Attachment to
HGN-112
Revision 0

GENERIC HYDROGEN CONTROL INFORMATION

FOR

BWR/6 MARK III CONTAINMENTS

Prepared for

The Hydrogen Control Owners Group

by

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Abstract

On October 2, 1980, the Nuclear Regulatory Commission (NRC) published in the Federal Register a notice of proposed rulemaking to dictate new hydrogen control requirements for degraded core accidents.

In December 1981, the NRC published for comment a proposed revision to 10CFR50.44 as an interim rule. The rule required all nuclear power plants applying for an operating license to implement systems for mitigating the consequences of an accident releasing large quantities of hydrogen (i.e., interaction of up to 75% of the zircaloy fuel cladding). The final version of this rule was published in February 1985.

In response to the proposed rule published in October 1980, utilities building Mark III containment facilities organized the Hydrogen Control Owners Group (HCOG) in May 1981 to address the relevant generic hydrogen control issues. The HCOG ultimately developed a comprehensive program of research, testing and analysis to characterize diffusive hydrogen combustion phenomenon and assure the survivability of equipment required to function during and after a hydrogen generation event.

The following report summarizes the bases for implementing a distributed hydrogen ignition system and associated tasks necessary to demonstrate compliance with the degraded core hydrogen control requirements.

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I. Introduction

In December, 1981, the Nuclear Regulatory Commission issued a proposed rule which required all plants applying for an operating license to include enhanced hydrogen control measures in the design of their facilities. The proposed rule indicated that these enhanced hydrogen control measures should be capable of mitigating the consequences of an accident which releases large quantities of hydrogen.

In response to the proposed rule and in order to address the generic issues in a unified and cost effective manner, the Mark III utilities formed the Hydrogen Control Owners Group (HCOG) in May, 1981. The HCOG was formed to identify an acceptable hydrogen control system, and to develop generic design, installation and operating criteria for the system. In addition, HCOG has defined a test and analysis program to assure survivability of safety related systems that may be exposed to the postulated hydrogen burns, and to evaluate the integrity of the containment structure in light of pressure excursions which may result from hydrogen burns.

The December, 1981 proposed rule defined the NRC's position that enhanced hydrogen control systems be provided that would be capable of mitigating the consequences of a total hydrogen release equivalent to that generated from a metal-water reaction involving 75 percent of the zircaloy cladding in the active fuel region. After a significant level of industry comment and discussion, a final hydrogen control rule for Mark III and ice condenser containment plants was issued as a revision to 10 CFR 50.44 in February, 1985. The final rule required: a) implementation of systems capable of controlling hydrogen equivalent to oxidizing 75% of the active fuel cladding; b) analyses to demonstrate that the primary containment's integrity would be maintained; and c) systems and components required to mitigate the consequences of a recoverable accident that leads to hydrogen generation must be capable of withstanding the effects of the accident.

The analytical tasks identified by the HCOG included the modification of computer programs to allow for both the prediction of hydrogen generation histories in a degraded BWR/6 core and the modeling of deflagration burns in the drywell or containment. Additional analyses were required to calculate the ultimate containment capacity, define the most probable accident scenario, and to quantify the thermal environment that results from hydrogen combustion and its effect on equipment required to survive the event.

In December, 1984, the HCOG submitted a Hydrogen Control Program Plan to the NRC for review and approval. This Program Plan defined HCOG's total test and analysis program for responding to the degraded core hydrogen control requirements. The Program Plan is used to identify and coordinate the various analytical, research and test oriented activities that are part of the program. This Program Plan is divided into fourteen primary tasks, with each task being comprised of multiple subtasks. These tasks and their related subtasks were reviewed in detail with the NRC in meetings held between January and March, 1985. As the program has evolved, additional revisions to this Program Plan have been submitted to and discussed with the NRC.

The following report delineates the results of the HCOG's Hydrogen Control Program. Due to the significant volume of data that has been issued to date on the results of the program, the report provides only brief discussions of the numerous submittals, but does reflect the pertinent information contained in each. To reiterate, this topical report is a summary document of generic report submittals that have been made to the NRC by the HCOG. The contents of this report and the submittals referenced within will be referenced by the HCOG member utilities in their final plant specific hydrogen control reports.

Since the Program Plan provides a comprehensive presentation of all aspects of the Hydrogen Control Program, its task/subtask format is utilized in this report to ensure a similarly comprehensive discussion of the results of this program.

This report does not supercede the Program Plan, but complements it as a closure document for the Hydrogen Control Program. The Program Plan will continue to be maintained to provide guidance to HCOG and NRC management in regards to program status and resource needs.

II. Task Synopsis

Task 1: ESTABLISH MOST PROBABLE HYDROGEN GENERATION EVENT

Subtask 1.2: Select Probabilistic or Deterministic Scenario

Purpose: In order to establish plant conditions associated with meeting the various requirements of the regulations (e.g., 75% metal-water reaction and recoverable core) it was necessary to determine if the scenario was best defined using deterministic or probabilistic methods.

Reference:

- Letter from HCOG to NRC, "Report on Hydrogen Control Accident Scenarios, Hydrogen Generation Rates, and Equipment Requirements," HGN-006-NP, dated September 9, 1982.

  This letter provides a discussion of the need to utilize both deterministic and probabilistic methods in defining an HGE that will result in significant hydrogen generation without substantial (i.e., non-recoverable) core melt.

Subtask 1.4: Most Probable Accident Scenario

Purpose: This subtask involved identifying the most probable sequence of events that would lead to a degraded core accident with resulting hydrogen generation matching proposed regulatory requirements.

Reference:

- Letter from HCOG to the NRC, "Report on Hydrogen Control Accident Scenarios, Hydrogen Generation Rates, and Equipment Requirements," HGN-006-NP, dated September 9, 1982.

  This report estimated the combined probability for all consolidated events which could lead to core melt. The most probable HGE sequence was modeled as a turbine trip with bypass and loss of feedwater. Failure of all other makeup systems resulted in a drop of RPV level due to inventory loss through the bypass pressure control system until vessel isolation occurs. Reactor pressure is then controlled by SRV action until the RPV is depressurized by the operator per emergency procedures. Event recovery occurs when ECCS injection is recovered and water injection established. Variations in the timing of operator actions to recover core makeup systems were included in the study. The study also addressed anticipated transient without scram events

(ATWS) as possible HGEs. The report concluded that a 75% MWR could not be achieved using a probabilistic scenario.

Subtask 1.5: Submit Report to NRC

Purpose: This subtask was established to document, to the NRC, the bases for the accident scenario that was determined to be the most probable HGE in Subtask 1.4.

Reference:

- See the report referenced under Subtask 1.4.

Although the most probable HGE represents a departure from the preliminary scenarios selected by HCOG, the preliminary scenarios were used as a basis for subsequent work for the following reasons:

1) Isolation with turbine bypass is not radically different from the SORV case;

2) The SORV results in a slightly faster inventory loss and earlier hydrogen production;

3) The DWB case is important in considering a possible hydrogen release in the drywell.

Subtask 1.6: Evaluate ATWS and SBO Accident Scenarios

Purpose: This subtask was established to document the bases for excluding Anticipated Transients Without Scram (ATWS) and Station Blackout (SBO) events from those events that could act as HGE initiators.

Reference:

- Letter from HCOG to NRC, "Report on Hydrogen Control Accident Sequences, Hydrogen Generation Rates, and Equipment Requirements," HGN-006-NP, dated September 9, 1982.

Section 3.4.3 of this report states that ATWS was considered to be an inappropriate choice for HGE. The expected frequency of ATWS and the probability of an ATWS event leading to core melt and containment failure from hydrogen combustion are very low. Furthermore an ATWS event can lead to accident conditions which are pertinent to hydrogen control considerations only if the accident sequence includes improper function of all the major water makeup systems, resulting in core damage prior to loss of containment integrity. The ATWS threat to containment integrity is related to inability to remove thermal energy and is not due to hydrogen generation. The combined probability of failure to scram plus improper function of all water makeup systems is even lower than the probability of failure to scram only. Also, if failure of the standby liquid control system (SLC) is postulated concurrent with ATWS, then the properly controlled emergency core cooling systems (ECCS) will be adequate to maintain core cooling but the capacity of the residual heat removal system (RHR) for removing heat from containment will not be adequate. In this case, the containment will lose its integrity (by overpressurization) prior to core damage, regardless of whether or not there is a hydrogen control system installed in the plant.

- Letter from HCOG to NRC, "Evaluation of SBO and ATWS Contributions to Hydrogen Generation Events", HGN-055-NP, dated September 27, 1985.

  This letter discussed results from Reactor Safety Study Methods Application Program (RSSMAP) analyses which were evaluated by HCOG. The RSSMAP analyses indicated that ATWS and SBO events which lead to containment failure due to hydrogen combustion in a recoverable degraded core accident are very low probability events.

Subtask 1.7: Resolve Questions on ATWS and SBO Evaluation

Purpose: This subtask was developed to track resolution of NRC concerns on the issue of ATWS and SBO events as HGE initiators.

Reference:

- Letter from NRC to HCOG, dated February 21, 1986.

  This letter provided the NRC's assessment of HCOG's SBO and ATWS evaluation (submitted under Subtask 1.6). The NRC agreed that ATWS events are not probable HGE initiators. However, they did not consider the RSSMAP study to be an adequate tool in assessing the probability of SBO initiated events leading to hydrogen combustion containment failure. The referenced letter requested response to several questions concerning the extent to which SBO events have been considered and encompassed during HCOG analysis and testing.

- Letter from HCOG to NRC, "Response to NRC Concerns Regarding Potential Impact of SBO Events on Operation and Performance of the Hydrogen Ignition Systems," HGN-114-NP, dated January 8, 1987.

Attachment one to the referenced letter contains responses to three specific NRC questions from the February 21, 1986 request for additional information (RAI) and supports HCOG's position that although SBO may be a dominant contributor to severe accidents, it should not be dominant for degraded core Hydrogen Generation Events (HGEs).

In the referenced RAI, the NRC staff noted that since NUREG-0979 suggests that SBO is a dominant contributor to probability of core damage, and therefore may be significant with respect to a hydrogen generation event, HCOG should address the potential impact of SBO events on the operation and performance of the hydrogen ignition system. HCOG's response to this recommendation delineated the reasons why the NUREG-0979 methodology and assumption are not consistent with those required for HGE analysis. Therefore, complete loss of AC power (Station Blackout) should not be used as an initiator for a recoverable core hydrogen generation event.

The referenced RAI asked HCOG to identify the extent to which SBO events are already encompassed implicitly within the hydrogen release histories that have been developed for use in the 1/4 scale test facility. HCOG explained that the hydrogen release histories used for 1/4 scale testing and analysis were calculated using the BWR Core Heatup Code (BWRCHUC) and the hydrogen release histories for an SBO event are enveloped by the BWRCHUC analysis results.

HGN-114-NP identified the provisions which are already in place to assure that containment and equipment failure due to deflagrations cannot occur if AC power were automatically restored to previously actuated igniters, under circumstances where an SBO occurs during a hydrogen generation event. These provisions are accomplished via implementation of contingent actions from Revision 2 to the HCOG Combustible Gas Control Emergency Procedure Guideline.

The NRC's February 21, 1986 letter also requested HCOG to explain how igniter actuation in the 1/4 scale test program would be modified, if necessary, to provide better simulation of potential SBO events. HCOG stated that changes to the 1/4 scale test program were not warranted because (as discussed previously) SBO considerations do not need to be specifically addressed in HCOG's program responding to the degraded core hydrogen control rule.

Task 2: SELECT MITIGATION SYSTEM

Subtask 2.1: Evaluate Industry Experience

Purpose: Prior to choosing a hydrogen control system, a review was conducted of the nuclear industry's experience with supplementary hydrogen control systems.

Reference:

- Letter from Mississippi Power and Light Company to NRC, "Description of Hydrogen Control Measures", AECM-81/139, dated April 9, 1981.

Section 2.1 of this submittal provides a listing of those systems that could potentially be used to control hydrogen following a degraded core accident. This list was subsequently utilized by HCOG in its review of potential hydrogen control systems.

HCOG reviewed the hydrogen control programs of three commerical nuclear power plants with a Westinghouse NSSS and an ice condenser type of containment, i.e., Tennessee Valley Authority's Sequoyah Nuclear Power Plant, American Electric Power Company's D.C. Cook Nuclear Power Plant and Duke Power Company's McGuire Nuclear Power Plant. These plants had already evaluated additional hydrogen mitigation systems and had selected distributed ignition systems.

Subtask 2.2: Develop Selection Criteria

Purpose: A set of criteria were established to assess the adequacy of the various hydrogen control systems identified in Subtask 2.1.

Reference:

- Letter from Mississippi Power and Light Company to NRC, "Description of Hydrogen Control Measures," AECM-81/139, dated April 9, 1981.

Section 2.2 of this letter delineates the design, operational and cost criteria used in assessing the adequacy of proposed hydrogen control systems. These criteria, although developed for the Grand Gulf Nuclear Station, were subsequently used by the other HCOG utilities.

Subtask 2.3: Perform Trade-Off Studies

Purpose: This subtask was established to perform an evaluation of the proposed hydrogen control systems identified in

Subtask 2.1 against the criteria developed per Subtask 2.2. The results of this evaluation would identify the most feasible hydrogen control system.

Reference:

- Letter from Mississippi Power and Light Company to NRC, "Description of Hydrogen Control Measures," AECM-81/139, dated April 9, 1981.

  Sections 2.1 and 2.3 of this submittal detailed the results of this evaluation. Again, as above, the original trade-off evaluation was performed for the GGNS facility, but since it was based on features common to all of the Mark III plants, its results were applicable to the other HCOG facilities.

Subtask 2.4: Select Mitigation System

Purpose: This subtask was established to choose a hydrogen control system based on the results of the evaluation performed for Subtask 2.3.

Reference:

- Letter from Mississippi Power and Light Company to NRC, "Description of Hydrogen Control Measures," AECM-81/139, dated April 9, 1981.

  Section 2.3.5 of this submittal indicates that the distributed hydrogen ignition system was chosen since it was the only proposed system that met all the criteria developed in Subtask 2.2.

Subtask 2.5: Prepare Mark III Unique White Paper on HIS

Purpose: HCOG considered the need to prepare a report summarizing the selection process which led to the decision to use a distributed hydrogen ignition system in Mark III facilities.

Reference:

- IDCOR Technical Report 13.2-3, "Evaluation of Means to Vent, Suppress or Control Hydrogen Burning in Reactor Containments," dated February, 1984.

