DONALD C. COOK NUCLEAR PLANT UNIT NOS. 1 AND 2

ENCLOSURE TO AEP:NRC:00500

FIRST QUARTERLY REPORT ON HYDROGEN ISSUES

1. INTRODUCTION

In our response to Mr. D. G. Eisenhut's letter of September 22, 1980, submittal no. AEP:NRC:00476, dated October 7, 1980, American Electric Power Service Corporation (AEP) described the efforts underway to investigate the need for additional hydrogen control capability in Indiana & Michigan Electric Company's Donald C. Cook Nuclear Plant. Our letter also stated that AEP, in conjunction with the Tennessee Valley Authority (TVA) and Duke Power Company (Duke) was involved in a research and development program to investigate additional hydrogen control measures for postulated accidents well beyond the Cook Plant design basis. This submittal is the first quarterly report and provides the status of these efforts and planned analytical and experimental programs. Those programs being jointly performed under the auspices of the AEP/TVA/Duke Task Force are described in Section 2 below. Efforts unique to AEP and the Donald C. Cook Nuclear Plant are described in Sections 4 and 5 below.

2. AEP/TVA/DUKE PROGRAMS IN PROGRESS

2.1 Fenwal Ignitor Tests

A series of tests were performed at the Fenwal Inc. Laboratories to determine the ignition characteristics of a General Motors AC (Model 7G) 'glow plug' type ignitor. The ignitor was tested in various mixtures of hydrogen, steam, and air and in the presence of water spray and fan flow. Representative 'safety-related' equipment (both with and without insulation) was placed in the test vessel and its temperature response to hydrogen combustion monitored.

The results of this testing, which have been previously submitted to the Commission by TVA, indicate that the Model 7G glow plug is a reliable ignition source for hydrogen concentrations between 6 and 12 volume percent. The temperature and pressure transients due to hydrogen combustion and the hydrogen burn fractions observed during the tests were consistent with previously published information. The benefit of insulating temperature sensitive equipment with a thin sheet of aluminum foil was clearly shown by the tests.

2.2 HALON Feasibility Study

The Atlantic Research Corporation (ARC) has been contracted to perform a feasibility study for the use of a HALON Injection System to suppress hydrogen combustion in ice condenser containments. The ARC study is expected to be completed by February 1, 1981.

A preliminary report by ARC (Attachment 1) indicates that HALON dissolation may be a significant concern in a post-LOCA environment. It should be noted that the pH of approximately 2.2 indicated in Attachment 1 does not account for the sodium hydroxide additive in the Cook Plant Containment Spray solution which would, of course, result in a less acidic solution.

2.3 Electromagnetic Interference Study

Dr. B. E. Keiser has been contracted to assess the electromagnetic interference (EMI) emissions from a spark discharge ignitor. Dr. Keiser's study is expected to be completed by April 1, 1981.

2.4 Catalytic Combustor Study

The AEP/TVA/Duke Task Force is reviewing a proposal by Acurex Corporation to test a catalytic combustor for possible use in a post-accident environment. This device would be tested under a series of conditions of varying hydrogen and steam concentrations both with and without the presence of poisons. If practical, a catalytic combustor would be placed on the discharge of each of the containment air recirculation fans to effectively control hdyrogen concentration without introducing the potential for widespread combustion throughout the containment as is the case with a Distributed Ignition System.

2.5 CLASIX Improvements

The AEP/TVA/Duke Task Force has given approval to Westinghouse (W) Offshore Power Systems (OPS) to implement a number of changes to CLASIX. In order to realistically assess the containment response of an ice condenser plant to hydrogen combustion the existing adiabatic burn models, which lead to excessive conservatism in the predicted results, should be modified. The duration of each burn has been estimated by CLASIX to be in the order of seconds; this implies that heat transfer between the combustion region and its surrounding might not be negligible. A containment structure heat sink model will be formulated and added to CLASIX to account for the heat dissipated to the containment environment; heat transport by means of convection and radiation will be explicitly modeled. Any latent heat released from the condensation process will also be included in the energy balance calculation of the containment. Using the multi-layer conduction model, the aforementioned heat transfer correlations will be incorporated in CLASIX to model structural heat sinks.

