Westinghouse Electric Corporation
Fi ergy Systems

Box 355
Pittsburgh Pennsylvania 15230-0355

NSD-NRC-97-5100
DCP/NRC0840
Docket No.: STN-52-0(3

April 30, 1997

Document Control Desk
Nuclear Regulatory Commission
Washington, D.C. 20555

ATTENTION: T. R. QUAY

SUBJECT: WESTINGHOUSE RESPONSE TO NRC REQUESTS FOR ADDITIONAL INFORMATION ON ADS VALVE TESTING

Dear Mr. Quay:

Enclosed are three copies of the Westinghouse responses for additional information relating to the automatic depressurization system (ADS) testing performed in support of the AP600 design. These responses are provided to close open items 27, 500, 1616, and 3397 in the open item tracking system (OITS).

OITS item 27 (RAI 952.96 Revision 2) provides a revised ADS Valve Testing Roadmap which describes additional testing to be performed outside of design certification. As requested by the staff in a telecon on October 29, 1996, this revision includes a discussion of the ADS Phase B1 tests used to obtain valve characteristics and how the ADS Phase B1 data is related to the overall valve qualification process. The roadmap has also been revised to include the 4th stage valves. Details of in-service testing to be performed on the ADS valves has been deleted since a description of the in-service testing is now included in SSAR section 3.9.6. For this RAI response, deletions from Revision 1 are indicated by a strikeout and additions to Revision 1 are indicated in italics.

OITS item 500 documents Westinghouse' response to an action item from a teleconference with the staff on November 11, 1994 concerning air clearing and steam condensation loads measured during the ADS test program. Additional technical information supporting this item was previously transmitted to the NRC in our letter dated February 03, 1997 delineating the AP600 Hydrodynamic Loads Roadmap.

E004

OITS item 1616 (DSER OI 21.3.2-2) reiterated the staff request for the ADS Valve Testing Roadmap in the Draft Safety Evaluation Report and is addressed by our response to OITS item 27 above.

0113H

1/1

OITS item 3397 (RAI 440.569) addresses staff questions from your letter dated February 13, 1996 on WCAP-14305, "ADS Phase B1 Test Analysis Report", June, 1995, concerning the use of the data analysis performed in the report and the relationship to the safety evaluations performed for the AP600.

Westinghouse requests the staff review these responses and inform Westinghouse of their status to be designated in the "NRC Status" column of the OITS. We suggest "Action N".

Westinghouse requests you provide any comments on this response by May 16, 1997 so that we can meet the milestone in SECY-97-051 to provide the final AP600 supporting documentation by May 30, 1997.

Please contact Brian A. McIntyre (412) 374-4334 if you have any questions concerning this transmittal.

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

/jwh

Enclosures

cc: W. Huffman, NRC - (w/enclosures)
N. Liparulo, NRC - (w/o enclosures)

Question 952.96 Revision 2

Re: Valve Testing Roadmap (OITS 27 and 1616)

Provide a commitment to submit a narrative of an ADS valve testing "roadmap". The road map is to include additional information on the testing to be performed outside of design certification was requested by the staff to assess the adequacy of the test plans.

Response:

AP600 Automatic Depressurization System *(ADS)* Valve Roadmap

The design of the ADS valves, as captured by text in the SSAR, is specified as "generic", with the specific valves to be determined later. For completeness, the system P&ID shows the ~~current~~ valve configuration used *in the ADS Phase B2 testing at the VAPORE facility.* ~~based upon tests and design selections made outside design certification. Inputs to safety analyses have assumed conservative values for valve resistance and valve opening time.~~ The design of the ADS stages 1/2/3 provides for staggering the opening of the upstream and downstream ADS valves. The upstream ADS valves (in each of the three stages) are designated ADS isolation valves, and these valves are sequenced to open before the downstream valves. The downstream ADS valves are designated ADS control valves, and these valves are sequenced to open after the upstream isolation valves are fully open. With this arrangement, the blowdown is *initiated and* controlled by the downstream valve, thus the term ADS control valve. The upstream isolation valves will open with no flow. *Similarly, each of the ADS Stage 4 flowpaths include an isolation and control valve. In this stage the upstream valve is normally open and is used only in an isolation function when the reactor is not operating. The normally closed downstream valve is opened to initiate the blowdown.* ~~The downstream control valves will be designed and qualified to open against full reactor coolant system pressure, temperature, and resultant blowdown flow rate. The upstream isolation will be designed and qualified to open against reactor coolant system pressure and temperature without blowdown flow rate. To provide margin in the ADS stages 1/2/3 design, the upstream isolation valves will also be designed to open against full RCS pressure, temperature, and resultant blowdown flow rates.~~

