REVISION C

DRAFT

GUIDELINES FOR PERMANENT BWR HYDROGEN WATER CHEMISTRY INSTALLATIONS

Prepared by

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ABSTRACT

Intergranular stress corrosion cracking (IGSCC) of austenitic stainless steel piping in BWRs has resulted in costly plant outages. One method shown effective in arresting pipe cracking and pipe crack growth is a process known as Hydrogen Water Chemistry (HWC). HWC consists of maintaining good water chemistry and adding hydrogen to the feedwater. Addition of hydrogen decreases the oxidizing power of the reactor water and reduces its aggressiveness toward plant structural materials. This document provides guidelines for design, construction, and operation of permanent hydrogen injection systems at BWRs to allow implementation under 10 CFR 50.59. The scope of this document includes the currently available on-site hydrogen and oxygen supply options (i.e., compressed gas, cryogenic liquid, and electrolytic generation) and the delivery system design and controls. Included are guidelines for design, operation, maintenance, surveillance, and testing to provide for safe system and plant operation. Compliance with these guidelines will ensure that this system installation and operation will not produce a safety concern.

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Section 1

INTRODUCTION

1.1 SCOPE

This document sets forth design, construction, and operational guidelines for permanent hydrogen injection systems at boiling water reactors (BWRs) to allow implementation under 10 CFR 50.59. As such, its purpose is to provide a reference document for utility use. NRC staff acceptance of these guidelines should minimize the amount of plant specific evaluations required.

The purpose of the hydrogen injection system is to inject hydrogen into the reactor coolant, presently via the feedwater system, to reduce the dissolved oxygen concentration. Reducing the dissolved oxygen concentration and maintaining high purity in the 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 scope of this document includes the currently available on-site hydrogen and oxygen gas supply options (i.e., compressed gas, cryogenic liquid, and electrolytic generation) and the gas delivery system design and controls. Included in this scope are the hydrogen injection system requirements for operation, maintenance, surveillance, and testing to provide for safe system and plant operation. Compliance with these requirements will ensure that no significant safety concerns exist with system installation and operation.

Requirements for short-term HWC preimplementation tests to determine the hydrogen flow sheet and radiological impact on a plant site are not in the scope of this document. Also, system availability and other issues that are required to obtain licensing credit for HWC (e.g., reduced in-service inspection) are not addressed.

There are two primary regulatory concerns related to the permanent implementation of HWC: the potential impact of failures in the oxygen and hydrogen storage/handling systems on the plant safety systems and increased dose rates due to increased N-16 carry-over in the steam. For the oxygen and hydrogen storage/

handling issue, this document addresses external events such as seismic, tornados, fire, vehicle hazards, etc. In addition, system internal events such as overpressurization and relief valve failures and the potential impact on plant structures and control room habitability are addressed. For these events, a mechanistic approach, as opposed to a probabilistic approach, is used as the basis for siting hydrogen and oxygen gas storage facilities. Using sufficiently conservative assumptions, the minimum distance between the hydrogen supply/generation facility and safety-related structures is prescribed.

Injection of hydrogen into the feedwater system of a BWR results in an approximate 3 to 5 fold increase in the activity in the steam. Consequently, HWC will result in a minor increase in the site personnel exposure. However, over the life of the plant, HWC offers the potential for significantly reduced exposures because of the avoidance of recirculation pipe replacement and reduced pipe crack repair and inspection. This document provides recommendations to minimize the radiological impact of permanent HWC installations and to maintain exposures as-low-as-reasonably-achievable (ALARA). In addition, the justification for increasing the main steam line radiation monitor setpoint to accommodate HWC is provided.

Other issues associated with permanent HWC programs are:

1. Materials impact
2. Fuel impact
3. Reactor physics impact
4. Equipment qualification

None of these issues will impact continued safe plant operation. Hydrogen water chemistry in combination with appropriate coolant conductivity control will suppress IGSCC of susceptible reactor materials, and laboratory tests have shown no substantial concerns with hydrogen embrittlement. No significant impact on fuel performance is expected. Although the dissolved hydrogen concentration in the core inlet water increases slightly, the impact on core reactivity is insignificant, and reactor physics will not be affected. With regards to equipment qualification, dose rates inside the drywell close to the recirculation piping will decrease due to the increased carry-over of N-16 in the steam. Outside the drywell, the increase in the dose rates is relatively small relative to the integrated dose assumed for qualification tests.

1.2 BACKGROUND

The recirculating coolant in BWRs is high-purity (no additive) neutral pH water containing radiolytically produced dissolved oxygen (100-300 ppb). This level of dissolved oxygen is sufficient to provide the electrochemical driving force needed to promote IGSCC of sensitized austenitic stainless steel piping and similar structural components if the other two prerequisites for IGSCC [a sensitized microstructure (chromium depletion at the grain boundaries) and a tensile stress above the yield stress] are also present.

A variety of IGSCC remedies have been developed and qualified which address the sensitization and tensile stress aspects of stress corrosion cracking. Another approach for suppressing IGSCC involves modifying the BWR coolant environment to reduce the electrochemical driving force for IGSCC.

The HWC technique consists of reducing the coolant oxygen level from the present f200 ppb to that which, in combination with water quality, has been shown to result in IGSCC immunity. The reduction in coolant oxygen is accomplished by the addition of hydrogen to the feedwater and the conductivity of the coolant is reduced (if needed) by improved water quality operational practices. The presence of hydrogen suppresses radiolytic oxygen formation. The feasibility of suppressing oxygen by this approach has been demonstrated in short-term demonstrations in eight BWRs. A long-term verification test which will extend over two or three 18-month fuel cycles was initiated at Dresden-2 in April 1983.

An extensive laboratory investigation of the material performance consequences of combining oxygen suppression with conductivity control has demonstrated that substantial mitigation and possibly complete suppression of IGSCC could be achieved in f280°C water with less than 20 ppb dissolved oxygen content if the conductivity was maintained below about 0.3)s/cm. Results of slow strain rate tests at Dresden-2 confirmed the anticipated improvement in the IGSCC resistance of sensitized austenitic stainless steel under HWC conditions and also supported other laboratory data indicating that HWC is a more innocuous service environment for most BWR plant structural materials than the non-HWC environment.

Section 2

GENERAL SYSTEM DESCRIPTION

Figure 2-1 shows the hydrogen addition system in simplified form. For this report, the system is divided into hydrogen supply, oxygen supply, hydrogen injection, and oxygen injection systems.

Options for hydrogen supply are discussed briefly below, and the main options are described in detail in Section 3. Oxygen supply is also described in Section 3. The gas injection systems are described in this chapter. Also described in this chapter are instruments and controls applicable to the entire system.

2.1 GENERAL DESIGN CRITERIA

The hydrogen water chemistry system is not safety-related. Equipment and components need not be redundant (except where required to meet good engineering practice), seismic category I, electrical class IE, or environmentally qualified.

Nevertheless, considerations of such things as proximity of system components to other plant systems or components that are safety-related require special consideration in the design, fabrication, installation, operation and maintenance, etc., of certain components of the HWC system.

Dissolved oxygen concentrations in the recirculation water should be low enough to suppress IGSCC at all reactor power levels at which the hydrogen addition system is operating. This is expected to be less than 20 ppb.

2.2 HYDROGEN SUPPLY OPTIONS

Hydrogen can be supplied from three sources: (1) a commercial hydrogen supplier; (2) onsite production from raw materials; or (3) recovery and recycle of hydrogen from the off-gas system. Any combination of these three methods may, in principle, be appropriate at a given facility.

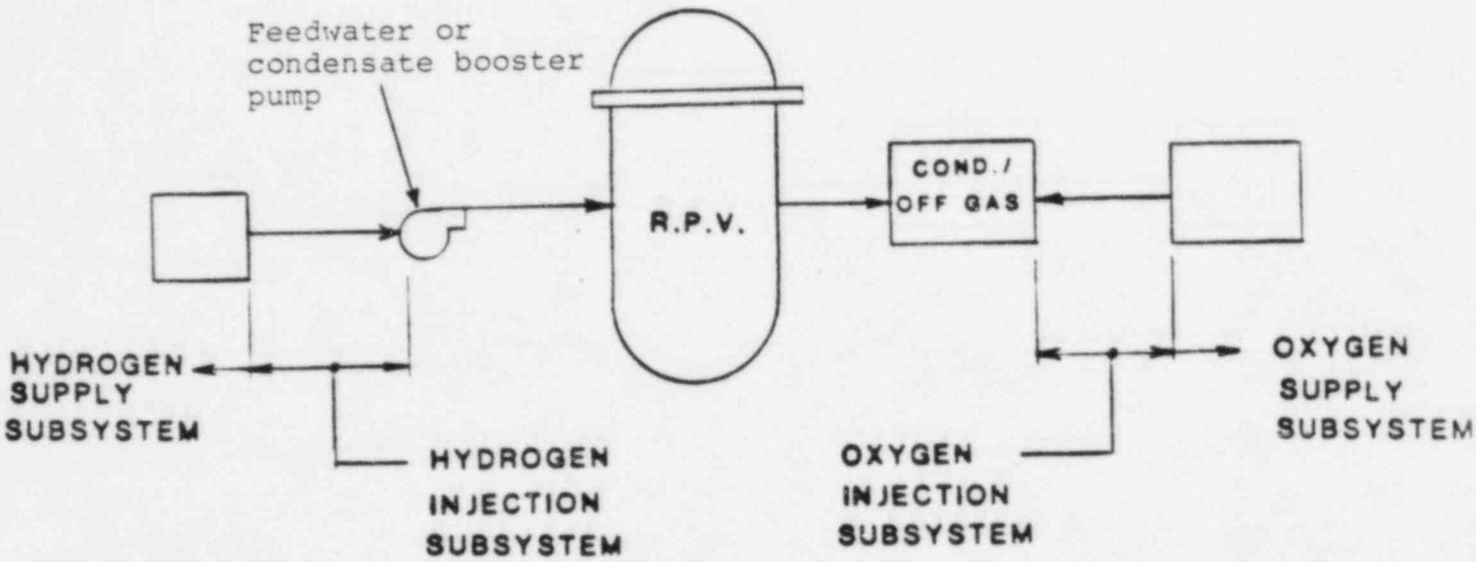

FIGURE 2-1

HYDROGEN ADDITION SYSTEM

2.2.1 Commercial Suppliers

Hydrogen can be obtained commercially from two types of sources: (1) merchant producers (i.e., companies that make hydrogen for the purpose of selling it to others) and (2) by-product producers (i.e., companies that produce hydrogen only as a by-product of their main business).

Detailed considerations for a hydrogen supply facility acquired by a utility in this way, whether the hydrogen be supplied as a high pressure gas or as a cryogenic liquid, are described in Sections 3.1 and 3.2 of this report, respectively.

2.2.2 On-Site Production

Industrial processes for hydrogen production can be divided into two groups: electrolysis of water and thermochemical decomposition of a feedstock that contains hydrogen.

Detailed considerations for onsite production of hydrogen by electrolysis are described in Section 3.3 of this report.

All other processes for producing high purity hydrogen involve thermochemical decomposition of hydrogen-containing feedstocks followed by a series of chemical and/or physical operations that concentrate and purify the hydrogen.

While these processes are feasible, in principle, they are not currently envisioned for implementation. Therefore, these processes are not addressed in this report.

2.2.3 Recovery

Many processes are commercially available for separating, concentrating, and purifying hydrogen from refinery or by-product streams or for upgrading the purity of manufactured hydrogen. Processes are also being developed for the recovery and storage of hydrogen by the formation of rechargeable metal hydrides.

Although recovery of hydrogen is a viable option, near-term implementation of this option is not envisioned. Therefore, this option is not addressed in this report.

2.3 GAS INJECTION SYSTEMS

2.3.1 Hydrogen Injection System

The hydrogen injection system injects hydrogen into the condensate/feedwater system. It includes all flow control and flow measuring equipment and all necessary instrumentation and controls to ensure safe, reliable operation.

2.3.1.1 Injection Point Considerations. Hydrogen shall be injected into the condensate/feedwater system at a location that provides adequate dissolving and mixing and avoids gas pockets at high points in the feedwater piping.

Experience has shown that injection into the suction of feedwater or condensate booster pumps is feasible.

Injection into feedwater pumps will require hydrogen at high pressures (e.g., 150-600 psig). This may require either a cryogenic hydrogen pump or a compressor, depending on the supply option chosen. In the case of a liquid hydrogen storage system, this can also affect the sizing of the liquid hydrogen tank.

There may be pressure fluctuations in feedwater systems, depending on reactor power level and pump performance. The hydrogen addition system shall be designed to accommodate the full range of such fluctuations.

2.3.1.2 Codes and Standards. This system shall be designed and installed in accordance with OSHA standards in 29 CFR 1910.103.

Equipment and piping shall be designed and fabricated to the appropriate edition of ANSI B31.1 or B31.3 for pressure-retaining components. Such components shall meet all the mandatory requirements and material specifications with regard to manufacture, examination, repair, testing, identification and certification.

Storage containers, if used, shall be designed, constructed, and tested in accordance with appropriate requirements of ASME B&PV Section VIII or API Standard 620.

All welding shall be performed using procedures meeting requirements in AWS D1.1, ANSI B31.1 or B31.3, or ASME B&PV, Section IX, as appropriate.

Inspection and testing shall be in accordance with requirements in ANSI B31.1, ANSI B31.3, or API 620, as appropriate.