  In lieu of developing an HCOG-unique report which presented information redundant with the referenced IDCOR report, HCOG chose to work with IDCOR in developing the referenced document. HCOG reviewed IDCOR's draft report and provided comments to IDCOR so that the report provided a complete summary of the advantages and disadvantages of the various options for hydrogen control systems.

TASK 3 - DESIGN HYDROGEN IGNITION SYSTEM

Subtask 3.3: Select Igniter Device

Purpose: This subtask was established to select an igniter capable of meeting the requirements identified in Task 3.2.

- Letter from Mississippi Power and Light to NRC, "Description of Hydrogen Control Measures," AECM-81/139.

This letter documented the selection of the GMAC Model 7G glow plug as the igniter device selected by MP&L for the Grand Gulf Nuclear Station hydrogen ignition system. After review of industry experience and evaluation of candidate igniters against regulatory requirements and postulated environments, HCOG chose to use the igniter device selected by MP&L.

Subtask 3.6: Specify Initiation and Operational Logic

Purpose: This subtask was created to establish system initiation and operation logic for the hydrogen ignition system.

Reference:

- Letter from HCOG to NRC, "Justification for Manual Initiation of Mark III Hydrogen Ignition Systems," HGN-073-NP, dated March 5, 1986.

Early in the development of the hydrogen control program, HCOG determined that manual initiation of the hydrogen ignition system was acceptable. The referenced submittal documented HCOG's position on the acceptability of manual initiation of the hydrogen ignition system and described operator response to hydrogen generation events. HCOG concluded that manual HIS actuation is acceptable based upon the time available during HGEs for event recognition and operator action prior to reaching a potentially threatening plant condition, simplicity in manually actuating the HIS and passivity of the igniter devices for non-HGEs.

Subtask 3.7: Location, Redundancy and Separation Criteria

Purpose: This subtask was established to develop generic criteria for the igniter systems related to location, redundancy and separation

Reference:

- Letter from Mississippi Power and Light to NRC, "Hydrogen Control," AECM-81/336 dated August 31, 1981.

This letter submitted MP&L's hydrogen control report to the NRC. Location, redundancy and separation criteria for igniters described in this document were used as guidance by HCOG in the development of design criteria for the HIS.

Subtask 3.12: Develop Technical Specifications

Purpose: This subtask was established to review plant specific Technical Specifications related to HIS Systems based upon data obtained in the 1/4 scale testing program. This review was completed to determine if program results support a revision to the existing plant specific technical specification requirements. Subsequent proposed changes would be applicable to all member plants.

Reference:

- Letter from HCOG to NRC, "Mark III Hydrogen Ignition System Technical Specifications," HGN-070-NP, dated April 16, 1986.

HCOG reviewed the data from scoping tests completed in the 1/4 scale test program and identified sufficient evidence to justify less restrictive technical specifications than those currently governing the operation of hydrogen ignition systems. This submittal provided a proposed standardized technical specification including surveillance requirements and detailed justification for each section.

TASK 4: CONTAINMENT ULTIMATE CAPACITY ANALYSIS

Subtask 4.1: Criteria, Ultimate Capacity Analysis

Purpose: This subtask established criteria for defining the ultimate capacity of the containment structure.

Reference: Letter from Mississippi Power and Light to NRC, "Hydrogen Control," AECM-81/336 dated August 31, 1981.

- This submittal described the Hydrogen Control Program for Grand Gulf Nuclear Station. The definition of ultimate capacity used by GGNS in this document was used by other HCOG member utilities as a model for completing the plant specific ultimate capacity analyses.

HCOG defined the ultimate capacity as the pressure beyond which the containment fails. Containment failure was defined to occur when the most limiting containment structural section reached a general state of yield.

Subtask 4.3: Burn Static or Dynamic

Purpose: This subtask was established to determine whether pressure loadings produced by deflagrations are static or dynamic.

Reference: Letter from Mississippi Power and Light to NRC "Hydrogen Control" AECM-81/336, dated August 31, 1986.

- This submittal described the Hydrogen Control Program for Grand Gulf Nuclear Station. This report provided justification for static analysis since the pressure loading from deflagrations is relatively slow considering dynamic response analysis. HCOG elected to use the GGNS justification as the basis for treating deflagration pressure loadings as static loadings.

Subtask 4.7: Document Exclusion of Local Detonation

Purpose: This subtask required the HCOG utilities to document to the NRC that local detonations were not sufficiently probable to warrant consideration. This included a discussion of Mark III containment features which preclude the accumulation of hydrogen concentrations to detonable levels.

Reference:

- Letter HCOG to NRC, "Responses to NRC Requests for Additional Information," HGN-011-NP, dated May 11, 1983.

This submittal documented HCOG's response to an NRC request for additional information (RAI) dated February 3, 1983. Item 12 from the referenced RAI requested that HCOG provide an analysis of the concommitant effects of the largest credible localized detonation which could occur in the Mark III containment and that it demonstrate that the effects of such an event could be safely accomodated by structures and essential equipment. HCOG responded that a generic or plant specific analysis of postulated local detonations was not needed. Based upon an extensive literature search conducted by Mississippi Power and Light Company, HCOG concluded that a transition to detonation cannot occur in the relatively open volumes which exist in the Mark III containment.

TASK 5: SELECTION OF CONTAINMENT RESPONSE ANALYSIS CODE

Subtask 5.4: Preliminary Verification of CLASIX-3

Purpose: This subtask was established to compare results from modeling pressure and temperature transients with CLASIX-3 and with analytical results from other verified and accepted containment response codes.

Reference:

- Letter from Mississippi Power and Light Company to NRC, Hydrogen Control AECM-81/336 dated August 31, 1981.

  This submittal transmitted the hydrogen control program for Grand Gulf Nuclear Station (GGNS) and was evaluated by HCOG in support of Subtask 5.4. Appendix C from the referenced document, titled "Verification of CLASIX-3", discussed comparisons between the CLASIX code and the TMD and COCO proprietary programs developed by Westinghouse Corporation. These programs were referred to as containment design analysis programs which had been accepted as valid by the NRC. Analytical results from TMD and COCO indicated that CLASIX provided reasonable containment temperature and pressure responses. Some unique portions of CLASIX-3 were verified by hand calculations as well as comparisons with accepted standard computer programs. These comparisons did not produce anomalous results. Hand calculations were performed for the suppression pool dynamics and mass energy balance.

Subtask 5.5: Develop Representative Mark III Model for CLASIX-3

Purpose: This subtask was established to develop a specific model of the Mark III containment for verification of the CLASIX-3 program.

Reference:

- Letter from Mississippi Power and Light to NRC, "Hydrogen Control," AECM-31/336, dated August 31, 1981.

  This submittal to the NRC describes the CLASIX-3 program and the specific model of the Mark III containment developed for verification of the program. Appendix C of this submittal discusses the verification of CLASIX-3 via comparison with other programs and hand calculations as referenced under Subtask 5.4, above.

- Letter from HCOG to NRC, "Submittal of CLASIX-3 Report," HGN-009-P, dated March 18, 1983.

This submittal provided the NRC with the report titled "The CLASIX-3 Computer Program for the Analysis of Reactor Plant Containment Response to Hydrogen Release and Deflagration." As documented in this report, Mississippi Power and Light Company's Grand Gulf Nuclear Station (GGNS) was chosen as being representative of the Mark III containment. GGNS specific features such as structural heat sinks, containment spray and appropriate design interactions between compartments were included in the model as well as specific input values such as containment and suppression pool volume and hydrogen evolution from the core. Hydrogen control systems such as the drywell hydrogen mixing system were also modeled.

Subtask 5.6: Perform Verification and Sensitivity Studies

Purpose: This subtask was established to assure that the CLASIX-3 model was not unduly sensitive to changes in particular input parameters as part of the process of verifying the code.

Reference:

- "CLASIX-3 Computer Program for the Analysis of Reactor Plant Containment Response to Hydrogen Release and Deflagrations," WCAP-10259-P, dated February 1983.

  This topical report documented a sensitivity analysis which was a part of the process of verifying CLASIX-3 in Subtask 5.9. The topical report was prepared by Offshore Power Systems and submitted with HGN-009-P to the NRC on March 18, 1983.

  Documented in this report were several transients which were selected and run with CLASIX-3 to identify potentially anomolous results. These provided variation in hydrogen burn parameters, hydrogen release conditions, concentrations and initial conditions for various compartment atmospheres. HCOG concluded that this report was extensive enough to envelope the sensitive parameters for the Mark III containments and that further studies by individual utilities should not be required. The report indicated that the CLASIX-3 model was a valid approach to the analysis of the temperature and pressure response of a Mark III containment to hydrogen burns initiated by operation of an igniter system and was not unduly sensitive to changes in input parameters.

Subtask 5.7: Submit Topical Report Verifying CLASIX to NRC

Purpose: This subtask was established to formally verify the base code CLASIX and submit it to the NRC in a topical report.

Reference:

- "CLASIX Computer Program for the Analysis of Reactor Plant Containment Response to Hydrogen Release and Deflagrations," OPS-07A35, dated October 1981.

  This topical report was prepared by Offshore Power Systems, Inc. and submitted to the NRC by Westinghouse Corporation in 1981. The report provided the staff with a formal verification of the base code CLASIX, including hand calculations and comparisons with other accepted codes (TMD and COCO codes).

Subtask 5.9: Prepare CLASIX-3 Verification Report

Purpose: This subtask was established to document details of the verification process for the CLASIX-3 code for submittal to the NRC

Reference:

- Letter HCOG to NRC "Submittal of CLASIX-3 Report," HGN-009-P dated March 18, 1983.

  Copies of the "CLASIX-3 Computer Program for the Analysis of Reactor Plant Containment Response to Hydrogen Release and Deflagration", prepared for the BWR Mark III Hydrogen Control Owners Group (HCOG) by Westinghouse in both proprietary and non-proprietary versions were included in this submittal. These documents provided verification details of the CLASIX-3 code to the NRC. Verification reports included numerous hand calculations, comparisons of particular code models with other accepted codes and independent verification of the suppression pool model.

Subtask 5.10: Submit CLASIX-3 Verification Report to NRC

Purpose: This subtask was established to provide NRC with the verification report on CLASIX-3 developed in Subtask 5.9.

Reference:

- See report referenced under Subtask 5.9.

Subtask 5.11: Validation of CLASIX-3 Against NTS Data

Purpose: This subtask was established to conduct comparisons of CLASIX-3 code prediction and NTS data.

Reference:

- During a meeting between HCOG and the NRC held on February 12, 1985, HCOG indicated that CLASIX-3/NTS comparisons were unnecessary. This was due to the fact that NTS is only a single compartment facility whereas the Mark III containment, which CLASIX-3 was developed to model, is a multicompartment facility.

- Letter from NRC to HCOG dated July 8, 1985.

  This letter from the NRC recommended that HCOG complete comparisons of CLASIX-3 code predictions and the NTS data.

  HCOG subsequently performed a limited validation of CLASIX-3 against NTS data and found that CLASIX-3 provided generally conservative predictions of pre-mixed combustion tests.

- Letter from HCOG to NRC, "Comparison of CLASIX-3 Predictions to Nevada Test Site Data," HGN-113-NP, dated January 8, 1987.

  This submittal documented the results HCOG's comparisons of CLASIX-3 predictions to the NTS data. These included the results of comparisons of two NTS tests with CLASIX-3 code predictions of the large scale volume burns observed in the NTS facility. HCOG concluded that the results of these comparisons showed good agreement of predictions to test data.

Subtask 5.12: Submit Report Detailing Validation of CLASIX-3 Against NTS Data

Purpose: This subtask was established to provide NRC with the CLASIX-3/NTS Validation Report prepared under Subtask 5.11

Reference:

- See the letter referenced under Subtask 5.11.

  This letter transmitted the CLASIX-3/NTS Validation Report under Subtask 5.11 to the NRC.

TASK 6: HYDROGEN COMBUSTION TESTING

Subtask 6.1: Evaluate Fenwal Test Results

Purpose: This subtask was established to review and evaluate the tests of the GMAC 7G glow plug conducted by Westinghouse at the Fenwal Testing Laboratory.

Reference:

- Letter from Mississippi Power and Light Company to NRC "Hydrogen Control," AECM-81/336, dated August 31, 1981.

- Section 5.0 of this letter discussed MP&L's evaluation of the results of various generic testing programs for igniters which were completed to determine the performance, ability to function and overall effectiveness of the glow plug igniter. These test results were reviewed by HCOG in support of Subtask 6.1. The Fenwal tests (Section 5.2) demonstrated that hydrogen combustion is initiated by GMAC Model 7G glow plug igniters between 6 and 12 percent hydrogen by volume. Complete combustion did not occur below volume concentrations of 8.5 percent hydrogen. Water sprays did not effect the ability of the glow plugs to initiate combustion. The sprays promoted more complete combustion at lower volumetric hydrogen concentrations. Steam concentrations up to 40 percent did not prevent combustion, but the presence of steam was shown to reduce the peak pressures produced by hydrogen combustion.

Subtask 6.2: Evaluate Lawrence Livermore Test Results

Purpose: This subtask was established to review and evaluate the tests of igniters which were conducted by Lawrence Livermore National Laboratory (LLNL) in support of the NRC review effort of the Sequoyah Interim Distributed Ignition System.

Reference:

- See the letter referenced under Subtask 6.1 (Section 5.3).

  The Lawrence Livermore Laboratory tests showed general agreement with the Fenwal tests indicating that igniters are capable of reliably initiating combustion at low concentrations of hydrogen (6-10 percent) in dry air. Partial combustion occurred at lower concentrations and complete combustion occurred at higher concentrations.

The glow plugs proved capable of reliably igniting a mixture of as low as 8 volume percent hydrogen and 30-40 volume percent steam. Anomalous results were obtained for steam fractions of 50 percent. There was no evidence of degradation in the ability of the glow plug to initiate combustion in dry mixtures at glow plug surface temperatures between 1310F and 1370F, and in steam tests between 1360F and 1480F.

Mixing or turbulence was shown to enhance combustion particularly at lower hydrogen concentrations.

Subtask 6.3: Evaluate Singleton Test Results

Purpose: This subtask was established to review and evaluate the tests conducted by TVA at their Singleton Laboratory to assess the performance characteristics of a number of commercially available glow plugs.

Reference:

- See the letter referenced under Subtask 6.1 (Section 5.1).

