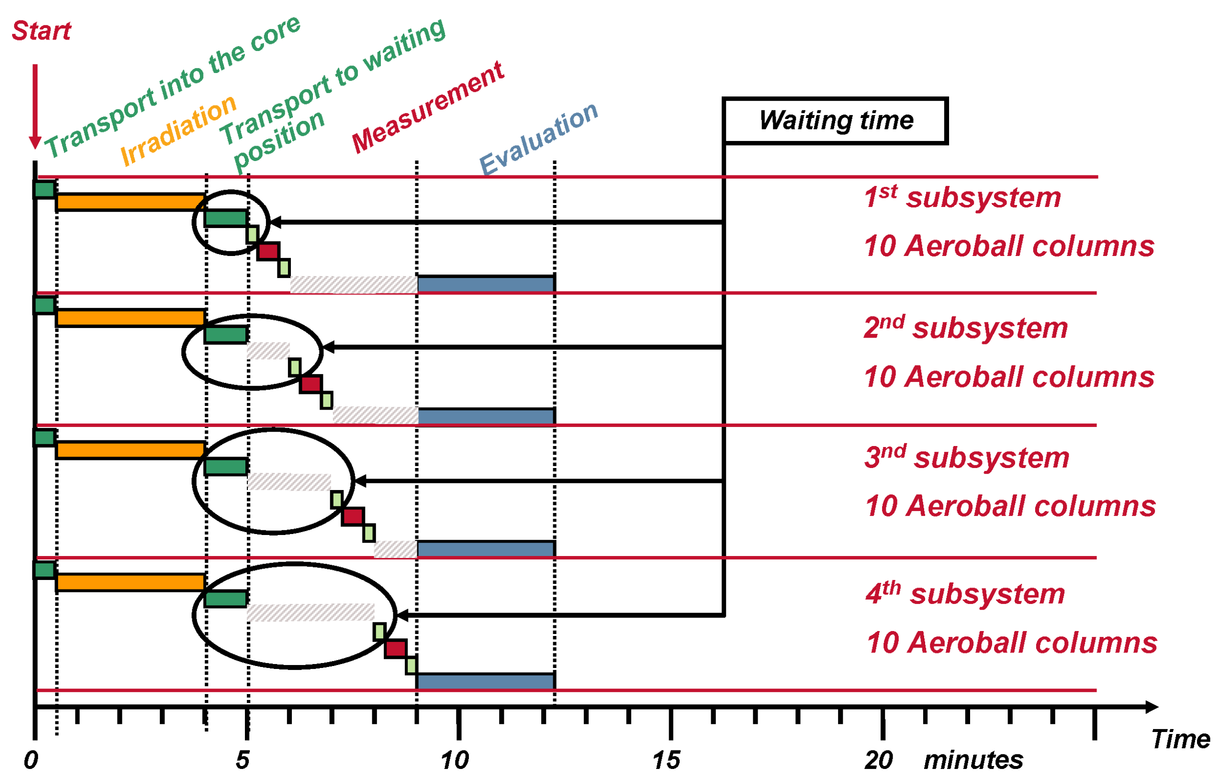

Figure 04.04-4-20: Duration of Aeroball Measurement

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Response to Question 04.04-4, Part 15:

Vanadium utilized in the Aeroballs produce a gamma decay signature readily discernable by the measurement software. When exposed to a neutron flux, the V^{51} used in the Aeroballs reaches a higher energy state, creating isotope V^{52}. After a half life of 3.7 minutes, V^{52} undergoes a β-decay to Cr^{52}. The AMS utilizes the Compton Effect during this decay for measurement of corresponding neutron flux. If subsequent measurements are performed immediately following one another, the AMS software factors residual decay energy from previous measurements into the calculations.

Measurements are initiated from the AMS computer to obtain controlled and activation values of the Aeroball probes. The activation values and any information about corrected or defective probes are compiled into a file that is sent to the POWERTRAX/E computer. Once the file is received by the POWERTRAX/E computer, the core simulator calculates the three dimensional power distributions and departure from nucleate boiling ratio (DNBR), and performs the adaptation from theoretical to actual measured activation values. Following the adaptation run, the calibration factors are calculated. The AMS computer controls the entire measuring and testing processes. It also calculates the adjusted count rates from the measured pulse counts measured by applying correction factors, such as decay of the activity during the measuring procedure, residual activities, and scattering effect.