In the existing CLASIX calculations, air recirculation fan flow characteristics and fan cooler performance are not modeled. The incorporation of the air recirculation fan/head flow curve into CLASIX will provide better flow descriptions between compartments; as a result, inter-compartment flow rates can be characterized by compartment differential pressure. The option of using the fan coolers which are designed to remove heat from the containment during normal plant operation will also be added to CLASIX.

These improvements are attempts to provide a more accurate description of the temperature and pressure response of the containment in the unlikely event of hydrogen combustion. Said improvements are scheduled to be completed by January 1981.

3. AEP/TVA/DUKE PROGRAMS PLANNED

In a joint effort with EPRI, the AEP/TVA/Duke Task Force has under consideration a research program to investigate various aspects of hydrogen-related issues; including ignitor tests, parametric studies of hydrogen combustion limits, and investigation of principles of hydrogen mixing and turbulence effects.

Four different efforts are scheduled to start in the first quarter of 1981. The determination of the scope and test parameters for these studies is to be decided upon between EPRI and the AEP/TVA/Duke Task Force in January 1981. The current proposals for these programs and their schedules are summarized below:

3.1 Rockwell International

Ignitor development tests will be performed by the contractor in which different ignitor types and designs will be tested. The test facility includes a cylindrical vessel, 5 foot diameter by 6 feet long with a pressure rating of 150 psi. Spark plug, hot surface and combustion wave ignitors will be used to ignite lean mixtures of hydrogen and air under steam or water spray environments. It is the intent of this effort to establish combustion characteristics of various ignitors and to evaluate their effectiveness. All testing is currently scheduled for completion by June 1981.

3.2 AECL Whiteshell

Experiments will be conducted in either an 8-foot diameter sphere or a 5-foot diameter by 19-foot high cylinder.

1. At hydrogen concentrations less than 10%, experiments will be conducted to determine whether size and shape of the vessel affects the extent of reaction. Results will be compared with data collected at Whiteshell in a 2-liter cylindrical vessel.

2. At hydrogen concentrations greater than 10%, the laminar burning velocity as a function of hydrogen concentrations and temperatures will be verified. Ignition of uniform hydrogen/air/steam mixtures will be investigated as a function of pressure, temperature and burn velocities.

3. Turbulence effects in a containment which may be caused by thermal convection currents or by obstacles, such as pipes, grids, etc. will be studied.

4. Flame propagation from one compartment to another at various hydrogen concentrations can also be investigated.

The first meeting to discuss the plan with the testing contractor is scheduled for early February. Experiments are expected to begin by April 1, 1981 and finish by August 1981.

3.3 Acurex Corporation

The contractor will perform studies on mitigation phenomena such as the effects of water spray, fog and Halon on ignition and combustion of hydrogen and air mixtures. A cylindrical vessel, 78" ID, 400 cubic feet will be used in the test. Controlled amounts of hydrogen, air, steam and water spray can be introduced in the test vessel to simulate various postulated conditions. Different types of igniters can also be installed in the test section to be tested. Uniform hydrogen concentration within the test vessel is ensured by the operation of a circulation fan. Provisions can be made available to obtain photographic records of the combustion process.

Contract negotiation is scheduled to begin in January of 1981 and the first test is expected to start in April. The experimental program is due to be complete by July 1981.

3.4 HEDL

Tests will be conducted at the HEDL Containment System Test Facility. These tests will not involve ignition of the test volume. The primary purpose of this study is to investigate hydrogen mixing, stratification and distribution in a large open volume (30,000 ft^3). Parameters which affect the distribution and mixing of hydrogen will be examined. They include: thermal gradients, effects of sprays, steam, natural and forced convection effects. Compartments can also be formed within the large volume to study hydrogen distribution under various conditions.

Details of the experimental program will be discussed in a forthcoming meeting planned for January with investigators from HEDL. The test program is expected to begin on March 1, 1981 and conclude by June 1981.

