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May 2, 1997

Re: Indian Point Unit No. 2
Docket No. 50-247

Document Control Desk
US Nuclear Regulatory Commission
Mail Station P1-137
Washington, D.C. 20555

SUBJECT: Reply to Request for Additional Information
Passive Autocatalytic Recombiners

Reference: Proposed Technical Specification for H2 Recombiners.

The attachment to this letter constitutes Con Edison's reply to the referenced request for additional information associated with the Passive Autocatalytic Recombiners.

Should you have any questions regarding this matter, please contact Mr. Charles W. Jackson, Manager, Nuclear Safety and Licensing.

Very truly yours,

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Attachment

cc: Mr. Hubert J. Miller
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RESPONSE
TO
REQUEST FOR ADDITIONAL INFORMATION

1) Why isn't the PAR included in the Indian Point 2 Environmental Qualification Program? The staff believes that if this device is to be credited to meet the requirements of General Design Criterion (GDC) 41 then it should be environmentally qualified.

Response:

The Passive Autocatalytic Recombiners (PARs) are included in the IP2 Environmental Qualification (EQ) program. They are being added to the EQ Master List in place of the current recombiners. As discussed below, the qualification is based on both pending testing (ref.-2,3) at Wyle Laboratories as well as earlier developmental and proof testing at German and French test facilities. The tests in Germany for product development and those in France sponsored by EPRI and EdF demonstrated performance in a wide variety of environmental conditions of temperature, pressure, humidity, iodine and smoke. The EQ testing at Wyle extends conditions to address plant specifics and aging conditions.

The following is a summary of the proposed tests for the environmental and seismic qualification of a PAR to be performed at Wyle Lab. The tests shall meet 10CFR50 Appendix B QA requirements. The tests will be performed in accordance with IEEE 627 for environment and IEEE 344 for seismic. A PAR section with the number of cartridges and flow channels to allow meaningful functional tests in the Wyle test vessel, will be used for all functional tests except the Seismic Simulation which uses a full-size (88-plate) device. Each functional test will be done at nominally the same pressure and temperature conditions. All cartridges to be used for this test contain the catalyst manufactured from the same batch used for the PARs to be installed at Indian Point 2.

The proposed test plan consists of the following:

- Qualification Plan preparation
- Receiving inspection
- Base line functional test-Dry
- Base line functional test-Wet
- Radiation Exposure (1.0E7 rads @ 1.0E6 rads/hr.)
- Thermal Aging (112 hours @ 150 degree C - 302 degree F)
- Seismic simulation (aged and exposed cartridges inserted into full-size device)
- Post-aging/radiation/seismic functional test - Dry
- Post-aging/radiation/seismic functional test - Wet
- Post test inspection.
- Report preparation.

The Qualification Plan shall define the scope of the program, qualification requirements, and qualification procedures. The plan will include the approach, methods, and philosophies for qualifying the PAR for use in Indian Point 2 containment.

Hydrogen functional testing shall be performed in Wyle's 12' H x 8' Dia. chamber. The volume of this chamber is approximately 500 cubic feet (14 cubic meters). The chamber includes spargers for distributed injection of steam or hydrogen. Hydrogen will be injected to bring the hydrogen concentration to approximately 3%. Hydrogen concentration shall be monitored and recorded. Temperature at inlet/outlet/catalyst shall be monitored and recorded. Also the chamber pressure shall be monitored and recorded.

A full size PAR with 88 cartridges shall be subjected to the seismic simulation. The seismic test will consist of triaxial random multifrequency tests using Indian Point 2 plant specific response spectra. The test will be performed per IEEE 344 - 1987.

The hydrogen concentration history measured during the baseline functional test and the post-aging/radiation/seismic functional test will be compared to demonstrate that the functioning of the PAR is not significantly impacted by the aging, radiation, shaking and chemical spray.

A formal test report will be prepared. This report will be incorporated into the Indian Point 2 Equipment Qualification Program Plan as an EQ file.

2) How are you going to determine the effect the following fission products would have on the ability of the palladium catalyst to recombine hydrogen and oxygen: (1) xenon, (2) krypton, (3) bromine, (4) methyl iodine, (5) cesium, (6) rubidium, (7) tellurium, (8) antimony, and (9) selenium?

Response:

The potential for catalyst degradation due to interaction with chemical inhibitors has been recognized in development of the PARs. One source of those chemicals would be as fission products released from the core in varying degrees depending on the severity of the accident. The following response provides both a qualitative description of the engineering evaluation essentially used by the PAR developers and then an indication of the results from studies by EPRI of past and on-going catalyst inhibitor testing.

PAR Development Evaluation:

Attached figure 2-1 represents the logic used by PAR developers.

First, clad- or core-damaging accident scenarios were studied for an understanding of the likely constituents of the post-accident containment environment. Because PARs were developed for severe accident service, core melt accidents were generally assumed such as those represented by TID-14844 or NUREG-1465 radiation source terms. Next, because accident radiation source term work generally centered on radioactive fission product elements released to the containment, lists of resulting chemical species as well as of non-radioactive accident chemicals were needed.