A. ~~Design Certification~~ *Full Flow System/*Valve ~~Performance~~ Testing

~~Within design certification a~~ *A* number of tests were performed to verify our capability to predict ADS system *flow capability* ~~performance~~. These *tests* included the ADS "single effects tests" at VAPORE *where actual valves were installed or orifices were used to simulate ADS valve performance. In addition* ~~as well as,~~ "integral system tests" *were performed at the* ~~on~~ SPES-2 and OSU *facilities* which included scaled ADS~~'s systems. Valves for these tests were selected to simulate ADS valve performance but were not used to select or qualify any particular valves~~ *valves/piping to verify the overall performance of the ADS integrated with the rest of the AP600 plant.*

The AP600 ADS Phase B1 test program at VAPORE, provided specific test data for use in the proper specification and procurement of ADS valves for the AP600 plant. The relationship between specific tests and the ADS valve characteristics for the plant is outlined below.

1) ADS Phase B1 steam only blowdown testing (Matrix tests 140, 110, 120, and 130)

A major objective of the ADS Phase B1 Test (WCAP-14324, April 1995) was to obtain data on the resistance and choked flow performance of the installed ADS valves and the ADS valve/piping package. This test was performed with a prototypic Stage 1 globe valve and prototypic Stage 2 and 3 gate valves installed in a valve/piping package with a prototypic layout. The Stage 1 gate valve and the Stage 2 and 3 globe valves were simulated with orifices. The tests were performed with the valve(s) in the appropriate stage(s) in a fully open position. Therefore, test data on the performance of the ADS valve package is not applicable to the short times during ADS blowdown when the valves are being opened.

- *Matrix test 140 was a blowdown performed with all three ADS stages open. The steam flow was not choked in any of the ADS valve/piping package components. Thus, this test provided data on the single-phase flow resistances of the ADS package piping, orifices, and the installed prototypic valves.*

- *Matrix test 110 was a steam blowdown through Stage 1 only. The steam flow was choked at the Stage 1 globe valve throughout this test, and the test data provides a basis for calculating the effective flow area of this valve. This effective flow area is 4.9 sq. in. In addition, the pressure drop vs. flow data for the piping and orifice upstream of the globe valve provided additional basis for the single-phase flow resistance of these components (see Matrix Test 140 above).*

- *Matrix test 120 was a steam blowdown through Stages 1 and 2. The steam flow was choked at the Stage 1 globe valve and the Stage 2 orifice throughout this test. Based on the effective flow area of the Stage 1 globe valve obtained in Matrix Test 110, the effective flow area of the Stage 2 orifice is calculated to be 21 sq. in., which is the actual flow area of the orifice. Conversely, knowing that the Stage 2 orifice has a 21 sq. in. flow area, the test data confirms that the Stage 1 globe valve effective flow area is 4.9 sq. in. In addition, the pressure drop vs. flow data for the components upstream of these choked flow locations, provided additional basis for the single-phase flow resistance of these components (see Matrix Test 140 and 110 above).*

- *Matrix test 130 was a steam blowdown through Stages 1 and 3. The steam flow was choked at the Stage 1 globe valve and Stage 3 orifice throughout this test. Based on the effective flow area of the Stage 1 globe valve obtained in Matrix Test 110, the effective flow area of the Stage 3 orifice is calculated to be 21 sq. in., which is the actual flow area of the orifice. Conversely, knowing that the Stage 3 orifice has a 21 sq. in. flow area, the test data also confirms that the Stage 1 globe valve effective flow area is 4.9 sq. in. In addition, the pressure drop vs. flow data for the components upstream of these choked flow locations, provided additional basis for the single-phase flow resistance of these components (see Matrix Test 140 and 110 above).*

