HYDROGEN CONTROL PROGRAM PLAN
FOR
PERRY NUCLEAR POWER PLANT

CLEVELAND ELECTRIC ILLUMINATING COMPANY

1.0 INTRODUCTION

Due to the event at Three Mile Island, the Nuclear Regulatory Commission (NRC) has required that all nuclear power plants, with a Mark III containment or ice condenser containment, applying for an operating license to consider the effects of hydrogen generation in excess of that required by the original design criteria of 10 CFR 50.44. In order to respond to these evolving requirements, Cleveland Electric Illuminating Company (CEI) has initiated a program for upgrading the capability of the Perry Nuclear Power Plant (PNPP) to mitigate the consequences of postulated hydrogen releases as specified by the NRC.

The purpose of this program document is to provide a management guide to the CEI hydrogen control program from program inception through its anticipated conclusion. The program document provides individual task descriptions and an overall program licensing schedule. It provides a single source reference defining the hydrogen program requirements identified by CEI as necessary to resolve the issue with the NRC.

CEI believes that completion of the program outlined in this program document will resolve the hydrogen issue in the most expeditious manner.

2.0 PROGRAM OVERVIEW

The NRC has required as a condition of licensing that nuclear power plants with Mark III containments design systems and perform supporting analyses to deal with significant amounts of hydrogen. Specifically, the NRC requires that CEI consider hydrogen releases into the containment resulting from a metal-water reaction of up to 75% of the zirconium fuel cladding.

Hydrogen release quantities associated with 75% clad-water reaction are well in excess of those considered in the original PNPP design basis. A major design analysis effort was therefore initiated to develop a hydrogen mitigation system and to demonstrate that there are sufficient design margins available in the PNPP containment and equipment to accommodate these new releases.

The necessary design, development and analysis effort has been organized into 9 interrelated tasks. Those tasks which have been completed are included as necessary to fully address the ongoing or remaining activities. Detailed descriptions of each task and subtask are given in Section 3.0. A schedule for completion of major licensing tasks is provided in Section 4.0.

The following paragraphs discuss briefly the major contents of each task:

Task 1.0 - Selection of Hydrogen Control System

Based on a review of previous studies on the advantages and disadvantages of alternative systems, CEI selected a Hydrogen Ignition System for PNPP.

Task 2.0 - Design of Hydrogen Ignition System

Establish design criteria and design the HIS for PNPP, including the initiation logic, controls and instrumentation. This task includes igniter qualification, development of Technical Specifications, and performance of preoperational tests.

Task 3.0 - Containment Ultimate Capacity Analysis

Perform analysis to determine the ultimate pressure capability of the PNPP containment during a postulated hydrogen generation event (HGE). In addition, perform evaluations to determine the potential for local detonation, and if necessary, establish the capability of the containment.

Task 4.0 - Containment Response Analysis

Select a containment response code and perform analysis to determine the PNPP containment response to postulated hydrogen deflagrations.

Task 5.0 - Develop Mechanistic Scenarios and Hydrogen Release Rates

Select a degraded core model; define parameters, criteria, and limits for the degraded core model; develop a postulated mechanistic accident sequence; and generate postulated degraded core hydrogen release rates.

Task 6.0 - Equipment Survivability Analysis

Determine the safety equipment necessary to survive a postulated HGE, define base case temperature and pressure environments, and demonstrate equipment responses within acceptable limits or identify alternative protective measures.

Task 7.0 - Hydrogen Combustion Testing and Analysis

Identify outstanding issues requiring resolution by testing and perform appropriate tests. Define PNPP quarter-scale testing objectives, develop a test matrix and complete quarter-scale testing to determine thermal profiles for diffusion flames. Evaluate the effects of testing results on previous analyses.

Task 8.0 - Resolve NRC Licensing Issues

Identify all potential licensing issues applicable to the PNPP from previous MP&L and HCOG efforts and develop appropriate responses for PNPP. Meet with NRC to establish a licensing schedule and submit documentation to resolve NRC concerns in accordance with the established schedule.

Task 9.0 - Develop Emergency Procedures for Control of Combustible Gas

Support the BWROG-EPC to finalize an emergency procedure guideline, develop a PNPP emergency procedure, calculate plant specific limits, and conduct operator training.

3.0 TASK AND SUBTASK DESCRIPTIONS

Task 1.0 - Select Hydrogen Control System

The NRC's interim rule published on October 2, 1980 required analysis and system design to consider generation of significant amounts of hydrogen, up to 75% metal-water reaction. The interim rule also specified studies should be performed to select a hydrogen control system which considered the advantages and disadvantages of alternative system concepts.

Previous generic industry studies and several studies performed by Mississippi Power and Light for Grand Gulf Nuclear Station, indicated that a hydrogen ignition system was an adequate system to migitate the consequences of a postulated hydrogen generation event. Based upon CEI's evaluation of these studies, an HIS was selected for PNPP.

Subtask 1.1 - Review Previous Industry Studies on Alternative Systems

Description:

The proposed NRC requirements are to design a system to control significant amounts of hydrogen well in excess of the original design basis by performing studies which evaluate the advantages and disadvantages of alternative system concepts. CEI began the process of selecting a hydrogen control system by reviewing previous industry studies and experience in this area.

Early studies performed by Tennessee Valley Authority and Duke Power Company for Westinghouse ice condenser containments were useful in verifying the NRC's goals for hydrogen control systems, providing a reasonably comprehensive listing of potentially viable hydrogen control systems, and establishing most of the important selection criteria. Additional evaluations used by CEI included studies of alternative hydrogen control concepts by IDCOR.

Subtask 1.2 - Review of GGNS Reports on Alternative Hydrogen Control Systems

Description:

MP&L, in support of GGNS Licensing, has performed several studies to evaluate the advantages and disadvantages of alternative hydrogen control systems. Based upon these studies, MP&L selected an HIS. These studies are more directly applicable to a Mark III containment.

