Hydrogen Water Chemistry Installation

Report for Amendment to Facility Operating License

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QUAD CITIES

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1.0 INTRODUCTION

This report describes the Hydrogen Water Chemistry System installed at the Quad-Cities Station. The purpose of the hydrogen water chemistry installation is to inject hydrogen into the reactor coolant, via the condensate system, to suppress the dissolved oxygen concentration. This suppression of the dissolved oxygen concentration coupled with a high purity reactor coolant will reduce the susceptibility of reactor piping and materials to intergranular stress corrosion cracking (IGSCC). This process is referred to as hydrogen water chemistry (HWC).

The guidance for the Quad-Cities HWC System came from the Electrical Power Research Institute (EPRI) report entitled "Guidelines for Permanent BWR Hydrogen Water Chemistry Installations," dated May 1985. However, all of the deviations and exemptions discussed in this submittal are based upon the September 1987 revision of this EPRI report (EPRI NP-5283-SR-A), which has been accepted by the US Nuclear Regulatory Commission (NRC) and will be referred to throughout this report as the "HWC Guidelines." All deviations and exemptions to the HWC Guidelines are discussed in section 10.

This document will describe the hydrogen and oxygen storage and supply systems and the injection systems for hydrogen and oxygen. This description will include the hydrogen water chemistry system requirements for operation, maintenance, surveillance, safety precautions, and testing to provide for safe system and plant operation.

2.0 GENERAL SYSTEM DESCRIPTION

Figure 1 shows a simplified drawing of the Quad Cities Hydrogen Water Chemistry (HWC) system. This system will be divided into four subsystems for an in-depth description. These are hydrogen supply, oxygen supply, hydrogen injection, and oxygen injection.

2.1 GENERAL DESIGN CRITERIA

The hydrogen water chemistry system is not safety related. Equipment and components are not redundant, seismic class I, electrical class 1E, or environmentally qualified, except where required to meet good engineering practice. However, the proximity of safety-related equipment or other plant systems requires special consideration in the design, fabrication, installation, operation, and maintenance of hydrogen addition components. Respective of this, quality assurance and quality control provisions were implemented, as discussed in section 9, to assure a safe and reliable hydrogen addition system.

During operation, the hydrogen addition system will maintain the dissolved oxygen concentration in the recirculation water at a level which will mitigate the consequences of IGSCC while ensuring that the hydrogen will be safely recombined in the off-gas system.

2.2 HYDROGEN SUPPLY OPTIONS

For HWC systems in general, the hydrogen can be supplied from any combination of the following three sources:

a. a commercial hydrogen supplier,

b. onsite production from raw materials, or

c. recovery and recycle of hydrogen from the off-gas system.

The initial interim supply option will be to use hydrogen gas furnished by a commercial supplier. This interim supply option will eventually be replaced by onsite storage of liquid hydrogen furnished by a commercial supplier.

2.3 GAS INJECTION SYSTEMS

2.3.1 Hydrogen Injection System

The hydrogen injection system, which is depicted in Figure 2, includes all flow control and flow measuring equipment and all necessary instrumentation and controls to ensure safe, reliable operation. This system is capable of providing up to 70 standard cubic feet per minute (scfm) of hydrogen, with a normal pressure range of 125 to 170 psig, to each Unit's condensate system.

2.3.1.1 Injection Point Considerations

The hydrogen is injected into the condensate pump discharge. This location provides adequate dissolving and mixing and avoids gas pockets at high points. The location of the hydrogen points for Unit 2 is depicted in Figure 3 at coordinates D-3, D-5, D-7, and D-9.

2.3.1.2 Codes and Standards

The hydrogen injection system has been designed and installed in accordance with OSHA standards in 29 CFR 1910.103. Piping and related equipment was designed, fabricated, inspected, and tested in accordance with ANSI B31.1 for pressure-retaining components. All components meet all the mandatory requirements and material specifications with regard to manufacture, examination, repair, testing, identification, and certification. All welding was performed using procedures that met the requirements of ASME Boiler and Pressure Vessel Section IX. The piping was uniquely identified through the display of an appropriate color field and legend markings. All underground piping had identification tape laid 6 inches above the pipe, before the trench was filled. Warning markers were also placed over the trench.

System design also conforms with pertinent portions of NUREG-0800, 10 CFR 50.48, Branch Technical Position BTP CMEB 9.5-1, and appropriate state and local building codes and standards.

2.3.1.3 System Design Considerations

The hydrogen piping is run underground from the hydrogen supply system to a point within several feet of the outside of the west wall for the Unit 1 turbine building.

A branch line tees off of the buried HWC system hydrogen supply line directly across from the generator hydrogen control cabinet, which is west of the Unit 1 turbine building. This branch line proceeds underground to the generator hydrogen control cabinet. It then splits into two lines above the ground at the control cabinet. Each line has a pressure regulator, a check valve, and upstream and downstream isolation globe valves. Each line then terminates at a tee into the existing Unit 1 and Unit 2 generator hydrogen supply lines just downstream of the control cabinet.

All underground piping has a factory-installed protective coating, and all joints have been covered with two (2) layers of a protective wrap to provide protection against corrosion. The routing and installed depth of the hydrogen piping took into account local soil conditions, such as frost depth and expected vehicle loading. The use of guard piping was considered in the design, but it was determined to be unnecessary. The hydrogen piping is electrically continuous from the hydrogen supply system to the condensate pumps, and is grounded on each end. The grounded connection at the condensate pumps is accomplished by providing electrical continuity between the hydrogen piping and the condensate piping, the condensate pump motor ground, the cable tray ground, and finally the ground grid. The hydrogen supply system is also grounded, in addition to the hydrogen piping being grounded near its connection to the hydrogen supply system.

An excess flow check valve is installed at the hydrogen supply site, before the hydrogen pipe enters the ground, and an additional excess flow check valve is installed within several feet of the hydrogen pipe's exit from the ground, near the Unit 1 turbine building. The individual hydrogen injection lines are equipped with check valves and solenoid isolation valves, which are interlocked with the condensate pumps. The individual solenoid isolation valves provide hydrogen supply system isolation if the associated condensate pump is not running and for all hydrogen injection system trips.

A nitrogen purge connection is provided downstream of each excess flow check valve, which are located at the hydrogen supply site and at the exit point of the hydrogen piping from the ground near the turbine building, and on each end of the four (4) hydrogen addition control stations. A purge line flame arrestor has also been connected to the hydrogen pipe following each units' hydrogen addition control station.

Area hydrogen concentration monitors have been installed to ensure that the hydrogen concentration around the hydrogen piping remains below the flammable limit. These monitors have been installed at high points where hydrogen might collect and above use points that constitute potential leaks. These monitors are connected to solenoid isolation valves, which are installed in each units' hydrogen feed line at its entrance to the turbine building, to provide hydrogen supply isolation if a high hydrogen concentration level is present.

The hydrogen addition system will increase the hydrogen concentration in the feedwater, reactor, steam lines, and main condenser. The following four (4) systems were reviewed for possible detrimental effects:

a. Main Condenser,

b. Off-Gas System,

c. Steam Piping and Torus, and

d. Sumps.

2.3.1.3.1 Main Condenser

The main condenser presently handles combustible gases at nonflammable levels, and the hydrogen addition system will not significantly change the concentration or volume of these gases. Therefore, it is not anticipated that hydrogen addition will affect the operation of the main condenser.

2.3.1.3.2 Off-Gas System

Oxygen or air is added into the off-gas system to recombine with the hydrogen flow. This limits the extent of the system which handles hydrogen-rich mixtures and reduces the volumetric flow-rate. The net effect from operating the HWC system is a revised heat input into the recombiner off-gas. However, this increased heat input has been analyzed by their manufacturer to be insignificant and will not affect operation of the off-gas system.

2.3.1.3.3 Steam Piping and Torus

The torus contains hydrogen monitors which will allow operators to identify any hydrogen concentration increase due to HWC system operation.

2.3.1.3.4 Sumps

The three (3) water systems that are affected by HWC are:

a. Main condenser condensate,

b. Feedwater, and

c. Reactor water.

For sumps which receive water from any of these three sources, the average hydrogen concentration may slightly increase. However, the maximum expected concentration levels of hydrogen in the sump atmospheres were determined to be less than the lower combustible limit of hydrogen in air. Therefore, the hydrogen addition system is not expected to affect the combustibility of the sump atmospheres.

2.3.2 Oxygen Injection System

The oxygen injection system, which is depicted in Figure 4, injects oxygen into the off-gas system to ensure that the excess hydrogen in the off-gas stream is recombined. It includes all necessary flow control and flow measurement equipment.

This system is capable of providing up to 35 scfm of oxygen or a combined air/oxygen flow to each Unit's off-gas system. A timer system will continue oxygen flow after the hydrogen injection system is tripped for 15 minutes before slowly decreasing the oxygen injection to zero, within an additional 5 minutes.

2.3.2.1 Injection Point Considerations

The injection point of oxygen is in a diluted portion of the off-gas system before the first stage of the Steam Jet Air Ejectors. The oxygen injection points for Unit 2 are depicted in Figure 5 at coordinates D-3 and D-4.

2.3.2.2 Codes and Standards

The oxygen injection system has been designed and installed in accordance with OSHA standards in 29 CFR 1910.104 and CGA G-4.4, Industrial Practices for Gaseous Oxygen Transmission and Distribution Piping Systems.

Piping and related equipment was designed, fabricated, tested and installed in accordance with ANSI B31.1. Additional guidance for materials of construction for oxygen piping and valves was given in Section 3.4. Welding was performed using procedures that met the requirements of ASME Boiler and Pressure Vessel Section IX. Piping was uniquely identified through the display of an appropriate color field and legend markings. All underground piping had identification tape laid 6 inches above the pipe before the trench was filled, and markers were placed over the filled trench. All applicable state and local codes were also followed.

2.3.2.3 Cleaning

All portions of the system that may contact oxygen were cleaned as described in Section 3.4 of this report and in accordance with CGA G-4.1 and G-4.4.

2.4 INSTRUMENTATION AND CONTROL

The instrumentation and controls include all sensing elements, equipment and valve operating hand switches, equipment and valve status lights, process information instruments, and all automatic control equipment necessary to ensure safe and reliable operation. Table 1 lists the trips of the HWC system. The instrumentation provides indication and/or recording of parameters necessary to monitor and control the system and its equipment. The instrumentation also indicates and/or alarms abnormal or undesirable conditions. Table 2 lists the installed instrumentation and functions. This table also includes instrumentation for hydrogen and oxygen supply options. Additional information on instrumentation and controls are provided in Section 3.

All control room instrumentation and controls for the HWC system are located on a new seismically installed nonsafety-related control panel. This panel also contains annunciators for local panel trouble alarms.

2.4.1 Hydrogen Injection Flow Control

The hydrogen injection flow control is through a parallel set of flow control valves. This parallel arrangement provides better system reliability and maintainability. The flow control can be adjusted either automatically, with the hydrogen addition rate based on the steam flow, or manually. The flow control valves will close to provide hydrogen isolation for all HWC system trips, and will fail closed upon loss of power.

Each injection line contains upstream and downstream manual isolation globe valves, which allows individual pump maintenance, and a solenoid operated isolation valve, which prohibits hydrogen injection into a non-operating pump. The solenoid isolation valves will isolate the HWC system during any HWC system trips and will fail closed upon loss of power.

2.4.2 Oxygen Injection Flow Control

Parallel flow control valves are provided in the oxygen injection line, for system reliability and maintainability. However, only one of the two trains carries pure oxygen from the liquid oxygen storage facility. The second train carries building air to supplement the regular oxygen supply, on operator demand.

The oxygen flow rate will be controlled to provide residual oxygen downstream of the recombiners. System controls are designed to provide that oxygen injection continues for 15 minutes after the hydrogen addition is terminated, so that all free hydrogen will be safely recombined to within the tolerances of the off-gas system.

2.4.3 Monitoring

The recirculation water oxygen concentration is continuously monitored by two dissolved oxygen analyzers, which are part of the orbisphere subsystem of the Hydrogen Water Chemistry Verification system. The sample flow for these analyzers is obtained via the Reactor Building Process Sample Panel sample line, which can be isolated from the reactor recirculation loop by two inline (inboard and outboard) containment isolation valves, classified as Group I valves. See section 5.1.2 and 5.2 for additional information on this subsystem.

Redundant oxygen analyzers have been added in parallel to the existing hydrogen analyzers, which are located downstream of the off-gas recombiners. These monitors have been provided to allow monitoring of the residual hydrogen and oxygen concentrations in the off-gas stream. Figure 6 depicts the oxygen and hydrogen monitoring of the off-gas stream for Units 1 and 2.

3.0 SUPPLY FACILITIES

3.1 GASEOUS HYDROGEN

3.1.1 System Overview

An interim storage system for gaseous hydrogen will be utilized until the design for the long-term liquid hydrogen supply system is completed. This interim hydrogen gas supply system will be provided by a supplier with extensive experience in the design, operation, and maintenance of gaseous storage and supply systems; however, an interim supplier has not been chosen at this time. When chosen, the interim storage and supply system will meet the intent of the provisions stated in the HWC Guidelines.

The initial hydrogen storage and supply system shall consist of the following subsystems:

a. Hydrogen Storage Vessels,

b. Pressure Reducing Station,

c. Tube Trailer Discharge Stanchion, and

d. Interconnecting Piping.

3.1.2 Hydrogen Storage Vessels

The interim gaseous hydrogen storage system will consist of two (2) tractor trailers. Each trailer will contain a bank of horizontal hydrogen gas vessels. These transportable vessels will be provided and maintained by the hydrogen supplier.

The tube bank will be supported to prevent movement in the event of a line failure, and each tube shall be equipped with a close-coupled shutoff valve. As an alternative, a single safety valve per bank of tubes could be used, provided the safety valve is sized to handle the relief from all of the tubes tied into it. Each bank of tubes shall also be equipped with any instruments required for proper filling.

3.1.3 Pressure Reducing Station

The pressure control station shall be of a manifold design with two (2) full-flow parallel pressure reducing regulators. The discharge pressure range of these regulators shall be fully adjustable to satisfy plant hydrogen injection requirements. Pressure gauges shall be provided upstream and downstream of the regulators, and a sufficient number of hand-operated valves shall be provided to ensure complete operational flexibility.

An excess flow check valve is installed downstream of both the interim tube trailer connection and the long-term hydrogen source (see Figure 5). This valve will limit the hydrogen release in the event of a line break. An additional excess flow check valve is installed in the hydrogen gas supply line near the west wall of the Unit 1 turbine building. The stop-flow setpoint for each of these flow control check valves is 200 scfm.

3.1.4 Tube Trailer Discharge Stanchion

A tube trailer discharge stanchion shall be provided for each trailer for gaseous product unloading. The stanchion shall consist of all necessary piping and valves to safely unload the gaseous hydrogen. It shall be separated from the filling apparatus for safety and convenience and be protected against vehicular collision. A tube trailer ground assembly shall also be provided on each discharge stanchion to ground the tube trailer before the discharge of hydrogen begins.

3.1.5 Interconnecting Piping

The equipment and interconnecting piping to be supplied with the hydrogen storage and supply system shall be installed in compliance with ANSI B31.1. All components that may contact the hydrogen shall be cleaned in accordance with standard industrial practices as recommended by the supplier prior to and following system fabrication to ensure that the surface is free from moisture, loose rust, scale, slag, and weld spatter and essentially free of organic matter, such as oil, grease, crayon, paint, etc.

3.2 LIQUID HYDROGEN

3.2.1 System Overview

The liquid hydrogen storage system will be provided by a supplier with extensive experience in the design, operation, and maintenance of liquid gas storage systems; however, the supplier has not been chosen at this time. When chosen, the long-term liquid hydrogen storage and supply system will meet the intent of the provisions stated in the HWC Guidelines.

The liquid hydrogen storage and supply system shall consist of the following subsystems:

a. Cryogenic storage tank,

b. Overpessure protection system,

c. Instrumentation

d. Liquid hydrogen pump and controls,

e. Interface with gaseous system, and

f. Hydrogen vaporization system.

The liquid hydrogen shall be provided in accordance with CGA G-5 and G-5.3.

3.2.2 Cryogenic Storage Tank

The liquid hydrogen storage system shall consist of one 20,000 gallon "inner vessel," constructed in accordance with Section VIII, Division 1 of the ASME Code for Unfired Pressure Vessels. The inner vessel will be subjected to a pressure test to ensure that no flaws exist that could cause a failure at or below the set pressure of the vessel's redundant relief devices. A 100% radiographic inspection of the inner vessel's longitudinal welds shall also be performed in addition to the ASME Code inspection requirements. This inner vessel is enclosed by a noncertified carbon steel "outer vessel" or "vacuum jacket." The annular space between the inner and outer vessels shall contain perlite, aluminized mylar, or a suitable equal for insulation, and this space shall be kept at a high vacuum of 50 microns or less.

All tank control piping and valving should be installed in accordance with ANSI B31.1, and all tank piping shall be constructed of wrought copper and stainless steel. The following tank piping subsystems shall be provided.

a. A fill circuit with top and bottom lines, which allow the tank to be filled without affecting continuous hydrogen supply.

b. A pressure build-up circuit to keep the tank pressure at operational levels.

c. Vacuum-jacketed liquid fill and pump circuits, where applicable.

3.2.3 Overpressure Protection System

Safety consideration for the tank are satisfied by both primary and secondary relief systems. The primary relief system shall consist of a pair of pipe legs coupled by a three-way valve. Each of these legs shall contain one safety valve and one rupture disk. This dual primary relief system will provide 100% standby redundancy, which will allow maintenance and testing to be performed without sacrificing the level of protection from overpressure. This primary relief system shall comply with the provisions of the ASME Pressure Vessel Codes and the Compressed Gas Association (CGA) Standards. The secondary relief system, which is not required by the ASME Codes, shall be totally separate from the primary relief system. This secondary system shall consist of a locked open valve, a rupture disk designed to burst at 1.33 times the maximum allowable working pressure, and a secondary vent stack.

Two annular space relief devices shall be installed in the outer vessel to relieve any excess positive pressure which might result from a leak in the inner vessel. Also, all system piping which may contain liquid and can be isolated from the tank relief devices shall be protected with thermal relief devices. All outlet connections from the safety relief valves, rupture devices, bleed valves, and the fill line purge connections shall be piped to an overhead vent stack, per CGA G-5, Section 7.3.7.