2. ***The AP600 Depressurization System Stage 1, 2, and 3 Cold Flow Test (WCAP-14676, May 1995)***

This test was performed with both a gate isclation valve and a globe control valve installed in each of the Stage 1, 2, and 3 flow paths (orifices simulating the Stage 1 gate and Stage 2 and 3 globe valves replaced with actual valves). This test consisted of blowdowns using cold water at low supply tank pressures to obtain single-phase, non-choked resistances of the ADS valve/piping package components with the valves fully open. This data confirms the single-phase resistances obtained in the steam only matrix tests 140, 110, 120, and 130 above. Additionally, the flow split between each of the ADS stages was indirectly measured by comparison of the delta-P across the globe valve in each stage. Individual test runs were performed for all ADS Stage 1, 2, and 3 flow path combinations.

3. ***The ADS Phase B1 Test (WCAP-14324, April 1995) series 200 and 300 matrix tests***

These tests were performed with two-phase, steam and water blowdowns in order to obtain two-phase flow and pressure drop data across each section of the ADS test flow path, at measured bulk fluid qualities. These tests show that Nelson Martinelli two-phase flow multipliers are directly applicable to the plant ADS (WCAP-14305, June 1995).

The flow resistance of the ADS test facility valve/piping package sections and resulting flow splits through the individual ADS stages obtained from the above testing have been compared with resistances calculated directly from the test facility piping layout, and the valve resistances provided by the valve manufacturers. This comparison provides the basis for assuring that the resistances calculated for the plant ADS piping layout and valves, which are used in the safety analysis, are conservative.

B. ADS Performance Analyses for the AP600 SSAR

The calculated ADS valve and valve/piping package resistances and the valve effective flow areas verified by the above testing are the input values used in the safety analysis. The analysis values include appropriate conservatism for the overall resistance and the effective flow area and the resistance of the ADS valves and valve opening times. Note that this same conservative calculational methodology is also applied to the piping, valve resistances, and the effective flow areas of the ADS stage 4 flowpaths for the safety analysis. For example, conservatively high resistances, small valve effective flow areas, and long valve opening times are assumed for the postulated event(s) where ADS flow determines the capability of the AP600 to successfully transition to its longer term cooling modes of IRWST injection and/or containment recirculation.

C. AP600 Plant ADS Valve Testing and Analysis

There ~~will be~~ *are* a number of additional tests and analyses performed during the development, manufacture, installation, and operation of the ADS valves *to verify that the characteristics of the actual valves used in the AP600 plant application and to verify that the valves are properly designed, operate properly, and are within the bounds of the safety analyses*
These tests and analyses ~~include~~ *support the following activities:*

— ~~Testing to support~~ ADS ~~stage 1/2/3 v~~ *V*alve type selection ~~and to support valve qualification testing~~

— Valve qualification ~~testing~~

— *Valve* ~~P~~ *p*roduction ~~testing~~

— Pre-operational ~~testing~~ *valve performance verification*

— In-service ~~testing~~ *valve operational readiness verification*

Testing associated with e~~E~~ach of these ~~tests~~ *activities* is further discussed below.

~~Stage 1/2/3~~ Valve Type Selection ~~Testing~~

~~For this testing, f~~*F*ull sized prototypic Stage 1/2/3 ADS valves were installed in an ADS valve package piping simulation. Different valve designs were tested for the ADS Stage 2 and 3 function to provide a basis for *mechanical* performance comparisons. Testing was performed over a range of flow conditions that bound the actual ADS operation *and plant in-service testing. In addition, testing included operation of two different 12-inch gate valve designs in the supply piping to the ADS valve package. These valves were operated to initiate and terminate ADS flow blowdown.*

~~The overall~~ A major objective of this testing was to characterize gate and globe valve *mechanical operation* ~~performance in this application~~ as an aid to the ~~final~~ selection of a specific valve type. ~~This information is not required for design certification.~~ Data obtained ~~on valve performance~~ included the measurement of valve operator mechanical and electrical performance; that is, the required thrust to unseat, open, close, and seat the valves. The valve seats and disks were visually examined after test runs to observe and document valve wear/damage.