System design shall also conform with NUREG-0800, 10CFR50 Appendix R and appropriate standards and regulations referenced in this document. Each utility is responsible for identifying additional plant-specific codes and standards that may be apply, such as State-imposed requirements, Uniform Building Code, ACI or AISC standards.

Piping shall be marked or identified in accordance with ANSI 235.1.

2.3.1.3 System Design Considerations. Hydrogen piping from the supply system to the plant may be above or below ground. Piping below ground shall be designed for the appropriate soil conditions, such as frost depth or liquefaction.

Piping below ground shall be designed for expected vehicle loads. Guard piping around hydrogen lines is not required, but each utility should consider providing it for such purposes as heavy traffic loads, monitoring, or isolation from nearby equipment, etc.

Excess flow valves should be installed in the hydrogen line at appropriate locations, to restrict flow out of a broken line so that in case of a line break flammable concentrations cannot be reached so as to not affect the plant safe shutdown analysis per 10CFR50, Appendix R.

Individual pump injection lines shall contain a check valve to prevent feedwater from entering the hydrogen line and protect upstream hydrogen gas components. Automatic isolation valves should be provided in each injection line, to prevent hydrogen injection into an inactive pump.

Purge connections shall be provided to allow the hydrogen piping to be completely purged of air before hydrogen is introduced into the line. Nitrogen or another inert gas shall be used as the purge gas. Gases shall be purged to safe locations, either directly or through intervening flow paths, such that personnel or explosive hazards are not encountered and undesirable quantities of gas are not injected into the reactor.

Area hydrogen concentration monitors are an acceptable way to ensure that hydrogen concentration is maintained below the flammable limit. If used, such monitors should be located at high points where hydrogen might collect and/or above use points that constitute potential leaks.

Sleeves or guard pipes can be used as an alternative method to mitigate the consequences of a line break.

A hydrogen addition system will increase the hydrogen concentration in the feedwater, reactor, steam lines and main condenser. Each of these systems shall be reviewed for possible detrimental effects. A discussion of possible concerns is presented below.

1. Main Condenser

   The main condenser presently handles combustible gases. The hydrogen addition system does not significantly change the concentration of non-condensables.

2. Off-Gas System

   Oxygen shall be added to recombine with the increased hydrogen flow into the off-gas system. The net effect will be an increased heat input into the recombined off-gas. The utility should review the off-gas system to ensure that it remains conservatively designed.

3. Steam Piping and Torus

   Hydrogen water chemistry may slightly increase the hydrogen addition rate to the torus via the safety relief valves. However, oxygen blowdown is decreased. Thus, the possibility of forming a combustible mixture is not significantly increased when compared to non-HWC operation.

4. Sumps

   There are three sources of sump water that may be affected by HWC: main condenser condensate, feedwater and reactor water. For sumps which receive water from any of these three sources, the average hydrogen concentration in the water may increase slightly. The maximum expected hydrogen in the sump atmosphere should be determined to ensure that the hydrogen concentration remains below the lower combustible limit of hydrogen in air.

2.3.2 Oxygen Injection System

The oxygen injection system injects oxygen into the off-gas system to ensure that all entrained hydrogen safely recombines. It includes all necessary flow control and flow measurement equipment.

2.3.2.1 Injection Point Consideration. Oxygen should be injected into a portion of the off-gas system that is already diluted and has no portion of the system that could become undiluted. If this is not possible, other system design

considerations shall be provided in plant-specific cases to reduce the chances for off-gas fires.

2.3.2.2 Codes and Standards. The system shall be designed and installed in accordance with OSHA standards in 29 CFR 1910.104, and CGA G4.4, Industrial Practices for Gaseous Oxygen Transmission and Distribution Piping Systems.

Equipment and piping shall be designed and fabricated in accordance with the appropriate edition of ANSI B31.1 or ANSI B31.3. Additional guidance on materials of construction for oxygen piping and valves is given in Section 3.4 of this report, and in ANSI/ASTM G63, Evaluating Nonmetallic Materials for Oxygen Service.

Welding shall be performed using procedures meeting requirements of AWS D1.1 or ASME B&PV, Section IX, as appropriate.

Piping shall be marked or identified in compliance with ANSI Z35.1.

Inspection and testing shall be in accordance with requirements in ANSI B31.1 or ANSI B31.3, as appropriate.

System design shall also conform with appropriate NFPA, CGA, and other standards and regulations referenced elsewhere in this document. Each utility is responsible for identifying additional plant-specific codes and standards that may apply, such as State-imposed requirements, Uniform Building Code, ACI or AISC standards.

2.3.2.3 Cleaning. All portions of the system that may contact oxygen shall be cleaned as described in Section 3.4 of this report, and in accordance with CGA G-4.1, Cleaning Equipment for Oxygen Service.

2.4 INSTRUMENTATION AND CONTROL

This subsection discusses the instrumentation, controls, and monitoring associated with the hydrogen addition system.

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 2-1 lists the recommended system trips.

The instrumentation shall provide indication and/or recording of parameters necessary to monitor and control the system and its equipment. The instrumentation shall also indicate and/or alarm abnormal or undesirable conditions. Table 2-2 lists the recommended instrumentation and functions. This table also includes instrumentation for hydrogen and oxygen supply options.

System instrumentation and controls shall be centralized where feasible to facilitate ease of control and observation of the system. As a minimum, there shall be a system trouble alarm and/or annunciator provided in the main control room.

2.4.1 Hydrogen Injection Flow Control

Parallel flow control valves should be provided in the hydrogen injection line, for system reliability and maintenance.

If flow control is automatic, hydrogen flow rate should be controlled as a function of plant process parameters such as steam or feedwater flow.

The capability should be provided to adjust flow rate to each pump manually, if this is found to be necessary to achieve adequate hydrogen mixing in the recirculation system.

Manual isolation valves shall be provided in each pump injection line to accommodate pump-out-of-service conditions.

Individual pump injection lines should contain automatic isolation valves interlocked to the corresponding pump, so that hydrogen is not injected into a pump that is not running.

Provisions for shut-off of hydrogen injection shall be provided in the control room.

2.4.2 Oxygen Injection Flow Control

Parallel flow control valves should be provided in the oxygen injection line, for system reliability and maintenance.

Oxygen flow rate shall be controlled to provide residual oxygen downstream of the recombiners.

Design of system controls shall ensure that oxygen injection continues after hydrogen flow stops. The purpose is to ensure that residual oxygen remains present after hydrogen injection ceases, so that all free hydrogen safely recombines.

2.4.3 Monitoring

Provision shall be made to monitor continuously the concentration of dissolved oxygen in the recirculation water. In obtaining samples of recirc water for this purpose, appropriate containment isolation shall be provided in accordance with 10 CFR 50, Appendix A, General Design Criteria 54, 55, 56, or 57.

Provision should be made to monitor continuously the level of oxygen in the off-gas flow downstream of the recombiners.

Table 2-1

RECOMMENDED HYDROGEN WATER CHEMISTRY SYSTEM TRIPS

- o Limiting low power level per plant safety analysis (Control Rod Drop Accident), if required by Tech Specs
- o SCRAM
- o Operator request (manual)
- o Low residual oxygen in off-gas
- o High area hydrogen concentration
- o Low oxygen injection system supply pressure
- o Offgas train or recombiner train trip
- o High hydrogen flow
- o Differential hydrogen vs. hydrogen injection flow rate*
- o Oxygen concentration in hydrogen compression module*

*Electrolytic generation option.

Table 2-2

HYDROGEN ADDITION SYSTEM INSTRUMENTATION AND CONTROLS

Portion of Overall System	Parameter Measured or Function Performed	Record	Indicate	High Alarm	Low Alarm	Auto Control
Injection systems (H_2 and/or O_2)	Hydrogen flow	(X)	X			Trip on high flow
	Oxygen flow	(X)	X			
	Offgas residual oxygen	(X)			X	Trip on low oxygen
	Recirc water dissolved oxygen	(X)	X	X		
	Area hydrogen concentration		(X)	(X)		Trip
	Hydrogen injection line pump interlock					Isolate when pump is not in operation
Hydrogen supply	Hydrogen storage tank level*		X		(X)	
	Hydrogen storage tank pressure gauge*		X			
	Hydrogen storage tank vacuum readout*		X			
	Hydrogen gas supply pressure*		X			
	Hydrogen gas storage temperature*		X			
	Differential, hydrogen generation vs. hydrogen injection flow rate**		X	X	X	Trip
	Oxygen concentration in hydrogen compression module**		X	X	X	Trip

Table 2-2 (Continued)

HYDROGEN ADDITION SYSTEM INSTRUMENTATION AND CONTROLS

Portion of Overall System	Parameter Measured or Function Performed	Record	Indicate	High Alarm	Low Alarm	Auto Control
Oxygen supply	Oxygen tank level gauge		X		(X)	
	Oxygen tank pressure gauge		X			
	Oxygen tank vacuum readout connection		X			

*If this supply option is used
**For electroytic generation option
X = required.
(X) = recommended.

Section 3

SUPPLY FACILITIES

3.1 GASEOUS HYDROGEN

3.1.1 System Overview

Hydrogen gas can be supplied from either permanent high-pressure vessels or from transportable tube trailers. For the permanent storage system, gaseous hydrogen is stored in seamless ASME-coded vessels at pressures up to 2,400 psig and ambient temperatures. The transportable DOT-coded vessels store hydrogen at pressures up to 2650 psig and ambient temperatures. With either storage design, the gas is routed through a pressure control station which maintains exiting hydrogen pressures. In any event, the gaseous hydrogen system shall be provided by a supplier who has extensive experience in the design, operation and maintenance of associated storage and supply systems. Gaseous hydrogen shall be provided per CGA G-5 and G-5.3.

3.1.2 Specific Equipment Description

3.1.2.1 Hydrogen Storage Vessels. The hydrogen storage bank shall be composed of ASME-coded gas storage vessels. Each tube shall be constructed as a seamless vessel with swagged ends. Specific tube design shall be based on ASME Unfired Pressure Vessel Code, Section VIII, Division 1 and Code Case 1205.

The tube bank shall be supported to prevent movement in the event of line failure. Each tube shall be equipped with a close-coupled shut off valve. Each bank shall be equipped with a thermometer and a pressure gauge, as is necessary for proper filling.

3.1.2.2 Transportable Hydrogen Storage Vessel. Transportable hydrogen vessels shall be constructed, tested, and retested (every 5 years), in accordance with specification DOT 3A, 3AA, 3AX, or 3AAX. All valving and instrumentation shall be identical to Section 3.1.2.1.

3.1.2.3 Pressure Reducing Station. The pressure control station shall be a manifold designed specifically for this installation. The automatic reducing manifold shall have two (2) full-flow parallel pressure reducing regulators. The discharge pressure range of these regulators shall be adjustable to satisfy plant hydrogen injection requirements. Pressure gauges shall be provided upstream and downstream of the regulators. Sufficient hand valves shall be provided to ensure complete operational flexibility.

An excess flow check valve shall be installed in the manifold immediately downstream of the regulators to forestall a hydrogen leak in the event of a line break. The stop-flow setpoint shall be determined by each plant and should be set between the maximum plant flow requirements and the full C_v of the valves.

3.1.2.4 Tube Trailer Discharge Stanchion. A tube trailer discharge stanchion shall be provided for gaseous product unloading. The stanchion consists of a flexible pigtail, shut-off valve, check valve, bleed valve, and necessary piping. Filling apparatus shall be separated from other equipment for safety and convenience, and supported in a manner to minimize damage from a collision.

A tube trailer grounding assembly for each discharge stanchion shall be provided. The function of this assembly is to ground the tube trailer before the discharge of hydrogen begins.

3.1.2.5 Interconnecting Pipeline. All equipment and interconnecting piping supplied with this system shall be installed in compliance with the following standards:

- American National Standards Institute (ANSI) B31.1, Power Piping, or B31.3, Chemical Plant and Petroleum Refinery Piping.
- National Fire Protection Association (NFPA) 70, National Electrical Code.
- NFPA-50A, Bulk Hydrogen Systems.
- All applicable local and national codes.

There are several suitable field installation techniques which are based on industrial experience. The following are guidelines which may be used for field connections:

- Copper-to-Copper, Brass-to-Brass, and Copper-to-Brass Socket Braze Joints.

--Silver Alloy	45% Ag, 15% Cu, 16% Zn, 24% Cd., ASTM B260-69T and AWS A5.8-69T, BAG-1 Melting Range-Solidus-607.2°C Liquidus-618.3°C
--Flux	Working Range 593.3°C to 871.1°C

- Copper, Brass, Carbon Steel, and Stainless Steel N.P.T. Threaded Joints.

--TEFLON* Tape	SCOTCH** Number 48 Tape or equal . -195.5°C to +204.4°C, 0 to 3,000 psig. Wrapped in direction of threads.

- Flange Joints (On all Materials).

--Ring Gasket Material, Low Pressure (720 psig maximum)	Precut T.F.E. impregnated asbestos, 1/16 inch thickness. Garlock 900 or equal. -195.5°C to +168.3°C, 0 to 900 psig.
--Ring Gasket Material, High Pressure	FLEXITALLIC*** Type. Material to be 0.175 inch thick 304 stainless steel with TEFLON filler and 0.125 inch carbon steel guide ring.
--Antiseize Compound	For flange face, nut, and bolt lubrication. Halocarbon 25-5S grease or equal. -195.5°C to +176.6°C, 0 to 3,000 psig. DO NOT USE ON ALUMINUM, MAGNESIUM, OR THEIR ALLOYS UNDER CONDITIONS OF HIGH TORQUE OR SHEAR.