4. REPORT ON AEP SPECIFIC WORK

4.1 CLASIX Analyses for Cook Plant

The Cook Plant ice condenser containment response to hypothetical hydrogen burn transients has been analyzed utilizing the Westinghouse/Offshore Power Systems' (OPS) CLASIX computer code. The results of the Cook Plant analyses are contained in the attached OPS report entitled "Summary of Analyses of D.C. Cook Containment Response to Hydrogen Transients" (Attachment 2).

The initial (pre-hydrogen generation) containment conditions input to CLASIX were obtained from the Westinghouse LOTIC computer code. The hydrogen generation rate for the S_2D sequence was obtained from the MARCH computer code as were the time dependent mass and energy release rates from the postulated break.

The assumptions utilized in the CLASIX anlayses are consistent with those used in the TVA and Duke studies. Parameters specific to the Cook Plant, such as fan flow rates and flow loss coefficients between compartments, are summarized in Table Nos. 3 and 4 of the OPS report. Unlike the TVA and Duke CLASIX studies, the Cook Plant calculational model included a separate nodal volume representative of the two fan/accumulator rooms and accounted for the presence of containment spray capability in both the lower compartment and the fan/accumulator rooms. The significance of these differences is discussed in Section 4.2 below.

Four cases were examined by CLASIX in which the criteria for ignition and flame propagation were varied. A summary of the results of these cases is contained in Table 5 of the OPS report.

The first case, JVAC1, does not account for containment spray flow in the lower compartment and fan accumulator rooms. This case, which is not typical of the Cook containment, was analyzed to obtain baseline information sufficient to allow comparison with the TVA and Duke studies. The remaining three cases account for spray flow in the lower compartment and the fan/accumulator rooms as well as the upper compartment and are reflective of the Cook systems.

4.2 Evaluation of CLASIX Results

Review of the OPS report indicates that the presence of lower compartment sprays has a significant beneficial effect on the containment response to hydrogen combustion. The most notable effects are the reduction of the peak temperature in the lower compartment by a factor of approximately two (relative to the JVAC1 case) and the temperature reduction between burns. It is also apparent that this additional spray capability effectively reduces the amount of ice melted as a result of a hydrogen burn(s).

Review of the time dependent temperature transients in the fan/accumulator rooms and the dead-ended volume for cases JVAC2, JVAC3, and JVAC4 suggests that hydrogen ignition inside, or flame propagation into, these areas is highly unlikely.

In only one instance (JVAC3) does the peak temperature in either of those areas exceed 270^{o}F. The JVAC3 case predicts two temperature spikes in the fan/accumulator rooms. These spikes, shown in Figure 26 of the

OPS report, appear to be of very short duration. The relative non-susceptibility of these areas to the adverse environment associated with hydrogen burning is a very important factor to be considered when evaluating equipment survivability. It was precisely for that reason; to determine the environmental conditions in these areas during hydrogen transients, that the Cook Plant calculational model was modified to include a separate fan/accumulator room nodal volume.

An independent evaluation of the CLASIX results is being performed by AEP. The intent of this effort is to provide a review of the assumptions and the analytical method used in CLASIX. Very important information on containment response resulting from hydrogen combustion has been provided by the computer code; however, in order to fully utilize the data, verification will be required. For instance, CLASIX results indicate that there are a series of burns occurring whenever there is combustion inside a compartment, the multiplicity of combustion and the duration time of each burn would have to be evaluated to ensure that they reflect the actual phenomenon and not the numerical or analytical scheme that is chosen in the code. Propagation to adjacent chambers is presently artificially imposed in the code and thus conditions for flame propagation are not explicitly modeled. The AEP review will attempt to identify some of the limitations of the code whereby CLASIX results can be more accurately interpreted and applied.

4.3 CLASIX Results Vs. Containment Ultimate Strength

Preliminary calculation of the containment ultimate strength shows that under the static load assumption, the limit of the containment shell is 69.7 psia and the equipment hatch is estimated to be 40.8 psia. It is prudent to recall that these limits were computed based on certain conservative assumptions; for instance, the selection of material strength.