Calibration of Detectors:

Passivated implanted planar silicon (PIPS) detectors (see Figures 04.04-4-22 and 04.04-4-23) are situated at regular intervals along the detector beam of the measuring table (see Figure 04.04-4-21). The PIPS have different effective sensitivities due to manufacturing tolerances. These differences in sensitivity are measured and taken into account by the AMS computer by the introduction of a corrective factor that will be specified for each detector during Aeroball measurements and residual activity measurements. During calibration, the calibration source is fixed in a calibration device next to the detector-mounting beam array. The PIPS detector data are loaded one after another into the calibration program. The resulting counting rate is a measure of the sensitivity of the detector channels and is used during calculation of activation values. Results of each calibration are displayed at the operator panel and the measured data is stored in a file that can be printed or displayed on the operator panel at any time.

Sensitivity to Calibration Techniques and Intervals:

In addition to the interference activities built up during the current activation, the Mn^{56} and In^{116} activities which are still present from previous measurements, as well as any V^{52} activity still present, are taken into account by means of computational corrections. The correction is performed using “residual activity files”. These are used to calculate residual activities at the time of the current measurement appropriately for the time interval that has elapsed between measurements. The results are taken into account in conjunction with interference activities built up during measurement in the form of an “overall background activity”. For the Aeroball system, the residual activity can be measured at any time using the “residual activity measurement” program, which can be started from the control panel of the control computer. The residual activity file also can be updated if necessary. It is also possible to check the accuracy of corrections using the “residual count rate measurement” program and other special measures — such as starting an Aeroball measurement with disabled solenoid stops (Aeroballs are not activated).

Calibration of the silicon surface detectors of the measuring table is performed using a Co^{60} source. This is usually done once per cycle, typically at the end of cycle before plant shutdown. This permits checking the impact of the calibration on activation values, while the plant is operating at power, and allows a comparison of these activation values with the values of a previous measurement. A single detector calibration is performed only if an individual detector drifts or a failed detector has been replaced.

Interference of γ Quanta from the Adjacent Detector Mounting Beam:

Despite mutual shielding of the detector mounting beams, γ quanta from the ball stacks lying under adjacent beams interfere with the semiconductor detectors or radiation extraction ports of the detector mounting beams (see Figure 04.04-4-24). The interference amounts to roughly one percent of the count rate measured in the adjacent beams. The only residual errors are inaccuracies in the calculation of interference factors. Their effect on power density values is reduced even further during normalization of power density distribution.

Table 04.04-4-4: AMS Performance Data

Description	Specification
Minimum power level required to produce a flux map for qualified statements	Approximately 30 percent Reactor Thermal Power (RTP) with three minute activation (measurement can also be performed with similar accuracy at 15 percent RTP with 10 minute activation)
Minimum time interval between two Aeroball measurement runs, with high accuracy in calculating activation values	10 minutes
Transit time for balls between the core and the counting table to ensure required accuracy level	< 25 second
Service life of Aeroballs	Averages 600 Aeroball measurement runs
Relative overall error ε (segment[1]) of the activation values[2] of a segment[1]	1 σ error: ε_{AV} (segment) = ± 0.9% 3 σ error: (segment) = ± 2.7%
Relative error ε (fuel assembly) of integrated activation values[2] over a fuel assembly	1 σ error: ε_{AV} (fuel assembly) = ± 0.6% 3 σ error: (fuel assembly) = ± 1.9%

Notes:

1. Segment = 1/36 of the Aeroball probe as the region measured by one semiconductor detector.
2. Activation values = measured values directly proportional to the activation of the Aeroballs in the core.