Based on the results of the Singleton Laboratory tests, the GMAC 7G glow plug was shown to be capable of achieving the desired minimum surface temperature of 1500F for a range of voltages. Additionally, a degree of confidence was gained on the performance of the glow plug for extended periods of operation at high surface temperatures.

Subtask 6.4: Evaluate On going Industry Effort

Purpose: This subtask was established to evaluate other research and analyses concerning hydrogen combustion for applicability to HCOG efforts.

Reference:

- Letter from Mississippi Power and Light Company to NRC, "Hydrogen Control," AECM-81/336, dated August 31, 1981.

Section 5.0 "Generic Testing Programs" described the numerous testing programs which were conducted to evaluate the performance, ability to function and overall effectiveness of a glow plug hydrogen ignition system. HCOG reviewed the results of these programs as part of Subtask 6.4. This review provided additional information to HCOG relevant to hydrogen combustion, distributed ignition system performance, and anticipated containment response.

Subtask 6.5: Monitor IDCOR Activities

Purpose: This subtask was established to maintain cognizance of IDCOR research and analysis applicable to HCOG's efforts.

Reference:

- IDCOR Subtask 15.1 "Analysis of In Vessel Core Melt Progression."

  This task included predictions of core behavior under severely degraded conditions. These predictions of core behavior were relevant to HCOG's predictions of hydrogen production during degraded core accidents.

- IDCOR Technical Report 13.2-3, "Evaluation of Means to Vent, Suppress or Control Hydrogen burning in Reactor Containments", dated February 1984.

  This report evaluated various hydrogen mitigation systems. It was referenced by HCOG in subtask 2.5 of HCOG's Hydrogen Control Program Plan in lieu of developing a redundant HCOG-unique report.

  Monitoring of applicable IDCOR programs will continue until the HCOG effort is complete.

Subtask 6.6: Monitor NRC/Sandia Activities

Purpose: This subtask was established to evaluate the results of research programs sponsored by the NRC at Sandia National Laboratory regarding hydrogen behavior for applicability to HCOG hydrogen control programs and analyses.

Reference:

- See letter referenced in Subtask 6.4.

  As described by MP&L in this submittal, Sandia has been a major contributor to research in the field of hydrogen combustion. HCOG has reviewed reports prepared by Sandia as well as those of other NRC contractors and will continue this monitoring role until the HCOG programs are complete.

Subtask 6.10: Investigate Mark III Unique Phenomena

Purpose: This subtask was established to identify any combustion phenomena which might be unique to the Mark III containment.

Reference:

- Letter from Mississippi Power and Light to NRC, "Report on Study of Hydrogen Control in Grand Gulf Nuclear Station," AECM-82/25, dated March 2, 1982.

  As documented in this submittal to the NRC by MP&L, Combustion and Explosives Research Inc. (COMBEX) completed an evaluation of the Mark III containment geometry, the distributed ignition system and postulated degraded core accident scenarios. Based upon this review, COMBEX suggested that two combustion phenomena other than deflagrations might occur in the Mark III containment. These included inverted diffusion flames in the drywell and diffusion flames on the suppression pool surface. COMBEX also provided recommendations for additional testing to investigate these phenomena.

Subtask 6.13: Define Hydrogen Rich Flammability Limit Test Program

Purpose: This subtask was established to define the hydrogen flammability limit in hydrogen rich, oxygen limited atmospheres.

Reference:

- Letter from HCOG to NRC, "Mark III Hydrogen Control Owners Group Final Whiteshell Ignition Test Report," HGN-017-NP, dated June 7, 1984.

  Following recommendations from COMBEX and EPRI, HCOG elected to conduct tests in a small scale facility at AECL's Whiteshell Laboratories. The Whiteshell test report, "Ignition Effectiveness of the GMAC 7G Glow Plug in Rich Hydrogen-Air-Steam Atmospheres," was submitted with the referenced letter to the NRC. A drywell break (in conjunction with an HGE) which has produced high concentrations of hydrogen in a steam-inerted atmosphere in the drywell may lead to a flammable mixture subsequent to the re-introduction of oxygen. These tests involved injecting varying concentrations of hydrogen, air, and steam in the facility containing a single hydrogen igniter. Numerous tests were completed to define the upper flammability curves for various conditions.

Subtask 6.14: Design 1/20 Scale Test Facility

Purpose: This subtask was established to determine if injection of hydrogen into the containment through the suppression pool would result in standing flames in the wetwell and provide a visual record of hydrogen combustion.

Reference:

- See the letter referenced under Subtask 6.13.

- Letter from HCOG to NRC, "Information on Hydrogen Combustion Test Programs," HGN-008-NP, dated January 14, 1983.

  This submittal included a description of the 1/20 scale hydrogen combustion facility constructed for EPRI, a draft test matrix, details of scaling relationships and a progress report on the 1/20 scale test program.

Subtask 6.16: Resolve Questions on Research Programs

Purpose: This subtask was established to respond to a draft evaluation of the HCOG test programs from the NRC staff and its consultant's which was received by HCOG on February 3, 1983.

Reference:

- Letter from NRC to HCOG, "Review of HCOG Program," dated February 3, 1983.

  This NRC letter included a draft evaluation of the HCOG program and several requests for additional information (RAI).

- Letter from HCOG to NRC "Responses to NRC Request for Additional Information," HGN-011-NP, dated May 11, 1983.

  Responses to all generic questions raised in the February 3, 1983 NRC RAI were included in this submittal.

Subtask 6.17: Complete Hydrogen Rich Flammability Test Program

Propose: The purpose for this subtask was to complete the tests to define upper flammability limits for hydrogen-steam-air mixtures at AECL's Whiteshell Laboratory initiated in Subtask 6.13.

Reference:

- See the report referenced under Subtask 6.13

  The Whiteshell report concluded that the GMAC 7G glow plug operated with a 12 VDC supply can ignite hydrogen rich hydrogen-air-steam mixtures at concentrations very close to the hydrogen rich flammability limits. Combustion was nearly complete in all cases, consuming all available oxygen. No marginal ignition was observed except near steam-inerting concentrations. The glow plug ignition temperatures were higher for hydrogen rich hydrogen-air-steam mixtures and were not significantly affected by steam concentration.

Subtask 6.18: Complete 1/20 Scale Testing

Purpose: This subtask was established to complete the 1/20 scale testing program.

Reference:

- Letter from HCOG to NRC, "Final 1/20 Scale Test Report," HGN-014-NP, dated February 9, 198[illegible].

  A total of 41 tests were conducted to assess the effects of varied hydrogen release rates, blockages above the pool surface, hydrogen release points, SRV spargers, suppression pool temperature and heat loss through the containment shell. Under this subtask, an additional test was conducted using a 1/5 scale sparger in a circular tank open to the atmosphere. It was conducted to determine a lower bound hydrogen mass flow which would support continuous diffusion flames and to verify that the 1/20 scale tests over predicted flame heights.

  This submittal also provided documentation of the 1/20 scale test program conducted by Accurex for EPRI.

Subtask 6.20: Prepare Final Hydrogen Rich Flammability Limit Test Report

Purpose: This subtask was established to document the test results obtained in Subtask 6.17.

Reference:

- See the report referenced under Subtask 6.13.

  This submittal contained the report titled "Ignition Effectiveness of the GMAC 7G Glow Plug in Rich Hydrogen-Air-Steam Mixtures," prepared by Whiteshell Nuclear Research Establishment under contract to EPRI.

Subtask 6.21: Submit Final Flammability Test Report to NRC

Purpose: This subtask was established to submit the final flammability test report to NRC with a description of the experimental setup, method and results from the Whiteshell Test Laboratory studies.

Reference:

- See report referenced under Subtask 6.13.

These tests confirmed that hydrogen rich mixtures of hydrogen, air, and steam would be ignited by the GMAC Model 7G glow plug as long as oxygen concentrations exceeded 5 percent by volume.

Subtask 6.22: Prepare Final 1/20 Scale Test Report

Purpose: This subtask was established to prepare the report documenting the test results from Subtask 6.18

Reference:

- Letter from HCOG to NRC, "Final 1/20 Scale Test Report," HGN-014-NP, dated February 9, 1984.

This two volume submittal documented the test results addressing Subtask 6.18. Volume one included a description of the 1/20 scale test facility, modeling considerations, instrumentation, test matrix, and interpretation of test results. Volume two provided summary data tables, strip chart records and a description of the test procedures. This report was prepared by Accurex Corporation under contract to EPRI and was titled "Hydrogen Combustion Testing in a One-Twentieth Scale Model of a BWR6/Mark III Containment".

Subtask 6.23: Submit Final 1/20 Scale Test Report to NRC

Purpose: This subtask was established to submit the 1/20 scale test report prepared in Subtask 6.22 to the NRC.

Reference:

- See the report referenced under Subtask 6.22.

The report indicated that for the range of hydrogen release rates tested, the hydrogen ignition system controlled hydrogen buildup by burning at its point of entry into the containment. Continuous diffusion flames were established at the pool surface for hydrogen release rates greater than 0.4 lbm/sec (full scale).

Subtask 6.24: Larger Scale Testing Required?

Purpose: A comparison of the 1/20 scale facility and 1/5 scale single sparger tests indicated that the 1/20 scale data tended to over-predict flame heights and resulting thermal environments. Based upon this comparison, HCOG made the decision to conduct additional tests in a larger scale facility to obtain thermal environment data more representative of a Mark III containment.

Reference:

- Letter from HCOG to NRC, "1/4 Scale Hydrogen Combustion Test Program," HGN-012-NP, dated August 12, 1983.

  This NRC submittal confirmed the verbal commitment, made during a meeting between HCOG and NRC held on July 28, 1983, to authorize initiation of construction and completion of the 1/4 scale Mark III Containment Hydrogen Combustion Test Program.

Subtask 6.25: Initiate 1/4 Scale Test Program

Propose: This subtask was established to initiate the larger scale testing program deemed necessary in Subtask 6.24.

Reference:

- See the letter referenced under Subtask 6.24

- As described in the referenced submittal, detailed scaling relationships were developed and Task 9 was initiated.

Subtask 6.26: Evaluate TVA Igniter Spray Tests

Purpose: This subtask was established to evaluate the performance of igniters in a spray environment as documented in the TVA test results.

Reference:

- Letter from HCOG to NRC, "Closure of Subtask 6.26 'Evaluate TVA Igniter Spray Tests,'" HGN-058-NP, dated October 31, 1985.

  Prior to HCOG's evaluation of the TVA Tayco igniter spray tests, the NRC had expressed concerns about the ability of a glow plug igniter to maintain sufficiently high temperature to reliably ignite hydrogen in a spray environment. TVA undertook a program to evaluate the Tayco igniter. HCOG agreed to evaluate the TVA program and in the process of their review, NRC suggested that HCOG also evaluate test results obtained from a test program completed at Sandia National Laboratories. HCOG agreed to also evaluate the Sandia test results.

This submittal documented the HCOG basis for concluding that the results of the TVA tests on the Tayco glow coil igniter were not applicable to the Mark III containment. It also documented the results of the evaluation of the Sandia Lab Tests. HCOG concluded that the results of the Sandia tests using shielded igniters were applicable to the Mark III containments and that those results indicated that a shielded igniter would function effectively in a spray environment.

TASK 7: <u>GENERATION OF HYDROGEN RELEASE HISTORIES</u>

Subtask 7.1: Preliminary Hydrogen Release Estimate

Purpose: The first step in the development of hydrogen release histories was to predict hydrogen generation as a function of time for accidents where 75% of the active fuel cladding is oxidized.

Reference:

- Letter from HCOG to NRC "Report on Hydrogen Control Accident Scenarios, Hydrogen Generation Rates and Equipment Requirements, "HGN-003-NP, dated April 8, 1982.

  Section 3 of this submittal, "Hydrogen Generation Rates," utilized the CHASTE code to predict hydrogen production rates. It was assumed that hydrogen production commenced one hour after the initiating event. Analyses indicated that a coolable core geometry could not be maintained for 75% metal water reactions. The CHASTE code used by GE in this report calculated a maximum of 12.5% MWR before gross core melting which would result in reactor pressure vessel failure. To obtain 75% MWR, an arbitrary extrapolation of the analysis results was used.

Subtask 7.2: Calculate Most Probable Hydrogen Release Rates

Purpose: Based upon the preliminary release rate estimate assumptions, the CHASTE code was used to develop the most probable hydrogen release rates as described above.

Reference:

- See the report referenced in Subtask 7.1.

  The hydrogen release histories and analyses described in this report comprised a "best estimate" utilized by HCOG in comments on the proposed rule making for 10CFR50.44.

  The report concluded that for a BWR6, the maximum credible zirconium - water reaction corresponds to approximately 12.5% of the cladding for recoverable degraded core accidents.

- Letter from HCOG to NRC "Report on Hydrogen Control Accident Scenarios, Hydrogen Generation Rates and Equipment Requirements," HGN-006-NP, dated September 9, 1982.

This submittal was a revision of HGN-003 and included of discussion on ATWS and reflood of the lower plenum. As described in the previous version of this report, a 75% MWR could only be obtained by extrapolating the results arbitrarily.

This revision included sensitivity studies where recovery of core cooling was significantly delayed. MWR fractions greater than 12.5% were achieved, however, severe core damage was predicted.

Subtask 7.7: Define Recoverable Accident Scenarios

Purpose: The purpose for this subtask was to establish accident scenario assumptions necessary for input to the BWR Core Heatup Code.

Reference:

- Letter from HCOG to NRC "Hydrogen Release Histories and Test Matrix for 1/4 scale Test Program," HGN-031-NP, dated March 11, 1985.

This submittal identified the scenario assumptions for input to the BWR Core Heatup Code. The assumptions made were expected to provide the best representation of anticipated plant/operator response. Some conservative assumptions were made to bound uncertainty. The base case addressed by this submittal assumes that the core is 3/4 uncovered after actuation of the automatic depressurization system (ADS) and core heatup starts approximately 2000 seconds after scram. The base case assumed vessel reflood flow rates of 300 GPM and 5000 GPM. The timing for the start of reflood was established so that the accident remained recoverable, with no more than 30% of the active core zircaloy inventory exceeding the zircaloy melting temperature at any one time.

Reflood rates and percentage of zircaloy exceeding melt temperature is discussed under Subtask 7.18.

Subtask 7.8: Calculate Degraded Core Hydrogen Release Histories.

Purpose: The purpose for this subtask was to develop hydrogen release histories for various reflood flow rates and reflood initiation times.