The hydrogen tank and delivery vehicle, when loading or unloading, shall be grounded per CGA P-12, Sections 5.4.5 and 5.7.1.2. The cryogenic tank shall also be protected from the effects of lightning per NFPA 78, Chapter 6.

Excess flow protection shall be added to the tank's liquid piping wherever a line break would release a sufficient amount of hydrogen to threaten safety-related structures (see also Section 4.2.2).

3.2.4 Instrumentation

The tank shall be supplied with a pressure gauge, a liquid level gauge, and a vacuum readout connection. Additional information on supply system instrumentation can be found in Section 2.4 and Tables 1 and 2.

3.2.5 Liquid Hydrogen Pump and Controls

The liquid hydrogen pump shall be of proven design to provide continuous hydrogen supply in unattended, automatic operation. This liquid hydrogen pump shall have the following subsystems and controls.

a. A positive isolation valve shall be provided to control the liquid feed into the pumping system per NFPA 50B. This valve shall be a pneumatically operated valve, which shall only open during pump operation, shall fail close in any fault mode, and shall be able to be remotely overridden in case of emergency.

b. The hydrogen pumps shall be shut down at high pressures to prevent system overpressurization.

c. A temperature switch downstream of the vaporizers to trip the hydrogen pump if a low temperature condition exists in the hydrogen gas line.

d. Pump operation shall be continuously and automatically monitored. Operation which results in pump cavitation, high temperature at the pump discharge, or low temperature downstream of the vaporizer shall trip the pump and indicate the fault on the remote control panel by an audible alarm and light indication.

e. Nitrogen shall be used to purge pump motors, control panels, and valves. All electrical components shall be designed in accordance with NFPA 70.

3.2.6 Interface with Gaseous System

Switchover controls shall be provided to allow operation of the liquid or gaseous hydrogen supply systems.

3.2.7 Vaporization

Vaporization of the liquid hydrogen shall be achieved by the use of ambient air vaporizers. The vaporizers shall be designed, installed and operated under guidance from NFPA 50A and 50B. The vaporizers shall be piped in parallel to allow periodic intervals for defrosting without interfering with the plant's hydrogen flow requirements of 140 scfm. The vaporizers shall have a design pressure consistent with plant injection requirements and be able to withstand the maximum pressures generated from the cryogenic pump.

3.3 LIQUID OXYGEN

3.3.1 System Overview

The liquid oxygen storage system will be provided by the Liquid Air Company because of their extensive experience in the design, operation, and maintenance of associated storage and supply systems. The liquid oxygen storage and supply system will consist of the following subsystems:

a. Cryogenic storage tank,

b. Overpressure protection system,

c. Oxygen vaporization station,

d. Pressure control station, and

e. Interconnecting piping.

The liquid oxygen will be provided per CGA G-4 and G-4.3.

3.3.2 Cryogenic Storage Tank

The liquid oxygen storage system consists of one 11,000-gallon "inner vessel," constructed in accordance with Section VIII, Division 1 of the ASME Code for Unfired Pressure Vessels. This inner vessel is enclosed by a noncertified carbon steel "outer vessel" or "vacuum jacket." The annular space between the inner and outer vessels contains perlite and is kept at a high vacuum of 50 microns or less.

All tank control piping and valving has been installed in accordance with ANSI B31.1 and all tank piping is constructed of wrought copper and stainless steel. The following tank piping subsystems have been provided.

a. A fill circuit with top and bottom lines, which allow the tank to be filled without affecting system operation. The filling of the tank will be performed by the liquid oxygen supplier with station personnel supervision.

b. A pressure build-up circuit to keep the tank pressure at operational levels. This pressure build-up circuit contains a shutoff valve and a check valve which allows removal and maintenance of the pressure regulator without service interruptions.

c. An economizer circuit to preferentially feed oxygen gas from the vessel vapor space into the oxygen discharge line.

3.3.3 Overpressure Protection System

Safety considerations for the tank are satisfied by dual full-flow safety valves and emergency backup rupture discs. The primary relief system consists of a pair of pipe legs coupled by a three-way valve. Each of these legs contain one safety valve and one rupture disk. This dual primary relief system provides 100% standby redundancy, which allows maintenance and testing to be performed without sacrificing the level of protection from overpressure. This primary relief system complies with the provisions of the ASME Pressure Vessel Codes and the Compressed Gas Association (CGA) Standards.

Two annular space safety heads are provided to relieve any excess positive pressure which might result from a leak in the inner vessel. Safety valves have also been installed in the following locations to protect piping and equipment which may contain liquid and can be isolated from the tank relief valves.

a. On the upper portion of the pressure build-up coil to provide additional protection to the inner vessel.

b. On the lower portion of the pressure build-up coil to protect the coil in case liquid is trapped in it when the shut-off valve is closed.

c. On the filling manifold to protect this equipment in case liquid is trapped between the valve in the bulk transport and the top and bottom fill control valves.

d. On each vaporizer branch to protect the pair of vaporizers in case the block valve ahead of the vaporizer pair is shut-off by mistake.

e. On the oxygen gas discharge line to protect equipment downstream of the pressure control station. A check valve on this line protects the oxygen storage and supply system from contamination and sudden increases in pressure from the oxygen injection system.

The tank has local indication of tank pressure, liquid oxygen level, liquid oxygen temperature, and vaporized oxygen supply pressure. These indicators are sufficient for normal monitoring of the tank condition.

3.3.4 Oxygen Vaporization System

The vaporization of the liquid oxygen is achieved by the use of ambient air vaporizers. Each vaporizer features a hex fin design, a 200-scfm flow capacity, and a design pressure of 500 psig. Two pairs of vaporizers are installed in parallel, which allows each pair to be independent of the other. This arrangement allows for periodic defrosting of one pair of vaporizers while not interfering with the plant's oxygen flow requirements of 70 scfm.

3.3.5 Pressure Control Station

The pressure control station is a manifold design. The manifold has two (2) full-flow parallel pressure reducing regulators. The discharge pressure range of these regulators is adjustable to satisfy plant oxygen injection requirements. Pressure gauges are provided upstream and downstream of the regulators, and a sufficient number of hand-operated valves are provided to ensure complete operational flexibility. A low temperature alarm is installed downstream from the vaporizer to protect system piping and equipment from liquid oxygen.

3.3.6 Interconnecting Piping

The design and installation of the oxygen piping valves and related-equipment was in conformance with ANSI B31.1 and CGA G-

4.4. All oxygen piping and equipment was cleaned in accordance with CGA G-4.1 and G-4.4 to remove all organic, inorganic, and particulate matter from surfaces to be exposed to the oxygen. The initial cleaning was accomplished by precleaning all parts of the system at the factory, maintaining cleanliness during shipping and construction, and completely purging the system after construction was completed.

4.0 SAFETY CONSIDERATIONS

4.1 GASEOUS AND LIQUID HYDROGEN

4.1.1 Site Characteristics of the Gaseous and Liquid Hydrogen Systems

4.1.1.1 Overview

A review of the following site characteristics was conducted for the location of the gaseous and liquid hydrogen storage site.

a. The location of the storage site in proximity to exposures as addressed in NFPA 50A and 50B,

b. The route of hydrogen delivery vehicles onsite, and

c. The location of the hydrogen storage site in proximity to safety-related equipment.

4.1.1.2 Specific Hydrogen Conditions

4.1.1.2.1 Fire Protection

The hydrogen storage site is located 1500 feet from the nearest safety-related structure. The site is also located such that it will be at least 75 feet from any future and present buildings. The location is shown in Figures 7 and 8. This site location meets or exceeds all requirements for protection of personnel and equipment as addressed in NFPA 50A, "Gaseous Hydrogen Systems," and NFPA 50B, "Liquefied Hydrogen Systems."

There is no need for additional fire protection systems based on an analysis of local conditions onsite, exposure to properties, water supplies, and the probable effectiveness of the plant fire brigade in accordance with NFPA 50A and 50B.

4.1.1.2.2 Security

The hydrogen storage site is completely fenced and is located inside the owner controlled area. Lighting is to be installed to facilitate night surveillance.

4.1.1.2.3 Route of Hydrogen Delivery on Site

The route to be taken by hydrogen delivery trucks on Commonwealth Edison property is shown on Figure 9. Truck barrier posts are located approximately at the fence perimeter to protect the gaseous and liquid storage vessels from mobile equipment.

4.1.1.2.4 Location of Hydrogen Storage Facility to Safety-Related Structures

The site location as shown in Figure 7 has been shown to be acceptable relative to safety-related structures and equipment considering the following hazards:

a. Gaseous or liquid storage vessel failure, and

b. Gaseous or liquid pipe breaks.

4.1.2 Gaseous or Liquid Storage Vessel Failure

The gaseous storage facility will consist of two tractor trailers, with each trailer containing a bank of hydrogen gas storage vessel. These vessels shall be capable of withstanding tornado missiles (NUREG-0800) and site-specific seismic loading due to horizontal and vertical accelerations acting simultaneously. A simultaneous failure of multiple vessels will not be discussed because of the inherent strength of the vessels which makes them unsusceptible to failures from outside forces. For this reason, the maximum postulated release of hydrogen from the gaseous storage facility in accordance with the HWC Guidelines is the instantaneous release of the fully pressurized contents of the largest single vessel. The gaseous hydrogen storage trailers will be anchored to remain in place for the design basis tornado and the storage facility is 38 feet higher than the plant elevation of 595 feet, to eliminate any flooding concerns.

The liquid storage facility will consist of a single 20,000 gallon liquid hydrogen storage vessel. This vessel, its foundation, and all liquid hydrogen piping up to and including excess flow protection devices shall be designed to withstand the design basis earthquake for the plant site. The tank and its foundation shall also be designed to remain in place during the design basis tornado, and the storage facility is 38 feet higher than the plant elevation of 595 feet, to eliminate any flooding concerns.

The potential consequences of a gaseous or liquid storage vessel failure are a fireball or an explosion.

4.1.2.1 Fireball

The thermal flux versus distance from a fireball center for two common gaseous commercial vessel sizes from the HWC Guidelines are shown in Figure 10. The individual storage vessels being considered for the facility contain 12,000 scf per vessel; hence, the required separation distance could not be calculated from Figure 10.

As a conservative estimate, it was approximated that the thermal flux for a fireball from the 12,000-scf gaseous hydrogen storage vessel equaled that of the 20,000-gallon liquid hydrogen storage vessel. Using conversion factors in the HWC Guidelines, the equivalent TNT for both storage facilities can be calculated. The 20,000-gallon liquid hydrogen storage facility is equivalent to 27,400 lbs of TNT, and one pressurized 12,000-scf gaseous hydrogen storage vessel equals 325 lbs of TNT. The significantly higher equivalent explosive content of the liquid hydrogen tank validates this assumption. The thermal flux versus distance from the fireball center for a liquid hydrogen storage system is shown in Figure 11. From this figure, it can be seen that for a 20,000-gallon liquid hydrogen tank with a fireball duration of 8.18 seconds, charring of wood surfaces occurs at 520 feet. Since the nearest safety-related structure is 1500 feet from the postulated fireball center, the effects of a fireball are insignificant.

4.1.2.2 Explosion

Figure 12 shows the minimum required separation distance for gaseous hydrogen storage systems to safety-related structures recommended by the HWC Guidelines. Using 12,000 scf of hydrogen gas per vessel, the minimum required separation distance to safety-related structures is approximately 140 feet. Since the actual distance is much greater than 140 feet, the effects of an explosion for the gaseous hydrogen storage option are considered insignificant.

An analysis was also performed for the minimum separation distance required for the 20,000-gallon liquid hydrogen storage tank. As shown in Section 4.1.2.1 the explosive content of the liquid hydrogen tank is significantly higher than that for the gaseous hydrogen storage vessels. Therefore, the bounding minimum separation distance should be based upon this more conservative analysis.

A calculation was performed using the recommendations in the evaluation entitled "Separation Distances Recommended for Hydrogen Storage to Prevent Damage to Nuclear Power Plant Structures from Hydrogen Explosion," which is included as Appendix B of the HWC Guidelines. This calculation yielded a result of 962 feet for the required separation distance. Since this is well below the actual distance of 1500 feet to the nearest safety-related structure, the effects of an explosion for the liquid hydrogen storage option are also considered insignificant.

4.1.3 Gaseous or Liquid Pipe Breaks

The criteria for acceptable siting of gaseous pipe breaks up to the point where excess flow protection is provided from the HWC Guidelines are;

a. Dilution of resultant release below the lower flammability limit of 4% before reaching air pathways into safety-related structures, and

b. Minimum separation distances for the blast damage criteria.

The hydrogen supply system piping diagram is shown in Figure 3. Excess flow protection for the system is provided as close as possible to the gaseous storage unit. This arrangement provides piping outside of the fenced area with excess flow check valve protection. Figures 13 and 14A from the HWC Guidelines shows the minimum separation distance between safety-related air intakes versus supply pipe diameter for gaseous releases from a 2450 psig gaseous hydrogen storage system and a 150 psig liquid hydrogen storage tank, respectively. The required separation distance of 375 feet for the gaseous hydrogen storage system and 500 feet for the liquid hydrogen storage system are significantly less than the actual 1500 feet distance to the nearest safety-related air pathway. Therefore, the effects of gaseous pipe breaks on safety-related air intakes is insignificant.

The criteria for acceptable siting of liquid pipe breaks up to the point where excess flow protection is provided is identical to that for gaseous pipe breaks. Figure 14B shows the minimum separation distance to air pathways into safety-related structures versus supply pipe diameter for liquid releases from a 150 psig liquid hydrogen storage tank. The maximum liquid hydrogen pipe diameter upstream of the first excess flow check valve shall be less than one half of an inch. This dimeter corresponds to a separation distance of approximately 1400 feet.

The excess flow check valves for the liquid and gaseous hydrogen piping are inside the fenced area of the hydrogen storage site. Therefore, the maximum overpressures produced by a pipe break would be enveloped by those produced by the explosion of the liquid hydrogen storage tank, which are below the HWC Guidelines blast criteria.

4.2 LIQUID OXYGEN

4.2.1 Site Characteristics of the Liquid Oxygen System

4.2.1.1 Overview

A review of the following characteristics was conducted for the location of the liquid oxygen storage system.

a. The location of the supply system in proximity to exposures as addressed in NFPA 50 and the hydrogen storage facility,

b. The route of liquid oxygen delivery on site, and

c. The location of the supply system in proximity to safety-related equipment.

4.2.1.2 Specific Oxygen Conditions

4.2.1.2.1 Fire Protection

The liquid oxygen supply facility is located 1000 feet from the nearest safety-related structure. The site location is shown in Figures 7 and 15. This site location meets or exceeds all requirements for protection of personnel and equipment as addressed in NFPA 50, "Bulk Oxygen Systems." A distance of 500 feet is provided between the oxygen and hydrogen supply sites. This provides as much separation distance as practical between the two sites.

4.2.1.2.2 Security

The oxygen supply facility is completely fenced and is located inside the owner controlled area. Lighting is to be installed to facilitate night surveillance.

4.2.1.2.3 Route of Liquid Oxygen Delivery on Site

The route to be taken by liquid oxygen supply vehicles on Commonwealth Edison property is shown on Figure 9. Truck barrier posts are located approximately at the fence perimeter to protect the facility from mobile equipment.

4.2.1.2.4 Location of Storage System to Safety-Related Equipment

The liquid oxygen supply system location has been shown to be acceptable considering the following hazards.

a. Liquid Oxygen Storage Vessel Failure, and

b. Liquid Oxygen Vapor Cloud Dispersion.

4.2.2 Liquid Oxygen Storage Vessel Failure, Vapor Cloud Dispersion

The vapor cloud instantaneously formed by a large liquid oxygen spill or tank failure could conceivably be injected into safety-related air intakes. The HWC Guidelines address this problem and provide acceptable locations to safety-related air intakes for various sizes of liquid oxygen storage tanks. The storage tank for the liquid oxygen storage facility is an 11,000-gallon tank. Using this tank size and Figure 16 taken from the BWR Guidelines, the acceptable location can be found. The nearest safety-related air intakes are the control room outside air ventilation intakes. These intakes are 28 feet above ground level and are located inside the plant security fence, which is located 850 feet from the oxygen supply facility. This location meets the acceptable location criteria of Figure 16. Since this figure assumes the origin of release is from the storage location, the tank and its foundation have been designed to remain in place for the design basis tornado, and the oxygen storage site is 20 feet higher than the plant elevation of 595 feet, to eliminate any flooding concerns.

5.0 VERIFICATION

5.1 HYDROGEN WATER CHEMISTRY VERIFICATION SYSTEM

The performance of the HWC System will be evaluated by a Hydrogen Water Chemistry Verification System (HWCVS) which is depicted in Figure 17, sheets 1 through 5. This system consists of an autoclave subsystem, an orbisphere subsystem, and a monitoring panel.

5.1.1 Autoclave Subsystem

The autoclave subsystem contains three autoclaves. Each autoclave receives 2 to 4 gallons/min of water from the Reactor Process Sample Panel line at up to 1250 psig and 575°F. The first autoclave contains a crack growth monitoring system, which is capable of detecting changes in sample crack length as small as 0.0002 inch. The second autoclave is a modular unit containing a constant extension rate tensile (CERT) test system. This system will perform a one week long CERT test on both cracked and uncracked samples when it is installed. After the test has been performed the sample will be examined to identify if intergranular fracture had occurred. The last autoclave contains an electrochemical potential monitoring system, which measures the corrosion potential in the water. After flowing through the final autoclave, the sample water will be cooled to below 150°F before being discharged to the suction header of the Reactor Water Clean-Up System Recirculation Pumps.

5.1.2 Orbisphere Subsystem

The orbisphere subsystem contains a single water conductivity analyzer and two dissolved oxygen analyzers. The orbisphere subsystem receives water from the Reactor Process Sample Panel at 150 psig and 120°F. After passing through the orbisphere subsystem the sample water is discharged to the Reactor Building Process Sample Panel Drain Header for the Reactor Building

Equipment Drain Tank.

5.1.3 Monitoring Panel

The monitoring panel contains a computerized Data Acquisition System (DAS), which monitors and records data for the HWCVS (as covered in Sections 5.1.1 and 5.1.2) in addition to plant power level, autoclave temperature and flow, and hydrogen injection rate. This system will be used to develop correlations between crack growth and plant water chemistry parameters.