Relative Overall Error of Activation Values:

Table 04.04-4-4 lists the relative overall error of the activation values of a segment (i.e., 1 σ error: ε_{AV} = ± 0.9%). Calculation of the relative overall error of the activation values of a segment is detailed in the following equation:

$$\varepsilon_{AV} = \sqrt{\varepsilon_R^2 + \varepsilon_S^2 + \varepsilon_H^2} = \pm 0.9\%$$

Where,

ε_H = Statistical Error: Assumption of a counting rate of 30.000cps (i.e. cps = counts per second) to 40.000cps and one second measuring time were made for this computation ➲ ε_H = ±0.6%

ε_S = Systematic Error: $\varepsilon_S = \sqrt{\varepsilon_{Det}^2 + \varepsilon_{tube}^2 + \varepsilon_{Van}^2} = \pm 0.4\%$

Where,

ε_{Det} = Differences in sensitivity of semiconductor detectors subsequent to calibration ➲ ε_{Det} = ±0.2%

ε_{tube} = Tolerance in wall thickness and diameter of ball tubes under measuring position ➲ ε_{tube} = ±0.2%

ε_{Van} = Differences in the Vanadium amount at the measuring position due to the external ball diameter (1.7mm) in comparison to the inner diameter of the ball tube (2.0 ± 0.1 mm) ➲ ε_{tube} = ±0.3%

ε_R = Residual Error: Residual Errors from count rate correction ➲ ε_R = ±0.5% taking into account an influence of one percent on the activation values for each of four correction procedures (with an error of 10% each), a maximum error of one percent for the activation of the balls during transport and a time correction factor of 0.37% due to the one percent error of the V^{52} decay constant.

SPND/AMS Classification and Calibration:

The SPNDs are part of a safety system. However, the Aeroballs are not part of a safety system and neither is POWERTRAX/E. POWERTRAX/E receives signals from the AMS to perform the three dimensional flux reconstructed power distribution. The three dimensional power distribution is used to calibrate the SPNDs. POWERTRAX/E receives input data to perform diagnostic and predictive core-follow type calculations for the physicist. However, these calculations are not transmitted to the control room or the Plant Process Computer since they are non-safety grade calculations. Aeroball measurements with PRISM calculations are used to construct the three dimensional measured/calculated power distribution of the core. The SPNDs are then calibrated to this reconstructed power distribution.

For additional information on POWRTRAX/E, see Section 3 of ANP10282P, “POWERTRAX/E Online Core Monitoring Software for the U.S. EPR Technical Report”.

The testing procedures for the SPND Co^{59} detectors will be written later in the design process for the U.S. EPR, an operational AMS reactor plant calibration procedure is provided below for information purposes:

[ ]

The measuring table is part of the Aeroball Measuring System AMS outside the reactor vessel and comprises the main parts:

- Frame
- Base plate with ball guide tubes
- Driving medium manifold

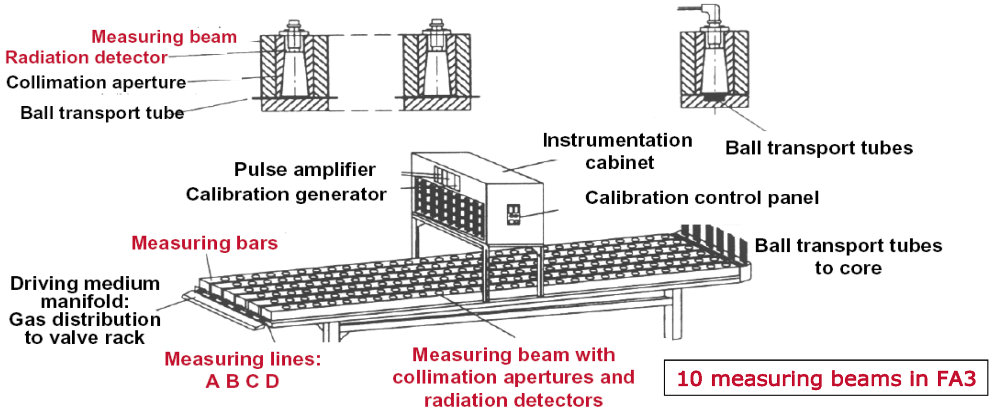

Figure 04.04-4-21: Aeroball Measuring Table

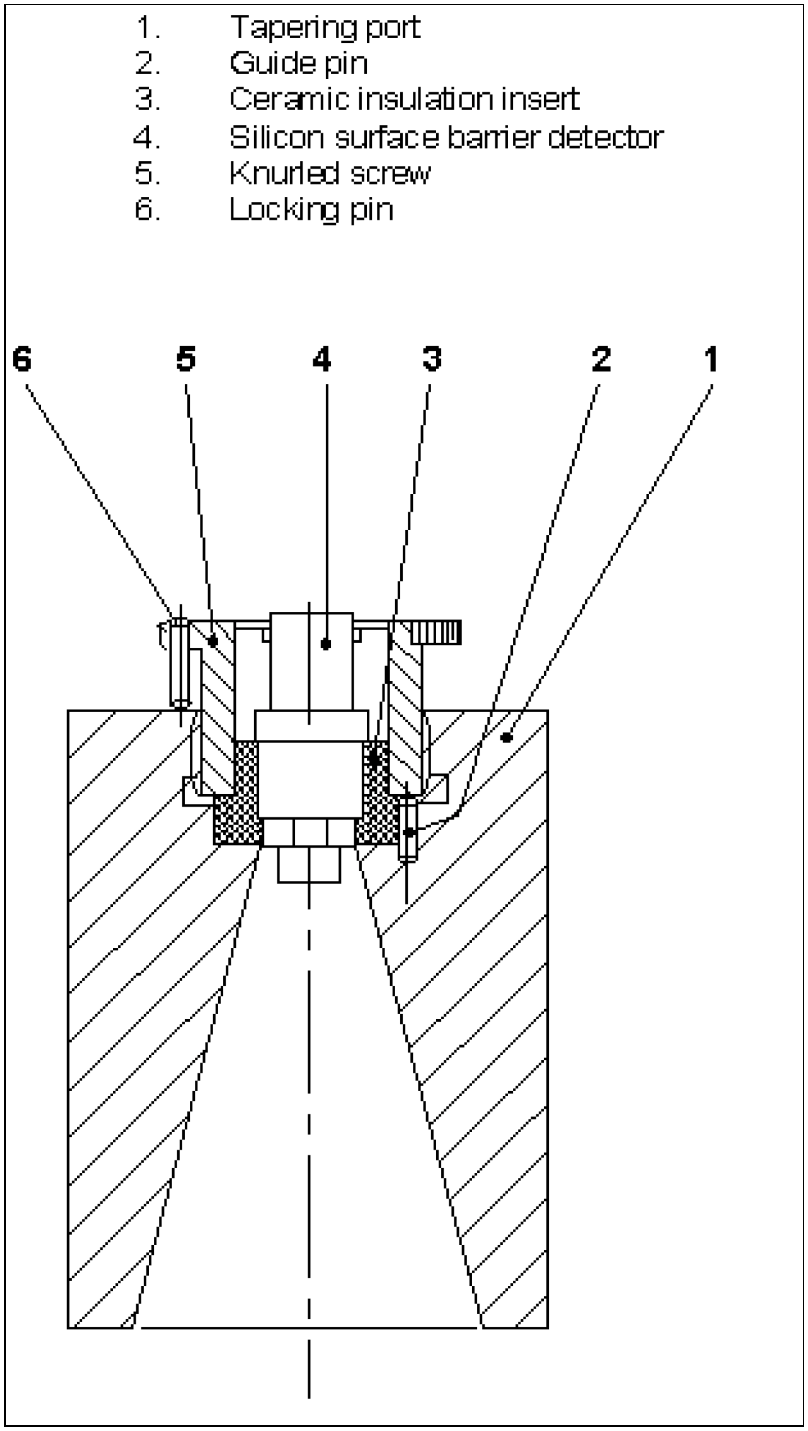

Figure 04.04-4-22: Tapering Port with Activation Detector

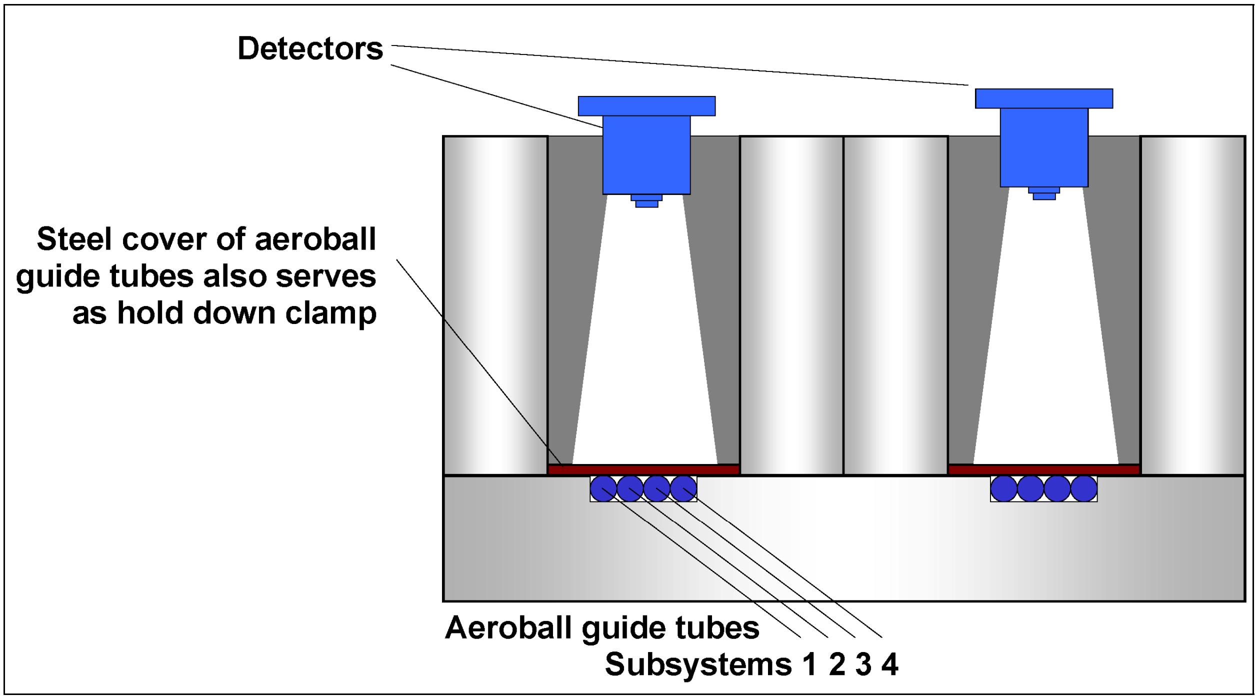

Figure 04.04-4-23: Activation Detectors Arrangement on AMS Table

Figure 04.04-4-24: Typical AMS Table Activation Detector

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Response to Question 04.04-4, Part 16:

If a bad count rate is detected (either too low or too high), the count rate of the detector is rejected and a linear interpolation of the both neighboring detectors is performed since the axial neutron flux is an analytical function without discontinuities. Typically, in currently operating Konvoi plants with 28 detectors per measuring bar, it is permitted to have three interpolated values on the same measuring bar. If abnormal values that are either too high or too low are detected on a forth detector, (compared to all other values of this measuring bar) the measurement of this bar is marked as "not successful". The interpolated values are indicated on the sheet of activation values, giving the operating staff the possibility to track the error (or possibly identify broken detectors).

The thermal limit calculation is not affected by bad measuring detectors, since the overall error of the measurement is generally not enlarged by the use of interpolated values. With four or more interpolated values per bar, the overall error is increasing; therefore, the measurement is marked as "not successful".

In operating Konvoi plants, as long as all ball stacks of the AMS are in operation at the beginning of the cycle, the AMS provides suitable core flux maps with up to 12 ball stacks inoperable, provided that the 12 inoperable ball stacks are more or less homogeneously distributed over the core. Refer to Figure 04.04-4-25 for U.S. EPR Aeroball measurement positions.

To prevent the transport of balls to an identified problem probe, individual solenoid stops can be disabled by the operator

The AMS is not explicitly included in the Technical Specifications. For further clarification, see the Response to Question 04.04-4, Part 6.

The Response to RAI 103, Supplement 1, Question 16-195 addresses the minimum number of SPNDs required for functional capability.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