As part of the final review of generic industry evaluations, CEI reviewed MP&L evaluations, and criteria for selection of an HIS. The criteria used by MP&L were based primarily on the ability of the system to control significant amounts of hydrogen, the effect on plant operation due to inadvertant operation, cost effectiveness, and availability of equipment. The specific criteria used included:

1. Ability to maintain hydrogen concentrations inside the containment and the drywell below detonable limits.

2. Must preclude local detonations.

3. Operation of system does not damage plant equipment or decrease plant margin of safety.

4. System must be reliable, controllable, testable, and operable assuming a variety of scenarios.

5. Operation of the system must not endanger the health and safety of the public.

6. Equipment must be available and capable of surviving the postulated accident while remaining functional.

7. After meeting criteria 1-6 above, the system should create minimal construction/licensing schedule impacts and entail the lowest cost.

Using these criteria, several systems were evaluated by MP&L in order to select a hydrogen ignition system. The systems considered were:

1. Hydrogen Inigition System

2. Pre-inerting

3. Halon deluge

4. Purge/vent

5. Waterfog/spray

6. Carbon dioxide deluge

7. Oxygen depletion

8. Additional recombiners

Subtask 1.3 - Establish PNPP Criteria and Basis for Selection of Hydrogen Control System

Description:

Based upon a review of previous industry and MP&L experience, CEI established the selection criteria for the Hydrogen Control System for PNPP. The criteria established were consistent with those of GGNS described in Subtask 1.2. Based upon this criteria applied against the alternative systems considered, CEI selected a Hydrogen Ignition System for PNPP.

Task 2.0 - Hydrogen Ignition System Design

The detailed design of the HIS must be sufficient to allow igniter installation and testing prior to plant startup (Full Power License). Design of the HIS includes developing the design criteria, specifying igniter device requirements, selecting the igniter and igniter locations, designing the igniter support system, controls and instrumentation, igniter qualification and preoperational testing.

Subtask 2.1 - Develop Design Criteria including Reliability Goals

Description:

In order to develop a detailed hydrogen ignition system design which meets all of the necessary requirements, the design criteria must be established. Design criteria which must be considered include: igniter location criteria, redundancy requirements, separation criteria, initiation criteria, testability, seismic requirements, power supply reliability, ability to operate through and after pool swell and other dynamic events, equipment qualification requirements, power supply reliability requirements, instrumentation and control requirements, etc. Design criteria were established based on a review of previous industry experience, particularly the criteria developed by other Mark III containments such as GGNS, a review of outstanding GGNS issues relevant to design considerations such as testability and reliability, and a determination of any PNPP unique features requiring special design considerations.

Subtask 2.2 - Specify Igniter Device Requirements

Description:

The functional requirements of the igniter must be specified along with the environmental conditions under which they will function, functional time duration, loading conditions, etc. In particular, the igniters must maintain a surface temperature which will sustain hydrogen combustion for all power supply voltage requirements, be capable of operating for a duration which will assure mitigation of any expected hydrogen generation event, and be able to withstand several imposed environments. Igniter device requirements were established based upon the experience and criteria established at other Mark III containments with due consideration for PNPP unique features.

Subtask 2.3 - Evaluate Industry Experience

Description:

Several plants with ice condenser containments and GGNS rely on igniters to mitigate postulated large hydrogen releases. In order to identify candidate igniters for PNPP, the studies and tests performed by these utilities were reviewed to assess igniter performance and applicability to PNPP.

Subtask 2.4 - Evaluate Against Requirements and Select Igniter

Description:

The candidate igniters were evaluated against the requirements specified in Subtask 2.2. Specifically, their ability to function continuously for the required time duration with the specified surface temperature in a post-LOCA environment of steam air and hydrogen and to withstand the containment sprays, pool swells, and other phenomena associated with the accident, including multiple burns will be assessed. The key part of the assessment includes a review of tests previously conducted by Tennessee Valley Authority, Duke Power Company and in particular, Mississippi Power and Light. Based on these evaluations, an igniter device was selected which meets the requirements identified.

Subtask 2.5 - Identify Igniter Location

Description:

Based on the criteria established in Subtask 2.1, preliminary igniter locations have been identified. In accordance with the criteria, the locations were selected in order to assure a maximum distance between igniters assuming all ESF power available and failure of one ESF power division, such that local pocketing of hydrogen is avoided. In addition, 2 igniters, 1 powered from each ESF division, are provided in each room where hydrogen could be postulated to pocket. These location requirements should be met with due consideration for ability to support the igniter seismically.

Subtask 2.6 - Specify Initiation Logic, Controls and Instrumentation

Description:

Following a review of postulated hydrogen generation event scenarios and proposed emergency procedure guidelines for dealing with combustible gas, the igniter initiation logic and the controls and instrumentation for the operators' use should be specified.

Subtask 2.7 - Design Power Supply, Instrumentation and Controls, and Support System

Description:

In accordance with the design criteria specified in Subtask 2.1 and the instrumentation and controls requirements identified in Subtask 2.6, the power supply, instrumentation and controls, and support system for the hydrogen ignition system will be designed. The supports are being designed for the criteria developed in Subtask 2.1 to withstand seismic, hydrodynamic, and pool swell loads as necessary.

Subtask 2.8 - Install HIS

Description:

The igniters and associated power supply and control cables are being installed in the PNPP containment and drywell in accordance with specified design criteria. The igniter locations will be finalized based on final adjustments in location which may be required to reflect local geometry and support member availability.

Subtask 2.9 - Specify HIS Environment and Quality Igniters

Description:

Identification of environmental conditions for the igniter and associated transformers, starters, power supply equipment, and cables have been developed. Lifetime (age), temperature, pressure, radiation, humidity, spray conditions and other pertinent parameters for both normal and accident conditions have been identified. The specified environment will be compared to environmental test reports for other comparable equipment used at GGNS which have been qualified. If the specified environmental conditions are below the GGNS equipment environmental test conditions, the equipment will be procured and used with no additional test or analysis necessary. If the PNPP specified environmental conditions exceed the GGNS test conditions, then additional analyses or testing will be identified and performed.

Subtask 2.10 - Develop Technical Specifications

Description:

Based upon the design criteria and system functional requirements, a set of proposed Technical Specifications will be developed which will assure that the

HIS will perform its intended function during an HGE. The Technical Specifications will include Limiting Conditions for Operation, Action Statements, and Surveillance Requirements. The LCOs will define the operational conditions for which the HIS is required and the number of igniters required to be operable in the drywell and containment for the HIS to meet functional requirements. Action Statements will be provided if Limiting Conditions for Operation cannot be met. Surveillance requirements will be provided which define periodic test requirements and test frequencies to ensure that the HIS will perform its intended function.