5.2 SAFETY CONSIDERATIONS

The new sample lines for the HWCVS were added to the existing sample line for each Unit's Reactor Process Sample Panel. These new sample lines are for the autoclave and orbisphere subsystems of the HWCVS. The existing sample line for the Reactor Process Sample Panel System is separated from the reactor recirculation Loop B for Unit 1 or Loop A for Unit 2 by dual Group I containment isolation valves.

On June 19, 1987, the NRC transmitted a revision to BTP MEB 3-1, of SRP 3.6.2 in NUREG-0800 entitled, "Postulated Rupture Locations in Fluid System Piping Inside and Outside Containment." It stated that for the following pipes, breaks do not need to be postulated:

a. Longitudinal breaks for high energy piping with a diameter less than 4 inches (Section B.3.b.(1)).

b. Leakage cracks for moderate and high energy piping with a diameter less than 1 inch (Section B.3.c.(1)).

It is also stated that piping used as instrument lines with a diameter less than 1 inch should conform with the provisions in Reg. Guide 1.11 to guard against circumferential line breaks (section B.3.a(10).

Both of the new lines have a diameter less than 1 inch and the high energy line to the Autoclave subsystem conforms with Regulatory Guide 1.11 (section c.2.b). Therefore, no new failure modes need to be analyzed.

6.0 OPERATION, MAINTENANCE, AND TRAINING

The operation of an HWC system will require operator and chemistry personnel attention. Because of the radiation increases that will result from using this system, an awareness of ALARA principles is required by all personnel. This system will also have an effect on the off-gas system and the plant fire protection program.

6.1 OPERATING PROCEDURES

Operating procedures design guidance will be implemented through provision of appropriate written operating instructions for all applicable site operations. Procedures will be provided for pre-operational testing and startup including system leak testing, system purging and system fill and vent (see Section 7.1); normal system operation including requirements for system alarm and trip functions, system restart and shutdown; system maintenance including preventative maintenance items and periodic retesting requirements (see Sections 6.1.3.4 and 6.2); and material handling including fire protection measures.

6.1.1 Integration Into Existing Plant Operation Procedures

Where appropriate, HWC system operation will be referenced in normal plant procedures and referred to appropriate system operating instructions.

6.1.2 Plant-Specific Procedures

Current off-gas system procedures will be modified to recognize required changes due to operation of the HWC system.

6.1.3 Radiation Protection Program

The operation of the hydrogen addition system will cause a slight reduction in the off-gas delay time due to the increase in the flow rate of noncondensibles resulting from the excess oxygen added. The maximum potential increase in the dose to the public which could result from operating with the hydrogen addition system has been conservatively estimated by assuming that the off-gas system was operated with 125 scfm of injected air in addition to an assumed 40-scfm condenser air inleakage. It was further assumed that this mode of operation was maintained for the full year, even though this is considered to be a backup or supplemental mode only.

Based on gaseous release data from the past six years, the maximum off-site dose under these circumstances is less than 3 mrem/year, which is well below any regulatory limit or level of concern. Therefore, the impact on the health and safety of the public due to this aspect of the hydrogen addition system is negligible. Additional information relating to radiological effects due to the operation of the HWC system can be found in Section 8.

6.1.3.1 ALARA Commitment

Commonwealth Edison management is committed to designing, installing, operating, and maintaining the hydrogen addition system in accordance with Regulatory Guides 8.8 and 8.10 to assure that occupational radiation exposures and doses to the general public will be "as low as reasonably achievable."

6.1.3.2 Initial Radiological Survey

A preliminary radiological survey has been completed to identify potential radiological effects on the Quad Cities Station. Areas of the station which may experience increased dose rates have been identified. The results of this survey will be confirmed and additional measures introduced, if required, when hydrogen injection is implemented.

6.1.3.3 Plant Shielding

Based on the survey completed in accordance with Section 6.1.3.2, and the experience at the Dresden Station, the shielding in the Quad Cities Station appears to be sufficient to attenuate the contributions from additional N-16 contained in the steam lines. These results will be confirmed and additional shielding will be provided, if required, when the hydrogen addition is implemented.

6.1.3.4 Maintenance Activities

Appropriate system design guidance will be incorporated into existing plant procedures to establish access control of radiation areas that are significantly affected by hydrogen addition. Also, guidelines will be established for any additional controls required for area posting and monitoring, that are necessary as a result of hydrogen injection.

6.1.3.5 Radiological Surveillance Programs

The existing radiological surveillance program as described in Section 8.4 of the Offsite Dose Calculation Manual is adequate for assuring compliance with regulatory requirements for offsite doses to the public. This is an ongoing program and has therefore yielded a data base of measured doses which arise from normal operation. The doses which are measured during operation with hydrogen addition will be compared with the existing data base to ensure that the impact on the public due to hydrogen addition is ALARA.

The existing on-site radiological survey program is adequate for determining the impact of hydrogen addition on station operation and ensuring that station operation will be ALARA. As experience is gained with the hydrogen addition system, the program will be modified if additional measures are required.

6.1.3.6 Measurement of N-16 Radiation

The survey meter which will be relied upon for N-16 measurements is the Eberline Model RO-3 ion chamber. The construction and energy dependence of this monitor is essentially the same as those of the Eberline Model RO-2 ion chamber. Vendor supplied data indicates that this series of ion chambers has a small over-response at 6 MeV (about 10%). Therefore, the accuracy of these meters is adequate for measurements of radiation fields due to N-16.

A review of plant personnel dosimetry will be conducted to ensure that appropriate calibration or correction factors are used.

6.1.3.7 Value/Impact Considerations

A radiological assessment at Dresden indicated that the total dose increase with HWC was approximately 0.5% of an annual basis (from 1935 to 1945 man-rem/year). While this increase is site dependent due to plant layout and shielding configurations, significant variances from the Dresden assessment are not anticipated. Thus, over the life of a plant (assuming a 25-year remaining life), the project total dose increase with HWC is 250-300 man-rems.

With HWC implementation, the potential exists to relax current augmented in-service inspection requirement imposed by NRC Generic Letter 84-11 and elimination of extended plant outages for pipe replacement and/or repair. The value/impact assessment presented in Appendix E to NUREG-1061 (Volume 1, August 1984) projects a 1161 man-rem (best estimate) savings over the life of the plant as a consequence of reduced inspections and repairs with HWC. Typical pipe replacement projects result in a total dose of 1400 to 2000 man-rem. Thus, HWC implementation could result in a significant savings in total dose over the life of the plant.

6.1.4 Water Chemistry Control

Commonwealth Edison Nuclear Operations Directive NOD-S17, "BWR Water Chemistry Control Program" has been issued to establish the objective, management policy, and method of control for assuring the high reactor water quality necessary to obtain the maximum benefit from the hydrogen addition system. The specific numerical water chemistry control requirements were primarily taken from the EPRI-BWR Owners Group report entitled "BWR Hydrogen Water Chemistry Guidelines," existing General Electric chemistry guidelines and known or suspected contaminant concerns at the company's BWRs. The Quad Cities station has incorporated the requirements of these guidelines into their procedures.

6.1.5 Fuel Surveillance Program

The station will consider the fuel surveillance program recommended by the fuel supplier, and in consideration of the HWC operating experience will request further guidance from the fuel supplier to implement or modify the initial recommended fuel surveillance program.

6.2 MAINTENANCE

System maintenance requirements and design guidance are to be met through incorporation of an appropriate preventative maintenance schedule and procedures into the station maintenance program. The preventative maintenance program will be based on manufacturer's recommendations, and will include surveillance inspections as well as hydrogen and oxygen subsystem excess flow check valve periodic retesting requirements. See Sections

6.1.3.4 and 7.2 for additional information.

6.3 TRAINING

The station training personnel will incorporate the design guidance into the station training program. HWC system training will provide instruction to personnel on related procedures and will include periodic training to update personnel on current system operating considerations. A student text will address the design and operation of the HWC System.

6.4 IDENTIFICATION

All hydrogen and oxygen piping was uniquely identified through the display of an appropriate color field and legend markings. Underground piping had identification tape laid 6 in. above the pipe, before the trench was filled, and markers placed over the filled trench.

7.0 SURVEILLANCE AND TESTING

7.1 SYSTEM INTEGRITY TESTING

Preoperational leak test requirements for the hydrogen piping will be met through the performance of a soap bubble leak test meeting the requirements of the 1986 edition of ANSI B31.1. This test uses nitrogen to pressurize the hydrogen piping to 150% of system design pressure for at least 15 minutes. Then the pressure is reduced to 100 psig to perform a soap bubble leak test on all of the pipe points. A retest will be performed following any modifications to the hydrogen piping that may affect the pressure boundary of the system. This retest will use nitrogen to pressurize the affected section of piping to 110% of system design pressure for at least 15 minutes. Then the pressure is reduced to 100 psig to perform a soap bubble leak test on the affected pipe joints.

7.2 PREOPERATIONAL AND PERIODIC TESTING

The following items are addressed in the Quad-Cities BWR Water Chemistry Installation Preoperational and Startup Test Procedure:

a. All trip and alarm functions,

b. Safety features,

c. Excess flow check valves, and

d. System controls and monitors.

Periodic retesting requirements shall be met through implementation of an appropriate retesting schedule and procedures, based on manufacturer's recommendations and in consideration of extended Hydrogen Water Chemistry system shutdown periods or other factors not consistent with normal system operation.

8.0 RADIATION MONITORING

8.1 INTRODUCTION

During normal operation of a BWR, nitrogen-16 is formed from an oxygen-16 (N-P) reaction. N-16 decays with a half-life of 7.1 seconds and emits a high-energy gamma photon (6.1 Mev). Normally, most of the N-16 combines rapidly with oxygen to form water-soluble, nonvolatile nitrates and nitrites. However, because of the lower oxidizing potential present in a hydrogen water chemistry environment, a higher percentage of the N-16 is converted to more volatile species. As a consequence, the steam activity during hydrogen addition can increase up to a factor of approximately five. The dose rates in the turbine building, plant environs, and off-site also increase; however, the magnitude of the increase at any given location depends upon the contribution of the steam activity to the total dose rate at that location. The specific concerns are:

a. The dose to members of the general public (40 CFR 190),

b. The dose to personnel in unrestricted areas (10 CFR 20), and

c. The maintenance of personnel exposure "as low as reasonably achievable" (ALARA).

8.2 MAIN STEAM LINE RADIATION MONITORING

The current Quad Cities Technical Specifications require a Main Steam Line Radiation Monitor (MSLRM) set point of seven (7) times the normal rated full-power background for Main Steam line Isolation and Reactor SCRAM. As part of the changes to the technical specifications Quad-Cities will utilize a single set point of three (3) times the full-power rated background with hydrogen addition. This exception to the guidelines is fully justified in the discussion below:

8.2.1 Dual MSLRM Set Point Recommendation

Commonwealth Edison takes exception to this recommendation. Calculations have been performed which indicate that the MSLRM will continue to perform its safety function with a single set point. The advantage gained from a single set point is that it eliminates the procedural actions which would be required to change between the dual set points during power ascension and descension. Minimization of required procedural actions during this phase of operations enhances overall operational safety by eliminating unnecessary operator diversions.

The proposed set point increase is to fifteen (15) times the current nominal full power background (NFPB). The factor of fifteen provides an adequate safety margin to assure that the MSLRM will perform its intended safety function while eliminating spurious challenges to the safety systems. It is based on allowing for a factor of five (5) increase in the current nominal full power background due to increased N-16 carry-over in the main steam, and a factor of three (3) in the monitor response variation (which is consistent with current generic BWR technical specifications). Note that the current technical specification set point is a factor of seven (7) times the current NFPB, so that the new value represents a net increase of a factor of approximately 2.5 rather than 5. As discussed in Section 8.2.2, sufficient margin exists at the new set point to assure that the MSLRM will perform its intended safety function following the design basis control rod drop accident.

8.2.2 MSLRM Safety Design Basis

The only design basis event in which the Quad-Cities Station takes credit for the MSLRM is the control rod drop accident (CRDA). For this accident the conservatively calculated dose rate at the MSLRM is 8 R/hr. The new setpoint is 1.5 R/hr, which is fifteen (15) times the current nominal full power operation background dose rate. Since the calculated dose rate from the CRDA is approximately five times the proposed set point, the MSLRM will retain the capability to initiate the required safety actions on the high radiation signal caused by the CRDA.

Raising the MSLRM trip set point from 0.7 R/hr to 1.5 R/hr will not significantly increase the radiological release from a CRDA. The difference between the time required to reach the current trip set point and the new trip set point is approximately 1/4 second, and the time required to reach the new trip set point remains less than 1/2 second. The time period permitted for completing closure of the main steam isolation valve is 5 seconds (Quad Cities Technical Specification 3.7/4.7 D.1). The increase in time-to-closure (due to the new trip set point) is only 5% of the current time-to-closure. This will have a small effect on the total release and concomitant dose to the public. Since the calculated dose from the CRDA is only 12 mrem, the increase will be very small and, therefore, does not involve a significant increase in the consequences of an accident previously evaluated.

Because the CRDA is the only accident which requires MSLRM initiated actions, the new set point does not create the possibility of a new or different kind of accident from any previously evaluated. No other previously analyzed accidents or malfunctions, as addressed in the UFSAR, are involved.

The MSLRM is provided only to mitigate the radiological consequences of a CRDA once fuel damage has occurred. Other means are provided to minimize fuel damage from a CRDA. Therefore the new set point does not involve an increase in the probability of a CRDA or any other accident.

The new set point does not involve a significant reduction in the margin of safety. It has been conservatively calculated that the margin required to assure that the monitor will trip and perform its intended function is 0.7 R/hr. When this value is added to the new s t point value of 1.5 R/Hr, the total dose rate required to assure that the monitor will trip is 2.2 R/Hr. As discussed above, the calculated dose from the CRDA is 8 R/hr. Therefore, the margin of safety between the trip set point and the calculated dose rate from the CRDA is more than enough to assure that the monitor will perform its intended function.

8.2.3 MSLRM Sensitivity

Conceptually, the sensitivity of the MSLRM to fission products is effectively reduced by the increase in the setpoint. However, it is still functional and capable of initiating a reactor scram. The main function of the instrument is to help maintain offsite releases to within the applicable regulatory limits. The MSLRM is supplemented by the off-gas radiation monitoring system which monitors the gaseous effluent prior to its discharge to the environs. The off-gas radiation monitor setpoint is established to help ensure that the equivalent stack release limit is not exceeded.

8.2.4 Conclusion

The only accident which requires the MSLRM is the CRDA. It has been shown that, for this scenario, the increased set point does not affect the ability of the MSLRM to perform its intended safety function, and has minimal impact or the health and safety of the public. It has also been shown that the increased set point has no affect on the capability of the station to detect noble gas releases from the reactor core. From the above discussion, it can be concluded that an increase in the MSLRM set point will not reduce the safety margins as defined by technical specifications, and therefore this changes does not constitute an unreviewed safety concern.

8.3 EQUIPMENT QUALIFICATION

Commonwealth Edison has estimated the expected radiation values for the Quad-Cities Station due to hydrogen addition. All environmental qualification of electrical equipment per 10 CFR 50.49 will remain bounding based upon these estimated dose increases. After the HWC system is operational, additional radiation surveys will be performed to determine the actual dose increase to equipment.

8.4 ENVIRONMENTAL CONSIDERATIONS

The radiological environmental effects of hydrogen addition have been evaluated for the Quad-Cities Station. It has been determined that the calculated annual average offsite dose, including the effects of hydrogen water chemistry, will be within the guidelines of 40CFR190. This evaluation was performed using the environmental dose models and techniques in the Commonwealth Edison Offsite Dose Calculation Manual (Rev. 11, March 1985) as modified to take into account current recreational river usage.

The dose evaluation accounted for the "skyshine" due to the increased N-16 in the turbine and main steam piping, the "worst case" effects of hydrogen addition on the plume shine dose, and currently existing onsite gamma radiation sources. Assuming that the N-16 in the main steam increases by a factor of 5, it has been conservatively estimated that the dose to the maximally exposed individual will be less than 20 mrem/year.

9.0 QUALITY ASSURANCE

Although the HWC system is non-nuclear safety related, the design, procurement, fabrication and construction activities shall conform to the quality assurance provisions of the codes and standards specified in this document. The following QA provisions were also followed to supplement the QA provisions of the codes and standards.

9.1 SYSTEM DESIGNER AND PROCURER

9.1.1 Design and Procurement Document Control

System design and procurement guidance is reflected in Sargent & Lundy specifications, instrument data sheets, and design drawings. The specifications were developed by Sargent & Lundy Engineers and then reviewed by Commonwealth Edison Company.

9.1.2 Control of Purchased Material, Equipment and Services

Measures have been developed to ensure that suppliers of material, equipment and construction services are capable of supplying these items to the quality specified in the procurement documents. This was accomplished by evaluations and surveys of the suppliers products and facilities.

9.1.3 Handling, Storage and Shipping

Instructions were provided in the procurement documents to control the handling, storage, shipping and preservation of material and equipment to prevent damage, deterioration, or reduction of cleanliness.

9.2 CONTROL OF HYDROGEN STORAGE EQUIPMENT SUPPLIERS

A supplier for the interim hydrogen storage facility has not been specified at this time. After this supplier is determined the design and manufacturing documents shall be audited to assure conformance to the procurement documents. Factory tests of the system shall also be specified which will assure operability of the supplier's equipment. These tests will be supervised by Sargent & Lundy personnel or their representatives.

9.3 SYSTEM CONSTRUCTOR

Quad-Cities Station Quality Control Department shall provide necessary inspection activities and identification of conforming and nonconforming items with regard to the requirements of the procurement documents or applicable codes and standards. They shall also identify the remedial actions to be taken to correct any nonconformances.

10.0 DEVIATIONS/EXEMPTIONS FROM THE BWR GUIDELINES

This section contains all deviations and exemptions from the design guidance stated in the BWR Guidelines.

10.1 DEVIATIONS FROM GUIDANCE ON PIPE IDENTIFICATION

These deviations are from Sections 2.3.1.2 and 2.3.2.2 Codes and Standards.

Deviation - The BWR Guidelines recommend all hydrogen and oxygen piping and equipment to be identified in accordance with ANSI Z35.1. However, the installed piping is not marked in accordance with this standard.

Justification - The intent of this standard is to ensure that all hydrogen and oxygen piping is readily identified from other plant piping. This intent has been met by uniquely identifying all hydrogen and oxygen piping through the display of color fields and legend markings.