From this list of potentially present chemicals, noble gases were immediately removed as possible inhibitors because such gases are not generally reactive and certainly not with noble metal catalysts. (Disposition "A" on Figure 2-1).

Next, particulate forms of potentially present chemicals were removed from consideration as chemical inhibitors because their physical form prevented them from significant chemical interaction with the noble metal catalyst sites. (See the response to questions 13 and 14 for discussion of "physical" inhibition by particulates and debris.) For added assurance, the supplier of the particular catalyst was asked to verify that they had no evidence of chemical poisoning by particulate forms of such chemicals, for example by revaporization at elevated temperatures. (Disposition "B" on Figure 2-1)

The chemicals remaining on the list needed to be dispositioned in one of three manners:

* Testing of the inhibition chemical at expected concentrations with the specific catalyst used. (Disposition "C" on Figure 2-1.)

* Review of test data from testing on comparable catalysts. (Disposition "D" on Figure 2-1.)

* Analysis that significant chemical damage to the catalyst would not occur, generally due to low concentrations present or limited time for the presence of chemicals or both. (Disposition "E" on Figure 2-1.)

For the development of the NIS Ingenieugesellschaft mbH (NIS) PAR only gaseous forms of iodine and mixtures of combustion gases were specifically tested (Disposition "C".) Nevertheless, Figure 2-1 indicates other possible dispositions for other chemicals. As described below, EPRI work (ref. 5) largely validates the overall list of potentially present inhibitors and should describe which additional chemicals can be assigned to Disposition "C" or "D".

After initial PAR development work, in order to support the generic qualification of PARs, EPRI initiated a compilation of available quantitative and qualitative information to assess the effects of potential chemical inhibitors on PAR catalyst. The information has been included in an EPRI ALWR program report "Effects of Inhibitors and Poisons on the Performance of Passive Autocatalytic Recombiners (PARs) for Combustible Gas Control in ALWRs" (ref. 5). This EPRI report provides technical understanding (based on established chemical/catalyst principles) of the mechanisms that can reduce recombination in PARs. The report also summarizes existing test data on the effects of suspected inhibitors on the types and forms of catalysts in PARs. The sources of test data include model recombination tests on two types of PARs conducted by NIS and another PAR supplier (ref. 6), by EPRI/EdF/CEA, and benchtop laboratory recombination tests on palladium and platinum catalyst pellet-bed filters subjected to a wide range of chemicals in the hydrogen/air feed stream. Among the potential inhibitors investigated by these test programs are chemicals, including elemental iodine, methyl iodide, chlorine, bromine, sulfur, tellurium, and selenium, known to inhibit noble metal catalysis and fission products chemicals, including cesium and rubidium, not expected to affect catalysis. The conclusion of the EPRI/ALWR report is expected to be that, although some of the chemicals to which a PAR may be exposed produce a measurable reduction in the recombination rate of palladium as catalyst, none of the chemicals tested reduce the recombination rates by an amount not accounted for in margins associated with DBA hydrogen generation assumptions and with the installed capacity at Indian Point 2. The calculated effects of this possible reduction are shown in Figure 1 of the August 1996 submittal.

The EPRI/ALWR program catalyst report will also describe a PAR test program being conducted in the "H2PAR" facility at the Cadarache research center by the French nuclear regulatory agency IPSN 10. These tests subject a PAR to a hydrogen/air atmosphere simulating a severe accident. Simulated fission product aerosols are released into the test facility by an induction furnace. Within the furnace, over two dozen elements are being used to simulate a reactor core inventory. Among these elements are all of the elements in Groups 2, 3, and 4 of the radionuclide groups in NUREG-1465 (Group 1, the stable noble gases xenon and krypton, are not included because they are not chemically active). An initial series of recombination tests using Siemens PARs (platinum catalytic plates) has been completed.

Figure 1 of Appendix B of the August 1996 submittal illustrates the excess capacity being installed in IP2. Note that the peak calculated hydrogen goes from about 1.5% to 1.75% assuming a degradation in PAR effectiveness from 100% to 50%. The 4% flammability limit, itself a conservative bound on flammability, was not calculated to be exceeded even if the effectiveness of one PAR were reduced to 10% and the second installed PAR was not considered at all.

3) The post-accident radiation load on the containment will decompose polyvinyl chloride insulation and yield vapor phase sulfur species and halogen compounds capable of poisoning palladium surfaces. Sulfur oxides, sulfurous acid and hydrogen sulfide are expected in the containment post-accident environment. How would these compounds affect PAR performance?