Subtask 2.11 - Develop Pre-Operational Test Procedures

Description:

Preoperational test procedures will be developed for testing the HIS against design requirements prior to startup. At a minimum, each igniter will be energized and the surface temperatures will be measured to verify the minimum temperature specified to assure adequate combustion.

Subtask 2.12 - Conduct Preoperational Tests

Description:

Following complete installation of the HIS and development of the preoperational test procedures, the preoperational testing will be conducted. Following completion of the test, the test results will be evaluated and any test exceptions justified prior to startup.

Task 3.0 - Containment Ultimate Capacity Analysis

Description:

In a letter dated December 19, 1980, the NRC requested nuclear power plants with Mark III containments perform an ultimate capacity analysis on the containment structure. The NRC requested that Mark III utilities determine the maximum pressure which the containment could withstand before failure. This analysis was considered by the NRC as a major factor for approving the selection of hydrogen mitigation systems, since most of the candidate mitigation systems could potentially produce pressures at or above the containment design pressure of 15 psig. The containment structural margins available to accommodate these higher pressures is therefore an important issue in assessing a systems acceptability.

Subtask 3.1 - Complete Ultimate Capacity Analysis

Description:

Based on the criteria and load combinations established, the performance of the ultimate capacity analysis was performed. The model of the containment cylinder and dome was developed, consistent with previous objectives, such that response of significant components can be determined.

Subtask 3.2 - Determine Containment Limiting Section

Description:

The containment structure is comprised of various structural sections or components, certain of which will reach nonlinear or ultimate states prior to the general failure of the structures. Since these components control the limiting response of the containment, they must be identified in order to adequately model the containment to determine the pressure at which the containment will fail.

Subtask 3.3 - Ultimate Capacity, Local Components

Description:

The ultimate capacity of local components should be determined separately from the ultimate capacity of the containment structure. Local components which must be reviewed include the drywell head, the air locks, the equipment hatches, penetration assemblies, and containment penetration piping. The analyses of the local components should be initially based on specified materials. The capabilities of these components should be evaluated relative to the ultimate structural capacity of the containment. Should their capacities be determined to be less than that of the containment, consideration of using actual material properties should be made.

Subtask 3.4 - Prepare Ultimate Capacity Report

Description:

Upon completion of the initial evaluation of the ultimate capacity of the containment, a report will be submitted specifying the methodology, criteria, scope, and results of the analysis. Any limiting section/components will be clearly specified and its failure mode described.

Subtask 3.5 - Containment Negative Pressure Analysis

Description:

In addition to consideration of ultimate positive pressures to which the containment may satisfactorily respond, the potential for negative pressures will be evaluated. Specifically, the timing, nature, and magnitude of the pressures should be established and compared to existing design pressures. Should anticipated pressures exceed design limits, consideration to generic margins which may exist in the design should be given prior to performing a new analysis. Existing industry and government data relevant to these potential margins should be reviewed.

Subtask 3.6 - Drywell Positive and Negative Pressure Analysis

Description:

In addition to consideration of ultimate positive pressures to which the containment may satisfac.orily respond, the potential for positive or negative pressures in excess of drywell design pressures will be evaluated. Specifically, the timing, nature, and magnitude of the pressures should be established and compared to existing design pressures. Should anticipated pressures exceed design limits, consideration to generic margins which may exist in the design should be given prior to performing a new analysis. Existing industry and government data relevant to these potential margins should be reviewed.

Subtask 3.7 - Local Detonations

Description:

The design of the hydrogen control system and the characteristics of the Perry containment will insure the burning of hydrogen prior to reaching local concentrations (pockets) of a magnitude capable of producing local detonations. Based upon design of the HIS, other unique PNPP features, existing analysis, and existing test results, evaluations will be performed to justify that local detonations are not credible.

Task 4.0 - Containment Response Analysis

Description:

Postulated hydrogen releases considered by this hydrogen control program are beyond the design basis for nuclear power plants. A familiar and extensive library of verified analytical codes for analysis of the containment response to such an event is not therefore available. Codes which could be used must be identified, developed, and/or adapted to perform the analysis of hydrogen burns to Mark III containments such as PNPP. They must, in addition, be verified as accurately predicting the containment response consistent with the limitations inherit in the model assumptions and input data. Complete documentation of the code and verification procedures must be provided for regulatory review.

Previous analysis and testing performed by the Hydrogen Control Owners Group, has identified the potential for standing diffusion flames on the suppression pool at high hydrogen release rates. At the present time, a computer code does not exist for accurately predicting the local temperatures for such hydrogen burning. Therefore, containment analysis issues related to diffusion flames will be resolved as part of the 1/4 scale testing discussed in Subtask 7.0.

Subtask 4.1 - Evaluate Available Computer Codes and Complete Code Selection

Description:

MP&L early in their efforts, surveyed available computer codes in the nuclear power industry to determine the best computer code for analysis of a postulated hydrogen deflagration in a Mark III containment. It was found that no available code adequately modeled the hydrogen burn in a compartmentalized pressure supression Mark III containment. However, the CLASIX code developed by Offshore Power Systems (OPS) for modeling hydrogen burn phenomena in a ice condenser containment could be adapted for Mark III containments. Although the CLASIX code had limitations, it had received relative acceptance by the NRC.

The CLASIX-3 code was used by HCOG (using GGNS containment parameters) for submittal of many sensitivity studies to resolve deflagration issues with the NRC. Therefore, much generic work has been completed regarding hydrogen deflagrations in a Mark III containment. CEI in order to take credit for this generic work, to minimize plant specific containment analysis, and to prevent the need for additional NRC computer code review, selected the CLASIX-3 computer code for performing plant specific base case containment analysis.

Subtask 4.2 - Modify Code for PNPP Features

Description:

The CLASIX-3 code is a modification of the CLASIX code to incorporate Mark III features. The Mark III used as a model was GGNS. There are few differences between GGNS and PNPP which could affect the CLASIX-3 code results, however, a review of the code was performed to evaluate if any modifications were necessary to incorporate PNPP features. In addition, the CLASIX-3 input parameters, such as heat sinks, spray flow rate, drywell purge flow rate, etc., were defined and provided in order to run PNPP specific containment analyses.