This deviation is from Section 6.4 Identification:

Deviation - The BWR Guidelines recommend color coding all hydrogen and oxygen lines in accordance with ANSI A13.1 to aid plant personnel. However, the installed hydrogen and oxygen lines are not marked in accordance with this standard.

Justification - The intent of this standard is to ensure that all oxygen and hydrogen lines are readily identified from other plant piping. This intent has been met by uniquely identifying all hydrogen and oxygen lines through the display of color fields and legend markings.

10.2 EXEMPTIONS FROM GUIDANCE ON HWC SYSTEM TRIPS

These exemptions are from Table 1, Suggested Trips for Hydrogen Water Chemistry System, which is referenced in Section 2.4 INSTRUMENTATION AND CONTROL

Exemption - High Residual Oxygen In Off-Gas Trip

Justification - A high residual oxygen concentration in the off-gas system implies that more oxygen is being injected into the off-gas stream than is necessary to recombine with the hydrogen in the off-gas. Therefore, there will not be an increase in the explosive concentration of hydrogen plus oxygen in the off-gas stream due to the low hydrogen level. The residual oxygen concentration in the off-gas system is monitored in the control room and can be manually adjusted.

Exemption - Low Oxygen Injection System Supply Pressure or Flow Trip

Justification - The intent of this trip has been met by augumenting the oxygen supply with building air. This allows part of the oxygen requirements to be met through building air. Therefore, in the event of a loss of oxygen supply, the building air will provide the necessary oxygen to prevent an excess hydrogen condition in the off-gas system.

Exemption - Off-Gas Train or Recombiner Train Trip

Justification - A procedure will be implemented to isolate the hydrogen and oxygen injection systems upon receiving an off-gas train or recombiner train trip. This procedure will request a manual trip of the hydrogen injection system and a manual adjustment of the oxygen flow controller to zero.

10.3 <u>DEVIATION FROM GUIDANCE ON SYSTEM INTEGRITY TESTING</u>

This deviation is from Section 7.1 System Integrity Testing.

Deviation - The HWC Guidelines recommend performing a Helium leak test on any portions of the hydrogen piping that is affected by modifications or maintenance.

Justification - Helium leak testing is not justified, as its performance would cause additional cost and unnecessary delay, as well as unwarranted and undesirable complications. The proposed nitrogen leak testing conforms with the 1986 edition of ANSI B31.1 and adequately proves system joint integrity, consistent with the initial system installation considerations.

10.4 DEVIATION FROM GUIDANCE ON MAIN STEAM LINE RADIATION MONITORING

This deviation is from Section 8.2 MAIN STEAM LINE RADIATION MONITORING.

Deviation - The BWR Guidelines recommend a dual set point for the MSLRM if credit is taken for a MSLRM-initiated isolation in the Control Rod Drop Accident (CRDA). This would require changing the MSLRM set point at a power level of 20%, to 3 times the normal rated full power background with hydrogen addition. Below 20% rated power the MSLRM set point would remain at its non HWC setting and the HWC system would not be allowed to operator. However, the Quad-Cities Station HWC system will utilize a single MSLRM set point with a setting of 3 times the normal rated full power background with hydrogen addition, even though credit is taken for a MSLRM-initiated isolation for the CRDA.

Justification - This exemption is justified in Section 8.2.

TABLE 1

TRIPS FOR THE HYDROGEN WATER CHEMISTRY SYSTEM

- Low Power Level[1]
- Reactor SCRAM
- Operator Request (Manual)
- Low Residual Oxygen In Off-Gas
- High Area Hydrogen Concentration
- High Hydrogen Flow
- Low Hydrogen Flow
- Hydrogen Storage Area Trouble

Note:

1. The operator can set the minimum steam flow point (0 to 100%) at which the hydrogen addition system will operate.

TABLE 2

HYDROGEN WATER CHEMISTRY SYSTEM INSTRUMENTATION AND CONTROLS

Portion of Overall System	Parameter Measured or Function Performed	Record	Indicate	High Alarm	Low Alarm	Auto Control	Notes
Injection Systems (Hydrogen/Oxygen)	Hydrogen Flow	X	X	X	X	Trip on high/low flow	1
	Oxygen Flow		X				2
	Off-Gas Residual Oxygen	X	X		X	Trip on low oxygen	1
	Recirc Water Dissolved Oxygen	X	X	X	X		3
	Area Hydrogen Concentration		X	X		Trip on high hydrogen concentration	1,4
	Steam Flow Low				X	Trip on low flow	1
	Hydrogen Injection Line Pump Interlock					Isolate when condensate pump not in operation	
Hydrogen Supply	Hydrogen Gas Supply Pressure		X				5
	Hydrogen Gas Storage Temperature		X				5
	Hydrogen Tank Level Gauge		X				5
	Hydrogen Tank Pressure Gauge		X				5

TABLE 2 (Cont'd)

HYDROGEN WATER CHEMISTRY SYSTEM INSTRUMENTATION AND CONTROLS

Portion of Overall System	Parameter Measured or Function Performed	Record	Indicate	High Alarm	Low Alarm	Auto Control	Notes
	Hydrogen Tank Vacuum Readout		X				5
	Low Temperature Downstream of Hydrogen Vaporizer		X		X	Trip Hydrogen Pump	5
	Hydrogen Pump High Discharge Temperature		X	X		Trip Hydrogen Pump	5
Oxygen Supply	Oxygen Tank Level Gauge		X		X		6
	Oxygen Tank Pressure Gauge		X				6
	Oxygen Tank Vacuum Readout Connection		X				6
	Low Temperature Down-stream of Oxygen Vaporizer		X		X		6

Notes:

1. The Hydrogen Injection System will be tripped on this signal. The Oxygen Injection System will hold at its set injection rate for 15 minutes and then decrease to zero flow within 5 additional minutes.

2. If a record of oxygen flow is determined to be necessary, it can be added to the second pen contained in the off-gas oxygen concentration recorder.

3. The Low Recirc Water Dissolved Oxygen alarm was provided as a means of preventing excess hydrogen use.

4. The indication for Area Hydrogen Concentration is installed on a local control panel.

5. These indicators are contained on a local control panel at the hydrogen storage area. The control room panel for the Hydrogen Water Chemistry system will contain an alarm for Hydrogen Storage Area trouble.

6. The indicators for the oxygen storage system are contained on a local control panel at the oxygen storage area. The control room panel for the Hydrogen Water Chemistry system will contain an alarm for Liquid Oxygen Storage Area trouble, which will activate on low tank level, high oxygen flow, low tank pressure, or low temperature downstream of oxygen vaporizer.

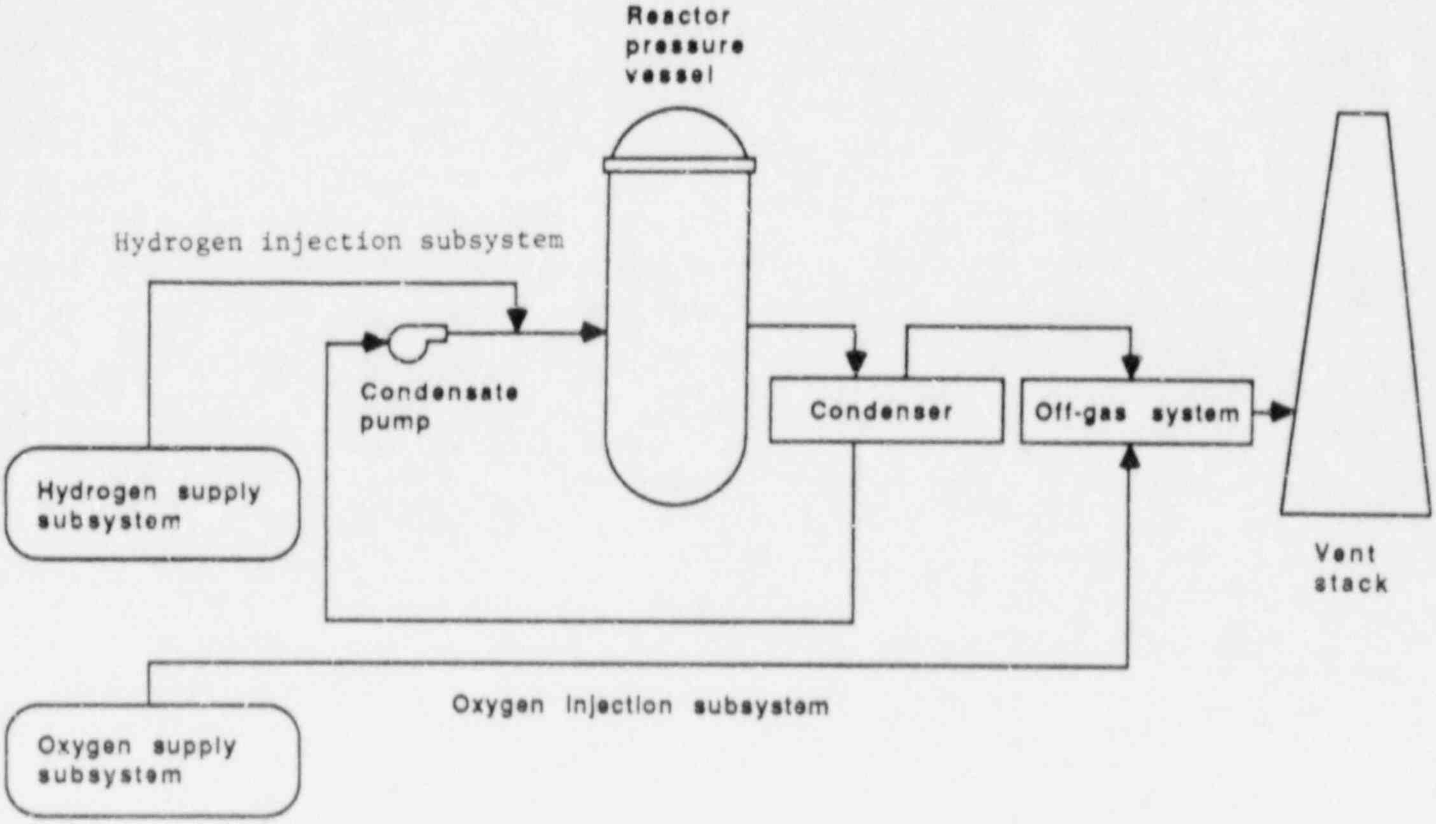
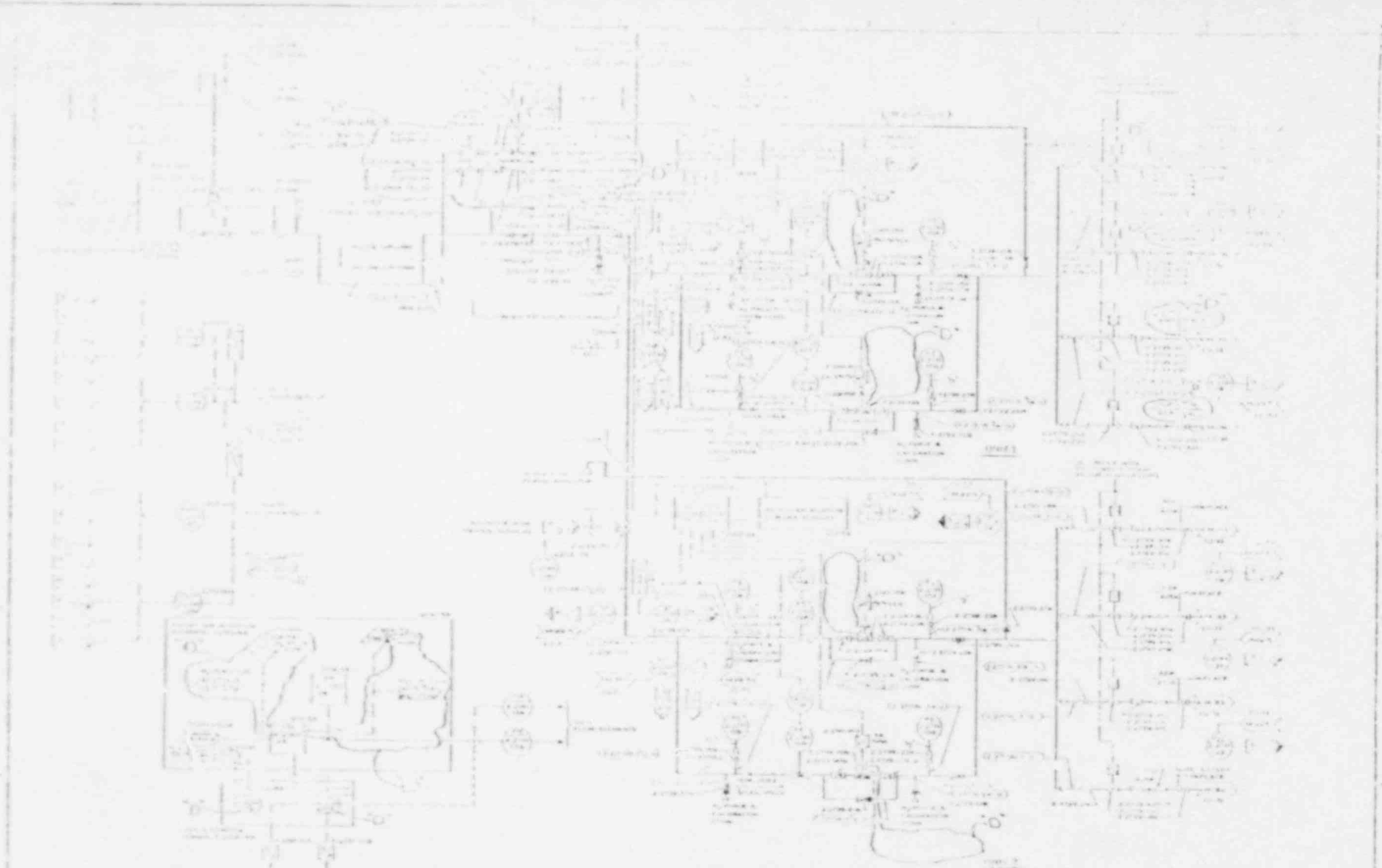