Response:

First it should be noted that because polyvinyl chloride (PVC) is susceptible to degradation from irradiation, its use inside containment is discouraged. The only cables containing PVC insulation used inside the containment at Indian Point 2 are cables for two radiation monitors, these are #22 cables and for motor bearing thermocouples for five Fan Coolers, these are #16 cables. None of these cables are near the PARs. Due to this insignificant amount of PVC cables used at IP 2, PVC is not likely to be a significant source of potential poisons. A more likely source of potential chemical poisons is the polymer chlorosulfonated polyethylene (CSPE), which is commonly used as a jacket material over electrical cables. Decomposition by radiation or fire can indeed produce the vapor phase sulfur species and halogen compounds identified by this question. The fire would also produce pure carbon (coke) particles that have been known to poison catalytic reactions in noble metals. To assess such effects, the EPRI/EdD/CEA test program at the KALI facility [Ref 7] included a test on the NIS-type PAR in which the recombination rate of a PAR model was measured after being exposed to the fumes from burning a length of chlorosulfonated polyethylene (CSPE)-jacketed cable immediately beneath the PAR model. The amount of fumes reaching the PAR in this test was expected to far exceed the fumes likely to be produced and to reach the PAR in a containment. The PAR model was dipped in water prior to the fire exposure so that moisture needed to produce acids such as hydrochloric and sulfurous acid would be present. For typical PWR conditions, the tests showed a decrease in recombination rate for an NIS PAR of at most approximately 10%.

Similar results have also been reported [ref 8] in German development tests for sample cable obtained from a German PWR.

See also the response to questions #13 and #14 concerning the expected impact of nonradioactive aerosols.

4) The submittal states that periodic surveillance will confirm that unexpected degradation does not go undetected. Provide a description of the proposed surveillance and the basis for the corresponding exit temperature for a particular hydrogen mixture test gas. What additional surveillances will be done if the sample plate tested should fail? This should be incorporated into the revised safety analysis report

Response:

Periodic surveillance will consist of visual examination plus testing of individual plates for indication of significant change in response to a known hydrogen gas mixture. This technique was developed by NIS and was also used by Wyle Laboratories in testing the effects of radiation on a single plate (ref-1).

The individual plate is inserted into the test chamber (see figure 4-1) and a known flow of 1%-hydrogen-in-air is injected into the chamber. The plate outlet temperature is measured and compared with measurements on new plates. The plate will be judged to be undegraded if the temperature developed is within the acceptable criteria. The acceptance criteria is being developed in baseline testing for the NIS test equipment.

Since there are no known or expected aging or degradation mechanisms to specifically examine, this comparative testing is considered adequate to detect unexpected changes in reaction rate of catalyst plates well prior to unacceptable deterioration in overall performance.

If a plate were to fail this surveillance the response would be determination and correction of the root cause of the failure.

A general discussion of surveillance will be included into the UFSAR section 6.8 UFSAR section 6.8 “Postaccident Hydrogen Control Systems”.

5) 10 CFR Part 50, 50.44 and 50.46 require, in part, that the capability for insuring a mixed atmosphere in the containment be provided. What system is being provided to mix the combustible gases within containment? A description of the system and its capability to provide sufficient mixing should be included in the safety analysis report revision.

Response:

Mixing is assured through the use of the existing, DBA-qualified, fan-cooler system. The UFSAR, Section 6.4, describes the containment air recirculation cooling and filtration system. As shown in UFSAR Figure 6.4-1, flow is directed to various locations including locations high in the containment. Three to five fan-coolers operate in the post-accident environment. Each fan is rated at 65,000 cfm at accident conditions. Based on this, the UFSAR notes in 6.4.2.1.2: "the recirculation rate with five fans operating is approximately 7.5 containment volumes per hour." The recirculation rate with three fans is approximately 4.5 volumes per hour.

6) PAR components should be capable of withstanding all related environmental conditions imposed on them, including external transient differential pressures and internal pressure surges without loss of function. A description of the design provisions and their supporting analyses or test results should be included in the safety analysis report revision.

Response:

The PARs will be located on the operating floor at the 95' foot elevation, outside the missile shield wall. This location is away from the reactor coolant piping and possible impingement from high flows due to line breaks. The PARs themselves are essentially open on top and bottom and not capable of developing a significant pressure difference across any side due to the transient pressure rise from the design basis LOCA. The UFSAR will be revised to include appropriate design information of the PAR, and its location.

7) Will the PAR system, including foundations and supports, be designated seismic Category I, i.e., designed to withstand the effects of the safe shutdown earthquake without loss of function, as recommended in Regulatory Guide 1.29?

Response:

The PAR system, including foundations and supports, is designated as Class A seismic consistent with Indian Point 2 Quality Assurance classifications.

A seismic qualification test using a full size PAR will be performed. This test will use Indian Point 2 plant specific response spectra for OBE and DBE. The test will be performed in accordance with IEEE-344-1987.

8) What are the specific data points that support the analyses of the functional capability of the PARs?

Response:

The combustible gas control calculation results submitted in the August 21, 1996 submittal were obtained using the STARGAP code. The hydrogen generation model is that used in the COGAP code. The calculation model for hydrogen removal by PARs is best-estimate, based largely on first-principles but also including a parameter originally benchmarked to early development testing. That factor has not changed as a result of extensive subsequent validation efforts.