Reference:

- See the letter referenced under Subtask 7.7

This submittal discussed the effect of reflood flow rates and initiation time upon hydrogen release histories. Postulated degraded core hydrogen release histories which were developed for the 1/4 scale test program were presented in this report, which incorporated the reflood flow rates and initiation times for three cases.

Subtask 7.9: Complete BWR Core Heatup Code Sensitivity Study.

Purpose: This subtask was established to define the sensitivity of the BWR Core Heatup Code to input parameter variation and modeling assumptions.

References:

- Letter from HCOG to NRC "Submittal of Information on BWR Core Heatup Code", HGN-032-NP, dated April 16, 1985.

- Letter from HCOG to NRC "Information Concerning the BWR Core Heatup Code," HGN-043-NP, dated June 14, 1985.

These submittals documented the changes in hydrogen release rates due to variation of reflood flow rate, reflood initiation timing, vessel pressure, initial core water level, core wide radiant heat transfer modeling, core nodalization, oxidation cutoff temperature, decay energy and fuel-clad gap conductance. The sensitivity of code predictions to timing for depressurizing the reactor vessel and the effect of varying the amount of zircaloy inventory melt considered to be recoverable were evaluated. Based upon meetings with the NRC and in response to NRC requests for additional information, additional code runs were completed. These sensitivity runs demonstrated that the controlling parameters for peak hydrogen rate, duration of hydrogen production, and total hydrogen production, are the reflood injection rate and reflood initiation timing. Resolution of questions in Subtask 7.12 was considered in these sensitivity studies.

Subtask 7.10: Submit BWR Core Heatup Code Details to NRC

Purpose: This subtask was established to provide the NRC staff with details on the BWR Core Heatup Code.

Reference:

- Letter from HCOG to NRC "Users Manual and Details of Modeling for the BWR Heatup Code," HGN-020-NP, dated September 5, 1984.

This submittal provided the NRC staff with the BWR Core Heatup Code Manual. This document discusses assumptions used in the code, equations solved by the code, required input, available output, and solution schemes.

Subtask 7.12: Resolve Questions on BWR Heatup Code

Purpose: This subtask was established to address NRC staff questions identified as a result of the review of the modeling and input assumptions implemented in the BWR Core Heatup Code.

Reference:

- During the review process to resolve BWRCHUC questions, several meetings were held between HCOG and the NRC staff. These are summarized as follows:

  1) On October 3-4, 1984, HCOG met with the NRC to discuss modifications to the BWRCHUC, 2) On November 15, 1984, HCOG met with NRC to address staff concerns identified at the October meeting; 3) On January 30, 1985, HCOG met with NRC for further discussions on the BWRCHUC and NRC presented HCOG with informal RAI's; 4) On June 4, 1985, HCOG met with the NRC to further discuss the BWRCHUC.

- Letter from HCOG to NRC "Submittal of information on BWR Core Heatup Code," HGN-032-NP, dated April 16, 1985.

  This submittal was provided to the NRC in response to informal requests for information concerning the BWRCHUC code generated during the January 30, 1985 meeting between HCOG and NRC. A portion of the requested information was provided in Attachment 1 of the submittal.

- Letter from HCOG to NRC "Information Concerning the BWR Core Heatup Code," HGN-043-NP, dated June 14, 1985.

  This submittal provided the balance of the information requested by the staff originally identified in HGN-032 and raised during the meeting with NRC on June 4, 1985.

- Letter from HCOG to NRC "Information Concerning the BWR Core Heatup Code," HGN-046-NP, dated June 28, 1985.

  This submittal provided the NRC staff with information requested during the June 4, 1985 meeting between HCOG and NRC.

- Letter from NRC to HCOG dated January 23, 1986.

This letter from the NRC staff transmitted an additional set of questions on the BWR Core Heatup Code.

- Letter from HCOG to NRC "BWR Core Heatup Code Responses," HGN-089-NP, dated June 9, 1986.

  The responses to questions from their January 23, 1986 letter were transmitted to NRC via HGN-089-NP, dated June 9, 1986.

Subtask 7.14: Resolve Questions on Accident sequences

Purpose: This subtask was developed to respond to any questions generated by the NRC staff following their review of the accident sequences proposed for use in the 1/4 scale test facility. These questions were identified during the meeting on January 30, 1985 meeting. Changes or clarifications were completed before the use of the hydrogen release histories in the 1/4 scale test program.

References:

See the references under Subtask 7.18. Documentation addressing the resolution of NRC concerns, pertinent to HCOG proposed accident sequences, were addressed under Subtask 7.18.

Subtask 7.15: Calculate 75% MWR Hydrogen Release History

Purpose: This subtask was established to calculate a hydrogen release history which would result in a total hydrogen production equivalent to oxidizing 75% of the active fuel zircaloy cladding.

References:

- Letter from HCOG to NRC "Model for Hydrogen Production Equivalent to 75% MWR," HGN-034-NP, dated May 17, 1985.

  Mechanistic calculations of total hydrogen production corresponding to 75 percent MWR for a recoverable degraded core accident have never been achieved. In order to comply with the hydrogen control rule, HCOG committed to complete a non-mechanistic calculation which would establish a methodology for calculating total hydrogen production equivalent to 75% MWR.

  The referenced submittal provided the NRC staff with a non-mechanistic model which was developed to allow prediction of hydrogen production equivalent to 75% metal water reaction. The non-mechanistic model of hydrogen production established a long term hydrogen production rate of 0.1 lbm/sec. HCOG combined this non-mechanistic hydrogen production with predictions from BWRCHUC to use in 1/4 scale testing as discussed in Subtask 7.18. Due to limitations in the capability of the test facility to exactly simulate a hydrogen injection flow rate of 0.1 lbm/sec full scale, HCOG committed to simulate this calculated hydrogen production with a full scale equivalent injection of 0.14 lbm/sec.

Subtask 7.16: Prepare Hydrogen Release History Report

Purpose: This subtask was established to prepare a report documenting the methodology and assumptions used to generate hydrogen release histories with the BWR Core Heatup Code (BWRCHUC).

References:

- Letter from HCOG to NRC "BWR Core Heatup Code Report," HGN-096-P, dated July 30, 1986.

  This submittal discussed the detailed methodology and assumptions used in the generation of hydrogen release histories with the BWRCHUC. It also documented the BWRCHUC sensitivity runs and provided a discussion of the effect on code output from varying initial parameters. In addition, this report documented HCOG's position on the basis for the irreversible oxidation cutoff used to terminate zircaloy oxidation in a given node.

Subtask 7.17: Submit Hydrogen Release History Report to NRC

Purpose: This subtask was developed to provide NRC with the report prepared in Subtask 7.16 documenting the assumptions and modeling used to generate the hydrogen release histories used in the 1/4 scale test program.

Reference:

See the report referenced in Subtask 7.16.

Subtask 7.18: Select Final Hydrogen Release Histories for Input to the 1/4 Scale Testing Program

Purpose: This subtask was established to select hydrogen release histories for input to 1/4 scale testing.

References:

- Letter from HCOG to NRC "Test Matrix for 1/4 Scale Test Program," HGN-031-NP, dated March 13, 1985.

  This submittal provided initial documentation of the selected hydrogen release histories for inclusion in the 1/4 scale test program. These included: 1) a release history which would represent the most probable hydrogen generation event; 2) a release history which results in a limiting diffusion flame thermal environment. A third release history was added later and used to validate the containment response analysis code selected under Task 5.

  During a meeting between HCOG and NRC on May 22, 1985, HCOG committed to modify the hydrogen release histories used in the 1/4 scale test program. HCOG agreed to include the 75% MWR hydrogen release history calculated in Subtask 7.15 in the 1/4 scale test program. HCOG also agreed to modify the "A" and "B" hydrogen release histories identified in HGN-031-NP to provide for a zircaloy melt fraction in the active core regions of 50% instead of 30%.

- Letter from NRC to HCOG dated June 24, 1985. The NRC staff proposed hydrogen release histories different from those proposed by HCOG in previous correspondence. The staff indicated that the following release histories would be acceptable:

  Case "A" calculated with an injection rate of 150 GPM at 3100 seconds, Case "B" calculated with an injection rate of 5000 GPM at 50% zircaloy melt, and Case "C" consisting of Case "A" with a constant 0.1 lbm/sec release following the Case "A" hydrogen release until the total amount of hydrogen released equaled a 75% metal water reaction.

- Letter from NRC to HCOG dated July 8, 1985.

  The NRC staff requested that HCOG recalculate the release histories after revising the BWRCHUC to account for the latent heat of fusion of zircaloy in the core.

- Letter from HCOG to NRC "Hydrogen Release Time Histories," HGN-052-NP, dated August 1, 1985.

  This letter provided the requested release histories to the NRC staff. Due to limitations in the design of the 1/4 scale facility, a hydrogen flow rate of 0.14 lbm/sec was specified instead of the calculated long term hydrogen production rate of 0.1 lbm/sec.

- Letter from NRC to HCOG dated August 16, 1985.

  The NRC accepted the hydrogen release histories described in HGN-052-NP. Since the 0.14 lbm/sec hydrogen flowrate produces a more limiting thermal environment than the calculated 0.1 lbm/sec, this modification was acceptable. HCOG used these release histories for the 1/4 scale test program and CLASIX analyses.

Subtask 7.19: Provide Basis for Selection to NRC.

Purpose: To provide the NRC staff with documentation of the HCOG basis for selecting the final hydrogen release histories for the 1/4 scale testing program.

Reference:

- Letter from HCOG to NRC "Test Matrix for 1/4 Scale Test Program," HGN-031-NP, dated March 31, 1985.
  This submittal provided the NRC staff with the basis for selecting final hydrogen release histories before initiation of the 1/4 scale test facility scoping testing.

  NRC provided guidance to HCOG on the hydrogen release histories to be used in testing as noted in Subtask 7.18. As indicated previously, HCOG will use the guidance provided by the NRC as the basis for selecting release histories for the 1/4 scale test program.

Subtask 7.20: Resolve Questions on Selection Basis

Purpose: Address additional questions generated from NRC staff review of the final hydrogen release histories selected for inclusion in the 1/4 scale test program.

Reference:

- See the letter referenced from Subtask 7.19. During a meeting between HCOG and the NRC staff on May 22, 1985, HCOG indicated that scoping tests would proceed with release history "A" identified in the referenced letter. HCOG reevaluated the hydrogen release histories to be used in production testing and modified the production testing hydrogen release histories as identified in Subtask 7.18. This was to assure agreement with the NRC staff on the accident sequences considered.

TASK 8: CONTAINMENT RESPONSE ANALYSIS

Subtask 8.2: Establish Generic Mark III Base Cases

Purpose: This subtask was established to identify the plant input parameters to be used in completing the generic Mark III base case studies.

Reference:

- Letter HCOG to NRC "Containment Sensitivity Study for Hydrogen Generation Event," HGN-001-NP, dated January 15, 1982.

HCOG elected to complete a generic analysis of hydrogen combustion in the Mark III containment including an extensive sensitivity analysis. MP&L's Grand Gulf Nuclear Station (GGNS) was selected as the representative plant. Information was assembled on GGNS including heat sinks, volumes, the containment spray system, etc.

Two generic base case analyses were identified: 1) a transient which resulted in SRV actuation with the failure of one SRV to close, and 2) a small break LOCA which introduced a portion of the total hydrogen produced into the drywell.

Subtask 8.3: Perform Generic Mark III Base Case Analysis

Purpose: This subtask was established to analyze the two base cases identified in Subtask 8.2 using CLASIX-3.

Reference:

- See the letter referenced under Subtask 8.2.

This report documented the generic base case analysis identified in Subtask 8.2. The resulting generic transient responses were considered as reference pressure and temperature responses for containment capability analyses.

Subtask 8.4: Specify Generic Mark III Runs

Purpose: This subtask was established to specify parameter variations for sensitivity studies using the base case analyses generated in Subtask 8.3

Reference:

- See the report referenced under Subtask 8.2.

This report included an extensive set of sensitivity studies which make the results applicable to a broad range of Mark III containment designs. The parameter variations selections used were also made in order to evaluate the sensitivity of the model to key assumptions due to uncertainties included in the accident scenario, system availability, input parameters and code model. These parameter variations were also selected to provide a high degree of confidence in the containment capacity for a wide range of conditions.

Two broad categories of accidents were analyzed. These included accidents involving a break in the reactor pressure coolant boundary in the drywell and transients produced by a stuck open safety relief valve. The cases selected provided variation in the hydrogen burn parameters, hydrogen release locations and initial conditions.

Subtask 8.5: Complete CLASIX-3 Sensitivity Runs

Purpose: This subtask was established to test the full range of CLASIX-3 capabilities to assure that the code provided consistent results.

Reference:

- See the report referenced under Subtask 8.2

The results of the CLASIX-3 sensitivity runs documented in this report were reviewed to assess reasonableness, and to assure that the Mark III containment would be able to withstand challenges associated with deflagrations when considering uncertainties in the analysis.

Subtask 8.6: Submit CLASIX-3 Report to NRC

Purpose: This subtask was established to provide the NRC with a report summarizing the sensitivity studies completed with the CLASIX-3 computer code.

Reference:

- See the report referenced under Subtask 8.2.

This report detailed the input to the CLASIX-3 computer code for each case analyzed and contained the output from each sensitivity run including pressures, temperatures and gas concentrations for the drywell wetwell and containment. General conclusions pertaining to the effect of variation in individual parameters were identified.

Subtask 8.7: Resolve Questions on Sensitivity Studies

Purpose: This subtask was developed to respond to Requests for Additional Information (RAIs) from the Nuclear Regulatory Commission. These RAI's were generated in response to staff review of submittals from HCOG on the use of CLASIX-3 and the selection of hydrogen burn parameters used in the base case analyses. Additional questions identified by the NRC Staff during meetings on the HCOG program plan relating to the effect of several parameters on temperatures predicted by CLASIX-3 were also addressed by this subtask.

Reference:

- Letter from NRC to HCOG, dated February 3, 1983.

  This letter from the NRC transmitted RAI's requesting HCOG to document the use of CLASIX-3 and the selection of hydrogen burn parameters used in the base case analyses submitted previously to the staff.

- Letter from HCOG to NRC "Responses to NRC Request for Additional Information," HGN-011-NP, dated May 11, 1983. This submittal was in response to the February 3, 1983 letter from the NRC referenced above.

- Letter from NRC to HCOG, dated September 14, 1984.