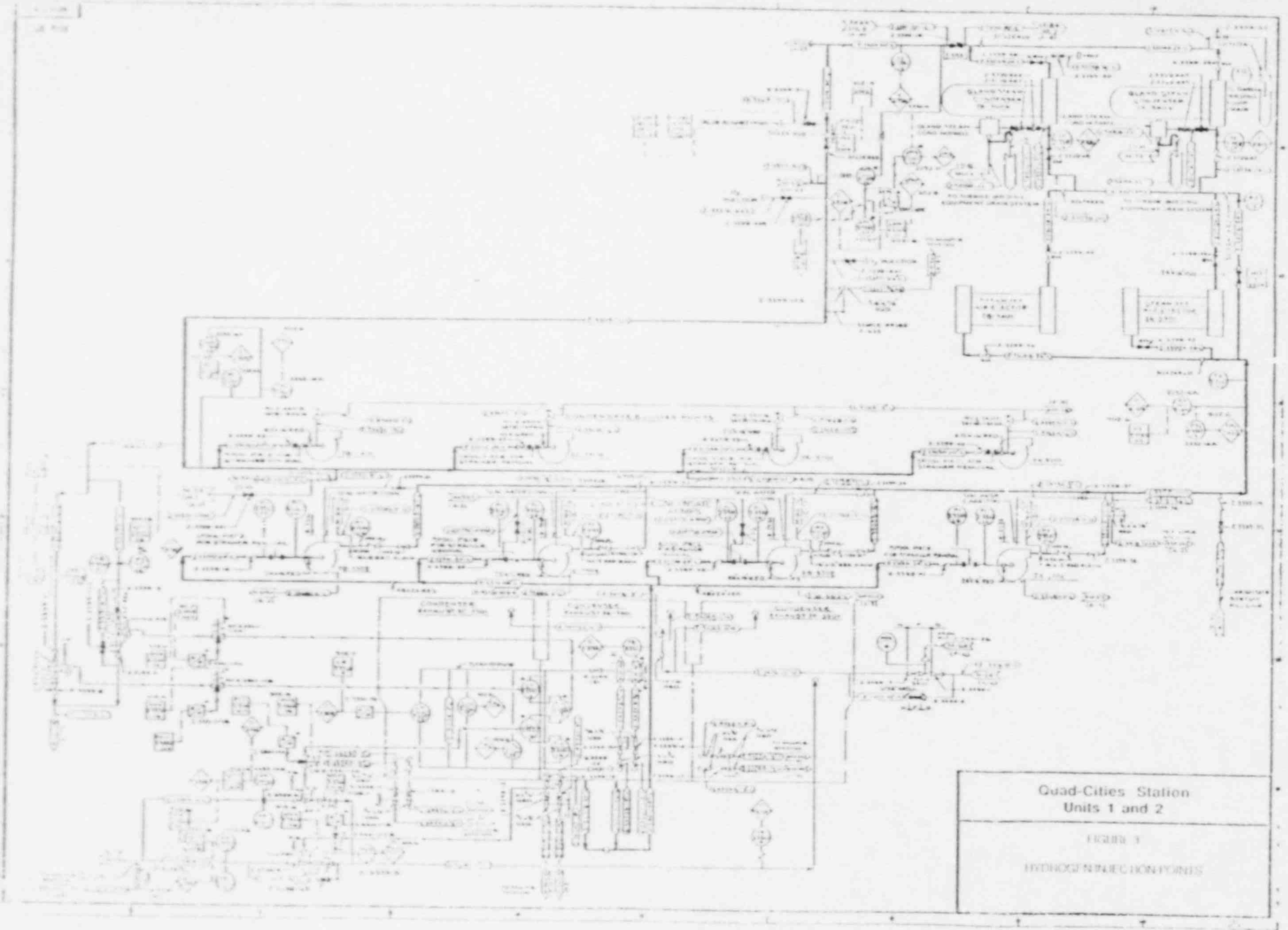
Figure 1

Hydrogen Water Chemistry System



Quad-Cities Station
Units 1 and 2

FIGURE 2



Quad-Cities Station
Units 1 and 2

FIGURE 3

HYDROGEN INJECTION POINTS

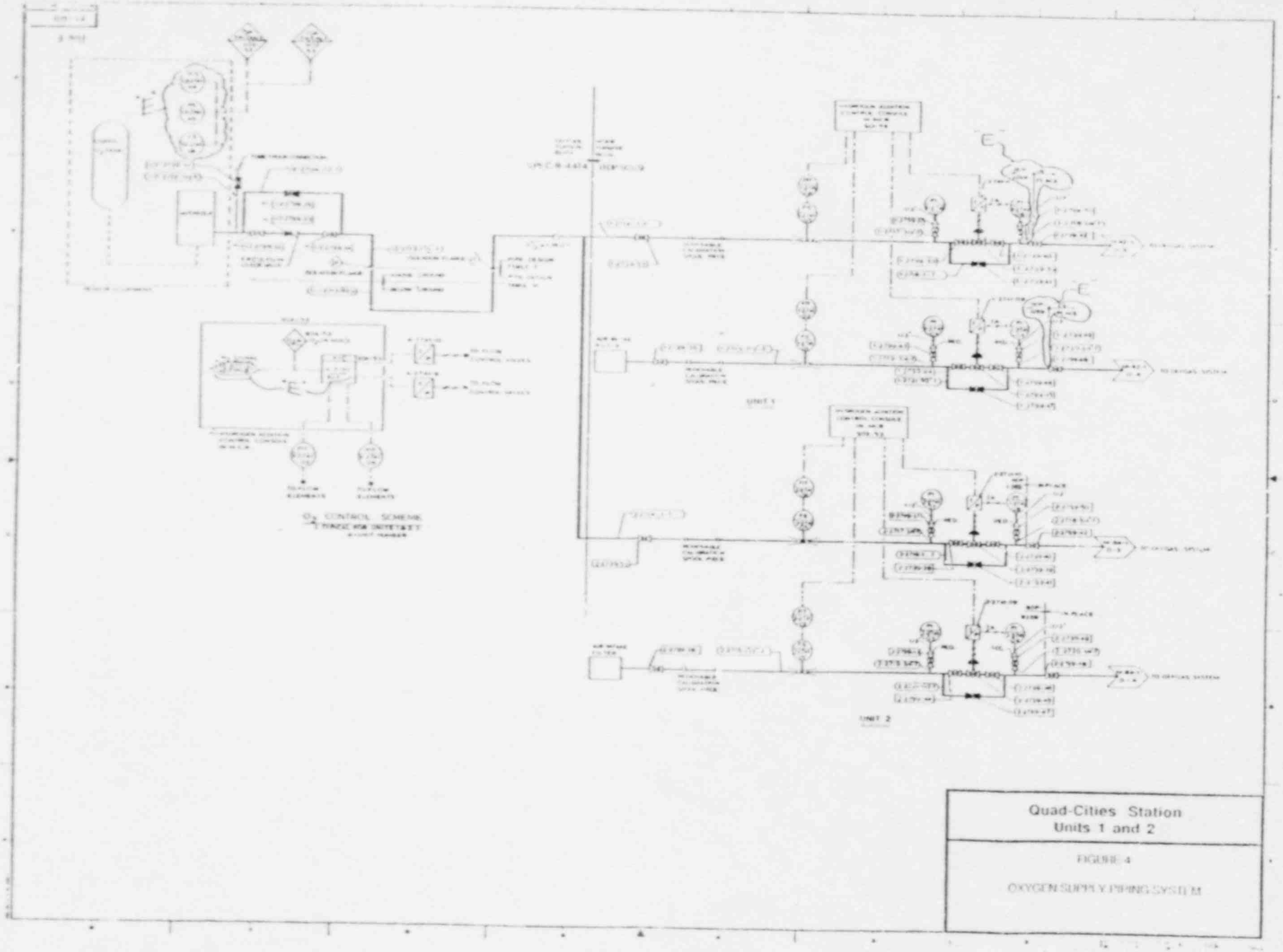

O2 CONTROL SCHEME
UNIT 1
UNIT 2
Quad-Cities Station
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FIGURE 4
OXYGEN SUPPLY PIPING SYSTEM