Subtask 4.3 - CLASIX-3 Verification

Description:

A significant amount of work has already been performed in verification of CLASIX and CLASIX-3. Both codes analyzed the pressure and temperature response of the containment during hydrogen combustion transients. However, other containment pressure and temperature transients, such as pipe break, can also be modeled in CLASIX or CLASIX-3. A small pipe break in the containment was modeled and analyzed with CLASIX. The same accident was modeled in a multi-compartmented code TMD and in the single compartment code COCO. The analytical results from TMD and COCO, indicated that CLASIX provides reasonable containment temperature and pressure responses. In addition, some of the unique portions of CLASIX were verified with hand calculations, including suppression pool dynamics and mass energy relationships.

Following the initial development of the GGNS model for CLASIX-3, several postulated hydrogen burn cases were analyzed to provide assurance that CLASIX-3 produces reasonable and consistent results. In addition, the sensitivity of the containment response to parameter variations was scoped and particularly sensitive parameters requiring additional study were identified as part of the process of verifying CLASIX-3. On March 18, 1983, the Hydrogen Control Owners Group submitted topical reports for CLASIX-3 which included detailed description of the verification process.

Subtask 4.4 - Define Base Case Transients/Scenarios to be Evaluated

Description:

The probability of an accident or transient which could lead to significant amounts of hydrogen generation and release into the containment is incredibly small. After early efforts by MP&L and the HCOG to develop a completely deterministic scenario which leads to significant amounts of hydrogen failed, it was decided that a scenario would have to be developed based on both deterministic and probabilistic methods. As a result of BWR risk assessments which indicated the highest probability for degraded core came from a transient initiated event, a stuck open relief valve transient was selected as the base case for analysis of postulated hydrogen burns in a Mark III containment. However, in order to envelope the two basic release points and address all major hydrogen combustion phenomena in a Mark III containment, a drywell break scenario was also selected for further analysis.

Various sensitivity studies were performed which addressed variations in the most significant parameters which would affect the results of containment response and involve both postulated scenarios, a stuck open relief valve and drywell break event. The sensitivity studies were completed and submitted to the NRC by the HCOG in January of 1982.

Since the sensitivity studies are performed only to bound the uncertainty in the analysis and to determine the effect of key parameters on the results of the analysis, the sensitivity studies are applicable to PNPP. Therefore, it is only necessary to analyze a base-case drywell break and stuck open relief valve scenario in order to develop the PNPP specific pressure and temperature response curves for later analysis, such as equipment survivability.

Subtask 4.5 - Define Burn Parmeters

Description:

Following identification of the transient/scenarios to be evaluated, the burn parameter inputs must be established for the base case analysis. Some of the more important input burn parameters include hydrogen volumetric concentration (v/o) for ignition, hydrogen v/o for propagation to other areas of the containment, burn fraction, minimum oxygen v/o for ignition, minimum oxygen v/o to support combustion, flame speed, hydrogen and mass-energy release rates, etc.

Subtask 4.6 - Conduct Base Case CLASIX-3 Analysis

Description:

Following verification of the code, definition of the transients and input burn parameters, the PNPP CLASIX-3 analysis was performed. Results of the CLASIX-3 analysis are in the form of pressure and temperature plots for the drywell, wetwell and upper containment areas. Also provided are differential pressure curves between the drywell and containment and oxygen, nitrogen, and hydrogen concentrations in all three compartments. These results will be used in later analyses such as equipment survivability.

Subtask 4.7 - Prepare Containment Response Report

Description:

All previous analyses performed under Task 4.0 will be summarized in a containment response report. The report will include a description of all analyses conducted, the results of the base case CLASIX-3 analysis, a description and results of any sensitivity studies conducted, identification of any issues and the methods utilized to resolve the issues, the results of all analyses with key assumptions and input parameters which were used and evaluation of analysis results.

Subtask 4.8 - Resolve Outstanding Containment Response Issues

Description:

As a result of previous work by NRC and the HCOG, proper characterization of the drywell combustion phenomena and temperatures has been identifed as a potential issue. A review of the base case PNPP CLASIX-3 analysis and other analyses conducted by HCOG or MP&L will be conducted to identfy if any additional analysis or testing is necessary to characterize the drywell hydrogen combustion phenomena.

Subtask 4.9 - Evaluate Results of 1/4 Scale Combustion Testing for Effect on Containment Analysis

Description:

At the present time the 1/4 scale test facility is scheduled to be completed and production tests conducted by early 1985. The primary objective of the testing is to develop thermal profiles for areas in the containment as a result of diffusion flames. However, hydrogen release histories used for testing in the 1/4 scale facility will include portions of time when deflagrations are the dominant mode of hydrogen combustion. Therefore, the results of the 1/4 scale testing will be evaluated to determine the effect on previous containment analysis.

Task 5.0 - Develop Mechanistic Scenarios and Hydrogen Release Rates

Description:

As discussed under Task 4.0, initial efforts by MP&L and HCOG to develop a determinstic scenario of a postulated transient or accident which resulted in generation of significant amounts of hydrogen failed. Therefore, a combination of deterministic and probabilistic methods were utilized to develop a base case scenario. Since computer codes for modeling degraded cores and generating hydrogen release rates were not readily available, MP&L and HCOG utilized the only available code, MARCH, which had been utilized by Battelle Columbus as part of the RSSMAP effort. The release rates from MARCH were known to be extremely conservative and had to be artificially modified after the initial part of the transient to account for core recovery. Early efforts by MP&L and HCOG showed that containment integrity was maintained and equipment survived for hydrogen deflagrations analyzed by CLASIX-3, even with the conservative base case MARCH hydrogen release rates and sensitivities performed with multiples of the base hydrogen release rates.

Additional effort by the HCOG identified the possibility of an additional type of burning above the suppression pool. The potential for such diffusion flames and the characteristics of the flame are dependent upon a set of variables including hydrogen release rates. Therefore, in order to improve the hydrogen release histories; the HCOG initiated efforts to evaluate, select, and modify if necessary, computer codes for modeling degraded cores.