CLASIX results tabulated in Table 5, Attachment 2, with complete combustion, predicted that 10 v/o hydrogen mixture the containment will experience a peak pressure of 27.5 psia whereas an 8% hydrogen combustion will yield a peak pressure of 25.0 psia. According to CLASIX, both of these maxima will occur in the ice condenser with the upper compartment experiencing a pressure peak of a similar magnitude. About a 10% reduction in maximum pressure in the lower compartment is reported.

The highest pressure calculated by CLASIX is 33.5 psia occurring in the upper compartment under a 10% combustion with flame propagation criterion to adjacent compartment at 8 v/o. A 31.0 psia peak is predicted inside the ice condenser and 26.5 psia peak in the lower compartment.

Based on CLASIX and ultimate containment strength calculations, the maximum peak containment pressure predicted in various selected hydrogen combustion scenarios is consistently below the ultimate static pressure capacity of the containment as calculated by Structural Mechanics Associates. Further studies are being conducted to assess with improved certainty the relationship between hydrogen combustion containment response and its ultimate strength capability.

5. COOK CONTAINMENT ULTIMATE CAPABILITY

5.1 Overview of Cook Containment Structural Design

Before discussing the AEP comments on the NRC consultant's report on the ultimate pressure capability of the Cook containment and AEP's own calculation, a brief summary is given in this Section of the structure design features related to ultimate containment strength.

The Donald C. Cook Nuclear Plant containment building is a steel lined reinforced concrete cylindrical structure with a hemispherical dome and a flat base mat. The normal concrete strength is 3500 psi at 28 days.

The reinforced concrete base mat has an average thickness of 10'-0". The top of the foundation mat is lined with ¼" thick steel plate and the plate is covered with a two foot thick reinforced concrete slab.

The cylinder has a diameter of 115'-0" inside to inside of the 3/8" thick liner. The reinforced concrete walls are 4'-6" thick at the base mat tapering to 3'-6" at seven feet above the base and continuing at 3'-6" to the spring line which is 113 feet above the base mat.

The reinforced concrete dome has an inside radius equivalent to that of the cylinder. The concrete thickness of the dome varies gradually from 3'-6" at the spring line to 2'-6" at the peak.

The base mat is made in two layers which are tied together by means of #11 reinforcing bars spaced at 6'-0" on center.

The reinforcing in the cylinder walls is generally two rows of #18 at 12" on center circumferentially and four rows of #18 at 9" on center to 14'-0" above the base; four layers of #18 at 9" on center between 14'-0" and 21'-0" above the base, two layers of #18 at 18" on center between 12'-0" and the spring line. Additionally, there are four layers of diagonally oriented #18 at 36" on center reinforcing. There is also shear reinforcing in zones between the base slab elevation and approximately 15' above the base and again, 35' to 56' above the base slab. Shear reinforcing is again provided at the spring line.

The dome hoop reinforcing consists of two layers of #18 at 12" on center to 35° above the spring line, and then two layers of #18 at 18" on center from 35° to the peak. Meridional reinforcing consists of two layers of #18 at 18" plus one layer of #11 at 18" to 50° above the spring line. There are two layers of #18 at 18" from 50° to the peak. Additionally, there are four layers of diagonally oriented #18 at 36" on center placed to 20° above the spring line and shear reinforcing to 10' above the spring line.

The re-bar is ASTM-615 Grade 40. The liner is ASTM A442 Grade 60. The personnel hatch is a 10'-0" diagonal barrel anchored into the containment cylinder wall.

The equipment hatch is a 20'-0" diagonal barrel anchored into the containment cylinder wall and having a 10'-0" diagonal personnel airlock insert.

The equipment hatch barrel and the personnel hatch barrel are each anchored to the containment by means of two 3/4" thick collars.

The materials of the personnel and equipment hatches are ASTM A516 Grade 70 and ASTM A193 Grade B7 for the bolting. The material of the anchored barrel is ASTM A300 firebox A516 Grade 70.

5.2 Comments on Dr. Harstead's Report

Item 1 of Attachment 3 to this report contains comments by Dr. J. D. Stevenson of Structural Mechanics Associates (SMA) on Dr. Harstead's report.