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*TEFLON is a trademark of E. I. duPont de Nemours & Co., Wilmington, DE 19898.

**SCOTCH is a trademark of 3M Company, St. Paul, MN 55101.

**FLEXITALLIC is a trademark of Flexitallic Gasket Co., Bellmawr, NJ 08031.

- Carbon Steel, Stainless Steel, and Aluminum Alloys Socket and Butt Welds.

--Welding Procedure	Metal Inert Gas, Tungsten Inert Gas, Metal Arc, or Plasma; with appropriate filler material and shielding gas. Proper surface and joint preparation (in regard to cleaning and clearances) should be exercised.

3.1.2.6 Component Cleaning. All components that contact hydrogen must be free of moisture, loose rust, scale, slag, and weld spatter; they must be essentially free of organic matter, such as oil, grease, crayon, paint, etc. During system fabrication, system components shall be cleaned to meet these objectives and then sealed to prevent contamination from dust and debris.

3.2 LIQUID HYDROGEN

3.2.1 System Overview

Liquid hydrogen is stored in a vacuum-jacketed vessel at pressures up to 150 psig and temperatures up to -403°F (saturated). Based on data relating hydrogen injection pressures to BWR plant power levels, hydrogen supply from a liquid source can be provided directly from a tank or pumped into supplemental gasous storage. Gaseous storage requirements are identified in Section 3.1.

Factors such as the following should be evaluated to determine the proper design of a liquid hydrogen system:

- Feedwater pressure requirements at the point of hydrogen injection.
- Pressure losses from hydrogen supply system to feedwater injection point.

Typically, feedwater pressure requirements must be such that hydrogen supply pressures directly from a liquid tank not exceed 120 PSIG.

In any event, the liquid hydrogen system shall be provided by a supplier who has extensive experience in the design, opera-

tion and maintenance of associated storage and supply systems, such as cryogenic pumping. Liquid hydrogen shall be provided in accordance with CGA G-5 and G-5.3.

3.2.2 Specific Equipment Description

3.2.2.1 Cryogenic Tank. Tanks for liquid hydrogen service, with capacities between 1,500-gallons and 20,000-gallons are similar in principle. An "inner vessel" or "liquid container" is supported within an "outer vessel" or "vacuum jacket," with the space between filled with insulation and evacuated. Necessary piping connects from inside of the inner vessel to outside of the vacuum jacket. Gages and valves to indicate the control of hydrogen in the vessel are mounted outside of the vacuum jacket. Legs or saddles to support the whole assembly are welded to the outside of the vacuum jacket.

Tank Construction--Inner vessels are designed, fabricated, tested, and stamped in accordance with Section VIII, Division 1 of the ASME Code for Unfired Pressure Vessels. For suitable liquid hydrogen vessel material, CGA G-5 states that materials must have good ductility at temperatures of-422°F. In addition to ASME Code inspection requirements, 100% radiography of the inner vessel longitudinal welds shall be completed. The tank outer vessel shall be constructed of carbon steel and shall not require ASME certification.

Insulation--Insulation between inner and outer vessels shall be either perlite, aluminized mylar or suitable equal. The annular space should be evacuated to a high vacuum (50 microns or less).

Internal/external tank piping--Tank control piping and valving should be installed in accordance with ANSI B31.1 or B31.3. All piping shall be either wrought copper or stainless steel. The following tank piping systems shall be subsystems.

- Fill circuit, constructed with top and bottom lines so that the vessel can be filled without affecting continuous hydrogen supply.
- Pressure-build circuit, to keep tank pressures at operational levels.
- Vacuum-jacketed liquid fill and pump circuits, where applicable.

3.2.2.2 Overpressure Protection System. Safety consideration for the tank shall be satisfied by dual full flow safety valves and emergency backup rupture discs. The primary relief system shall consist of two sets of two (2) rupture disks and safety valves piped into separate "legs." Selector valves shall be interlocked by a tie bar so that one valve opens when the other closes. With this arrangement, one safety valve and two rupture disks are available at all times. The dual primary relief systems with 100% standby redundancy allows maintenance and testing to be performed without sacrificing the level of protection from overpressure.

The safety valve shall be the primary relief device as specified by the American Society of Mechanical Engineers (ASME) Pressure Vessel Codes and is set to relieve at 1.0 times the Maximum Allowable Working Pressure (MAWP). This valve shall be sized to accommodate all "normal" overpressure demands. The rupture disk shall be a "supplemental pressure relieving device" for "unexpected sources of external heat." The ASME code allows such devices to relieve at 21% above the MAWP. All rupture disks on the tank shall be specified and purchased to burst at 1.2 MAWP.

Additionally, the tank shall be supplied with a secondary relief system not required by the ASME Codes. The system shall be totally separate from the primary relief system. It consists of a lock open valve, one rupture disk, and a secondary vent stack. The rupture disk shall be specified and purchased to burst at 1.33 MAWP.

Supply system piping that may contain liquid and can be isolatable from the tank relief valves shall be protected with thermal relief valves. 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 C-5, Section 7.3.7.

Two lift-plate relief devices shall be installed in the tank's outer vessel to relieve any excessive pressure buildup in the annular space.

Two grounding assemblies shall be used to arrest static electricity. One shall be connected to the frame of the vessel and the other to the base of the vent stack. Each shall be connected with bare wire to ground rods buried into the earth. During unloading operation, the liquid delivery trailer ground wire shall be clamped to the tank or vent stack ground wire (Reference CGA P-12).

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. An acceptable methodology is identified in Section 4.3.2, "Pipe Breaks." The use of excess flow protection in conjunction with seismic pipe support from tank penetration to the excess flow assembly will arrest this problem.

3.2.2.3 Instrumentation. The tank shall be supplied with a pressure gauge, a liquid level gauge, and a vacuum readout connection. These gauges are sufficient for normal monitoring of the tank condition. Instrumentation for remote monitoring, such as high/low-pressure switches, pressure and level transmitters may be added. A complete listing of supply system instrumentation and control is identified in Section 2.4.

3.2.2.4 Liquid Hydrogen Pump and Controls. The liquid hydrogen pump shall be of proven design to provide continuous hydrogen supply in unattended, automatic operation. The following items comprise the more important system controls.

3.2.2.4.1 Positive isolation valve. A positive isolation valve is used to control the liquid feed into the pumping system per NFPA 50B. The valve shall be a failed-closed, pneumatically operated valve. The valve will only be open during pump operation, closes in any fault mode, and can be remotely overridden in case of emergency.

3.2.2.4.2 System overpressure shutdown. Although the system is protected by safety relief valves and rupture discs, system overpressure shall be avoided by shutting down the pumps at high pressure.

3.2.2.4.3 Temperature indicating switch. The temperature switch shall continuously monitor the downstream gas line for low temperature. The temperature switch shall be provided to protect downstream equipment from low temperatures.

3.2.2.4.4 Pump operation. Pump operation is continuously monitored. A cavitation condition or high or low temperature at the pump shall cause the pump to be shut down. The remote control panel shall announce the fault by an audible alarm and light indication.

3.2.2.4.5 Purging of controls. All electrical components in hydrogen service SHOULD be designed in accordance with NFPA 70. Nitrogen or air may be required for purging pump motors, control panels and valves.

3.2.2.5 Interface with Gaseous System. Liquid hydrogen pump systems typically require a gaseous storage system as a surge or back-up to plant hydrogen supply. These storage systems shall be designed in accordance with Section 3.1, GASEOUS HYDROGEN. Whenever a gaseous back-up is used in conjunction with a liquid hydrogen system, an automatic switchover assembly shall be used to handle changes in the supply of hydrogen. This assembly should use an adjustable pressure switch, an electric control panel, and two solenoid valves to allow hydrogen gas flow from the appropriate storage facilities.

3.2.2.6 Vaporization. The vaporization of the liquid hydrogen SHOULD be achieved by the use of ambient air vaporizers.

The vaporizer should feature a star fin design and aluminum alloy construction. For a combined liquid and gaseous storage system, the vaporizers used SHOULD have a design pressure CONSISTENT WITH PLANT INJECTION PRESSURE REQUIREMENTS. The units are piped in parallel so that each unit can operate independently. Parallel vaporizer assemblies shall be sized for the hydrogen peak flow required for each plant and shall provide FOR periodic intervals for defrosting as appropriate.

For a PUMPED liquid only storage system, the vaporizer must withstand maximum pressures generated from the cryogenic pump. These vaporizers shall be equipped with stainless steel lining DESIGNED TO 3500 psig.

3.2.2.7 Hydrogen Storage Vessels (Refer to Section 3.1 Gaseous Hydrogen)

3.2.3 Site Characteristics of Gaseous and Liquid Hydrogen

3.2.3.1 Overview. Review of the following site characteristics shall be conducted by each BWR facility in locating the gaseous and/or liquid hydrogen supply systems:

1. Locating of supply system to exposures as addressed in NFPA 50A and 50B.

2. Route of hydrogen delivery on site.

3. Location of supply system relative to safety-related equipment.

3.2.3.2 Specific Considerations.

3.2.3.2.1 Fire Protection. The area selected for liquid hydrogen system siting shall meet or exceed all requirements for protection of personnel and equipment as addressed in NFPA 50A and 50B, gaseous and liquified hydrogen systems, respectively. Each standard identifies the maximum quantity of hydrogen storage permitted and the minimum distance from hydrogen systems to exposures.

The need for additional fire protection for other than the hydrogen facility shall be determined by an analysis of local conditions of hazards on-site, exposure to other properties, water supplies, and the probable effectiveness of plant fire brigades in accordance with NFPA 50A and 50B.

3.2.3.2.2 Security. All liquid hydrogen storage system installations shall be completely fenced, even when located within the owner-controlled area. Lighting shall be installed to facilitate night surveillance.

3.2.3.2.3 Route of liquid hydrogen delivery on site. Each plant should determine the route to be taken by liquid hydrogen delivery trucks through on-site and off-site areas. In order to protect the hydrogen storage area from any vehicular accidents, truck barriers shall be installed around the perimeter of the system installation.

Within the security area all deliveries are controlled by plant security personnel, per the requirements of 10 CFR 73.55.

3.2.3.2.4 Location of storage system to safety-related structures. Each plant shall determine that the location of the liquid hydrogen storage system is acceptable considering the hazards described in Section 4.2.

3.3 ELECTROLYTIC

3.3.1 System Overview

The disassociation of water by electrolysis is an acceptable method of obtaining the gases needed for hydrogen water chemistry. This can be done on site and the gases can be conveniently generated at the rate used. The electrolytic gas generator can be proven equipment the same as used in other industrial applications. Depending on the generator operating pressure, either hydrogen compressors or pressure breakdown (control) is utilized to match plant hydrogen injection pressure requirements. The electrolytic system shall be provided by a supplier who has extensive experience in the design, operation and maintenance of these systems.

3.3.2 Specific Equipment Description

Equipment and processes associated with the electrolytic method of providing the HWC gases include rectifiers, the electrolytic cells, scrubbers, compressors, piping, valves and associated controls.

Gas Generator

Water is disassociated into hydrogen and oxygen in the electrolytic cells by the direct current electricity provided by the rectifiers. The water flows into the cells, at the rate dissociated, where it forms a solution with the electrolyte used to carry the electrical current from one electrode to the other. Hydrogen is formed at one electrode and oxygen at the other, which is dependent on current direction. The electrodes are separated which keeps the gas bubbles separate as they rise to the collection outlets of the cells.

Vessels

Unless exempted because of size (smaller than 120 gallons of water) or pressure (less than 15 psig), for industrial safety reasons, the requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code Section VIII, Division 1 shall apply to the design and construction of vessels. The code design pressure and temperature shall be selected to be above the highest pressure and temperature that can be reached during operation.

Piping

Piping and related equipment shall conform to the American National Standard Code (ANSI) for Piping B31.1 or B31.3 except that non metallic-materials may be used in low pressure applications if supported by experience and/or tests which have demonstrated their suitability for the service conditions, and operating pressure and temperature conditions are within the material manufacturer's specifications.

Valves

Valves should be designed such that the prevention of hydrogen leakage into an enclosed area does not rely on a single packing. Valves in any portion of the hydrogen flow path that is at subatmospheric pressure should be designed for zero inleakage of air.

Welded connections shall be used on all hydrogen piping that may operate below atmospheric pressure.

The oxygen flow path, including valves, shall not contain combustible greases, including traces of oils, or other combustible materials not demonstrated by long usage to not ignite at the conditions of temperature and velocity.

Valves in the hydrogen flow path in or downstream of any point where the pressure can be below atmospheric should have spark resistant rubbing and impacting surfaces if the rubbing or impacting velocities can exceed the spark threshold.

A helium leak test shall be performed to assure a leak tight system after installation.

Compressors

If a mechanical method of gas compression is employed, it should be located at the gas supply facilities. A gas pressurization method may be employed which does not require mechanical compressorsand which permits gas generate at a rate equal to gas usage, thereby avoiding the need for gas storage volume to match the difference in duty between the gas generator and the use rate. However, if a mechanical compressor is used, it shall meet the following requirements: The pressure gradient at any seal should be outward whenever the compressor

contains hydrogen. The shaft seal leakage shall not discharge into any enclosed space that is not either continuously purged with an inert gas or ventilated to avoid an explosive mixture of air and hydrogen assuming the greates potential rate of shaft seal leakage. The compressor shall not introduce unacceptable levels of organics and/or fluorides/chlorides into the hydrogen. The compessor shall be designed to permit purging of all compartments before and after maintenance.