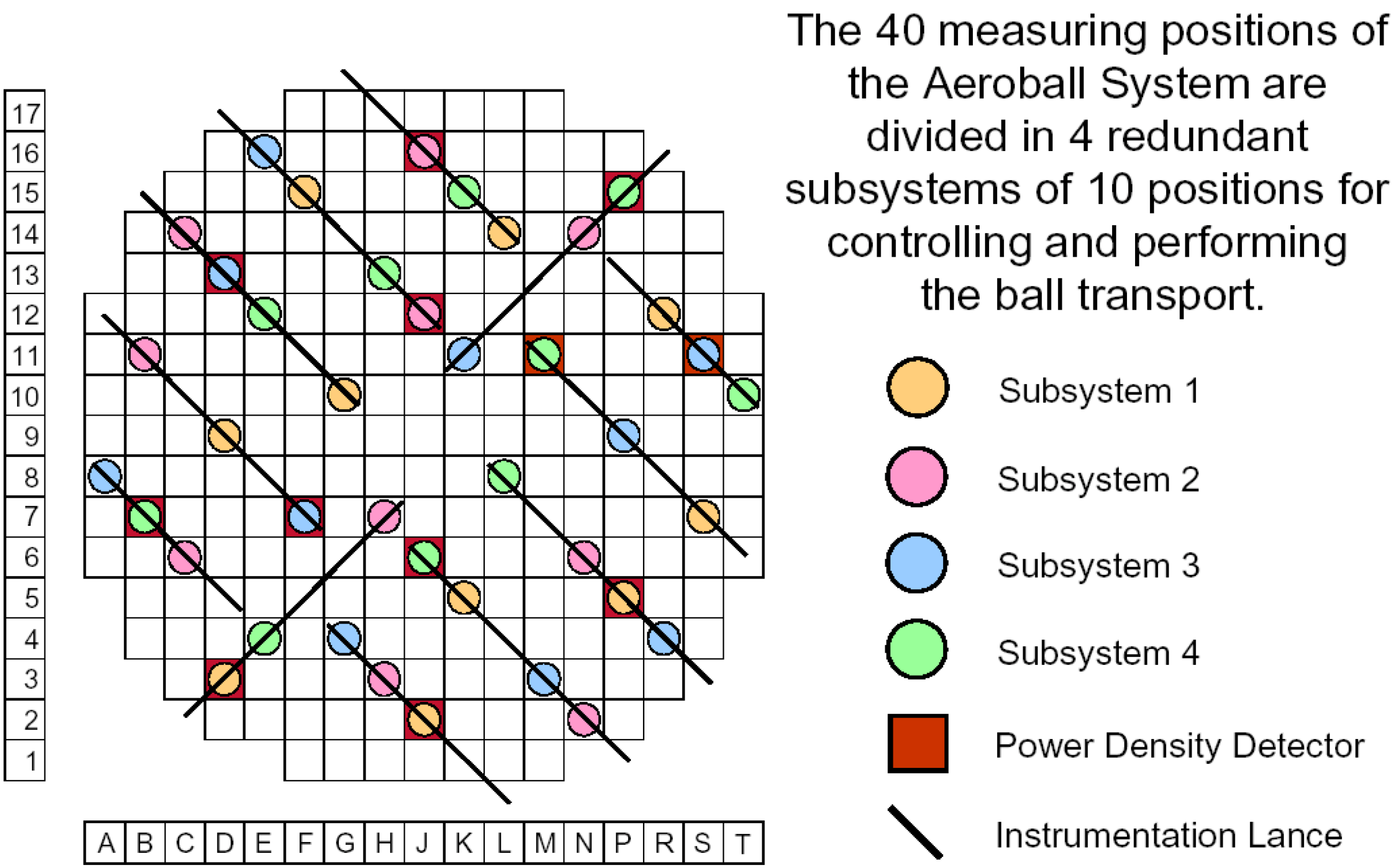

Figure 04.04-4-25: Measuring Positions of EPR Aeroball Measurement System

Response to Question 04.04-4, Part 17:

When the Aeroball stops are opened, the Aeroball stacks move pneumatically (using nitrogen gas) through the 0.079 inch (2 mm) inner diameter Aeroball tube, with 0.020 inch (0.5 mm) wall thickness, to their activation positions in the reactor core. See Figure 04.04-4-13 and Figure 04.04-4-14 for additional information on the Aeroball transport system.

The linear expansion coefficient of the Aeroballs is the same as the linear expansion coefficient of the tubing material up to the sixth digit. Therefore, the effect of expansion on the balls is negligible and has no affect on the balls traveling through the tube. Each ball stack is irradiated in one core position and is transported to the measuring table (and back) in an individual, closed tube that does not have any transitions to tubes of other core positions so there is no shuffling.