These tests ~~will~~ also provide input to the valve specification including fluid conditions, flow, temperature/pressure, differential pressure conditions, and IST conditions. They ~~will~~ also provide input to the valve qualification testing to determine the ~~limiting~~ *required* test conditions (flow, fluid~~,~~ temperature/pressure, and differential pressure).

As discussed above, the upstream valve in each ADS path is designated as an ADS isolation valve. The functional requirements for this valve specify it to be a very leak-tight valve to prevent operational and safety complications arising from an RCS pressure boundary leak. ~~Although t~~*The ADS Stage 1, 2, and 3 isolation* valves are designed to open against differential pressures up to the maximum RCS operating pressure (i.e., 2485 psig) at blowdown conditions, *although* their design basis safety requirement is to open with no flow and high differential pressure. ~~The upstream valve in each ADS path is designated as an ADS isolation valve.~~ Based on the results of the ADS test program ~~conducted outside of design certification~~, a ~~the~~ gate valve ~~type best suited to~~ meet*s* the requirements for the ADS isolation valves ~~is a gate valve~~. *Five different gate valves, in* three ~~types of gate valves~~ *different sizes from four different vendors* were tested. All ~~three types of~~ *five* gate valves tested exhibited superior leak-tightness. In addition, due to design modifications on these valves, bonnet pressurization was not observed. Thermal binding effects were observed on the wedge gate valves although not of a magnitude to prevent opening of the valve under design conditions.

The downstream valve in each ADS path is designated as an ADS control valve. The functional requirements for this valve specify it to provide a controlled blowdown ~~from the pressurizer~~ at a sufficient flow to meet the ADS venting requirements. The safety-related function of the ADS first stage control valve is to open against differential pressures up to the maximum RCS operating pressure (i.e., 2485 psig) at blowdown conditions. The valve is also designed to be used by the operator to manually depressurize the RCS in some beyond design basis events. However, this function is not ~~considered~~ safety-related.

~~Based on the results of the ADS test program, the valve type best suited to meet the requirements for the ADS first stage control valve is a globe valve. Furthermore, the globe valve opening characteristics should be such that the valve does not exhibit significant tensile loads upon opening. Simply stated, the peak operating loads for the valve during blowdown conditions should not exceed the opening loads at static conditions. The globe valve tested as a first stage control valve was a 4 inch body-guided plug globe valve with control valve trim.~~

The safety-related function of the ADS second, ~~and~~ third stage control valves is to open against differential pressures up to the maximum RCS pressure *that* they are required to open against during ADS. This has been specified to be 1200 psig for the second stage ADS valves and 500 psig for the third stage ADS valves. These values are based on the safety analysis results for an inadvertent ADS. However, the valve*s and their* ~~motor~~ operators will be designed to open against full RCS operating pressure (i.e., 2485 psig) to ~~provide sufficient~~ *provide high* ADS reliability for beyond design basis events, such as the postulated ~~while considering~~ ~~the possibility of the~~ failure of the first stage ADS valves to open.

~~In summary, the~~ *A* valve type ~~best~~ suited to meet the requirements for the ADS first, second, and third stage control valve is a globe ~~isolation~~ valve. ~~Furthermore, the globe valve opening characteristics should be such that the valve does not exhibit tensile loads upon opening as described above.~~ The globe valves tested as second and third stage ADS control valves included ~~the 8-inch gate valves described earlier~~, an 8-inch globe valve with a full body guided disk-piston, and an 8-inch globe valve with dual seats and a balanced cage guided trim package. The 8-*i*nch globe valve with full body guided disk-piston performed well under *ADS initiation and* blowdown conditions and provided sufficient leak-tightness for the ADS valve application.