  This letter from the NRC transmitted RAI's concerning the incorporation of the NUREG-0588 heat transfer methodology, suppression pool bypass leakage and reactor coolant pressure boundary heat loads.

- Letter from HCOG to NRC, "Responses to Requests for Additional Information on the CLASIX-3 Computer Code," HGN-026-NP, dated March 6, 1985.

  This submittal provided a partial response to the September 14, 1984 RAI referenced above. Additional responses to the RAI were provided by HGN-092-P, as discussed below.

  Additional NRC questions concerning the effect of several parameters on temperatures predicted by CLASIX-3 were also identified during meetings on the Program Plan.

- Letter from HCOG to NRC "Report of CLASIX-3 Generic Analyses and Validation of CLASIX-3 against 1/4 Scale Test Facility Data," HGN-092-P, dated June 10, 1986.

Questions on the heat transfer methods used in CLASIX-3, the effects of sensible heat loss from the RPV and the effects of bypass leakage which were submitted to individual HCOG members were addressed generically by HCOG in this submittal.

Subtask 8.9B: Develop Revised Base Case

Purpose: A revised base case was prepared to resolve NRC concerns pertaining to the original Mark III base cases and to factor into HCOG's program the significant amount of additional information which has evolved since completion of the initial generic analyses.

Reference:

- Letter from HCOG to NRC "Report of CLASIX-3 Generic Analyses and Validation of CLASIX-3 against 1/4 Scale Test Facility Data," HGN-092-P, dated June 10, 1986.

This report provided the NRC staff with base case analyses which have been revised to include an intermediate volume between the wetwell and the upper containment and a natural circulation model. More realistic combustion parameters were used in the new base case analyses. The SORV transient and DWB accident were analyzed. The revised base cases utilize Perry Nuclear Power Plant (PNPP) parameters as the generic base case. Other significant revisions included the use of NUREG-0588 heat transfer methodology natural circulation suppression pool bypass leakage and RPV heat loss and more representative hydrogen release rates.

Subtask 8.9C: Complete Revised Base Case Analyses

Purpose: This subtask was established to analyze the two base cases identified in Subtask 8.9B.

Reference:

- See the report referenced in Subtask 8.9B.

This report documented the revision of CLASIX-3 to include NUREG-0588 heat transfer assumptions, suppression pool bypass leakage, and reactor pressure vessel heat loads and natural circulation. The revised base case analysis provided predictions of compartment temperatures, pressures and gas concentrations.

Subtask 8.9D: Specify Additional Mark III Sensitivity Studies

Purpose: Based upon several code and model revisions, HCOG recognized that additional sensitivity studies were necessary. This subtask was initiated to specify those additional sensitivity runs required to evaluate the sensitivity of CLASIX-3 to various input parameters.

Reference:

- See the report referenced in Subtask 8.9B.

Section 6.0 of the referenced report described the future analyses which would be conducted to assess important effects associated with implementing model and code changes. Seven sensitivity runs were concerned with containment response analysis for events initiated by a stuck open relief valve and the remaining four sensitivity studies with drywell break analysis. The sensitivity studies affecting containment response analysis for SORV events include varying the timing for initiation of containment sprays, varying the wetwell spray carryover fraction, decreasing the sheet flow effectiveness, decreasing the hydrogen release history tail and decreasing the natural circulation flow area. The sensitivity studies effecting the drywell break response analysis include decreasing the break size, delaying the ADS injection, varying the CGCS/vacuum breaker flow characteristics and eliminating NUREG-0588 heat transfer assumptions. As delineated in Subtask 8.9H, these sensitivity runs were performed using the revised CLASIX-3 code.

Subtask 8.9E: Prepare Report on Modified Base Case

Purpose. This subtask was established to document the results of work on the modified base case in a generic report.

Reference:

- See the report referenced in Subtask 8.9B.

Results from the work completed as part of Subtasks 8.9B through 8.9D were documented in the referenced generic report. This report describes the revised base case analyses and delineates the sensitivity studies to be performed.

Subtask 8.9F: Submit Report to NRC

Purpose: This subtask was established to formally submit the generic report on the modified base case to the Nuclear Regulatory Commission for review.

Reference:

- See the report referenced in Subtask 8.9B.

The referenced generic report prepared in Subtask 8.9C was formally submitted to the NRC staff for review.

Subtask 8.9H: Complete Additional Generic Sensitivity Studies

Purpose: This subtask was established to complete the generic sensitivity studies delineated in Subtask 8.9D.

Reference:

- Letter from HCOG to NRC, "CLASIX-3 Generic Sensitivity Analysis," HGN-109-P, dated December 9, 1986.

HCOG originally submitted a set of CLASIX-3 sensitivity studies via HGN-001-NP. The NRC subsequently provided HCOG with their review of that submittal as well as a set of questions in a letter dated September 14, 1984. In response to NRC's questions and in order to better model the combustion phenomena, HCOG further modified CLASIX-3 and the base cases. These modifications were discussed in HGN-092-P.

As a result of these modifications and to adequately address NRC concerns on the sensitivity studies submitted via HGN-001-NP, HCOG has conducted additional sensitivity studies. As specified in HGN-092-P, HCOG has conducted thirteen additional sensitivity studies. These studies investigated the effects of varying several parameters. The results of twelve of these studies were presented in the submittal referenced above (HGN-109-P). The remaining sensitivity report evaluates the effect of delaying actuation of the automatic depressurization system until the vessel level reaches core mid-plane. The results of this sensitivity study will be provided in a future submittal.

Subtask 8.9I: Prepare Report

Purpose: This subtask was established to conduct the results of the sensitivity studies performed under Subtask 8.9H in a report.

Reference:

- See the letter referenced under Subtask 8.9H

This report was prepared and detailed the CLASIX-3 sensitivity studies as described in Subtask 8.9H.

Subtask 8.9J: Submit Report to the NRC

Purpose: This subtask was established to provide the report described in Subtask 8.9I to the NRC staff for review.

Reference:

- See the letter referenced under Subtask 8.9H.

  This report was submitted to the NRC under HGN-109-P as described above.

Subtask 8.11: Establish Common CLASIX-3 Assumptions

Purpose: This subtask was established to provide HCOG member utilities with a list of a common assumptions for use in completing plant specific hydrogen deflagration analyses.

Reference:

- See the report referenced under Subtask 8.9B.

  HCOG documented a list of common CLASIX-3 assumptions to ensure that parameters which have been investigated by HCOG are treated in a conservative and consistent manner. These assumptions would be used in analyses performed by the individual utilities if additional analyses were required.

Task 9: DIFFUSION FLAME THERMAL ENVIRONMENT

Subtask 9.1: Set Goals for Test Program

Purpose: This subtask was established to clearly specify the technical goals of the diffusion flame thermal environment test program.

Reference:

- Letter from HCOG to NRC "Final 1/20th Scale Test Report," HGN-014-NP, dated February 9, 1984.

  This submittal contained the report entitled "Hydrogen Combustion Testing in a One-Twentieth-Scale Model of a BWR6/Mark III Containment," written by EPRI. This document finalized the completion of Subtask 6.23 and supporting subtasks. Data from the 1/20 scale test report were considered by HCOG to establish goals for the diffusion flame thermal environment test program. In general goals were established to accomplish the following:

  1. Construct an appropriate scaled test facility to allow evaluation of diffusion burning of hydrogen which can be related to the behavior of a full scale Mark III containment.

  2. Measure the temperature response of the containment air space and structures affected by diffusion burning.

  3. Measure dynamic velocities of containment gases.

  4. Allow validation of standard methods for calculating radiant heat flux from hot gases.

  5. Provide measurement of hot structure temperatures to allow prediction of radiant heat flux.

  6. Determine the mixing characteristics for a Mark III containment equipped with a distributed ignition system.

  7. Measure the facility response to hydrogen flow rates below the diffusion flame threshold to obtain data to verify that previous deflagration modeling provides conservative predictions of deflagration thermal environments.

- Letter from NRC to HCOG dated December 8, 1983.

The referenced letter transmitted several requests for additional information (RAIs). Question #1 from this letter stated that the 1/4 scale test program should have a broader technical objective not confined to determine local heat fluxes, and that the program should investigate the phenomena of hydrogen combustion and its consequences in the wetwell and upper containment regions of the Mark III containment.

- Letter from HCOG to NRC, "Responses to NRC Requests for Additional Information," HGN-016-NP, dated April 2, 1984.

This submittal to the NRC staff was in response to RAIs transmitted with the December 8, 1983 letter referenced above.

HCOG provided a detailed response to the NRC staff's request to modify the technical goals of the diffusion flame thermal environment test program. HCOG stated that analyses and testing completed to date by the industry did not identify a need for further testing to assess deflagrations. The primary issue remaining to resolve the hydrogen control issue for Mark IIIs is the evaluation of thermal loads on equipment due to diffusive burning.

Subtask 9.2: Design Test Facility

Purpose: This subtask was established to design an appropriate test facility which would enable HCOG to achieve the diffusion flame thermal environment program goals as identified in Subtask 9.1.

Reference:

- Letter from HCOG to NRC "1/4 Scale Hydrogen Combustion Test Program," HGN-012-NP, dated August 12, 1983.

This submittal confirmed HCOG's commitment to execute the 1/4 scale Mark III Containment Hydrogen Combustion Test Program. Three attachments describing the 1/4 scale test program were provided with this letter. The first was a detailed development of the theoretical basis and a review of the empirical data base which confirms the validity of Froude modeling to simulate diffusion flame behavior at reduced scale. The second attachment was a draft description of the 1/4 scale Mark III Containment Hydrogen Combustion Test Facility. As a result of preliminary HCOG and EPRI review some modifications were incorporated. These changes were described in the third attachment as an addendum to the draft design report.

Subtask 9.3: Submit Draft Design Report to NRC

Purpose: This subtask was established to provide the Nuclear Regulatory Commission with additional information on the design of a test facility to define the diffusion flame thermal environment.

Reference: See the report referenced under Subtask 9.2

This report described the 1/4 scale test program's technical objectives, the test site layout, experimental facility and the instrumentation and data acquisition system. Also included were modeling assumption descriptions used to scale the facility.

Subtask 9.5: Resolve Questions on Facility Goals and Design

Purpose: This subtask addressed NRC requests for additional information about the 1/4 scale test facility's goals, design and use.

Reference:

- Letter from NRC to HCOG "Request for Additional Information - Hydrogen Control" dated December 8, 1983.

  This letter contained RAI's pertaining to the 1/4 scale test facility addressing a broad range of topics about the 1/4 scale test facility's goals, design and use.

- Letter from HCOG to NRC, "Responses to NRC Requests for Additional Information," HGN-016-NP, dated April 2, 1984.

  Attachment 1 to this letter contained the HCOG responses to the requests for additional information (RAIs) submitted with the letter of December 8, 1983 referenced above.

- Letter from HCOG to NRC, "1/4 Scale Test Facility Igniter Placement and Containment Thermocouple Temperature Response and Location," HGN-049-NP, dated August 28, 1985.

  This submittal was made in response to a conference call between the HCOG and the NRC staff on March 27, 1985, during which a number of informal questions were asked of HCOG regarding the igniter locations in the 1/4 scale test facility and containment thermocouple temperature response and location.

- Letter from HCOG to NRC, "Vertical Flow Blockages and Containment Spray Carryover Fraction," HGN-054-NP, dated August 28, 1985.

In the letter from HCOG to NRC HGN-016-NP (referenced above), HCOG provided information to the NRC staff on how blockage simulations would be studied to assess their effect on test results. HCOG indicated that in order to assure conservatism in the temperatures measured in the 1/4 scale facility, no attempt would be made to include heat sinks and blockages which represent the large amount of equipment and material located in the Mark III containment. Following review of this submittal, the NRC staff indicated that their questions on the effects of blockages were not fully addressed. HGN-054 was submitted in response to the staff's additional concerns. This letter indicated that a 50% blockage to gas flow would be installed in the facility to represent the level of blockage present in the plant, except in the chimney in which the equipment hatch is located. HGN-054-NP also stated that additional blockage would be installed to create a 100% line of sight blockage which would virtually eliminate carryover of spray droplets from the upper containment to the wetwell.

- Letter from HCOG to NRC "Blockages to Horizontal Flow," HGN-094-NP, dated June 2, 1986.

  This letter responded to NRC questions regarding: 1) vertical blockages to horizontal flow fields and the potential for high local velocities near blockages that could affect the heat transfer mechanism to equipment required to survive hydrogen combustion; 2) vertical blockages in the River Bend Station in the vicinity of the unit cooler exhaust ducting and the effect of this blockage on the ability of the unit cooler to distribute cool air.

  HCOG concluded that the presence of equipment and structural blockage in either the 1/4 scale test facility and the prototype plants will have an insignificant effect on horizontal velocities. Therefore, the 1/4 scale facility was deemed acceptable in its current configuration with regard to this concern.

- Letter from HCOG to NRC, "River Bend Station Unit Coolers," HGN-101-NP, dated July 30, 1986.

  This submittal responded to NRC questions regarding the modeling of the River Bend Station Unit Coolers. These questions were identified during a meeting between HCOG and NRC on November 20, 1985. HCOG concluded that the River Bend Station safety related unit cooler system had been adequately simulated in the quarter scale test facility.

Subtask 9.6: Construct Test Facility

Purpose: This subtask provided for the construction of the 1/4 scale test facility designed under Subtask 9.2 in preparation for the performance of testing to measure the diffusion flame thermal environment.

Reference:

- Letter from HCOG to NRC, "1/4 Scale Hydrogen Combustion Test Program," HGN-012-NP, dated August 12, 1983.

  This document indicated that the estimated date for completion of construction of the 1/4 scale test facility was May 1984. Initial construction was started in August, 1983 and was completed in January, 1985. The 1/4 scale test facility is located at Factory Mutual Research Corporation's remote test site in West Gloucester, Rhode Island.

Subtask 9.7: Draft Test Matrix

Purpose: This subtask was established to prepare a draft test matrix for submittal to the Nuclear Regulatory Commission.

Reference:

- Letter HCOG to NRC, "Meeting Basis Submittal," HGN-018-NP, dated July 6, 1984.

  This submittal was provided to the NRC prior to an HCOG-NRC meeting on August 28 and 29, 1984. This information was provided to enable review of the progress of the 1/4 scale test program. The draft test matrix for the 1/4 scale test facility was included as an attachment to this letter. A three phase testing program was outlined, and the philosophy behind the shakedown, scoping and production test phases was described.