Subtask 5.1 - Evaluate Available Codes for Modeling Degraded Cores

Description:

A combination of deterministic and probabilistic methods were initially utilized by MP&L and HCOG to develop a postulated base case scenario for CLASIX-3 analysis. Since computer codes for modeling degraded cores and generating hydrogen release rates were not readily available, MP&L and HCOG utilized the only available code, MARCH, which had been utilized by Battelle Columbus as part of the RSSMAP effort. The release rates from MARCH were known to be extremely conservative and had to be artificially modified after the initial part of the transient to account for core recovery. These extremely conservative release rates were used for the PNPP base case CLASIX-3 analysis.

As part of IDCOR, a significant amount of work had already been conducted in evaluating degraded core models. As part of the IDCOR effort, a new model, BWR Core Heat-up code was developed by EPRI. Following discussions between HCOG, EPRI, and IDCOR representatives, HCOG determined that the best code available in the time frame necessary for improving the modeling of hydrogen release rates would be the BWR Core Heat-up code.

Subtask 5.2 - Select Degraded Core Model

Description:

As discussed under Subtask 5.1, the HCOG determined that the best code available in the time frame necessary was the BWR Core Heat-up code developed by EPRI as part of the IDCOR effort. Therefore, HCOG sponsored EPRI to initiate efforts to define hydrogen release histories for 1/4 scale testing based upon the BWR Core Heat-up code.

Subtask 5.3 - Conduct Degraded Core Analysis and Generate Hydrogen and Mass Energy Release Rates

Description:

Based upon information from initial evaluations using the BWR Core Heat-up Code, HCOG and EPRI will identify the final hydrogen and mass energy release rates for use in the 1/4 scale test facility. EPRI will generate the hydrogen and mass energy release histories and provide a report which describes the BWR Core Heat-up code and the basis for the hydrogen/mass energy release rates.

Subtask 6.0 - Equipment Survivability Analysis

In the unlikely event of a hydrogen generation event, certain equipment must survive the event in order to recover the core, maintain core cooling, and protect containment integrity. The equipment necessary must be identified, and then analyses and/or testing conducted in order to demonstrate that for any postulated conditions which occur during a hydrogen generation event, the equipment will survive to perform the function necessary for the event.

The first step involves identification of the safety functions necessary to mitigate the consequences of a postulated hydrogen generation event. Then systems necessary to achieve the safety functions must be identified, followed by identification of the components within a system necessary to fulfill the system safety function. Following identification of the components that must survive, they must be located in the containment and the key heat transfer properties of the equipment identified for use in heat transfer modeling.

Due to the two types of hydrogen combustion which exist for varying hydrogen release rates, deflagrations and diffusion flames, the equipment must be shown to survive for both temperature profiles. Deflagrations are characterized by multiple high temperature spikes which occur for short durations throughout the entire containment volume. Diffusion flames are characterized by localized high temperatures with a slow increase in overall containment temperature. The temperature profiles for deflagrations will be obtained from the CLASIX predictions, whereas the atmospheric temperature profiles for diffusion flames will be generated from the 1/4 scale test facility. These temperature profiles will be used in heat transfer codes for analysis of equipment survivability.

Subtask 6.1 - Develop Criteria for Equipment Required to Survive a Hydrogen Generation Event

Description:

The equipment survivability program begins with the selection of criteria for use in identifying equipment which is required to survive a hydrogen generation event. The selection criteria should be generic and agreed upon by all Mark-III facilities as part of the HCOG efforts. The criteria for systems necessary to survive a hydrogen generation event approved by the HCOG are as follows:

1. Systems and components which must function to mitigate the consequences of the event;

2. Systems and components needed for maintaining the integrity of the containment pressure boundary;

3. Systems and components needed for maintaining the core in a safe condition; and

4. Systems and components needed for monitoring the course of the accident.

This criteria will be used by each utility in developing its plant specific list of equipment required to survive a hydrogen burn.

Subtask 6.2 - Define Criteria for Survivability

Description:

As part of the survivability analysis the criteria for survivability must be defined. Specifically, what acceptance criteria will be used for showing that equipment survives the predicted temperatures. If the calculated peak equipment temperature is below the environmental qualification temperature, then the equipment can be shown to survive the event. However, if the peak equipment temperature exceeds the equipment qualification temperature, the equipment may still survive, but auditional analysis is necessary. An acceptance criteria must be defined for evaluating the equipment temperatures to s' ow that the component will perform its required safety function.

Subtask 6.3 - Determine Systems Required for HGE

Description:

Using the selection criteria developed in Subtask 6.1, to the maximum extent possible, a generic list of systems required to survive a hydrogen burn should be developed. This will insure a consistent interpretation of the criteria developed in Subtask 6.1 and minimize the need for additional review by the NRC.

Subtask 6.4 - Determine Components Required to Satisfy System Safety Function for HGE and Develop Equipment List

Description:

Based on the criteria for equipment required to survive a hydrogen generation event, develop in subtask 6.1 and the generic list of systems developed by the HCOG under Subtask 6.3, CEI will determine any additional plant specific systems which are necessary to meet the criteria for equipment required to survive as well as components within the systems necessary to satisfy the system safety function for postulated hydrogen generation events.

Subtask 6.5 - Determine Location of All Components Required to Survive an HGE

Description:

Following identification of required equipment completed in Subtask 6.4, additional information which is necessary to conduct equipment survivability analysis must be identified for the equipment list. The required information must be identified and obtained for each piece of equipment. The information includes specific locations in the containment of all components, location of supporting equipment (such as, cable, termination boxes, penetrations, etc.), type of equipment, manufacturers nameplate data, key heat transfer information such as types of material, thicknesses, dimensions, emissivities, etc. This information will be used to complete an equipment survivability table.

Subtask 6.6 - Review Equipment Qualification Data and Identify Limits and Limting Components

Description:

The initial approach to demonstrating equipment survivability is to show that the calculated peak equipment temperatures do not exceed the equipment qualification limits. For all of the components identified in Subtask 6.4 above the equipment temperatures and pressures for which it is qualified should be identified and added to the table. Additionally, a review of vendor equipment qualification reports may provide some indication as to limiting components and failure mechanisms which will be required for survivability analysis if equipment temperatures do not stay below qualification limits. As much information as is readily available should be obtained regarding equipment qualification limits, limiting components, and failure mechanisms.