Where gas storage volumes are employed, their size should be minimized. Where practical for the application, a type of compressor should be used that does not require surge tanks.

Gas Generator Shelter

Passive ventilation shall be provided for the gas generating room of the equipment shelter. Inlet openings shall be provided at floor level in exterior walls and outlet openings shall be located at the high point of the room. Inlet and outlet openings shall have an arrangement and sufficient area to assure fault-free passive ventilation. The discharge from outlet openings shall be directed to a location that has no ignition sources.

The gas generating room of the shelter shall be partitioned away from all other rooms that could contain ignition sources. The rectification equipment shall be partitioned away from the gas generation equipment.

Equipment for space heating of the gas generating room shall not contain any ignition sources and shall not allow gases, including air, to pass out of the room to an ignition source in a heating system.

Windows and doors shall be in exterior walls only. Windows shall be made of shatterproof glass or plastic in metal frames.

The shelter shall be of non-combustible materials (except for the transparent materials used in windows).

3.4 LIQUID OXYGEN

3.4.1 System Overview

Liquid oxygen is stored in a vacuum-jacketed vessel at pressures up to 250 psig and temperatures up to -251°F (saturated). Oxygen is taken from the vessel and vaporized through ambient air vaporizers. The "warmed" oxygen is routed through a pressure control station which maintains exiting oxygen gas pressures WITHIN THE DESIRED RANGE. The liquid oxygen system shall be provided by a supplier who has extensive experience in the design, operation and maintenance of associated storage and supply systems. Liquid oxygen shall be provided per CGA G-4 and G-4.3.

3.4.2 Specific Equipment Description

3.4.2.1 Cryogenic tank. Tanks for liquid oxygen service, with capacities between 3,000 gallons and 11,000 gallons are similar in principle. An "inner vessel" or "liquid container" is supported within an "outer vessel" or "vacuum jacket," with INSULATION IN THE SPACE BETWEEN THE TANKS. Necessary piping connects from inside of the inner vessel to outside of the vacuum jacket. Gages and valves to indicate the control of product in the vessel are mounted outside of the vacuum

jacket. Legs or saddles to support the whole assembly are welded to the outside of the vacuum jacket.

Tank Construction--Inner vessels are designed, fabricated, tested and stamped in accordance with Section VIII, Division 1, of the ASME Code for Unfired Pressure Vessels. For suitable liquid oxygen vessel materials, CGA G-4 states that materials must have good ductility at cryogenic temperatures of -300°F. The outer vessel is constructed of carbon steel and does not require ASME certification.

Insulation--Insulation between inner and outer vessels shall be either perlite, aluminized mylar or suitable equal. The annular space should be evacuated to a high vacuum (50 microns or less).

Internal/External Tank Piping--Tank control piping and valving should be installed in accordance with ANSI B31.1 or B31.3. All piping shall be either wrought copper or stainless steel. The following tank piping systems shall be subsystems:

- Fill circuit constructed with top and bottom lines so that the vessel can be filled without affecting system operation.
- Pressure build circuit, to keep tank pressures at operational levels.
- Economizer circuit, to preferentially feed oxygen gas from vessel vapor space to process.

Since the analysis assumes the vapor cloud originates from the tank location, the tank and its foundation shall be designed to remain in place during the design basis tornado.

3.4.2.2 Overpressure Protection System. Safety consideration for the tank shall be satisfied by dual full flow safety valves and emergency backup rupture discs. The primary relief system shall consist of two sets of one (1) safety valve and one (1) rupture disc piped into separate legs, coupled by a three-way valve. This dual primary relief system with 100% standby redundancy allows maintenance and testing to be performed without sacrificing the level of protection from overpressure.

The safety valve shall be the primary relief device as specified by the American Society of Mechanical Engineers (ASME) Pressure Vessel Codes and is set to relieve at 1.0 times the Maximum Allowable Working Pressure (MAWP). This valve shall be sized to accommodate all "normal" overpressure demands. The rupture disk shall be a "supplemental pressure relieving device" for "unexpected sources of external heat." The ASME code allows such devices to relieve at 21% above the MAWP. All rupture disks on the tank are specified and purchased to burst at 1.2 MAWP.

Annular space safety heads shall be provided to relieve any excess positive pressure buildup, which might result from a leak in an inner vessel. Supply system piping that may contain liquid and can be isolatable from the tank relief valves shall be protected with thermal relief valves

Instrumentation--The tank shall be supplied with a pressure gauge, a liquid level gauge, and a vacuum readout connection. These gauges are sufficient for normal monitoring of the tank condition. Instrumentation for remote monitoring, such as high-low-pressure switches, pressure and level transmitters may be added. A complete listing of supply system instrumentation and control is identified in Section 2.4.

3.4.2.3 Vaporization. The vaporization of the liquid oxygen shall be achieved by the use of ambient air vaporizers.

The vaporizer should feature a star fin design and extruded aluminum alloy construction. The design pressure of these units shall be at least 300 psig. The use of mulitiple vaporizers, piped in parallel and sized to handle peak plant flow requirements should be considered.

3.4.2.4 Pressure Control Station. The pressure control station shall be a manifold designed specifically for this installation. The automatic reducing manifold shall have two (2) full-flow parallel pressure reducing regulators. The discharge pressure range of these regulators shall be adjustable to satisfy plant oxygen injection requirements. Pressure gauges shall be provided upstream and downstream of the regulators. Sufficient hand valves shall be provided to ensure complete operational flexibility.

Protection from low oxygen temperatures shall be included in the system design.

3.4.3 Materials of Construction for Oxygen Piping and Valves

The design and installation of oxygen piping systems shall be in accordance with the latest ANSI B31.1 or B31.3 code and the following guidelines for material selection for oxygen systems.

Observations of past oxygen fires indicate that ignition can occur in carbon steel and stainless steel piping systems operating at, or near, sonic velocity. Friction from high velocity particles is considered to be the source of ignition. Copper, brass, and nickel alloys have the characteristic of melting at temperatures below respective ignition temperatures. This makes them extremely resistant to ignition service, and once ignited, they exhibit a much slower rate of burning than carbon or stainless steels.

As a result of these observations, the following materials, in order of preference, are acceptable for oxygen service. In the case of carbon steel or stainless steel, the maximum velocity of gaseous oxygen must be within guidelines established by the Compressed Gas Association CGA Pamphlet CG-4.4, "Industrial Practices For Gaseous Oxygen, Transmission and Distribution Piping Systems."

- Copper
- Brass
- Monel
- Stainless Steel
- Carbon Steel

If steel pipe is used and some local flow conditions cause the velocity to exceed that established in CGA G 4.4, then that portion of the system must be converted to a copper-base alloy and extend a minimum of 10 diameters downstream of the point of return to the allowable velocity. These local flow conditions may occur at control valves, orifices, branch line take-off points, and in the discharge piping of safety relief devices.

Valves that open rapidly are not suitable for oxygen service, since rapid filling of an oxygen line will result in a temperature increase due to adiabatic compression. As a result of this phenomenon, ball valves and automatic valves have the following restrictions:

- Valve bodies shall be made of a copper alloy. Balls shall be monel or brass. Valve seats and seals should be teflon, non-plasticized Kel-F, Kalrez, or Viton.
- Ball valves may not be used as process control valves in throttling or regulating service. Ball valves may be used as isolation valves, emergency shutoff valves, or vent or bleed valves where they are either fully open or fully closed.

- Pneumatic or electric ball valves used for on-off services shall have an actuation time from fully closed to fully open of 4 seconds or greater for pressures up to 250 psig. No restriction is placed on actuation time from fully open to fully closed. Piping immediately downstream must be a straight run of copper-bearing material for a minimum of 10 diameters.

- Pneumatic or electric ball valves used for emergency service may be fully open or fully closed to the emergency position, with no restrictions on actuation time.

Suitable valve packing, seats, and gasket materials are listed below in order of preference from the oxygen compatibility basis only.

- Teflon
- Glass-filled Teflon
- Nonplasticized Kel-F
- Garlock 900
- Viton or Viton A

3.4.4 Oxygen Cleaning

All piping, fittings, valves, and other material which may contact oxygen shall be cleaned to remove internal organic, inorganic, and particulate matter IN ACCORDANCE WITH CEA 4. Observation has shown that ignition can occur in properly designed piping systems when foreign matter is introduced. Therefore, removal of contaminants such as grease, oils, thread lubricants, dirt, water, filings, scale, weld spatter, paints, or other foreign material is essential. Cleaning should be accomplished by precleaning all parts of the system, maintaining cleanliness during construction, and by completely cleaning the system after construction.

3.4.5 Site Characteristics of Liquid Oxygen

3.4.5.1 Overview. Review of the following site characteristics shall be completed by each BWR facility as part of their efforts to locate the liquid oxygen storage system.

1. Location of supply system to exposure as addressed in NFPA 50.
2. Route of liquid oxygen delivery on site.
3. Location of supply system relative to safety related equipment.
4. LOCATION OF HYDROGEN STORAGE

3.4.5.2 Specific Considerations.

3.4.5.2.1 Fire protection. The area selected for liquid oxygen system siting shall meet or exceed all requirements for protection of personnel and equipment as addressed in NFPA 50, Bulk Oxygen Systems.

The standard identifies the types of exposures under consideration. The number of exposures warrants a plant-specific review for proper code compliance. As much separation distance as practical should be provided between the hydrogen and oxygen systems.

3.4.5.2.2 Security. All liquid oxygen supply system installations shall be completely fenced, even when located within the security area. Lighting shall be installed to facilitate night surveillance.

3.4.5.2.3 Route of liquid oxygen delivery on site. Each plant should determine the route to be taken by liquid oxygen delivery trucks through on- and off-site areas. In order to protect the oxygen storage area from any vehicular accidents, truck barriers shall be installed around the perimeter of the system installation.

Within the security area all deliveries are controlled by plant security personnel, per the requirements of 10 CFR 73.55.

3.4.5.2.4 Location of storage system to safety-related equipment. Each plant shall determine that the location of the liquid oxygen supply system is acceptable considering the hazard described in Section 4.4.

3.4.6 Properties of Liquid Oxygen

Liquid oxygen is pale blue in color, extremely cold, and nonflammable. Oxygen supports life. It readily combines with other elements. It is a strong oxidizer, and an oxidizer is necessary to support combustion.

- Oxygen will react with nearly all organic materials and metals. Materials which burn easily in air usually burn more vigorously in oxygen. Equipment used in oxygen service must be designed to utilize materials that have high ignition temperatures and are nonreactive with oxygen under the service conditions of the contemplated system.

Section 4

SAFETY CONSIDERATIONS

4.1 GASEOUS HYDROGEN

(LATER)

4.2 LIQUID HYDROGEN

4.2.1 Properties of Liquid Hydrogen

Hydrogen is colorless as a liquid. Its vapors are colorless, odorless, tasteless, and highly flammable.

Liquid hydrogen is noncorrosive, and therefore, special materials of construction are not required. However, because of its extremely cold temperature, equipment must be designed and manufactured of material which is suitable for extremely low temperature operation.

The following identifies the properties of liquid hydrogen:

Molecular Weight	2.016
Boiling Point @ 1 atm	-423.0F (-252.8C)
Freezing Point @ 1 atm	-434.5F (-259.2C)
Critical Temperature	-399.8F (-239.9C)
Critical Pressure	188 psia (12.8 atm)
Density, Liquid @ B.P., 1 atm	4.423 lbs./cu.ft.
Specific Gravity, Liquid @ B.P., 1 atm	0.0710
Specific Volume @ 68F (20C), 1 atm	191.3 cu. ft./lb.
Latent Heat of Vaporization	389 Btu/lb. mole
Flammable Limits @ 1 atm in air	4.00% - 74.2% (by volume)
Flammable Limits @ 1 atm in oxygen	4.65% - 93.9% (by volume)
Detonable Limits @ 1 atm in air	18.2% - 58.9% (by volume)
Detonable Limits @ 1 atm in oxygen	15% - 90% (by volume)
Autoignition Temperature @ 1 atm	932F (500C)
Expansion Ratio, Liquid to Gas, P.B. to 68F (20C)	1 to 848
Spec Gravity, Sat. Vapor @ B.P	1.12

4.2.2 Storage Vessel Failure

For this report, storage vessel failure is defined as a large breach resulting in the rapid emptying of the entire contents of liquid hydrogen. It is assumed that the tank is full at the time of failure and that the entire spill vaporizes instantaneously. The following enumerates potential causes of vessel failure and the required design features that mitigate or alleviate these potentials.

Seismic

The tank and its foundation shall be designed to meet the seismic criterion for critical structures and equipment at the plant site (i.e., design basis earthquake).

Tornado and Tornado Missiles

The tank and its foundation shall be designed to withstand the "design basis tornado characteristics" as outlined in Regulatory Guide 1.76. As a minimum, the tank shall remain in place so that any liquid spillage will originate from the tank location.

Design basis tornado-generated missiles are capable of breaching all known commercially available liquid hydrogen storage vessels. Therefore, tornado missiles are a potential cause of "storage vessel failure."

Aircraft

A large aircraft crashing directly into the storage area is capable of breaching all known commercially available liquid hydrogen storage vessels. Therefore, aircraft crash is a potential cause of "storage vessel failure."

Fire

The overpressure protection system shall be sized to accommodate the worst-case vaporization rate caused by a hydrocarbon fire engulfing the outer shell with loss of vacuum and hydrogen in the annulus of the double-wall storage tank (as per Compressed Gas Association 5.3 and ASME Section VIII requirements).