The safety-related function of the ADS fourth stage control valve is to open with the RCS pressure ≤ 200 psig, after the RCS has been depressurized by the operation of the first three stages of the ADS. This valve will be designed to open at a 1000 psi delta-P.

An explosively actuated squib valve has been selected as the ADS Stage 4 control valve, in order to provide a highly reliable and diverse means of venting the reactor coolant system. This selection is based on the industry experience and testing of this type valve.

The configuration shown on the system P&ID includes gate valves for isolation for four stages, globe valves for control for stages ~~1/2/3~~ *1, 2, and 3* and squib valves for control for stage 4.

Valve Qualification ~~Testing~~

Valve qualification will occur after vendor selection and is a three step process of analytical qualification, functional testing of the valve/operator assembly, and IEEE qualification of the operator.

Analytical Qualification

~~Prior to qualification testing, v~~*V*endors will perform analytical ~~qualification~~ calculations to confirm that their *valve* designs are acceptable for the ADS application. These calculations include:

— An ASME Code Class 1 design report to verify valve integrity under the design conditions in the equipment specification ~~to~~ includ~~e~~*ing* specified nozzle loads and design transients

— A seismic analysis to verify operability for the specified seismic accelerations at the maximum operating load

— A weak link analysis to provide the maximum loads the valve components can withstand *for* both test and operating conditions

— Operat*or*~~ing~~ sizing calculations using both the manufacturer's and EPRI's *"MOV Performance Prediction Models"* ~~methodology~~ (~~when~~ *as* applicable).

— *An analysis to establish that the valve L/D or single-phase flow resistance, and the critical flow through the control valves is within the bounds used in the AP600 safety analysis*

Functional Testing

Based on acceptable analytical qualification, *prototype* valves *for each ADS application* will be manufactured for functional testing. The valve/actuator assembly to be tested will be ~~identical~~ *prototypical* to that used in the plant with respect to configuration, materials, and dimensions. Prior to assembly, each test valve will be dimensionally inspected. Critical dimensions will be recorded with any special features that are critical to operation. Testing is performed with instrumentation to measure stem thrust, torque, switch actuation, travel,

motor speed, motor temperature, ~~accelerations~~ *natural structural frequencies* ~~and fluid temperature, pressure, flow, differential pressure~~ and opening/closing times. The test conditions will be determined with input from the type selection testing discussed above *but will include valve open/close cyclic mechanical testing, valve opening tests at safety function and full design differential pressures, and verification of the valve flow resistance. The functional testing of the ADS stage 4 squib valves will include actuation tests at their safety function and design differential pressures, flow resistance testing, and critical flow capacity testing.*

IEEE Qualification

The operator will require separate qualification based on IEEE-382 which will include cyclic aging, vibration aging, seismic testing, ~~and~~ environmental aging, *and environmental effects due to LOCA and MSLB* ~~to include LOCA/HELB~~.

Supplemental testing may be required to address separate issues related to the electric actuators, such as, effects of operating time on motor temperature and speed, motor temperature effect on motor output torque, and motor speed effect on torque capability.

***Valve* Production ~~Testing~~**

~~An ITAAC Type test will be performed as necessary for each type of valve selected to confirm that the valves of each type can be procured to perform as required.~~ Each valve will be subjected to production testing *which* ~~to~~ include*s* a hydrostatic shell test of the body~~/bonnet~~, hydrostatic disc test, leakage tests on the seat, backseat and packing, and a functional test. The hydrostatic test will be consistent with the ASME Code, Section III, NB-6000. ~~The~~ *For motor operated valves,* functional test*s* ~~is~~ *are* performed at nominal and reduced voltage without flow but with the valve *initially* closed and at the design pressure differential at room temperature. Finally, a cyclic test is performed for a number of cycles with no pressure or flow.