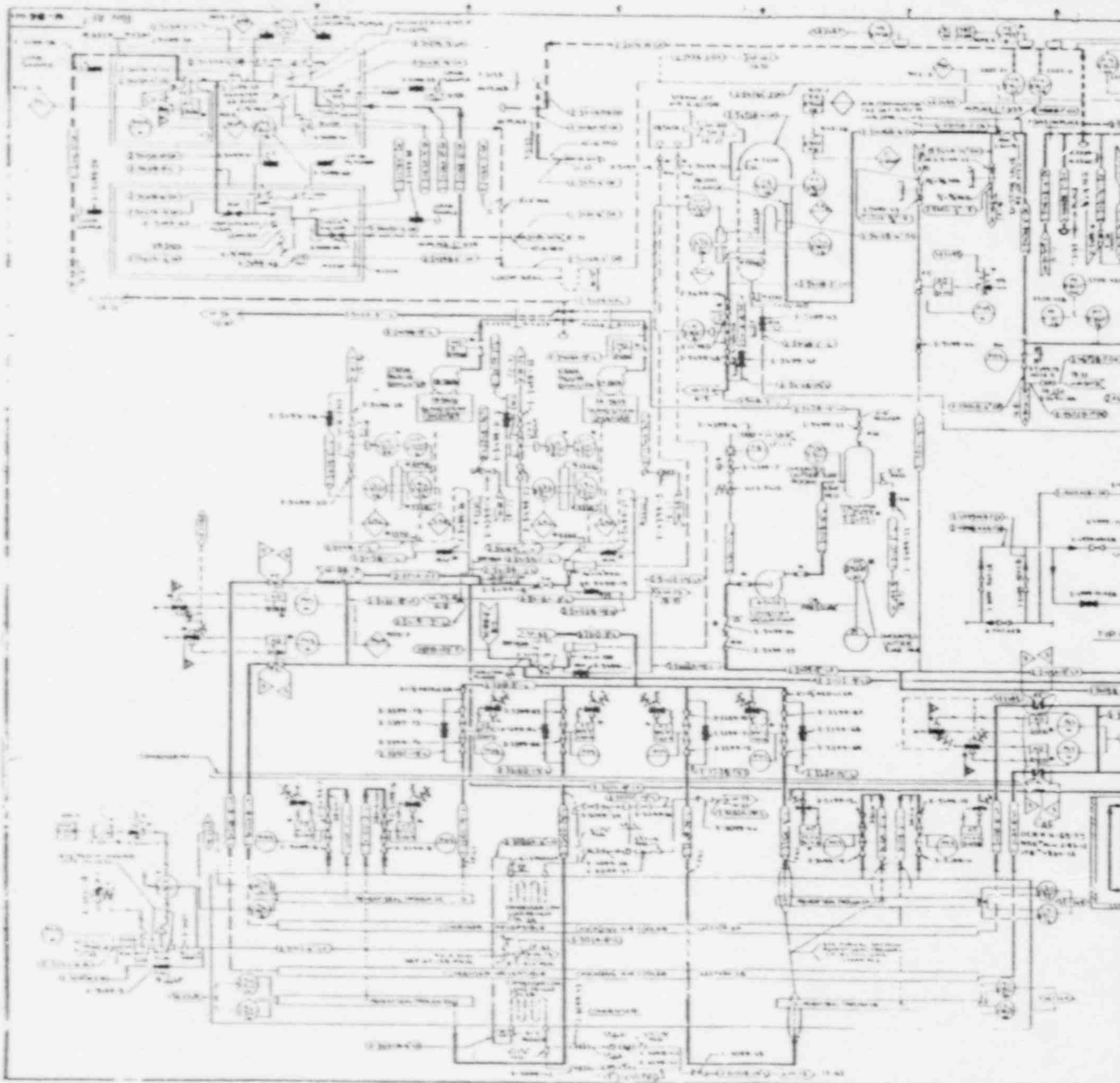

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FIGURE 5

OXYGEN INJECTION POINTS

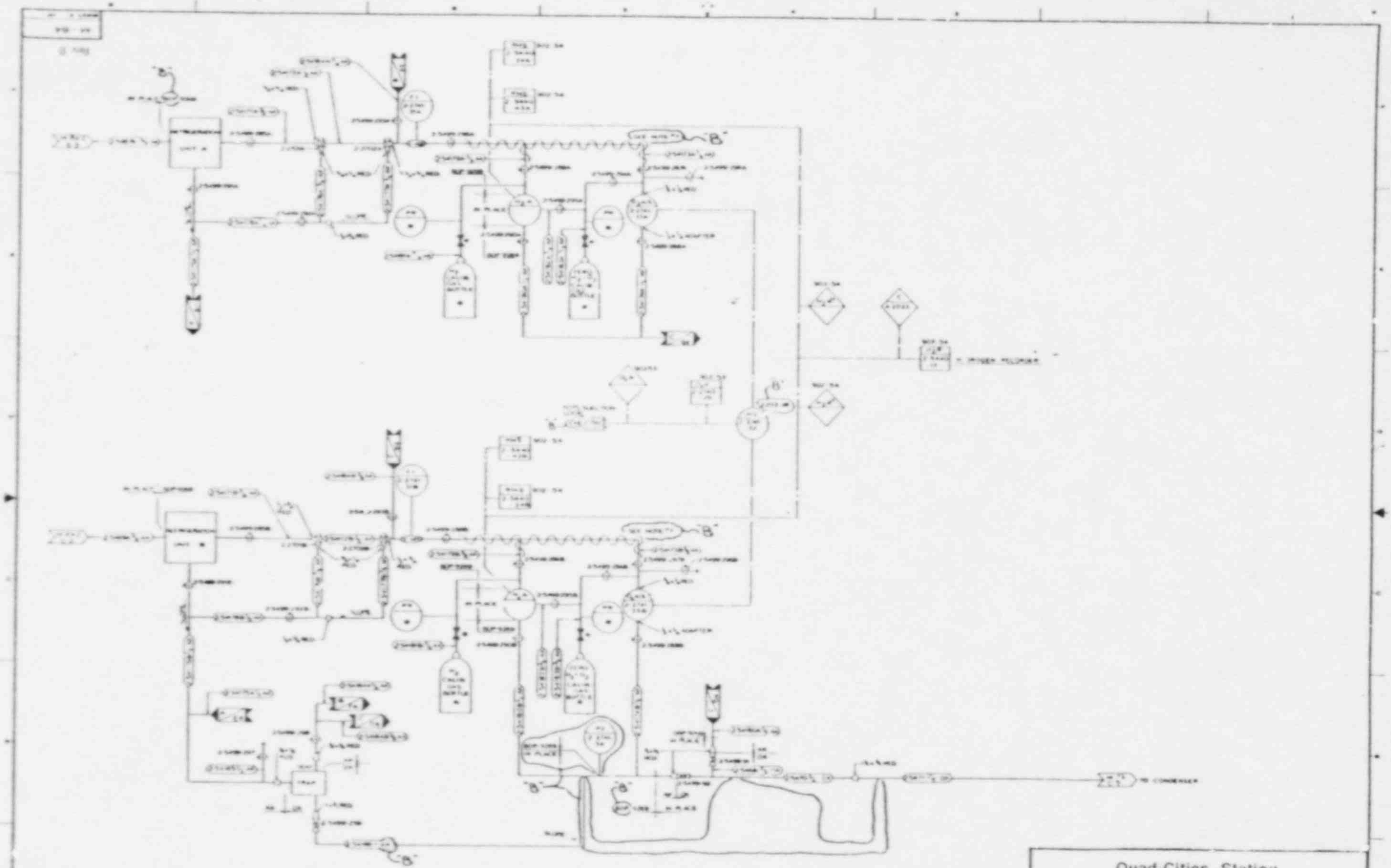

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FIGURE 6

OFF-GAS OXYGEN ANALYZERS

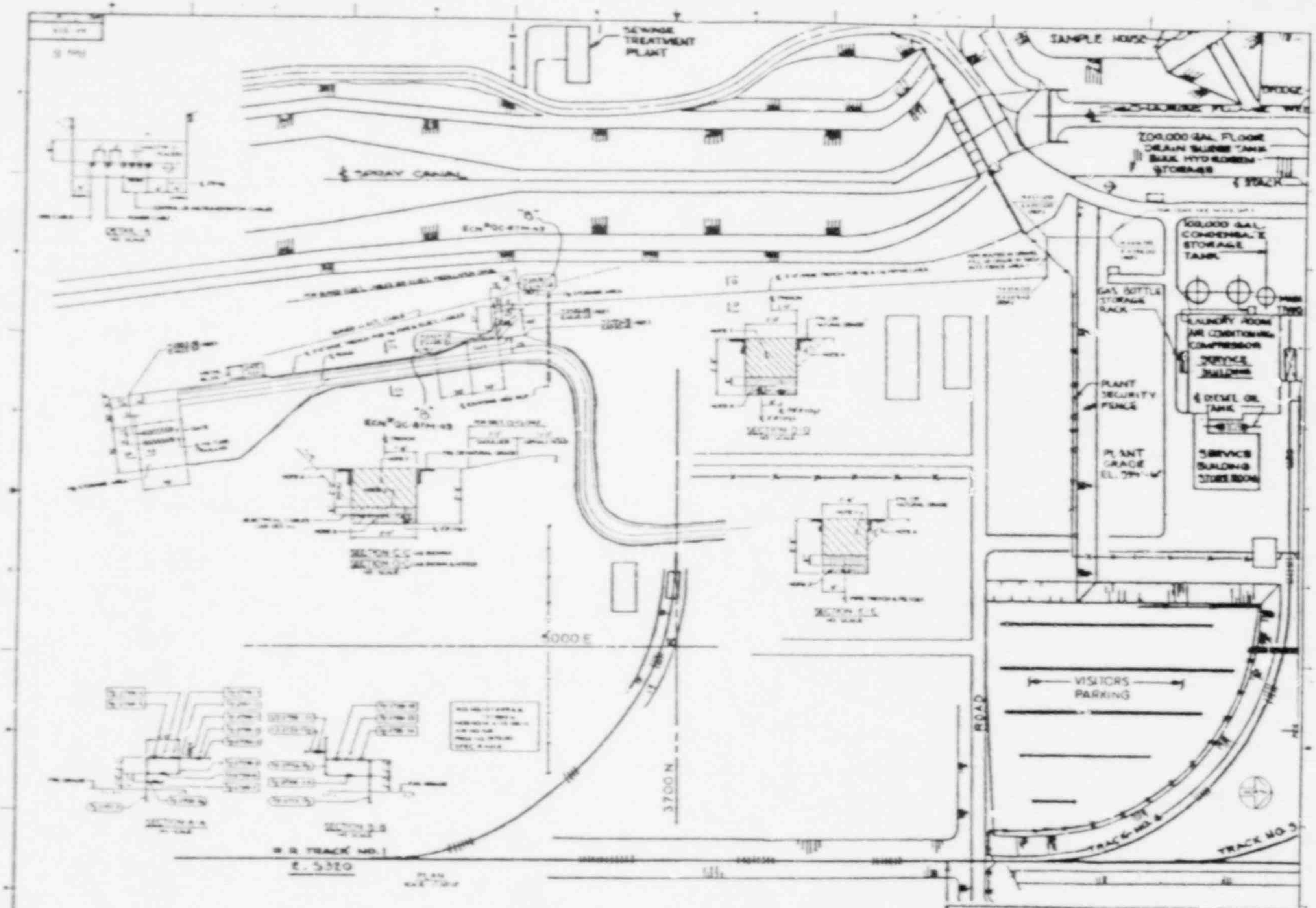

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FIGURE 7

GASEOUS HYDROGEN & LIQUID OXYGEN STORAGE FACILITY SITE LOCATION

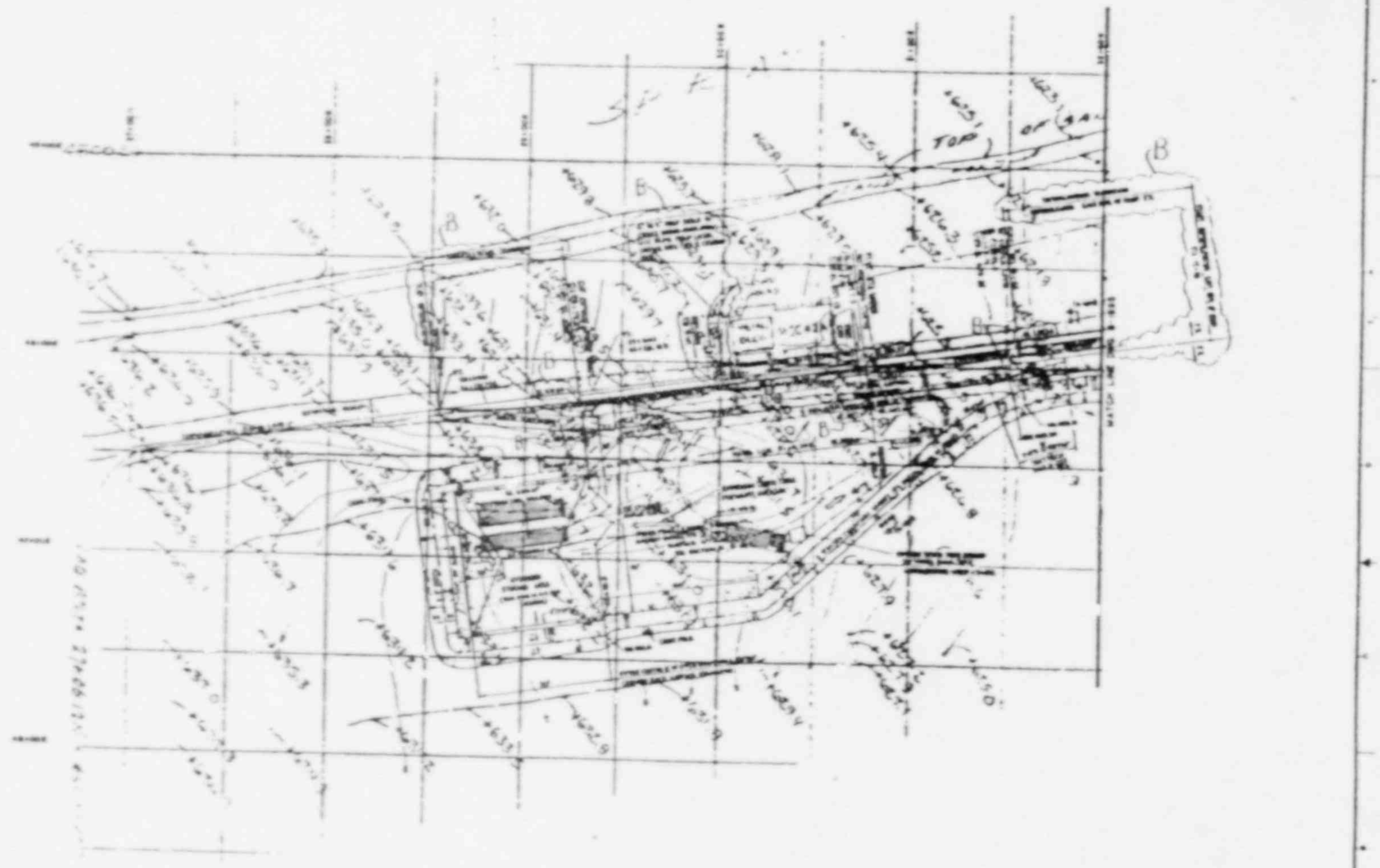

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FIGURE 8

GASEOUS HYDROGEN STORAGE FACILITY
SITE LOCATION

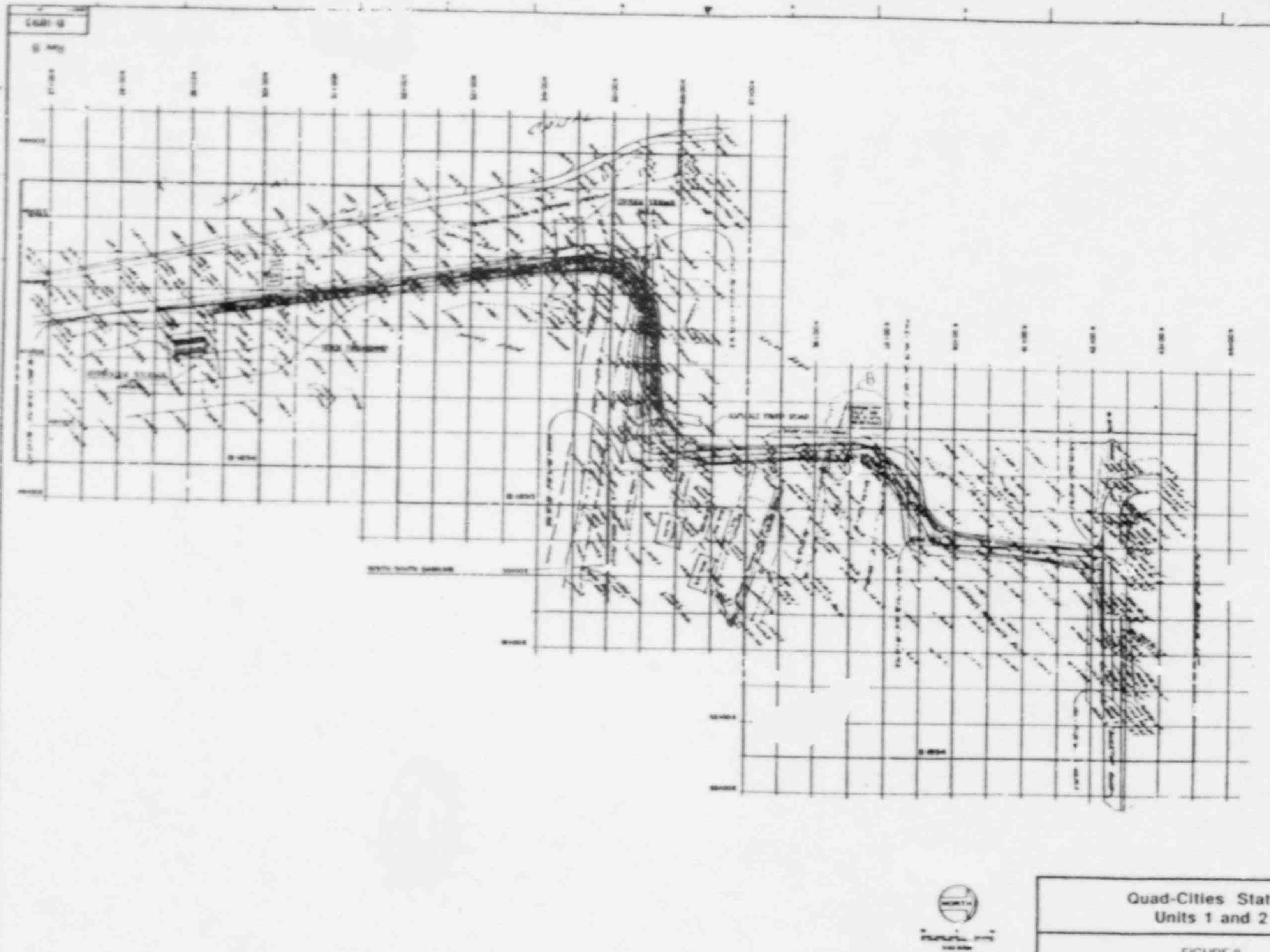

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FIGURE 9

ROUTE OF HYDROGEN & OXYGEN
SUPPLY DELIVERY

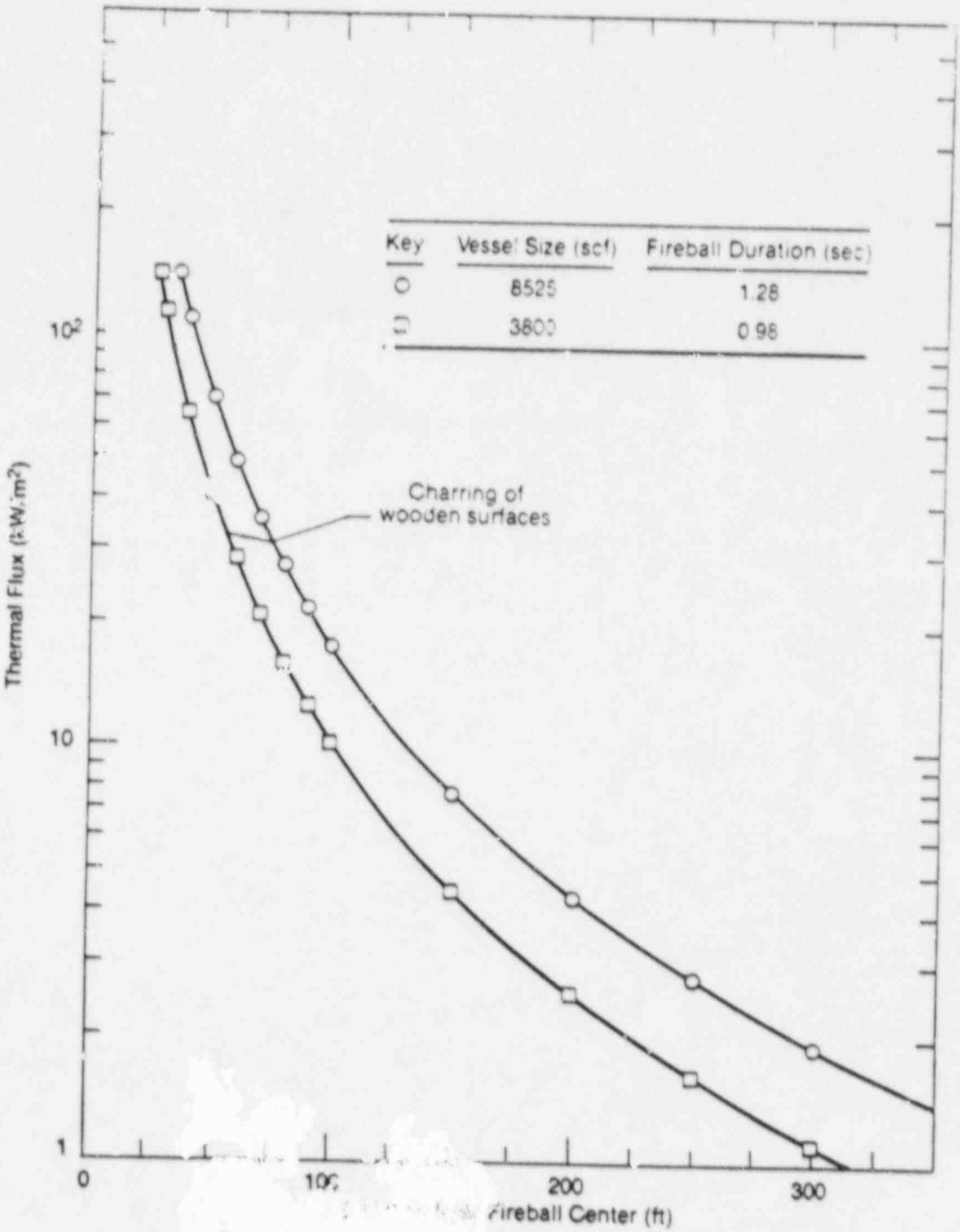

FIGURE 10. [illegible] VS. DISTANCE FROM FIREBALL CENTER FOR [illegible] HYDROGEN STORAGE SYSTEM

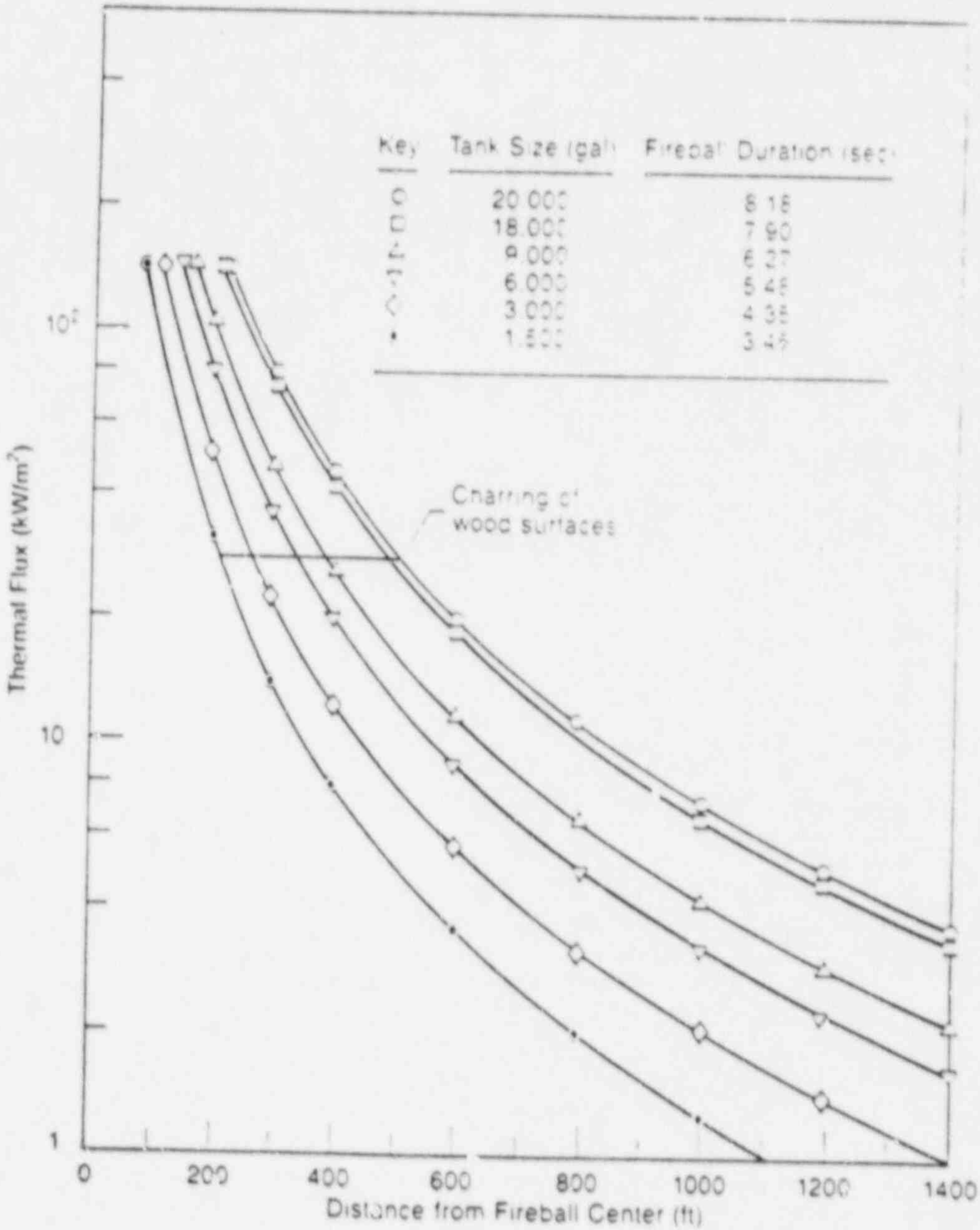

FIGURE 11. THERMAL FLUX VS. DISTANCE FROM FIREBALL CENTER FOR LIQUID HYDROGEN STORAGE SYSTEM

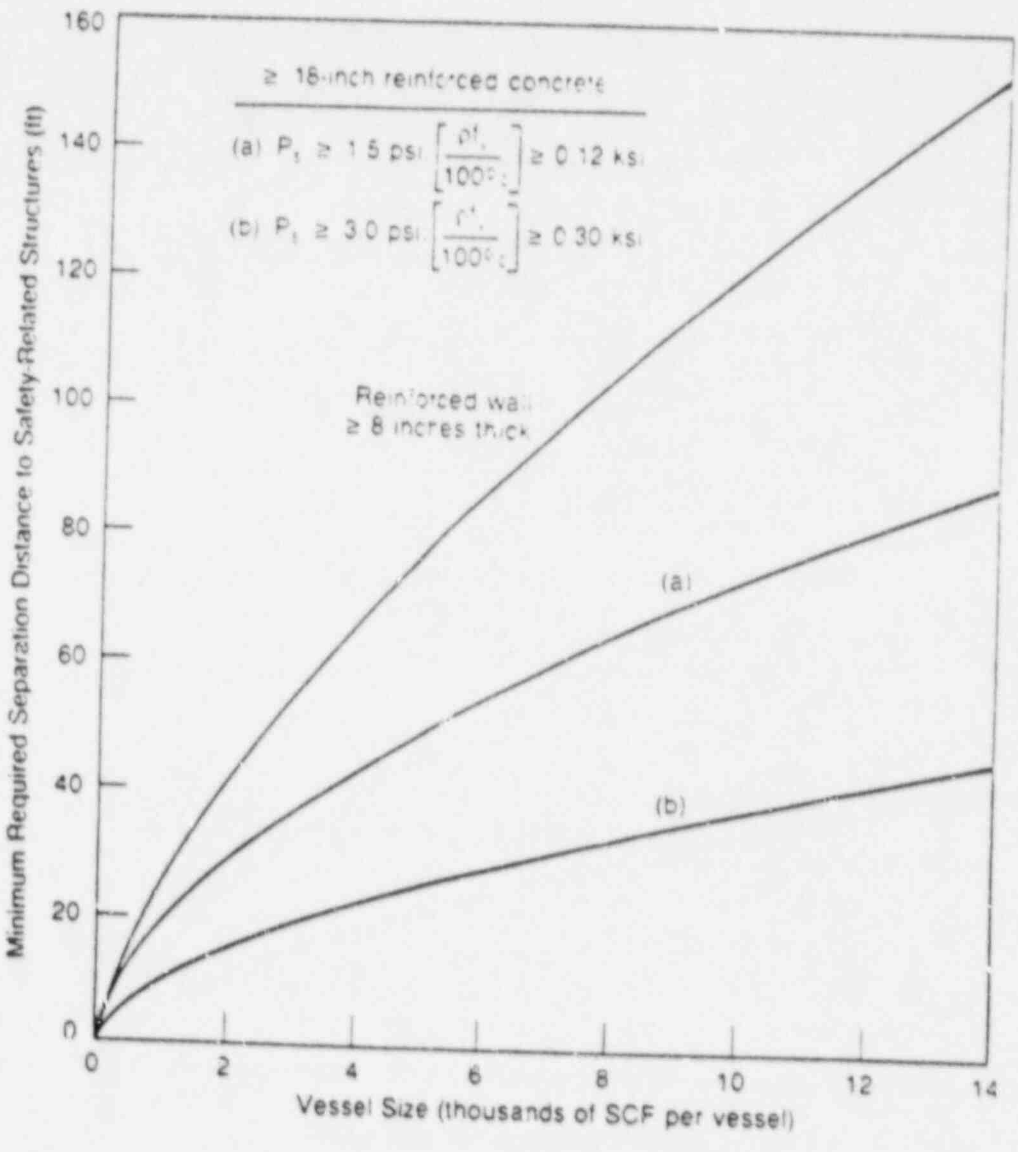

FIGURE 12. MINIMUM REQUIRED SEPARATION DISTANCE TO SAFETY-RELATED STRUCTURES VS. VESSEL SIZE FOR GASEOUS HYDROGEN STORAGE SYSTEM