Subtask 6.7 - Define Base Case Temperature and Pressure Environments

The basic information necessary to perform the equipment survivability analysis is the containment temperature and pressure in the area where required equipment is located. Because of the significant difference in the pressure and temperature profiles for the two types of hydrogen combustion which can occur, deflagrations and diffusion flames, the ambient temperatures for each case must be developed from two different methods.

Subtask 6.7.1 - Deflagrations

Description:

The ambient containment pressure and temperatures to be used to demonstrate equipment survivability for hydrogen deflagrations will come from the base case CLASIX-3 analysis performed in Subtask 4.7. CLASIX-3 provides the pressure and temperature in each of the three compartments (drywell, wetwell, and containment) for both the drywell break and stuck open relief valve transients. Therefore, out of the six temperature and six pressure profiles, a decision must be made as to which is the proper temperature and pressure history for the appropriate equipment. Therefore, an evaluation must be performed in order to determine the proper pressure and temperature profiles from the existing base case CLASIX-3 analysis for conducting equipment survivability analyses for deflagrations. In some cases, prior analysis conducted by MP&L or HCOG may be used in lieu of the PNPP base case analysis if it can be shown to be bounding or generate comparable equipment temperatures.

Subtask 6.7.2 - Diffusion Flames

Description:

At the present time there is no analysis or computer codes available to predict the local temperature for diffusion flames. The diffusion flame and thus the local temperatures, are dependent upon a complex set of variables, including hydrogen release rates and containment geometries. Therefore, a large scale test is required in order to define the temperature profiles resulting from diffusion flames. Upon completion of the 1/ scale testing, the scaling relationships developed as part of the test program will be used to define the full scale containment temperatures. These thermal profiles will then be used as the ambient temperature for conducting additional equipment survivability analysis to show that the equipment will survive diffusive burning.

Subtask 6.8 - Evaluate and Select Heat Transfer Codes Available

Description:

In order to calculate the peak equipment temperatures which result from the ambient temperatures defined in Subtask 6.7 above, a heat transfer computer code must be selected. The computer code used should be generic for Mark-III containments in order to minimize additional NRC review and to maximize the amount of generic work which can be accomplished, such as, equipment models for equipment which is common to all Mark-III containments. Once the heat transfer model has been selected an appropriate verification program will be identified and conducted.

Subtask 6.9 - Develop Equipment Models

Description:

As part of the HCOG efforts, each utility's list of equipment required to survive a hydrogen generation event will be compared to determine which equipment can be modeled generically. Following this effort, the remaining items for PNPP required to survive will be modeled for use on the appropriate version of the heat transfer code.

Subtask 6.10 - Prepare Initial Equipment Survivability Report

Description:

In order to provide advance information to the NRC to obtain approval of the methodology as early as possible, an initial equipment survivability report will be prepared. The report will contain the equipment survivability list, a description of the heat transfer code, the verification process conducted, and the methodology for conducting the equipment survivability.

Subtask 6.11 - Calculate Peak Equipment Temperatures

Description:

Utilizing the temperature and pressure profiles developed as part of Item 6.7 above, and the equipment models developed as a part of Subtask 6.9, the peak equipment temperatures for deflagrations and diffusive burning will be calculated.

Subtask 6.12 - Compare HGE Peak Equipment Temperature and Peak Containment Pressures Against Equipment Qualification Limits

Description:

As part of Subtask 6.2 above, criteria for survivability will be defined. The PNPP criteria for survivability will be consistent with the following:

1. The maximum external surface temperature response is below the equiment qualification temperature, or

2. The maximum internal temperature response of the limiting components are below the equipment qualification temperature, or

3. The limiting component can be shown to maintain its post-accident function based on reported test data.

Based on the results of the peak equipment temperatures calculated in 6.10 above, for both deflagrations and diffusion flames, the peak equipment temperatures will be compared against the qualification temperatures to verify survivability. The equipment qualification temperature and limiting component temperature data will be determined based on the results of Subtask 6.6 above.

Subtask 6.13 - Identify Limiting Components, Failure Mechanisms and Perform Survivability Analysis

Description:

If equipment evaluated as part of Subtask 6.11 above have peak temperatures greater than the equipment qualification temperatures, then a more rigorous equipment survivability analysis will be performed. This analysis will evaluate limiting components and failure mechanisms to justify that the component will perform its post-accident function as required. The analysis will be based on additional calculations or reported test data. If justified, additional testing may be performed to demonstrate survivability of the equipment.

Subtask 6.14 - Identify and Select Alternative Protective Measures

Description:

If the peak temperature of the critical components is greater than equipment qualification temperatures and the additional survivability analysis performed in 6.12 above cannot justify survivability of the equipment during a hydrogen burn, alternative protective measures will be identified and the appropriate measures selected.

Possible protective measures may include additional survivability testing, replacement of the equipment, relocation of the equipment, providing thermal shields to protect the equipment, additional mitigation systems or systems designed to protect the equipment.

Subtask 6.15 - Prepare Schedule for Alternative Protective Measure Implementation

Description:

Following the results of the engineering evaluations conducted in Subtask 6.13 above, to determine the appropriate protective measures for equipment which initially failed the survivability criteria, a basic design and a proposed schedule for implementation will be developed.

Subtask 6.16 - Prepare Equipment Survivability Report

Description:

Following completion of all equipment survivability analysis and identification of alternative protective measures which may be necessary, a comprehensive equipment survivability report will be prepared and submitted to the NRC.

Task 7.0 - Hydrogen Combustion Testing

As a result of the analysis conducted by Mississippi Power and Light Company and the Hydrogen Control Owners Group, two outstanding issues were identified as requiring additional testing for resolution. The first issue, hydrogen combustion in hydrogen rich environments, resulted from analysis of hydrogen burns resulting from drywell break scenarios. Due to the limited test data available for hydrogen burning at the upper end of the flammability curve, additional testing was performed to verify the assumptions made in the CLASIX-3 analysis.