Validation of the best estimate model for steady-state hydrogen removal was done using the Battelle "model" and "containment" (full-scale PAR) tests. It was also validated against the earliest test results from the EPRI/EdF/CEA KALI test program. STARGAP calculations were also compared with the NIS calculational model which was itself based on Battelle testing.

Subsequently, the PAR recombination model from STARGAP was extended to include BWR (oxygen-limited) conditions and transient (startup) conditions. This later version of the code is designated STARGAP1 and uses the same steady state recombination model used in the August 1996 submittal. Validation of STARGAP1 included additional applicable tests from the EPRI/EdF/CEA test program at the KALI facility.

Margins and Treatment of Uncertainty:

The STARGAP hydrogen recombination model used in the August 1996 submittal is best-estimate and does not incorporate startup delays or the potential effects of catalyst degradation. Startup delays of up to an hour have been measured for coated catalyst representative of the IP2 PAR design. This time is inconsequential in the time scales associated with the 10 CFR 50.44 accident hydrogen generation.

Limited catalyst degradation by iodine and by fire smoke and fumes has been shown in tests. However, it is not practical to perform parametric studies of the poisoning effects to develop analytical correction factors representing, for example, "poisoning as a function of catalyst exposure". Similarly, there does not seem to be a basis for any specific "derating factor" to be applied throughout the range of operation of the PAR. Instead, ample conservatism is found in two areas:

* assumptions for DBA hydrogen generation, and
* excess installed capacity

The hydrogen generation assumptions were noted in Table 2 of Appendix B of the August 1996 submittal. Each assumption is a bound on expected values.
The more significant conservatism are:

* Zirconium oxidation: 5%. This is two and one half times the amount previously assumed and the previous assumption was considered to meet the requirements of 10 CFR 50.44.
* Hydrogen yields in core and sump: 0.5 molecules/100ev. This value, specified by Regulatory Guide 1.7, is a significant increase (~15% to 65%) in the previous values even though previous values are still considered technically valid.
* Halogen energy absorbed in sump: 50%. This essentially ignores the amount of iodine that would be fixed onto containment structures

including walls, coolers and filters. With existing IP2 systems this may be conservative by an order of magnitude or more.

* Aluminum and Zinc corrosion surfaces: The assumptions for these values were expanded significantly to well beyond the surfaces known to exist inside the IP2 containment. Corrosion rates were also increased to the RG 1.7 values even though the previous assumptions are still considered technically valid.

Figure 1 of Appendix B of the August 1996 submittal illustrates the excess capacity being installed in IP2. Note that the peak calculated hydrogen goes from about 1.5% to 1.75% assuming a degradation in PAR effectiveness from 100% to 50%. The 4% flammability limit, itself a conservative bound on flammability, was not calculated to be exceeded even if the effectiveness of one PAR were reduced to 10% and the second installed PAR was not considered at all.

Ultimately, validation of the hydrogen recombination model in STARGAP (and STARGAP1) will have used experimental data from five test programs by four organizations in three countries. While the model does not decrease recombination for the potential effects of degradation mechanisms, overall margins are considered to be more than adequate. Hydrogen generation assumptions, both those specified in regulatory guidance and those selectable under that guidance, are very conservative. We believe this provides adequate basis for concluding that the PAR system installed at Indian Point 2 is adequate to meet the acceptance criteria of 10 CFR 50.44.

9) To satisfy the design requirements of GDC 41, combustible gas control system designs should include instrumentation needed to monitor system or component performance under normal and accident conditions. The instrumentation should be capable of determining that a system is performing its intended function. The instrumentation should have readout and alarm capability in the control room. The containment hydrogen monitor shall meet the requirements of Item II.F.1 of NUREG-0737 and NUREG-0718, and the Appendix of Regulatory Guide 1.97. The fact that PARs begin recombining well below 1% on their own and cannot be controlled by the operator means that hydrogen indication is no longer the most accurate indication of core damage. Will the technical specification bases and accident management guidance be changed to reflect this? The revised safety analysis report should address this requirement.

Response:

As described in UFSAR Section 6.8.2.3, Indian Point 2 has a containment hydrogen concentration monitor that was evaluated by the NRC against the requirements of Item 11.F.1 of NUREG-0737 and Regulatory Guide 1.97 and determined to be acceptable. Technical Specification 3.5.6 provides limiting conditions for operation, allowed outage times, and action statements for the instrument. The provision of PARs to replace the current hydrogen recombiners does not impact the instrument or the requirements for the instrument. The hydrogen monitor will continue to provide indication of containment hydrogen concentration, and allow the operators to determine if the combustible gas control system is performing its intended function of removing hydrogen to prevent a containment overpressure condition due to uncontrolled combustion of hydrogen.