Subtask 9.8: Submit Test Matrix to NRC

Purpose: This subtask provided the NRC staff with the technical basis for the 1/4 scale test program draft test matrix.

Reference:

- See the letter referenced under Subtask 9.7.

  This submittal provided the NRC staff with the draft test matrix. As described in Subtask 9.7, HCOG met with the NRC to discuss the draft test matrix. This meeting was held August 28, 29, 1984.

Subtask 9.9: Resolve Questions on Test Matrix

Purpose: This subtask was established to achieve resolution of the NRC staff questions on the draft test matrix assumptions and methodology. This was necessary to ensure agreement on the important parameters to be addressed by the various scoping and production tests.

Reference:

- Letter from HCOG to NRC, "Meeting Basis Submittal," HGN-018-NP, dated July 6, 1984.

  The draft test matrix for the 1/4 scale facility (QSTF) was included as an attachment to this submittal. This proposed test matrix was sent to the NRC for comment so that HCOG and NRC could reach agreement on the tests to be conducted in the QSTF.

- HCOG met with NRC on August 28-29, 1984 to discuss the progress of the 1/4 scale test program and the revisions to development of the proposed test matrix submitted to the staff under HGN-018.

- Letter from HCOG to NRC, "Hydrogen Release Histories and Test Matrix for 1/4 Scale Test Program," HGN-031-NP, dated March 13, 1985.

  Attachment one to this letter was the final test matrix for the 1/4 scale test program. This test matrix was revised from the August 1984 proposed test matrix as a result of numerous discussions between HCOG and the NRC staff. The revision included an additional scoping test which would evaluate the effect of increasing the blockage fraction present in the 1/4 scale test facility.

- HCOG met with NRC on July 17, 1985 to discuss the final scoping test matrix and review the results of the scoping test program.

- Letter from HCOG to NRC, "Evaluation of Scoping Test Results," HGN-053-NP, dated August 1, 1985.

  This submittal documented the material presented to the NRC during the HCOG/NRC meeting held July 17, 1985. An updated scoping test matrix and a revised production test matrix were provided with this submittal.

- Letter from NRC to HCOG dated August 16, 1985.

This letter contained comments from the NRC staff on the scoping and production test matrix submitted under HGN-053-NP.

- HCOG met with NRC on September 5, 1985 to discuss, at length, staff comments on the 1/4 scale test matrix.

- Letter from NRC to HCOG dated September 19, 1985.

  This letter documented the NRC staff's position on the 1/4 scale test matrix as presented during the September 5, 1985 HCOG/NRC meeting.

- Letter from HCOG to NRC, "Submittal of Final Scoping Test Matrix and Revised Production Test Matrix," HGN-060-NP, dated October 29, 1985.

  This submittal documented the revisions to the scoping and production test matrices which were made in response to numerous discussions with the NRC and the correspondence referenced above.

- Letter from NRC to HCOG, dated November 29, 1985.

  This letter provided the NRC staff response to a number of HCOG submittals, including those concerned with resolution of the final test matrices. The final scoping test matrix was found acceptable without further staff recommendations. The production test matrix was also found acceptable with the addition of a test with a hydrogen release history B without sprays.

Subtask 9.13: Identify any Facility Changes to NRC

Purpose: This subtask was established to notify the NRC staff of any substantial modifications to the test facility which were identified during the shakedown testing program.

Reference:

- Letter from HCOG to NRC, "Hydrogen Control Program Plan Subtask 9.13, Identify any Facility Changes to NRC," HGN-038-NP, dated June 17, 1985.

  This submittal notified NRC that the final shakedown test was conducted on May 6, 1985, and documented the adequacy of the facility as a result of this testing. The submittal reported to the NRC that the systems and instrumentation in the 1/4 scale test facility functioned as required. Therefore, no modifications to the test facility were required.

Subtask 9.14: Prepare Final Design Report

Purpose: This subtask was established to document the final design of the 1/4 scale test facility to the NRC staff.

Reference:

- Letter from HCOG to NRC, "1/4 Scale Test Facility Final Design Report," HGN-115-NP, dated February 10, 1987.

- This submittal documented the actual design of the 1/4 scale test facility that was utilized through the end of the scoping test series and superceded the conceptual design submitted to the NRC staff under HGN-012-NP.

Subtask 9:15: Submit Final Design Report to NRC Staff.

Purpose: This subtask was established to submit the report documenting the final design and configuration of the 1/4 scale test facility to the NRC staff.

Reference:

- See the report referenced under Subtask 9.14.

Subtask 9.16: Finalize Scoping Test Matrix

Purpose:

This subtask was established to resolve questions from the NRC staff pertaining to HCOG's proposed scoping test matrix.

Reference:

- Letter from HCOG to NRC, "Meeting Basis Submittal," HGN-018-NP, dated July 6, 1984.

  This submittal documented the draft scoping test matrix for the 1/4 scale test facility which originally included 14 tests.

- HCOG met with NRC on August 28-29, 1984. During this meeting the draft scoping test matrix was discussed.

- Letter from HCOG to NRC, "Hydrogen Release Histories and Test Matrix for 1/4 Scale Test Program," HGN-031-NP, dated March 13, 1985.

  This submittal included a revised scoping test matrix. This was in response to NRC concerns identified during the August meeting and subsequent discussions with the staff.

- HCOG met with NRC on July 17, 1985 to discuss the final scoping test matrix and review the results of the scoping test program.

- Letter from HCOG to NRC, "Evaluation of Scoping Test Results," HGN-053-NP, dated August 1, 1985.

  This submittal documented the material presented to NRC during the July 17, 1985 meeting and provided the NRC staff with an updated scoping test matrix.

- Letter from NRC to HCOG dated August 16, 1985.

  This letter contained comments from the NRC staff on the scoping test matrix which was submitted under HGN-053-NP.

- HCOG met with NRC on September 5, 1985 to discuss staff comments on the scoping test matrix which were included in the August 16, 1985 letter to HCOG.

- Letter from NRC to HCOG dated September 19, 1985.

  This letter documented the NRC staff's position on the 1/4 scale scoping test matrix as presented during the September 5, 1985 HCOG/NRC meeting.

- Letter from HCOG to NRC, "Submittal of Final Scoping Test Matrix and Revised Production Test Matrix," HGN-060-NP, dated October 29, 1985.

  This submittal documented revisions to the scoping test matrix which were made in response to numerous discussions with the NRC and the correspondence referenced above.

- Letter from NRC to HCOG, dated November 29, 1985.

  The letter provided HCOG with NRC acceptance of the final scoping test matrix submitted under HGN-060-NP.

Subtask 9.18: Analyze Scoping Test Results

Purpose: This subtask was established to determine from the analysis of the scoping test results whether or not specific assumptions made by HCOG for the proposed production test matrix were correct. These assumptions were as follows:

1. The effects of hydrogen released through spargers is limiting compared to releasing hydrogen through both the LOCA vents and spargers.

2. Effects of injecting steam and hydrogen simultaneously is negligible when compared to releasing hydrogen alone.

3. The Perry Nuclear Power Plant configuration and Grand Gulf Nuclear Station configuration are similar enough so that data obtained for GGNS is applicable to both plants. (Later circumstances resulted in testing both GGNS and PPNP.)

4. No hydrogen pocketing will occur in the facility.

Reference:

- Letter from HCOG to NRC, "Evaluation of Scoping Test Results," HGN-053-NP, dated August 1, 1985.

A final report summarizing the scoping tests was provided under Subtask 9.24.

Test results summarized in this letter indicated that steam had no measurable effect on the thermal environment produced by hydrogen combustion. The LOCA vents and grating on the other hand appeared to have a small, but noticeable effect and were included in the production test matrix. The scoping tests also included several tests designed to both examine the threshold for sustaining diffusion flame burning on the pool surface and define the test conditions for the 75% MWR production tests that would result in the thermally limiting environment.

Subtask 9.19: Production Test Matrix Acceptable?

Purpose: This subtask was established to determine whether the proposed production test matrix required modifications based upon a comparison of the scoping test results with assumptions regarding the planned production tests.

Reference:

See the letter referenced under Subtask 9.18.

The assumptions identified in Task 9.18 were reviewed against scoping test results. Based upon this review, HCOG decided to include additional tests in the production test matrix. These additional tests involved hydrogen injection through SRV spargers and LOCA vents. HCOG also decided to perform a full set of production tests with the facility representing the geometry of the Perry Nuclear Power Plant. A late input from Subtask

9.25 after formal submittal of scoping test results in HGN-053 resulted in a revision to the production test matrix in order to resolve NRC concerns.

Subtask 9.20: Revise Production Test Matrix

Purpose: This subtask was established to modify the production test matrix, as required, by comparison of planned production tests with scoping test results and in response to NRC concerns.

Reference:

- See the letter referenced under Subtask 9.18.

  This letter provided NRC with the initial revision of the production test matrix which was based upon comparison of planned production tests with scoping test results.

- Letter from NRC to HCOG dated August 16, 1985.

  In this letter and during a meeting between HCOG and NRC on September 5, 1985, the NRC stressed the need for a production test matrix which reflected additional tests to determine the thermal environment produced by hydrogen combustion in the absence of containment spray operation.

- Letter from HCOG to NRC, "Submittal of Final Scoping Test Matrix and Revised Production Test Matrix," HGN-060-NP, dated October 29, 1985.

  This submittal transmitted a revised production test matrix to address the concerns of the NRC staff. This revised test matrix reflected an increased number of tests to be completed without operating the simulated containment sprays.

- Letter from NRC to HCOG dated November 29, 1985.

  The NRC staff indicated in this letter that a test designated to be carried out with the "B" release history should be performed without sprays.

- Letter from HCOG to NRC, "Revision to Production Test Matrix," HGN-079-NP, dated April 2, 1986.

  This submittal provided HCOG's response to the referenced letter from NRC dated November 29, 1985. HCOG agreed to modify the current production test matrix to require all production tests run with a Case B release history to be conducted without sprays in order to resolve this NRC concern.

Subtask 9.24: Submit Preliminary Scoping Test Results

Purpose: The purpose for this subtask was to organize scoping test data, correlate the data into a preliminary scoping test report and submit the report to the NRC staff.

Reference:

- Letter from HCOG to the NRC, "Evaluation of Scoping Test Results," HGN-053-NP, dated August 1, 1985.

  This submittal provided the NRC staff with the preliminary scoping test data and HCOG's evaluation of this information.

  The results summarized in both the HCOG/NRC meeting held July 17, 1985 and the referenced report indicated that steam had no measurable effect on the thermal environment produced by hydrogen combustion, while both the LOCA vents and grating appeared to have a small, but noticeable effect. Therefore, the grating and LOCA vents were included in the production test matrix. Further, the scoping test results included several tests designed to both examine the threshold between diffusion flame burning and deflagrations, and to define the test conditions for production tests that would simulate 75% MWR and result in the thermally limiting environment. Detailed results of these tests were presented in Attachment 1 to the report. Attachment 2 provided a revised instrument layout for the 1/4 scale test facility.

- Letter from HCOG to NRC, "Scoping Test Report," HGN-098-P, dated July 18, 1986.

  This submittal provided an enhanced discussion of the scoping tests discussed under HGN-053-NP and provided a comprehensive assessment of the seven additional scoping tests conducted since August 1985.

Subtask 9.25: Resolve Questions on Scoping Test Results

Purpose: This subtask was established to address NRC's response to the preliminary scoping test results included in HGN-053-NP from Subtask 9.24.

Reference:

- Letter from NRC to HCOG dated August 16, 1985.

The NRC staff's detailed review of the scoping test data report generated questions which were documented to HCOG in this letter.

- See the letter (HGN-098-P) referenced under Subtask 9.24.

  The NRC staff's questions concerning the scoping test data were documented in the August 16, 1985 letter and addressed by HCOG in HGN-098-P.

Subtask 9.31: Verify Adequacy of 1/4 Scale Heat Loss Modeling

Purpose: The intent of this subtask was to show that the Froude modeled 1/4 scale test facility provides an acceptable representation of temperatures in a full scale facility.

Reference:

- Letter from HCOG to NRC, "Report Concerning the Adequacy of 1/4 Scale Heat Sink Modeling," HGN-037-NP, dated June 4, 1985.

  The NRC identified concerns regarding scaling of heat losses from the 1/4 scale test facility to a full scale Mark III containment. HCOG committed to complete a study addressing these concerns in August 1984, including both the assessment of scaling effects and the effects of equipment present in a full scale facility.

  This submittal provided the NRC with results of a study performed to assure that the gas temperatures measured in the 1/4 scale test facility would be conservative or comparable to the temperatures which would be expected following a degraded core accident in a full scale plant.

- In a meeting on September 5, 1985, between HCOG and the NRC, the staff identified concerns over the the 1/4 scale test facility measured test data and heat loss report predictions. At that time HCOG indicated that heat loss report predictions for the 1/4 scale test facility response were being revised.

- A meeting between HCOG and the NRC staff was held on December 19, 1985 to discuss the revisions to the heat loss model. HCOG indicated that it was still investigating the heat transfer characteristics of the facility's insulation at that time.

- Letter from HCOG to NRC, "Final Report Assessing the Adequacy of Heat Sink Modeling in the 1/4 Scale Test Facility," HGN-085-NP, dated May 5, 1986.

The final results of HCOG's assessment were presented during a March 13, 1986 meeting. The above submittal provided the NRC staff with a report which documented those results. HCOG concluded that the report represented a best estimate model reflecting the phenomenological data and knowledge gained from the 1/4 scale test program. Sophisticated analytical techniques were utilized in modeling both the complex facility geometries and the combustion phenomena. The report indicated that the 1/4 scale test facility adequately represents full scale heat losses. Although modeling uncertainties remain, HCOG evaluated the level and nature of those uncertainties and determined that further refinement of the models was not warranted. This decision was made in light of the good agreement achieved between predicted 1/4 scale behavior and actual test data.

Task 10: EVALUATION OF DRYWELL RESPONSE TO DEGRADED CORE ACCIDENTS

Subtask 10.1: Modify CLASIX-3 to Utilize NUREG-0588 Assumptions

Purpose: This subtask was established at the request of the NRC to provide a more conservative prediction of the drywell thermal environment produced during a degraded core accident by incorporating NUREG-0588 heat transfer methodology into the CLASIX-3 code.

Reference:

- Letter from NRC to HCOG dated September 14, 1984.