The second outstanding issue which required testing, dealt with the type of combustion phenomena existing above the suppression pool. Because of the potential for locally high temperatures, a large test facility, 1/4 scale, was authorized by the Hydrogen Control Owners Group. Construction of the test facility and conduct of the testing will be performed by Factory Mutual under contract to EPRI. The results of this test will be used as part of the equipment survivability analysis discussed in Task 6.0 previously.

Subtask 7.1 - Define PNPP 1/4 Scale Testing Objectives

Description:

Any issues which are identified as requiring resolution by 1/4 scale testing will be used as a basis to clearly define the PNPP 1/4 scale testing objectives. Additional factors such as the representativeness of the 1/4 scale facility to the Perry Plant will be used in developing the final set of objectives CEI desires to accomplish with the 1/4 scale test facility.

Subtask 7.2 - Define 1/4 Scale Test Matrix for PNPP Unique Features

Description:

As part of the evaluation to define the PNPP 1/4 scale testing objectives in Subtask 7.1 above, an evaluation will be conducted to determine the representativeness of the 1/4 scale facility to PNPP and the applicability of the proposed testing considering PNPP unique features. A final test matrix will be developed in order to support shakedown tests.

Subtask 7.3 - Select Hydrogen Release Histories

Description:

Upon completion of Subtask 5.3 described previously, a set of proposed hydrogen release histories will be developed and recommended to the HCOG by EPRI. CEI, as a member of HCOG, will participate in the selection of hydrogen release histories.

Subtask 7.4 - Perform Shakedown Tests

Description:

Following completion of the 1/4 scale test facility, an initial set of shakedown tests will be performed in order to verify the acceptability of the test facility, identify any problems which may have resulted from construction or which were unidentified in the initial design, and to determine the final testing which must be performed during production tests.

Subtask 7.5 - Evaluate Shakedown Tests

Description:

Following completion of shakedown tests, results will be evaluated in order to assure that the facility is ready for production tests, and to verify that test objectives will be accomplished by the final production tests.

Subtask 7.6 - Complete 1/4 Scale Production Testing

Description:

Production tests will be performed and completed in accordance with the approved HCOG test matrix developed and approved as part of Subtask 7.2 described previously.

Subtask 7.7 - Review Test Results for Applicability to PNPP and Effect on Previous Analysis

Following completion of the 1/4 scale protection test, the preliminary evaluation of the test results will be conducted in order to determine:

1. That tests were conducted properly;

2. That tests are adequate to resolve outstanding licensing issues;

3. That tests met the test objectives;

4. If additional tests are warranted;

5. Any anomalies;

6. The preliminary effect on previous analysis.

Following completion of development of the plant specific full scale thermal profiles based upon the 1/4 scale testing results, a final review will be conducted to verify the items discussed above. In addition, an evaluation will be conducted which identifies areas which are affected by the 1/4 test results or why the previous analysis is still acceptable.

Subtask 7.8 - Develop Plant Specific Thermal Profiles

Description:

Based upon the results of the 1/4 scale testing and using the scaling factors and relationships developed during the initial phases of the 1/4 scale test program, the plant specific full scale thermal profiles will be developed. The results of Subtask 7.6 will include thermal profiles throughout the 1/4 scale test facility, a set of scaling laws and relationships, and a description of how the thermal profiles and scaling laws should be used to develop the full scale plant specific thermal environments. This information will be used to develop the full scale PNPP ambient temperature profiles.

Subtask 7.9 - Calculate Peak Equipment Temperatures

Description:

For that equipment identified which requires further consideration, the full scale thermal profiles developed in Subtask 7.9 will be used as the ambient temperature profiles for additional equipment survivability analysis. The equipment models developed under Subtask 6.9 will be used to calculate the peak equipment temperatures.

Subtask 7.10 - Complete Equipment Survivability Analysis

Description:

Following completion of Subtask 7.10, the calculated peak equipment temperatures, will be compared against the equipment qualification temperatures and the limiting component temperatures for survivability as necessary. The equipment survivability analysis described in Subtask 6.12 through 6.14 will be performed, as necessary, for the full scale diffusion flame thermal environments.

Subtask 7.11 - Prepare 1/4 Scale Test Report

Description:

A comprehensive 1/4 scale test report will be prepared which provides the scaling laws and justification for using 1/4 scale test results for developing full scale thermal environments, a description of the testing completed, and the test results obtained.

Subtask 7.12 - Prepare PNPP 1/4 Scale Test Report

Description:

An additional report will be prepared which provides the plant specific full scale thermal environments calculated from the methodology and data provided in the previous report. This report will also include a description of the applicability of the test results to PNPP and a description of how the test objectives were met.

Subtask 7.13 - Conduct Hydrogen Rich Testing

Description:

CLASIX-3 analysis of the drywell break scenario made certain assumptions regarding the burning of hyrdogen at the upper end of the flammability curve. In order to verify that the initiation criteria for burning of hydrogen at the upper end of the flammability curve used in CLASIX-3 are acceptable, the HCOG initiated testing in a hydrogen rich enivronment to confirm these assumptions. Testing was completed in a dewar at the Whiteshell Test Facility in Canada.

Subtask 7.14 - Prepare Evaluation of Hydrogen Rich Testing and Test Report

Description:

The hydrogen rich testing described in Subtask 7.14 was completed and a test report prepared by EPRI. The test report describes the testing, the results of the testing, and in general, is an objective report of the test. Therefore, an evaluation of the test results and their applicability and a description of how the test results meet the test objectives, i.e., confirmation of the assumptions used in CLASIX-3 analysis, must be prepared.

Subtask 7.15 - Define and Conduct Additional Hydrogen Combustion Testing, If Necessary

Description:

If it is determined as a result of Subtask 4.8 that additional testing is necessary to resolve issues related to the drywell combustion phenomena, such testing will be defined and conducted.

Task 8.0 - Resolve NRC Licensing Issues

At the present time, Cleveland Electric Illuminating, as a member of the HCOG, is participating in the generic resolution of the Hydrogen Control issue with the NRC staff. A considerable amount of effort has already been expended by Mississippi Power & Light Co. and the HCOG in resolving the hydrogen control issue for Mark-III containments. However, a significant amount of effort will also be required by each utility to resolve the issue cn a plant specific basis.