Regulatory Guide 1.97, Revision 2 specifies the purpose of the Type C variable "Containment Hydrogen Concentration" as detection of the potential for breach of Containment, which is theoretically possible due to uncontrolled hydrogen combustion. Containment hydrogen concentration is currently considered in assessing core damage (Procedure NEP-1, "Methodology for Assessment of Core Damage Following a Postulated Accident'), but it is not a precise indicator. Other indicators currently used are containment radiation level, core exit thermocouple readings, RVLIS level indication, and reactor coolant system fission products.

Core damage assessment guidelines being developed under the Westinghouse Owners Group (WOG) Severe Accident Management Guidance project relies on two primary indicators for assessing the type and degree of core damage (both fuel rod clad damage and fuel over temperature damage): the core exit thermocouples and the containment high range radiation monitor. A number of confirmatory indicators (containment hydrogen concentration, RVLIS level, hot leg temperature, and source range indication) for fuel over temperature damage are also identified in the core damage assessment guidance. The intent is to use the primary indicators to make a quantitative estimate of the type and degree of core damage and then use knowledge and judgment to determine whether the estimates are supported by the confirmatory indications. Based on severe accident analyses, it is difficult to correlate containment hydrogen concentrations to the accident progression with any certainty (guidance allows a 25% difference in core damage estimates between containment radiation monitor and core exit thermocouple estimates and the containment hydrogen estimate). Containment hydrogen concentration is not a confirmatory indicator for fuel rod clad damage assessment.

When Severe Accident Management Guidance is implemented at Indian Point 2, the confirmatory indication of containment hydrogen concentration will have to be evaluated for its usefulness and any deviation from the WOG generic guidance will have to be justified. It is likely that containment hydrogen concentration would not be used as a confirmatory indication of fuel over temperature damage. In that event, three other confirmatory indicators remain (RVLIS level, hot leg temperature, and source range indication).

10) How will the capability for controlled purging of the containment to aid in post-accident cleanup be provided?

Response:

As described in UFSAR Section 6.8.2.2, Indian Point 2 has a post-accident containment venting system requirement which is contained in Technical Specifications 3.3.G and 4.5.G.

The high reliability of the PAR system is expected to reduce the likelihood that the post-accident containment venting system would be needed to control post-accident combustible gas. Nevertheless, installation of the PAR does not alter the capability of the venting system to perform as described in the UFSAR.

11) What size will the 88 PAR cartridges be?

Response:

Each cartridge will be:

Length:	approximately 450 mm (17.7 inches)
Height:	approximately 200 mm (7.9 inches)
Thickness	approximately 10 mm (0.4 inches)

12) What affect will the containment spray hood have on PAR performance? What affect would chemical additives in the containment spray have on PAR performance?

Response:

The PAR configuration that is being installed at IP2 is shown in figure 12-1.

The spray hood is expected to have a neutral to positive effect on PAR gas flow rate compared with test configurations used for validation noted in question #8. Such testing was done without the spray hood. Calculations done by NIS have indicated a very minor theoretical decrease in flow due to the turning-portion of the hood but that decrease is significantly less than the increase of flow due to the height of the spray hood itself.

Wyle will be conducting tests using plant specific chemical spray which are expected to indicate that the spray chemical additives do not have a significant impact on the reaction of a PAR section with hydrogen. NIS is conducting similar "single cartridge" testing.

13) What effect would nonradioactive aerosol masses have on the operation of the PAR?

Response:

See response to question number 14.

14) Explain why the diffusion-filter nature of the PAR's design is not expected to be affected by even severe accident levels of particulates?

Response:

The chemical effects of nonradioactive aerosols have been addressed as part of questions #2 and #3. Physical blockage by aerosols, whether radioactive or nonradioactive, whether coming from condensation of corium or from fire or accident-generated debris is addressed here.

To physically limit PAR effectiveness, aerosols would have to block diffusion of hydrogen and oxygen to the catalyst surfaces or large-scale debris or deposition would have to generally block the PAR inlet or outlet. The likelihood of debris blockage of the PAR outlet is reduced by locating the PAR away from sources of debris and by the incorporation of the spray hood into the design. The likelihood of gross blockage of the PAR inlet is similarly reduced by location away from sources of debris. Since the flow velocity through the PAR is relatively slow and upward, entrainment of significant debris to the inlet is not expected. Any inlet blockage caused by debris would also decrease the flow velocity even further and entrained debris could be expected to drop away due to reduced flow. Finally, two physically separated PARs are used, either one of which has sufficient capacity to maintain containment hydrogen below limits.

Nevertheless, fine aerosols can be entrained in the gas flow to the PAR. Inside the PAR, in the flow area between plates, velocities of one to one and a half feet per second are estimated for a 4%-hydrogen-in-air gas mixture. Flow in the channels is not expected to be sufficiently turbulent to cause significant impact deposition on the catalyst surfaces. Only a limited amount of aerosol diffusion to the cartridge surfaces is expected with most of the aerosols simply passing completely through. (Diffusion coefficients for gases such as hydrogen and oxygen are significantly higher than those for aerosols.) Finally, the catalyst surfaces will be warmer than the gas/aerosol stream so there will be no drivers for temperature-dependent deposition mechanisms. A conservative calculation for this deposition of particulates on PAR plates during a severe accidents is described in Reference 5. This has been borne out by both NIS and EPRI/EdF/ CEA testing with aerosol loading by combustion products. Those tests showed only limited (10 to 15%) decrease in test PAR effectiveness.