  The NRC staff review of CLASIX-3 included comparisons with analyses of the drywell compartment run with the CONTEMPT-LT containment response code. The CONTEMPT-LT code incorporates conservative heat transfer methods for predicting temperatures corresponding to the methodology in NUREG-0588. The NRC believed that the NUREG-0588 methodology should be used to provide a more conservative prediction of temperatures.

  To provide a more conservative prediction of the thermal environment prior to hydrogen ignition, an option to use heat transfer models based on NUREG-0588, Branch Technical Position CSB 6-1 and the CONTEMPT-LT program was included in the CLASIX-3 code.

  This letter requested information concerning the incorporation of the NUREG-0588 heat transfer methodology, suppression pool bypass leakage, and reactor coolant pressure boundary heat loads into the CLASIX-3 analyses.

- Letter from HCOG to NRC, "Responses to Requests for Additional Information on the CLASIX-3 Computer Code," HGN-026-NP, dated March 6, 1985.

  This submittal provided a partial response to the NRC RAI of September 14, 1984 referenced above and indicated HCOG's intent to include NUREG-0588 methodology for passive heat sink modeling into future CLASIX-3 analyses.

- Letter from HCOG to NRC, "Report of CLASIX-3 Generic Analyses and Validation of CLASIX-3 Against 1/4 Scale Test Facility Data," HGN-092-P, dated June 10, 1986.

  This submittal responded to the balance of the NRC concerns in the referenced RAI and described the model and assumptions to be used by HCOG in Tasks 8 and 10 of

the HCOG Hydrogen Control Program Plan.
The methodology for incorporation of NUREG-0588 was described in this report.

Subtask 10.2: Define Accident Sequences

Purpose: This subtask involved identifying the accident sequences which should be evaluated to define the drywell's response to degraded core accidents.

References:

- Letter from HCOG to NRC, "Event Scenarios for Evaluation of Drywell Response to Degraded Core Accidents," HGN-072-NP, dated March 5, 1986.

  This submittal indicated that the small break LOCA inside the drywell was selected by HCOG as an appropriate sequence on which to base drywell equipment survivability analyses since large break sizes such as feedwater, steamline or recirculation line have a much smaller contribution to the total core melt frequency. Break location was chosen to be a steamline since this will result in the greatest energy addition to the drywell environment. Additionally, the break size chosen for analysis corresponds to the inside diameter of a safety relief valve. HCOG analyzed a drywell break accident in order to evaluate the effect of possible hydrogen combustion in the drywell on equipment and structures since containment failure was shown not to be a concern.

Subtask 10.6: Complete Blowdown Analysis

Purpose: This subtask was established to perform a blowdown analysis up to the point at which the reactor pressure vessel is depressurized using the MAAP code.

Reference:

- Letter from HCOG to NRC, "Report of CLASIX-3 Generic Analysis and Validation of CLASIX-3 Against 1/4 Scale Test Facility Data," HGN-092-P, dated June 10, 1986.

  Using realistic drywell initial conditions, and accident sequences leading to degraded core conditions, a drywell blowdown analysis up to the point at which the vessel has been pressurized was completed for selected break sizes.

  As documented in this submittal, the MAAP code was used in this analysis to define the time history of break flow into the drywell, mass and energy addition to the drywell, and the reactor pressure vessel flow split between the drywell and suppression pool.

Subtask 10.7: Define ADS Timing

Purpose: This subtask was established to examine all the potential factors which could determine when the operator actuates ADS.

Reference: See the report referenced in Subtask 10.6.

Section 4.0 of the referenced report discusses the relationship between ADS and drywell break flow and the timing relationship which determines when ADS would be expected to occur.

Subtask 10.8: Calculate Drywell Break - SRV Flow Split

Purpose: This subtask was established to define a realistic division of flow for steam and hydrogen between the drywell break and the SRV's which will be used as input to define the drywell thermal response.

Reference: See the report referenced under Subtask 10.6

During a drywell break accident, hydrogen can either be released through the line break to the drywell or through the SRVs which have been opened to depressurize the vessel.

As described in this report, MAAP automatically calculates the two flows as a function of the instantaneous conditions and provides them separately in the output for the first few minutes of the drywell break transient. To provide a realistic estimate of the flow split from reflood to the end of the hydrogen release, the MAAP results subsequent to actuation of ADS were used. These results provide an estimate of the fractions of the steam flow which will be discharged through the spargers as a function of the total steam flow rate.

Because of the low volumetric flow rate of hydrogen in comparison with steam, the hydrogen flow rate can be ignored for the period of interest. Above a steam flow of about 35 pounds per second the flow is critical and the flow split is constant with 91% of the steam being discharged through the spargers.

Subtask 10.9: Analyze Drywell/Containment Response using CLASIX-3

Purpose: This subtask was established to analyze the thermal response of the drywell and containment using CLASIX-3.

The composite release history from Subtask 10.8 above, which takes into account ADS timing and DWB-SRV flow split, the steam and hydrogen release history generated as part of Subtask 7.15, and the emergency procedure actions from Subtask 13.10 were inputs into this analysis.

Reference:

- See the reports referenced under Subtask 10.6 and 8.9H

The CLASIX-3 analyses documented by these reports used the blowdown history from Subtask 10.8 and appropriate combustion parameters for the drywell. These analyses also accounted for the effects of drywell bypass leakage on the wetwell and upper containment response. Deflagrations were not predicted to occur in the drywell for the base case. One deflagration was predicted to occur in the 2 inch pipe break sensitivity study. These analyses will allow HCOG to determine if inverted diffusion flames can be established at the exit of the CGCS compressor or from other oxygen sources in the drywell.

Subtask 10.12: Define Criteria for Existence of Inverted Diffusion Flames

Purpose: This subtask was established to enable assessment of the potential for the formation of inverted diffusion flames within Mark III containments.

Reference:

- Letter from HCOG to NRC, "Criteria for Existence of Inverted Diffusion Flames in the Drywell," HGN-091-NP, dated June 25, 1986.

Inverted diffusion flames are a phenomena which may occur in a hydrogen rich/oxygen lean environment. When oxygen is re-introduced in the presence of an ignition source, a diffusion flame results at the location of the oxygen source. Such a phenomena might occur in the drywell when the hydrogen concentration is high, oxygen is absent and air is subsequently introduced via vacuum breaker actuation or operation of the drywell mixing system. Resultant inverted diffusion flames (if they occur) could be of concern because of their possible impact upon the thermal environment.

This submittal defined a conservative set of conditions and criteria which must be present for inverted diffusion flames to exist. The letter concluded that any burning which occurs below a bulk hydrogen concentration of 19% and steam concentration of 81% can be characterized as weak discontinuous burns which should not challenge the survivability of equipment.

Subtask 10.29: Submit Criteria for Existence of Inverted Diffusion Flames to NRC

Purpose: This subtask was established to respond to the NRC's request that these criteria be submitted for staff review prior to completion of Subtasks 10.13, 10.18, or 10.19.

Reference:

- Letter from HCOG to NRC, "Task 10.12 Criteria for Existence of Inverted Diffusion Flames in the Drywell," HGN-091-NP, dated June 25, 1986.

  This submittal provided the NRC staff with the requested criteria as described under Subtask 10.12 above.

Task 11: EQUIPMENT SURVIVABILITY ANALYSIS PROGRAM

Subtask 11.1: Criteria for Equipment Survivability

Purpose: This task was established to define the criteria which will be used by HCOG to determine if a piece of essential equipment in the containment or drywell survives a degraded core accident.

Reference:

- Letter from HCOG to the NRC, "Generic Equipment Survivability List," HGN-084-NP, dated May 16, 1986.

This submittal provided the NRC with a generic list of equipment required to survive a degraded core hydrogen combustion event and a guide to be used by the HCOG utilities for the preparation of plant unique equipment survivability lists. Section 2.0 of this letter identified the criteria for specifying equipment required to survive degraded core accidents. The criteria used to determine if a piece of essential equipment in the containment or drywell can survive a degraded core hydrogen combustion event are based on the current equipment qualification program in accordence with NUREG-0588. If the pressure spike or differential pressure to which a component is exposed, as determined from containment deflagration analysis (acceptable per criteria identified in Task 8) is below the static qualification pressure, the equipment is expected to survive. The equipment is also expected to survive if it can be shown to be insensitive to pressure increases during a hydrogen burn. The equipment is expected to survive if: 1) the surface temperature for the equipment is calculated to remain below the qualification temperature; or 2) the critical component temperature remains below its qualification temperature; or 3) the equipment surface temperature remains below the designated survivability temperature, which is higher than the qualification temperature.

Subtask 11.2: Identify Equipment Required to Survive

Purpose: This subtask was established to develop a generic list of equipment required to survive a degraded core accident with significant hydrogen production.

Reference:

- See the letter referenced in Subtask 11.1 above.

This submittal provided the NRC staff with a generic list of equipment required to survive a degraded core accident. Five criteria were used in the selection of this equipment: 1) systems and components required to maintain the core in a safe shutdown condition, 2) equipment and structures required to maintain the integrity of the containment pressure boundary, 3) equipment and systems which must function to mitigate the consequences of the event, 4) instrumentation and systems which will be used to monitor the course of the event and provide guidance to the operator for initiating actions in accordance with the Emergency Procedure Guidelines, and 5) components whose failure could preclude the ability of the above systems to fulfill their intended function.

Subtask 11.6: Establish Drywell Thermal Profile for Analysis

Purpose: This subtask was established to define a time history of the thermal environment due to convective and radiative heat transfer for each piece of drywell equipment to be evaluated. This information will be used in Subtask 11.11 to predict the thermal response of equipment and components exposed to drywell conditions.

Reference:

- Letter from HCOG to NRC, "CLASIX-3 Generic Sensitivity Analysis," HGN-109-P, dated December 9, 1986.

- Letter from HCOG to NRC, "Report of CLASIX-3 Generic Analysis and Validation of CLASIX-3 Against 1/4 Scale Test Facility Data," HGN-092-P, dated June 10, 1986.

These documents provide the time-temperature profile for the drywell break scenarios as predicted using CLASIX-3.

Subtask 11.8: Establish Containment Deflagration Thermal Profile

Purpose: This subtask was established to define the thermal environment based on the analysis completed in Task 8.0, Deflagration Thermal Environment Definition. This information will be used in Subtask 11.11 to predict the thermal response of essential equipment and components.

Reference:

- See the report referenced under Subtask 11.6.

This document provides the time-temperature profile for deflagrations in the containment. The survivability analyses completed under Subtask 11.11 will utilize these temperature profiles as boundary conditions.

Subtask 11.24: Prepare Thermal Environment Definition Report

Purpose: This subtask was established to generate a report to the NRC staff, describing the methodology developed in Subtask 11.7. This report provided the methodology for determinating local gas temperatures and the approach used to calculate the convective and radiative heat transfer to equipment.

Reference:

- Letter from HCOG to NRC, "Submittal of Hydrogen Control Owners Group Diffusive Combustion Thermal Environment Methodology Definition Report," HGN-103-NP, dated July 30, 1986.

  This report was submitted to define the methods which will be used to determine the full scale plant containment thermal environments from the 1/4 scale test data. The full scale environmental conditions will ultimately be used as boundary conditions for the HEATING-6 computer code to analyze the response of containment equipment during postulated diffusive combustion events. Attachment 1 to this submittal described the generic methodology to be used to establish Mark III plant specific diffusion flame environments, which included a definition of how 1/4 scale test data will be used to define the component thermal environment and the approach to be used for radiant and convective heat transfer.

Subtask 11.25: Submit thermal Environment Definition Report to NRC

Purpose: This subtask was established to submit the report generated in Subtask 11.24 to the NRC staff.

Reference:

- See the report referenced under Subtask 11.24

Task 12: VALIDATION OF ANALYTICAL METHODS

Subtask 12.1: Develop CLASIX-3 Model of 1/4 Scale Test Facility

Purpose: This subtask was established to develop a model of the 1/4 scale test facility using the CLASIX-3 code in order to verify the conservatism of the overall analytical approach for defining deflagration thermal environments.

Reference:

- Letter from HCOG to NRC, "Report of CLASIX-3 Generic Analyses and Validation of CLASIX-3 Against 1/4 Scale Test Facility Data," HGN-092-P, dated June 10, 1986.

The actual QSTF design parameters were used for developing the CLASIX-3 model. These included such parameters as heat transfer surface areas, heat sink thicknesses and properties, spray and hydrogen flow rates, and compartment initial conditions just prior to hydrogen release.

Since the QSTF has no physical representation of the drywell it was not represented in the CLASIX-3 input model. The wetwell, intermediate volume and upper containment were modeled, however. The model also included a natural circulation "chimney" to represent the free flow path between the wetwell and the containment volume.

Subtask 12.2: Specify CLASIX-3 Input

Purpose: This subtask was established to determine the steam and hydrogen flows, compartment initial conditions, burn parameters, flow path parameters, spray system parameters, heat sinks and suppression pool level to define the input parameters for the CLASIX-3 analysis for the 1/4 scale test facility response.

Reference:

- See the report referenced in Subtask 12.1.

This submittal described the input parameters and their values which were used in the CLASIX-3 prediction of the 1/4 scale test facility response.

Two cases were chosen for analysis, one with containment sprays and one without sprays. The tests used to validate CLASIX-3 used hydrogen release histories with flow below the diffusion flame extinguishment limit.

Subtask 12.3: Complete CLASIX-3 Prediction

Purpose: This subtask was established to use the CLASIX-3 model of the 1/4 scale test facility developed in Subtask 12.1 with the input data file from Subtask 12.2 to predict the 1/4 scale test facility response.

Reference:

- See the report referenced under Subtask 12.1.

This submittal contained an analysis which predicted the containment gas temperatures, constituent gas concentrations, and containment pressure response for the low hydrogen flow rate tests completed in the 1/4 scale test facility.

Subtask 12.4: Design Complex Calorimeter

Purpose: The complex calorimeter was designed to permit the validation of the equipment survivability analysis methodology in the 1/4 scale test facility in various locations. This device was also designed to represent different types of equipment geometries such as rectangular and cylindrical components.

Reference:

- Letter from HCOG to NRC, "1/4 Scale Test Facility 3-D Complex Calorimeter," HGN-027-NP, dated February 13, 1985.

This submittal to the NRC was in response to a specific request made by the NRC staff for additional detailed information concerning the complex calorimeter. Design details on the complex calorimeter, its location in the quarter scale test facility and instrumentation located near the calorimeter were provided to the NRC staff via this letter.

Subtask 12.5: Prepare Model of Complex Calorimeter

Purpose: In order to predict the response of the complex calorimeter using the modeling instructions and format specified for the survivability analysis code established in Subtask 11.3, a model of the complex calorimeter was prepared.