Pre-Operational Testing

Static baseline testing will be performed prior to startup to verify that the *ADS Stage 1, 2, and 3 valves and the Stage 4 isolation valves are* ~~is set up and~~ properly functioning ~~correctly~~. Following the static test, the Stage 1, 2, and 3 valves will be subjected to ~~individual valve~~ tests with ~~low~~ *water* flow ~~and with design differential pressure (initial)~~ *as part of the verification of the overall ADS path resistance.* Finally, a blowdown test will be performed on the first AP600 from an elevated RCS pressure and temperature which will ~~actuate~~ include actuation of ADS Stages 1, 2, and 3. *A* Stage 4 *squib valve* will be *actuated and all Stage 4 flow paths will be* flow tested *with the squib valve opened or removed.* These tests ~~will be~~ *are* described in Chapter 14 of the SSAR.

AP600

In-service Testing

The ASME code requires valve exercise tests be performed on safety-related valves. ~~on a quarterly schedule In addition, in Generic Letter 96-xx the NRC requires safety-related power operated valves be tested to verify their capability to perform their safety-related function. These valve operability tests are to be performed at operating conditions (differential pressure and flow) as near as practicable to the conditions expected during the valves' performance of their safety-related missions. These tests are excepted to be performed once every five years or every 3 refueling outages consistent with Generic Letter 96-xx. The ability to do meaningful operability tests is an important functional requirement for the ADS valves. The COL applicant is responsible to specify and perform specific tests for specific valves.~~ *As specified in Section 3.9.6 of the SSAR, the capability of the ADS valves to perform their mission is periodically tested. This testing includes verification of proper position indication and proper stroke time, as applicable.*

~~An in-service stroke time test will be performed at the required interval at zero differential pressure, ambient temperature. Periodically, during a refueling outage, a flow/differential pressure test will be performed at low flow, a pressure differential between 400 and 1200 psi, and a temperature of 300 degrees. The squib valves, currently specified for the fourth stage, would not be subject to these tests but will have unique IST requirements (such as periodically actuating their charges outside the ADS valves).~~

~~Periodically, verification testing will be performed on valve set-up and operator capabilities in accordance with GL-89-10, and GL-96-xx as specified by COL applicant. This would require a flow test be performed on these valves during a refueling shutdown prior to depressurizing the RCS below 300-400 psig. A simple exercise test of a globe isolation valve with low differential pressure and no flow will provide a meaningful test of the operability of the ADS control valves. Therefore, the AP600 Inservice Test Plan as documented in the SSAR will reflect the simplified IST approach.~~

~~In summary, to meet the requirements for inservice testing as described in SSAR Section 3.9.6, the following IST commitments for the ADS valves are:~~

~~**ADS Isolation Valves**~~

- ~~Exercise test periodically as specified by COL applicant. These tests are conducted at-power with no flow and no differential pressure across the valve.~~

- ~~Operability test periodically as specified by the COL applicant. These tests are conducted at full RCS pressure with no flow and high differential pressure.~~

~~**ADS Control Valves**~~

- ~~Exercise test periodically as specified by the COL applicant. These tests are conducted at-power with no flow but with the potential for a differential pressure across the valve.~~

Westinghouse

- ~~Operability test periodically as specified by the COL applicant. These tests are conducted during shutdown operation with no flow and low differential pressure. There are no RCS pressure requirements for these tests.~~

~~A one-inch solenoid operated test valve is provided with each ADS valve package. This valve is provided to equalize the pressure across the ADS gate isolation valves prior to exercise testing of the valve. This practice has been shown to be effective in reducing wear on the gate valves that may develop from repeated exercise tests. It is not required to equalize the pressure across the ADS globe valves for exercise testing. The globe valves will not experience significant wear during exercise testing.~~

Post-maintenance testing of the operator and valve will be required whenever changes are made that may affect the required operating loads or operator output.

Valve Design Control

Design control is not a part of testing. However, it is required to establish the linkage among the designed valves, the tested valves, the production valves, and the installed valves. Production valves will be purchased to the same equipment specification requirements as the tested valves. Dimensional inspection of critical parts will be performed and recorded to verify that they are within required tolerances. The critical dimensions will be determined based on a review of the test results and design configuration by the valve manufacturer and Westinghouse.