5.3 AEP Specific Calculation Results

Item 2 of Attachment 3 contains a summary of AEP containment analyses presently underway.

5.4 Dr. Stevenson's Presentation at December 18, 1980 Meeting

Item 3 of Attachment 3 contains a summary, including slides, of the presentation given by Dr. Stevenson at the AEP-NRC meeting held in Bethesda, Maryland on December 18, 1980.

6. DISTRIBUTED IGNITION SYSTEM DESIGN STUDY

As stated in our AEP:NRC:00476 submittal, AEP is proceeding with a design study for installation of a Distributed Ignition System (DIS) in the Cook Plant containments. To as great an extent as possible, the Cook DIS design parallels the Sequoyah and McGuire designs. It is our intention to install the in-containment portion of the DIS during the 1981 refueling outages, if required.

The DIS consists of sixty-eight igniter assemblies located in distinct areas of the containment building. Two igniter assemblies, one from each of Trains 'A' and 'B', shall be located in each of thirty-four designated areas. Each igniter assembly consists of a thermal resistance heating element (glow plug), General Motors AC Plug Type 7G, and a Dongan Electric Control Power Trnasformer (Model 52-20-435). The glow plug and transformer are mounted in a sealed box which employs heat shields to minimize the temperature rise inside the box and a 'drip shield' to reduce direct water impingement on the thermal element.

6.1 DIS Design Criteria

The intent of a DIS is to reliably initiate combustion of relatively lean hydrogen mixtures. The following criteria were used in the selection of the recommended igniter locations contained above.

1. All proposed igniter locations are in areas well mixed by the hydrogen skimmer/air recirculation fan systems.

2. In general, igniters should be mounted near the ceiling within a given volume.

3. All igniters with the exception of those in the vicinity of the PRT are to be located above maximum flood-up level.

4. All DIS cables installed inside containment must be protected from or qualified to withstand the environment associated with a small LOCA and hydrogen combustion.

5. All DIS cables outside containment must be protected from or qualified to withstand the environment associated with a worst case high energy line break.

6. Trains 'A' and 'B' of the DIS are to be electrically isolated from each other.

7. DIS components are to be supported to Seismic Category I standards.

6.2 Igniter Locations

The preliminary DIS for the Cook Plant has igniters in the following locations; equally distributed between Trains 'A' and 'B':

Area	No. of Igniters	Approximate Location
Lower Volume	12	Uniformly spaced around the biological shield wall.
Lower Volume	2	In the vicinity of the PRT rupture disk.
Fan Rooms (2)	8	Four igniters (in each F/A room) equally separated within the volume.
SG & PR Enclosures	10	Two igniters inside each of the five enclosures.
Upper Volume	12	Located in the upper dome area; uniformly spaced.
Upper Volume	10	Two igniters located on the outside of the SG & PZR enclosures.
Ice Condenser	14	Two igniters each in the upper plenum area of Bay Nos. 3, 6, 9, 12, 15, 18, and 21; mounted on the containment wall.

7. ELECTRIC HYDROGEN RECOMBINERS

Westinghouse, at the request of AEP, has investigated the potential for increasing electric hydrogen recombiner (EHR) capacity to the extent necessary to mitigate degraded core/hydrogen events. Westinghouse has determined that an inordinate number of (the equivalent of several hundred) EHRs would be required to provide sufficient hydrogen recombination capacity so as to mitigate an event in which the hydrogen from 75 w/o zirconium oxidation is released to the containment (linearly) over an eight hour time period.

It is important to realize that the above calculation does not account in any way for the ignition capabilities of the presently installed EHR; which are, in effect, large-sized glow plugs. It would be reasonable to expect the EHRs to act as ignition sources if and when the hydrogen concentration exceeded the 'recombination' level. CLASIX analyses might be performed to evaluate the effectiveness of deliberate ignition, by the EHRs, only in the upper volume.