References:

Note: Completed references are available for NRC review either on-site or, with proper provisions for protecting proprietary information, as docketed submittals.

1. Wyle Laboratories test report 45971-1 " Function Testing and Radiation Exposure Test Report on A Passive Autocatalytic Recombiner Plate for Consolidated Edison Company Indian Point Station # 2." April 11, 1997.

2. Wyle Test on EQ. (Future report)

3. Wyle Test on Seismic. (Future report)

4. Polestar Applied Technology, memo from D.Leaver to J.D.Trotter, Chemical Species Released from a PWR during Core Melt, April 1, 1997.

5. EPRI ALWR Program Report, Effects of Inhibitors and Poisons on the Performance of Passive Autocatalytic Recombiners (PARs) for Combustible Gas Control in ALWRs, April 30, 1997 (Draft).

6. R. Heck, W. Heinrich, and V. Scholten, Igniters and Recombiners for Hydrogen Reduction Following Severe Accidents, Service Report No. 14, Siemens, September, 1991.

7. EPRI/EDF/Report, Generic Tests of Passive Autocatalytic Recombiners (PARs) for Combustible Gas Control in Nuclear Power Plants, Volume 1, 2 and 3, EPRI Final Report TR-107517, June, 1997. (April 1997 Draft).

8. Batelle Institute Report Experimental Investigations of the Behavior of the NIS-Developed Catalyst Module in Full Scale under Various System Conditions in the Model Containment, Behrens, U., June 1991 (Proprietary).

9. R.G. Gido, COGAP: A Nuclear Power Plant Containment Hydrogen Control System Evaluation Code, NUREG/CR-2847, LA-9459-MS, Los Alamos National Laboratory, January, 1983.

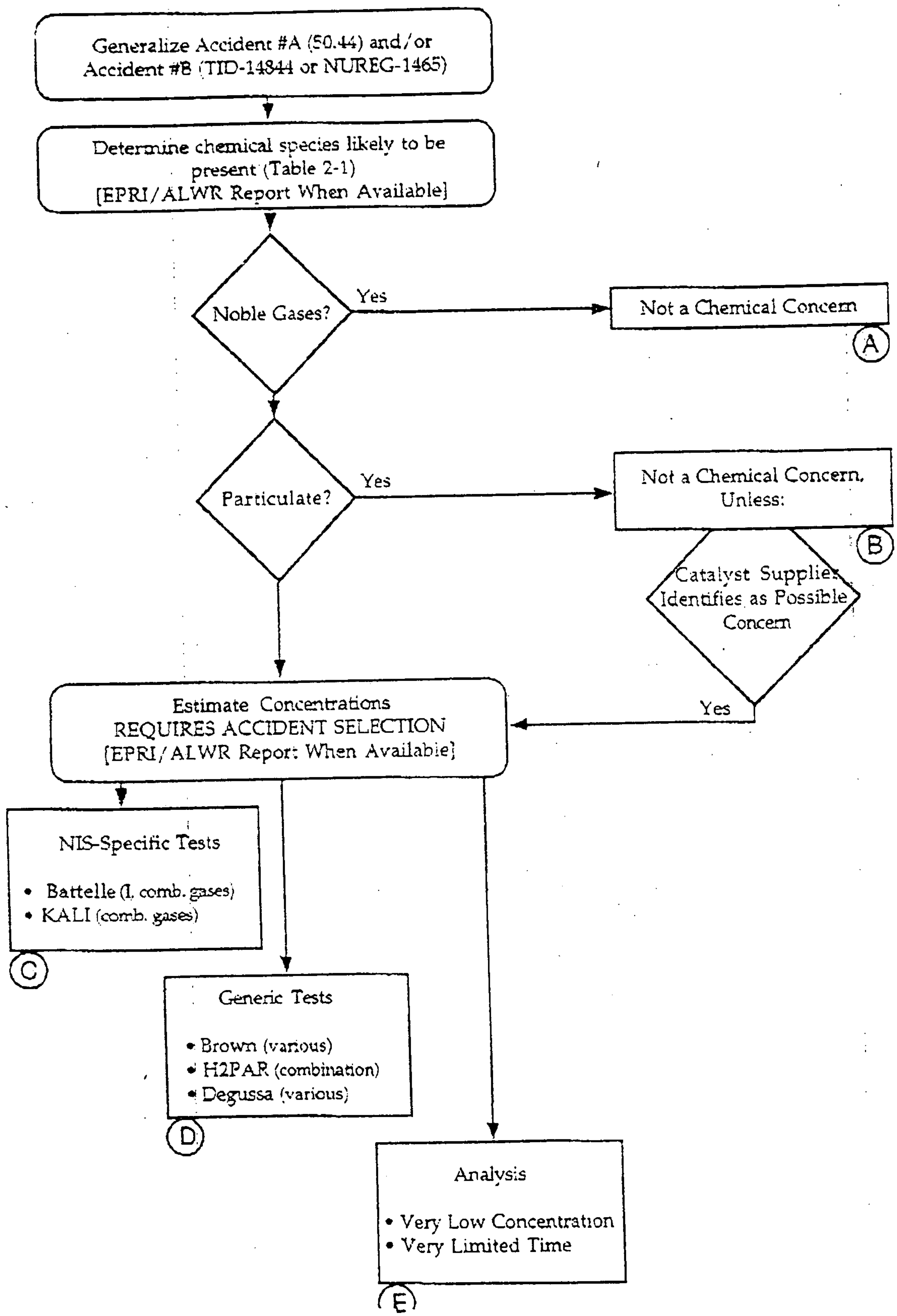
10. Battelle Institute Report Experimental Studies on the Behavior of the model of NIS-developed Catalyst Module in Different System States and Positioning, Behrens, U., March 1991 (Proprietary).