Flood

The following flood conditions could result in vessel failure:

- o High water reaches the top of the vent stack for the overpressure protection system.
- o High flood velocities dislodge the tank.

Under either condition, water could enter the vent system and defeat the overpressure protection system. Therefore, the tank shall be located such that maximum flood heights cannot exceed the vent stack elevation and that high flood velocities cannot occur.

Vehicle Impact

The storage vessel shall be protected from the impact of a large vehicle (e.g., semitrailer truck) by a barricade capable of stopping such a vehicle.

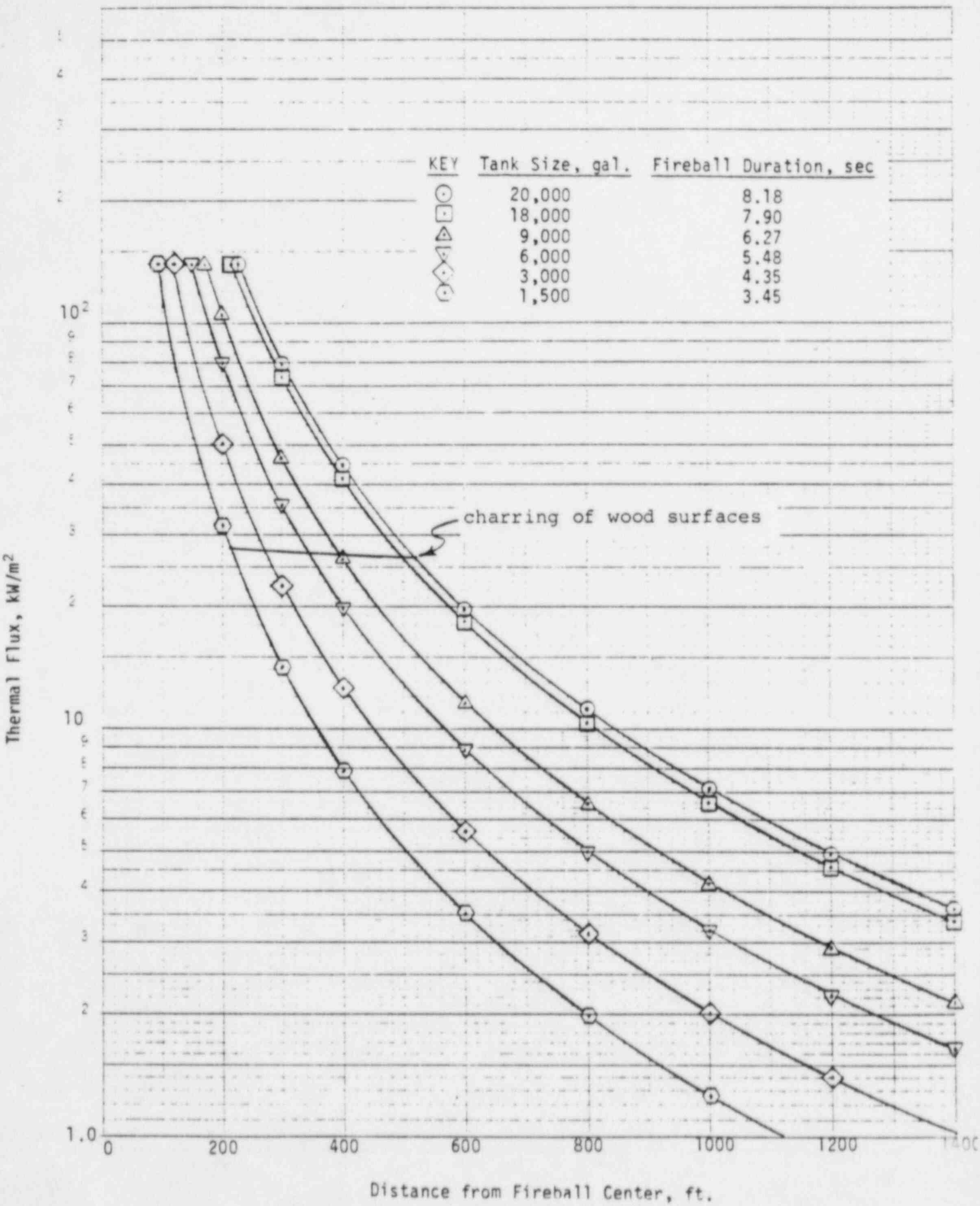
Structural Vessel Failure

The storage vessel shall be designed, constructed, inspected and operated to assure an extremely low likelihood of structural tank failure during its tenure on site. A vessel designed in accordance with this document complies with this low probability requirement.

4.2.2.1 Fireball. For the two potential causes of "storage vessel failure," tornado missiles and aircraft impact, a fireball at the tank location is the expected result. The major reasons for this is the high ignitability of hydrogen and the density of ignition sources in the aftermath of these causal events. Details of these considerations are given in reports for the Dresden plant (Reference 4-1).

The thermal flux versus distance from the fireball center (tank location) is shown on Figure 4-1 for the range of commercially available tank sizes. The durations of the various fireball sizes are also given. These fluxes and durations will not adversely affect equipment or personnel enclosed in the concrete/steel safety-related structures. However, each utility shall review any unique site characteristics to assure all safety-related equipment will function in the event of a fireball.

Thermal Flux vs. Distance from Fireball Center



4.2.2.2 Explosion at Tank Site. For the instantaneous release of the entire tank contents, the following were used to determine blast parameters for an explosion at the tank site:

1. Gaussian F weather stability
2. Detonation limits of hydrogen, 18.3-59%
3. TNT - hydrogen equivalent of 20% on an energy basis (520% on a mass basis)

The above results in an equivalence of 1.37 lbs of TNT per gallon of tank size. Using this conversion factor and U.S. Army Technical Manual TM5-1300, blast overpressures and impulses can be calculated as a function of distances from the site for any size of tank.

These blast parameters could then be compared to the dynamic strength of safety-related structures. This concept of dynamic response strength of structures is illustrated on Figure 4-2 for the threshold of partial demolition of residential brick construction. This curve represents many "data points" for homes damaged during World War II from known size bombs at various standoff distances. Brick buildings subjected to incident impulses/overpressures to the right and above this curve will receive more severe damage. Points to the left and below the curve will be under the threshold for this damage criterion. In order to determine the required separation distances, similar curves to this could be generated for specific related structures at each nuclear power plant. As an alternative to individual strength calculations, it would be conservative to assume that the heavily reinforced concrete safety-related structures could withstand the blast parameters for this damage criterion. Further discussion of this criterion can be found in reference 4-1.

Therefore, the minimum required separation distances from the storage tank to safety-related structures or equipment for the event of an explosion at the tank site shall meet the criterion depicted on Figure 4-3. Alternatively, a dynamic strength analysis may be performed for a specific safety-related structure if closer siting is desired.

Figure 4-2

Damage Curve for Residential Brick Buildings

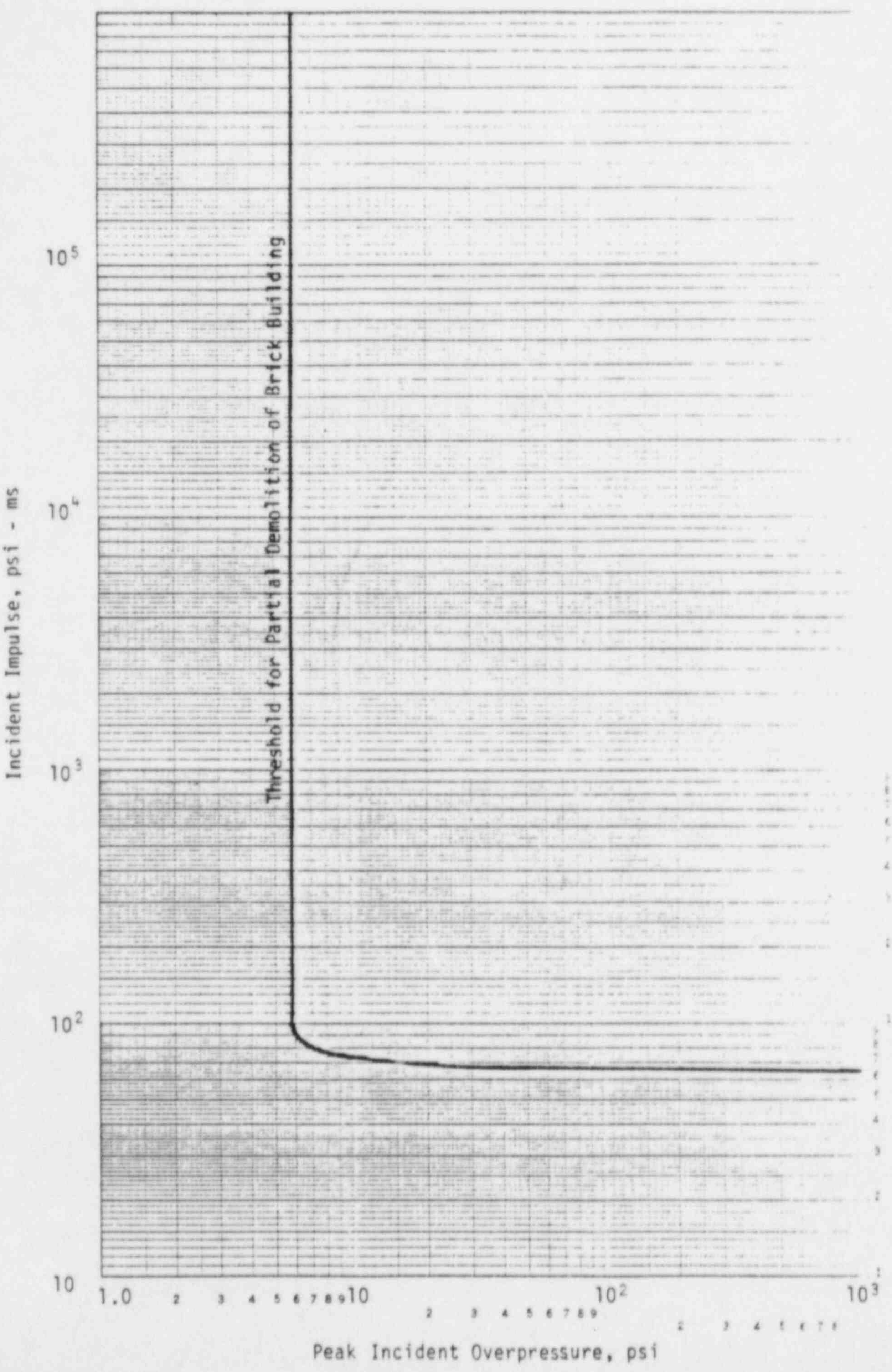
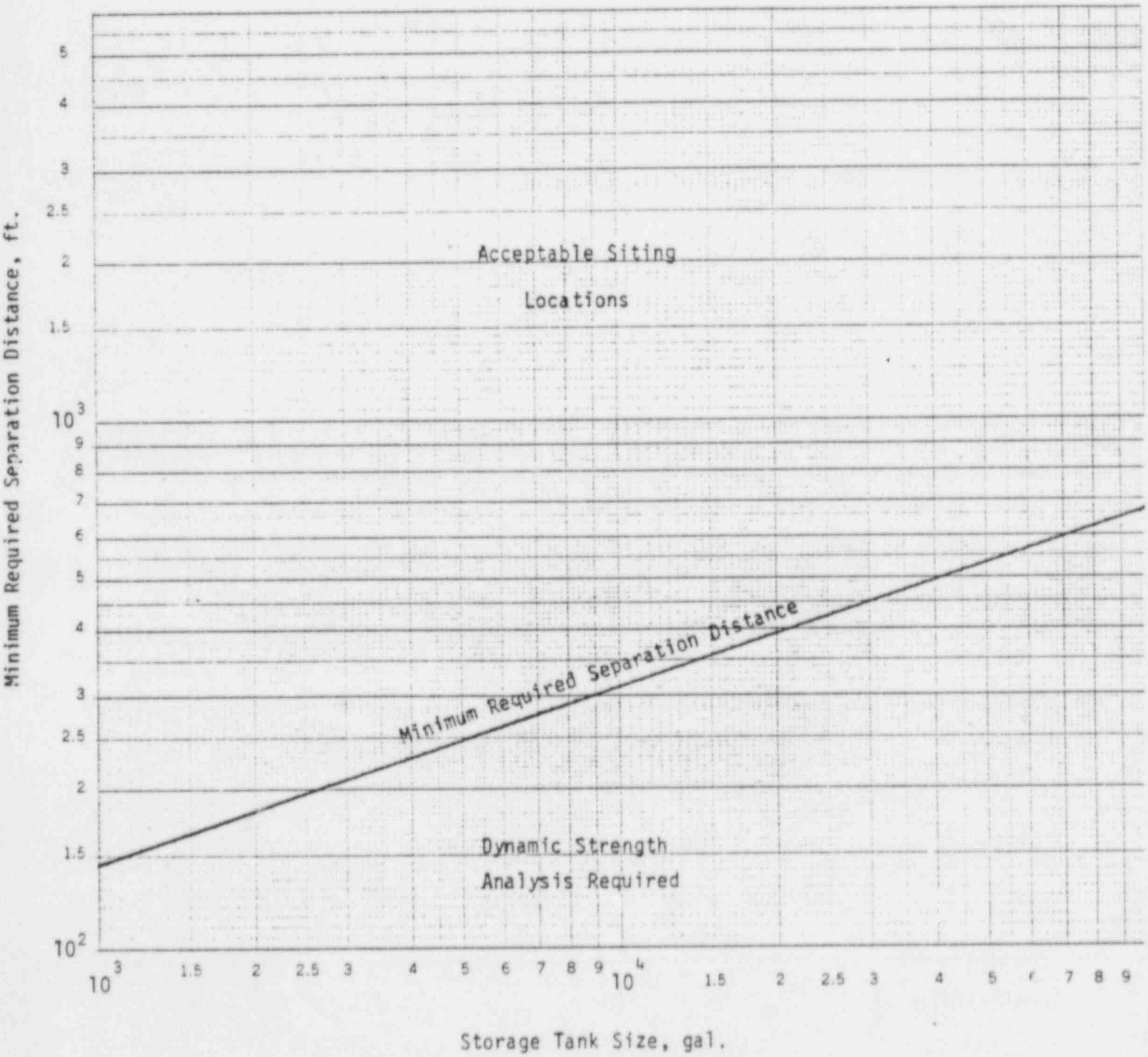


Figure 4-3

Minimum Required Separation Distance vs. Storage Tank Size

for Instantaneous Release of Entire Tank Contents and Explosion at Tank Site

F Weather Stability



4.2.3. Pipe Breaks

This section addresses the requirements for gaseous and liquid hydrogen piping systems attached to the storage vessel up to the point where excess flow protection is provided. The criteria for acceptable siting for the event of a pipe break are:

1. Dilution of resultant release below the lower flammability limit of 4% before reaching safety-related air intakes.

2. Maximum overpressures below the blast damage criterion outlined in Section 4.2.2.

It is conservatively assumed that all releases occur while the storage vessel is at 150 psig. This is the maximum allowable working pressure of the majority of commercially available tanks.