ATTACHMENT 1 TO AEP:NRC:00500

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November 26, 1980

Dr. Wang Lau
Tennessee Valley Authority
400 Commerce Avenue
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Reference: Contract TV-55205A - "System Feasibility Analysis of Using Halon 1301 in an Ice Condenser Containment"

Dear Dr. Lau:

This summary letter report is being submitted per the contract requirement to provide an interim report in the course of the program. Up to the present time a visit was made to the Watts Bar plant by five technical persons associated with the study, numerous telephone discussions have been held with TVA, AEPSC and Duke Power personnel, and a group from Duke Power visited Atlantic Research for a review of the Halon system and our opinion about alternative approaches.

We have had requests to accelerate progress if possible, which we are trying to accommodate but, as explained, much of the work follows a sequential path and certain tasks cannot be completed until other prior work has been performed.

In broad summary, it can be reported that a Halon 1301 system is certain to be able to provide full safety against any possible hydrogen hazard following a LOCA in an ice condenser containment. The matter that remains does not concern safety acceptability, but rather concerns the question of how much corrosion might certain materials be subjected to, and will the primary and secondary systems meet specifications and be recoverable after a LOCA if they were exposed to Halon decomposition products.

Briefly, the corrosion problem is as follows: Halon itself is stable and inert toward materials. However, if needed following a LOCA, Halon gas could dissolve to a small extent in the emergency cooling water (its solubility is 150 ppm by weight in water at 77°F and 0.5 atm). Radiolytic decomposition can then occur, the result of which could be the formation of bromides (and fluorides) in low concentration (about 400 ppm Br^-) in the water. Therefore, the question being addressed is what effect such a solution will have on reactor materials, particularly stainless steels.

If unfavorable answers emerge from the materials study, then the options are the following:

- Plan to install a Halon 1301 system to provide safety during the interim while an alternative system is being developed, using the rationale that the likelihood of having to employ Halon is extremely small.

- Study the effect of exposure of stainless steels to hydrogen. Since hydrogen has an embrittling effect on steels, it may be that hydrogen alone is deleterious enough that the reactor system could not be recovered anyway, even if Halon were not used.

- Investigate means of eliminating or reducing the effect of bromides. The general approach would be to find additives that defeat the Halon radiolytic decomposition mechanism in solution. Several candidate approaches have been considered:

  - Determine if Halon decomposes in solution in the presence of hydrogen as rapidly as in its absence. Hydrogen may compete with Halon for solvated electrons, the species responsible for initiating Halon degradation.

  - Add an additive to the water that will precipitate bromide in inert form. (A search for candidate additives will be made.)

  - Add an additive to the water that will produce hydroxyl radicals in solution. These radicals are thought to react with bromide ions to reverse the decomposition reaction. Alcohols may be good candidates.

  - Determine whether decomposition of Halon will occur to the same extent over a range of pH values.

  - Generally attempt to find additives that may be effective in reversing Halon degradation.

Substantial progress has been made on three tasks of the program and each of these is reviewed below.

System Design

If no credit is allowed for steam inerting, it will require 191,600 lb mass of Halon 1301 to inert the total containment, including upper and lower compartments and ice condenser plenums (1.2 x 10^6 ft^3). The Halon requirement is derived from the flammability data obtained in the previous ARC study and the assumption of 75% zirconium cladding reaction releasing 1450 lb mass of hydrogen. Assuming negligible losses and specifying a 20% excess, the total Halon requirement will be 230,000 lb. Neglecting losses is justified because the containment leak rate is essentially zero, and the loss to cooling water is 4540 lb via Halon decomposition and 880 lb through dissolution. The containment partial pressures will be (70°F basis):

Air	1.000 atm	=	14.70 psia	
H_2	0.234 atm	=	3.44 psia	
Halon	0.493 atm	=	7.25 psia	
	1.727 atm	=	25.33 psia	= 10.7 psig

A storage and piping configuration has been designed which is based on the guiding principle that the system must function properly even if two independent malfunctions occur simultaneously. The Halon would be stored in five 316 stainless steel tanks, four of which would contain the required 230,000 lb and an identical fifth back-up tank would contain 57,500 lb. The storage tanks are sized to contain the Halon at temperatures in excess of 130°F where the liquid density is 77.6 lb/ft^3. Each tank would have an equivalent spherical diameter of 12 feet with a wall thickness of three inches. This provides a working pressure of 600 psig for the system, conforming to Section VIII of the ASME Unified Pressure Vessel Code.