Reference:

- Letter from HCOG to NRC, "Submittal of Diffusive Combustion Heat Transfer Methodology Validation for Equipment Survivability in Mark III Containments," HGN-105-P, dated August 29, 1986.

This submittal provided the NRC staff with the details of the complex calorimeter model development.

Subtask 12.6: Compare CLASIX-3 Predicted Results with Measured Results

Purpose: This subtask was established to compare measured test results from the 1/4 scale test facility with CLASIX-3 predictions of temperatures, pressures and gas concentrations in the wetwell, intermediate volume and upper containment.

Reference:

- Letter from HCOG to NRC, "Report of CLASIX-3 Generic Analyses and Validation of CLASIX-3 Against 1/4 Scale Test Facility Data," HGN-092-P, dated June 10, 1986.

This submittal documented a comparison of the CLASIX-3 predictions of temperatures, pressures and gas concentrations with actual results from two scoping tests. The temperatures measured locally in the facility were combined to produce volume weighted average temperatures which were compared to global temperatures predicted by CLASIX-3. Because of the conservative nature of the CLASIX-3 model and the burning phenomenon it simulates, average temperatures higher than the two scoping tests resulted for the CLASIX-3 predictions as anticipated. The two base line temperatures were, however, very similar, indicating that the modified CLASIX-3 adequately models the QSTF.

Similarly, a comparison of measured pressures with those predicted by CLASIX-3 also indicates that CLASIX-3 closely models the actual test results but in a conservative manner.

Gas concentrations predicted by CLASIX-3 also compared favorably with the measured results from the two scoping tests used in the comparison.

Subtask 12.9: Apply measured Diffusion Flame Environments to Complex Calorimeter Model

Purpose: This subtask was established to determine the diffusion flame thermal environments in the vicinity of the complex calorimeter and calculate the thermal response of the calorimeter.

Reference:

- See the report referenced under Subtask 12.5.

The application of diffusion flame thermal environments to the complex calorimeter was described in this report.

Subtask 12.10: Compare Measured Results with Thermal Response Predictions

Purpose: This subtask was established to compare the data from Subtask 9.23, which defines the measured responses of the complex calorimeter in the 1/4 scale test facility to diffusion flames, with the predicted responses of the model in Subtask 12.9 to assess whether the predicted response is conservative.

Reference:

- See the report referenced under Subtask 12.5.
  The measured response of the complex calorimeter was compared with the results of HEATING-6 calculations for the complex calorimeter.

  As described in the referenced report, the predicted response of the complex calorimeter was conservative compared to the measured responses. Thus validation of the techniques and assumptions used to construct the model and the assumptions used in defining the thermal environments was achieved.

Subtask 12.13: Prepare Final Report on Methodology Validations

Purpose: This subtask was established to provide the NRC with a report documenting the validation of the methodology for analyzing equipment response in a diffusion flame environment. This report also demonstrated the conservatism in previous deflagration thermal environment definitions.

Reference:

- See the report referenced under Subtask 12.5

  As described in the referenced report, HEATING-6 calculations of the complex calorimeter response (methodology developed under Subtask 11.24) were compared with the measured response of the device under test conditions in the QSTF. The predicted response of the complex calorimeter was shown to be conservative when compared to the measured response. Therefore, this report provided the validation of the equipment response analysis methodology developed for a diffusion flame environment.

Subtask 12.14: Submit Final Report on Methodology Validation to NRC

Purpose: This subtask was established to formally submit the report prepared under Subtask 12.13 to the NRC staff.

Reference:

- See the report referenced under Subtask 12.5.

Task 13: <u>COMBUSTIBLE GAS CONTROL EPG</u>

Subtask 13.1: Draft Emergency Procedure Guideline

Purpose: This subtask was established to develop an emergency procedure guideline (EPG) for hydrogen control using the methodology from NUREG-0737 for symptom-based emergency procedures.

Reference:

- Letter from HCOG to NRC, "Combustible Gas Control Emergency Procedure Guideline," HGN-064-NP, dated November 12, 1985.

  This submittal provided the NRC staff with the Combustible Gas Control Emergency Procedure Guideline (EPG) developed by the Mark III Containment Hydrogen Control Owners Group.

  The EPG provided guidance on operator actions regarding use of hydrogen igniters, drywell hydrogen mixing systems, thermal recombiners and containment venting to assure structural integrity is maintained and that equipment which is required to survive these transients remains functional for hydrogen combustion or deflagrations.

- Letter from HCOG to NRC, "Combustible Gas Control Emergency Procedure Guideline," HGN-086-NP, dated June 3, 1986.

  This submittal provided the NRC staff with a revised version of the EPG which addressed NRC concerns identified during a meeting between HCOG and NRC on December 18, 1985.

Subtask 13.9: Determine Spray Timing

Purpose: This subtask established the expected timing for actuation of containment sprays based upon the thermocouples which would be used to define bulk average containment atmosphere temperature, and the time required for the spray pumps to deliver water to the spray headers.

Reference:

- Letter from HCOG to NRC, "Spray Actuation Criteria for the QSTF," HGN-074-NP, dated February 17, 1986.

  This submittal provided the NRC staff with a discussion of the timing for actuating containment sprays in the

1/4 scale test facility. The time required to actuate containment sprays is used in the 1/4 scale test procedures to control spray actuation during testing. Containment spray actuation timing was examined in the context of diffusive combustion thermal transients and the emergency procedures. The spray timing consists of three components: 1) the time before containment pressure or temperature exceeds the initiation points defined in the emergency procedures, 2) the time delay introduced by control room instrumentation and the operator recognition of the need to actuate sprays, and 3) the delay incurred because of the containment spray electromechanical system response time.

The locations of the test facility thermocouples used for spray actuation were representative of actual (full scale) plant thermocouples used for containment temperature monitoring.

Subtask 13.15: Develop Technical Justification for the Steps of the EPG

Purpose: This subtask was established to prepare a technical justification for each step of the Combustible Gas Control EPG.

Reference:

- Letter from HCOG to the NRC, "Appendix B to the Combustible Gas Control EPG," HGN-090-P, dated July 3, 1986.

  This document provides a technical justification for each step of the combustible gas control EPG. Each step is presented first, followed by a detailed discussion justifying the prescribed operator actions for the step.

- Letter from HCOG to the NRC, "Revision 2 to the Hydrogen Control Owners Group Combustible Gas Control Emergency Procedure Guideline and Supporting Appendices," HGN-110-P, dated December 1, 1986.

  Attachment 4 of this submittal consists of a revision to Appendix B of the Combustible Gas Control EPG which was transmitted in HGN-090-P. Appendix B was revised to reflect the changes to the CGCEPG described in Attachment 3 of HGN-110-P.

Subtask 13.16: Prepare Report on Action Limit Calculation Procedures and Example Curves

Purpose: This subtask was established to prepare a report detailing the procedure for calculating the action limits including the HDTL and HDOL curves for submittal to the NRC staff.

Reference:

- Letter from HCOG to NRC, "Revision 2 to the Hydrogen Control Owners Group combustible Gas Control Emergency Procedure Guideline and Supporting Appendices," HGN-110-P, dated December 1, 1986.

  Attachment 2 to the referenced submittal provided the methodology for calculating the HDTL curve including example calculations and the resulting HDTL curve.

  HCOG concluded that since the HDOL and HDTL results are nearly the same using conservative assumptions, and test data have demonstrated cable survivability at higher hydrogen concentration burns than allowed by HDOL, elimination of the HDTL is justified. The HDOL will be used for determining required operator actions. This approach simplifies the CGCEPG and thus has a favorable impact on the procedures from a human factors standpoint.

  Attachment 5 to this submittal consists of Appendix C to the Combustible Gas Control emergency Procedure guideline. Appendix C identifies the methodology used in calculating the HDOL curve. Example calculations and the resulting HDOL curve have also been provided with Appendix C.

Subtask 13.17: Submit Action Limit Calculational Procedure and Example Curves to NRC

Purpose: This subtask was established to submit the report prepared under Subtask 13.16 to the NRC staff for their review.

Reference:

- See the letter referenced under Subtask 13.16

  The referenced letter transmitted the action limit calculation procedure and example curves to the NRC.

Subtask 13.18: Prepare Report on Assumptions in Analysis and EPG

Purpose: This subtask was established to document in a report to the NRC staff the results of HCOG's review of the assumptions made in the analysis and in the EPG as detailed in Subtask 13.10.

Reference:

Letter from HCOG to NRC, "Evaluation of Emergency Procedure Guidelines Operator Actions Against HCOG Assumptions for Analysis of a Hydrogen Generation Event," HGN-104-NP, dated August 28, 1986.

The primary objective of the study documented by this submittal is to assure that assumptions used by HCOG for analyzing hydrogen production and containment response to a Hydrogen Generation Event (HGE) are consistent with operator actions directed by Revision 3 of the generic Emergency Procedure Guidelines (EPG's) and Revision 1 of the HCOG Combustible Gas Control EPG. Potential discrepancies identified when comparing probable operator actions from the EPG's to HCOG assumptions were evaluated and found to be minor in nature. Therefore, the conclusion of this report was that the assumptions made by HCOG for analysis and testing of an HGE are consistent with EPG operator actions.

Subtask 13.19: Submit Report on Assumptions in Analysis and EPG to NRC

Purpose: This subtask was established to submit the report prepared in Subtask 13.18 to the NRC staff for their review.

Reference:

- See the report referenced under Subtask 13.18.

Task 14: NEVADA TEST SITE DATA EVALUATION

Subtask 14.1: Identify all NTS Tests Completed During Program

Purpose: This subtask was established to conduct a review of all NTS test data to determine which tests were applicable to the Mark III containment.

Reference:

- Letter from HCOG to NRC, "Nevada Test Site Data Evaluation," HGN-100-NP, dated July 31, 1986.

HCOG committed to review the Nevada Test Site test results and evaluate them for applicability to the Mark III containment. This submittal summarized that review and evaluation by HCOG. HGN-100-NP explained that the NTS tests reviewed by HCOG consisted of 40 separate tests in two general classes. Twenty-four tests involved pre-mixed combustion. Sixteen tests were conducted which involved continuous injection of hydrogen. HCOG studied the test data for all NTS tests to identify those warranting further evaluation.

Subtask 14.2: Summarize Test Data

Purpose: This subtask was established to assemble the EPRI NTS test data summaries for further evaluation.

Reference:

- See the letter referenced under Subtask 14.1.

As described in this submittal, summaries of test data and data plots from the NTS facility were obtained by HCOG. The test results were formalized and issued by EPRI in two reports:

1. "Large Scale Hydrogen Combustion Experiments," EPRI NP-3878 Research Project 1932-11, Final Draft 1986

2. "Large Scale Hydrogen Burn Equipment Experiments," EPRI NP-4354 Research Project 2168-3 Final Report, December 1985, Prepared by Westinghouse

Subtask 14.3: Identify Applicable Tests and Equipment used in Mark III Plants

Purpose: This subtask was established to identify those NTS tests selected in Subtask 14.1 and summarized in Subtask 14.2 to assess which tests provide pertinent information concerning assumptions used in licensing analyses or concerning behavior of equipment used in Mark III containments in hydrogen burn environments.

Reference:

- See the report referenced under Subtask 14.1

As documented in this submittal, the NTS facility was a large spherical volume not modeled to represent the multiple compartments that exist in the Mark III containments. Similarly, the NTS dewar did not attempt to model the Mark III features which would affect the combustion phenomena or the resulting thermal environments. Based upon these differences, the report concluded that the test results at NTS are not directly applicable to the Mark III containments or associated equipment.

Although HCOG concluded that the NTS tests represented substantially different environments from those postulated for Mark III containments, there were two sections from the NTS tests that could be further utilized in understanding the potential consequences of postulated hydrogen burns in a Mark III containment. The pre-mixed and continuous injection tests offered the opportunity to better understand and evaluate the different effects with regard to combustion of hydrogen in large test volumes.

Table 4-1 of the reference submittal provided the NRC staff with a comparison list of equipment in the NTS test facility with Mark III equipment and identifies which equipment is representative of that installed in the Mark III containments owned by members of HCOG.

Subtask 14.4: Determine Which Equipment Failed and Cause

Purpose: This subtask was established to examine the NTS equipment data to determine which equipment failures were applicable to HCOG member plants and to identify the apparent failure mechanisms.

Reference:

- See the letter referenced under Subtask 14.1

As documented in this submittal, the NTS data was examined to determine which equipment, was applicable to HCOG member plants, what NTS equipment failed and its apparent failure mechanism. Of particular interest was whether or not the failure mechanism was related to hydrogen combustion. Operability was defined as performance of a function (a mechanical motion, generation of a signal, or maintenance of a pressure). The equipment was monitored for operability before, during and after each burn test. No equipment failures in equipment applicable to Mark III containment plants occurred due to hydrogen combustion. HCOG therefore concluded that the NTS data indicates that equipment in a Mark III containment can be expected to survive CLASIX-3 predicted volumetric burns.

Subtask 14.5: Identify Any Differences Between Licensing Assumptions and NTS Results

Purpose: This subtask was developed to compare the conclusions derived from the evaluation of the NTS test series with the assumptions used for the HCOG CLASIX-3 analysis in order to identify differences which might impact those assumptions.

Reference:

- See the letter referenced under Subtask 14.1.

This submittal documented HCOG's comparison between conclusions drawn from the NTS evaluation and those used by HCOG. Specifically, this comparison involved NTS results in five different areas:

1) The concentration at which ignition occurs
2) Burn durations observed in the facility
3) Burn completeness for various conditions
4) Effects of steam injection on combustion
5) Effects of flames and sprays on combustion

HCOG concluded in this submittal that the NTS tests were not directly applicable to the Mark III containments. However, since the tests were of a much larger scale than previously conducted tests in the industry, they provided an opportunity to reevaluate assumptions used in previous analyses.

Specific differences identified in the NTS evaluation were evaluated for their effect on previous analytical work by HCOG. This information was used in Subtask 8.8 to determine if additional generic CLASIX-3 containment response analyses with modified assumptions were required.

Subtask 14.6: Submit Evaluation Results to the NRC

Purpose: This subtask was established to provide the results of the HCOG review of NTS data and the assessment of this data to the NRC.

Reference:

- See the letter referenced under Subtask 14.1

  This submittal provided the NRC staff with a report which documented completion of Subtask 14.1 through 14.6 as described above.