Typically, the Aeroball tubes are manufactured from type 321 stainless steel (321-SS). Other potential types of stainless steel (SS) include 347-SS and 316-SS. Table 04.04-4-5 provides detailed information on the properties of type 321 stainless steel (SA-240 Type 321), including the thermal expansion coefficient (α). Additional example information pertaining to incore instrumentation (e.g., AMS) material parameters is provided in Table 04.04-4-1.

The design of the tube and ball diameter, including tolerances, ensures that there is no axial shuffling. During normal operating conditions, any Aeroball tube growth or deformation resulting from operating temperature and neutron flux does not affect Aeroball stack travel or movement through the Aeroball tubes.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Table 04.04-4-5: ASME SA-240 Type 321 Properties

SA-240 Type 321 18Cr-10Ni-Ti UNS S32100							
Temp °F	**E, x 10^6 psi**	**Mean α, x 10^{-6} in/in/°F**	**Sm ksi**	**Sy ksi**	**Su ksi**	**TC Btu/hr-ft-°F**	**TD ft^2/hr**
70	28.3	8.5	20	30	75	8.2	0.139
100		8.6	20	30	75	8.3	0.14
150		8.8		28.1		8.6	0.142
200	27.5	8.9	20	27	71.1	8.8	0.145
250		9.1		25.8		9.1	0.147
300	27	9.2	20	24.8	66.9	9.3	0.15
350		9.4				9.5	0.152
400	26.4	9.5	20	23	65.5	9.8	0.155
450		9.6				10	0.157
500	25.9	9.7	19.3	21.5	65.5	10.2	0.16
550		9.8				10.5	0.162
600	25.3	9.8	18.3	20.3	65.5	10.7	0.165
650		9.9	17.9	19.8	65.5	10.9	0.167
700	24.8	10	17.5	19.4	65.5	11.2	0.17
Ref. [1], Part D	Table TM-1 Page 696-697 Group G	Table TE-1 Page 669 Group 3	Table 2A Pages 332-334 Line 16	Table Y-1 Pages 578-581 Line 39	Table U Pages 464-465 Line 31	Page 686, Table TCD Group K	

NOTES:

1. (Ref. [1], Part D) is referring to American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, 2004 Edition without Addenda.

Response to Question 04.04-4, Part 18:

The activation devices used in the Aeroball measuring system of the incore instrumentation are balls with a 0.067 inch (1.7 mm) diameter. The balls are stacked in columns of a length slightly longer than the active core height, for a total of 40 ball stack columns. These ball stacks are transported through the core by a gas driving medium (N_2), leaving the core through magnetic stops and passing into the measuring table.

Documentation of each manufactured ball stack is included in a conditioning report. Typically, the conditioning report contains the following information:

- Technical data: ball diameter, manufacturer, material, material charge, ball stack length, and ball stack weight.
- Cleaning and using Molykote microfine powder.
- List of measuring devices used (scales).
- Test protocol.

The alloy compositions for the AMS activation probes, Aeroballs, are nominal values. The alloy composition of each production batch will be determined when the U.S. EPR Aeroballs are fabricated. Each production batch will be accompanied by as-manufactured specifications. The typical alloy composition information of the AMS activation probes, (i.e., Aeroballs) is shown below:

- Chromium ($_{24}Cr^{50}$) weight percent in Aeroball: 14.5
- Iron ($_{26}Fe^{56}$) weight percent in Aeroball: 83.36
- Vanadium ($_{23}V^{51}$) weight percent in Aeroball: 1.54
- Carbon ($_{6}C^{12}$) weight percent in Aeroball: 0.6

The composition content of manganese ($_{25}Mn^{55}$) is less than 0.1 percent and therefore not modeled (i.e., $_{25}Mn^{55}$ is considered a trace element). **[**

] The variations are small enough to be considered insignificant.

Aeroball errors resulting from varying vanadium content do not arise. Typically, the Aeroballs are manufactured in the same production batch. The Aeroballs are mixed when forming the Aeroball columns and the vanadium concentration of the batch is controlled through analysis. In the special case when Aeroball columns are produced from different batches, the difference in the vanadium concentration, determined from analysis, is incorporated via correction factors when performing the analysis. However, variation in vanadium content of balls in the same column is an anomalous error and not considered in error correction.

After fabrication, the specified alloy element contents of the Aeroballs are verified by chemical analysis to be within their tolerances.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.