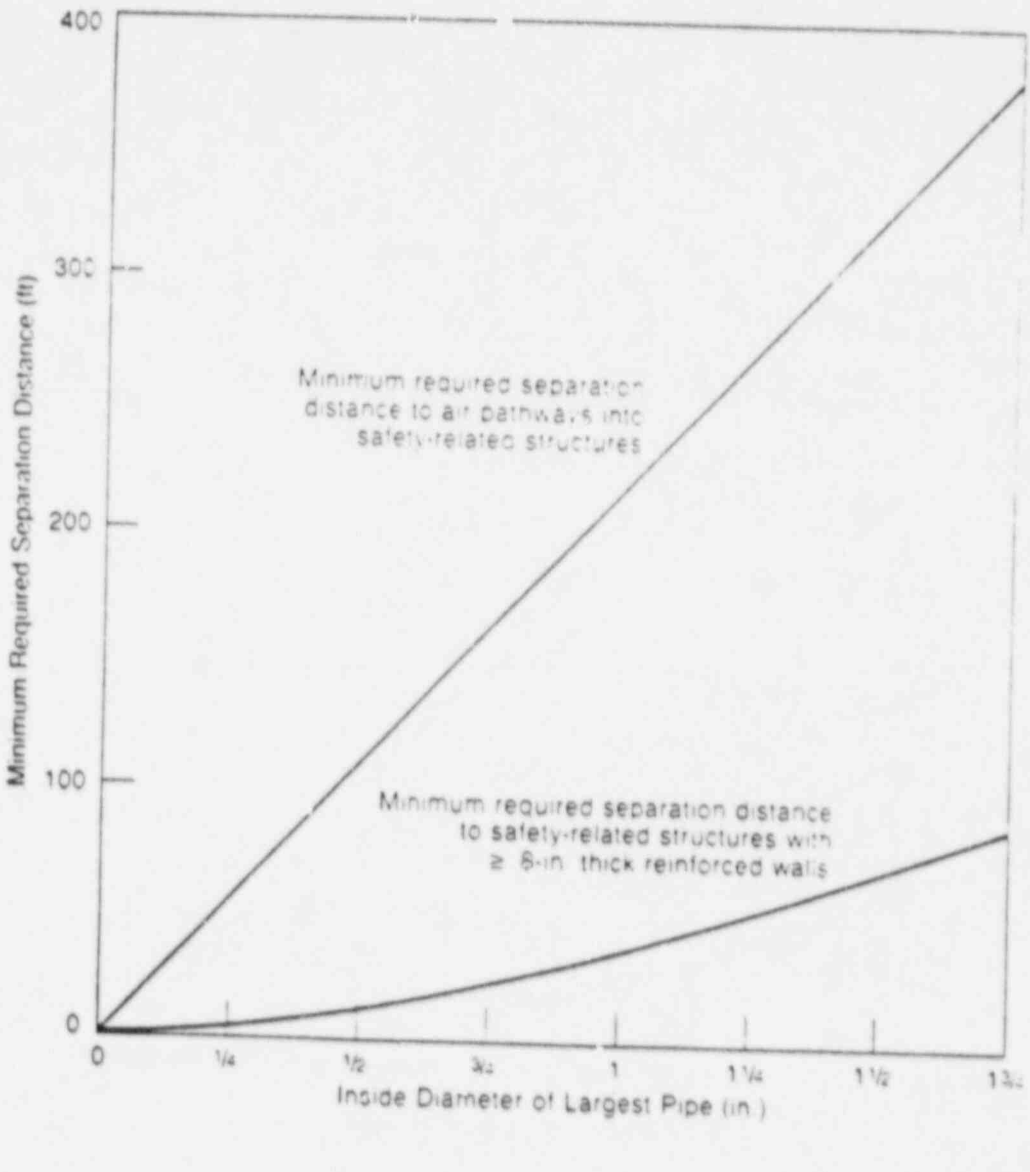

FIGURE 13. MINIMUM REQUIRED SEPARATION DISTANCE VS. ID OF PIPE FOR RELEASES FROM 2450 PSIG GASEOUS HYDROGEN STORAGE SYSTEMS

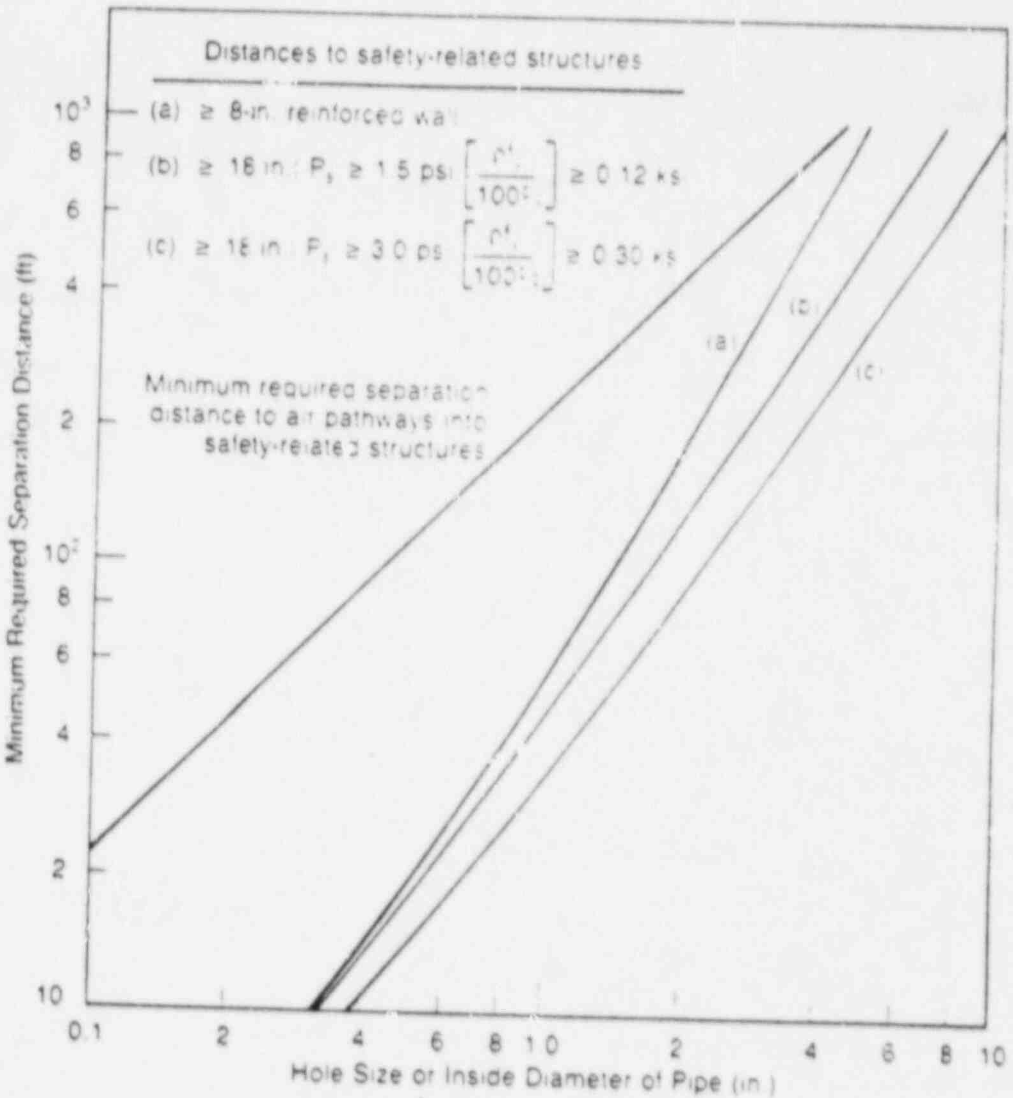

FIGURE 14A. MINIMUM REQUIRED SEPARATION DISTANCE VS HOLE SIZE AND ID OF PIPE FOR GASEOUS RELEASES FROM 150 PSIG LIQUID HYDROGEN STORAGE TANK

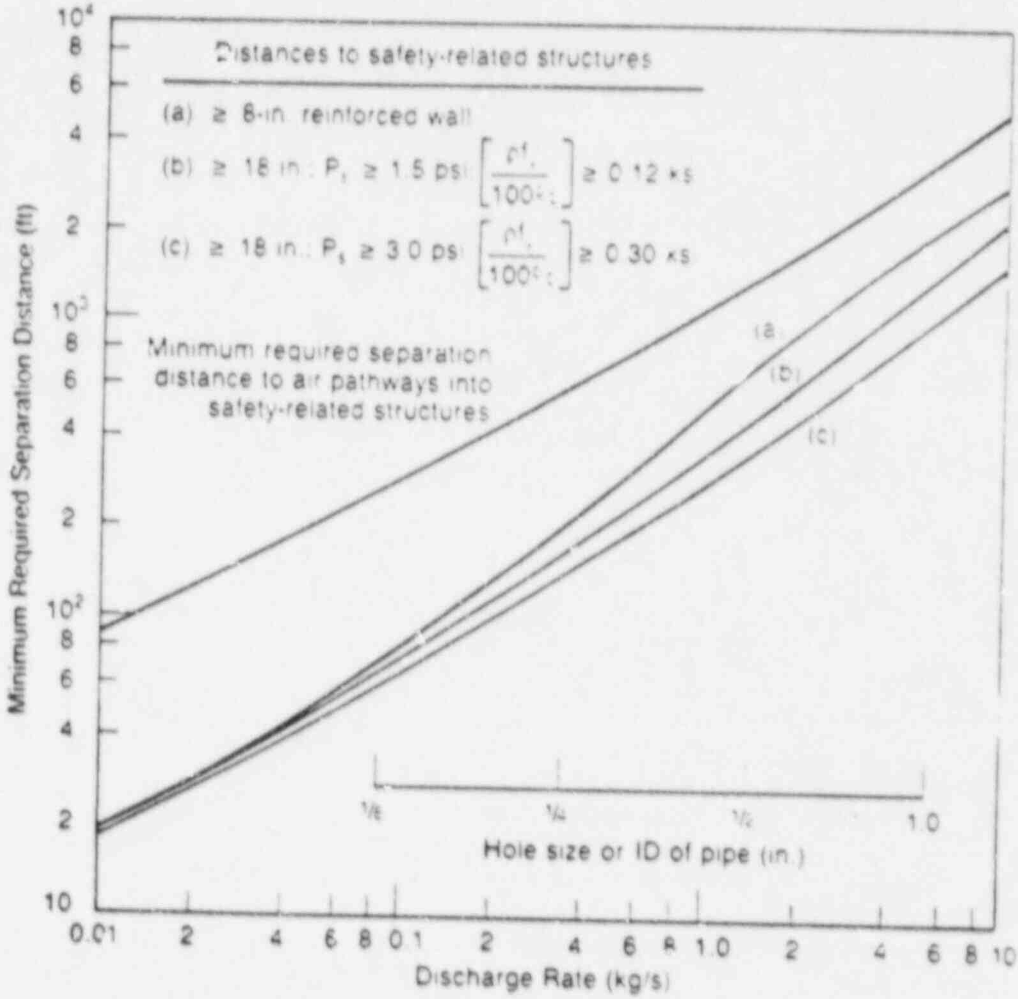

FIGURE 14B. MINIMUM REQUIRED SEPARATION DISTANCE VS HOLE SIZE AND DISCHARGE RATE FROM 150 PSIG LIQUID HYDROGEN STORAGE TANK (F WEATHER STABILITY, 1 M/S WIND VELOCITY)

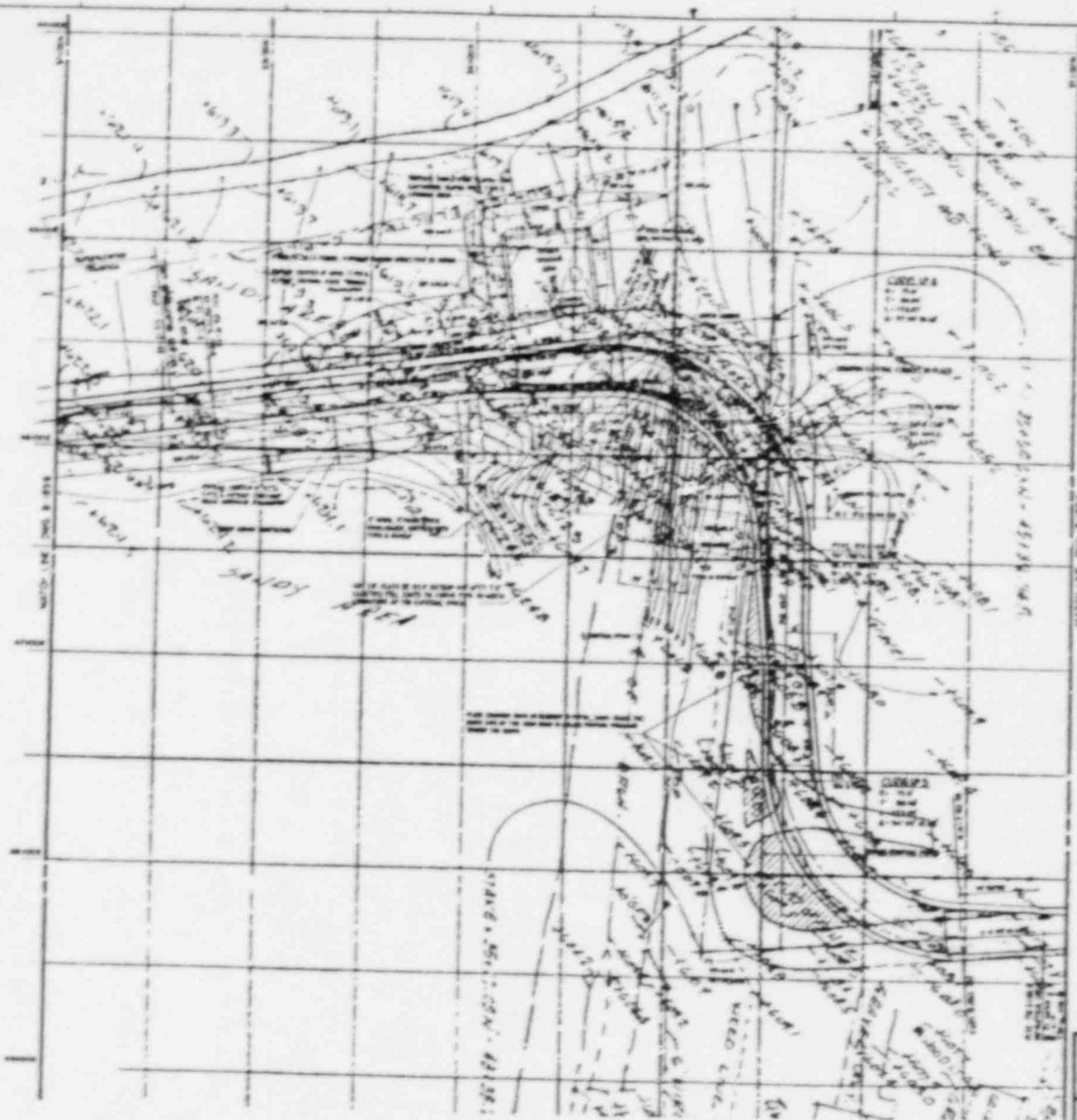

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FIGURE 15

LIQUID OXYGEN STORAGE FACILITY
SITE LOCATION

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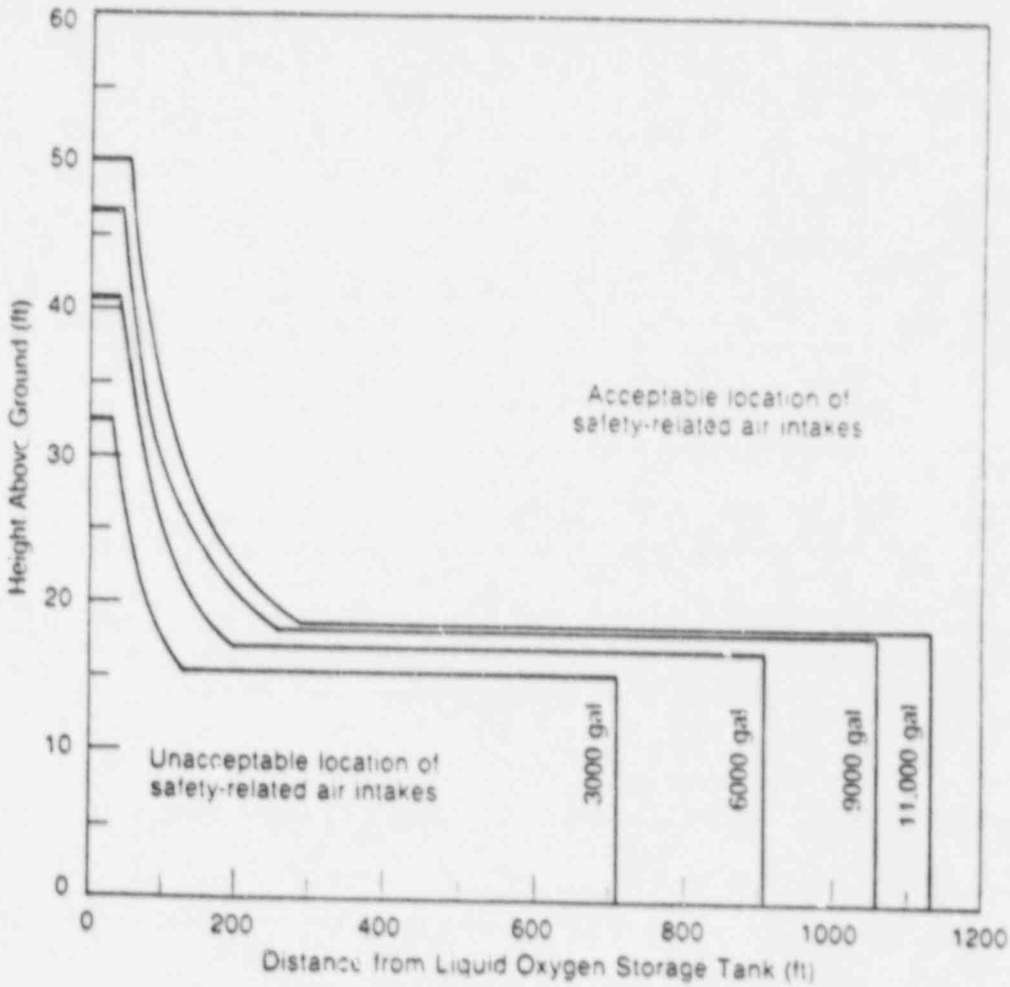