Gaseous Piping

Gaseous releases at elevated pressures result in supersonic jet velocities and a dispersion process that is momentum-dominated. Under these conditions, the Gaussian dispersion model unrealistically overestimates the amount of hydrogen in the explosive region and the distance to the lower flammable region. Therefore, these properties of gaseous releases were calculated using a jet dispersion model described in Reference 4-1.

The results of this modeling are shown in Figure 4-4 as minimum separation distances between safety-related structures and air intakes versus hole size or inside diameter of the pipe. Each utility shall determine that the storage vessel piping and location meet these minimum requirements or show that less stringent criteria should be applied to a specific case. An example of such an exception would be if the air intakes have automatic shutters controlled by hydrogen analyzers thus preventing the ingestion of a flammable mixture.

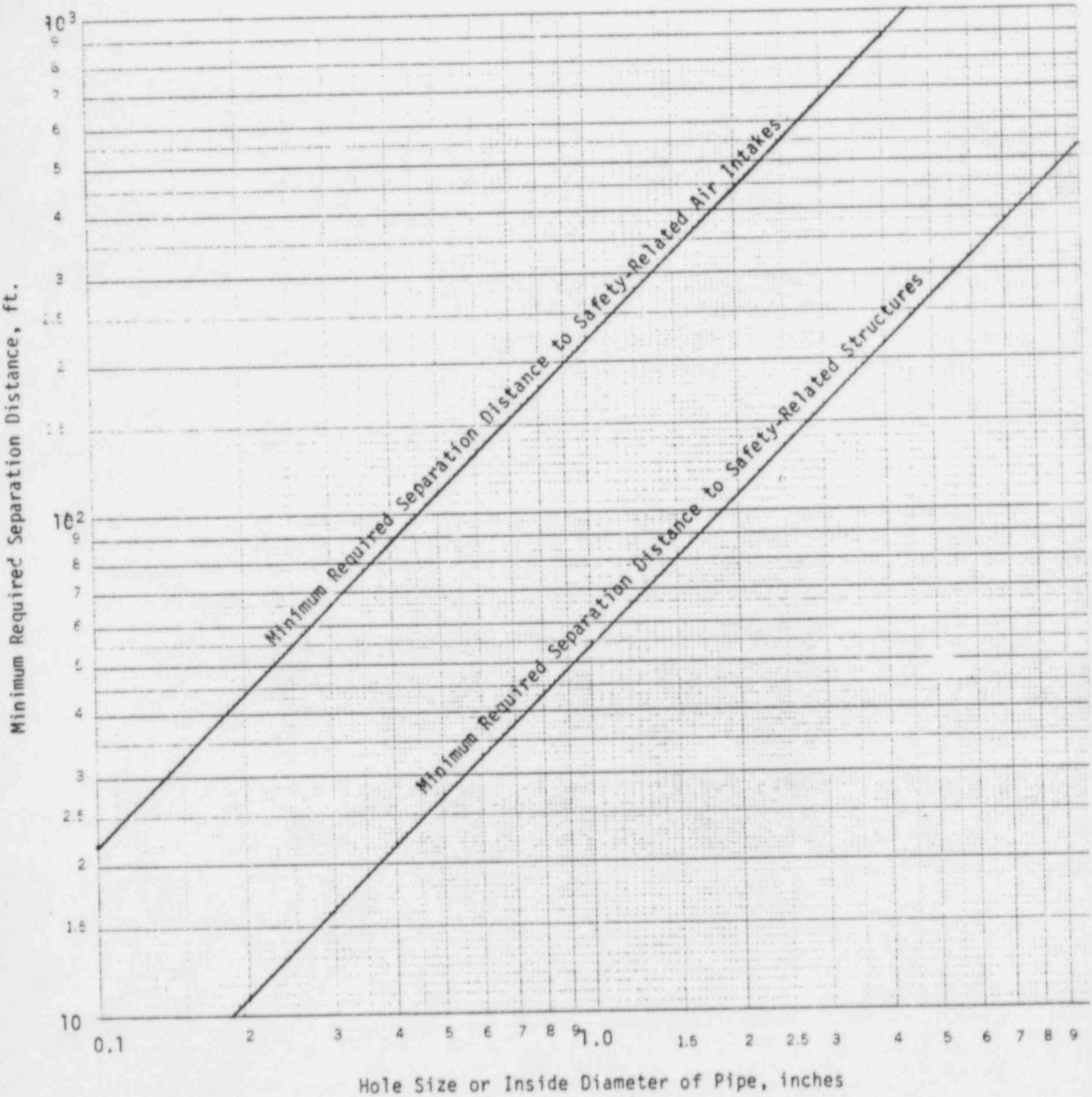
Liquid Piping

The vapor cloud formed by the flashing and rapid vaporization of a liquid release is nearly neutrally buoyant and has little momentum associated with its formation. Under these conditions, it is appropriate to use the continuous Gaussian dispersion model. It is conservatively assumed that liquid discharges will instantaneously vaporize.

Figure 4-4

Minimum Required Separation Distance vs. Hole Size and ID of Pipe

for Gaseous Releases from 150 psi Liquid Hydrogen Storage Tank



The minimum required separation distances to safety-related structures and air intakes, using the above assumptions, are given on Figure 4-5 as a function of discharge rate. These distances shall be applied to all liquid piping, including those from any pump discharges, that are not seismically supported or protected by excess flow devices. For convenience, hole size or inside diameter of pipe for the worst-case break geometry is also plotted on Figure 4-5.

4.3 ELECTROLYTIC

4.3.1 General

The electrolytic supply option need not constitute storage of hazardous materials on-site if it operates at approximately atmospheric pressure and involves the storage of no more than 2500 scf of hydrogen and 1250 scf of oxygen. If these limits are met, and the system is designed as described in Section 3.3, it need only be analyzed as described below. Other system designs have not yet been considered. Compressed gases utilized in conjunction with electrolytic systems shall be in accordance with Sections 3.1 and 4.1.

Events important to industrial safety (abnormal transients, accidents and external events) must be evaluated to identify those which could result in any of the following conditions:

1. Hydrogen accumulation to a combustible mixture in an enclosed space.
2. Air or oxygen mixing with hydrogen within electrolytic system components.
3. Hydrogen fires.

When the potential exists for the above undesired conditions to occur, appropriate mitigating features shall be incorporated ir the design or operation of the system or the consequences with respect to plant and personnel safety shall be evaluated or determined to be acceptable.

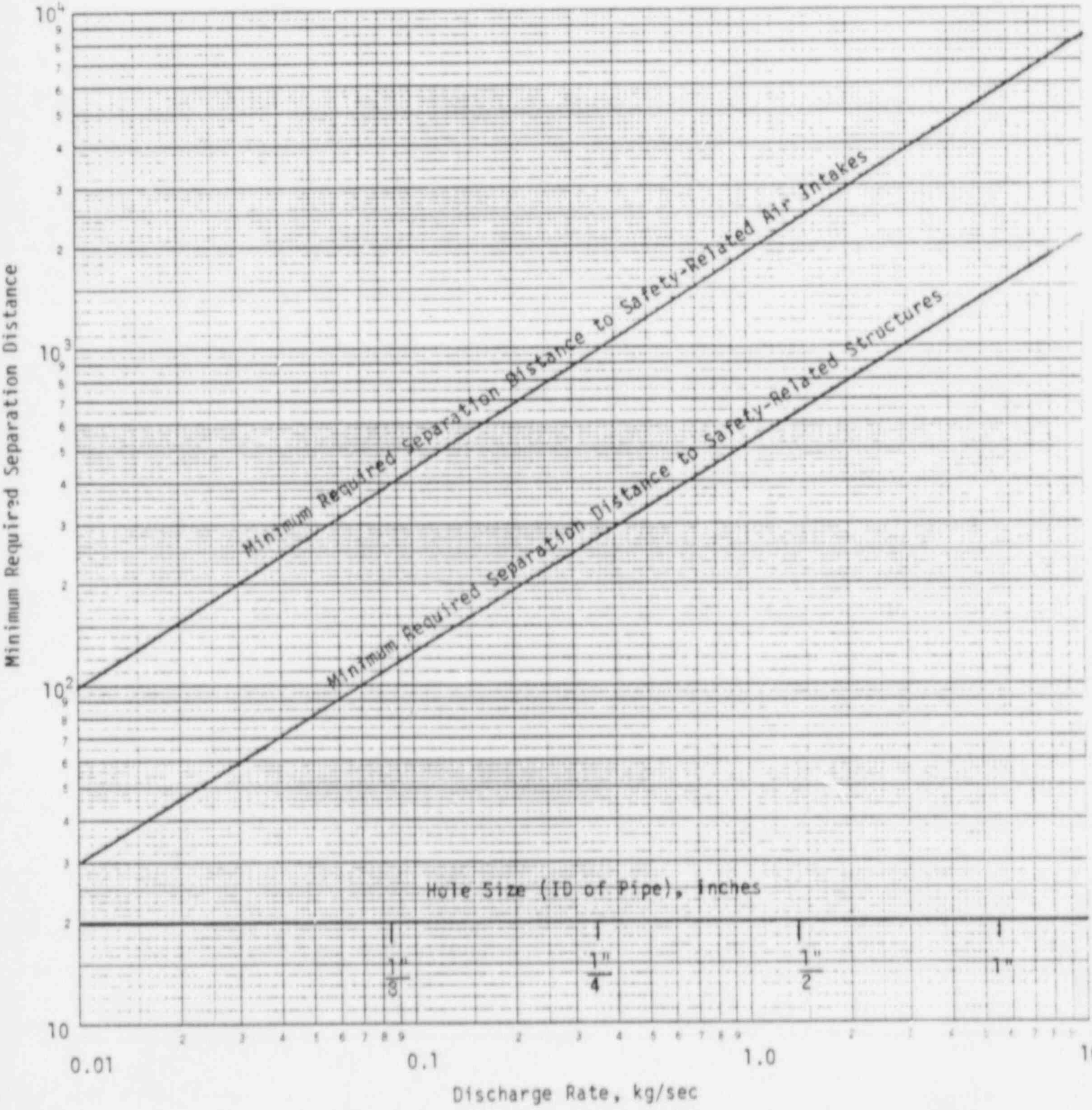
4.3.2 Purity of Gases

The gases as collected from the electrolytic cells in a well working system will be over 99% pure and concentration of the oxygen in the hydrogen stream and the concentration of hydrogen in the oxygen stream will be well below the ignition limits. However, over time, purity may tend toward acceptable limits due to the build up of oxides or contaminants on the electrodes. This trend is a very slow process detectable by periodic purity testing well before combustible mixtures are

Figure 4-5

Minimum Required Separation Distance vs. Hole Size and Discharge Rate for Liquid Releases from 150 psi Liquid Hydrogen Storage Tank

F Weather Stability, 1 m/s Wind Velocity



reached. The time that it takes depends on materials of the electrodes, and impurities in the water. To monitor cell performance and avoid combustible mixtures, gas purity shall be periodically or continuously measured. As a second precaution against an unsafe condition, the equipment shall be designed to contain an internal explosion.

4.3.3 Air Inleakage

The electrolytic cells and their gas collection headers shall be controlled to a pressure above atmospheric.

Since nearly any method of compression will cause a reduction of pressure at the inlet of the compression device, the equipment at and between the pressure regulating device (for maintaining the gas generator pressure) and the compressor must be designed to avoid air inleakage. This equipment shall be designed to (1) not contain sufficient hydrogen to represent a hazard to plant safety, (2) not have any ignition sources in the hydrogen flow path, and (3) avoid combustible gas mixtures. Valves in this flow path should have spark-resistant seat and stem guides. The design should be capable of containing an internal explosion.

4.3.4 Out Leakage

The system must be designed to avoid combustible gas mixtures which could result from unintentional outleakage. Controlled venting to safe locations in the atmosphere is acceptable.