~~Any m~~ Modifications to the original design must be reviewed, evaluated, and approved by Westinghouse prior to implementation by the manufacturer.

SSAR Revision: None

~~The preoperational testing of the ADS valves will be included in Chapter 14, Initial Test Program of the SSAR.~~

Question 440.569

Re: Automatic Depressurization System Testing (OITS 3397)

The ADS Phase B1 TAR does a reasonably good job in explaining the kinds of analyses that where performed on the data, e.g., two-phase multipliers, critical flow, etc. What is not clear is how this information is going to be used.

a. Are specific models for two-phase subsonic and critical flow in piping networks and valves going to be validated for use in the AP600 accident analysis codes? Or is the analysis simply an aid to better understanding of the behavior of the system during these tests?

b. On page 4-22 in the TAR, it is stated that "it is not essential to make a determination of whether choking occurred in the ADS test components. The pertinent issue is whether the computer models used to analyze the AP600 plant ADS can correctly predict the two-phase pressure drops and flow measured in the tests." The data from these tests establish a basis for validation of analytical models. However, the implication of the statement seems to be that if the calculations of overall pressure drops and flows through the piping/valve network are acceptably accurate, details of the various component pressure drops and flows do not matter. The staff does not agree with Westinghouse's implied approach, which would seem to provide little confidence that the code models would be able to predict accurately any conditions that fell outside the relatively narrow range represented by the ADS tests that were analyzed (including those of the second train of ADS in the plant, since the piping network is somewhat different from the first ADS train). This is especially true considering that flow splits in the ADS tests were inferred, and there appears to be no way to confirm the inferred flow distribution.

   Since flow split depend on pressure loss characteristics of the various network components and the condition of the flow passing through those components (choked or unchoked), please explain how the data can be used to differentiate between choked and unchoked flow, to provide a basis for comparison to the computer code models used to calculate flow behavior in the ADS valves and piping.

c. With regard to Westinghouse's explanation of the difficulties in determining whether the flow is choked, the staff takes note of the discussion in Section 4.4.3, e.g., the tendency of orifices not to "choke" in the classic sense. However, there are models that predict the limiting flow condition.

In addition, the discussion in the TAR seems to imply that the gate and globe valves represented by orifices in VAPORE would, in fact, behave like orifices in a thermal-hydraulic sense. However, there are no data presented in the report to substantiate such a claim. In light of the difficulties described by Westinghouse in determining the flow conditions in the ADS network, the staff requests that:

i. Westinghouse provide a quantitative analysis of the data to substantiate any conclusions concerning the relationship of actual valve behavior to the behavior of the components used to simulate those valves in VAPORE (possibly including comparison to data from the Phase B2 series of tests); and

ii. Westinghouse explain how the models used to calculate ADS 1/2/3 performance represent the thermal-hydraulic conditions in the piping/valve network.

Response:

a. The AP600 accident analysis utilizes established models to calculate the performance of the ADS. These models include a traditional evaluation of the ADS piping resistance, combined with two-phase flow multipliers from the Martinelli-Nelson correlation, for subsonic flow; and the Fauske-HEM critical flow correlation combined with the flow area at the locations where/when sonic flow occurs. The analysis presented in the ADS Phase B1 TAR provides comparisons of the test data to these established methods of determining the flow at a given driving pressure and fluid conditions and is an aid to understanding the behavior of the system during the test.

b. The ADS Stage 1, 2, and 3 Cold Flow Test data (WCAP-14676) combined with data from the ADS Phase B1 steam only blowdown matrix tests 110, 120, 130, and 140 (WCAP-14324) provide a consistent basis for single-phase, non-choked flow losses through the ADS test facility and individual components. In addition the Phase B1 steam only blowdown test data provides consistent information on choked flow through the most limiting component in each ADS stage; namely, the Stage 1 globe valve and the Stage 2 and 3 orifices, which simulated globe valves. This agreement was obtained when choked flow is assumed whenever the ratio of downstream pressure to upstream pressure was < 0.58. The above information provides data for the calculation of the flow splits based on the overall resistance through each stage, or based on the delta-P across single components like the globe valves, all of which closely agree.