11. Polestar Applied Technology, STARGAP, A Code for Evaluating the Performance of Passive Autocatalytic Recombiners (PARs) to Mitigate Combustible Gas Concentrations in Nuclear Power Plant Containments Following Design Basis Accidents: Code Description and Validation and Verification Report, PSAT C108.04, August 1996 (Proprietary).

12. Polestar Applied Technology, STAREGAP1, A Code for Evaluating the Performance of Passive Autocatalytic Recombiners (PARs) to Mitigate Combustible Gas Concentrations in Nuclear Power Plant Containments Following Design Basis Accidents: Code Description and Validation and Verification Report, PSAT C110.04, April 1997, (Proprietary).

13. Westinghouse, Westinghouse Owners Group Core Damage Assessment Guidance, WCAP-14696, July 1996.

Figure 2-1 -- Evaluation of PAR Chemical Environment



Equipment for Catalyst Cartridge

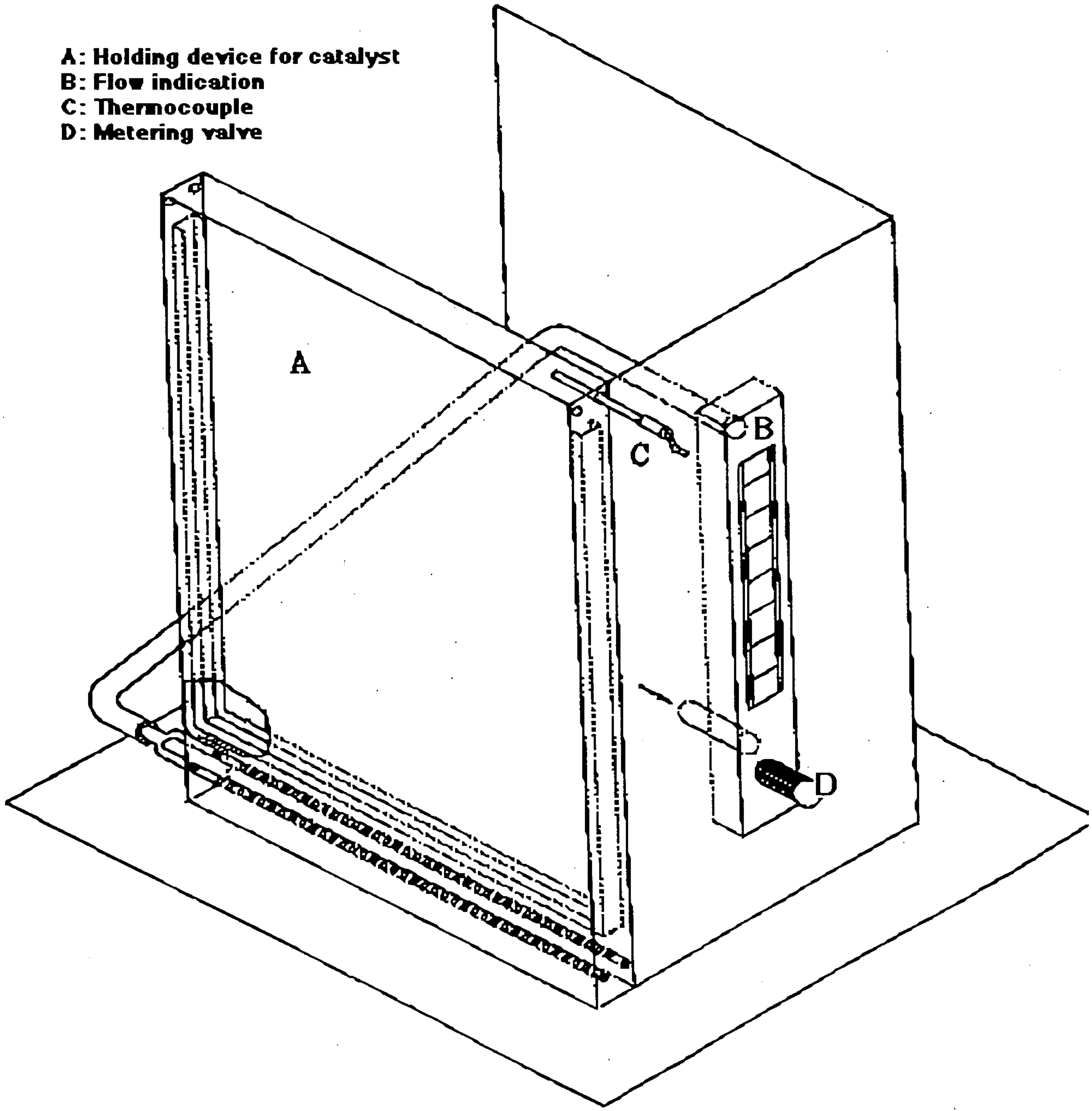


FIGURE 4-1

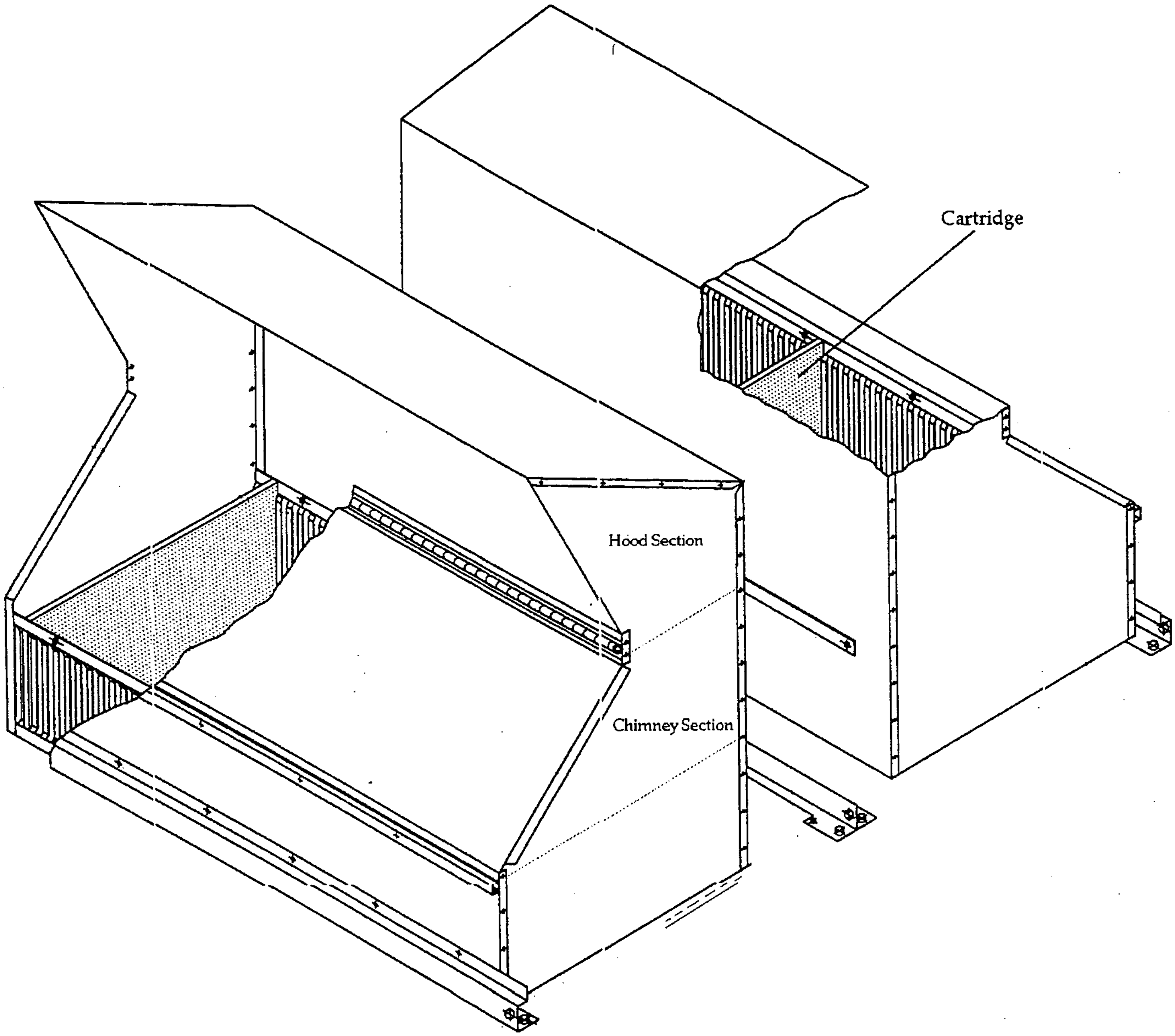


FIGURE 12-1