The kindling temperatures of combustible materials decrease with increased concentrations of oxygen. Therefore, oxygen must not be vented in the vicinty of combustible materials that would be at temperatures above the kindling temperature in a pure oxygen concentration.

4.3.5 External Events

External events such as seismic, tornado, aircraft crash and flood cannot result in consequences more severe than cited above and need not be considered further.

4.4 LIQUID OXYGEN

4.4.1 Liquid Oxygen Storage Vessel Failure

The liquid oxygen storage vessels are vulnerable to the same potential causes of failure as the liquid hydrogen vessels but the consequences of failure are much less severe. The potential threat from a liquid oxygen spill is the ingestion of oxygen-enriched air into safety-related air intakes. If this were to occur, the effective combustibility of ignitable materials in the enriched area would increase. For the purpose of this report, it is conservatively assumed that total oxygen concentrations above 30 vol. % (21% O_2 in air + 9% enriched O_2) will increase the effective combustibility of ignitible materials in the area.

4.4.2 Liquid Oxygen Vapor Cloud Dispersion

The instantaneous vapor cloud formed by a large liquid oxygen spill will have a density of 3.59 relative to air. Such a cloud will experience considerable gravity-driven slumping as it disperses and translates with the wind. This process has been described by the DEGADIS model developed by Prof. J. A. Havens of the University of Arkansas. His model has been found to agree well with published data on large releases of dense gases conducted by the U.S. Department of Energy, U.S. Coast Guard and others.

The DEGADIS model has been used to determine the height of the vapor cloud as a function of distance for various sizes of commercially available liquid oxygen storage tanks. It was conservatively assumed that any vessel failure would result in the instantaneous vaporization of the entire tank contents. Figure 4-6 shows the results of this study for the worst-case weather conditions of F stability and a 10-meter per second wind speed. For dense gas dispersion, lower wind speeds result in more radial spreading with a lower cloud height and shorter maximum drift distance. Higher wind speeds will translate even the largest release past safety-related intakes in less than 10 seconds, giving little time for ingestion of enriched air.

Therefore, liquid oxygen storage vessels shall be located such that safety-related air intakes are within the acceptable region defined by Figure 4-6 or alternative analyses shall be performed to justify the location.

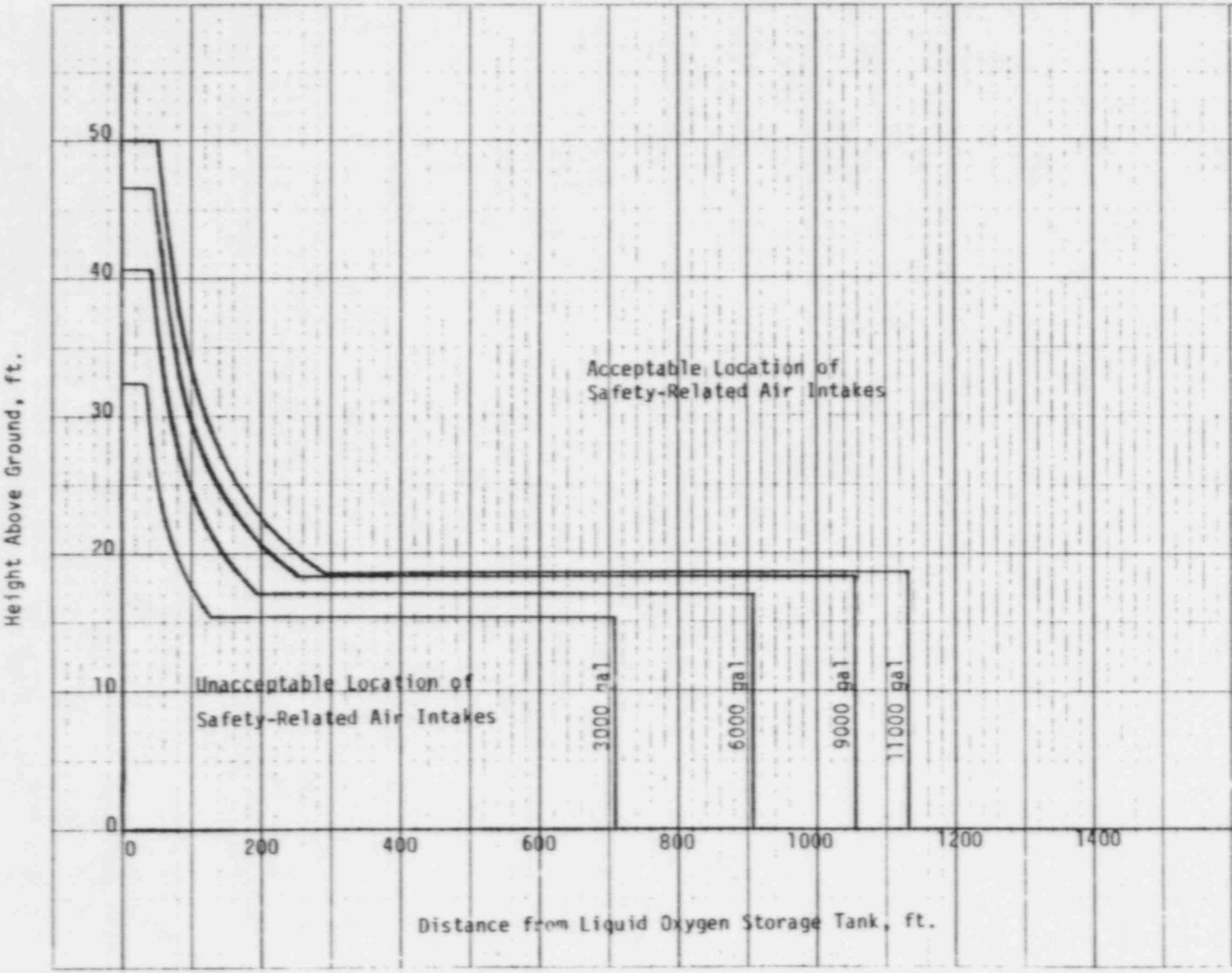


Figure 4-6

Acceptable Locations of Safety-Related Air Intakes
for Various Sizes of Liquid Oxygen Storage Tanks

4.5 REFERENCES

4-1 Air Products document, later

Section 5

VERIFICATION

The various methods of verifying the effectiveness of HWC (i.e. electrochemical potential, constant extension rate tests, etc.) are not within the scope of this document. Appropriate methods of verification should be selected and implemented on a plant specific basis.

Section 6

OPERATION, MAINTENANCE, AND TRAINING

This section gives recommendations to the operating utility for operation, maintenance, and training in order to meet the design intent of the hydrogen water chemistry (HWC) system.

The operation of a HWC system will require operator and chemistry personnel attention, which will increase their work load. Because of the radiation increases that this system causes, an awareness of ALARA principles is required by all plant personnel. This system could also have an effect on the off-gas system and the plant's fire protection program.

6.1 OPERATING PROCEDURES

Written procedures describing proper valving alignment and sequence for any anticipated operation should be provided for each major component and system process. Check-off lists should be developed and used for complex or infrequent modes of operation. Operating procedures should be considered for the following operations:

1. Hydrogen addition system startup, normal operation, shutdown and alarm response
2. Material (gas or liquid) handling (filling of storage tanks) operations which are consistent with the supplier's recommendations
3. Purging of hydrogen and oxygen lines
4. Operation of on-site gas generation system (if appropriate)
5. Fire protection or safety measures for hydrogen or oxygen enhanced fires and hydrogen or oxygen spills.
6. Calibration and maintenance procedures as recommended by equipment or gas suppliers
7. Routine inspection of HWC system equipment

8. Adjustment of the main steam line radiation monitor setpoints (if appropriate)

6.1.1 Integration Into Existing Plant Operation Procedures

Where appropriate, operation of the HWC system shall be incorporated into normal plant procedures such as plant startup and shutdown.

6.1.2 Plant-Specific Procedures

Appropriate procedures shall be developed to provide guidance for plant operators when operation of the HWC system necessitates operation of an existing system in a different mode or raises new concerns. Areas which should be considered are:

1. Operation of the off-gas system
2. Possible off-gas fires

6.1.3 Radiation Protection Program

Operation of a HWC system results in an increase in radiation wherever nuclear steam is present. The radiation protection program shall be reviewed and appropriate changes made to compensate for these increased radiation levels.

The following guidelines are established to ensure that radiological exposures to both plant personnel and the general public are consistent with ALARA requirements. Compliance with these requirements eliminates all radiological significant safety hazards associated with HWC implementation. The operation of a hydrogen addition system may at some plants have a slight effect on the off-gas delay time due to the excess oxygen added. This may slightly increase plant effluents and should be reviewed. However, since the design objectives and limiting conditions for operation as defined by 10 CFR Part 50, Appendix I, are not impacted, no Appendix I revision is required.

6.1.3.1 ALARA Commitment. Permanent hydrogen water chemistry systems and programs will be designed, installed, operated, and maintained in accordance with the provisions of 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 Radiolgical Survey. Prior to long-term hydrogen injection, a comprehensive radiological survey should be performed to quantify the impact of hydrogen water chemistry on the environs dose rates, both within and outside the plant. This survey should be used to determine if signficant radiation changes occur in restricted areas and at the site boundary. Based upon the magnitude of the change, it should be determined if new radiation areas or high radiation areas need to be created. Appropriate posting, access, and monitoring requirements for the affected areas should be implemented. Plant operating and surveillance procedures should be revised, as required, to minimize the time and number of personnel required in radiation areas for operations, maintenance, in-service inspection, etc.

6.1.3.3 Plant Shielding. The radiological survey of subsection 6.1.3.2 should be used to determine the adequacy of existing plant shielding. In addition, the radiation levels from sample lines, sample coolers and monitoring equipment may increase due to HWC and should be checked for adequate shielding. If required, measures for selective upgrading of plant shielding should be implemented to reduce both work area and site boundary dose rates.

6.1.3.4 Maintenance Activities. Hydrogen water chemistry will have minimum impact on occupational exposures resulting from maintenance activities. Plant procedures should incorporate appropriate requirements for access to and monitoring of areas where increased dose rates exist with HWC to satisfy ALARA requirements. For extended maintenance, plant procedures should include provisions to terminate the hydrogen injection. Due to the short half-life of N-16, radiation levels will return to pre-HWC conditions within minutes of hydrogen shutoff.

6.1.3.5 Radiological Surveillance Programs. Dose rate surveys should be conducted and radiation levels should be monitored periodically to ensure compliance with the radiological limits imposed by 40 CFR Part 190, 10 CFR Part 100, and 10 CFR Part 20. Additional surveys may be required to comply with ALARA requirements.

6.1.3.6 Measurement of N-16 Radiation. The radiological surveillance program should include special provisions for N-16 surveys. Selection of appropriate health physics instrumentation and application of correction factors are required to provide accurate dose measurements. (This correction is required due to the

effect of the energenic N-16 gamma on instrumentation calibrated with less energenic gamma sources.) All plant survey meters should be reviewed and appropriate calibration and correction methods accounted for in plant procedures.

A review of the plant personnel dosimetry program shall be conducted to ensure that the appropriate cailbration or correction factors are used in areas when significant N-16 radiation is present.

6.1.3.7 Value/Impact Considerations. The following discussion reviews the total dose impact on a plant which implements HWC.

A radiological assessment at Dresden indicates that the total dose increase with HWC is approximately 0.5% on an annual basis (1935 to 1945 man-rem/year) (Ref. 6-1). 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 projected total dose increase with HWC is f250-300 man-rems.

With HWC implementation, the potential exists to relax current augmented in-service inspection requirements imposed by NRC Generic Letter 84-11 (Ref. 6-2) and elimination of extended plant outages for pipe replacement and/or repair. The value/impact assessment presented in Appendix E to Ref. 6-3 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

Procedures should be developed to maintain the high reactor water quality necessary to obtain the maximum benefit from the HWC system. The EPRI-BWR Owners Group has developed "BWR Water Chemistry Guidelines" which should be used in developing these procedures (Reference 6-4).

6.1.5 Fuel Surveillance Program

No significant effect of hydrogen injection on fuel performance has been observed nor is expected. However, since in-reactor experience with hydrogen water chemistry is limited, utilities should consider the fuel surveillance programs recommended by their fuel suppliers.

6.2 MAINTENANCE

A preventative maintenance program should be developed and instituted to ensure proper equipment performance to reduce unscheduled repairs. All maintenance activities should be carefully planned to reduce interference with station operation, assure industrial safety, and minimize maintenance personnel exposure. Written procedures should be developed and followed in the performance of maintenance work. They should be written with the objective of protecting plant personnel from physical harm, radiation exposure and to reduce hydrogen addition system downtime. Radiation exposure should be reduced by shortening the time required in a high radiation field and by reducing its intensity by turning off the HWC system or other means prior to maintenance.

6.3 TRAINING

In order for the HWC system to maintain its system integrity and to provide the expected benefits from its use, the system must be operated correctly. The most effective means of reducing the potential of operator error is through proper training.

Training should be provided to:

1. Instruct operators on the function, theory and operating characteristics of the system and all its major system components;

2. Advise operators of the consequences of component malfunctions and misoperation and provide instruction as to appropriate corrective actions to be taken;

3. Advise operations and maintenance personnel of the potential hazards of gases in the system, and provide instruction as to appropriate procedures for their handling;

4. Instruct emergency response personnel on appropriate procedures for handling fires or personnel injuries involving H_2 or O_2 liquid and gases.