   The single-phase resistances and effective flow areas with choked flow derived from the above test data were input into the NOTRUMP analysis and the code properly predicted the two-phase flows and pressure drops through the test facility for tests with two-phase flow. This information is included in the NO-TRUMP V&V Final Validation Report (WCAP-14807, Rev. 1, Jan. 1997).

c. Close agreement between the test data and the test analysis choked flow model are obtained whenever the downstream to upstream pressure ratio is < 0.58. This same choked flow discriminator is used in the NOTRUMP computer model.

Response to additional Items i and ii. The responses to Items a, b, and c above provide the requested information.

SSAR Revision: None

OITS Item 500

ADS Air Clearing and Steam Condensation Load Roadmap

As agreed to in a teleconference (11/21/94) on ADS Testing, below is a "road map" of testing activities which address air clearing loads, condensation loads, vacuum breaker concerns.

RESPONSE

Throughout the automatic depressurization system (ADS) B1 testing program, no adverse effects due to air clearing loads, or due to steam condensation when ADS flow was terminated, were observed. The test facility was instrumented to observe these phenomena and the tests were performed in a manner that simulated AP600 plant ADS operation. Based on the ADS testing experience, the AP600 design precludes large air clearing loads from occurring due to the slow opening valves and large loads due to steam condensation in the discharge line can readily be avoided by the use of vacuum breakers. This information supplements the IRWST hydrodynamic load roadmap provided in letter NSD-NRC-97-4973, 2/3/97.

Air Clearing Loads

The ADS Phase B1 testing was performed with air initially in the ADS discharge piping, and the air was discharged into the quench tank through the ADS sparger at the initiation of the steam or steam/water blowdowns. Since the ADS discharge piping downstream of the ADS valve package had a total volume similar to the AP600 plant ADS piping, and since the blowdowns were initiated over a time period that was similar to, or faster than the actual plant valves would open; the ADS Phase B1 test runs included protypic or conservative air clearing in the quench tank. These air clearing quench tank pressure pulses were included in the data reported in WCAP-14324, Rev. 0. These air clearing pressure pulses were considered with the steam condensation pressure pulse vs. time histories in developing bounding loads for the structural analysis of the IRWST and plant. The time over which the air was discharged through the sparger can be obtained from the data based on the time difference between the start of pressurization of the ADS valve package, and the increase in the fluid temperature measured in the sparger arms.

Condensation Loads, Vacuum Breakers

The ADS test facility included two small vacuum breakers and an absolute pressure measurement instrument in the 16-inch discharge piping. This absolute pressure sensor (PE-22) had a range from 0 to ~35 psia and was located near the vacuum breakers, just upstream of where the discharge piping entered the facility quench tank. Data obtained from this instrument is reported in WCAP-14324, Rev. 0 and shows that only one or two small pressure oscillations of 2 to 3 psi vacuum occurred in the ADS discharge piping when the ADS flow was terminated at the end of the test runs. There was often an audible indication of rapid steam condensation when the flow was terminated. However, these were not loud, and there was no indication of piping movement or water hammer damage even though the piping was lightly supported. Note that the steam/saturated water test runs were terminated from high ADS flow by closing the partially open Atwood Morrill gate valve, so that the test flow was stopped much faster than could occur in the AP600 plant. Similarly, the steam only blowdown flows were terminated at a faster rate in the test than would occur when the Stage 1 globe valve is closed in

the plant. The above information indicates that the gradual termination of the ADS flow in the AP600, as compared to the much more rapid termination that would occur if relief valve closure terminated flow, greatly reduces the likelihood of large negative pressures in the discharge line.

AP600 Design, Future Testing

In the AP600, vacuum breakers will be installed in each of the two ADS discharge lines to assure that no damaging water hammer occurs. These vacuum breakers will be located in the 16-inch discharge piping upstream of where the lines enter the IRWST. Testing will be performed as part of the initial test program, to verify proper operation of these devices.