FIGURE 16. ACCEPTABLE LOCATIONS OF SAFETY-RELATED AIR INTAKES FOR VARIOUS SIZES OF LIQUID OXYGEN STORAGE TANKS

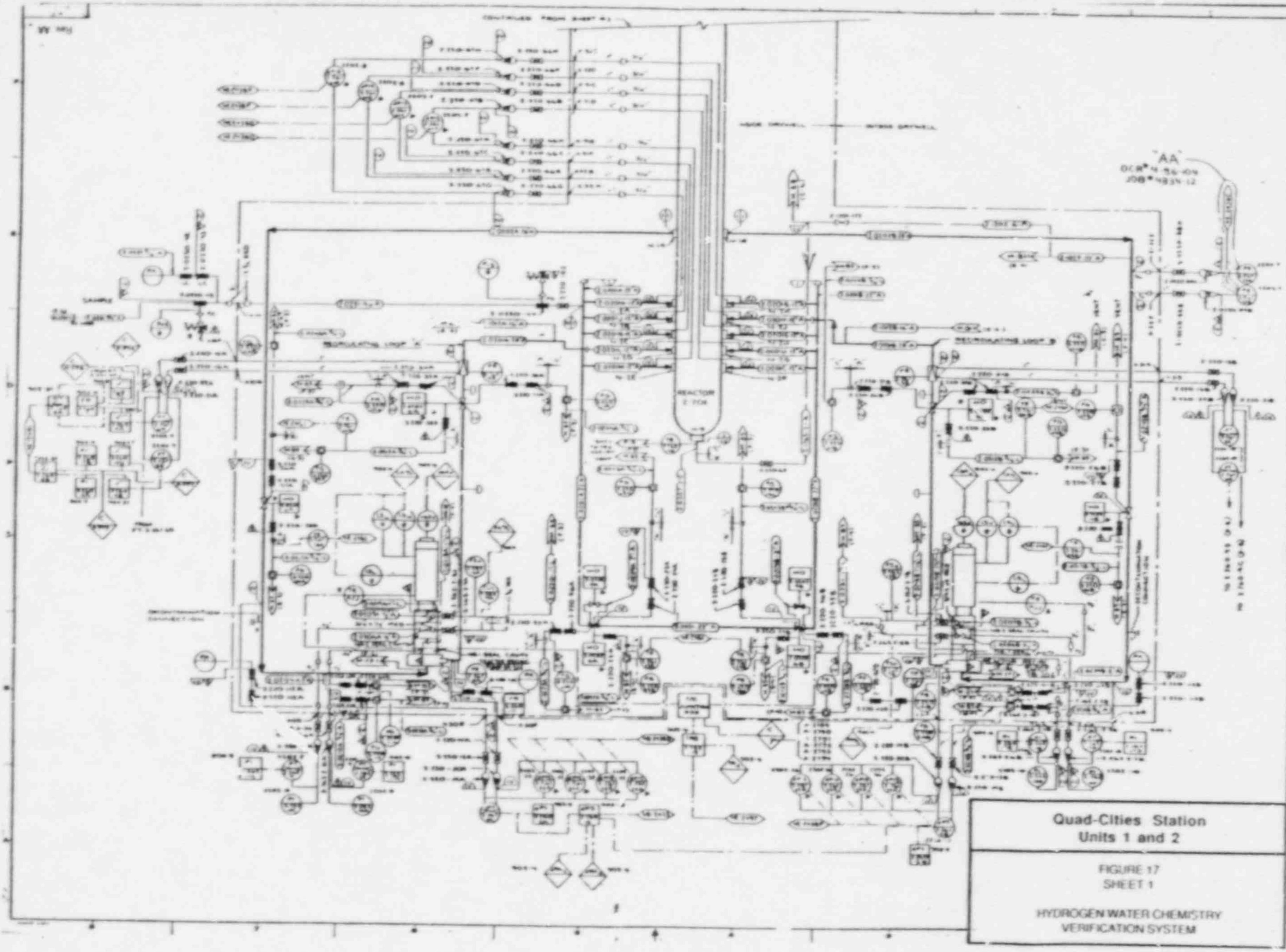

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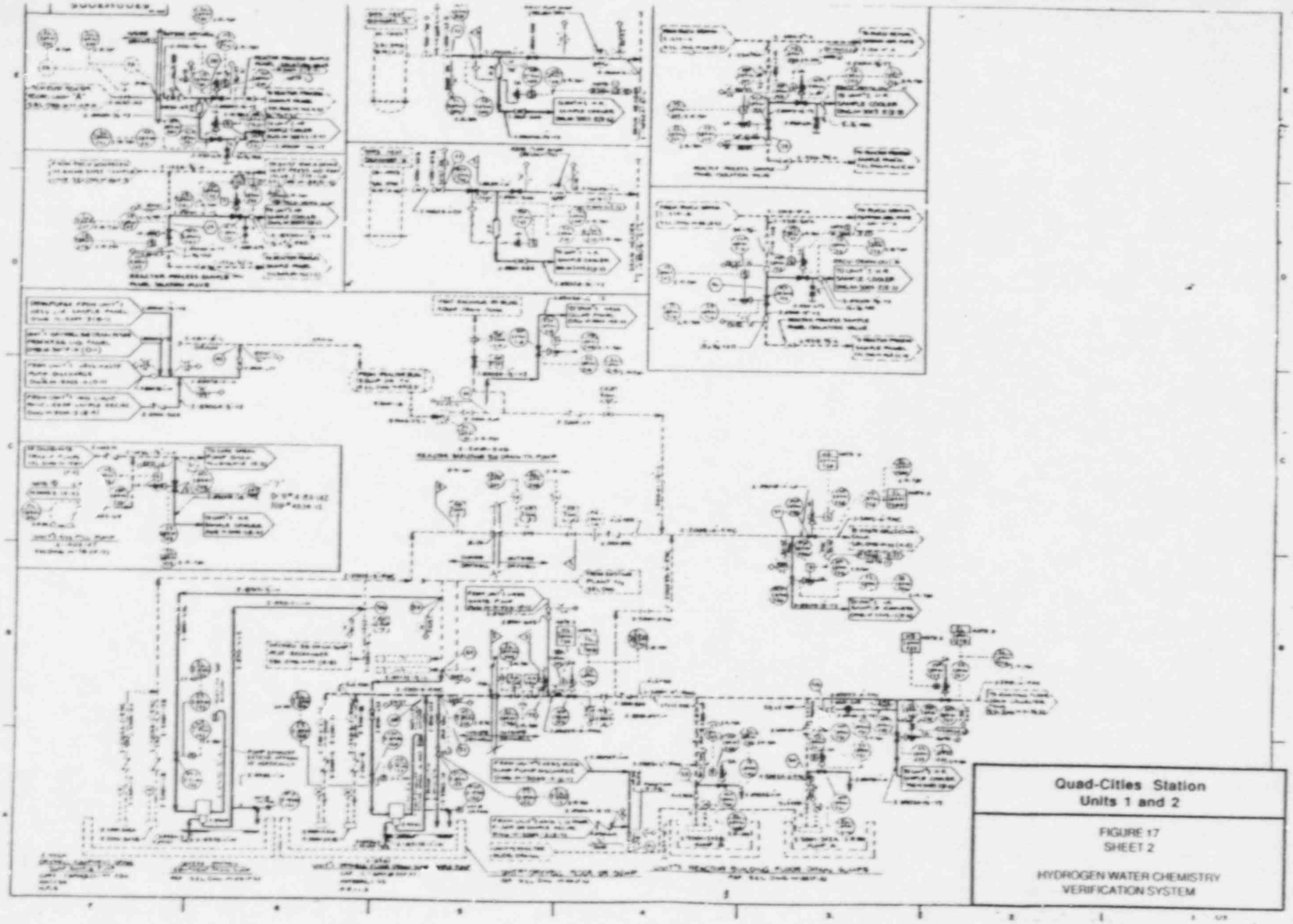
FIGURE 17
SHEET 1

HYDROGEN WATER CHEMISTRY
VERIFICATION SYSTEM



Quad-Cities Station
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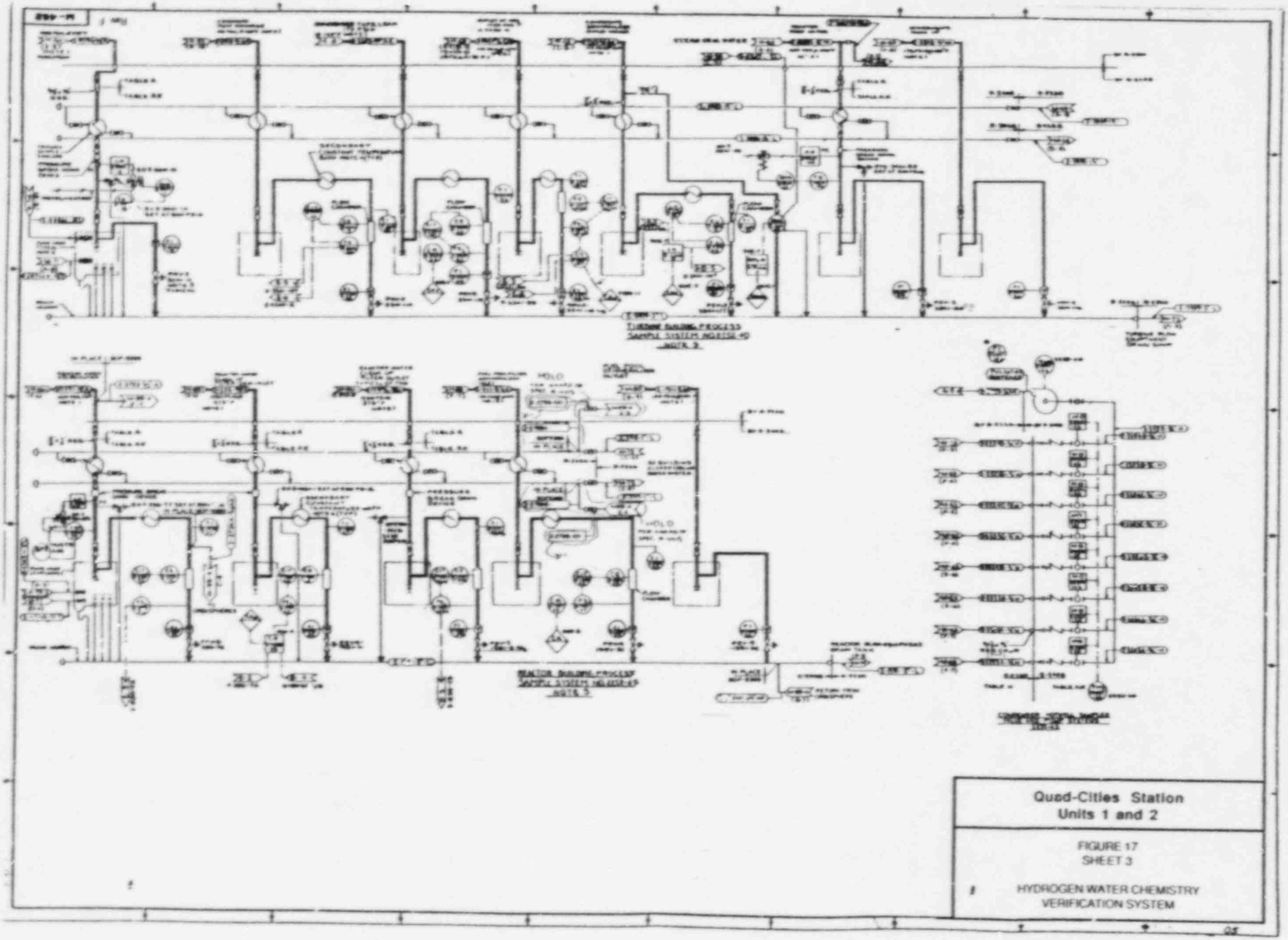
FIGURE 17
SHEET 2

HYDROGEN WATER CHEMISTRY
VERIFICATION SYSTEM



Quad-Cities Station
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FIGURE 17
SHEET 3

HYDROGEN WATER CHEMISTRY
VERIFICATION SYSTEM

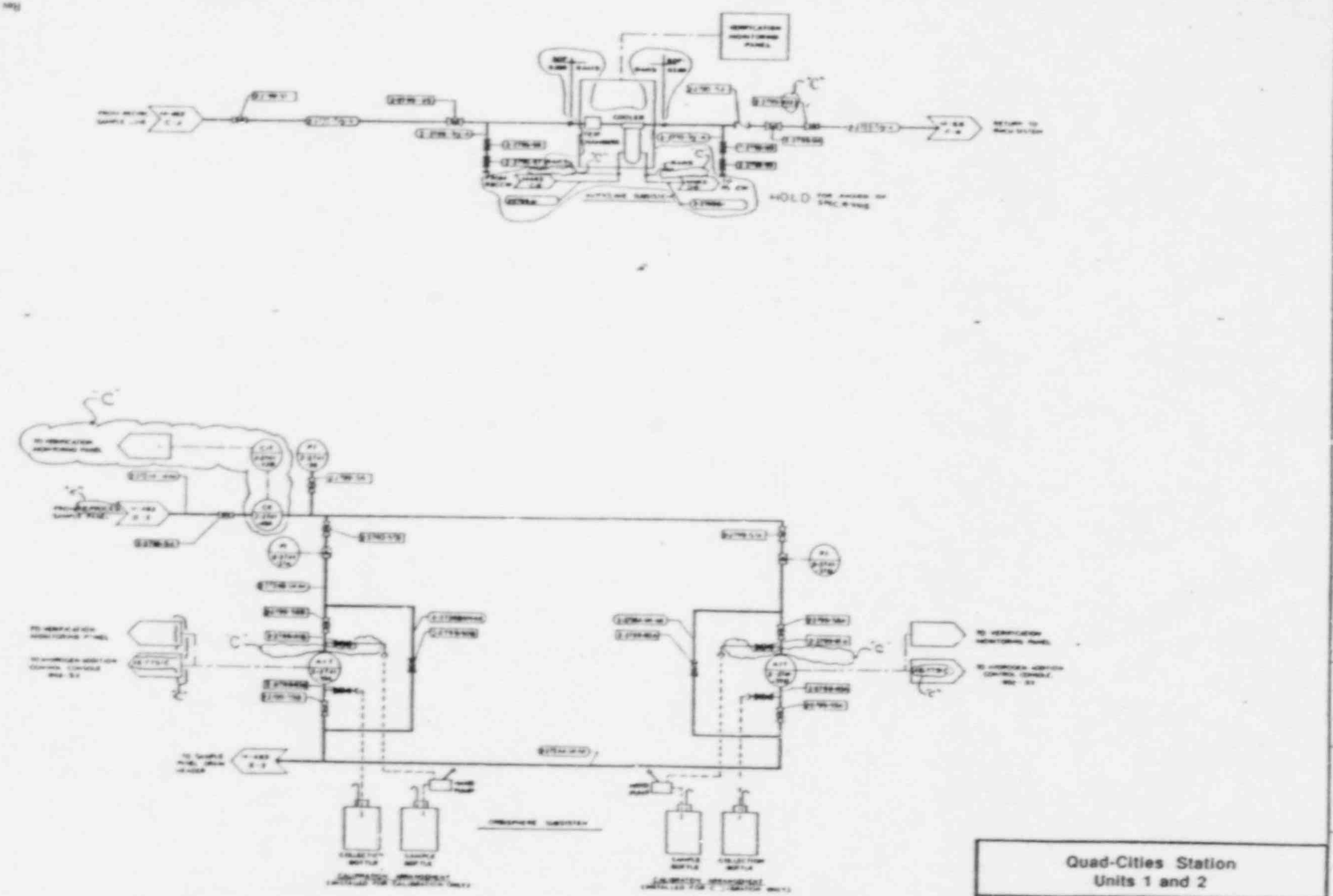

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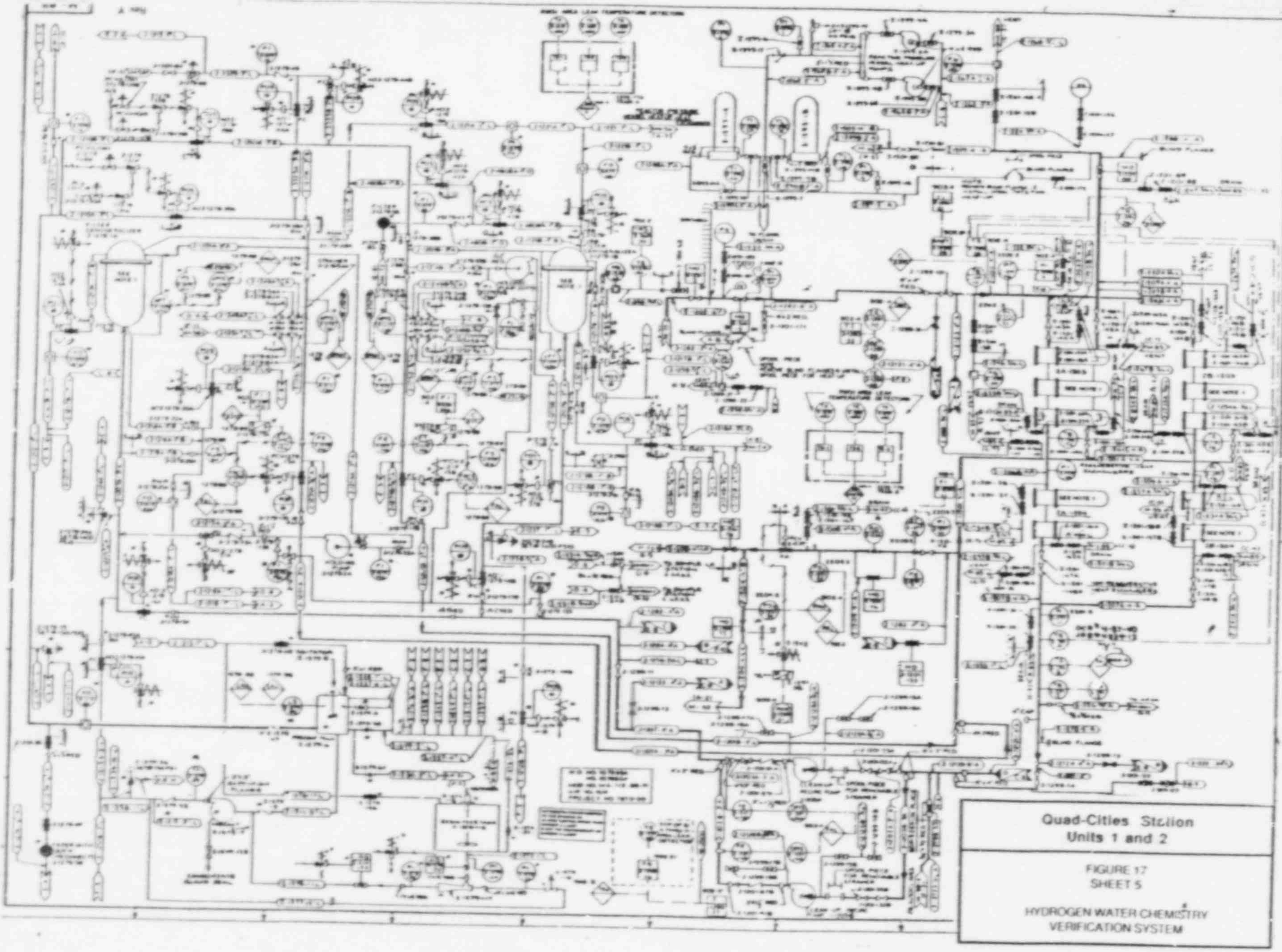
FIGURE 17
SHEET 4

HYDROGEN WATER CHEMISTRY
VERIFICATION SYSTEM



Quad-Cities Station
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FIGURE 17
SHEET 5

HYDROGEN WATER CHEMISTRY
VERIFICATION SYSTEM