Each tank would have an associated tank of nitrogen gas connected to it which would maintain a delivery pressure of 600 psig if the Halon had to be discharged. The five Halon tanks are valved independently to two manifolds of four-inch SS Schedule 40 pipe. (The manifold piping diameter may have to be larger if a total run of much more than 300 - 400 feet is required.) Two penetrations of the containment will be required for the four-inch pipes. The piping will conform to ANSI B-31.10 classification. Inside the containment, the piping branches to the upper and lower compartments, each accumulator compartment and the instrument room to maximize coverage of isolated compartments.

An array of spray nozzles comes off each manifold pipe inside the containment. The requirement is to deliver 230,000 lb Halon in 1000 seconds or 1330 gpm at 130°F. One arrangement to accomplish this is to use 20 full cone nozzles of 15/32" orifice on each manifold, one of which is sufficient. This feature of the system design is being left open at present. The exact nozzle system configuration would have to be determined by actual inspection of the containment and computation of the requirement in each area.

The final report will present the system design in much greater detail. Other aspects of the design are also being worked on, including instrumental analysis requirements.

Halon Decomposition and Bromide Ion Concentration

Since the net decomposition of Halon ceases at equilibrium Br^- concentration of 5.2×10^{-3} moles/l, the total quantity of Halon decomposed depends (at equilibrium) upon the total quantity of water in the containment (6.46×10^{-3} lbs Halon decomposed per gallon of water). For the maximum amount (702,950 gallons, re: TVA letter of Oct. 31, 1980), the quantity of Halon decomposed is 4540 lb, independent of the fission product release to the water. An additional 880 lb will remain dissolved in the water.

The rate of Halon decomposition also depends upon the quantity of water in the containment. The time-dependent quantity of Halon decomposed for several potential values of the containment water inventory has been computed and will be given in the final report.

Decomposition of Halon yields Br^- in solution which acts as a scavenger for the OH radical and tends to suppress further Halon decomposition. Equilibrium is attained at a Br^- concentration of 5.2×10^{-3} moles/liter also.

Water Chemistry and pH

Br^- is presumably formed as HBr and decomposition of Halon also produces HF at concentrations 3 times that of HBr. HF ionization, however, is suppressed by the H^+ from HBr ionization, and at equilibrium most of the HF is undissociated.

The pH changes depend upon the initial chemical composition and pH of the water in the containment system. Although the system water will likely be slightly alkaline (pH >7) and perhaps buffered (presence of sodium borate, for example, to prevent criticality), calculations of the pH changes have been made conservatively assuming pure water (pH of 7.0) in the containment system initially. Assuming complete ionization of HBr and an ionization constant of 3.53×10^{-4} for HF, the resulting pH at equilibrium would be ~2.2, determined principally by the HBr, with HF ionization largely suppressed.

Ignition of H_2-Air-Halon Mixtures by Shock

Hydrogen-air mixtures can be inerted against combustion by addition of Halon 1301, and a large body of data on the flammability limits of such mixtures has been developed previously using sparks and squibs as ignition sources. The question has arisen as to whether a shock wave could ignite mixtures that are so inerted. In order to answer this question, a literature search is being conducted to determine if the matter has ever been studied, and an analysis of the hydrogen combustion chemistry is being performed. To date, the literature search has not turned up any direct information. The analytical work, although still incomplete, is indicating that once inerted against sparks or pyrotechnic ignition, a mixture cannot be shock initiated. This is the type of question that lends itself to analytical study wherein definite conclusions are possible because hydrogen-oxygen combustion is the best understood of all fuel systems.

In addition, we are examining the question of what structural effects would be expected from explosion of uninerted pockets of H_2-air of various dimensions.

Very truly yours,

ATLANTIC RESEARCH CORPORATION

Edward T. McHale

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ATTACHMENT 2 TO AEP:NRC:00500