Task 8.1 - PNPP Licensing Approach

Since the hydrogen control issue has been primarily resolved on the GGNS docket, the NRC staff will review most other Mark-III plants in relationship to the MP&L program, systems, and analyses as well as past and ongoing HCOG activities. Therefore, in order to expedite the licensing review for PNPP, efforts have been initiated to identify all GGNS licensing issues for hydrogen control and to determine if the resolution was acceptable to PNPP, not applicable to PNPP, or an additional position must be taken to resolve it on PNPP. Additionally, all of the HCOG requests for additional information (RAIs) have been evaluated to determine if the response by the Owners Group should be endorsed, to identify RAIs which require plant unique responses, and to identify those RAIs which require additional information for resolution on a plant specific basis.

To initiate the licensing effort, a preliminary meeting will be held with the NRC staff to discuss the hydrogen control program for PNPP and a proposed licensing schedule. During this meeting, CEI will present their basic approach to resolving the hydrogen control issue for PNPP. The meeting will include a discussion of the approach taken by CEI to resolve the issue, the activities that will be pursued, the interface that will be undertaken with the NRC staff, the issues that will be dealt with on a plant specific basis and those that will be dealt with by the HCOG, and a preliminary or proposed licensing schedule.

Subtask 8.2 - Identify all Previous GGNS Hydrogen Control Issues

Description:

In order to expedite the PNPP licensing schedule, a review has been initiated to identify all previous GGNS hydrogen control licensing issues. The licensing issues will then be classified into the following categories:

1. Not applicable to PNPP.

2. Applicable to PNPP, however, GGNS resolution is acceptable for PNPP resolution.

3. Applicable to PNPP but requires additional action for PNPP resolution.

The results of the evaluation will be documented in a report which will identify the issues and conclusions which apply to PNPP from the GGNS SER and supplements. For those issues which fall into categories 1 or 2 above, justification will be provided for the applicability of the resolution to PNPP or the PNPP unique features which makes them not applicable.

Subtask 8.3 - Review All Existing HCOG Requests for Additional Information (RAIs)

Description:

In order to expedite the licensing process for PNPP as described in Subtask 8.1 above, an additional review of all outstanding HCOG RAI's has been performed in order to classify them as follows:

1. HCOG resolution acceptable and requires PNPP endorsement.

2. HCOG resolution not acceptable for PNPP, requires plant specific response.

3. Plant specific response required.

As appropriate, justification will be provided for any HCOG RAIs with acceptable resolution for PNPP.

Subtask 8.4 - Prepare PNPP Plant Specific Responses to Appliable HCOG RAIs

Description:

Those HCOG RAIs which are identified as Category 2 or 3 in Subtask 8.3 (HCOG resolution not acceptable, and requires plant specific response or plant specific response required) will require development of a plant specific PNPP response. The response will be based on existing analysis or planned activities to the maximum extent possible.

Subtask 8.5 - Submit HCOG RAI Endorsements/Plant Specific Responses

Description:

Following completion of the development of plant specific responses to applicable HCOG RAIs, CEI will submit the responses as well as any endorsement of HCOG RAIs which are applicable to PNPP, as appropriate.

Subtask 8.6 - Prepare and Submit Documentation to Support Licensing

Description:

Throughout the resolution of the hydrogen control issue for PNPP, a significant number of reports, responses to NRC questions and other documentation will have to be submitted for resolution of the licensing issue. In general, documentation will be submitted as necessary, to support the NRC staff. When appropriate, initial or advance reports will be prepared and submitted in order to obtain NRC comments and approval as early in the licensing schedule as possible. Specific reports that have been identified in the PNPP hydrogen control program which will require submittal, have been included in the schedule diagrams in Section 6.0.

Subtask 8.7 - Meet with the NRC to Resolve PNPP Issues

Description:

Meetings will be held with the NRC, as necessary, to resolve NRC staff licensing issues for PNPP. In addition, as a member of the HCOG, CEI will meet with the NRC on generic hydrogen control issues as necessary.

Task 9.0 - Develop Emergency Procedures for Control of Combustible Gas

Description:

The BWR Owners Group - Emergency Procedures Subcommittee (BWR-EPC), has responsibility for developing symptom based emergency procedure guidelines for use by all BWR product lines to develop plant specific emergency operating procedures. At the present time, an emergency procedure guideline for control of combustible gas is being developed by the BWR-EPC. A significant amount of work has been done in order to develop an emergency procedure guideline for use by Mark-III containments to address the hydrogen control issue. The emergency procedure guideline will be developed in order to handle design basis hydrogen concentrations as well as significant hydrogen concentrations which may result from degraded cores.

Following completion of the emergency procedure guideline, PNPP will develop plant specific limits for the emergency operating procedure, and conduct operator training on the procedure.

Subtask 9.1 - Finalize Emergency Procedure Guideline

Description:

A significant amount of work has been completed by the BWR-EPC, supported by the HCOG, to develop an emergency procedure guideline for use by Mark-III containments to address the hydrogen control issue. The emergency procedure guideline will be developed in order to handle design basis hydrogen concentrations as well as significant hydrogen concentrations which may result from degraded cores.

Subtask 9.2 - Develop PNPP Emergency Operating Procedure

Description:

Based upon the approved EPG, a plant specific PNPP emergency operating procedure (Plant Emergency Instruction, PEI) will be developed. The procedure will follow the EPG, but include any plant specific steps to account for unique PNPP features.

Subtask 9.3 - Calculate Plant Specific Limits

Description:

Based upon the identified limits in the EPG for which operators must take certain actions, this task will include calculation of the PNPP plant specific limits for the PEI.

Subtask 9.4 - Conduct Operator Training

Description:

Upon completion of a training guide and lesson plan, operator training will be conducted on the HIS design, the PEI, and the applicable bases.

Subtask 9.5 - Evaluate Effect of EPG on Existing Analysis and Testing

Description:

Much of the analysis and testing performed to resolve the hydrogen control issue was conducted prior to or in conjunction with the development of the emergency procedure guideline. The emergency procedure guideline was developed to be consistent with the existing analysis and testing. However, an evaluation will be conducted to confirm that the operator actions are consistent with the applicable analyses and testing.

4.0 SCHEDULE

PNPP H_2 CONTROL LICENSING SCHEDULE