5. Instruct plant personnel on the expected radiation changes due to the operation of the HWC system and the appropriate ALARA practices to be taken to minimize dose.

6. Instruct appropriate personnel on the benefits of HWC.

7. Advise maintenance and construction personnel of the routing of hydrogen lines and of the appropriate protective actions to be taken when working near these lines.

Periodic training should be provided to reinforce information described above and to communicate information regarding any modifications, procedural changes, or incidents.

6.4 IDENTIFICATION

In order to aid plant personnel in identifying hydrogen and oxygen lines, these lines should be color coded as required by ANSI-Z 35.1.

6.5 REFERENCES

6-1 "Environmental Impact of Hydrogen Water Chemistry," EPRI Hydrogen Water Chemistry Workshop, Atlanta, Georgia, December 1984.

6-2 "Inpsection of BWR Stainless Steel Piping," NRC Generic Letter 84-11, April 19, 1984.

6-3 "Report of the United States Nuclear Regulatory Commission Piping Review Committee," NUREG-1061, Volume 1, August 1984.

6-4 "BWR Water Chemistry Guidelines," EPRI Report NP-3589-SR-LD, April 1985.

Section 7

SURVEILLANCE AND TESTING

7.1 SYSTEM INTEGRITY TESTING

In addition to the testing required by the applicable design codes, completed process systems which will contain hydrogen shall be leak tested with helium prior to initial operation of the system. All components and joints shall be so tested in the fabrication shop or after installation, as appropriate. Appropriate helium leak tests shall be performed on portions of the system following any modifications or maintenance activity which could affect the pressure boundary of the system.

7.2 PREOPERATIONAL AND PERIODIC TESTING

Completed systems should be tested to the extent practicable to verify the operability and functional performance of the system. Proper functioning of the following items should be verified:

1. Trip and alarm functions per Table 2-2
2. Gas purity, if generated on site
3. Safety features
4. Excess flow check valves
5. System controls and monitors per Table 2-2.

A program should be developed for periodic retesting to verify the operability and the functional performance of the system.

Section 8

RADIATION MONITORING

8.1 INTRODUCTION

This section reviews the radiological consequence of hydrogen water chemistry (HWC) and presents the basis for increasing the main steam line radiation monitor setpoint to accommodate HWC. It is concluded that implementation of HWC does not reduce the margin of safety as defined in the basis of the technical specification setpoint.

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 is increased a factor of three to 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 include:

1. The dose to members of the general public (40 CFR 190),
2. The dose to personnel in unrestricted areas (10 CFR 20), and
3. The maintenance of personnel exposure "as low as reasonably achievable" (ALARA).

8.2 MAIN STEAM LINE RADIATION MONITORING

As noted in the previous section, the main steam line radiation will increase 3- to 5-fold with hydrogen water chemistry. The majority of BWRs have a technical specification requirement for the main steam line radiation monitor (MSLRM) setpoint that is less than or equal to three (3) times the normal rated full power background. For these plants an adjustment in the MSLRM setpoint is required to allow operation with hydrogen injection. For earlier BWRs with MSLRM setpoints of

seven (7) to ten (10) times normal full power background, a set point change may not be required.

8.2.1 Dual MSLRM Setpoint Recommendation

For plants at which credit is taken for an MSLRM-initiated isolation in the control rod drop accident (CRDA), a dual setpoint approach may be utilized. Above 20% rated power the setpoint should be readjusted to 3 times the normal rated full power background with hydrogen addition. Below 20% rated power or the power level required by the FSAR or technical specifications (see Table 2-1), the existing setpoint is maintained and hydrogen should not be injected into the feedwater system. If an unanticipated power reduction event occurs such that the reactor power is below this power level without the required setpoint change, control rod motion should be suspended until the necessary setpoint adjustment is made. At newer plants, credit is not taken for an MSLRM-initiated isolation after a CRDA, and a dual set point is not needed at these plants.

8.2.2 MSLRM Safety Design Basis

The only event for which some plants may take credit for main steam isolation valve (MSIV) closure on main steam line high radiation is the design basis control rod drop accident (CRDA). As documented in Ref. 8-1, the CRDA is only of concern below 10% of rated power. Above this power level the rod worths and resultant CRDA peak fuel enthalpies are not limiting due to core voids and faster Doppler feedback. Since the current MSLRM setpoint will not be changed below 20% rated power, the MSLRM sensitivity to fuel failure is not impacted and the FSAR analysis for the CRDA remains valid.

The licensing basis for the CRDA states that the maximum control rod worth is established by assuming the worst single inadvertent operator error (8-2). From Refs. 8-2 and 8-3, the maximum control rod worth above 20% rated power, assuming a single operator error, is <0.8% WK/K. Parametric studies utilizing the conservative GE excursion model (Ref. 8-1) indicate that the maximum peak fuel enthalpy for a dropped control rod worth of 0.8% WK/K is less than 120 calories per gram (Ref. 8-3). Consequently, the conservatively calculated peak fuel enthalpy for a CRDA above 20% rated power will have significant margin to the fuel cladding failure threshold of 170 calories per gram.

An increase in the MSLRM setpoint will not impact any other FSAR accident or transient analysis since no credit is taken for this isolation signal.

Consequently, a technical specification change which adopts the recommended dual setpoint approach will not reduce overall plant safety margins.

8.2.3 MSLRM Sensitivity

Conceptually, the sensitivity of the MSLRM to fission products is effectively reduced by the increase in the setpoint above 20% power. 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 offgas radiation monitoring system which monitors the gaseous effluent prior to its discharge to the environs. The offgas radiation monitor setpoint is established to help ensure that the equivalent stack release limit is not exceeded.

8.2.4 Conclusions

From the above discussion, it can be concluded that an increase in the MSLRM setpoint above 20% rated power does not reduce the safety margins as defined by technical specifications and the offsite radiological effects as a consequence of design base accidents do not exceed 10 CFR Part 100 limits. Furthermore, since this change to the MSLRM can be justified independent of HWC, this change does not result in an unreviewed safety concern.

8.3 EQUIPMENT QUALIFICATION

Outside primary containment the increase in dose rates with HWC is relatively small relative to the integrated dose assumed for equipment qualification (EQ) tests. Furthermore, dose rates inside the drywell will decrease because of the increased carryover of N-16 in the steam. Each utility should review the resultant dose increases to ensure that the doses assumed in the EQ test required of electrical equipment per 10CFR Part 50.49 remain bounding.

8.4 REFERENCES

8-1 R. C. Stirn et al., Rod Drop Analysis for Large Boiling Water Reactors, General Electric Company, March 1972 (NEDO-10527).

8-2 R. C. Stirn et al., Rod Drop Accident Analysis for Large Boiling Water Reactors Addendum No. 2 Exposed Cores, General Electric Company, January 1973 (NEDO-10527, Supplement 2).

8-3 R. C. Stirn et al., Rod Drop Accident Analysis for Large Boiling Water Reactors Addendum No. 1 Multiple Enrichment Cores With Axial Gadolinium, General Electric Company, July 1972 (NEDO-10527, Supplement 1).

Section 9

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 herein. In addition, or where not covered by the referenced codes and standards, the following quality assurance features shall be established.

9.1 SYSTEM DESIGNER AND PROCURER

1. Design and Procurement Document Control - Design and procurement documents shall be independently verified for conformance to the requirements of this document by individual(s) within the design organization who are not the originators of the design and procurement documents. Changes to design and procurement documents shall be verified or controlled to maintain conformance to this document.

2. Control of Purchased Material, Equipment and Services - Measures shall be established 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 may be done by an evaluation or a survey of the suppliers' products and facilities.

3. Handling, Storage, and Shipping - Instructions shall be provided in procurement documents to control the handling, storage, shipping and preservation of material and equipment to prevent damage, deterioration, and reduction of cleanliness.

9.2 CONTROL OF HYDROGEN STORAGE AND/OR GENERATION EQUIPMENT SUPPLIERS

In addition to the requirements in Section 9.1, the system designer should audit the design and manufacturing documents of the equipment supplier to assure conformance to the procurement documents. The system designer shall specify specific factory tests to be performed which will assure operability of the supplier's equipment. The system designer or his representative should be present for the factory tests.

9.3 SYSTEM CONSTRUCTOR

1. Inspection -- In addition to required code instructions, a program for inspection of activities affecting quality shall be established and executed by, or for, the organization performing the activity to verify conformance with the documented instructions, procedures, and drawings for accomplishing the activity. This shall include the visual inspection of components prior to installation for conformance with procurement documents and visual inspection of items and systems following installation, cleaning, and passivation (where applied).

2. Inspection, Test and Operating Status -- Measures shall be established to provide for the identification of items which have satisfactorily passed required inspections and tests.

3. Identification and Corrective Action for Items for Nonconformance -- Measures shall be established to identify items of nonconformance with regard to the requirements of the procurement documents or applicable codes and standards and to identify the remedial action taken to correct such items.

APPENDIX A

CODES, STANDARDS. AND REGULATIONS APPLICABLE TO HYDROGEN WATER CHEMISTRY INSTALLATIONS

This Appendix lists codes, standards, and regulations which may be applicable to specific hydrogen water chemistry installations.

10 CFR 20,	Standards for Protection Against Radiation
10 CFR 50.49	Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants
10 CFR 50	Appendix A, General Design Criteria for Nuclear Power Plants, General Design Criteria 54, 55, 56, or 57.
10 CFR 73.55	Requirements for Physical Protection of Licensed Activities in Nuclear Power Reactors Against Radiological Sabotage
10 CFR 100	Reactor Site Criteria
29 CFR 1910	Labor - OSHA Health Standards
29 CFR 1910.103	Hydrogen
29 CFR 1910.104	Oxygen
40 CFR 190	Protection of Environment - Environmental Radiation Protection Standards for Nuclear Power Operations

ASME Boiler and Pressure Vessel Code, Section VIII, Pressue Vessels

ASME Boiler and Pressure Vessel Code, Section IV, Heating Boilers

ASME Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications

ANSI B31.1	American National Standards Institute, Power Piping
ANSI B31.3	American National Standards Institute, Chemical Plant and Petroleum Refinery Piping
ANSI 235.1	Accident Prevention Signs, Specification for
ANSI/ASTM G63	Evaluating Nonmetallic Materials for Oxygen Service
API Standard 620	Design and Construction of Large, Welded, Low-Pressure Storage Tanks, Recommended Rules for

AWS D1.1	Structural Welding Code
NFPA50	Bulk Oxygen Systems
NFPA 50A	Gaseous Hydrogen Systems at Consumer Sites
NFPA 50B	Liquified Hydrogen Systems at Consumer Sites
NFPA 70	National Electrical Code

Compressed Gas Association G-4, Oxygen

Compressed Gas Associated G-4.1 Cleaning Equipment for Oxygen Service

Compressed Gas Assocation G-4.3, Commodity Specification for Oxygen

Compressed Gas Association G-4.4, Industrial Practices for Gaseous Oxygen Transmission and Distribution Piping Systems

Compressed Gas Association G-5, Hydrogen

Compressed Gas Association G-5.3, Commodity Specification for Hydrogen

Compressed Gas Assocation P-12, Safe Handling of Cryogenic Liquids

U.S. Army Technical Manual TM5-1300

U.S. Department of Transportation Specification 3A, 3AA, 3AX, 3AAX

U.S. Nuclear Regulatory Commission Regulatory Guide 1.76, "Design Basis Tornado for Nuclear Power Plants"

U.S. Nuclear Regulatory Commission Regulatory Guide 8.8, Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Reasonably Achievable (ALARA)"

U.S. Nuclear Regulatory Commission Regulatory Guide 8.10, "Operating Philosophy for Maintaining Occupational Radiation Exposures As Low As Reasonably Achievable"

PDR

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

OCT 11 1985

MEMORANDUM FOR: Victor Benaroya, Chief
Chemical Engineering Branch, DE

FROM: Frank J. Witt
Chemical Technology Section
Chemical Engineering Branch
Division of Engineering

SUBJECT: MEETING WITH BWR OWNER'S GROUP FOR IGSCC RESEARCH

Introduction

We met with the BWR Owner's Group on IGSCC Research, Hydrogen Installation Subcommittee, on October 9, 1985 in Bethesda, Maryland. The subcommittee briefed us on the design, construction and operational guidelines for permanent hydrogen injection systems.

The attendees of the meeting are listed in Enclosure I.

A draft of Guidelines for Permanent BWR Hydrogen Water Chemistry Installations, Revision C is attached as Enclosure II.

The Group briefly reviewed the scope of the guidelines for the currently available on-site hydrogen and oxygen gas supply options (i.e., compressed gas, cryoginic liquid, and electrolytic generation). Included in this scope were the hydrogen injection system requirements for operation, maintenance, surveillance, and testing to provide for a safe system and safe plant operation. The draft document does not cover the section on safety considerations for a gaseous hydrogen facility. Tests will be conducted soon to validate a new model on near field buoyancy effects for gaseous hydrogen releases. This section should be completed by the end of November 1985. A licensee by complying with these requirements will ensure having an approved system.

Conclusion

We informed the Owner's Group that under the present circumstances, a review would not be performed on the draft document. However, the Owner's Group could get in touch with NRC top management to establish priority on the review of this document.

Frank J. Witt

Frank J. Witt
Chemical Technology Section
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~~8510170385~~ 3PP

Enclosures: As stated

cc: See next page

OCT 11 1985

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ENCLOSURE I

BWR OWNER'S GROUP
HYDROGEN WATER CHEMISTRY

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